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# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-TWO, SUMMER 1991

## REAR ADMIRAL THOMAS DANIEL DAVIES, USN (Retired)
## 1914-1991

Rear Admiral Thomas D. Davies, United States Navy (Retired), died on January 21 of this year at the age of 76. He was a decorated Navy pilot who set several aviation records and was also a diplomat, and an expert and innovator in several scientific fields, including navigation and optics. He was also a linguist and artist. Most recently he received international attention for his exhaustive analysis of Admiral Robert E. Peary's claim to have reached the North Pole in April of 1909.

His long professional involvement in the science and art of celestial navigation began as a Midshipman in Annapolis, where he studied under Arthur Ageton and published his first article in the *Naval Institute Proceedings* in 1937. During his lengthy naval career he had occasion to address navigation problems both at sea and in the air. Based on his experience and research he developed two new methods for celestial sight reduction.

Admiral Davies was born in Cleveland, Ohio, on November 3, 1914. His father, David A. Davies, was a turn-of-the-century businessman who had followed in the industrial tradition of his Welsh ancestors. The Davies had developed early gantry cranes to be used in shipbuilding. David Davies and his brother were executives in the Acme Machine Company. In this environment young Tom Davies developed his interest in the world of engineering and science.

*RAdm. Thomas D. Davies displays Robert Peary's sextant at a press conference held at the Naval Academy in February 1989.* *(Credit: Capital Photo).*

After graduating from high school Tom Davies entered the Case Institute of Technology, which he attended from 1931 through 1933. It was while a student at Case Institute that he developed a lifelong interest and love for physics and for optical physics in particular. While a student at Case he felt he was fortunate to have attended lectures in physics by guest lecturer Albert Einstein.

In 1934 he was accepted as a Midshipman at the United States Naval Academy at Annapolis, Maryland. After having attended Case Institute for two years, his first years at the Naval Academy were a time for building upon his knowledge and engineering insights already acquired. It was during this period, while studying naval ordnance and gunnery, that he became aware of the difficulty that the navy was experiencing in determining the accurate range of targets.

To Midshipman Davies there was an obvious solution. That solution was to develop a new type of stereoscopic range finder. Working in the Naval Academy Physics laboratory, Midshipman Davies developed a workable model of the range finder. His target for his range tests was the dome of the Maryland State Capital Building.

His tests were so successful that senior officers in the Bureau of Ordnance asked him to brief them on the range finder. He explained the workings and accuracy

*(continued on page 2)*

of his invention to these senior officers, and they saw the great potential of such a range finder sight. Further development readied the optical range finder sight for the major ships with large caliber guns of the fleet. The sight developed by Midshipman Thomas D. Davies was used on all ship with large caliber guns of the United States Navy during World War II and on ships used for coastal bombardment during the Korean War. These sights are still visible on the battleships that have been preserved in museum status. For example, one can still be seen on the battleship *North Carolina* at Wilmington, North Carolina.

In addition to being a gifted engineer and innovator, as a student Midshipman Davies was also an artist and a young man of letters. At the Naval Academy he was Art Editor of the "Log," and Associate Editor of the "Trident." In addition to his duties as Editor and Associate Editor, he contributed a number of pieces to the Naval Academy Log and the midshipman humor magazine, and he also put his artistic talents to work designing the class ring.

After graduating from the United States Naval Academy with the class of 1937, Ensign Davies was assigned initially to the cruiser *U.S.S. Portland,* stationed in the Pacific. In February 1939 he commissioned his second ship, the heavy cruiser *U.S.S. Wichita.* The Wichita became a particular favorite. While aboard the Wichita, he put his artistic talents to work and created a beautiful painting of his ship, which hung in a place of honor in his home for many years.

Ensign Davies left the surface navy and entered the navy flight training program in early 1942. He completed flight training and was designated a Naval Aviator in late 1942 and assigned to Bombing Squadron 129 (VPB-129) as executive officer.

Bombing Squadron 129 (VPB-129), flying PV-1 Venturas, was fighting a little publicized antisubmarine war in the South Atlantic against German U-Boats. Flying from airfields in Brazil, Squadron 129 was charged with the protection of coastal shipping along the coast of South America. On one antisubmarine surveillance mission, Aircraft Plane Commander Davies engaged the German Submarine U-604. His attack scored a direct hit. For his attack on the German submarine, Davies received the Distinguished Flying Cross for "heroism and superb airmanship contributing to the destruction of an important enemy vessel."

As was the case in every assignment, Davies became interested in the language of the country. His forays into the villages and towns of Brazil during the two years of his assignment to Squadron 129 provided Davies an opportunity to develop his language ability. He learned to read and write Portuguese, skills he used later when he was assigned as Commanding Officer of the U. S. Brazilian Training Unit. He used his linguistic talents to write a manual in Portuguese and to assist the Brazilian Navy in translating English maintenance manuals into Portuguese, and to organize their maintenance and flight training efforts. Later, this ability to read, write and speak Portuguese was a great asset in allowing him to translate original Portuguese navigation documents into English for his research in Portuguese navigation techniques.

Following his tour as Commanding Officer of the U.S. Brazilian Training Unit, he became intimately involved in naval aircraft development. On February 19, 1943 a letter of intent had been given by the Navy Department to Lockheed Aircraft Company to initiate the development of two XP2V-1 Neptune Series of land-based aircraft. The design drawing had just begun on the Neptune when Commander Davies assumed his new duties at the United States Navy's Bureau of Aeronautics as the Patrol Plane Contracting Officer in Washington, DC. His task was to research and help select the next land-based patrol plane to replace the PV-1 Ventura.

Being assigned to this project was a rare opportunity for young Commander Davies. The responsibilities and authority inherent in his position as Contracting Officer during those years gave him the chance to help dictate the final design of the XP2V-1. It was during this initial development his superior engineering ability was allowed free reign. His assistance to the engineers of Lockheed and his insistence on extended flight duration for navy patrol aircraft, laid the groundwork for a subsequent world distance record in heavy propeller-driven aircraft.

Tom, who was then serving as the head of the patrol plane desk in the Bureau of Aeronautics, originated the idea of modifying the first production model of the new Lockheed P2V for a long distance flight to demonstrate the ability of Navy air antisubmarine warfare forces to reach targets anywhere in the world. With the approval of the Chief of Naval Operations, Admiral Nimitz, Davies developed and executed the plan, establishing a distance record of 11,256 miles which held for sixteen years.

In September 1946, a modified version of one of the first two prototype XP2V-1 Neptunes was ferried to Perth, Australia, by island hopping. This was to be "The Truculent Turtle" that Commander Davies and his crew were going to fly for a world distance record. Commander Davies, his crew, and engineers from Lockheed Aircraft Company, checked the plane in minute detail. The engineers were worried that the aircraft was grossly overloaded because of the much greater quantity of fuel that was required for the distance record flight. The oleo shock absorber struts were completely compressed during the taxi tests. The tires had very little room to spare between the rim of the wheel and the face of the tire. Even a bump could have caused the rim to cut the tire with disastrous results. While the Lockheed engineers worried and fretted, Commander Davies was confident, from his own personal calculations, that the aircraft would fly.

As the crew was boarding the aircraft, the Lord Mayor of Perth arrived to wish them luck. He also brought with him a small kangaroo in a wooden cage for Commander Davies to fly to the United States. For the Lockheed engineers, this was the end. They were already convinced that the aircraft was grossly overloaded, but to add additional weight, especially a kangaroo in a wooden cage, was unthinkable. Commander Davies accepted the kangaroo for the people of the United States, and directed his crew to load the crate in the tail of the aircraft. He remarked to the worried engineers that "the plane was already overloaded so a little more weight would not hurt."

As history records, the plane did get into the air after an unusually long take-off run. To conserve fuel the rate of climb was kept to a minimum and the altitude was under 6,000 feet for the first several thousand miles. For his achievement in the flight, Tom, along with his crew of three other pilots, was awarded a Gold Star in lieu of a second Distinguished Flying Cross, by President Truman in a White House ceremony.

After this, Commander Davies continued to push the frontiers of naval aviation. On April 27, 1948, as Commander of Task Group 68.7, in the first carrier launching of planes of this size and weight, two P2V-2 Neptunes, one piloted by Commander Tom Davies, made Jet Assisted Take Offs (JATO) from the deck of the *U.S.S. Coral Sea* (CV-43) off Norfolk, Virginia. These tests proved the practicability of operating long-range heavy attack planes from Navy carriers. These tests resulted in establishing a Navy, carrier-based nuclear bombing capability. For a short time Tom held the worlds piston aircraft speed record from the east to west coast of the United States. He stated he was able to capture this speed record with the P2V Neptune because all other speed records were from west to east to utilize the prevailing westerly winds. Also, using the Neptune he was able to complete the entire distance without refueling.

As a member of Admiral Robert E. Byrd's staff Davies continued to distinguish himself as a thinker, innovator and engineer. He designed the first set of skis for tricycle landing gear aircraft and developed the Sky Compass for navigation at the Poles where conventional instruments are unreliable. This new compass was later incorporated into celestial navigation equipment used by commercial airlines for early trans-polar flights to Europe. He also equipped two aircraft with special navigation and photographic equipment for use in mapping the Antarctic continent.

The Sky Compass was a set of polarized lenses mounted in a frame that penetrated the top of the aircraft. By rotating the lenses, an accurate relative bearing of the sun could be made while the sun was still well below the horizon. By using this relative bearing and the known longitudinal position of the sun, taken from the Nautical Almanac, the gyro compasses could be accurately realigned. This procedure allowed the aircraft to navigate in polar regions where all other compasses of that time were useless. Magnetic compasses could not be used and gyros compasses precessed to a degree that they were utterly useless unless frequently corrected. For this necessary and useful invention, Commander Davies, received the Thurlow Award for the Outstanding Contribution to the Science of Navigation for 1949 from the Institute of Navigation.

For the years of 1950-1952 Davies was assigned to be in charge of the aircraft overhaul and repair facility at Naval Air Station, Sand Point, in Seattle. He was then transferred to the Staff of the Commander, Fleet Air Mediterranean where he remained until 1954.

While stationed in Italy, Tom Davies continued to build on his language capabilities and to exercise his engineering abilities. The U.S. Navy's presence in the Mediterranean included navy patrol aircraft based out of Sigonella, Sicily. Sigonella had the only adequate maintenance facilities for these patrol planes. Periodically the squadrons would base in the eastern Mediterranean. Without maintenance facilities their availability quickly deteriorated. Commander Tom Davies installed maintenance facilities in an LST which could beach near the airfield and provide maintenance vehicles, shops and spare parts to the deployed aircraft squadrons. On his return from Italy, Commander Davies was assigned as Commanding Officer of the Naval Air Engineering Facility at Philadelphia, where he had responsibility for arresting gear and catapults for aircraft carriers. Commander Davies was intimately involved in the development of the navy's steam catapult and arresting gear systems. He remained at the Naval Air Engineering Facility until 1958, when he was reassigned to service in Washington, D.C.

In 1960 and 1961 Captain Tom Davies commanded the fleet oiler *U.S.S. Caliente* deployed in the Western Pacific. Here he continued to practice his navigation and improve his abilities in celestial navigation.

This assignment was followed in 1962 and 1963 by service as Commander, Fleet Air Wing Three located in Brunswick, Maine. The Cuban Missile Crisis occurred during this tour, and his command was an important part of U.S. aerial surveillance forces. It was during the surface surveillance that the importance of accurate navigation was again proven necessary for comprehensive search and detection of surface shipping. The lessons he learned during the Missile Crisis were later used to develop a command and control system for his carrier division.

In 1963 and 1964 Captain Davies commanded the Naval Air Station at Norfolk, Virginia, and he thereafter returned to Washington, D.C. and was selected as a Flag Officer. Rear Admiral Davies joined the staff of the Secretary of the Navy where he remained from 1965 to 1967. He founded the Office of Program Appraisal within the Office of the Secretary. Under the charter of OPA, RAdm. Davies was responsible for reviewing all of the Navy's major programs for engineering, funding and, most of all, usefulness.

In 1967 RAdm Davies was assigned as Commander Carrier Division 20. It was in this capacity that he continued to develop his surface surveillance/command and control system. The thoroughness of the system for data collection, ship identification, electronic emission control and navigation allowed RAdm Davies to evade all Soviet surveillance ships that had been trailing U.S. aircraft carriers since the beginning of the Cold War. These trailing Soviet ships were a major concern of the Navy Department since it would mean that each carrier would be continually targeted. If hostile action occurred, the carriers would be the first targets. With the Davies system of command and control, constant track was kept of the trailers, and they were avoided by tactics of silence and subterfuge. His command and control system, which identified all surface contacts and kept track of their position, was a major assist in locating submarines. Knowing the exact position of every surface contact, having it identified and knowing the acoustic properties of each contact's propulsion, were key factors in locating all five Soviet submarines operating in the Mediterranean. His system drew attention from all levels, and his subordinates spent the next four years training Commanders of Carrier Divisions, commanding officers and command and control officers in the techniques developed by Admiral Davies.

In 1969 RAdm Davies was made the Chief of Naval Development/Chief Oceanographer of the Navy. In this position he was able to continue to develop weapons systems from ideas he had conceived while a Carrier Division Commander. As Chief of Naval Development he helped develop two systems that were used in the recent Mideast confrontation—the vertical launcher for shipboard missile systems and the cruise missile. Meanwhile, his command and control system continued to be of major interest to fleet commanders, and 29 units of a display system that he invented were installed on major ships of the navy. As Chief Oceanographer, RAdm. Davies had the opportunity to work with Jacques Cousteau.

In 1973 RAdm Davies retired from the U.S. Navy to accept a presidential appointment as Assistant Director of the U.S. Arms Control and Disarmament Agency (ACDA). He held this position for seven years under three different presidents and led two U. S. Delegations on negotiations with the Soviet Union. In his first position as Assistant Director his bureau had the responsibility for nuclear non-proliferation, nuclear test ban matters, chemical and biological weapons control and strategic arms limitation talks (SALT). He continued in this position during 1974, when he represented ACDA in the U.S. Delegation to the Threshold Test Ban (TTB) negotiations in Moscow. That agreement was signed by President Nixon in 1974.

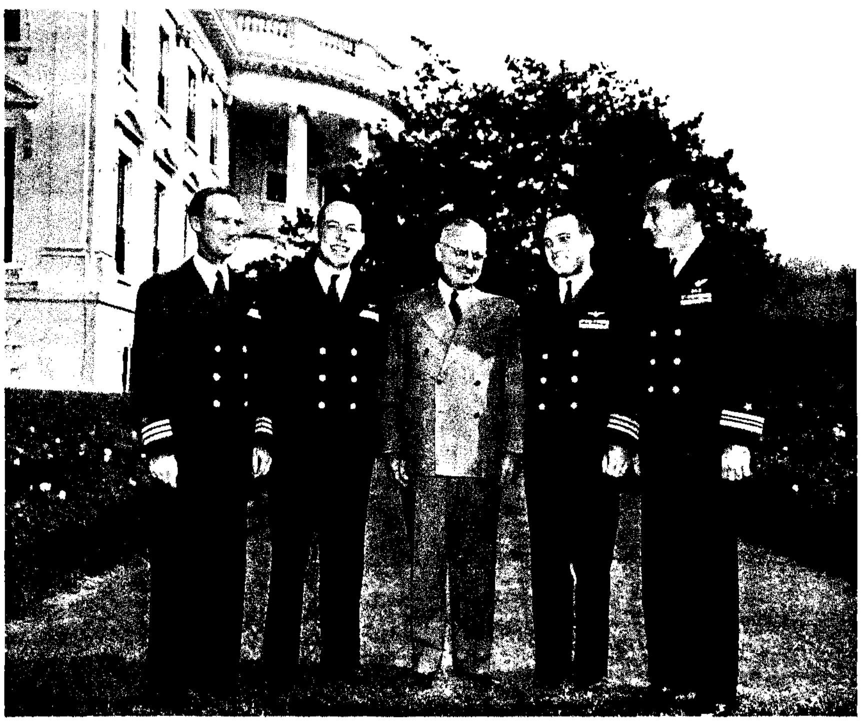
During 1975, President Ford signed the instrument of ratification whereby the United States became a party to the Geneva Protocol prohibiting gas warfare, and in 1976 he also signed the Peaceful Nuclear Explosion Treaty. Both agreements limited nuclear explosions above a certain yield. Admiral Davies played a principal role in achieving these agreements.

In 1975 Admiral Davies became an Assistant Director in a new capacity as head of the Nonproliferation and Advanced Technology Bureau. He continued in that position during 1976 and was active in promoting the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques. In 1974 and 1975, he headed the U.S. Delegation to the bilateral negotiations with the Soviet Union that preceded the multilateral development of this agreement. It was signed by President Carter in 1977. Had he lived another month or two he would have been profoundly shocked by the recent environmental holocaust in the Gulf.

Under President Carter and ACDA Director Paul C. Warnke, Admiral Davies became Assistant Director for Multilateral Affairs. That Bureau continued to address advanced technology matters over which Admiral Davies had special expertise, such as a comprehensive nuclear test ban and the further control of chemical, biological and radiological weapons, nuclear free zones and environmental modification. In addition, he acquired more responsibility for multilateral arms control negotiations at the United Nations and the Conference on Disarmament in Geneva, Switzerland. He chaired an interagency backstopping group supporting many arms control initiatives in those fora.

It was during the latter part of 1977, while at ACDA, that Admiral Davies completed his development of his *Star Sight Reduction Tables for 42 Stars: Assumed Altitude Method of Celestial Navigation* (page 614 Bowditch Vol. 1, 1984). In 1982 Admiral Davies expanded the tables and published *Sight Reduction Tables for Sun, Moon and Planets: Assumed Altitude Method of Celestial Navigation.* The method utilizes the observed altitude to identify a star and reduce the sight in a single operation. This is accomplished by generating an assumed altitude by rounding the observed altitude to the nearest degree. The method provides accurate and simple solution for most latitudes and altitudes. His *Concise Tables for Sight Reduction* were developed in conjunction with the Naval Observatory and have now been incorporated in the U.S. and British Nautical Almanacs.

It was also during this time period that Admiral Davies developed the Prism Level, a device used to improve the accuracy of the sextant when used in celestial navigation. With the Prism Level it is easy to maintain a vertical plane with the sextant on a small boat in rough weather. The Prism Level is in wide use and is available for a number of sextants. In 1980 Admiral Davies conceived the idea of The Foundation for the Promotion of the Art of Navigation to advance the art of celestial navigation. The Foundation now has worldwide membership and conducts an active program in both theoretical analysis and in the development of practical seagoing experience. In addition to the quarterly newsletter, the Foundation also publishes a condensed *Navigator's Almanac*, and provides a central point from which members can acquire navigation charts, publications and books.



*The crew of the Truculent Turtle, from left, CDR Reid, CDR Davies, CDR Rankin, and LCDR Tabeling, is congratulated by President Harry Truman at a White House ceremony in 1946.*

In 1988 Admiral Davies and the Navigation Foundation were invited by the National Geographic Society to examine the 80-year old controversy over Admiral Robert E. Peary's claim to have reached the North Pole on April 6, 1909. After a year of extensive research and thorough analysis, his final report considered all relevant factors including time and distance, polar celestial observations, navigation, and depth sounding of the ocean bottom. In addition, Davies, for the first time, applied modern photographic analysis techniques to the sun's shadows that were evident in Peary's photographs taken in the vicinity of the pole. Using spherical trigonometry, this new shadow evidence proved to substantiate Peary's claim. This innovative work was further reinforced after the original report had been published when new photographs that included the sun itself were discovered.

As a result of his exhaustive studies, Admiral Davies concluded that Peary was probably within 5 to 10 miles of the North Pole. He consistently indicated, however, that his conclusion wan not based on any single source of information, but rather on the broad framework of data that was completely consistent with this finding. Though skeptics may persist, Admiral Davies himself was confident that Peary had succeeded, as were the other members of the Foundation's Board of Directors.

Rear Admiral Davies' military decorations included the Distinguished Service Medal, two Distinguished Flying Crosses and the Legion of Merit medals. Foreign awards were the Order of the Southern Cross, and the Comte de la Vaulx medal of the FAI.

In addition to a bachelor of science degree from the United States Naval Academy, Admiral Davies held a master's degree in international relations from the George Washington University. He also was graduated with distinction from the National War College in 1962.

He married the former Eloise English in 1945. He is survived by his widow and four children. The members of the Foundation's board of Directors join the Davies family in their sense of loss and in a sense of admiration and respect for this remarkable man that is deep and everlasting.

Every effort will be made to carry on the work of the Foundation, which is the work of Tom Davies. Among his many legacies is the commitment of his Foundation colleagues to the purposes and goals which he established in 1980, and which are just as valid today as they were eleven years ago.

*—by Capt. Terry Carraway and Roger Jones*

# ACTIVITIES

## Peary Update

The Navigation Foundation was represented by member Douglas R. Davies (filling in for his father, Admiral Davies) at a U.S. Naval Institute seminar entitled "All Angles: Peary and the North Pole" on April 19, 1991. Davies, who was a technical consultant on the Foundation's Peary Report, was joined on the panel by polar navigation expert Lt. Col. William Molett, USAF (Ret.) and Peary critics Dennis Rawlins, Wally Herbert, and Ralph Plaisted.

The morning session included 15 minute presentations by each speaker, followed by a short rebuttal by each speaker and a question and answer period.

Wally Herbert led off, emphasizing that, based on his Arctic sledging experience (he was the first person after Peary to reach the North Pole by dogsled), he did not believe Peary's claimed distances. Herbert noted that Peary made the round trip to and from the pole in about the same number of days that Will Steger's modern expedition took just to reach the Pole.

Ralph Plaisted, who was the first man after Peary to travel over the ice to the North Pole (by snowmobile) doubted Peary's claim that he returned over the same trail used to reach the Pole, since in Plaisted's experience, trails were broken up by movement of the ice in a short time.

Col. Molett, who was navigator on over 90 flights to the North Pole explained a simple and accurate method that Peary could easily have used to stay on course. This method involves comparison of the sun's altitude on each prime vertical. Molett concluded that since Peary would not have been significantly off course, there was no reason for him to have turned back short of the Pole (given that he had only 135 miles to cover after April 1, 5 days before arriving at his final camp).

Dennis Rawlins focused on a number of minor inconsistencies in Peary's 1909 records and lack of documentation of Peary's 1906 "discovery" of Crocker Land (which does not exist and may have been a mirage or an ice island). According to Rawlins, these inconsistencies so discredit Peary that his claim should not be accepted. Rawlins acknowledged that a key photograph analyzed in the Foundation's Supplemental Report showed the sun at precisely the right elevation for a shot at the Pole. Rawlins' explanation for this result is that Peary, although far from the Pole, carefully staged the photograph by taking it when the sun rose to the correct altitude for a shot at the Pole.

Davies began by responding to Herbert's suggestion that Peary's distances were impossible. Davies noted that other explorers, and especially Will Steger, have concluded that Peary's distances were plausible, particularly if, as Peary and all of his travelling companions maintained, the ice was relatively smooth. Other explorations since Peary have similarly encountered smoother ice above 88°. Davies noted that Steger's total time to reach the Pole is not a proper comparison to Peary's time, since for much of the trip Steger was using a relay system (shuttling back and forth to move supplies) that required traveling over each leg of the trail three times.

Davies responded to Rawlins' suggestion that Peary had staged crucial photographic evidence by noting that it is unreasonable to believe that Peary went to the trouble of staging the photograph and then made no effort to use it (despite the perfect result) to bolster his claim when it came under attack. Davies then summarized the principal evidence underlying the conclusion in the Foundation's Report that Peary reached the Pole. The hard data relating to the trip (depth soundings, sextant observations, photographs, diary entries recording distance estimates and wind speeds) are all consistent with Peary's claim. In fact, the data are irreconcilable with any estimate of Peary's track that does not place him within at least the very near vicinity of the Pole.

An informal afternoon session for the die-hards provided a spirited debate among the panelists and an audience that represented strong viewpoints on both sides of the controversy. Tom Miller, an anthropologist from the American Museum of Natural History in New York made an interesting revelation during this session: the museum has a collection of photographs taken by Peary's companion at the Pole, Matt Henson.

Davies and Foundation Board member Terry Carraway recently travelled to New York to inspect these photographs, and found 106 photographs that are catalogued as having been copied from negatives lent to the museum by Matt Henson in October 1909. These photographs apparently are the approximately 100 photographs that Dennis Rawlins, in his 1973 book, accused Peary of trying to suppress.

Peary did indeed reclaim these photographs from Henson (pursuant to an agreement that Peary had with all members of his expedition to turn over their diaries and photographs and giving Peary exclusive lecture rights). Further, documents turned up in the Foundation's research showed that Peary was angered by rumors that Henson had copied the photographs before turning them over to him.

Rawlins speculated that, rather than merely protecting his exclusive lecture rights, Peary was trying to suppress damaging evidence. These "suppressed" photographs recently took on greater importance when Rawlins speculated that they were suppressed because they would support Rawlins' claim that the crucial Peary photograph referred to above was staged.

A cursory review of the Henson photographs shows that perhaps as few as 2 or as many as 15 of them were taken at or near the final camp. None show the sun directly, and there is nothing in any of them that Peary could have viewed as potentially damaging. A few may be susceptible of analysis by modern photogrammetric methods. Any results will be reported in the Newsletter as they become available.

## Charts Available

After 10 long years the Foundation has become a chart dealer for National Ocean Service Charts. Our thanks and a debt of gratitude to members Dave and Elsie Nelson and their Congressman Dick Schulze, whose diligent efforts finally penetrated the bureaucracy.

For members, the discount is 20% on all orders up to $50 and 25% for all orders $50 and over. As usual, we must ask for any postage or UPS fees required to send the charts to you.

More on this later when we have had a chance to "shake down" our new-found service for members.

## Contributors

Any members with interested in writing articles for the Newsletter should contact the Foundation. Though no payment is offered you will receive a year's free membership if your article is published.

## Mailing List Problems

Please check your mailing label carefully. Due to a recent disk crash there may be errors in our records. If there is a problem, please let the Foundation know.

## Business Reply Postage

A reminder to all members that the U.S. Postal Service charges business reply rate for all letters in business reply envelopes, so save your stamps. We thank you for trying to save the Foundation postage but you have to use a regular envelope if you choose to use your own stamp.

## Thankyou

A heartfelt thankyou from all the directors of the Foundation for your letters encouraging us to continue. I assure you that we want very much to continue the services, information, and clearing house aspects of the Foundation that Admiral Davies started and loved. Let us know, from time to time, how we are doing.

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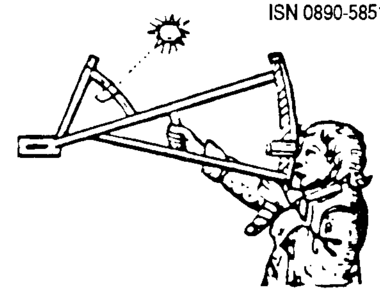
# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-THREE, FALL 1991

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*by Roger H. Jones*

### Awards

The Foundation continues to sponsor awards for excellence in the study of navigation. This year's recipient of the Dutton Award at the U.S. Naval Academy is Midshipman Geoffrey S. Royal of Houston, Texas. The 1991 award at the Gould Academy in Bethel, Maine, goes to Basil A. Blastos of Pittsburgh, Pennsylvania. Blastos will enter the U.S. Naval Academy as a member of the Class 1995. Our best wishes and congratulations go to both of them.

### Charts

A series of correspondence has been received from members Dick and Elsie Nelson in the course of which the Foundation has also received copies of a letter written by Congressman Richard T. Schulze (PA) to the National Oceanic & Atmospheric Administration regarding its policy that agents selling NOAA charts must operate a retail store. Congressman Schulze's efforts have paid off. The Foundation is now an agent for purposes of sales of NOAA charts. The discount is 20% up to $50 and 25% for orders over $50, plus postage. Chart orders take from 2 to 4 weeks depending on the availability of charts in NOAA's stock. In-stock charts have been arriving at the Foundation in 10 to 14 days. Out of print and reprintings have taken about 4 weeks to arrive. If you are planning to make a trip and need charts, please plan ahead and get your order in early.

### Index

In the "Activities" column in issue Thirty-One, Admiral Davies noted that work has been started on an Index of back issues and articles. This project was interrupted by the death of Admiral Davies, but will be completed soon and readers will be informed when the Index is available. Meanwhile, this issue of the Newsletter contains a listing of all of the previous Navigation Problems that was being prepared for inclusion in issue Thirty-Two. That issue was recast completely in the format of a biographical sketch of Thomas D. Davies. With this issue, we resume regular format.

### Book List

In issue Thirty-One it was also noted that work was underway on a list of the Foundation's collections of books and publications on nevigation which will be permanently lodged at the Naval Observatory. That list will also be completed and published in the Newsletter.

### Membership

A reminder to members: in Issue 29, Summer 1990, the Foundation increased the annual contribution requested of our members from $25 to $30. This was the first increase in the membership contribution since the establishment of the Foundation. This change in annual contribution was due to the rise, over the years, in postage and printing costs. Personnel costs are negligible since our staff is primarily volunteer and unpaid.

### New Foundation President

Douglas R. Davies has been elected President of the Navigation Foundation by the Board of Directors. Davies, the son of Rear Admiral Thomas D. Davies, USN (Retired) 1914-1991, was the primary consultant to the Foundation on the Robert E. Peary Report for the Navigation Foundation. He was co-designer of the methodology and techniques of the photogrammetry used to analyze the Peary photographs to determine that Peary actually did arrive at the North Pole.

Davies ably defended the Peary Report against its critics at the U.S. Naval Academy this spring. Next to his father, he is the most knowledgable person about the Foundation's analysis of Robert E. Peary's accomplishments. He is currently waiting for copies of Matthew Henson's long lost photographs to arrive to determine if there is sufficient data to warrant additional analysis.

Please join us in welcoming Douglas R. Davies as the second President of the Navigation Foundation.

We wish to express our deepest appreciation for all the kind letters and telephone calls concerning the special issue of the newsletter dedicated to Admiral Davies.

# READERS FORUM

We have received many letters in the aftermath of the death of Tom Davies. It would be impossible to acknowledge all of them individually. The Directors of the Foundation and the members of the Davies family are very grateful for those letters, a number of which also contained generous contributions to the Foundation in memory of the Admiral. Those contributions will, indeed, serve his memory and the continuation of the Foundation and its activities.

The following summarizes the context of letters we have received. With the next issue, we will resume our practice of printing or excerpting letters from readers.

Dr. Richard T. Callaghan of the University of Calgary has written to inquire if the data used to compile the pilot charts published by the Defense Mapping Agency Hydrographic/Topographic Center are avaiable on magnetic tape or in any other computer readable form. While we will attempt to follow up on this inquiry, if any reader knows the answer to this question, we would appreciate being advised. Such advice should also be sent to Dr. Callaghan at the Department of Archaeology, University of Calgary, 2500 University Drive, NW, Calgary, Alberta, Canada T2N 1N4.

James Teachey of Greensboro, North Carolina, has written as an avid and apparently self-taught student of navigation. His experiments have included the taking of sights from a mountain elevation requiring a very large dip correction.

C. Huguenin, Charge d'Affairs in the Swiss Embassy in Tripoli, Libya, has written regarding the articles on artificial horizon sextants by John Luykz which were concluded in Issue Twenty-Eight. Mr. Huguenin, who has admitted to a passion for land and desert navigation, has made comparative observations using a Hughes MKIX sextant and the much more expensive C. Plath Navistar Classic. He notes that hundreds of observations were taken from the roof of his residence in Tripoli, the coordinates of which were checked by map and by Magellan GPS. Navistar observations, resolved in conjunction with a HP-41CX computer, resulted in intercepts of as much as 5 nautical miles from the actual position, whereas the second-hand Hughes sextant (costing one-tenth the amount of the Plath) yielded more accurate results and was reportedly more comfortble to handle.

Confirming the old adage that the "oldies are often the goodies," Huguenin also notes that E. H. Thompson devised a simple astro navigation instrument for land use at the beginning of W.W. II, which was later described by R.A. Bagnold in the British Journal of Navigation, vol. 6, 1953, p. 188. Hobby-craftsmen who are interested in recreating such a device may wish to correspond with C. Huguenin (Tripoli), OFAE/Section Courrier, 3003 Berne, Switzerland.

Robert C. Stirling of Cape Coral, Florida has written as a result of the January, 1990 article in National Geographic on the Peary project. He enclosed a copy of a report entitled "Position Indication at Sea by Astro-Photogrammetry," which was published in 1963 by M.I.T. as a result of a contract with the U. S. Naval Oceanographic Office. Stirling, while assigned to the Oceanographic Office, conducted preliminary experiments and tests on land, and a prototype system was developed by the Experimental Astronomy Laboratory at M.I.T.under the direction of Professor Winston Markey. Two shipboard tests were conducted at the Atlantic Missile Range, with results indicating extremely high accuracies. Electronic satellite systems being developed at the same time offered similar accuracies, plus the advantage of all-weather, real time position determination. Consequently, work on the protogrammetry method was not carried forward. The report forwarded by Stirling will find a permanent home with the Foundation's collection, and it offers further confirmation of the method used to analyze the much more rudimentary photographs taken by Peary in 1909.

Finally, in going through a mountain of correspondence that was in Tom Davies' possession, we have come across the interesting letter from James M. Furlong of Fulton, Texas. Furlong writes with the high style and storyteller's flair of a Tristan Jones. He describes adventures dating back to his days as a merchant marine galley boy just after Pearl Harbor and extending over the next several decades, with interesting duties as a navigator sailor aboard an old cutter in the North Sea and Caribbean and points in between. Furlong exclaims: "En garde and batten down the hatches; I'm 'clabbering' up to blow again!" More the power to you, Captain Jim. Let us hear from you.

# NAVIGATION BASICS REVIEW

## Celestial Navigation in the Arctic: Special Problems

*By Robert Eno Iqaluit, Northwest Territory, Canada*

This article will focus on some practical aspects of celestial navigation as it applies to surface travel in the arctic. It is by no means intended to be a comprehensive discourse on arctic navigation. It is aimed at giving a brief outline of the problems which I have experienced and which are likely to present themselves to the prospective polar navigator when fixing his position by celestial means. Celestial navigation in the arctic is essentially not very different from what it is in more southerly latitudes. The principles, tables, formulae and skills required of the navigator are the same. There are, however, a few "twists" which the navigator should be aware of when taking observations of celestial bodies "north of sixty".

One of the most important factors to consider is the intense cold and the strong winds which are common throughout most of this part of the world. Picture this writer sitting on a patch of frozen ground, bundled up in several layers of clothing, with sextant in mitted hand. The wind is howling around him, blowing snow; the temperature hovers around -35°C. The telescope eyepiece is constantly fogging up, he's shivering from the cold, and in between all of this, he's trying to fine tune his sextant.

Until one has tried to take an observation under these conditions, one cannot fully appreciate how difficult it is and how much these difficulties can adversely affect the accuracy of one's observations. It can be brutal work; but it can also be very satisfying and enjoyable if one is able to surmount those obstacles which stand between him and a reasonably accurate reading.

The first step one must take is to have one's sextant relubricated with a low temperature lubricant that is rated to at least -40°C. I cannot stress adequately how important this is. Ordinary lubricants will freeze, and what you will be stuck with - literally - is a piece of metal and glass without moving parts. A silicone-based lubricant called "Dow-Corning #33" is the only one I know of which provides an adequate solution to this problem. It has a temperature range of -73°C to +204°C, which makes it more suitable for both winter and summer use.

Fogging of the telescope is more than just a minor nuisance. To alleviate this problem, I apply an anti-fogging solution, which can be obtained at most optical supply stores. Unfortunately, this provides only a temporary treatment, therefore a new coat should be applied to the lens' surface prior to each set of observations.

Before commencing your observations, it is advisable to set the sextant outside for a period of 10 or 15 minutes, allowing it to adjust to the outside temperature. Always carry out an IC check before and after a set of observations. Do not return the sextant indoors until after you have completed all your observations. Doing so will result in a buildup of condensation on the sextant and when it is brought back outside, it will freeze up.

Obtaining a sharp horizon in the arctic is also problematic. Generally, when navigating overland or over ice, one does not have the benefit of a sharp sea horizon and even if it were available, there is evidence to suggest that, because of abnormal and variable terrestrial refraction, it would be unreliable and might introduce serious errrors into the observation. The English explorer, William E.Parry, noted this phenomenon in his "Journal of a Second Voyage for the Discovery of a Northwest Passage" (Parry 1825). One must therefore resort to an artifical horizon, either a bubble type incorporated into the sextant or an external reflective type.

Many polar explorers of long ago used a dish of mercury as an artificial horizon. While it is self-levelling and relatively easy to set up, mercury has a tendency to pick up ice crystals and snow, thus diminishing its reflective qualities. Furthermore, it will freeze at -39°C, and, considering its toxicity, I do not recommend using it. Some navigation texts suggest using a pan of motor oil as an artificial horizon. It does work, but it is somewhat messy and impractical for travel in the arctic. Although oil does not freeze, except at extremely low temperatures, it does become quite viscous and difficult to handle under arctic conditions. Like mercury, it too has a tendency to pick up ice crystals and snow.

I use a Freiberger artificial horizon, which consists of a polished black glass plate mounted in a metal housing with three levelling footscrews. This has proven to be a satisfactory instrument but it is not without its problems. It can be mean work trying to level it when the temperature is 30 degrees below zero. Frozen fingers become the order of the day. The levels are highly sensitive, thus brisk winds can make it difficult and sometimes impossible to achieve perfect levelling. Even after the 3 pound unit is set up, gusts of wind can be strong enough to jostle it; on a few occasions, I have seen the reflected image "jump" up to meet the sextant image before I had a chance to adjust the micrometer drum. Aside from getting out of the wind into a more sheltered area, there is

not much one can do about this problem except to be aware that it does occur and that it will affect the accuracy of your obsevations. Snow and ice crystals will tend to accumulate on the glass plate, but can easily be dusted off. I always carry along a small paintbrush for this purpose. Do not attempt to blow debris off; the moisture from your breath will form a thin coating of ice on the cold surface of the glass.

Whatever type of external artificial horizon one chooses to use, observing even the brightest stars and planets is an arduous task. The reflecting surface (of the artificial horizon) absorbs a substantial portion of the celestial body's light, reducing the apparent magnitude. This problem is compounded by an atmospheric phenomenon common to the arctic - suspended ice crystals - which causes a noticeasble reduction in the perceptible luminosity of the stars and planets (MacDonald 1991). Aurora Borealis, snow, blowing snow and ice-fog will further reduce the clarity of the night sky. The importance of overcoming this difficulty is most apparent during the winter months when the sun remains below the horizon for long periods of time and the navigator becomes dependent on stellar observations. Raising the artificial horizon on a platform to about chest level will partially alleviate the problem of trying to observe dim celestial bodies, because one can get up close with the sextant and benefit from the maximum available reflected light. In addition, it becomes easier to hold the body in view. With a bit of ingenuity, a platform can be mounted on a camera tripod.

Bubble horizon attachments for marine sextants, and/or bubble sextants designed for air and land use are an attractive alternative to external artificial horizons, in that they are relatively easy to use and do not require any setting up procedures. A major disadvantage of a bubble horizon is a loss in accuracy. Almost every navigator whom I have ever queried on this subject has expressed the view that the most accuracy one can expect from a bubble horizon or bubble sextant is no greater than 2' - 5'. This limitation is confirmed in the "American Practical Navigator" (Bowditch 1984). However, one individual, an acknowledged expert in the field, has assured me that the MK IXA aircraft sextant is capable of accuracies of better than 1', and he has documented evidence to support his conviction (Luykx 1991).

The type of bubble sextant that I have been using is the afore-mentioned MK IXA, a British aircraft sextant from the World War II era. Despite its age, this instrument has provided me with years of reliable and trouble-free service. I have used it in temperatures as low as - 40°C and have never experienced any problems with the merchanism or the bubble unit. The fluid in the bubble chamber, hexane, has a freezing point of -95°C (Bartlett 1989), which is more than sufficient for the climatic conditions of the arctic. On a good day, I have been able to achieve accuracies in the order of 1'-2' with this instrument.

I have never used the type of bubble horizon that attaches to a marine sextant, so I cannot comment directly on their performance. The navigator on the 1988 Steger North Pole Expedition used one of these units (a 1941 "C. Plath") and apparently achieved remarkable accuracy with it - as much as 0.1 NM (Schurke 1990). Shurke's experience provides more evidence to suggest that a bubble horizon is capable of great accuracy.

In the final analysis, it is really up to the individual navigator to decide which system he prefers. If only one option were available, I would have to recomnend a bubble horizon attachment (for a marine sextant) or bubble sextant. While they may fall short on accuracy, they come out far ahead in terms of ease of operation and versatility.

An arctic summer presents the phenomenon of extended hours of daylight and twilight. This occurs between the months of March and September and varies in duration, from two weeks of extended twilight at 60°N, where the sun does not dip more than 6° below the horizon, to six months of continuous daylight at 90°N, where the sun remains above the horizon 24 hrs/day. During these periods, only the sun and occasionally the moon will be available for observation. There are also periods when no celestial bodies will be available for observation. This occurs when the sun dips below the horizon, but does not sink far enough to effect a twilight suitable for stellar/planetary observations. The most extreme example of this occurs at the north pole where continuous twilight prevails from about 23 September to 9 October (Greenaway 1951) and from the 5th to the 20th of March. However, at certain times during these twilight periods, Venus will be visible and can be observed with a sextant (Greenaway 1991).

Another problem associated with the arctic summer is biting insects. This should not be dismissed as an incidental triviality. Blackflies, sandflies and mosquitoes abound by the millions in many parts of the arctic and life can be absolute misery for any warm-blooded creature during the "bug" season. Every exposed area of flesh is a target and soon becomes covered with stinging, blood-sucking pests. Attempting to take accurate observations in the midst of this is an extremely frustrating experience. It is nearly impossible to maintain any semblance of concentration or composure. Consequently, the results of one's observations may be rather skewed.

In times of utter exasperation, I like to apply what I call the "B.I.T.E." (Biting Insect Terminal Error) correction to my observations. This amounts to about +/- 10'. In other words, ignore that observation and attempt to take another. The best way to overcome this problem, which usually occurs only during those rare occasions when there is little wind, is to site yourself on the highest piece of ground in your immediate area where there is likely to be a breeze. The wind, which was an adversary in the winter, becomes a revered ally in the summer, since it keeps the insects at bay. Be warned, however, that if the breeze is not substantial enough, and the celestial body happens to be in the downwind direction, the insects will take full advantage of the wind shadow created by your body.

Timing of sights is not as crucial a factor in the arctic as it is in the lower latitudes due to the decreased angular velocity of the earth with increasing latitude. A 30 second error in timing at the equator would result in an east-west error of 7.5 NM; at latitude 40°N the error would be 5.7 NM; at 65°N the error would be 3.0 NM and at 85°N it would be 0.7 NM. While I am not suggesting that the navigator bcome lax in the timing of his sights, he should keep in mind that when forced to take 'quick and dirty' sights due to inclement weather (or insects), a few seconds of error in timing will not make a great deal of difference in the accuracy of the observation.

Now that you've taken your observations, the rest is straight-forward. Reduce as you normally would, but when taking into account the refraction corrections, pay particular attention to the "Additional Corrections" section in the Nautical Almanac, for air temperature (and pressure). Standard refraction tables are fine for temperatures of 10°C, but for very low tempertures, an additional (refraction) correction is required. A more comprehensive table for air temperature corrections can be found in Volume II of the "American Practical Navigator" (Bowditch 1981).

As well, it should be noted that there are frequent aberrations of atmospheric refraction in the arctic, in all seasons. This can affect the accuracy of a sextant reading by several minutes. Unfortunately, there is no way to predict when these aberrations will occur, nor can they be quantified to any degree, at least not to my knowledge. Furthermore, the elevations of the sun and the planets are generally low in the arctic, which adds to the problem of refraction. Do not expect pinpoint accuracy at all times. If you achieve it, the gods were with you that day.

Sight reduction methods are a matter of individual preference. HO 249 (Sight Reduction Tables for Air Navigation) or the spherical trigonometric formulas, facilitated by a calculator, are my own preferred methods. Whatever tables you decide to use, examine them carefully to ensure that they adequately cover the high latitudes. There are numerous compact tables available to the modern navigator and many of them are suitable for arctic navigation.

Electronic calculators have become popular with many navigators because of their compactness and the rapidity with which one can reduce one's sights. There is a temptation, therefore, to dispense with the many pounds of books which were formerly required for sight reduction. This is not a good idea. Calculators are wonderful labor-saving devices but, like any other electronic device, they are subject to failure, particularly in cold conditions where they may become sluggish or cease to function altogether. A navigator friend of mine carries his in a pouch slung around his neck and under his clothes to keep it warm. He maintains that, used properly under extreme conditions, calculators will perform admirably. We both agree on the necessity of a conventional backup system. Always carry a set of printed tables; as with navigation at sea or in the air, it is always a good idea to become familiar with several sight reduction methods in case your preferred method fails you or becomes lost.

The question now arises: What type of plotting chart should one use? Standard Mercator charts, which are the traditional choice of marine navigators, are not suitable for arctic navigation because of the excessive distortion in scale at high latitudes. The chart projections most commonly used in the arctic are the Lambert Conformal Conic and the Polar Stereographic. These projections are used by air navigators for flights into the high arctic and I have found that they are equally useful on the ground for plotting lines of position. The resultant fix can be transferred onto a topographic map to further assist the navigator in finding his way.

As you can see, taking celestial observations in the arctic seldom coincides with what one would consider "ideal" conditions; in fact, the reader may get the impression that it is an ordeal to be avoided if at all possible. It is not always bad. I've been at it for a number of years now and I still enjoy it immensely. The navigator need only be aware of the problems he will be faced with in the arctic, and take the appropriate measures to overcome them. Finally, he must retain his sense of humor, even though at times it will appear that nature is conspiring against him. When this is achieved, he will not only develop his skill and accuracy, but will begin to take pride in his ability to overcome the rigorous conditions presented to him by the harsh arctic environment.

*Editor's Note: Eno has lived in the arctic for 12 years and has practiced navigation in the arctic regions since the early 1980s. He is an environmental protection officer employed by the government of the Northwest Territories. He uses his sextant frequently on hiking and skiing trips.*

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# HISTORY OF NAVIGATION

## Celestial Navigation by Chronometer Time Sight

*By John M. Luykx*

Prior to the development of position line navigation in the mid-nineteenth century (i.e., the Sumner Line - 1837 and the Marcq St. Hilaire altitude intercept method - 1875) the most common procedure for finding the position at seas was a) to observe the altitude of Polaris for latitude at both morning and evening twilight; b) to observe the altitude of the sun for longitude by chronometer time sight both in the morning and afternoon when the sun was on or near the prime vertical and c) to observe the altitude of the sun at meridian passage for latitude at noon.

In addition to the sextant, this procedure basically required the use of a chronometer with an accurately established daily rate, an almanac and a set of trig tables. No plotting was required.

In South latitudes where Polaris was not available for observation, some other star was used when available such as the constellation of the Southern Cross for which as early as 1505 rules had already been provided for obtaining the latitude.

The day's work consisted basically of the following steps.

1. Advancing the morning twilight observation of Polaris for latitude to the morning observation of the sun for longitude using mid-latitude or mercator sailing procedures in accordance with the course steered and the distance made good by log between the two observations.
2. Advancing the morning sun observation for longitude by time sight to the noon latitude obtained at the time of meridian passage using mid-latitude or mercator sailing procedures in accordance with the course steered and distance made good by log between the morning and noon sun observations.
3. Advancing the noon latitude observation to the afternoon sun observation for longitude by time sight using mid-latitude or mercator sailing procedures in accordance with the course steered and the distance made good by log between the noon and afternoon sun observations.
4. Advancing the afternoon observation of the sun for longitude to the evening twilight Polaris observation for latitude using mid-latitude of mercator sailing procedures in accordance with the course steered and the distance made good by log between the two observations.

Note: The longitude by chronometer time sight is particularly dependent on an accurate latitude if the sun is not due East or West (on the prime vertical) at the time of observation.

For the chronometer time sight solution, the observer's latitude (L) the body declination (d) and the observed altitude (Ho) are required. Given the three sides of the navigation triangle, the meridian angle *t* is then computed using the formula:

$$\cos t = (\sin Ho - \sin L \sin d) / (\cos L \cos d)$$

When computed, the meridian angle *t* is applied to the GHA to obtain the longitude.

When advancing the latitude and longitude using traverse and mid-latitude sailing procedures, the following definitions and formulae apply:

1. Traverse sailing (see Traverse Table 3 Bowditch Vol. II.) The Traverse Table lists the East/West and North/South components of any course from 0° to 359° and distance from 0 to 600 miles. The East/West component in nautical miles is known as departure (p) and the North/South component as latitude difference (l) in nautical miles. For example:
   Departure (p) = 18.1 mi
   Latitude Difference (l) = 8.5 mi
2. Mid-latitude Sailing. Mid-lat procedures are used to convert departure (p) from miles to difference of longitude (Dlo) in degrees and minutes of arc for any value of the mid-latitude; i.e. the latitude midway between the latitude of the point of departure and the latitude of the point of arrival. Definitions:
   Lm = Mid-Latitude
   Dlo = Difference of longitude in degrees and minutes of arc
   p = Departure in nautical miles.

Formulae:

$$Dlo = p \sec Lm$$

$$p = Dlo \cos Lm.$$

SAMPLE PROBLEM

In order to better understand what is involved in the day's work using the chronometer time sight, the following sample problem with solutions is presented: On 24 June 1991, a sailing vessel is underway from Chesapeake Bay Entrance to Bermuda on course 115 T at a speed estimated at from 3-1/2 to 7 knots. The 08-00 GMT DR position is N 33°28.0′ W 66°56.0′

At GMT 08-50-6 the altitude of Polaris was observed; Ho 33°51.9′. The log read: 494.2

```
        GHA:    44°39.9'
       Long:    66°51.0'
          t:    22°11.1'
        LHA:   337°48.9'
         Ho:    33°51.9'
 correction:       -24.6'(p.276 Naut. Alm.)
        Lat:    33°27.3'
```

At 13-01-20 the sun's altitude was observed near the prime vertical: Ho 43°51.9'. Log reading: 513.3

```
 1) Advance Polaris latitude: 115°T/19.1
miles
          l =  8.1 miles
          p = 17.3 miles
 2) Latitude =  33°27.3'
                   -8.1'
         Lat: =  33°19.2'
 3) Time Sight
cos t = (sin Ho-sin L sin d)/(cos L cos d)
 where Ho = 43°51.9'
         L = 33°19.2'
         D = 23°25.0'
   Cos t  = .61901
          = 51°45.4'
 4)  Longitude
       GHA:    14°45.6'
      + t :    51°45.4'
   = Long:  W 66°31.0'
```

At meridian passage, the sun's altitude was observed: Ho 80°10.7'. Log reading: 523.9.

```
 1) Advance morning longitude:115°T/10.6
miles
          l =  4.3 miles
          p =  9.3 miles
        Dlo = 11.1'
 2) Noon Longitude
     Long:   W 66°31.0' (morning)
   - Dlo:        -11.1'
     Long:   W 66°19.9' (noon)
 3) Noon Latitude
                90°00.0'
      -Ho       80°10.7'
 = Zenith Dist: 9°49.3'
     +Dec:      23°24.9' (Naut.Alm.p.127)
      Lat:     N33°14.2'
```

At GMT 19-52-40 the sun's altitude was observed near the prime vertical: Ho 43°59.5'. Log reading: 542.9.

```
 1) Advance Noon Latitude:   115°T/19.0
miles
          l =  8.0 miles
          p = 17.2 miles
 2) Latitude = 33°14.2'
                  - 8.0'
        LAT = 33°06.2'
 3) Time Sight
cos t = (sin Ho-sin L sin d)/cos L x cos d
   where Ho = 43°59.5'
          L = 33°06.2'
          d = 23°24.7'
      cos t  = .62122
          t  = 51°35.7'
 4) Longitude
       GHA:   117°34.8'
       -t :    51°35.7'
    = Long:  W 65°59.1'
```

At GMT 00-05-13 the altitude of Polaris was observed: Ho 32°11.8'. The log read 563.1.

```
 1) Advance afternoon longitude: 115°T120.2
miles
          l  =  8.5 miles
          p  = 18.2 miles
        Dlo  = 21.7
 2) Longitude
      Long:  W 65°59.1'
       Dlo:      -21.7'
    = Long:  W 65°37.4'
 3) Latitude
       GHA:   273°56.7'
    - Long:    65°37.4'
       LHA:   208°19.3'
        Ho:    32°11.8'
      Corr:       +46.2'(Naut. Alm. p.275)
       Lat:  N32°'58.0'
```

The sample problem shows that the typical day's work in the early days of chronometer navigation could be accomplished without plotting lines of position on a chart. Such a procedure may find favor among yachtsmen today. It is simple and forthright and only requires an almanac and trigonometry table.

This procedure is ideally suited for the navigation of slow moving vessels. It is faster and even more reliable and accurate when a scientific or mathematics calculator is substituted for trigonometry tables.

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Solution to Problem No. 33 in Issue 31.

Answer

A quick and practical method of determining if the data may be optimum for a sun-moon fix is to look up the age of the moon in the daily pages of the *Nautical Alma-*

*nac*. When the moon's age is between 6 and 8 days and 21 and 23 days it is a waxing half moon and a waning half moon, respectively. The waxing half moon will be near the observer's meridian at sunset, and the time for a moon observation is mid- afternoon. The waning half moon will be near the meridian at sunrise, and the time for a moon observation is mid-morning. In pracical terms, these dates can be extended for a range of 4 to 10 days and 19 to 25 days, respectively, thereby giving a two-week period each month when moon-sun combinations are quite feasible.

The Star Finder can be used to determine the relative positions of the sun, moon, and Venus. From the *Almanac*, look up the rising, meridian passage, and setting times. (For Venus only the meridian passage time is given, but the rising and setting times can be closely estimated by comparing its meridian passage time with that of the sun). Next convert these times to GMT, and then figure the GMT time interval when these bodies will be above the horizon at the same time. Then estimate the time, to the nearest hour, that is about mid-way through this interval. Use this mid-way GMT to look up the declination and GHA of the bodies, and also record the GHA of Aries at that GMT. Derive the SHA's of the bodies and the rim scale values, and then plot them on the white disk. Then use the appropriate blue template. By rotating it from sunrise to sunset, you can record the respective heights and directions of the sun, moon, and Venus at one hour intervals. The differences in bearings will be the angles between the LOP's if you took observations of the three bodies at any of the given hours indicated.

*Editor's Note: With this issue of the Newsletter we again pause to take stock. For the benefit of readers who may have joined in midstream, the following is a listing of all of the previous problems, togther with the Issue in which they appear. Any reader who wishes to obtain copies of previous issue may do so by contacting the Foundation. The nominal charge covering our costs is $2.00 per issue. Due to the length of the following list, we are not publishing a new problem in this issue.*

Issue No. 4 was the first one in which a navigation problem appeared. It furnished basic data on the DR, the time, the watch error, the height of eye, and the sextant altitude, and posed the question of what intercept and azimuth would be used to plot the LOP, and what would be the EP from this single sun line. In succeeding issues, the problems were numbered as follows:

Issue No. 5. Problem 1. Estimation of the time of LAN when there is no westward or eastward movement of the vessel.

Issue No. 5. Problem 2. Determination of the latitude from the local apparent noon shot of the sun.

Issue No. 6. Problem 3. Determination of the time of LAN from altitude shots of the Sun before and after the meridian crossing.

Issue No. 6. Problem 4. Determination of longitude from the time of the Sun's meridian crossing at LAN.

Issue No. 6. Problem 5. Determination of the set and drift of the current by comparison of a celestial navigation postiion with an earlier DR.

Issue No. 7. Problem 6. Planning the time of star shots using the Almanac twilight data.

Issue No. 7. Problem 7. Use of the Almanac to identify planets that may be of use.

Issue No. 7. Problem 8. Use of H. O. 249, Volume 1, to pre-plan star shots.

Issue No. 7. Problem 9. The problem of using a true horizon when a shore line "horizon" is visible beneath the celestial body.

Issue No. 8. Problem 10. Determination of the time of LAN when there is present a component of vessel movement eastward or westward.

Issue No. 9. Problem 11. Various methods of star identification, including: the "Star Finder", the Davies Assumed Altitude Tables, and Volume I of H.O. 249.

Issue No. 10. Problem 12. Use of the Davies Assumed Altitude Tables.

Issue No. 11. Problem 13. Determination of latitude from an observation of Polaris.

Issue No. 12. Problem 14. The problem of the International Date Line Crossing.

Issue No. 13. Problem 15. A method for verifying that the vessel is on course, using only one sight per day.

Issue No. 14. Problem 16. A Moon problem involving a mistake by the navigator.

Issue No. 15. Problem 17. The little used technique of the backsight.

Issue No. 16. Problem 18. A non-chart method to determine great circle courses and distances.

Issue No. 17. Problem 19. Star shots using H. O. 249, the timing of successive star shots, corrections for Precession and Nutation.

Issue No. 18. Problem 20. Use of the Star Finder to plot the positions of planets.

Issue No. 19. Problem 21. Use of an extremely high altitude shot of the Moon, and special plotting techniques.

Issue No. 20. Problem 22. Note: with Problem 21, the vessel Backstaff completed a circumnavigation of the world. Beginning with No. 22, a series of problems on emergency techniques was present. No. 22 dealt with a technique for gaining useful information as to longitude by using the time of sunrise but without use of a sextant.

Issue No. 21. Problem 23. Recovery of GMT when no radio time check is available.

Issue No. 22. Problem 24. An emergency method for gaining the equation of time when no Almanac is available.

Issue No. 23. Problem 25. Finding due East or West when the vessel is within the tropics and declination is known.

Issue No. 24. Problem 26. Finding due East or West when the vessel is not within the tropics.

Issue No. 25. Problem 27. An emergency solar time method for determining the azimuth of the sun at various times throughout the day.

Issue No. 26. Problem 28. Use of the Moon in a method of determining direction through the course of the night.

Issue No. 27. Problem 29. An emergency method for determining latitude from stars that appear low above the horizon.

Issue No. 28. Problem 30. A simple means of polar navigation (the same as used by Peary in his 1909 expedition).

Issue No. 29. Problem 31. Use of the Star Finder to identify lesser stars that are not plotted on the base plate.

Issue No. 30. Problem 32. Use of the Star Finder to identify an unknown body that is not a star.

Issue No. 31. Problem 33. Use of the Star Finder, without calculation, to determine if the date may be optimum for a Sun-Moon fix, and to determine the relative positions of the Sun, Moon and Venus.

Address all correspondence to:
The Navigation Foundation
P.O. Box 1126, Rockville, MD 20850
Telephone 301-622-6448

# NAVIGATION PERSONALITIES

## Sir Francis Beaufort (1774-1857)

*By Roger H. Jones*

To the modern mariner the name Beaufort is associated with the international scale of wind forces that was first devised by Sir Francis. To cryptographers, the name identifies a famous cipher. However, these contributions to widely divergent areas of inquiry rather inadequately portray the enormous accomplishments of one of the nineteenth century's most gifted and complex figures.

Admiral Sir Francis Beaufort's greatest achievement was his revitalization of the Hydrographic Office and the perfecting of the Admiralty Chart. Indeed, the latter represents a standard for accuracy from the 1850's that extends to the 1990's. Some of Beaufort's own surveys, including those of the coast of Turkey, are still an official authority more than 160 years after they were first made.

Beaufort left school at the age of fourteen, and was a virtually self- educated man. He served in the Royal Navy during the Napoleonic Wars, and he suffered nineteen wounds in capturing an enemy vessel from under the guns of a Spanish fort. He also came close to death again from a fanatic's bullet while surveying the Turkish coast.

Struggling against enormous odds in a system where nobility of birth counted for much, Beaufort eventually became head of the Hydrographic Office, a post he held longer than any person before or since. He forged it into the finest chart-making and maritime science center of its age, and formed many lasting alliances with notable scientists. It was through Beaufort's connections with Cambridge scientists that Charles Darwin was selected to sail on the Beagle.

The greatest observatories at Greenwich and the Cape of Good Hope came under his administration, and for more than eight years he presided over the Arctic Council in its searches for Sir John Franklin, who was lost on his last polar voyage to discover the Northwest Passage. Nevertheless, Beaufort's career was one of alternating triumph and despair. For long years he was denied the naval advancement that he merited - so much so that the injustice done to him became notorious among his fellow naval officers. More than 2,000 letters and journals, some of them written in cipher, reveal his deep and intense personal emotional conflicts.

At age 55, an age when his present-day successors are obliged to quit the post, Beaufort finally became Hydrographer of the Admiralty. He remained in that position for more than a quarter of a century. His obsession with producing accurate charts came from a time, at the age of fifteen, when he was shipwrecked and in danger of death because of the lack of an accurate chart. That he fulfilled his quest is a fact that led to the coinage of a famous British phrase. Americans once said, in choosing a simile for integriy, "sound as a dollar," and in Great Britain the equivalent was "safe as an Admiralty chart."

It was only very late in his life that just honors were paid to him. He was knighted, given an admiral's flag, and awarded an honorary DCL from Oxford. He was also made a member of professional societies in the U.S., France and Italy, as well as in Great Britain. These honors are universally recognized in the twentieth century as richly deserved. Commander L. G. Dawson, who wrote the first history of the Hydrographic Office from a vantage point of 135 years, concluded that: "The master mind of Beaufort . . . did more for the advancement of maritime geography than was effected by all the surveyors of European countries united."

Readers of this Newsletter who want to read a remakable biography of Beaufort are directed to *Beaufort of the Admiralty*, by Alfred Friendly, Random House, New York, 1977.

# MARINE INFORMATION NOTES

*Compiled by Ernest Brown*
The following information is reprinted.

## Satellite Position Indicating Radio Beacon (EPIRB)

Emergency position indicating radio-beacons (EPIRBs), devices which cost from $200 to over $2000, are designed to save your life if you get into trouble by alerting rescue authorities and indicating your location. EPIRB types are described below:

| Type | Frequency | Description |
|---|---|---|
| Class A | 121.5/243 MHz | Float-free, automatically-activating, detectable by aircraft and satellite. Coverage limited. |
| Class B | 121.5/243 MHz | Manually activated version of Class A. |
| Class C | VHF ch 15/16 | Manually activated, operates on mari-time channels only. Not detectable by satellite. |
| Class S | 121.5/243 MHz | Similar to Class B, except it floats, or is an integral part of a survival craft. |
| Cat I | 406/121.5 MHz | Float-free, automatically activated EPIRB. Detectable by satellite anywhere in the world. |
| Cat II | 406/121.5 MHz | Similar to Category I, except is manually activated. |

121.5/243 EPIRBs. These are the most common and least expensive type of EPIRB, designed to be detected by overflying commercial or military aircraft. Satellites were designed to detect these EPIRBs, but are limited for the following reasons:

1) Satellite detection range is limited for these EPIRBs (satellites must be within line of sight of both the EPIRBs and a ground terminal for detection to occur) (see Chart).

2) EPIRB design and frequency congestion cause these devices to be subject to a high false alert/false alarm rate (over 99%); consequently, confirmation is required before search and rescue forces can be deployed.

3) EPIRBs manufactured before October 1989 may have design or construction problems (e.g. some models will leak and cease operating when immersed in water), or may not be detectable by satellite.

Class C EPIRBs: These are manually activated devices intended for pleasure craft that do not venture far offshore and for vessels on the Great Lakes. They transmit a short burst on VHF-FM channel 16 and a longer homing signal on channel 15. Their usefulness depends upon a coast station or another vessel guarding channel 16 and recognizing the brief, recurring tone as an EPIRB. Class C EPIRBs are not recognized outside of the United States.

406 MHz EPIRBs: The 406 EPIRB was designed to operate with satellites. Its signal allows a satellite local user terminal to accurately locate the EPIRB (much more accurately than121.5/243 MHz devices), and identify the vessel (the signal is encoded with the vessel's identity) anywhere in the world (there is no range limitation). These devices also include a 121.5 MHz homing signal, allowing aircraft and rescue craft to quickly find the vessel in distress. These are the only type of EPIRB which must be certified by Coast Guard approved independent laboratories before they can be sold in the United States.

An automatically activated, float-free version of this EPIRB will be required on Safety of Life at Sea Convention vessels (passenger ships and ships over 300 tons, on international voyages) of any nationality by 1 August 1993. The Coast Guard requires U.S. commercial fishing vessels carry this device (by May 1990, unless they carry a Class A EPIRB), and will require the same for other U.S. commecial uninspected vessels which travel more than 3 miles offshore.

The COSPAS-SARSAT system (COSPAS): Space System for Search of Distress Vessels (a Russian acronym; SARSAT: Search and Rescue Satellite-Aided Tracking. COSPAS-SARSAT is an international satellite-based search and rescue system established by the U.S., U.S.S.R., Canada and France to locate emergency radio beacons transmitting on the frequencies 121.5, 243) and 406 MHz. Since its inception only a few years ago, COSPAS-SARSAT has contributed to the saving of 1240 lives (as of June 6, 1989), 554 of these mariners. The Coast Guard operates two local user teminals, satellite earth stations designed to receive EPIRB distress calls forwarded from COSPAS-SARSAT satellites located in Kodiak, Alaska and Point Reyes, California. The Air Force operates a third terminal at Scott Air Force Base, Illinois.

Testing EPIRBs: The Coast Guard urges those owning EPIRBs to periodically examine them for water tightness, battery expiration date and signal presence. FCC rules allow Class A, B and S EPIRBs to be turned on briefly (for three audio sweeps, or one second only) during the first five minutes of each hour. Signal presence can be detected by an FM radio tuned to 99.5 MHz, or an AM radio tuned to any vacant frequency and located close to an EPIRB. FCC rules allow Class C EPIRBs to be tested within the first five minutes of every hour for not more than five seconds. Class C EPIRBs can be detected by a marine radio tuned to channel 15 or 16. 406 MHz EPIRBs can be tested through its self-test function, which is an integral part of the device.

# BOOK REVIEW

*By Roger H. Jones*

## Antique Scientific Instruments

by Gerard L. E. Turner

*Blandford Press, Ltd. Link House, West Street Poole, Dorset, BH15 1LL England (1980) 168 pages; 70 color plates; $15.95*

Now and then we review in these pages an older book of merit that may not be well known or which is unusual in one or more respects. *Antique Scientific Instruments* by Gerald Turner was first published ten years ago and is now out of print. Nevertheless, it may occasionally be found, and new copies (unused) may be obtained from: Harding's Scientific Antiques, 103 W. Aliso St., Ojai, California 93023, Telephone 805-646-0204.

It is a reasonably priced, compact volume that will easily fit in a small vessel bookshelf. Most books which deal with antique scientific instruments are printed in a large and heavy format suitable for coffee table display, and they tend to be very expensive. Despite its small size (5 1/2 x 8 x 3/4 inches), the 70 color plates are of excellent quality, including the 20 or so of early navigational instruments. The latter include astrolobes, quadrants, nocturnals, a universal ring, planetariums, a back-staff, an early octant, an early sextant, and other antique instruments of the navigator's art as practiced in the 15th, 16th, 17th, 18th and 19th centuries.

While the book deals with instruments for astonomy and time telling, navigation, surveying, drawing and calculating, optical purposes, medicine, weights and measures, and other purposes, its sections on astronomy and navigation are particularly interesting. Turner presents succinct text on the history and use of over 40 different types of early astronomy and navigation instruments, including some that many readers may never have heard of. How many have heard of the dipping needle invented by Elizabethan navigator, Robert Norman, in the late 1570s? How many are familiar with the reflecting circle, whose ultimate accuracy exeeded that of the sextant, and which was used after 1750 in determining longitude by the lunar distance method?

Turner was a Curator of the Museum of the History of Science at Oxford University. He is an internationally recognized authority on antique scientific instruments with a wide range of publications to his credit. Navigators will find that they do not stop after the sections on astronomy and navigation. They will go on into surveying and drawing, because of the relevance of those subjects to navigation then and now. Indeed, in the middle of the section on surveying, there jumps out at the reader a table showing the magnetic declination (variation) at London from 1580 to 1910 which documents the shift from 11 degrees, 15 minutes east to 24 degrees, 38 minutes west from 1580 to 1818 (35 degrees in 238 years).

In the section on drawing and drafting, the astute modern navigator will be interested in the pantograph and eidograph, early instruments for reducing or enlarging drawings. This reviewer keeps a modern pantograph aboard to copy nautical charts in a larger or smaller scale. The not so squeamish modern navigator may even delve into the section on early medical instruments. It will renew his or her faith in the ability in 1991 to deal with shipboard medical problems in a somewhat more satisfactory manner than was prevalent 300 years ago. (Trepanning was done with a trepan saw that bored a hole in the skull to release demons causing headaches. That was in the early 17th century. O, ye navigators, thank heaven for aspirin!)

From microscopes to telescopes, quadrants to sextants, sand-glasses to chronometers, and from lodestones to compasses, this book is fascinating. If the reader is into hardware, Harding's (as mentioned above) will steer you towards the 18th century ebony and ivory octant that you've long coveted, or perhaps merely the 1940 brass sextant that you've searched for. Turner will also counsel you on dating old instruments and on collecting. He'll whet your appetite for at least an armchair journey into the past of Prince Henry the Navigator, Columbus, Cook, John Hadley, John Harrison, and many long-forgotten captains of the treasure and exploration fleets.

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# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-FOUR, WINTER 1991

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Disadvantaged Youth Program

*Tandemeer* is finally in a material condition to be utilized as was visualized by Rear Admiral Davies when the Foundation originally considered acquiring a boat. His intent was to use *Tandemeer* for members, who were developing navigational techniques and equipments, to have a platform from which to experiment. We also visualized programs to promote interest in navigation, while at the same time assisting disadvantaged youths in focusing their abilities by providing them a goal.

To that end, work has progressed over the last several years rebuilding the electrical system, acquiring new sails and doing the myriad of things that are required to make any boat a reliable and safe vessel. *Tandemeer* is now ready to carry out the Foundation's purposes.

In furthering the desire to help disadvantaged youth, I gave a presentation to the Kiwanis at their monthly meeting on the evening of 14 November 1991. The acceptance of the idea of joining them in their program of helping disadvantaged youth was overwhelming. Many of the members immediately volunteered to provide their services. Thus, the Foundation has joined with the Kiwanis of Olney, Maryland in working with and teaching disadvantaged youth the fundamentals of safe boating, sailing, piloting and navigation.

The Olney Kiwanis club has had a long history of working with the Regional Institute for Children and Adolescents (RICA). This work provides us with the necessary organization to fulfill our goal of providing these youth with help and an opportunity to achieve. The coordinated efforts of the Olney Kiwanis and RICA will help the Foundation in providing adult supervision during the boating trips.

### Navigation Courses

Member William O. Land is currently providing celestial navigation instruction. If anyone in the Norristown, Pennsylvania area is interested, please write Bill Land, 1521 W. Main Street, (E-1) Norristown, PA 19403 or call (215)539-0790.

### Index

The Index of back issues and articles has been completed and will be published as part of the Spring 1992 newsletter.

## READERS FORUM

We have a number of letters that were received some time ago, and which have not yet been included in this Forum due to the interruption of our Newsletter sequence by the special issue on Admiral Davies. We apologize for the delay, and include them below.

**Richard M. Tishler**, a retired merchant marine captain from Baldwin, NY has written an interesting letter about the apparent similarities between his vintage Plath sextant and the one used by Peary. He notes: "An old Norwegian captain (Frederick Larsen) taught us to polish the silver arc (as infrequently as possible) with a tiny pinch of cigarette ash and to lubricate it with a drop of gyro compass oil. To this day, the arc graduations are as clear, legible and accurate as ever."

**Anthony Kelly** of Hicksville, New York has inquired if any work is being done on a "salvage" technique for sights over 80° for use with the *Nautical Almanac* sight reduction method. He recalls, of course, that there were several techniques for use with H.O. 211 (the Ageton Tables) to salvage sights when K was between 85° and 95°. In answer, John Luykx has written to the Naval Observatory Nautical Almanac Office, but there has been no answer to date.

From Vero Beach, Florida, **Henry L. Gauntt**, has written that he has reworked two WW II Fairchild A10 bubble sextants, and he can furnish instructions that will aid another in doing this. He may be reached at 495 Nieuport Drive, Vero Beach, FL 52968.

**Major G. W. Waxler**, USAF (Ret.), of 1599 Amy Ave., Jensen Beach, FL 34057 is interested in hearing from any reader who may have information on the brass vernier sextant (with silver insert scale) that was manufactured by J. W. Ray & Coy of Liverpool, England.

We have received several interesting letters from **Stanley Rosen** of Orlando, FL in regard to an invention by Richardson O. Browning dealing with "Improvement in or Relating to Angle Measuring Instruments." John Luykx, in the course of this correspondence, also received a copy of the Canadian Patent and a photograph of the patent model. John is conducting an evaluation of the documentation and of what appears to be an interesting artificial horizon sextant as devised by Browning. The patent was issued in 1949, and it appears that the sextant incorporated several improvements that have not been incorporated in commercially available artificial horizon sextants. Members interested in these devices may wish to contact John Luykx by writing to the Foundation.

**Steven F. Olson** is a minerals exploration geologist working in landlocked Mali in West Africa. He uses an artificial horizon and sextant for determining locations in the bush. He would be interested in hearing from any reader who can furnish references on the reduction of astronomic coordinates to geodetic coordinates. The Foundation is in the process of tracking down some possible references, but we urge any reader with information on this to write to him at: BHP-Utah Minerals Exploration, 550 California Street, San Francisco, CA 94104.

**Dr. Carlos Perez Martinez**, P.O. Box 783, Bucaramanga, Columbia, is a reseacher into old methods of navigation, and is particularly interested in the methods that may have been emlployed by Columbus. He has written an article on this and is interested in hearing from others who may have conducted research on Columbus' methods and the methods used by other mariners of even earlier periods.

**Walter R. Johnson** of 705 Americana Drive, #35, Annapolis, Maryland 21403, spotted an error in the article on chronometer error that was published in Issue 30. This error related to the GHA of Procyon. Any other readers who spotted this may wish to write to him. In addition, he has forwarded a set of computations relating to great circle courses. Due to the wealth of material that we have for Issue 34, we are unable to include this material, but readers interested in great circle course computations may also wish to write to Mr. Johnson.

Finally, we are in further correspondence with **C. Huguenin**, Switzerland's Charge 'd'affaires in Tripoli. He has furnished a 32-page document entitled "Land Navigation: The Sun Compass - How To Make Your Own." This document is quite detailed with clear illustrations. Any reader wishing a copy should write to the Foundation, or to Mr. Huguenin: The Charge d'affaires of Switzerland, C. Huguenin (Tripoli), DFAE/Section Courrier, 3003 Berne, Switzerland. Mr. Huguenin would also be interested in hearing from anyone willing to sell to him an "Abrams" sun compass or a Hughes Bubble Sextant.

# NAVIGATION BASICS REVIEW

## The Accuracy of Mechanical, Spring-Wound Navigation Chronometers and Deck Watches

*By John M. Luykx*

Although the quartz chronometer and watch have largely replaced mechanical spring-wound instruments for navigation use, a large number of the latter are still in use today either as the principal time reference aboard ship or as a substitute or "back-up" navigation timepiece.

The accuracy of the modern quartz movement is well-known; some quartz chronometers achieving a daily rate of less than 0.03 seconds; i.e., less than 1 second per month with little variation in the daily, weekly or monthly rates. With such a timepiece, it is possible to predict the correct time to within a second or two at the end of a year's time without benefit of a time check during the entire twelve month period.

Accuracy of this order is not possible with the mechanical spring-wound movement. However, tests of mechanical chronometers and deck watches manufactured by the more famous English, French, Swiss, German, Japanese and American makers show that remarkable accuracy is possible with these instruments when they are properly adjusted and managed. The accuracy to be expected from the mechanical movement can best be determined by testing a number of such watches and chronometers which have been specifically designed for use in either air or marine navigation.

Using a two-day chronometer and a number of two and eight day deck watches (both gimballed and ungimballed) from the author's collection of navigation timepieces, a test was conducted during the spring of this year to determine how well each instrument maintained its daily and weekly rate over a period of two weeks and how accurately each could then predict the correct time over a period of four successive weeks without a time check.

In essence the best timepiece is that which predicts time with the greatest accuracy; i.e., the timepiece which has a minimum daily/weekly rate as well as a minimum rate of change of rate.

### Test Instruments

The chronometer and watches used during the test were:

#1 Hamilton, Model 21, 85 size (4.0" dial) full size, twelve-hour dial, two-day chronometer. Overhauled March 1988 (Fig. 1)

#2 Hamilton, Model 22, 35 size (2.4" dial) twelve-hour dial, two-day deck watch, gimballed. Overhauled February 1991 (Fig. 2)

#3 Hamilton, Model 22, 35 size (2.4" dial) twelve-hour dial, two-day deck watch, ungimballed. Overhauled April 1988 (Fig. 3)

#4 Hamilton (A) Model 4992B, 16 size (1.7" dial) two-day, 24-hr. dial, GMT master navigation watch. Overhauled February 1991 (Fig. 4)

#5 Hamilton (B) Model 4992B, 16 size (1.7" dial) two-day, 24-hr. dial, GMT master navigation watch. Overhauled February 1989 (Fig. 4)

#6 Hamilton (C) Model 4992B, 16 size (1.7" dial) two-day, 24-hr. dial, GMT master navigation watch. Overhauled February 1989 (Fig. 4)

#7 Hamilton (D) Model 4992B, 16size (1.7" dial) two-day, 24-hr. dial, master navigation watch set to sidereal time. Overhauled February 1986 (Fig. 4)

#8 Waltham, 37 size (2.5" dial) eight-day, gimballed 12-hr. dial deck watch. Overhauled June 1989 (Fig. 5)

#9 Waltham, 37 size, (2.5" dial) eight-day, gimballed 12-hr. dial deck watch. Overhauled March 1990. (Fig. 5)

Note: The timepieces #1-#7 are fitted with a monometallic balance wheel and *Elinvar* hairspring. Timepieces #8 and 9 are fitted with bi-metallic balance wheel and steel hairspring.

## The Test

The test was conducted during the period 8 April 1991 - 27 May 1991 at an ambient temperature which varied from 73° to 75° F.

1. The period from 8 to 15 April was devoted to the adjustment of each timepiece so that its daily rate would be within 2 seconds per day.

2. During the period 15 April to 29 April, the mean weekly rate of each timepiece was computed.

3. During the period 29 April - 27 May (at weekly intervals, May 6, May 13, May 20 and May 27) the actual error of each timepiece was compared to the error predicted by the timepiece based on the weekly rate computed during the period 15-29 April.

4. All the timepieces were wound at 0900 each day. At the time of winding, the error was determined from WWV time signal and recorded in a log.

## Test Results

Test results are given below in Tables 1 and 2.

Table 1 shows for each timepiece:

a.) The computed weekly rate in seconds for the period 15-29 April.

b.) The actual error in seconds on Monday 6 May, 13 May, 20 May and 27 May.

c.) The error of the timepiece in seconds as predicted for Monday, May 6, May 13, May 20 and May 27 based on the weekly rate computed during the period 15-29 April.

d.) The difference between the predicted error and the actual error in seconds for each timepiece on Monday, May 6, May 13, May 20 and May 27.

e.) The variations in the difference from the prior week.

Table 2 shows:

The mean error of prediction for all timepieces tested.

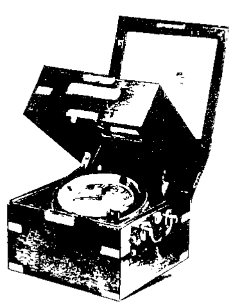


Fig. 1

Fig. 2

Fig. 3

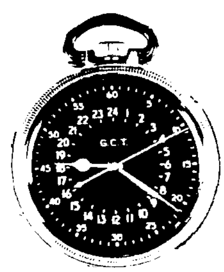


Fig. 4

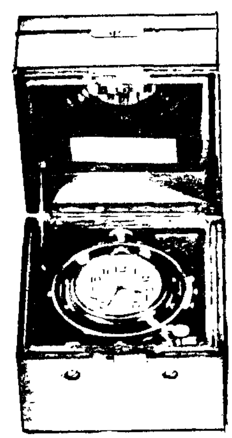


Fig. 5

TABLE I

### Timepiece #1 — Hamilton Model 21 Chronometer

1. Weekly Rate:

Error: 15 April: +9.0
Error: 29 April: +24.1
(15.1/2)
Weekly Rate: +7.6

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | 34.1 | 31.7 | -2.4 | - - - |
| 13 May | 44.7 | 39.3 | -5.4 | 3.0 |
| 20 May | 56.2 | 46.9 | -9.3 | 3.9 |
| 27 May | 65.2 | 54.5 | -10.7 | 1.4 |

### Timepiece #2 — Hamilton Model 22 Gimballed Chronometer Watch

1. Weekly Rate:

Error: 15 April: -7.5
Error: 29 April: -17.0
(-9.5/2)
Weekly Rate: -4.8

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | -21.2 | -21.8 | +0.6 | - - - |
| 13 May | -24.3 | -26.6 | +2.3 | +1.7 |
| 20 May | -30.3 | -31.4 | +1.1 | -1.2 |
| 27 May | -37.8 | -36.2 | -1.6 | -2.7 |

### Timepiece #3 — Hamilton Model 22 Deck Watch

1. Weekly Rate:

Error: 15 April: -11.0
Error: 29 April: - 0.2
(10.8/2)
Weekly Rate: +5.4

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | +4.5 | +5.2 | +0.7 | - - - |
| 13 May | +7.8 | +10.6 | +2.8 | +2.1 |
| 20 May | +15.0 | +16.0 | +1.0 | -1.8 |
| 27 May | +26.3 | +21.4 | -4.9 | -5.9 |

### Timepiece #4 — Hamilton Model 4992B Navigation Watch

1. Weekly Rate:

Error: 15 April: -8.0
Error: 29 April: -24.8
(-16.8/2)
Weekly Rate: -8.4

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | -32.7 | -33.2 | +0.5 | - - - |
| 13 May | -44.0 | -41.6 | -2.4 | -2.9 |
| 20 May | -58.2 | -50.0 | -8.2 | -5.8 |
| 27 May | -71.2 | -58.4 | -12.8 | -4.6 |

### Timepiece #5 — Hamilton Model 4992B Navigation Watch

1. Weekly Rate:

Error: 15 April: -11.0
Error: 29 April: -10.2
(0.8/2)
Weekly Rate: +0.4

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | -16.5 | -9.8 | -6.7 | - - - |
| 13 May | -13.5 | -9.4 | -4.1 | +2.6 |
| 20 May | - 7.0 | -9.0 | +2.0 | +6.1 |
| 27 May | - 5.2 | -8.6 | +3.4 | +1.4 |

### Timepiece #6 — Hamilton Model 4992B Navigation Watch

1. Weekly Rate:

Error: 15 April: -20.5
Error: 29 April: -41.0
(-20.5/2)
Weekly Rate: -10.3

2. Error:

| *Date* | *Actual* | *Pred.* | *Diff.* | *Var.* |
|---|---|---|---|---|
| 6 May | -53.5 | -51.3 | -2.2 | - - - |
| 13 May | -65.0 | -61.6 | -3.4 | -1.2 |
| 20 May | -75.3 | -71.9 | -3.4 | 0.0 |
| 27 May | -89.3 | -82.2 | -7.1 | -3.7 |

Timepiece #7 — Hamilton Model 4992B Navigation Watch Set to Sideral Time

1. Weekly Rate:

| | | |
|---|---|---|
| Error: | 15 April: | +17.0 |
| Error: | 29 April: | +27.5 |
| | | (10.5/2) |
| Weekly Rate: | | +5.3 |

2. Error:

| Date | Actual | Pred. | Diff. | Var. |
|---|---|---|---|---|
| 6 May | +32.5 | +32.8 | +0.3 | - - - |
| 13 May | +35.5 | +38.1 | +2.6 | +2.3 |
| 20 May | +41.0 | +43.4 | +2.4 | -0.2 |
| 27 May | +45.0 | +48.7 | +3.7 | +1.3 |

Timepiece #8 — Waltham, 37 size, 8-day Gimballed Chronometer Watch

1. Weekly Rate:

| | | |
|---|---|---|
| Error: | 15 April: | -22.0 |
| Error: | 29 April: | -18.0 |
| | | (4.0/2) |
| Weekly Rate: | | +2.0 |

2. Error:

| Date | Actual | Pred. | Diff. | Var. |
|---|---|---|---|---|
| 6 May | -16.5 | -16.0 | -0.5 | - - - |
| 13 May | -14.5 | -14.0 | -0.5 | 0.0 |
| 20 May | -23.0 | -12.0 | -11.0 | 10.5 |
| 27 May | -26.4 | -10.0 | -16.4 | -5.4 |

Timepiece #9 — Waltham, 37 Size, 8-Day Gimballed Chronometer Watch

1. Weekly Rate:

| | | |
|---|---|---|
| Error: | 15 April: | +0.2 |
| Error: | 29 April | +4.3 |
| | | (4.1/2) |
| Weekly Rate: | | +2.1 |

2. Error:

| Date | Actual | Pred. | Diff. | Var. |
|---|---|---|---|---|
| 6 May | +6.8 | +8.4 | +1.6 | - - - |
| 13 May | +10.4 | +8.5 | -1.9 | -3.5 |
| 20 May | +11.4 | +10.6 | -0.9 | +1.0 |
| 27 May | +11.8 | +12.7 | +0.9 | +1.8 |

TABLE 2

| Week | Time Period | Mean Absolute Error of Prediction |
|---|---|---|
| 1 | 4/29-5/6 | +1.7 seconds |
| 2 | 4/29-5/13 | +2.8 seconds |
| 3 | 4/29-5/20 | +4.4 seconds |
| 4 | 4/29-5/27 | +6.8 seconds |

## Conclusion

When maintained in a stable environment and wound daily, most mechanical spring-wound chronometers and watches designed for navigational use will provide sufficient accuracy to predict time (without a time check) to within a few seconds per month. At sea, however, due to the continually changing environment and the effects of vessel motion in a seaway, it is anticipated that the accuracy of prediction will be reduced to some degree. Nevertheless, the test results indicate that the mechanical chronometer and navigation deck watches when used at sea will provide sufficient accuracy for modern navigation purposes, even under the extraordinary circumstance when a time check may not be available for a period of two or three or even more weeks.

# HISTORY OF NAVIGATION

## The Quincentenary of the First Columbus Voyage to the Americas

*by John M. Luykx*

In October 1992 the nation will celebrate the 500th anniversary of Columbus' first landfall in the Western Hemisphere. As a maritime achievement, the first voyage of Columbus from 3 August through 12 October must be reckoned as an event of the greatest historical importance. Many scholars, especially in recent years, have devoted the greater part of their lives and energies in researching, analyzing and describing the personal and public events which influenced the planning, administration and direction of this momentous voyage. The results of many of these studies, including biogaphical works, have been published in English and are available to the public in libraries and in book stores.

Books of parallel interest dealing particularly with fifteenth century navigation techniques and seamanship practice are also available in large number. These are invaluable to the reader/yachtsman/navigator who desires to truly assess the magnificence of Columbus' achievement as a mariner and as an expedition leader who ventured into the unknown Western Atlantic in 1492.

All of the excellent works on Columbus and 15th century navigation are too numerous to mention here. The following works are recommended as they are valuable sources, are readily available and should be of particular interest to navigators:

*Admiral of the Ocean: A Life of Christopher Columbus* by Samuel Eliot Morison. Little, Brown 1942.

*The European Discovery of America: The Southern Voyages 1492-1616* by Samuel Eliot Morison. Oxford University Press 1974. The late Admiral Morison is the chief modern advocate of the argument that Watling Island; i.e., San Salvador Island, is the site of the October 12, 1492 landfall in the eastern Bahamas.

Of equal interest, and in contrast to Morison, is *The Log of Christopher Columbus*, translated by Robert H. Fuson and published by the International Marine Publishing Co. in 1987. Dr. Fuson is an advocate of Samana Cay as the landfall site of Columbus' first voyage, a point 65 miles South South East of Watling Island.

An excellent discussion of recent thinking regarding the true point of the Columbus landfall in the Bahamas is given in the November 1988 issue of the National Geographic Magazine in an article by Joseph Judge entitled *Where Columbus Found the New World.* Also included in this issue is an interesting description of the *Nina* as well as a series of charts showing a detailed analysis of Columbus' track across the Atlantic and among the eastern Bahama Islands, based on current and leeway data applied to Columbus' log entries.

Other interesting narratives of his life are:

1. *Christopher Columbus* by Salvador de Madrariaga originally published by MacMillan in 1940 and republished in 1978 in paperback; *Columbus and the Conquest of the Impossible* by Felipe Fernandez-Armesto, Saturday Review Press 1974 is particularly interesting for its profuse illustrations.

2. In the *Seafarers* collection of Time-Life Books (1978), the volume entitled *Explorers* by Richard Humble contains a chapter entitled *West From Spain to a Vast New World* which describes in broad terms the epic voyages of Columbus. Of interest in the chapter are eight different Columbus portraits as well as a drawing of the "Nina". This chapter could well serve as an excellent introduction to the life and achievements of Columbus.

3. Peter Stanford, President of the National Maritime Historical Society, 132 Maple Street, Croton-on-Hudson, New York 10520, Tel. 914-271-2177, has written, as of this date, five extremely informative articles on the life of Columbus in *Sea History* magazine, the official publication of the Society. The articles so far published are included in the Spring 1980, Summer 1990, Autumn 1990, Winter 1990 and Summer 1991 issues. Mr. Stanford plans two more articles in the series to be published in the Autumn 1991 and Winter 1991 issues of *Sea History*.

4. A humorous article by Donald Dale Jackson entitled *"Who the heck did 'discover' the New World?"* in the September 1991 issue of Smithsonian Magazine should not be overlooked. Chinese, Japanese, Irish, Welsh, English and Viking seafarers may all have visited America before Columbus, according to the author.

For readers interested in navigation methods in use during the 14th through 16th centuries, the following works are recommended:

1. *Portugal-Brazil The Age of Atlantic Discoveries.* The Brazilian Cultural Foundation 1990. This book in paperback accompanied the exhibition Portugal-Brazil at the New York Public Library June 2 to September 1, 1990. Included in this book are excellent chapters on *The Art of Astronomical Navigation* by Luis de Albuquerque and *Exploring the Atlantic* by Francis M. Rogers.

2. *The Divided Circle, A History of Instruments for Astronomy, Navigation and Surveying* by J. A. Bennett, Phaidon Christies. Oxford 1967. Chapter 2 entitled *The Beginnings of Oceanic Navigation* is particularly valuable.

3. *The Haven Finding Art, A History of Navigation from Odysseus to Captain Cook* by E.G.R. Taylor, American Elsevier Publishing Co. 1971. Chapters 7 and 8, *The Portugese Pioneers* and *The Errors of the Compass* and *Plain Chart* describe navigation methods at the time of the Columbus voyages.

4. *The Art of Navigation in England in Elizabethan and Early Stuart Times* by D. W. Waers, Yale University Press 1958. Chapter II of Part I entitled *The Development of the Art of Navigation* contains a valuable and comprehensive discussion of the state of the art of navigation at the end of the 15th Century and during the early decades of the 16th Century.

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

In the last issue there appeared a listing of the thirty-three previous problems that have dealt with distinctly different aspects of celestial navigation. Some related to the basics, and some involved more sophisticated concepts. We've had comments from experts and from novices. On the basis of these comments, we pause at this point and return to the basics in a somewhat different form.

In this and the next several issues, we will address the underlying theory of celestial navigation—not in a manner that will require the reader to push a pencil or delve into tables - but in a manner that will ask the reader to delve into the recesses of his or her own mind. The approach will be to ask and answer some questions in a purely narrative form. The perspective throughout will be: (1) the basic principle underlying celestial and all forms of navigation; (2) the great navigational triangle; (3) the tools of the navigator; and (4) what one is really doing when he uses the tools to make a sextant observation, determine Greenwich or local hour angle, or determine an azimuth and altitute intercept.

Problem No. 34.

What is the basic principle underlying all forms of navigation, and in celestial navigation what is the great navigational triangle?

# NAVIGATION PERSONALITIES

## George W. Mixter (1877 - 1947)

*By Roger H. Jones*

George Webber Mixter was born in Rock Island, Illinois. His boyhood years and his career path would not have suggested to his peers that he would, late in his life, become the author of the *Primer of Navigation*, which was a major contribution to the science of navigation and to the training program of the armed services of the United States in World War II.

As a boy of ten, young Mixter got out a newspaper with two friends, setting the type himself. He also operated his own private telegraph line, and built a canoe in which he cruised the length of the Connecticut River. Other favorite pastimes were camping, fishing, hunting, and photography. At the age of nineteen he was graduated from Yale's Sheffield Scientific School with a degree in electrical engineering, and in the summer of 1896 he went to work for Deere & Webber in Minneapolis, a distributor of Deere farm machinery. Soon thereafter he joined the Deere Company itself, and was an early cost accountant and production line innovator. He became vice president in charge of manufacturing.

In 1917 he left Deere to enter the U.S. Army's Air Service as a major. Rising to the rank of Colonel, he became Chief of Aircraft Production and Inspection. After World War I, he was a partner in engineering firms in Philadelphia and New York until his death in 1947.

Between the wars Colonel Mixter took part in the 1926 and 1928 Bermuda races aboard Findley Downs' schooners, *Black Goose* and *Malabar VIII*. Not daunted by the loss of one eye in a yachting accident in 1927, he began in 1928 the construction of his own schooner, *Teragram*.

Mixter absorbed everything he could about navigation, and became an able skipper and navigator in the Bermuda races of the 1930s. One of his first shipboard pupils was Chick Larkin, who was to become a prominent navigator in his own right.

Throughout the 1930s navigation became Mixter's consuming hobby, and the first edition of *Primer of Navigation* was published in 1940. His lecture, "Lighthouses in the Sky," given at the Franklin Institute in 1958 was widely hailed as a great contribution toward simplification of navigation for the layman, and it later became a chapter in his book.

His researches put him in touch with navigators and astronomers in the U. S. and abroad, including many men of navigational science at the U. S. Naval Observatory, and U. S. Coast Guard, and the Hydrographic Office. These colleagues recognized the contributions that this amateur student of celestial navigation made to the vastly improved *Air* and *Nautical Almanacs*, beginning with the *Air Almanac* in 1933.

By 1940 Europe was ablaze, and America was arming. *Primer of Navigation* quickly became a standard text, and more than 100,000 wartime navigators learned their trade from the *Primer*. It was a work that took the mystery out of the underlying science, and it was presented in a style and a layman's language that appealed to professionals and amateurs alike.

The sixth edition, published in 1979 by Van Nostrand Reinhold Company, is testament to the work started aboard *Teragram* with Mixter's notes and observations in the late 1920s. George W. Mixter was, indeed, a bit of the "Renaissance Man" in his wide range of interests and accomplishments. The art and science of celestial navigators in the days before the electronic black boxes were his beneficiaries.

# MARITIME INFORMATION NOTES

*Provided by Ernest Brown*

## Tidal Current Tables Corrections

Current predition for Aransas Pass based on Table 2 corrections on Galveston as published in NOAA's *Tidal Current Tables 1991 - Atlantic Coast of North America* may deviate from the times of actual tidal currents by as much as 2 hours. Maximum observed current velocities may at times be double the predicted velocities.

Oceanographic measurements were acquired in 1990 in the Aransas Pass-Corpus Christi area to address the quality assurance (QA) of (NOAA) current preditions. The differences result from dredging, filling, shoaling, and other modifications both at Aransas Pass and its reference station Galveston, Texas. Funding for a new circulation survey of the Aransas Pass-Corpus Christi area to correct this problem is presently not available.

## SafetyNET Trials

Prior to the introduction of the Global Maritime Distress and Safety System (GMDSS) on 1 February 1991, tests will be run on SafetyNET to:

a) verify that Enhanced Group Call (EGC) SafetyNET will provide services as designed for broadcast of Maritime Safety Information (MSI)

b) help registered information providers. e.g. the Defense Mapping Agency, gain experience in SafetyNET operations, and

c) finalize development of the Operational Guidance, Annex 4, of the Provisional International SafetyNET Manual.

Tests are anticipated to commence on or about 1 October 1991. The Defense Mapping Agency expects to promulgate NAVAREA IV and XII navigational warnings via INMARSAT commercial satellites. Users of an INMARSAT-C terminal or an INMARSAT-A terminal with EGC capability will be able to copy these satellite transmissions provided their terminal has been commissioned and they have selected the appropriate broadcast channel of that ocean region's satellite.

## The SafetyNET System

SafetyNET is an international automatic direct-printing satellite-based service for the promulgation of navigational and meteorological warnings, meteorological forecasts and other urgent safety related messages—Maritime Safety Information (MSI)—to ships. It has been developed as a safety service of INMARSAT's EGC system to provide a simple and automated means of receiving MSI on board ships at sea and in coastal waters, where appropriate. The information transmitted is relevant to all sea-going vessels and the message selection features ensure that mariners can receive safety information broadcasts tailored to their particular needs.

SafetyNET will fulfill an integral role in GMDSS developed by the International Maritime Organization (IMO) and incorporated into the 1988 amendment to the International Convention for the Safety of Life at Sea (SOLAS) 1974 as a requirement for ships to which the Convention applies. The ability to receive SafetyNET service information will be generally necessary for all ships which sail beyond coverage of NAVTEX (approximatley 200 miles from shore) and is commended to all administrations having responsibility for maritime affairs and mariners who require an effective MSI service in waters not served by NAVTEX.

SafetyNET offers the ability to direct a call to a given geographical area. The area may be fixed, as in the case of a NAVAREA or weather forecast area, or it may be uniquely defined by the originator. This will be useful for messages, such as a local storm warning or a shore-to-ship distress alert, for which it is inappropriate to alert ships in an entire ocean region.

SafetyNET messages can be originated by a Registered Information Provider anywhere in the world and broadcast to the appropriate ocean area via an INMARSAT-C Coast Earth Station. Messages are broadcast according to their priority, i.e. distress, urgent, safety, and routine.

Virtually all navigable waters of the world are covered by the operational satellites in the INMARSAT system. Each satellite transmits EGC traffic on a designated channel. Any ship sailing within the coverage area of an INMARSAT satellite will be able to receive all SafetyNET messages broadcast over this channel. The EGC channel is optimized to enable the signal to be monitored by a small receive-only ship earth station which is dedicated to the reception of EGC message. This capability can be built into other standard ship earth stations. It is a feature of satellite communications that reception is not generally affected by the position of the ship within the ocean region, atmospheric conditions or time of day.

# FEATURE

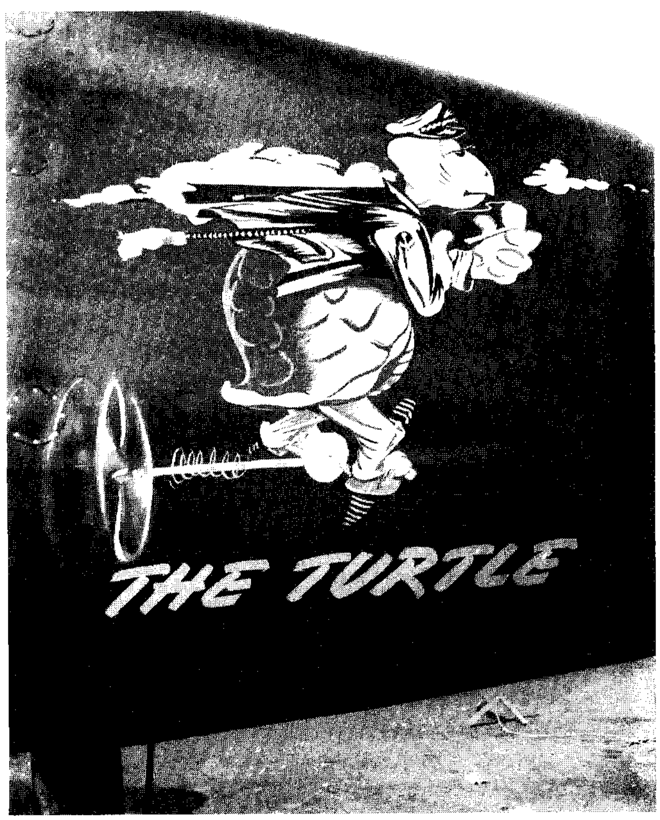
## Flight of the Truculent Turtle

*By Commander Edward P. Stafford, U.S. Navy (Retired)*

*EDITOR'S NOTE: The following article first appeared in the August issue of the U.S. Naval Institute Proceedingss. Reprinted with special permission from the U.S. Naval Institute.*

Truculent—1: feeling or displaying ferocity; cruel, savage; 2: deadly, destructive; 3: scathingly harsh, vitriolic; 4: aggressively self-assertive, belligerent. No matter which definition you use, this turtle—and most notably its crew—boldly took off in 1946 to set a flight distance record that would stand for 16 years.

Commander Tom Davies, U.S. Navy, stood on the brakes and pushed both throttles forward to takeoff power. At the other end of the mile-long runway, he could make out a knot of news photographers. Scattered across the air base, hundreds of picnickers stood at the



sound of the engines and riveted their attention to the plane. But for Davies and the four-man crew, this was no picnic. He and Commander Gene Rankin, U.S. Navy, in the co-pilot's seat, scanned the engine instruments. All normal, Davies then released the brakes, and the "Truculent Turtle" began to roll. On this day, 29 September 1946, the Turtle was a veritable winged gas tank, 15 tons over maximum gross weight with fuel, so heavy it could not taxi for fear of breaking the landing gear in a turn (the fuel had been loaded in takeoff position on the runway).

The plane rumbled and jounced slightly, as the speed built up. As each 1,000-foot sign went by, Rankin called out the speed and compared it to predicted figures on a clipboard in his lap. With the second sign astern, the Turtle was committed. Davies could no longer stop the charging, gas-filled aircraft on the runway. It was now, quite literally, fly or burn.

When the wavering airspeed needle touched 105 knots, Davies punched a button jury-wired to his yoke, and four jet-assisted takeoff bottles (JATO) fired from their attachment points aft on the fuselage. The crew could hear the roar of the bottles and feel their push. For a critical 10 seconds they provided the thrust of a third engine. The 4,000-foot sign and 115 knots came up at the same time, and Davies pulled the nose wheel off. There were some long seconds while the main wheels continued to rumble on the last of the runway, then they were still, spinning silently as the last pounds of weight were shifted to the wings, and the Turtle flew.

The instant he was sure he was airborne Davies called "gear up" and jerked his right thumb upward. Rankin hit the wheel-shaped actuator on the pedestal betwen the pilots, and the gear came up. The wheel doors closed just as the JATO burned out. Behind the pilots, Commander Walt Reid kept his hand on the dump valve that could drop 500 galloms of fuel a minute. Lieutenant Commander Roy Tabeling, at the radio position, kept all his switches off for now to prevent the slightest spark.

Now the Turtle was out over the Indian Ocean. With agonizing deliberation, altimeter and airspeed crept upward. Walt Reid jettisoned thempty JATO bottles. At 125 knots—stall speed with flags up—Rankin started the flaps coming in by careful small increments. At 165 knots Davies made his first power reduction, back to maximum continuous.

The sun was setting and the lights of the city blinking on as the Turtle circled back over Perth at 3,000 feet and headed out across the 1,800 miles of the central desert of Australia. On this record-breaking flight, one already had been broken. Never before had two engines carried so much weight into the air.

The plan was to stay low—about 3,500 feet—for the first few hundred miles, burning off fuel and reducing weight so the climb to cruising altitude would require less gas. But the southwest wind, burbling and eddying across the hills northeast of Perth, brought turbulence that shook and rattled the overloaded Turtle, threatening the integrity of the wings themselves. Davies took her up to 6,500, where the air was smoother, reluctantly accepting the sacrifice of enough fuel to fly an extra couple of hundred miles at the other end of the flight.

*Members of the crew of the P2V Neptune—The Truculent Turtle—left to right: Cdr. T.D. Davies, USN, pilot and plane commander, E.P. Rankin, USN, co-pilot; W.S. Reid, USN, co-pilot and navigator; and, Lt. Cdr. R.H. Tabeling, USN, communications officer.*

Alice Springs at Australia's center slid under the long wings at midnight and Cooktown on the northeast coast at dawn. Then it was out over the Coral Sea where only just more than three years before the *Lexington* (CV-2) and *Yorktown* (CV-5) had put down the Japanese ship *Shoho* and turned back *Shohaku* and *Zuikaku* to win the first carrier battle in history and prevent the cutoff and isolation of Australia.

At noon the Turtle skirted the 10,000-foot peaks of southern New Guinea, and in mid-afternoon detoured around a mass of boiling thunderheads over Bougainville in the Solomons. As the sun set for the second time since takeoff, the Turtle's crew stood out across the vast and empty Pacific Ocean and established an "at sea" routine, standing two-man, four-hour watches, washing, shaving, and changing to clean clothes each morning, eating regular meals. The two Wright 3350 engines ran smoothly—on all the gauges the needles were in the green—and every hour another 200 miles of the Pacific had passed astern. The crew's only worry was Joey, a nine-month-old, 35-pound female kangaroo destined for the Washington Zoo. She had hunched unhappily in her crate and refused to eat or drink.

Dawn of the second morning found the Turtle over Maro Reef, halfway between Midway and Oahu in the long chain of Hawaiin Islands. In the first voice-radio contct of the flight, Honolulu Radio warned of icing and severe turbulence over Seattle, the Turtle's planned landfall in the united States. Davies changed course to hit the coast in northern California, dropped the empty 200-gallon fuel tanks from the wing tips and eased up to

10,000 feet. At noon Reid came up to the cockpit smiling. "Well," he reported, "the damned kangaroo has started to eat and drink again. I guess she thinks we're going to make it."

The mission in which Joey's dim marsupial brain may or may not have acquired confidence was no stunt, despite her presence. In this early fall of 1946, the increasingly hostile Soviet Union was pushing construction of a submarine force nearly ten times larger than Adolf Hitler's at the start of World War II. Antisubmarine warfare was the Navy's responsibility. The Truculent Turtle was the first of the P-2V "Neptune" patrol planes designed to counter the sub threat. Tom Davies' orders derived straight from the office of Secretary of the Navy James V. Forrestal and the Chief of Naval Operations, Fleet Admiral Chester W. Nimitz. A dramatic demonstration was needed to prove beyond question that the new patrol plane, its production representing a sizeable chunk of the Navy's skimpy peacetime budget, could do the job. With its efficient design that gave it four-engine capability on two engines, the mission would show the Neptune's ability to cover the transoceanice distances necessary to perform its ASW and sea-surveillance functions. And at a time when roles and missions were being developed to deliver nuclear weapons, it would not hurt a bit to show that the Navy, too, had that capability.

So far, the flight had gone according to plan. But now as the second day in the air began to darken, the Pacific sky, gently clear and blue for so long, turned rough and hostile. An hour before landfall, great rolling knuckles of cloud punched out from the coastal mountains. The Turtle jolted and jarred. Ice crusted on the wings. Static blanked out radio transmission and reception. The crew strapped down hard, turned up the red instrument lights and took turns trying to tune the radio direction finder to a recognizable station. It was midnight before Roy Tabeling, with his years of electronics training and experience, succeeded in making contact with the ground and requested an instrument clearance eastward. A delightfully female voice reached up through the murk from Williams Radio, 70 miles south of Red Bluff, California.

*Ground crew members wave goodbye.*

"I'm sorry," the voice said. "I don't seem to have a flight plan on you. What was your departure point?"

"Perth, West Australia."

"No, I mean where did you take off from?"

"Perth, West Australia."

"Navy, zero eight two, you don't understand. I mean what was your departure airport for this leg of the flight?"

"Perth, West Australia."

"But that's halfway around the world!"

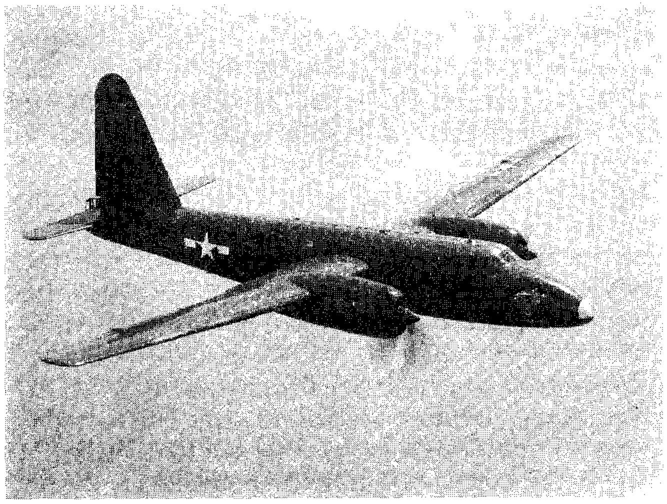
"No, only about a third. May we have that clearance?"

But the static and atmospherics closed in again, and now the weird and wonderful phenomenon of St. Elmo's fire added to the problems of the Turtle's crew. The two propellors whirled in rings of blue-white light. Violet tongues licked up between the laminations of the windshield. Eerie purple spokes protruded from the Neptune's nose. All those distracting effects would increase in brilliance with an accompanying rise in the volume of static on all radio frequencies, then suddenly discharge with a blinding flash and a thump and begin slowly to rebuild. It was not for another hour, somewhere over the cliffs and ridges of the Donner Pass, that an instrument clearance could be patched together and the flight could proceed in regulation fashion.

The St. Elmo's fire had been annoying but not dangerous. Now came a serious threat to the mission. At the left center of the instrument panel a red-lighted pointer that all during the flight had been aligned parallel to its mate—as though a pair of red clocks both read five minutes past one—flickered, oscillated, dropped down to the left, came back up momentarily, then dropped off again, farther this time, built up and again dropped off. In the language of engine instruments, that tachometer was announcing that the Turtle's left engine was failing.

In the jarring, crackling night sky somewhere over Nevada, Davies suddenly had much to ponder. Navy and civil flight regulations and common sense required an immediate landing at the nearest available field in the event of engine failure. But where was that? Probably Reno. Would that field be open, or did the present foul weather extend all the way to the deck? And what about the mission record? The Turtle was now 9,000 miles from Perth, 1,000 better than the old mark. But was that good enough? The Neptune was now light enough for single engine flight, but how much farther could it go on one engine? And was it worth risking this first expensive aircraft of what should one day be a family of hundreds for the sake of improving a distance record?

Whatever the answers to all those questions, the first thing to do was to shut down the bad engine, reducing its drag, and minimizing the damage. Davies reached up for the button that would feather the prop. But at that moment it struck him that something about this sick engine was not normal. The altimeter showed no loss of altitude. Control pressures remained unchanged—no retrimming or extra force had been needed on yoke or



rudders. He jabbed the beam of a flashlight over his left shoulder. The prop out there whirled normally. There was no sign of smoke or oil. He checked the panel. Manifold pressure, oil pressure, oil temperature, and fuel flow all were normal. Davies ran the throttle forward on the port engine and felt a welcome swerve under his hands and feet. Relief surged. That beautiful left engine was as good as ever. Only the tachometer was faulty.

The weather finally broke with the dawn of the Turtle's third day in the air, and all morning Davies followed the section lines of the plains states to the eastward. Nebraska, Iowa, and the Missouri and the Mississippi rivers slid past below. To the north, the haze of Chicago was in sight. But now, not surprisingly, fuel was becoming a problem. The wingtip tanks had long ago been emptied and jettisoned over the Pacific. The bomb bay tanks, the nose tank, and the big fuselage tanks were empty. The fuel gauges for the wing tanks were moving inexorably toward zero. Davies and his crew consulted, tapping the panel, calculating and recalculating remaining fuel, and cursing the gauges on which one-eighth of an inch represented 200 gallons—more than an hour's flight, nearly 200 miles. At noon they concluded they could not safely stretch the flight beyond Columbus, Ohio.

At quarter past one that afternoon the runways and hangars of the Columbus airport were in sight. The Turtle's crew were cleaned up and shaven and in uniform. And the fuel guages all read empty.

With the landing checklist completed and wheels and flaps down, Davies cranked the Turtle around into final approach. As the plane leveled out in final, the left engine popped, sputtered and cut out. Not now, he thought, palms moist on yoke and throttles, not after all the miles, just one mile from touchdown! But the right engine continued to provide power and the left caught and ran again (a fuel boost pump had acted up). At 1325 on 1 October, the Neptune's wheels once more touched the earth—touched it hard, with tires that had been inflated to support the ten Cadillacs' weight of fuel that had now been burned—11,236 miles and 55 hours and 16 minutes from where they had taken off.

Before that day was over, the Turtle's crew had been decorated by Secretary Forrestal and were scheduled to meet with President Harry S. Truman. And Joey, observably relieved to be back on the solid earth, had been installed in luxurious quarters in the Washington Zoo.

The record established by Tom Davies and the Truculent Turtle stood not just for a year or two or three, but through the remaining 1940s and the entire decade of the 1950s—for 16 years, until early in 1962.

A thousand sisters followed the Turtle. For a quarter-century after that epic flight, seven generations of Neptunes painted with the colors of a half-dozen nations have patrolled the oceans of the world and provided an effective global counter to the threat of hostile submarines.

And today, that first long-legged Neptune with the Disney turtle painted on its nose stands in honored dignity at the Naval Aviation Museum in Pensacola, Florida, an inspiration to all, but especially to the generations of patrol-plane pilots who have followed in the daringly professional tradition of Commander Tom Davies and his crew.

Commander Stafford is a prolific freelance writer whose work has appeared many times in *Proceedings*. Among the many publications for which he has written are *National Geographic* and *Reader's Digest*. Commander Stafford is perhaps best known as the author of the World II history of the USS *Enterprise* (CV-5), *The Big E*, now available as part of the U.S. Naval Institute's Classics of Naval Literature series. Commander Stafford, who is the grandson of Admiral Robert E. Peary, made invaluable contributions to the Navigation Foundation's study of Peary's North Pole expeditions.

# BOOK REVIEW

*By Roger H. Jones*

## Radar Trainer - A Home Study Computer Course in Radar Observing

By David Burch and Randel Washburne

Published by STARPATH, 311 Fulton St., Seattle, Washington 98109-1740 (1990) Tel. 1-800-955-8328
*80 pages, together with a 5.25" computer disk*

Readers of the Newsletter will recognize the name of David Burch. He is the author of a number of books previously reviewed, including *Emergency Navigation* and *2102-D Star Finder - A User's Guide*. He operates the Starpath School of Navigation in Seattle, which has trained over 8,000 classroom students, and which, at any given time, also has several hundred home-study correspondence students.

David is joined by Randel Washburne in recognition of the need for an updated method of presenting material on the use of marine Radar, and this new manual with its associated computer disk is the result. There are seven chapters, each of which is keyed to the 1991 world of Radar operation and image interpretation using the very thoughtfully prepared computer program. The basic thrust is to teach the motions and relative motions of Radar targets. It is not a program primarily intended to teach the use of Radar in position fixing, but there are certain uses of buoys included in the program.

This package is novel, and it is state of the art. In addition to providing detailed instructions at the outset as to initial installation of the computer program on one's own personal computer, it also provides a special file on the disk that sets screen height and width coordinates so that the computer screen appears round, as in real world Radar displays.

The screen lettering, targets, target tracks and graphics are all very distinct with excellent contrast. The program encompasses one million combinations of target vessels, courses, speeds and sequences of various operations. Some of the more than fifty individual topics covered are: the bird's eye view vs. Radar view; using the Radar trace option; parallel, crossing and collision courses; following a buoy channel in a current; effect of course and speed changes; problems in closest point of approach and estimated times of arrival; and the setting up of one's own target configurations and exercises.

The main menu, the procedures for rebooting and resolution of image problems related to individual user hardware, and the detailed exercise instructions are extremely well conceived and written. The English language used is directed to the mariner - not the laboratory computer technician. The illustrations and exercise problems are excellent, and they reflect the insights of the master mariner who has sent years on the bridge in a fog-shrouded world of grey.

Those who have a personal computer will be fascinated to turn it into a Radar screen, and to turn their home environments into the oceans of the world. This home study course is highly recommended to all who use or contemplate using marine Radar, from ships' captains to yachtsmen, and even to armchair sailors who may not otherwise dwell in that fog-shrouded world of grey.

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# THE NAVIGATOR'S NEWSLETTER

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FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-FIVE, SPRING 1992

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

*Editors Note: Quite a few people have commented on the Foundation's logo which appears above. Do you know . . . the name of the instrument depicted in the logo and by whom it was invented? (Answer appears at the end of this issue).*

## ACTIVITIES

*By Terry Carraway*

### NOAA to Distribute DMA Products

On October 1, 1992, NOAA will assume responsibility for the Defense Mapping Agency (DMA) public sales program for nautical and astronatical products. The discussions and arrangements necesary to implement this transfer have been underway since the spring of 1990. At that time, the two agencies agreed that the American public would be better served if there is just one point of contact for obtaining Federal Government-produced aeronautical and nautical public sale products.

As an NOS sales agent, The Navigation Foundation will continue to provide the same chart and publication service as it has in the past. New NOS catalogs will be available by September, 1992 so be prepared for some confusion and delays during the transition period.

### Discontinued Charts

Effective November 22, 1991, NOS discontinued the publication of the Tidal Current Charts of New York Harbor and San Francisco Bay.

The waterproof version of the following Chesapeake Bay charts will be dicontinued with the new revisions: 12233 - Chesapeake Bay to Piney Point, 12266 - Choptank River and Herring Bay Cambridge, 12270 - Chesapeake Bay - Eastern Bay, South River, and Selby Bay.

### Membership

Over the years, members and others have presented recommendations to increase the membership of the Navigation Foundation. We appreciate receiving these recommendations and thank each one of you who has taken the time and interest to want to help. Each recommendation has been carefully considered, in light of the aims and goals as they were originally established. In each case it was decided that our main goal was being accomplished. With minimal advertising, and a low key and all-volunteer organization, we are slowly attracting the members that we desire: the true navigation aficionados. You, the members who are passionately devoted to preserving the art of navigation, are the backbone and reason for the continuance of the Foundation. Just gaining members to increase the rolls would not be in the best interest of all.

### Disadvantaged Youth Program

The Foundation is continuing with its plans to commence a program for disadvantaged youth, in cooperation with the Olney Kiwanis Club and the Regional Institute for Children and Adolescents (RICA). I am planning to take the adult supervisors on an orientation voyage in late May or early June. The reason for the late start this season is due to time constraints. TANDEMEER needs to be de-winterized, instruments repaired, bimini replaced and the fresh water system flushed and sanitized. As soon as de-winterizing is completed and my schedule permits, there should be no other delays.

More Activities (see page 12)

## READERS FORUM

Ivan Trofimoff, Ibsen 33-102, Mexico, D. F. 11560, has written inquiring as to sources of expertise on polar navigation. He is planning a Mexican expedition to the North Pole. He has been referred to John Flint of the Explorers Club in New York City. Any Foundation member who is able to provide additional information may wish to contact Mr. Trofimoff at the above address.

Rafael Martinez-Ona Lopez, c/.Ferraz, 61, 28008 Madrid, Spain, wrote to the Foundation some time ago inquiring about Islamic maritime vessels, trade routes, and maritime history during the period 711 - 1500 A.D. John Luykx of the Foundation has responded with a list of references and articles which is by no means complete. If any reader is able to furnish further thoughts about sources of information on Islamic navigation in the Mediterranean during the early Middle Ages, please correspond with Mr. Martinez-Ona Lopez.

William B. Benzer, Sr., 3359 Sheffield Circle, Sarasota, Florida, 34239, has inquired if there is an IBM-compatible computer program that will convert LORAN TDs to LAT/LON coordinates. John Luykx has determined that such a program does exist. Interested readers may wish to contact John at the Foundation's mailing address.

Robert M. Girdler, P.E., 4269 Vaucluse Road, Aiken, South Carolina 29801, wrote to the Foundation enclosing a prototype of the "Celestial Slide Rule" which he developed but has never put into commercial production. John Luykx has examined this device with interest, and has found it to be useful by itself in computing true azimuths for magnetic compass checks and true courses for Great Circle Sailing, with accuracies to the nearest whole degree. Other uses include: location of a particular star or Planet; determination of times of rising or setting of the upper limb of a body; azimuths at the rising or setting of a body; the GMT of the Prime Vertical of a body; and latitude by meridian altitude. Readers of the *Newsletter* who are interested in obtaining the "Celestial Slide Rule" may do so for a very nominal cost by contacting Mr. Girdler who, in addition to being a professioanl engineer, is also an instructor in celestial navigation at a branch of the University of South Carolina.

J. P. Mudd, Jr., M.D., 222 W. Church Street, Jackson, Alabama 36545, has forwarded a copy of his letter to the Eighth Coast Guard District in New Orleans. The letter was triggered by Dr. Mudd's reading in the Local Notice to Mariners of a plan to convert various values to the metric system. Dr. Mudd suggests "going all the way" and converting the circle to 400 degrees. He notes that if each degree were divided into 100 minutes, there would be 10,000 minutes in a quarter circle, and that there are approximately 10,000 kilometers in a quarter of the Earth's circumference. This leads to the notion that a speed of one kilometer per hour would become the "new knot." Others have suggested conversion of the circle to metric values. The Foundation hesitates to comment on the possible consequences of a step such as that suggested by Dr. Mudd, but others who have pondered the "anomaly" of the 360 degree circle may find food for thought.

J. S. DeSanto, Box 91, Babb, Montana 59411, is interested in hearing from any reader who may have information on the navigation techniques employed by the Northwest Boundary Survey of 1857 - 1861 and the follow-on survey of 1872 - 1874. Any reader who is a civil engineer or surveyor with a flair for the 19th Century methods used on land may wish to contact Mr. DeSanto.

# NAVIGATION BASICS REVIEW

*Editor's Note: In the last issue of the* Newsletter *there appeared an article by John Luykx on the accuracy of mechanical, spring-wound navigation chronometers. The following is a companion piece on the accuracy of quartz chronometers. In the next issue (Summer, 1992) there will be a further article on proofing the navigator's watch —the problem of getting accurate time from inaccurate timepieces. This forthcoming article is by Stephen D. Matthews, Ph.D.*

## The Accuracy of Quartz Timepieces

*By John M. Luykx*

This article describes a test of quartz timepiece accuracy which is the general continuation of a similar article on mechanical spring-wound chronometer and deck watch accuracy published in the last issue (#34) of the *Navigator's Newsletter*, Nine quartz watches and clocks were selected from the author's collection for the test, which was conducted from 30 September 1991 to 25 November 1991.

1. The period from 30 September to 14 October was devoted to the adjustment of each timepiece. All timepieces used in the test were capable of adjustment for + or - rate.

2. During the period 14 October to 28 October, the mean weekly rate of each timepiece was computed and recorded.

3. During the period 28 October to 25 November (at weekly intervals: 4 November, 11 November, 18 November and 25 November) the actual error of each timepiece was compared to the error predicted by the timepiece based on the weekly rate computed during the period 14-29 October. The error of each timepiece, determined by radio time signal, was recorded in a log each Monday morning at approximately 09-00, 14 October through 25 November.

4. During the test all timepieces were located in a room where the ambient temperature was maintained at between 72° and 75° F.

TEST INSTRUMENTS

The quartz watches and clocks used during the test were:

#1 Staiger clock, twelve hour, 1-3/4" dial in wood case

#2 Sharp, Elsie Mate LCD electronic calculator watch, Model CT 500.

#3 Staiger clock, twelve hour, 1-3/4" dial in wood case

#4 Weems and Plath table clock 12-hour, 2" dial in wood case

#5 Sport wrist watch with Miyota movement 12-hour analog as well as 24-hour LCD dial.

#6 Consort 12-hour dial wristwatch

#7 Girard Perregaux 12-hour dial wristwatch

#8 Weems and Plath brass table clock, 12-hour, 2" dial

#9 Weems and Plath brass table clock, 12-hour, 2" dial

TEST RESULTS

The test results are given below in Tables 1 and 2.

1. Table 1 shows for each timepiece:

a) The computed weekly rate in seconds for the period 14 to 28 October.

b) The actual error in seconds for each watch on Monday, 4 November, 11 November, 18 November and 25 November.

c) The predicted error in seconds for Monday, 4 November, 11 November, 18 November and 25 November based on the weekly rate computed during the period 14 to 28 October.

d) The difference between the actual and predicted error, in seconds, for each timepiece on Monday 4 November, 11 November, 18 November and 25 November.

CONCLUSION

The test results indicate that quartz watches are more accurate than mechanical spring-wound watches (See Issue #34 *Navigator's Newsletter* and that the error of prediction of quartz watches is approximately 10% of that generally obtainable with mechanical watches. Some of the quartz watches showed a prediction error of as little as 0.1 seconds per month, which means they are capable of predicting time to within a second and a half per year without reference to time signals.

However, the harsh sea environment as well as the varying conditions of temperature and humidity at sea will most probably reduce the accuracy of prediction to a large degree. Even if the quartz watch were capable, however, of predicting time only to within 2 or 3 seconds per month, a navigator could still feel reasonably confident of the accuracy of his watch, although it may be necessary for him to remain at sea for long periods of time (i.e., as much as six to eight weeks) without the availability of radio time signal.

TABLE 1

Timepiece #1

```
1.. Weekly Rate
    Error  14 Oct:   -2.0
    Error  28 Oct:   -2.4
                   2/-0.4
    Weekly Rate:     -0.2
```

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | -2.6 | -2.6 | 0.0 | |
| 11 Nov | -2.5 | -2.8 | -0.3 | -0.3 |
| 18 Nov | -2.5 | -3.0 | -0.5 | -0.2 |
| 25 Nov | -2.5 | -3.2 | -0.7 | -0.2 |

Timepiece #2

```
1.  Weekly Rate
    Error  14 Oct:   -12.3
    Error  28 Oct:   -12.6
                   2/-0.3
    Weekly Rate:      -0.15
```

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | -12.7 | -12.8 | -0.1 | |
| 11 Nov | -12.7 | -12.9 | -0.2 | -0.1 |
| 18 Nov | -12.7 | -13.1 | -0.4 | -0.2 |
| 25 Nov | -12.5 | -13.2 | -0.7 | -0.3 |

Timepiece #3

```
1.  Weekly Rate
    Error  14 Oct: +18.0
    Error  28 Oct: +18.4
                  2/+0.4
    Weekly Rate:    +0.2
```

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | +18.7 | +18.6 | -0.1 | |
| 11 Nov | +19.0 | +18.8 | -0.2 | -0.1 |
| 18 Nov | +19.3 | +19.0 | -0.3 | -0.1 |
| 25 Nov | +19.6 | +19.2 | -0.4 | -0.1 |

### Timepiece #4

1. Weekly Rate
   Error 14 Oct: +8.7
   Error 28 Oct: +9.8
   2/+1.1
   Weekly Rate: +0.55

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | +10.3 | +10.4 | +0.1 | |
| 11 Nov | +10.8 | +10.9 | +0.1 | 0.0 |
| 18 Nov | +11.4 | +11.5 | +0.1 | 0.0 |
| 25 Nov | +11.9 | +12.0 | +0.1 | 0.0 |

### Timepiece #5

1. Weekly Rate
   Error 14 Oct: 0.0
   Error 28 Oct: -0.1
   2/-0.1
   Weekly Rate: -0.05

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | -0.2 | -0.2 | 0.0 | |
| 11 Nov | -0.2 | -0.2 | 0.0 | 0.0 |
| 18 Nov | -0.2 | -0.3 | -0.1 | -0.1 |
| 25 Nov | -0.2 | -0.3 | -0.1 | 0.0 |

### Timepiece #6

1. Weekly Rate
   Error 14 Oct: -0.2
   Error 28 Oct: -0.1
   2/+0.1
   Weekly Rate: +0.05

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | -0.1 | 0.0 | -0.1 | |
| 11 Nov | +0.2 | 0.0 | -0.2 | -0.1 |
| 18 Nov | +0.2 | +0.1 | -0.1 | +0.2 |
| 25 Nov | +0.4 | +0.1 | -0.3 | -0.4 |

### Timepiece #7

1. Weekly Rate
   Error 14 Oct: +5.1
   Error 28 Oct: +6.6
   2/+1.5
   Weekly Rate: +0.75

2. Error

| Date | Actual | Pred | Diff | Diff |
|---|---|---|---|---|
| 4 Nov | +7.6 | +7.4 | -0.2 | |
| 11 Nov | +9.0 | +8.1 | -0.9 | -0.7 |
| 18 Nov | +10.8 | +8.9 | -1.9 | -1.0 |
| 25 Nov | +11.2 | +9.6 | -1.6 | +0.3 |

### Timepiece #8

1. Weekly Rate
   Error 14 Oct -15.8
   Error 28 Oct -16.4
   2/-0.6
   Weekly Rate: -0.3

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | -16.6 | -16.7 | -0.1 | |
| 11 Nov | -16.4 | -17.0 | -0.6 | -0.5 |
| 18 Nov | -16.2 | -17.3 | -1.1 | -0.5 |
| 25 Nov | -16.5 | -17.6 | -1.1 | 0.0 |

### Timepiece #9

1. Weekly Rate
   Error 14 Oct: +1.4
   Error 28 Oct: +1.2
   2/-0.2
   Weekly Rate: -0.1

2. Error

| Date | Actual | Pred | Diff | Var |
|---|---|---|---|---|
| 4 Nov | +1.2 | +1.1 | -0.1 | |
| 11 Nov | +1.2 | +1.0 | -0.2 | -0.1 |
| 18 Nov | +1.2 | +0.9 | -0.3 | -0.1 |
| 25 Nov | +1.2 | +0.8 | -0.4 | -0.1 |

### TABLE 2

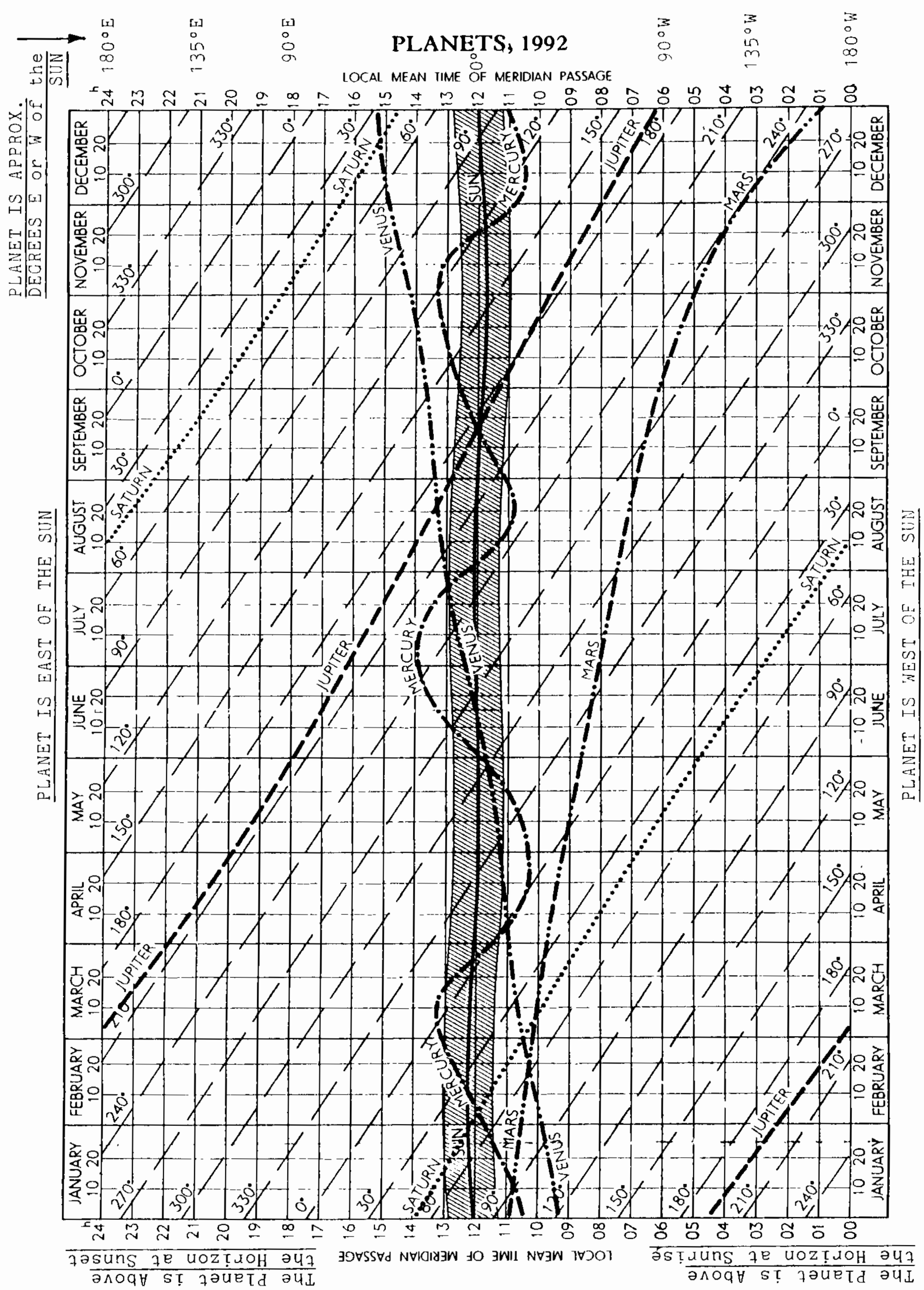
| Week | Time period | Mean error of prediction (All Watches) |
|---|---|---|
| 1 | 28 Oct - 4 Nov | 0.1 seconds |
| 2 | 28 Oct - 11 Nov | 0.3 seconds |
| 3 | 28 Oct - 18 Nov | 0.5 seconds |
| 4 | 28 Oct - 25 Nov | 0.6 seconds |

## Local Mean Time of Meridian Passage of the Planets

*By William O. Land*

On page nine of the Nautical Almanac there is a graph showing the Local Time of Meridian Passage of the four navigational planets plus Mercury. Sometimes Celestial Navigation students become confused when using this graph as to whether the planet or the Sun rises first or sets first. With the addition of these quoted notations "The planet is above the horizon at sunrise, " "the planet is above the horizon at sunset," "planet is east of the Sun," "planet is west of the Sun," and "The planet is approximately..... degrees E or W of the Sun," the confusion is solved.

Illustrated is a reproduction of this graph of the planets with the notations shown.



# HISTORY OF NAVIGATION

## The Quincentenary of the First Columbus Voyage to the Americas

*(A continuation of the discussion which appeared under the same name in Issue #34.)*

*By John W. Luykx*

COLUMBUS' FIRST LANDFALL IN AMERICA

On Friday, 24 April 1992 at Mahan Hall at the U.S. Naval Academy, the U.S. Naval Institute will sponsor a seminar entitled "Where Did Columbus Land? — the Evidence to Date." Columnist and author William F. Buckley, Jr., a member of the Navigation Foundation, will be moderator for this seminar which is part of the USNI 118th Annual Meeting. Among the panelists will be Samuel L. Morison, grandson of Samuel Eliot Morison, who wrote the two vlume biography of Columbus, *Admiral of the Queen Sea* published in 1942, in which Watlings Island (San Salvador) is proposed as the point of first landfall on 12 October 1492. Joseph Judge, author of the article *Where Columbus Found the New World*, published in the November 1986 issue of the National Geographic Magazine is also a panelist. As a senior associate editor of the National Geographic in 1986, Mr. Judge argues that Samana Cay, 65 miles south southweast of Watlings Island, is the site of Columbus' first landfall. Dr. Steven Mitchell, the third panelist, believes Conception Island, 30 miles wet southwest of Watlings Island, to be the point of landfall. Professor Mitchell teaches Geology at California State University at Bakersfield.

Readers who would like more information should write or call the U.S. Naval Institute, 2082 Generals Highway, Annapolis, Maryland 21401 or U.S. Naval Academy, Preble Hall, Annapolis, Maryland 21402, Telephone:1-410-224-3378.

The February 1992 issue of the U.S. Naval Institute contains a brief presentation of the three varying points of view to be discussed at the seminar.

NEWSPAPER/MAGAZINE ARTICLES

Two articles of interest regarding the Columbus voyages have appeared recently. One is a special issue of Newsweek which appeared in December/January 1991-1992 entitled *1492-1992 When Worlds Collide — How Columbus' Voyages Transformed Both East and West.* Topics included in the essay are: 1) The World Before Columbus, 2) Columbus and Those Who Followed, 3) The Seeds of Change, and 4) The Quincentennial.

In *Time* magazine, October 7, 1991, an article entitled *The Trouble With Columbus* discusses two views regarding the 500th Anniversary of Columbus' first voyage:

1) "Columbus' journey was the first step in a process that produced a daring experiment in democracy which in time became a symbol and a haven of liberty."

2) "Indigenous peoples were doomed by European arrogance, brutality and infectious diseases. Columbus' gift was slavery to those who greeted him; his arrival set in motion the ruthless destruction of the natural world he entered."

COMING EVENTS

Included here is a short listing of upcoming events associated with the Columbus Quincentennial.

• "The Year of Columbus" (New York City). The Intrepid Sea Air Space Museum is planning a year long series of exhibitions, March 1992 - March 1993.

• "Ameriflora 1992" (Columbus, Ohio). "Ameriflora" will feature outdoors performances, exhibits and 88 acres of garden! April 20, 1992 - October 12, 1992.

• "Christofo Columbo: Ships and the Sea" (Genoa, Italy). An exposition on the development of navigation from the 15th Century to the present. May 15, 1992 - August 15, 1992.

• "Discovering America" (Williamsburg, Virginia) Historic Jamestown settlement will open an exhibit exploring many "discoverers" of America. June 1992 - March 1993.

• Visits of vessel replicas of Nina, Pinta and Santa Maria are schedule as follows for the spring and summer of 1992. The caravel port visits scheduled for the U.S. from February through August are:

Miami: February 14 - March 1
Houston: March 13 - 22
New Orleans: March 27 - 29
St. Augustine: April 3 - 19
Charleston: April 23 - 25
Norfolk: May 5 - 10
Boston: May 22 - June 7
Newport: June 12 - 14
New York: June 19 - July 12
Philadelphia: July 24 - August 9
Wilmington: August 14 - 16
Baltimore: August 21 - 30

• American Sail Training Association (ASTA) 1992 rallies will be held in accordance with the following schedule:

Chesapeake Bay: June 19 - 29
Boston/Newport: July 11 - 19
Southern California: September 19 - 27
San Francisco: October 10 - 18

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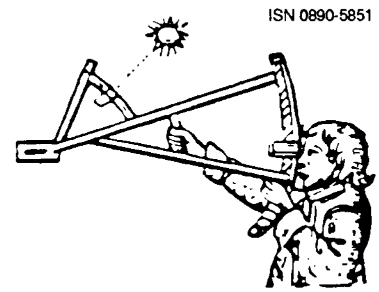
# THE NAVIGATOR'S NEWSLETTER



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The Foundation for the Promotion of the Art of Navigation
Box 1126, Rockville, MD 20850

• Mariner's Museum (Newport News, Virginia) "Age of Exploration Gallery" Exhibition of 15th - 17th Century developments in technology, shipbuilding, navigation and cartography, March - December 1992.

• OPSAIL regattas —120 sailing vessels operating in company will make visits to the U.S. according to the following schedule:

San Juan, PR: 10 June
New York City: 4 July
Boston: 12 July

Navigation Foundation members who are interested in learning more about the exhibitions, regattas, rallies and festivities celebrating the Columbus Quincentennial should call or write to:

The Christopher Columbus Quincentenary
Jubilee Commission
1801 F Street, NW., 3rd Floor
Washington, DC 20006
Telephone: (202)632-1992

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 34, Answer.

The basic principle underlying all forms of navigation — land, sea, air and even space navigation — is that an unknown position may be determined by means of direction and distance from a known position. That known position may be a fixed position, as in land, sea or air dead reckoning, and as in the case of various methods of navigation by LORAN, RADAR, or radio direction finder. For example, if an automobile traveler is able to determine that he is 10.5 miles north of the toll booth at the southern end of the New Jesey Turnpike, he is able to pinpoint his position on a road map. If a vessel is 10.5 nautical miles from the eastern end of the Marine Del Ray, California, breakwater and the true bearing of the breakwater is 012 degrees, the vessel's position may be pinpointed on the nautical chart. And if an airplane is 10.5 statute miles from the Baltimore VOR on the 033 degree radial, the position may be pinpointed on an aeronautical chart.

The known position may also be a moving position, as in celestial navigation. In this case, it is that position on the surface of the Earth which would be intersected by a figurative straight line drawn from the center of the Earth out through space to the center of a celestial body. It is that position on the Earth's surface that, at any instant in time, lies directly "beneath" the celestial body, and it is moving because of the Earth's rotation on its own axis. It moves at a precisely known rate in an ever westward direction from the Greenwich Meridian, until about twenty-four hours after momentarily being on that meridian it is again on the meridian of Greenwich, England. If the celestial navigator can, for a given instant in time, determine the exact coordinates on the Earth's surface of that point which is directly beneath the chosen celestial body, and if he can determine his direction and distance from that known position, he can determine his own unknown position at sea. To do this he employs the great navigational triangle.

One point of that triangle is always the geographic pole of the northern or southern hemisphere in which he is located. The second point is the geographical position on the Earth's surface that lies directly "beneath" the celestial body. The third point is the position of the vessel. The great circles on the surface of the Earth that connect these three points are the sides of the triangle. These "great circles" would appear on a globe as straight lines connecting the three points. Because they are drawn on a sphere, they are arcs at the surface of the sphere whose common center is the center of the sphere (or Earth). The common term for those arcs is "great circle". Because the great triangle is "drawn" on the surface of a sphere, it is a "spherical triangle."

Problem No. 35.

What is the great principle by means of which the navigator can use the navigational spherical triangle to determine the position of the vessel, and what are the basic tools of the navigator that enable him to so use the great triangle?

# NAVIGATION PERSONALITIES

*By Roger H. Jones*

## Tristan Jones

The Navigation Personalities column of this *Newsletter* has presented a series of brief portraits of individuals whose contributions to the science and practice of navigation have been noteworthy. All too often it has been the succeeding generations that have recognized these contributions and given them their due respect after the passing of the individuals themselves. In a departure from this tradition, this issue will recognize a man who has become a legend in his own time.

Tristan Jones was born aboard his father's merchant vessel in 1924 near the island of Tristan de Cunha in the South Atlantic. His boyhood years were spent in a small

Welsh village near the seacoast where the ability to tell a story well in a warm kitchen was a thing admired. He was a good listener. Little did he know that an author of fourteen books and many articles was being forged.

He was apprenticed to the master of a sailing barge at the age of fourteen. Plying the English Channel, Dutch and German ports, it carried bricks and other heavy cargo—all of it hand loaded by Jones and one other lad. With the outbreak of World War II in 1939, he lied about his age and entered the British Navy with initial seaman's training at the famous (or infamous) H.M.S. Ganges facility where young tars were indeed brutalized.

He saw service aboard combat vessels engaged in protecting the cold North Atlantic convoys, and was a witness to the sinking of H.M.S. Hood and of the great German battleship Bismarck. He survived the sinking of three naval ships before he was eighteen. After the war he transferred to the Royal Hydrographic Service until 1952 when a survey vessel he was aboard was blown up by guerrillas. He suffered a severe spinal injury and was told he would never walk again. In truth his incredible life had only just begun.

Mustered out on very meager disability pay, he acquired and converted a beach-launched life boat built in the early years of the 20th Century. He went back to sea, and over the next forty years logged well over 400,000 unsponsored miles in sailing vessels. He is the holder of the most single-handed sailing records ever achieved. He is a Fellow of the Royal Geographical Society and the Explorers Club. He is a member of the Royal Naval Sailing Association, an honorary lifetime member of the Slocum Society, and the Society of Authors. He holds the *First Award for Literature in Wales.*

He has crossed the Atlantic at least twenty times, nine times alone. Of far greater significance, he is the first person to cross the continent of South America by seaworthy small vessel—from the waters of Lake Titicaca down through the never before explored upper reaches of the Paraguay River to the Atlantic Coast. He was accompanied by one young Indian from the high Andean plateau. Their trip, in the early 1920s, nearly cost both of them their lives. It has never been repeated by any other person. He is the first and still the only person to command a vessel (a trimaran) voyaging from the West Coast of Europe up through the Rhine River systems to the headwaters of the Danube, and thence down that river to the Black Sea. This voyage was accomplished in the mid 1980s when the political climate in Bulgaria and Rumania was still quite hostile to persons from non-communist nations. And, Jones is the first and only person to command a seagoing vessel on a voyage across the Kra Peninsula of Thailand. This latest voyage was accomplished in the late 1980s and is the subject of Jones' latest book, *To Venture Further.*

In earlier voyages, Tristan Jones was locked in the ice well above the Arctic Circle for a year, was threatened by hostile tribesmen in the countries bordering the Red Sea, and was in equally dangerous waters on the Columbian coast of South America. His left leg was amputated in 1982, and he completed his Danube and Kra Peninsula voyages as a one-legged seafarer. He has recently lost his right leg as well.

As a navigator, story-teller, and explorer, he is without peer. His books reveal a rare character. He is a modest man who identifies with the poor and the suffering, and who is now spending his time showing handicapped youngsters in Thailand that they are capable of a full life.

Most of his books are true accounts of his incredible voyages. They are backed by logs, passport entries, and other documentary evidence. One or two are fiction, and one is a book of practical advice for the sailor, entitled *One Hand for Yourself, One for the Ship.* Each and every one is well worth reading—both for content and inimitable style. Here is a man who is a practitioner of some of the most extraordinarily difficult navigation that has ever been achieved. Tristan Jones, well done!

# MARITIME INFORMATION NOTES

*Provided by Ernest Brown*

## Areas to be Avoided

The National Oceanic and Atmospheric Administration (NOAA) is initiating enforcement of the statutory prohibition against vessel traffic within Areas to be Avoided (ATBA) located along the Florida Keys National Marine Sanctuary. Operation of tank vessels and vessels greater than 50 meters in length is prohibited within areas described by the ATBA boundary coordinates published in NM 38/91. The term "tank vessel" is defined to mean "a vessel that is constructed or adapted to carry, or that carries, oil or hazardous material in bulk as cargo or cargo residue." 46 U.S.C. Section 2101 (39).

The prohibited areas were established by Congress under the Florida Keys National Marine Sanctuary and Protection Act, Pub.L.101-605 (November 16, 1990), in order to reduce the risk of large vessel groundings which are found to constitute a serious threat to the continued vitality of the marine environments of the Florida Keys.

Consistent with generally recognized principles of international law, and NOAA's jurisdiction under section 307 of the Marine Protection Research and Sanctuaries Act, 16 U.S.C. Section 1437, enforcement actions may include assessment of civil penalties of not more than $50,000 per violation. The above prohibition does not apply to necessary operations of public vessels, including operations essential for national defense, law enforcement, and responses to emergencies that threaten life, property, or the environment.

The International Maritime Organization (IMO) has approved and adopted the establishment of Areas to be Avoided (ATBAs) off of the California Coast effective 0000 GMT 16 November 1991. In order to avoid risk of pollution in the area designated as the Channel Islands National Marine Sanctuary, all ships, except those bound to and from ports on one of the islands within the area, engaged in the trade of carrying cargo, including, but not limited to, tankers and other bulk carriers and barges, should avoid the areas published in Section I of NM46/91.

### Hydraulic Jump Off Moss Landing, California

The U.S. Coast Guard has reported investigating an incident at the Pacific Gas and Electric Co. terminal located off Moss Landing. The terminal is located at the head of Monterey Canyon. The incident was apparently caused by strong currents moving landward through Monterey Canyon and resulted in a "hydraulic jump" where the canyon narrows and finally ends. USCG reports indicated that a tanker was "set on" the oil terminal buoy at the facility. The chain that connects the buoy and the transfer hose became fouled around the propeller of the tanker. Extreme caution should be exercised while in this area, particularly while engaged in transfer operations.

### Quarterly Pilot Charts

In order to operate more effectively, the Defense Mapping Agency (DMA) intends to reconfigure the Quaterly Pilot Charts of the North Atlantic (PILOT 16) and the North Pacific (PILOT 55) and the Pilot Chart Atlases (PUBs 105-109). DMA plans to establish one product line of five Atlases.

The Quarterly Pilot Charts (PILOTs 16 and 55) will be replaced by the following two new publications:

*Atlas of Pilot Charts North Atlantic Ocean*
*Atlas of Pilot Charts North Pacific Ocean*

The Pilot Chart articles printed on the reverse side of the Quarterly Pilot Charts will be published in each Atlas.

The regional Pilot Chart Atlases of Central America (NVPUB 106) and Northern North Atlantic (NVPUB 108) will be replaced by Atlas of Pilot Charts North Atlantic Ocean (NVPUB 106). The Pilot Chart Atlases of the South Atlantic Ocean (NVPUB 105), South Pacific Ocean (NVPUB 107), and Indian Ocean (NVPUB 109) will not be affected by this change. A ten-year updating cycle will be established for all the Atlases.

The new renumbering scheme will be as follows:

NVPUB 105: Atlas of Pilot Charts South Atlantic Ocean
NVPUB 106: Atlas of Pilot Charts North Atlantic Ocean (renamed Atlas)
NVPUB 107: Atlas of Pilot Charts South Pacific Ocean
NVPUB 108; Atlas of Pilot Charts North Pacific Ocean (renamed Atlas)
NVPUB 109: Atlas of Pilot Charts Indian Ocean.

# FEATURE

## Pilgrimage to the Prime Meridian

*By Allan E. Bayless, M.D.*

*Editor's Note: Allan Bayless, a Director of the Foundation, first wrote this article in 1969 for publication in the Housatonic River Power Squadron's* Spindrift. *It was later published by the Power Squadron in 1977 in "The Ensign," and is reprinted here by permission of the Editor of "The Ensign." The* Newsletter *has contained many references to the Greenwich Meridian, including those in* A Navigation Problem *in this issue. We thought the readers of the* Newsletter *might like to get to know the Prime Meridian on more intimate and human terms.*

It was a warm hazy day in London last year when Barbara and I made a long anticipated cruise down the Thames by river boat to the National Maritime Museum at Greenwich. History crowds the shores of the Thames. The tower of Big Ben loomed over the quay at Westminster where we boarded the boat. The coal-blackened bulk of old "New Scotland Yard" was a stone's throw away as we left the Victoria Embankment. We passed Whitehall, Cleopatra's Needle, and not long afterward the ancient Tower of London, its walls and the infamous and forbidding Traitor's Gate at the river's edge. In the background soared the great dome of St. Paul's Cathedral. We passed under the many bidges - Hungerford, Waterloo, Southwark and the Tower Bridge. London Bridge, about half dismantled, was listing noticeably. The watercraft criss-crossing the river were as fascinating as the waterfront; all were squat craft with practically no superstructure so they could clear the low bridges. We saw one large boat with a hinged stack that it lowered each time it went under yet another low bridge. The large seagoing vessels that come up the Thames must stop short of all these bridges and it is downriver that the great harbor complex is to be found, almost entirely concealed from the river itself as these basins are entered through narrow inlets.

The helmsman kept up a descriptive patter all the way to Greenwich where we disembarked practically under the bowsprit of the Cutty Sark, last of the great tea clippers. Here the shoreline is dominated by the majestic buildings of the Royal Naval College. The view from the water has hardly changed in 200 years. Behind the College buildings is the Maritime Museum and behind it a long grassy hill with the Old Royal Observatory perched on its brow.

Greenwich itself is ancient. It was here in 1012 that the Danes left their long ships when they raided Canterbury and again in 1016 when they attacked London. In 1400 Henry IV built a summer house here, Bella Court, which became the birthplace of Henry VIII, Mary I and Elizabeth I. In 1427 Henry V built a watch tower on the nearby hill and this is the site of the present observatory. The center building of the several that comprise the Maritime Museum was built for his wife by James I in 1616 and it is interesting that this building, "Queen's House", was probably the inspiration for our White House.

But back to nautical matters. In the latter part of the 17th century, after 150 years of expanding maritime exploration and merchant trading, the necessity for a method of determining longitude at sea had become all too obvious. The mariner's only method of keeping his longitude was by dead reckoning, soon totally unreliable when out of sight of land, and he had no way of finding it again. Many lives and vessels were lost on this account. By happy circumstance, Charles II had become acquainted with yachting while exiled in Holland (he subsequently had several yachts of his own) and consequently became very interested in the problems of navigation. In 1675 he commissioned Sir Christopher Wren to build the Royal Observatory:

"Charles Rex. Whereas in order to the finding out of the longitude of places and for perfecting navigation and astronomy, we have resolved to build a small observatory within our park at Greenwich."

This small observatory was also the living quarters of the Astronomer Royal of whom the first, John Flamsteed, promptly began to chart the positions of the stars to a greater degree of accuracy than had ever been done before.

The problem of finding the longitude at sea remained unsolved, however, and increasingly crucial so that in 1714 Parliament formed the "Board of Longitude" to evaluate any likely method submitted to it for evaluation. The Board offered a prize of 20,000 pounds for a successful solution. Sir Isaac Newton, the Board's most distinguished member, summarized the various possibilities, ". . . true in the Theory, but difficult to execute."

"One is, by a Watch to keep time exactly: But, by reason of the Motion of a Ship, the Variation of Heat and Cold, Wet and Dry, and the Difference of Gravity in different Latitudes, such a Watch hath not yet been made."

He also discussed observations of eclipses, occultations, the use of Jupiter's satellites, and the motion of the moon by measuring the angular distance of this rapidly moving body from the sun or conspicuous stars.

Ultimately two of these methods became practical: The lunar distance method and by marine chronometer. Both solutions were achieved by Englishmen and the Royal Observatory was vital to both. It is a result of this circumstance that longitude 0 degrees 00.0' passes through Greenwich — here is the "G" that appears on every time diagram that JN's and N's construct! Here the longitude was found! Here is the Navigator's Mecca!

The lunar distance method became practical with the publication of "The Nautical Almanac" in 1767 by Nevil Maskelyne, the 5th Astronomer Royal and also as a result of the invention of the sextant in 1730. The Almanac contained tables showing the angular distance from the moon of the sun and stars at three hour intervals. The navigator measured such a distance and after several formidable mathematical corrections, was able to deduce his longitude by comparing his result with the table.

It was difficult and often none too accurate, but it was a giant step. Joshua Slocum still found his way around the world by this method in 1898 using sextant, almanac and his famous battered alarm clock with missing minute hand.

[36] MARCH 1767.

Diſtances of ☽'s Center from ☉, and from Stars weſt of her.

| Days. | Stars Names. | 12 Hours. ° ′ ″ | 15 Hours. ° ′ ″ | 18 Hours. ° ′ ″ | 21 Hours. ° ′ ″ |
|---|---|---|---|---|---|
| 3 | The Sun. | 47. 35. 32 | 49. 14. 7 | 50. 52. 15 | 52. 29. 58 |
| 4 | | 60. 31. 52 | 62. 6. 53 | 63. 41. 28 | 65. 15. 37 |
| 5 | | 72. 59. 57 | 74. 31. 33 | 76. 2. 45 | 77. 33. 33 |
| 6 | | 85. 1. 42 | 86. 30. 12 | 87. 58. 22 | 89. 26. 11 |
| 7 | | 96. 40. 30 | 98. 6. 26 | 99. 32. 5 | 100. 57. 27 |
| 8 | | 108. 0. 35 | 109. 24. 27 | 110. 48. 7 | 112. 11. 34 |
| 9 | | 119. 6. 21 | | | |
| 6 | α Arietis. | 36. 56. 52 | 38. 32. 5 | 40. 7. 2 | 41. 41. 42 |
| 7 | | 49. 30. 50 | 51. 3. 51 | 52. 36. 36 | 54. 9. 5 |
| 8 | Aldebaran. | 30. 50. 33 | 32. 16. 45 | 33. 43. 9 | 35. 9. 45 |
| 9 | | 42. 24. 35 | 43. 51. 40 | 45. 18. 45 | 46. 45. 51 |
| 10 | | 54. 1. 29 | 55. 28. 35 | 56. 55. 42 | 58. 22. 48 |
| 11 | | 65. 38. 23 | 67. 5. 29 | 68. 32. 35 | 69. 59. 42 |
| 12 | Pollux. | 34. 42. 35 | 36. 10. 18 | 37. 38. 5 | 39. 5. 57 |
| 13 | | 46. 26. 22 | 47. 54. 39 | 49. 23. 0 | 50. 51. 26 |
| 14 | Regulus. | 21. 13. 28 | 22. 42. 27 | 24. 11. 34 | 25. 40. 48 |
| 15 | | 33. 8. 32 | 34. 38. 25 | 36. 8. 24 | 37. 38. 30 |
| 16 | | 45. 10. 46 | 46. 41. 36 | 48. 12. 32 | 49. 43. 36 |
| 17 | | 57. 20. 54 | 58. 52. 45 | 60. 24. 45 | 61. 56. 54 |
| 18 | Spica ♍ | 15. 48. 39 | 17. 20. 33 | 18. 52. 46 | 20. 25. 17 |
| 19 | | 28. 12. 30 | 29. 46. 44 | 31. 21. 15 | 32. 56. 1 |
| 20 | | 40. 53. 41 | 42. 30. 0 | 44. 6. 34 | 45. 43. 27 |
| 21 | | 53. 51. 55 | 55. 30. 27 | 57. 9. 17 | 58. 48. 25 |
| 22 | | 67. 8. 48 | 68. 49. 50 | 70. 31. 11 | 72. 12. 52 |
| 23 | Antares. | 34. 55. 40 | 36. 39. 31 | 38. 23. 42 | 40. 8. 14 |
| 24 | | 48. 56. 5 | 50. 42. 38 | 52. 29. 31 | 54. 16. 45 |
| 25 | | 63. 17. 49 | 65. 6. 58 | 66. 56. 24 | 68. 46. 7 |
| 26 | β Capricorni. | 23. 43. 43 | 25. 32. 9 | 27. 21. 11 | 29. 10. 44 |
| 27 | α Aquilæ. | 46. 57. 42 | 48. 20. 33 | 49. 44. 53 | 51. 10. 35 |
| 28 | | 58. 36. 8 | 60. 7. 55 | 61. 40. 21 | 63. 13. 19 |

*Fig. 1—A page from The Nautical Almanac for 1767, showing the tabulation of "lunar distance," to the precision of 1", for every three hours of apparent time.*

The Prime Meridian in 1767 was reckoned the location of the transit telescope installed by Bradley, the 3rd Astronomer Royal; after 1850 from a similar but larger instrument installed by George Airy, the 7th Astronomer Royal, about fifteen feet west of its predecessor. This instrument's meridian is the current standard. It is traditional, and almost obligatory, for the wayfarer to be photographed astride the Prime Meridian (Airy's) which is marked in the Observatory courtyard; Barbara did the honors.

The second practical solution of the longitude problem was the construction of a chronometer which would remain accurate despite the rigors of sea travel. This was accomplished by John Harrison, ultimately the winner of the Board of Longitude prize, and who was, of all things, a carpenter. He began work on the first of his five celebrated timepieces in 1736.

No. 1, six years in the making, was sufficiently accurate that he was advanced funds to build another. No. 2 was never tried at sea nor was No. 3. All of these contained numerous entirely original innovations. No. 3, the most intricate and weighing 102 pounds, required seventeen years to construct! It was not tested at sea because No. 4, a meticulously made though fairly ordinary appearing watch five inches in diameter, and originally intended only as an auxiliary deck watch, was fully as accurate. It was this watch that won the prize though it required the personal intervention of George III to pry the money away from the Board, and this in 1773, three years before Harrison's death at the age of 83.

A duplicate of No. 4 constructed by Larcum Kendall and known as K1, was used by Captain Cook in his later voyages and proved so accurate that he relied on it for his longitude and used "lunars" only to check its rate.

So in 1762, and certainly by 1775, the method of lunar distances was outmoded, but tables for this computation were to be found in the Nautical Almanac into the beginning of the twentieth century, principally because chronometers only very gradually became sufficiently plentiful and cheap that all shipmasters could be expected to have one.

The immortal timepieces of Harrison, including a subsequent No. 5 (which persuaded George III of Harrison's right to the prize) and Kendall's K1 are all preserved in the Navigation Room of the National Maritime Museum at the foot of the hill — and all are in running order! (A tribute to Lieut. Cdr. Gould who spent twelve years restoring them more than thirty years ago.)

The old Royal Observatory is now a museum (London fog and smoke forced the working observatory to move to Sussex) and in it and in the National Maritime Museum are innumerable fascinating models, instruments, paintings and exhibits — all worthy of prolonged study — but to me, anyway, this was a pilgrimage to the Temple of Longitude, the sacred relics of which live on at the Old Royal Observatory and in the horological masterpieces of Harrison.

# BOOK REVIEW

*By Roger H. Jones*

## ABHAV (Abbreviated Haversine) Method of Sight Reduction and Great Circle Sailing

By John D. Woodworth

*This "book" is not available from a commercial publisher. It may be obtained directly from the author at 209 Cedar Street, Oakhurst, New Jersey, 17755. 70 pages.*

John Woodworth wrote to the Foundation in December of 1991, and enclosed the manuscript which is the subject of this review. He has taught celestial navigation in the Power Squadron forum for thirty years, and he developed this simplified method of sight reduction as an alternative to the Ageton and the other abbreviated methods.

John Luykx has examined the manuscript with interest, and he plans to work a number of problems for comparison of the method with the results that are obtained in using H. O. 229, H. O. 249 and H. O. 211. Without the benefit of John's forthcoming work, this reviewer nevertheless has found himself somewhat intrigued by some of the apparent advantages of the ABHAV method. While it is reported by Woodworth to have better accuracy than the Ageton method (H.O. 211), what is more readily verifiable is the fact that it seems to require no interpolation, no signs to look up, no multiple choice steps (as in Ageton), and it results in a plot from the DR position.

Data to the nearest minute is entered on a simplified work form, the instructions for which seem to be a step in the direction of simplification. The azimuth is always referenced to the North Pole. Moreover, there are no decimals except within five degrees of zero and 180. When a tabulated number approaches zero, only one decimal place is used.

Woodworth has compiled his tables in a sixty-page format. The whole manuscript is no more than a quarter of an inch thick. A blank work form is furnished as is a work form that is filled in illustrating a sight reduction problem. The same blank and executed approach is taken to illustrate a great circle sailing problem.

This reviewer is not in a position to offer any definitive comment on the ABHAV method. Readers are merely urged to write directly to John Woodworth. But for its seventy-page length, we might well have printed the manuscript in the *Newsletter*. It certainly is a continuing testament to the innovative and inquiring mind of many of the members of the Foundation.

## Davies Goes To Alaska To Lecture On Peary

As this issue went to press, Foundation President Douglas R. Davies returned from a trip to Alaska where he discussed the Foundation's research on Admiral Peary. Doug was a guest lecturer at the Northern Studies Department at the University of Alaska, Fairbanks and the keynote speaker at the Alaska Surveying & Mapping conference in Anchorage. In addition to public lectures in each city, Doug addressed two elementary schools and a University geography class studying cold lands. The subject of these lectures was the Foundation study for the National Geographic Society in 1988-89 and the considerable research that Doug has been doing since then. He plans to write an article for the next Newsletter describing his latest findings. A number of people at each of the public lectures expressed interest in becoming members of the Foundation. The Surveying & Mapping conference showed its support for the Foundation's purposes by making a generous contribution.

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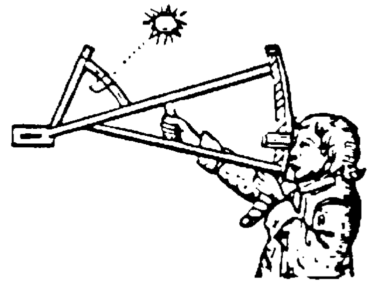


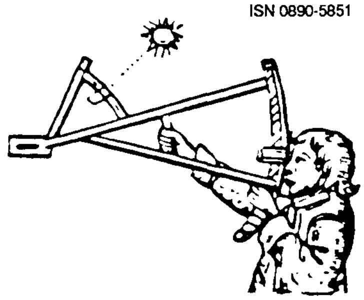
DO YOU KNOW . . . The question and the following answer are provided by Allan E. Bayless.

The instrument is the back-staff, which was invented by John Davis. In England it was known as the Davis Quadrant, and in France as the Quartier Anglais.

Davis addressed the main problem of the cross-staff, which required the user to look simultaneously at the horizon and the sun. Needless to say, this was hard on the eyes of the observer of four hundred years ago who did not have optical sun shades. Davis solved the problem of the blinding sun. He described the back-staff in *The Seaman's Secrets* in 1607. The observer faced away from the sun, and the top of the half-cross cast a shadow on a small plate at the end of the staff, which had a slit for simultaneous observation of the horizon. An improved version became quite popular, and the height of the sun was the sum of the angles indicated on the two arcs. Instruments derived directly from the back-staff were used still in the early years of the eighteenth century.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-SIX, SUMMER 1992

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Navigation Awards

Spring is again the time for the annual awards, presented by the Navigation Foundation. The Navigation Department of the U.S. Naval Academy selected Midshipman Stephen D. Bates as the 1992 recipient of the Dutton Award. Gould Academy did not submit a name for an award for this year.

### Disadvantaged Youth Program

The Disadvantaged Youth Program is still proceeding. On June 13 twenty-two members of the Olney Kiwanis Club were taken on an orientation voyage. These were the adults who will accompany the under-privileged youth groups as adult assistants. The voyage was to acquaint them with *Tandemeer* and to give them an opportunity to learn to handle the many lines, sheets and halyards. It was a great experience for everyone and necessary because the size of *Tandemeer* intimidates even those with sailing experience.

On 27 June we took the first group of six under-privileged youth for a day's experience in sailing. The trip was very successful and not only enjoyable but educational for all. We are now setting a schedule for the remainder of summer.

### Late Newsletter

The tardiness of the Newsletter has to be attributed to me. After gathering all of the material, I sent it via over night mail to Roger Jones' office, although he had informed me that he would be home recovering from surgery. Because of my mistake, the material languished in his office for a considerable time before he was informed it had arrived. I take full responsibility for the delay and apologize to you all.

### Membership Contribution

From time to time the question arises, from members, on methods of making annual contributions. Many would like to have their contributions debited to their credit cards, but the most difficulty is experienced by our foreign members who want to pay by personal check.

Members who wish to pay by credit card have been too few for the Foundation to make an arrangement with the credit card companies. In addition, the many different credit cards and the very slim margin of income with which the Foundation must work makes such an arrangement impractical.

The other dilemma that our foreign members encounter is our local banking requirement. Local banks charge a $12.00 fee for all international transfer of funds. This fee is applied to all foreign checks that do not have an affiliate in the United States and the name of the affiliate printed on the face of the check. Again, with the slim margin of income, the $12.00 fee is difficult to absorb.

Many members have found reasonable ways around this problem. Our Canadian members can use postal money orders made in U.S. dollar amounts. Other country members have either a bank that has an affiliate or purchase a bank check that has their bank's U.S. affiliate printed on the face of the check. I regret having to return your contributions made on personal checks without the U.S. affiliate imprinted, but I really have no other recourse.

Do not worry about sending in your contribution late. I will not drop you as an active member if you have a delay in getting to a post office or bank.

### NOAA To Distribute DMA Products

A reminder that on October 1, 1992, NOAA will assume responsibility for the Defense Mapping Agency (DMA) public sales program for nautical and astronautical products. At present I do not foresee any problems, but I will keep you informed of progress of this shift.

There has been no mention of a change to the Government Printing Office as the source of the Nautical Almanac. While on the subject of the Nautical Almanac, I called to try and determine the date of availability of the 1993 Almanac and was told, "We do not know when it will be available." More information on this subject when I can get a definitive answer from the GPO.

# DO YOU KNOW...?

*By Allan Bayless*

We all know Harrison was the inventor of the first sufficiently accurate chronometer to find longitude. Larcum Kendall's copy, K1, of Harrison's No. 4 was used by Captain Cook in his later voyages. It is not as widely known that Kendall made a second copy, K2. Who was the famous Captain who used it and what happened to it? (Answer appears at the end of this issue.)

# READERS FORUM

Heartwarming confessions are always good for the soul. We've had an interesting letter from a retired Air Force Colonel in Westminster, California, enclosing his membership application. He notes that he holds an FAA Flight Navigator Certificate, and has conducted many Flight Navigator examinations for the FAA, but that he never considered himself a real navigator —interested in the art but not proficient.

Terry Carraway, in his answer, has put all of our minds at ease. Terry, a carrier pilot trained in the late 1940s, notes that although he was required to study navigation for 21 months, as soon as he finished flight training the only navigation he used in carrier duty was Dead Reckoning, and that one had to be very proficient in determining wind vectors, magnetic headings and time on course to ever get back to the ship. (Thank you for that, Terry. As Editor of this newsletter and as the one who has held a pilot's license for more than 34 years, I, too, would confess that it was Dead Reckoning, more often than not, that got me to my destination.

Charles Lindbergh, with whom I corresponded in 1966, hit the coast of Ireland within just a few miles of his flight-planned route on his 1927 flight to Paris, and it was Dead Reckoning—not my Grandfather's Earth Inductor Compass—aboard the Spirit of St. Louis that got him to Paris and many an earlier and subsequent destination. My salute goes to Colonel Roscoe Johnson in Westminster, California, Terry Carraway, Charles Lindbergh, and the legions of "real navigators" who know from experience how important Dead Reckoning is in itself and in the art of celestial navigation. Roger H. Jones.)

Mike Hollis of 405 Falkirk Court, Falmouth, Virginia 22406, writes that he would be interested to hear from other navigators regarding their time piece preferences. He also asks the question: "If you could design your own watch, what functions would you request? Digital/ conventional face? Time zones? Battery/self-wind? Alarm? Waterproof? Stopwatch? Countdown? Split Time? Cost? etc. ..." He'd like to hear from other members.

(My answer, Mike, is this: Give me an inexpensive battery-operated quartz wristwatch with a conventional face, including sweep second hand, and a small window with a digital readout in 24-hour time, showing hours, minutes and seconds. The conventional face would be set to local time, and the digital readout to Greenwich time. For celestial work, I'd take the sextant shot, mentally count five seconds, and while counting, look at the digital readout. At the fifth second, by mental count, note the digital second count, and then simply subtract five to get the GMT of the sextant shot. Forget any fancy stopwatch work. You can do just as well with a practiced mental count. Use a radio time tick to check the GMT, and keep a record of your watch's rate of change.

The only other feature I would want is that the watch be waterproof to at least 150 feet of sea water. That is because I make my watch do double duty as a diver's watch, and I have found that a watch assembled to SCUBA specifications is more rugged for all around shipboard use. It cost me $35 ten years ago, and has never been off my wrist except to have the batteries replaced. I don't baby it. The pressure and temperature changes of diving don't seem to affect its rate. I still use it for celestial work. It was made in Hong Kong, but the maker's name has long since been rubbed "too thin" to read—Roger H. Jones.)

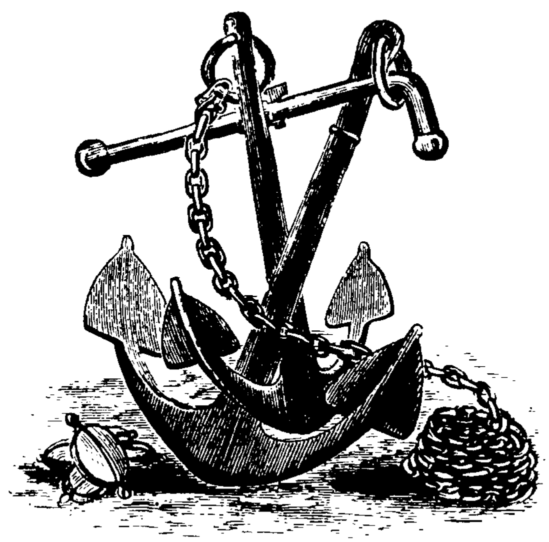
Robert Abell of Galena, Ohio, has written acknowledging that he obtained charts for an Atlantic crossing through the Foundation, and that he visited the Greenwich Royal Observatory while in England. Allan Bayless' feature article in Issue 35, "Pilgrimage to the Prime Meridian," brought back fond memories to him. Other members are reminded that the Foundation can assist with the procurement of charts at a discount. Please contact Terry Carraway.

Member David Bishop has written inquiring about possible life membership in the Foundation. The reply noted that when the Foundation was established this was considered, but rejected. The Foundation is carried on by volunteers who receive no monetary gain. When the original founders, directors, and officers are no longer able to serve, the Foundation may not be able to be continued unless some new blood steps forward. To date that has not happened, but we would welcome hearing from anyone who would be interested in pitching in. Roger Jones, who now edits the *Newsletter* and who has written columns in it since its inception, will be leaving with his boat to go cruising in late 1993, or early

1994. He may be gone three to five years. Terry Carraway will not be able to sustain the 20 to 30 hours a week he puts in indefinitely. Doug Davies and M. Davies Hadaway are busy with full-time careers. John Luykx, Allan Bayless, Ernest Brown and the other Directors have similar limits on their time. The Foundation is strong and is continuing unabated for the time being, but it will eventually need a new complement of people on the "bridge." *David Bishop's letter is timely, because we do need to hear from members who might be willing to lend a hand.*

Member Norman Cubberly of Grafton, Virginia has written anew. It's been some time, and we're glad to hear from him again. He has found the articles by John Luykx on chronometers to be very useful, and speculates that a further article on the effects of battery age might be of interest. He continues as Master of USNS Stalwart, and notes that he has aboard a personal copy of the Davies "Assumed Altitude Tables" which are used when the ship is not in the Arctic. The problem is that the publisher has not updated the precession and nutation tables. That is indeed a problem, and it is a shame, because those assumed altitude star tables are superb in that they permitted the use of "targets of opportunity" without any need to know in advance the identity of the star.

D. F. Stechman, 4 Sea View Court, MacFarlane Avenue, Simonstorn, 7995 Republic of South Africa, has written inquiring about the photogrammetric rectification method used in the study of Peary's 1909 North Pole Expedition. His is a thoughtful letter, but he notes that he did not have available a copy of the full report of the Foundation entitled: *Robert E. Peary At the North Pole.* Indeed, Mr. Stechman, that report does deal with the details of the methodology, and it includes an Appendix C submitted by William G. Hyzer, a consultant in engineering and applied science, who verified the method used. The report is out of print, but we are sending copies of relevant sections. He may be reached at 136 S. Garfield Avenue, Janesville, Wisconsin, 53545, USA.



# NAVIGATION BASICS REVIEW

## Great Circle Sailing and Triple Interpolation

*By William O. Land*

Publication No. 229 (formerly referred to as H.O. 229) "Sight Reduction Tables for Marine Navigation" is the most accurate method available of sight reduction using inspection tables. This data is for the solution of any spherical triangle of which two sides and the included angle are known, and it is necessary to find the values of the third side and adjacent angle. The navigational triangle is a special spherical triangle on the surface of the earth in which the three points are 1.) the elevated pole, 2.) the G.P. (Geographical Position) of the celestial body and 3.) the position of the ship.

Publication No. 229 can be used to solve any spherical triangle if we use substitute names for the three points, the three sides and the three included angles. On page XXI Pub. 229, vol. 3 we are given an example of this to find the distance and the initial great circle course for a ship sailing between two ports. The point of departure is Fremantle, Australia (S32°03', E115°45') and the destination is Durban, Africa (S29°52', E31°04'). Pub. 229 gives an abbreviated explanation with several steps omitted with the results: initial course 246.3° true, and the distance 4235 nautical miles. But it assumes the reader is familiar with sight reduction and triple interpolation. The triple interpolation solution is not given, but the general work-form used is shown on page XXIV. However, these figures shown relate to an entirely different problem pertaining to compass error.

For the less experienced navigator the following is a complete solution of this great circle problem from Fremantle to Durban including the triple interpolation and the plot to determine the correct distance, with all the steps included. Look at the "Great Circle Sailing Work Form," *Figure I.* Line 18 is the initial compass course and Line 28 is the intial distance. Also note at the top of the form the two columns entitled <u>Actual</u> and <u>Base</u>. Actual is the actual latitude and longitude of the starting point and the destination. Base is the change we must make to enter Pub. 229, work form lines numbers 1, 2 and 7 (circled).

To get the initial compass course Line 18 and the distance Line 28 we will solve a nautical triangle using Pub. 229 just as we do for the sight reduction of a celestial body, but we will change the names of the members of the triangle to suit our purpose. See *Figure II.* The name of the south pole remains the same but we change the other members as follows:

AP becomes the starting longitude and latitude.
G.P. star becomes destination latitude and longitude.
Destination latitude becomes declination.
Zn (azimuth) becomes Cn (course).
Z (Azimuth angle) becomes C (course angle).
90° - Hc = distance from starting point to destination.
L.H.A. remains L.H.A.
So, it is the same triangle, just other names.

Refer to the work-form, *Figure I* and the instructions line by line to complete it:

LINE 1. Starting Latitude, N/S, Actual
From page XXI in Pub. 229 vol. 3 enter the starting latitude (Departure) into Line 1, actual column. It is S32°03.0, putting the S into the top of the oval.
Base Column. Change it to S32°00.0' which is the nearest whole integral degree.

LINE 2. Destination Latitude, N/S Actual
The destination latitude is S29°52.0'. Enter this into the actual column with the 5 in the lower part of the oval.
Base Column. Drop the minutes, entering S29°00.0' with the S in the lower part of the oval. Do not round it off to the nearest whole degree. Just drop the minutes.

LINE 4. Destination Longitude E/W Actual
Skip line 3 for the moment. Enter the destination longitude which is E31°04.0'.
Base Column. Repeat the destination longitude E31°04.0', no change.

LINE 3. Starting Longitude E/W, Actual
Enter the starting longitude, E115°45.0'.
Base Column. Change the minutes to 04.0' to match the minutes of line 4. Then bring over from the actual column the E115° to the base column, but change it to E116° so that the change will be less than 1/2° or 30.0' (the same as we do for assumed longitude in sight reduction) between the

| | | |
|---|---|---|
| base column | = | E116°04.0' |
| actual column | = | E115°45.0' |
| difference | = | 0°19.0' which is less thasn 30.0' |

LINE 5. Difference in Longitude
Take the difference between lines 3 and 4 in both columns. It should read 84°41.0' and 85°00.0'.

LINE 6. Correction
Here we don't need the +-360° or the +-60.0'.

LINE 7. L.H.A.
This is the same as line 5 after we make corrections and should read 84°41.0' and 85°00.0'.

LINE 8. Hc (Table)
Enter Pub. 229 with the base values of lines 1, 2 and 7, the same as you do for sight reduction. Use SAME table.
Line 1 is Latitude 32°
Line 2 is Declination 29°
Line 7 is L.H.A. 85°
The Hc should be 18°45.4'.

LINE 9. d Tens + -
This is d +27.0 which is put into the parenthesis. It is treated the same in the interpolation tables as for sight reduction inside the front and back covers of Pub. 229. Use the minutes of line 2 actual, which is 52.0'. Interpolated it is +17.3 and enter it on the same line outside the parenthesis.

LINE 10 d Units + -
This is the "units" increment and is solved the same as for sight reduction in the interpolation tables. It should be +6.1'

LINE 11. Double Second Difference
There is no D.S.D. in this problem.

LINE 12. Hc
Add lines 8 + - 9 + - 10 + 11 = 18°68.8'.

LINE 13. Correction
Enter +1° -60.0' to reduce the 68.8'.

LINE 14. Hc
This is the same as line 12 after the correction has been made. Hc = 19°08.0'.

LINE 15. Z = Uncorrected course angle = C. From Pub. 229, the same place we found Hc and d, find Z = 66.9'. Put this value into line 15 so it reads N/S 66.9° E/W. Then look at the note (15) at the bottom of Figure I. Circle the S because it is the same as the starting latitude line 1. Circle the W because our destination is West of Fremantle. See lines 3 and 4.

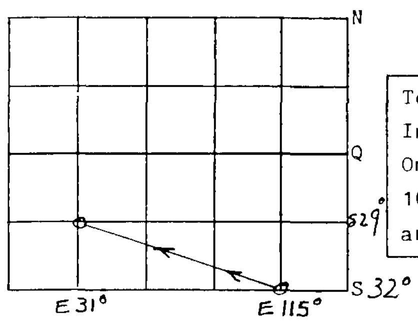
LINES 16, 17 and 18 we will temporarily skip because they are part of triple interpolation and we will return to them later.

LINE 19. Zn. = Uncorrected Course = Cn
Look at the instructions at the bottom of Figure I, for line 18. Since line 15 is S66.9W we find that for S and W, Zn = 180° + 66.9° = 246.9°. This is the uncorrected course Cn, and is taken from True north, not magnetic north.

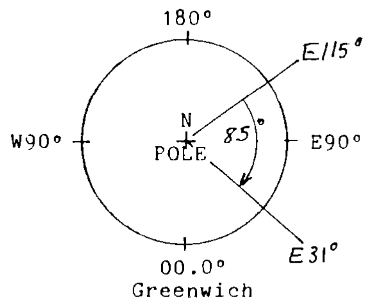
LINE 20
This is 90°00.0' = 89°60.0' which we will use to find the distance to our destination.

GREAT CIRCLE SAILING. GIVEN: Lines #1,2,3,4. FROM: *FREMANTLE*......
H.O. 229 Vol. 3, Page XXI FIND: Lines #18, 28. TO: *DURBAN*..........

| | | Actual | Base | |
|---|---|---|---|---|
| Starting Lat. N/S | (1) | (S) 32°03.0' | (S) 32° 00.0' | LAT. Chg. to nearest ° |
| Dest. Lat. N/S | (2) | (S) 29°52.0' | (S) 29° 00.0' | DEC. Drop the MM.m'. |
| Starting Long. E/W | 3 | E 115°45.0' | E 116°04.0' | Change the MM.m'. |
| Dest. Long. E/W | 4 | E 31°04.0' | E 31°04.0' | Same as "Actual" Column. |
| Diff. in Long. | 5 | 84°41.0' | 85° 00.0' | Line (3) ~ (4). |
| Correction | 6 | ° . ' | ° 00.0' | Need ± 360° or ± 60.0' ? |
| L.H.A. | (7) | 84°41.0' | 85° 00.0' | L.H.A. (Same or Contrary?) |
| Hc (Table) | 8 | 18°45.4 | | |
| "d" Tens ± | 9 | (+27.0)+17.3' | Inc'r. MM.m' from Line (2) "Actual". | |
| "d" Units ± | 10 | +6.1' | " " " " " " . | |
| Double 2nd. Diff. | 11 | ( 0.0)+0.0' | | |
| Hc | 12 | 18°68.8' | Add Lines (8)±(9)±(10)+(11). | |
| Correction | 13 | +1°-60.0' | Need ± 60.0'?. | |
| Hc | 14 | 19°08.8' | | |
| Z =Unc'rr'd. C'rse=C | 15 | N (S) 66.9° E (W) | See Note (15) below. | |
| Triple Interpolation | 16 | -0.6° | See H.O.229 Vol.3 Page XXIV. | |
| Z=Corrected Course = C | 17 | S 66.3° W | Line (15) ± Line (16). | |
| Zn= Corrected Course=Cn | 18 | 246.3° | See Note (18) below. | |
| Zn=Unc'rr'd C'rse = Cn | 19 | 246.9° | See Note (18) below. | |
| | 20 | 89° 60.0' | | |
| Hc ± ? Fr. Line (14) | 21 | − 19°08.8' | See Note Line (21) below. | |
| Distance in Arc ° | 22 | 70°51.2' | Line (20) ± (21). | |
| 60 x ° only | 23 | x60. | | |
| | 24 | 4200.0' | | |
| Add Minutes only | 25 | 51.2' | From Line (22). | |
| Total Dist.Unc'rr'd. | 26 | 4251.2 | Add (24)+(25). Naut. Miles Uncorrected | |
| Plotted Correction ± | 27 | −15.8 | See H.O.229 Pages XXI and XXII. | |
| Total Distance Corr'd. | 28 | 4235.4 | Nautical Miles, Corrected, | |




To Omit Triple Interpolation, Omit Lines # 16, 17, 18, 27 and 28.




Line (15) N/S = Same sign as the Starting Latitude, Line (1).
E/W = Is the Destination E or W of the Starting Longitude Line (3)?

Line (18) N and E Zn = Z
N and W Zn = 360° - Z
S and E Zn = 180° - Z
S and W Zn = 180° + Z

Line (21) Distance Greater than 90° (5400 N.M.), Hc = +.
Distance Less than 90° (5400 N.M.), Hc = −.

FIGURE I

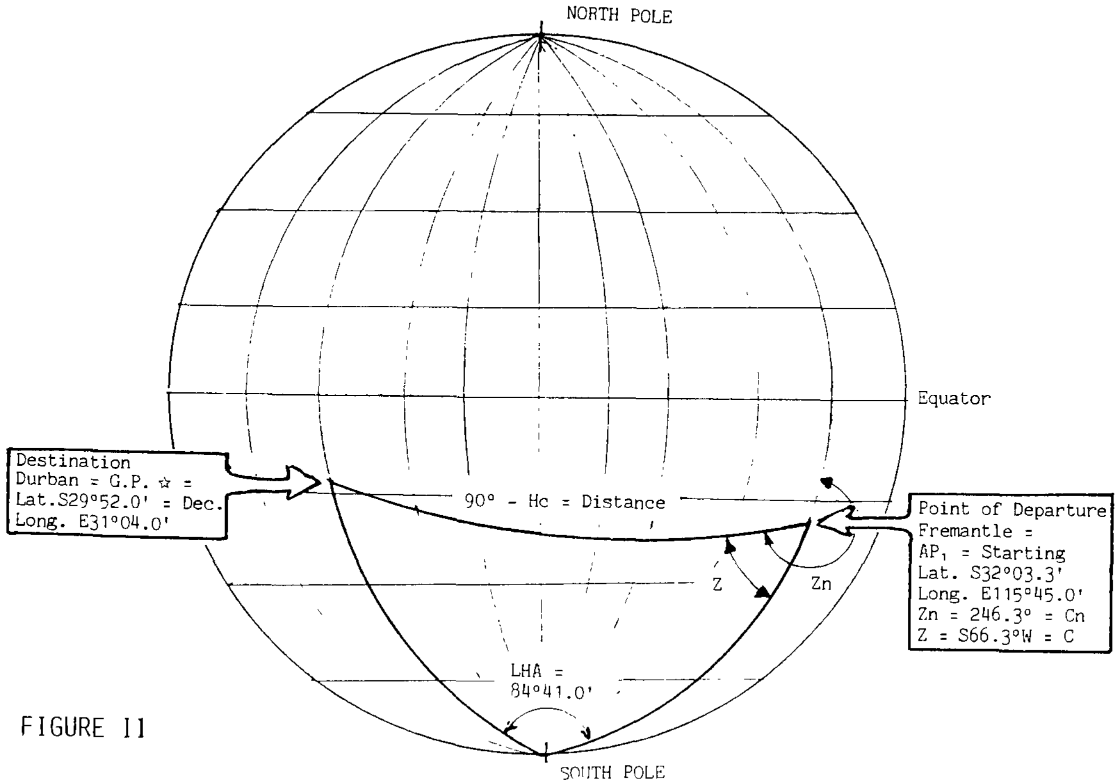


FIGURE II

LINE 21. Hc + -
Bring down the Hc of line 14 = 19°.08.8 and see the note in Figure I for line 21 to determine if it is to be + or -. If the distance between the start and the destination is 5400 miles or greater we make line 21 (+). Less than 5400 miles it is (-). 5400 miles is determined because 90° x 60.0' = 5400 miles. Any voyage we make will be less than 5400 miles before we stop or have to make a turn to avoid an island or shoal. For this problem, line 5 we went 84°, which is less than 90° so let's make line 21 (-). It will read -19°.08.8.

LINE 22. Distance in Arc
This is the great circle distance in terms of arc. Subtract line 21 from line 20. It should read 70°51.2'.

LINE 23. 60 x Degrees Only
Since ° = 60.0 nautical miles we shall multiply 70° x 60. The answer should be 4200 nautical miles.

LINE 24
Line 23 x Line 24.

LINE 25. Add minutes only
Bring down the minutes of line 22, which are 51.2'.

LINE 26. Total Distance (uncorrected)
Add lines 24 and 25 which should be 4251.2 nautical miles uncorrected between Fremantle and Durban. This is the value shown on page XXI in Pub. 229, Vol. 3.

LINES 27 and 28
This small correction is determined by a plot on the Universal Plotting sheet VP-OS, and will be described following the Triple Interpolation section. See Figure IV.

TRIPLE INTERPOLATION. See Pub. 229 page XXIV for the triple interpolation method. Page XXIV however does not show the figures for this problem, so use the values shown in *Figure III*.

LINE 16. Triple interpolation
We entered Pub. 229 with three values:
Line 1 Latitude = 32°
Line 2 Declination = 29°
Line 7 L.H.A. = 85°
But the actual values were:
Line 1 Longitude = 32.03.0'
Line 2 Declination = 29°52.0'
Line 7 L.H.A. = 84°41.0'
Therefore, we must make a correction for the three increment values we omitted:
03.0'
52.0'
41.0'

We will do this, all three numbers at the same time, thus: Triple Interpolation.

COLUMNS A, B, C, D, E *(Figure III)*
For lines 1, 2, and 7 simply copy the numbers from the work form. Column E is from the work form line 15.

COLUMN F
To get these values we fill in the base arguments below.

In line 1 base argument take the starting latitude and add 1° to it because the actual (32°03.3') is greater. The declination is 29° and the L.H.A. 85° is unchanged. Then enter Pub. 229 with these values and get Z = 67.3°.

In line 2 base argument use the starting latitude 32° but add 1° to the declination because the actual declination (29'52.0') is greater than 29°. The L.H.A. will remain 85°. Then enter Pub. 229 to find the Z value which is Z = 66.0°.

In line 3 base argument use latitude 32°, dec. 29.0° but subtract ° from 85° because the actual (84°41.0') is less than 85°. Enter Pub. 229 and find Z = 67.4°. These three Z values are entered into column F on the appropriate lines.

COLUMN G is the Z difference between column E and Column F. Subtract the lesser value from the greater, and the + or - sign is determined by the notes at the bottom of the E and F columns.
If the E value is greater G is -
If the F value is greater G is +

COLUMN H
This is the increment difference between column C and column D.

COLUMN I
Correction
This is: $\frac{\text{Z difference} \times \text{increments}}{60}$

or,

$$\frac{\text{column G} \times \text{column H}}{60}$$

When making these multiplications and divisions be aware of the + and - signs. When these three values are determined, add them and the total should be -0.6° which is entered into line 16 of the great circle work form.

LINE 16. Triple Interpolation
Enter -0.6° from column I.

TRIPLE INTERPOLATION FOR GREAT CIRCLE SAILING H.O. 229

FREMANTLE TO DURBAN
H.O. 229 VOL. 3 PAGE XXI CASE I

| A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|
| Line # | | Actual | Base Arguments | Base Z | Table Z | Z Diff. | Increments | Correction (Z Diff. x Inc.) / 60 |
| 1 | Stg.Lat. | S 32°03.0' | 32° | 66.9° | 67.3° | +0.4° | 03.0' | +0.02° |
| 2 | Dec. | S 29°52.0' | 29° | 66.9° | 66.0° | -0.9° | 52.0' | -0.78° |
| 7 | L.H.A. | 84°41.0' | 85° | 66.9° | 67.4° | +0.5° | 19.0' | +0.158° |
| | | | | Greater - | Greater + | | | -0.6° Total Corr. Put this number into Line (16) |

Line #1
Base Arguments Stg. Lat. +/- 1° = 33° Z = 67.3°
" " Dec. = 29°
" " L.H.A. = 85°

Line #2
Base Arguments Stg. Lat. = 32° Z = 66.0°
" " Dec. +/- 1° = 30°
" " L.H.A. = 85°

Line #7
Base Arguments Stg. Lat. = 32° Z = 67.4°
" " Dec. = 29°
" " L.H.A. +/- 1° = 84°

NOTE: See page XXIV in Publication H.O. 229 vol 3 for Triple Interpolation instructions and explanation.

NORRISTOWN, PA. 19403

Col. A. From Work Sheet Number Column
Col. B. From Work Sheet Name Column
Col. C. From Work Sheet Actual Column
Col. D. From Work Sheet Base Column
Col. E. From Work Sheet Line (15)
Col. F. From Base Arguments (Above)

Col. G. = Diff. between Col. E. and Col. F.
Col. H. = Diff. in [illegible] between Column C and Column D.
Col. I = $\frac{\text{Col. G. times Col. H.}}{60}$

FIGURE III

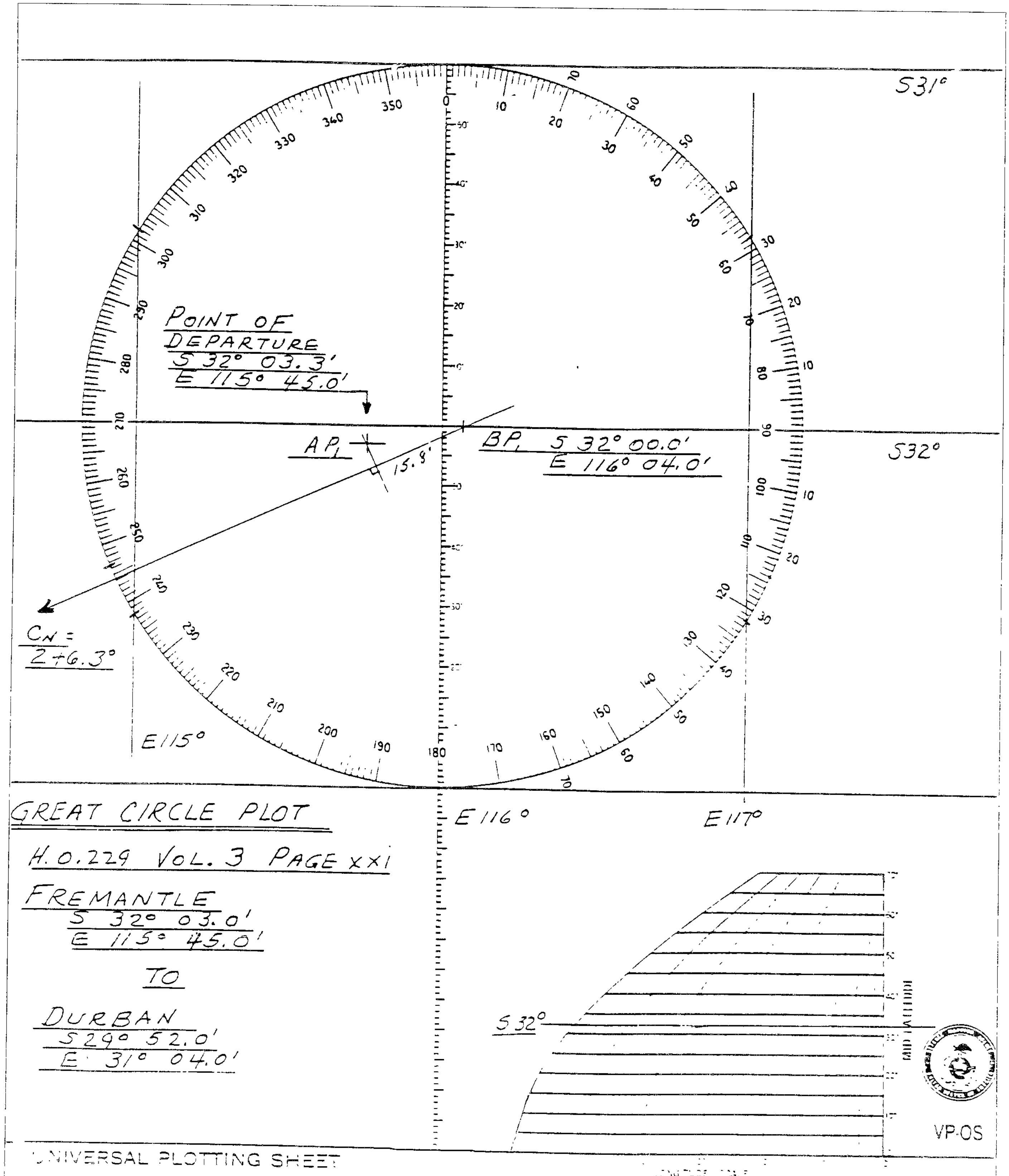

S31°
POINT OF DEPARTURE
S 32° 03.3'
E 115° 45.0'
AP1
15.8'
BP1 S 32° 00.0'
E 116° 04.0'
S32°
CN = 246.3°
E115°
E116°
E117°
GREAT CIRCLE PLOT
H.O.229 VOL. 3 PAGE xxi
FREMANTLE
S 32° 03.0'
E 115° 45.0'
TO
DURBAN
S 29° 52.0'
E 31° 04.0'
S 32°
VP-OS
UNIVERSAL PLOTTING SHEET

FIGURE IV

LINE 17. Z Corrected course = C
Add lines 15 and 16. Line 17 should read S66.3°W.

LINE 18. Zn = Corrected Course - Cn
Refer to the note below on Fig. 1 for line 18. It is Zn = 180° + 66.3° = 246.3° which we enter into line 18. Note that the difference between the corrected course and the uncorrected course is only 0.6°.

LINE 27. Plotted Correction
Note that the latitudes and longitudes of the starting point and the destination are different for actual and base. For a correction for the distance we must make a plot on a sheet of VP-OS plotting paper and here are the steps: See *Figure IV*.

1.) On a sheet of VP-OS prepare the lines the same as we do for a sight reduction plot. Mark the horizontal S32° and the vertical line E116°. Also show the vertical lines for E117°, E115° and the S32° line on the longitude scale graph in the lower right hand corner.

2.) On the S32° line put a dot at the Base Starting Latitude and Longitude of S32°00.0 and E116'04.0'. Mark it BP, meaning Base Position.

3.) We now put a dot at the point of departure, i.e. the actual starting latitude and longitude of S32°03.0' and E115°45.0'. Mark it AP, meaning actual position.

4.) With your parallel rules, and from the center of the compass rose determine the corrected course (line 18) of Cn = 246.3°. Transfer this linear direction of 246.3° to the BP, dot and draw a line through the dot. Mark the 246.3° end with an arrow and label it Cn = 246.3°.

5.) With your plotter draw a line at right angles (90°) to the Cn line which will pass through the AP, dot. Mark the right angle with a small square.

6.) With your dividers measure the distance between the BP, dot and the intersection at the 90° square.

7.) Detrmine this distance from the vertical scale. It should scale 15.8'. Enter this value into line 27.

8.) Now we must deterrmine whether the 15.8' correction is + or -. By inspection of the plot we just completed determine if the BP, or the AP, is closer to our destination. Our course is 246.3° as indicated by our Cn line. Therefore, AP is closer to our destination than is BP, and so our corrected distance is 15.8 miles less than the uncorrected distance of line 26. Put a (-) in front of the 15.8 of line 27 making it read -15.8.

LINE 28. Total Distance Corrected
Subtract line 27 from line 26 and the answer should be 4235.4 nautical miles which agrees with the values on page XXI of Pub. 229 vol. 3.

*Editor's Note: William Land's article fills in the gaps in the explanation of great circle sailing that appears in H.O. 229. He uses this material in his own course on celestial navigation. He may be reached at: 1521 West Main Street, (E-1) Norristown, PA 19403.*

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## The Computer in Celestial Navigation
*By John M. Luykx*

GENERAL

At the present time computers have now pretty well taken over as the primary mathematical tool by engineers, physicists, accountants, general scientists and astronomers. Navigators may wish to consider using them as a mathematical tool as well.

The history of navigation science shows only too clearly how the practice of navigation has continually improved with time as its tools and instruments have constantly and progressively developed from early instruments such as the sounding line and compass of the 13th Century to the sophisticated mechanical and electronic navigation systems of today. The computer, especially the small pocket hand-held type, can be considered as basically the most modern tool in the history of the solution of problems in small vessel celestial navigation; i.e. this type of computer is basically the latest phase in the continual development of mathematical methods and procedures for navigational use which began in the 13th and 14th Centuries in western Europe. The process of development then continued a) with the Trigonometric Tables of Regiomontanus (mid-15th Century); b) with the early logarithm tables of Edmund Gunter (late 17th Century; c) with the French and English nautical almanacs of the late 17th and 18th Centuries respectively; d) with the short-method inspection tables that became popular especially among British navigators during the late 19th Century and eventually e) the early 20th Century tabular methods of Aquino and Ogura culminating in the well-known modern series of tables introduced in the U.S. and Britain such as H.O. 208 (Dreisenstock), H.O. 211 (Ageton), H.O. 214, H.O. 229, H.O. 249 and the Concise Sight Reduction Tables now included in the U.S. and British Nautical Almanacs.

Small hand-held (pocket) completely programmable computers, with comprehensive programs, have particular advantages for celestial navigation over tabular methods. Some of these are: a) the DR, instead of an assumed position, is used as a reference; b) solutions are accurate; c) solutions are rapid; d) plotting of multiple lines of position is not required to obtain a fix, and human error in plotting LOPs thereby significantly reduced; e) rapid and accurate calculation of Great Circle, Composite, Mercator and Traverse problems are possible; and f) poor observations and blunders are easily and rapidly recognized.

It is interesting to note what Captain Alton B. Moody states in this regard on page 10 of his book *Celestial Navigation in the Computer Age*; i.e. "The disadvantage of the type of computer discussed in the previous paragraph (in the book) does not apply to a computer that can be programmed to perform computations of the type encountered in celestial navigation. Such a computer can provide fast, essentially error-free results. Further, if the computer can store or compute ephemeris data, both sight reduction tables and almanacs can be relegated to standby status. Whether sight reduction by computer is easier, faster, more accurate, or otherwise preferable is a matter for you to decide based upon your own preferences and your computer's capability. Each method properly used and understood can provide satisfactory results."

As a result of much practical experience (over 45 years) in taking and reducing celestial observations at sea and ashore, the author now employs a pocket programmable computer with internal clock and fix routing for multiple observations as the primary tool or method for celestial sight reduction. This computer is also a great advantage in voyage planning which includes great circle, composite, traverse and mercator sailing computations. When a computer is used, the Nautical Almanac and Sight Reduction Tables can be utilized as the back-up system for celestial sight reduction.

With regard to other calculations during the day's work, the computer is also used to great advantage in such calculations as star identification in celestial body position prediction, and in the rapid computation of rising, setting, twilight and meridian passage data for the sun and moon. Accurate and rapid latitude of Polaris as well as latitude by meridian passage observations are also enhanced with modern pocket celestial navigation computers.

Experience over the years has convinced the author that, as a computing tool, the hand-held comprehensive pocket programmable computer is far superior to the sight reduction table when solving typical problems encountered during the "day's work at sea."

The navigator of a yacht or small vessel who is, as yet, unfamiliar with the use of the computer for navigation should, the author believes, seriously consider its many advantages in navigation. Surely, its comprehensive programs, its portability, its accuracy, its rapidity of calculation and the fact that it can be made impervious to the sea environment are recommendations for its use.

The art of navigation as expressed in Chapter I of Bowditch is the process of safely directing the movements of a craft from one point to another. Commander W. E. May goes a bit further in the introduction to his book *A History of Marine Navigation* when he writes that "...he merely exercised the art of the navigator by taking into account the best information available to him...."

The computer, simply and basically stated, is just the latest in a long line of tools and instruments developed over many centuries which invariably and uniformly has improved the manner in which the navigator is able to practice his art.

# HISTORY OF NAVIGATION

## The Quincentenary of the First Columbus Voyage to the Americas

*By John M. Luykx*

*Editor's Note: This is a continuation of the discussion which appeared under the same name in Issue #35).*

TELEVISION, VIDEOS, BOOKS

Earlier this year the Public Broadcasting System (PBS) aired a series of television programs under the title *Columbus and the Age of Discovery*. It was a co-production between WGBH—Boston and several foreign partners: BBC—England, TVE and EQC—Spain, RAI—Italy, NHK—Japan, and NDR—Germany. The series was well received in this country and is currently available commercially to the public both as a set of seven video tapes and as a well-illustrated 370-page book under the same title by Zvi-Dor-Ner (producer of the television series) and published in 1991 by William Morrow Company, Inc. of New York.

In the introduction Zvi-Dor-Ner explains that ... "The historical record contains an infinite number of events, pieces of information, opinions and personalities. One needs some criteria to sift through it all to give it meaning. I have come to believe that the main purpose of documentary history is to teach us about the present; to answer questions; How did we come to be *what* we are? *Who* are we? *Where* are we? Columbus might have reduced it to dead-reckoning navigation: You have to know where you started to know where you are going ..."

The book is available from bookstores. The seven set video tape series may be ordered by contacting:

Films for the Humanities
P.O. Box 2053
Princeton, New Jesey 08543
Phone: 800-257-5126, Ext. 229

In association with the visit of the replica Voyage of Discovery ships, the *Santa Maria*, the *Pinta* and the *Nina* to this country in 1991, 1992 and 1993, an interesting book has been published both in English and Spanish by the SOCIEDAD QUINTO CENTENARIO, C/Aravaca 22, 28040 Madrid Spain, entitled THE NINA, THE PINTA AND THE SANTA MARIA. It is a 130-page hard-cover color-illustrated documentary of the design and construction of these ships and the historic voyages in 1991 of Columbus' replica ships in the Mediterranean and the Atlantic prior to their Atlantic crossing. Among the many photos, illustrations and drawings contained in the book are reproductions of some of the sixteenth century architectural renderings showing the original designs of ships similar to the nao and caravels used by Columbus during his first voyage to the Americas in 1492. The book also contains a large number of excellent color photos taken of the replica fleet while at sea.

SHIP VISITS

The revised schedule of the ports of call in the United States of the Columbus replica ships, *Santa Maria, Pinta* and *Nina* is as follows:

Annapolis: June 6-11, 1992
Philadelphia: June 13-22
New York: June 25-26
New London/Mystic: July 28-31
Boston: August 3-13
San Francisco*: October 7-25
Santa Barbara: October 30-1 November
Los Angeles*: November 8-29
San Diego*: December 11-3 January 1993

*Note:* * *The West Coast itinerary is still tentative.*

The Grand Regatta Columbus 1992 departed Genoa April of this year to arrive Liverpool in August. The Regatta visited Lisbon 23-25 April, Cadiz 29 April-3 May, the Canaries 11-13 May, San Juan, PR 10-14 June and will visit New York 3-7 July and Boston 10 to 18 July before re-crossing the Atlantic to visit Liverpool 10-15 August.

More information about participating vessels can be obtained from the National Maritime Historical Society, Box 68, Peekskill, New York 10566.

The TOPSAIL Parade in Boston 1992— The parade of tall ships in Boston will be greeted by the USS Constitution which will get underway especially for this occasion. The tall ships may be visited in Boston from 12 to 15 July. For more information contact:

SAIL Boston 1992
250 Summer Street
Boston, MA 02210
Phone: 617-330-1992

MARITIME EXHIBITS

Members interested in learning more about the exhibitions, regattas, rallies and festivities celebrating the Columbus Quincentennial should call or write:

The Christopher Columbus Quincentenary
Jubilee Commission
1801 F Street, NW, 3rd Floor
Washington, DC 20006
Phone: 202-632-1992

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 35, Answer.

The great principle, by means of which the navigator can use the navigational triangle to determine his position, is well known to students of trigonometry. Simply stated, it is this: if you know the length of two of the three sides of any triangle, and if you know the size of the angle that is formed where these two sides meet (the "included angle"), you can determine the length of the third side and the size of the other two angles formed where that third side intersects the first two sides. In the days before there were inspection tables or electronic means of solving ther spherical trigonometry problem, the navigator (who was most likely the Captain) had to do the tedious trigonometry by hand. Today, the navigator, if he knows how to use the tables and other tools of the trade, needs little more than simple addition and subtraction skills.

How does this great principle relate to the real world of the man at sea? Again, the answer may be simply stated. The navigator always maintains a DR track. At the time of his celestial shot, he presumably has a DR position, and it doesn't have to be a precisely accurate one. The length of one side of the great triangle is the arc length from his DR to the Pole nearest his DR position. At his DR he is on some meridian of longitude. The distnce along that meridian from his DR to the Pole is that same length of the first side.

From the *Almanac* the navigator determines the exact latitude and longitude of the position on the surface of the Earth that lies directly beneath the celestial body observed at the second in time of the observation. The length of the second side of the triangle is the arc length from that exact position to the same Pole. The angle between these two sides is the angle where those two meridians meet at the Pole. That angle is the difference in longitude between the DR position and the position of the celestial body. (The third side and the other two angles will be discussed in Issue No. 37).

What are the basic tools then used by the navigator? Apart from the sextant and the chronometer employed in timing the celestial shot, they are: a current year *Almanac*, a set of sight reduction tables (or perhaps electronic means of solving the problem), a set of plotting instruments (parallel rules, plastic triangles, plotter with compass rose, etc.), and a chart or universal plotting sheet upon which to make the plot. Also a radio, receiver capable of picking up the time ticks, is fairly essential in checking the accuracy of the chronometer.

Problem No. 36.

How does the navigator use these tools in determining his position; what is the practical meaning of the information obtained form the sextant shot, the Almanac, and the sight reduction tables?

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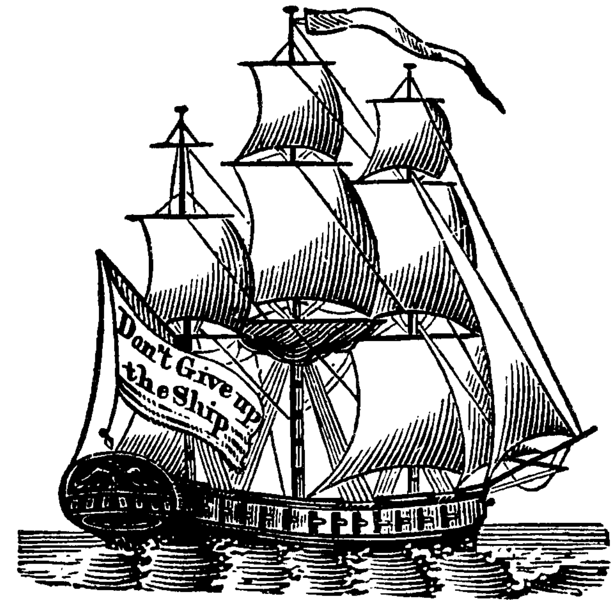
# NAVIGATION PERSONALITIES

*By Roger H. Jones*

## Captain Joshua Slocum

The series of biographical portraits of navigation personalities first appeared in Issue 12. In reviewing the list of persons presented thus far, this Editor was struck by one name that has thus far been omitted—that of Captain Joshua Slocum.

Slocum was the first person to make a sole circumnavigation of the world, which was accomplished during the period April 24, 1895 - June 27, 1898. His book and account of that epic voyage, *Sailing Alone Around the World*, was first published in 1899, and for ninety-three years that book has stood the test of time. It is one of the




great classics in its field, and has been translated into many foreign languages.

Slocum was a merchant marine Captain who had seen his share of commands during the last great age of sail. At the time when his great voyage started, he was fifty-one years old. He had been ashore, without command for a number of years, when he was offered a derelict thirty-seven foot sloop that was forlorn and almost forgotten. The year was 1892, and on a midwinter day in Boston Slocum met an old acquaintance, a whaling captain, who said: "Come to Fairhaven and I'll give you a ship." But, he added, "she wants some repairs." This ship turned out to be the "Spray." Propped up in a field some distance from salt water, she was indeed in sore need of heavy work.

Slocum set the local tongues abuzzing. He went to work on her and eventually completely rebuilt her. His total cost was $553.62 for materials, and thirteen months of his own labor. He then spent a season in the newly rebuilt "Spray" fishing on the New England coast, only to find that he (in his own words) "had not the cunning to properly bait a hook." He therefore resolved to make a world voyage, and at noon on Aril 24, 1895 he weighed anchor and made his way out to sea from the port of Boston. He, of course, had no engine or other modern appliances. What he did have aboard was a large store of dried cod, a barrel of oil to calm heavy seas, an oil lantern, a castaway dory cut into two pieces that was both his dingy and his laundry tub, a sextant, and no chronometer. To clean and adjust his old time piece would have cost $15.00, and this was an expense he elected to forego. Later he was to make good use of an old clock with one hand missing. For longitude he employed the lunar distance method.

He crossed over to Gibraltar. After an encounter with pirates on the North African coast, he recrossed the Atlantic, and followed Magellan's course southwest. He passed through the Straits of Magellan, nearly losing his vessel to unfriendly Indians in the Cape Horn region, and also nearly losing it in the maelstrom of the Milky Way, a vicious area of swirling water and rock on the Pacific side of the tip of South America. Eventually, he traversed the Pacific and Indian Oceans, rounded the Cape of Good Hope, and crossed the Atlantic a third time, dropping anchor on June 27, 1898, in Newport Rhode Island. He had cruised over 46,000 miles entirely alone, and entirely by sail. He had rebuilt "Spray" well, and much of he time, with her helm lashed, she sailed herself. There was no autopilot, and no wind vane.

Along the way Slocum lectured, and he was generally greeted with incredulity by mariners and landsmen alike. No one could at first believe that this brown-bearded, bald-headed son of Massachusetts was really carrying out this voyage totally alone. Those who met him in the far flung ports of the world soon came to understand that indeed, he was alone, totally self-sufficient. They came to appreciate that he was a master navigator and sailor of almost unparalleled skill. Those who later read his book came to view him with awe.

From his royalties and earnings from lecturing, Slocum bought his first home on land in 1902—an old house and acreage on the edge of the village of West Tisbury, Massachusetts. There, with retired whaling captains for neighbors, he became a farmer for a season or two. However, his heart was aboard the "Spray." In the autumn of 1905, Joshua Slocum sailed once more alone with a destination of the West Indies. He was back the following spring, but he did not stay long. He again sailed to the West Indies in the succeeding two or three years. Vineyarders said that he would plant his bones in that boat he had rebuilt and taken around the world.

In the fall of 1909, at the age of 65, Joshua Slocum again set out alone. His plan was to explore the Orinoco, to sail up that river into the Rio Negro, and thence to the Amazon. He vanished somewhere along the way, for he was never seen or heard from again. Some years later he was declared legally dead.

Here was a master mariner and navigator. He was frequently without charts, relying entirely upon his skill as an interpreter of the signs of the sea. He did his trigonometry by hand. He made his own plotting sheets. Somehow, he managed to be on watch when danger was present, and to sleep when it was lessened. He truly paved the way for the legions of small boat sailors who would follow in his wake. Few, if any of them, however, would presume even to imagine in moments of fantasy that they might one day become the truly proficient navigator that was Captain Joshua Slocum.

# MARITIME INFORMATION NOTES

*Provided by Ernest Brown*

## European Maritime Radio Beacons

Major changes to radiobeacons within the European maritime area are due to take place commencing April 1992. These changes are the result of resolutions agreed upon at the Conference for the Planning of the Maritime Radionavigation Service in the European Maritime Area, 1985 (The Geneva Plan).

At present many radiobeacons transmit a continuous carrier signal with an amplitude-modulated tone. This emission is a double sideband signal. Starting April 1992 many radiobeacons will transmit only a carrier signal. The carrier will be keyed to provide a Morse call sign for identification of the station.

Beginning April 1992 the composition of signals will be based on a one-minute duration with a format as follows:

| | |
|---|---|
| Identification: at least twice | 13s |
| Long Dash | 47s |
| Total | 60s |

Radiobeacons can currently operate either within a group of beacons or as a single beacon. Their transmissions are either time-shared or continuous. Starting April 1992 many radiobeacons will begin to operate individually and continuously.

Changes to U.S. charts and publications will be made as specific detailed information is received from the originating sources.

## Global Maritime Distress And Safety System SafetyNET Trials

The Defense Mapping Agency is testing the SafetyNET system to:

a) verify that Enhanced Group Call (EGC) SafetyNET will provide services as designed to broadcast of Maritime Safety Information (MSI)

b) help registered information providers, e.g. the Defense Mapping Agency, gain expereience in SafetyNET operations

c) finalize development of the Operational Guidance, Annex 4, of the Provisional International Maritime Organization (IMO) SafetyNET Manual.

Sporadic NAVAREA IV and XII navigational warnings are currently being transmitted via INMARSAT commercial satellites as part of the test. Users of INMARSAT who are equipped with a terminal with EGC capability should be able to copy these satellite transmissions provided their terminal has been commissioned and the appropriate satellite channel has been selected [Atlantic Ocean Region West (AOR-W) for NAVAREA IVs and Pacific Ocean Region (POR) for NAVAREA XIIs].

Users copying these satellite transmissions are requested and encouraged to provide feedback to the Defense Mapping Agency regarding reception, timeliness, and other notable features of this new communications medium via the following:

*By mail:*
Director
Defense Mapping Agency
Hydrographic/Topographic Center
Attention: MCC (Mail Stop D-44)
4600 Sangamore Road
Bethesda, MD 20816-5003

By telex: 898334 DMAHTC WSH
Easylink mailbox: 62554950

By AUTODIN
message: DMAHTCNAVWARN WASHINGTON DC

By FAX: (301)227-3731

Tentative Schedule:
Until 1 June 1992, only a sampling of NAVAREA IV and XII messages will be sent Monday through Friday.

From 1 June 1992 (or earlier, if possible) all NAVAREA IVs and XIIs will be sent via satellite.

## Floppy Almanac Available for 1992 and 1993

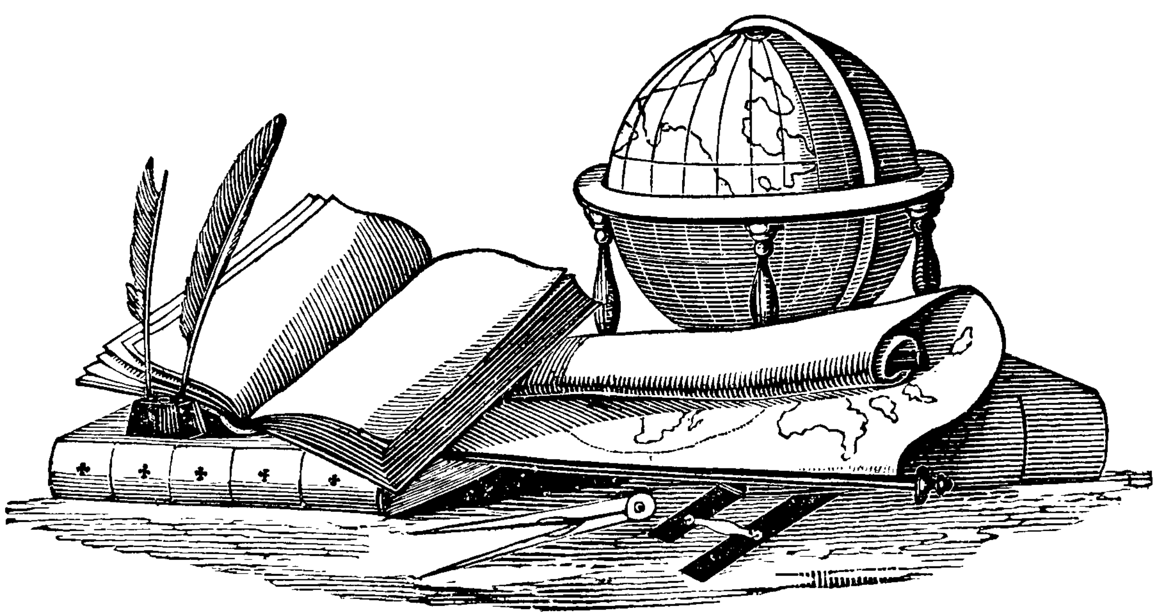
The Floppy Almanac is a microcomputer software product of the U.S. Naval Observatory which can compute and display most of the information contained in one year's editions of the Astronomical Almanac, Nautical Almanac, and Air Almanac, providing the data for specific times and locations. The Floppy Almanac can provide, for any date and time within the year, the apparent positions of the Sun, Moon, planets, and stars; sidereal time, rise, set, and transit times for any object and any location; navigational information sufficient for sight reduction; and other information.

The Floppy Almanac runs under MS-DOS on PC-compatible microcomputers with at least 210K of free memory. A hard disk is not required. A numeric coprocessor will be utilized if available and considerably improves response time. The Floppy Almanac is distributed as an executable module, with associated data files, on one MS-DOS-compatible floppy diskette, valid for one specific year. A User's Guide is included.

Distribution to DoD installations and vessels is free of charge. POC is: AA Dept. U.S. Naval Observatory, Washington, DC 20392-5100; DSN 294-1547 or 294-0020. Diskettes for 1992 and 1993 are available.

Distribution to non-DoD government agencies, civilian organizations, and the public is handled by the National Audiovisual Center, (800)788-6282, at a cost of $30 for a package containing the 1992 and 1993 diskettes.

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126
Rockville, MD 20850
Telephone 301-622-6448



# BOOK REVIEW

*By Roger H. Jones*

*EDITOR'S NOTE: Occasionally in the Newsletter we have departed from th practice of reviewing new books on navigation. From time to time there have apeared reviews of old classcs, video tapes, and even books that are more in the nature of true accounts of significant voyages by noteworthy navigators. We again depart somewhat in this issue. At the present time there do not appear to be any significant new books of a 1992 vintage on navigation per se, but there are new offerings that should be of interest to the 1992 navigator. One of the purposes of the Foundation is to keep its members up to date on these new publications, even if they are not strictly about navigation. In keeping with that purpose, the following is focused on a topic that has become of vital importance to every captain/navigator.*

## Boarded - A Guide to Understanding the Coast Guard Boarding

By Joe Meek
Copyrighted in 1991 by Joe Meek, and available in nautircal book stores. 43 pages, $6.95

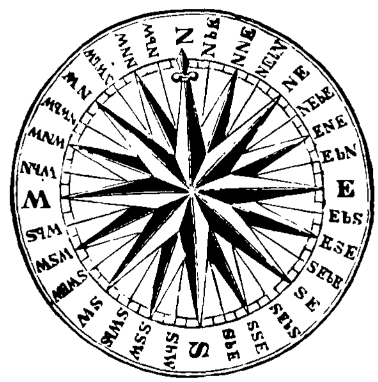
Jo Meek's little book on the subject of boarding is must reading for every skipper/navigator. Meek wrote his book from the vantage point of thirteen years of experience as a Coast Guard law enforcement Boarding Officer. It is addressed to the really practical sort of information that informs the reader how to avoid possible trouble by saying and doing the right things in the presence of a boarding officer. It is full of information about the wrong things that a mariner might innocently say or do.

The Coast Guard is now conducting thousands of boardings each year. In about 40% of these boarding cases, a violation of some type is noted. A violation can cost you $25 to $5,000, or even forfeiture of the vessel. It may also result in destructive search of the vessel, with consequent damages costing tens of thousands of dollars to repair. The Government may or may not foot the repair bill.

Meeks fully explains what authority the Coast Guard and its boarding officers have, and what authority the vessel's captain and crew may have. It addresses the real world problem of the skipper with an "attitude" and how this may influence the outcome of the boarding. It addresses the question of what the boarding officer is looking for, and how he will conduct his examination of the vessel. It tells you in plain terms how to act and how not to act towards the boarding officer. It tells you specifically how to answer questions relating to ownership, name of the vessel, country of registry and homeport, ports of call, purposes of the voyage, people on board, nationalities, documentation or registration numbers, weapons on board, and many other topics.

Joe Meeks dwells on dockside boardings, open sea boardings, boardings at night, and the types of searches that may be conducted. This includes the destructive search. He explains the emerging role of the U.S. Navy, the U.S. Air Force, and the air wing of the U.S. Army.

The author concludes with sections on how to deal with violations and the various types of violations, information on how to complain to the Coast Guard, and specific addresses and telephone numbers of Coast Guard offices. This reviewer has been an attorney for many years, and in truth, a reading of this book changed my view and gave me some valuable insights. I have not been boarded, but Meek's book will assist me in preparing for a possible boarding. As a navigator, it is my responsibility to get the vessel to where she's going, and that may well include dealing sensibly with a boarding along the way. Readers of the Newsletter, if you spot a copy of this little book in a nautical book store, don't pass it by.



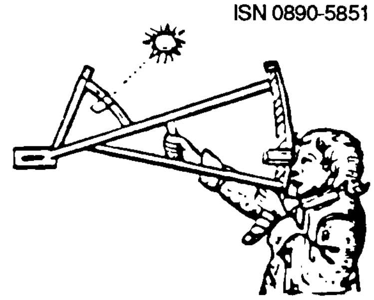
DO YOU KNOW. . . The question and the following answer are provided by Allan Bayless.

Larcum Kendall's second copy, K2 of Harrison's No. 4 was issued to Captain Bligh of the *Bounty*. The chronometer stayed with the mutineers aboard the ship and accompanied them to Pitcairn Island.

It ultimately found its way back to England, and is now on exhibit with Harrison's five chronometers and Kendall's K1 at the National Maritime Museum.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-SEVEN, FALL 1992

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Government Charts And Publications

As noted in the Summer Issue of The Navigator's Newsletter, NOAA has assumed responsibility for all nautical, astronautical, navigation charts and publications. This includes aeronautical, international, coastal and inland charts previously issued by the Defense Mapping Agency, in addition to charts, all sight reduction tables, Bowditch and the other tables and lists published by the DMA. The Government Printing Office will still issue the Nautical Almanac.

Members can continue to place orders for all charts and publications by a telephone call, note, letter or a FAX (on call only). Delivery time will continue to be from three to six weeks depending on the speed that NOAA ships the charts to the Foundation. Chart list prices as of 1 October 1992 are as follows: Charts $14.00; Coast Pilots $20.00; Tide Tables, Tide Current Tables $10.00; Tidal Current Charts and Diagrams $8.00. We do not have the revised price of Bowditch, sight reduction tables or the Nautical Almanac at this time. I do not expect a large change in price of these publications; however, anything is possible in this economic climate.

Members still receive a 20% discount on all chart orders under $50.00 and on all publications. For chart orders only, members receive a 25% discount on all charts. We regret that we must continue to charge postage or shipping costs for the foreseeable future.

### Disadvantaged Youth Program

The Disadvantaged Youth Program has concluded for the season. We had an interesting if rocky start, but with the lessons learned this summer I believe that we can continue next season with a good group of youth who will benefit by the program.

We plan to get an early start next season by commencing classroom lectures and discussions in April. This will prepare the Youth for their first time aboard and will eliminate the time aboard required to teach terminology and routines.

## READERS FORUM

Michael J. Hollis of Falmouth, Virginia has written requesting comments on various artificial horizons inasmuch as he has moved to an area where he has no clear horizon for celestial observations. John Luykx' reply may be of interest to some readers. John wrote back: "... I would recommend for general use a bubble artificial horizon which can be fitted to your sextant in lieu of the sextant telescope. The disadvantage of the Davis and Freilberger artificial horizon is that it is limited in use to altitudes which are equal to 1/2 the arc range in degrees of the sextant in use. For example, if a sextant with a range of arc of 120 is used . . ., the highest observed altitude could only be 60, hardly enough to determine the noon latitude . . . at a location such as Falmouth during the month of June and part of July. On the other hand, a bubble artificial horizon attached to the sextant is capable of measuring angles up to 90 and can be used at any time and at any place."

P.M. Janiczek, Director of the Astronomical Applications Department at the U. S. Naval Observatory, has furnished to John Luykx a detailed letter which explains a useful method for using the Concise Tables for high altitude sights. John replied that he hoped to try this solution to the problem during the summer. Readers interested in this may wish to correspond with John. Meanwhile, a copy of Director Janiczek's letter is included as an addendum at the end of this Newsletter.

Steve Kent of Calgary, Canada, has written inquiring about the article mentioned in Issue 31 which was to be a "somewhat different approach to lunar distances" as proposed by Admiral Tom Davies. Admiral Davies' untimely death intervened, but he explained that his method would use a unique method of establishing the Moon's path and that it would reduce the steps for both calculating the lunar distances and "clearing" it for corrections. John Luykx replied to Mr. Kent that the article is not yet complete. John is working on it, and if possible, the article originally mentioned by Tom Davies may yet be published. It requires a considerable amount of detailed work, as it proposes a comprehensive listing of the sequential procedures required in clearing a lunar distance with examples of all the typical solutions.

Captain Norman Gubberly of Grafton, Virginia, a frequent contributor to the Newsletter, has written with several inquiries. One of these related to the rating of inexpensive quartz watches. John Luykx, whose series of articles on the subject of marine chronometers appeared in this Newsletter, has noted that many of the Casio watches, which are quite inexpensive, can provide accuracy to within one second per month at a constant temperature. John has little detailed information on the effect of battery age, except that when the battery weakens appreciably, the watch accuracy will drop off rapidly. He has found that watch accuracy is maintained for generally 95 to 99% of battery life. Editorial comment: Roger Jones is experimenting with rechargeable AA and C cells in two different chronometers (not watches) aboard his 43-foot cutter, and has noticed a marked error that appears near the end of the charge.

Captain Cubberly also noted in his letter that at the June, 1991 meeting of the Institute of Navigation in Williamsburg, Virginia, mention was made of the possibility of Peary having used observations of the Sun at East or West transit to determine right or left drift. On the basis of the exhaustive study done on the Peary 1909 expedition by the Foundation, it was concluded that Peary did not require such observations, as he relied on noon transits which cast a shadow to indicate True North. He did, however, establish his current position at the Pole itself on April 7, 1909, using an observation of the Sun to the East.

Corey Bohling of St. Albans, Missouri, has inquired as to the specifics of using a short wave radio with a "note book" computer to obtain weather fax information. He also inquires if such a computer can be used to send a fax over a single sideband radio. Readers who are Ham radio operators may wish to furnish their views to Mr. Bohling at Tavern Creek Ranch, St. Albans, MO 63073. Editor's note: Write to the American Radio Relay League, 225 Main Street, Newington, CT 06111. Inquire about articles on this subject in QST, the informative and often technical magazine of ARRL.

Several readers of the Newsletter have written to inquire about the little book, *Boarded*, that was reviewed in the last Issue. Interested members may write to Roger Jones, 13900 Panay Way, M-115, Marina del Rey, California, 90292. He has obtained a copy for one member from a nearby nautical store, and would be happy to do so for any other person. The cost is $6.95, plus tax and postage. The store is The Ship's Store, 14025 Panay Way, Marina del Rey, California 90292; its telephone number is 310-823-5574.

# DO YOU KNOW...?

*Provided by Roger Jones*

Most readers know that the bubble sextant was used for air navigation aboard the trans-oceanic clippers in the 1930s and that many World War II air navigators were trained in its use. In effect, it was a sextant with its own artificial horizon in the form of a small bubble level that was observed via a mirror placed at a 45 degree angle above it. Do you know when the bubble sextant first came into use and in what mode of navigation it was used? (Answer appears at the end of this issue.)

# NAVIGATION BASICS REVIEW

## An Ancient Interception Device: A Pre World War I Torpedo Director

*By William O. Land*

Recently while leafing through some volumes of an old encyclopedia in my library, I came across an article describing a device used by the Navy to aim torpedoes back before World War I. Basically, the problem was to determine the exact instant to fire a torpedo from a ship or submarine to have it intercept a moving target. The speed of the torpedo is known, but the speed and the compass course of the target must be estimated. This device is designed to be used on the deck, so the submarine must surface to use it, and must have a clear view of the target. Here is how it works: Refer to the diagram.

A is a metal sector, graduated in degrees along arc E.
B is a movable arm with the pivot at P, the center of arc E, set parallel to the torpedo tube.
F is the screw clamp for arm B.
C is a movable arm with the pivot at sliding block G.
D is a movable arm with the pivot at M. Arms B and C are graduated into equal and similar divisions representing the speed of the torpedo and the estimated speed of the target respectively.

K is the scale representing the speed of the torpedo.

L is the scale representing the estimated speed of the target.

Sliding block H is set at the scale division indicating the estimated target speed and clamped.

Sliding block G is clamped at the scale division indicating the torpedo speed.

Arm C is swung around point G until arm C is parallel to the estimated course of the target.

M is the screw clamp for arm D.

N is the screw clamp for arm C.

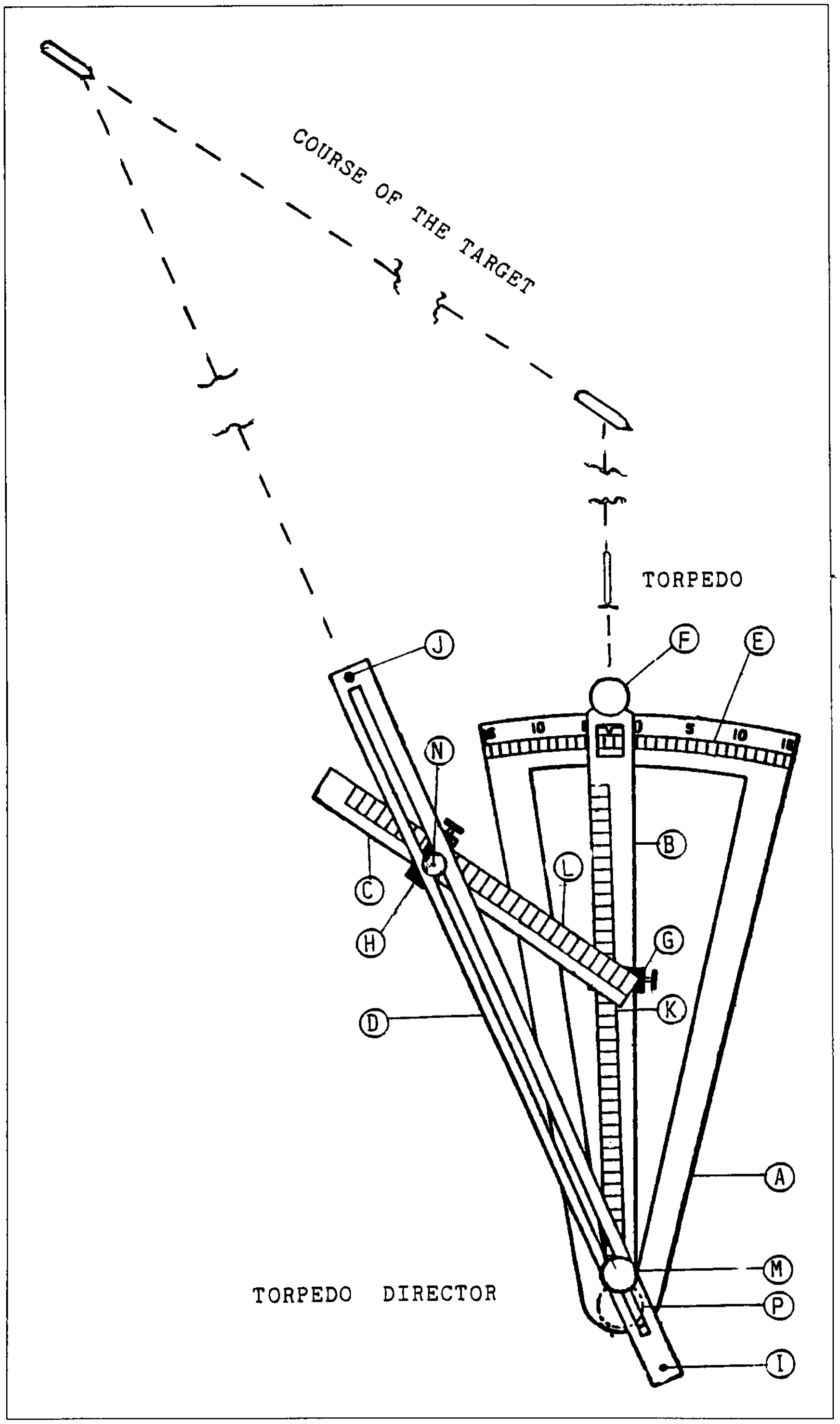
I is the rear sight on arm D.

J is the front sight on arm D.

The moment the target appears in line with sights I and J, the torpedo is fired in the direction M - F of arm B. If all estimates and variables are correct, the target and the torpedo will arrive at the same point at the same moment of time.

The article concludes that "Other means of ascertaining the direction in which to fire the torpedo have superceded this torpedo director."

This is a typical rendezvous or interception problem in navigation. A very good example with an explanation is shown on pages 208 and 209 in the 14th edition of *Dutton*, chapter 14, article 1415, "Interception of another Vessel". In the *Dutton* example a ship in distress 200 miles away is steaming on a course of 90° at 6 knots and requires assistance. Using a maneuvering board we calculate that our ship with a speed of 20 knots will require a course of 45° to intercept it in 16.5 hours.



TORPEDO DIRECTOR

## The Use of the Calculator in Navigation

*By John M. Luykx*

Captain Henry H. Shufeldt USNR (Retired) who passed away some years ago (November 1985) wrote in 1980 an invaluable book for navigators entitled: *The Calculator Afloat, A Mariner's Guide to the Electronic Calculator.* It was first published by the Naval Institute Press of Annapolis, MD and later on by a firm in England. This book was based on an earlier edition entitled *Slide Rule for the Mariner* which anticipated the almost universal use of the calculator today and which included many of the formulae required for the rapid solution of navigation problems. The use of small hand-held computers and scientific calculators as forseen by Captain Shufeldt is so prevalent today that it may be worthwhile to provide an outline in this newsletter of the solution to navigation problems described by Captain Shufeldt in his book. Although the book is out of print, it is available in libraries and may be found in used book stores.

Almost all the problem computations associated with the typical "Navigator's Day's Work at Sea" can be solved by the small hand-held scientific calculator. It need not be programmable. In fact, for the navigation purist all the formulae in Captain Shufeldt's book may be solved by a basic calculator having trigonometric functions, although the speed of calculation will be enhanced by using an instrument which also converts from polar to rectangular coordinates and has summation capability.

Anyone fortunate enough to have a copy of this book in his possession or who has already read it or who has had access to a copy of it knows how valuable it is in better understanding the secrets as well as the principles of accepted navigation practice.

Listed below are some of the problems and situations commonly faced by navigators during the "Days Work" and which are discussed by Captain Shufeldt in his book. For each situation a) the navigation problem is presented in a simple manner; b) the formula is then provided; and c) finally, a sample solution by calculator followed by a discussion is given — an altogether ideal way to learn or review the solution to a navigation problem.

## I. Coastal Piloting

A. Distance off by sextant angle
   1. Distance to the horizon
   2. Dip of the horizon
   3. Distance short of horizon (horizon to base)
   4. Distance short of horizon (base to top)
   5. Distance of visibility of objects
   5. Distance beyond the horizon

B. Distance by bearings
   1. Distance off abeam by one bearing and run
   2. Distance off abeam two bearings and run between
   3. Run to a given bearing and distance off on that bearing
   4. Distance off from land or sea marks
   5. Heading to bring light to specific bearing and distance and run

C. Tides - Currents - Wind
   1. Height of tide at any time
   2. Predicting drift at any time
   3. Predicting time when drift will be of specific speed
   4. Duration of slack water
   5. Wind currents at sea
   6. Finding course to steer and speed of advance
   7. Course and speed when track and SOA are specified
   8. Set and Drift between fixes
   9. Current sailing using vector addition
   10. Direction and speed of true wind

## II. The Sailings—The Track-Voyage Planning

A. Plane Sailing
B. Mid-Latitude Sailing
C. Mercator Sailing
D. Rhumb line sailing
E. Great Circle Sailing
   1. Conversion Angle
   2. Distance and initial heading
   3. Coordinates of the vertex
   4. Coordinates of intermediate points
   5. Latitude at the meridian
F. Composite Sailing
G. Time/Speed/Distance

## III. Celestial Navigation

A. Sextant altitude corrections
   1. Dip of the horizon
   2. Dip short of the horizon
   3. Mean refraction
   4. Mean refraction - non-standard pressure and temperature
   5. Sea-Air Temperature difference
   6. Order of sextant altitude corrections

B. Sight Reduction
   1. Altitude
   2. Azimuth
   3. Cosine-Haversine method
   4. Combined altitude-azimuth method
   5. CosZ formula
   6. Longitude by time sight
   7. Horizon sights
   8. Noon sights
      a) Time of LAN
      b) Latitude at LAN
      c) Longitude by equal altitude
      d) Reduction to the meridian
   9. Latitude by Polaris observation
   10. Fix by two observations
   11. Fix by observation of single body

C. Rising Setting Twilight Phenomena
   1. Sunrise/Set
   2. Moonrise/Set
   3. Twilight
   4. Amplitudes

D. Miscellaneous calculations
   1. Time and altitude on prime vertical
   2. Rate of change of altitude
   3. Rate of change of azimuth
   4. Star and planet identification
   5. Line of position bisectors
   6. Lunar distance
   7. Long term sun almanac
   8. Long term Aries and Star Ephemeris

## A DR Independent Two Celestial Body Solution

*By R. B. Derickson*

As modern navigation systems become more ubiquitous, fewer navigators rely on celestial navigation; and among them fewer rely on traditional methods, i.e., almanacs and sight reduction tables. Although celestial remains radio independent the argument for celestial as the ultimate backup is not so loud, as hand-held waterproof GPS receivers become less expensive. Within a few minutes, a GPS receiver provides continuous fix, course and speed over the ground. Perhaps introducing another sight reduction method is a little late, but here goes anyway. To my knowledge, no direct mathematical solution has been presented for the observations of two celestial bodies with no assumed position.

The complexity of the algorithm makes it cumbersome to solve without at least a calculator. Some hand-held programmable scientific calculators are suitable as hosts for solving this problem, along with the other related problems (sextant corrections, almanac, dead reckoning, body identification, etc.) required for a comprehensive celestial navigation package. This sight reduction method eliminates the necessity of a DR (assumed) position, while the Marcq St.-Hilaire method assumes a position and then computes an altitude and azimuth for comparison to an observed altitude, from which a line of position near the assumed position is plotted.

The two body solution presented here utilizes the relative positions of bodies observed. By finding the distance between the bodies and the direction of one from the other, observer information becomes accessible including latitude, longitude and azimuths of the observed bodies. Ship's advance during the observation interval is compensated for by adjusting the observed altitude of the first observation. This has the same effect as advancing a line of position.

As the number of observations comprising a fix increases, the number of intersections increases rapidly, e.g., a five body fix has 10 intersections. To solve the two body problem 10 times would be cumbersome. A practical method is to solve the two body problem first, and then continue with Marcq St.-Hilaire, using the two body fix as the reference for assumed positions.

A Sharp EL-9000 pocket sized programmable calculator was used to verify the design. By the time it was verified and debugged, a celestial navigation package had evolved . . . more about that in a subsequent article.

Mathematical Sight Reduction for Two Bodies

The intersections of two circles of equal altitude are determined analytically, by solving a succession of sides and angles of interrelated spherical triangles *(Figure 1).*

*Arguments:*

Greenwich hour angle of First body (GHA1)
Declination of first body (Dec1)
Observed altitude of first body (Ho1)

Greenwich hour angle of second body (GHA2)
Declination of second body (Dec2)
Observed altitude of second body (Ho2)

Time interval between observations
Ship's course
Ship's speed

*Respondents:*

Latitude of Fix (Lat)
Longitude of Fix (Lon)

Latitude of other intersection
Longitude of other intersection

Figure 1.

If GHA1, Decl. Hol, GHA2, Dec2, Ho2, are known, then Lat and Lon may be determined by solving a succession of sides and angles.

Pn is North Pole, GPI is geographic position of body 1, GP2 is geographic position of body 2, and M is the position of the observer. The order of solutions follows:

side GP2 GP1
angle Pn GP1 GP2
angle M GP1 GP2
side M Pn (90 - Lat)
angle GP1 Pn M (GHA1 - Lon)

Another observer located at X would have observed the same Hol and Ho2. Because of symmetry, angle X GP1 = angle M GP1 GP2 but with the opposite sense (angle X GP1 GP2 = - angle M GP1 GP2).

Mathematical Solutions for Spherical Triangle

*Arguments:*

side a
side b
angle C (included)

Figure 2.

*Respondents:*

side c
angle B
angle A

c = COS-1 (COS(a b)-SINa*SINb*(1-COSC))
B = COS-1 ((COSb-COSa*COSc)/(SINa*SINc))
A = COS-1 ((COSAa-COSb*COSc)/SINb*SINc))

The unknown side, c, and angles B and A are found by the equations shown. If only sides a, b, c are known, then angles B and A may still be found.

Sides a, b, c are always considered positive. If angle C is negative then angle B and angle C must also be considered negative.

## Steps for Two Body Sight Reduction

Sign Convention: North = +, South = -
West = +, East = -

Step 1 *(See Figure 3A)*

| If: | Then: |
|---|---|
| a = 90-Dec2 | c = GP2 GP1 |
| b = 90-Dec1 | A = bearing of GP2 from GP1[2] |
| C = GHA1-GHA2[1] | (Bng GP2 GP1) |

Step 2 *(See Figure 3B)*

| If: | Then: |
|---|---|
| a = 90-Ho2 | A = reflect angle (RA) |
| b = 90-Ho1 | C = lop angle (LA) |
| c = GP2 GP1 | |

Step 3 *(See Figure 3C)*

| If: | Then: |
|---|---|
| a = 90-Ho1 | Lat = 90 - c |
| b = 90-Dec1 | Lon = GHA1 - A[3] |
| C = (Bng GP2 GP1)-RA[1] (parallactic angle) | AZ1 = -B[4] |

Step 4

Adjust 90-Ho1 for DR advance:
COS (course - AZ1) x speed x time interval
And repeat steps 2 and 3
If Lat and Lon are remote, go to step 5.

1 Normalize between -180° and 180°.
2 Set sign of A = sign of C.
3 Set sign of A = sign of C, then normalize Lon between -180° and 180°
4 Set sign of B = sign of C.

Step 5 *(See Figure 3D)*

Change sign of reflect angle (RA) and LOP angle (LA) and repeat steps 3 and 4.

EXAMPLE:

| Given: | | |
|---|---|---|
| GHA1 = 235° | GHA2 - 173° |
| Dec1 = 19° | Dec2 = 12° |
| Ho1 = 46° | Ho2 = 45° |

Ship's speed = 0, somewhere in the Coral Sea.

Step 1
a = 90° - 12°
b = 90° - 19°
C = 235° - 173°

Solve spherical triangle:
c = GP2 GP1 = 59.875°
A = Bng GP2 GP1 = 86.880°

Step 2
a = 90°- 45°
b = 95° - 46°
c = 59.875°

Solve spherical triangle:
A = RA = 54.830o

Step 3
a = 90° - 46°
b = 90° - 19°
C = 86.880° - 54.830°

Solve spherical triangle:
c = 90° - Lat = 37.730°
Lat = 90° - c = 52.270°
= 52° 16.2' N

A = GHA1 - Lon = 37.041°
Lon = 235° - A = 197.959°
normalized = -162.041°
= 162° 02.4' E

Step 4
Ship's speed = 0, no DR advance

The position of 52° 16.2' N, 162° 02.4 E is remote, continue with step 5.

Step 5
Change sign of RA = -54.830o

Step 3 (second pass)
a = 90° - 46°
b = 90° - 19°
C = 86.880° - (-54.830°)

Solve spheric1 triangle:
c = 90° - Lat = 106.339°
Lat - 90° - c = -16.339°
= 16° 20.4' S
A = GHA1 - Lon = 26.651°
Lon - 235° - A = 208.349°
normalized = -151.651°
= 151° 39.1' E

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126
Rockville, MD 20850
Telephone 301-622-6448

# HISTORY OF NAVIGATION

## The Quincentenary of the First Columbus Voyage to the Americas

*By John M. Luykx*

As reported in the last issue of the Navigator's Newsletter, a seminar entitled *Where Did Columbus Land — The Evidence to Date* was sponsored by the U.S. Naval Institute and held 24 April 1992 at Annapolis during the USNI Annual Meeting. Videotapes are now available of the seminar and the meeting. The historical part of the seminar (Video 2), which deals with the Columbus landfall, was moderated by William F. Buckley, Jr. and included the panelists Joseph Judge, Dr. Steven Mitchell and Samuel L. Morison, grandson of the naval historian. The tape can be ordered directly by calling the toll-free number 1-800-233-USNI Monday - Friday 8 AM to 5 PM EST. The price is $24.95 for non-members of the USNI and $19.96 to members.

A reprint of the papers presented at the seminar is available for $4.95 and can also be purchased along with

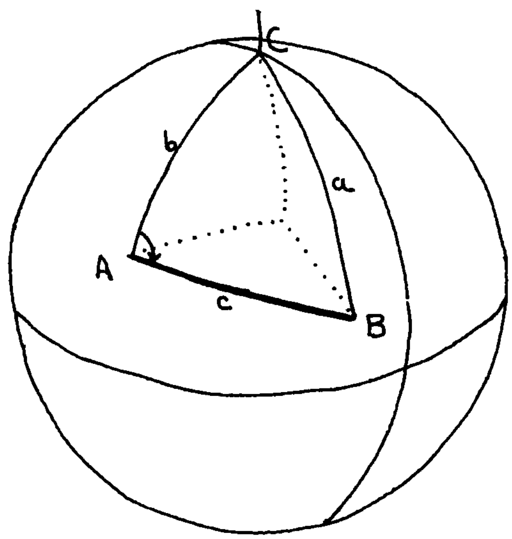



FIGURE 3A

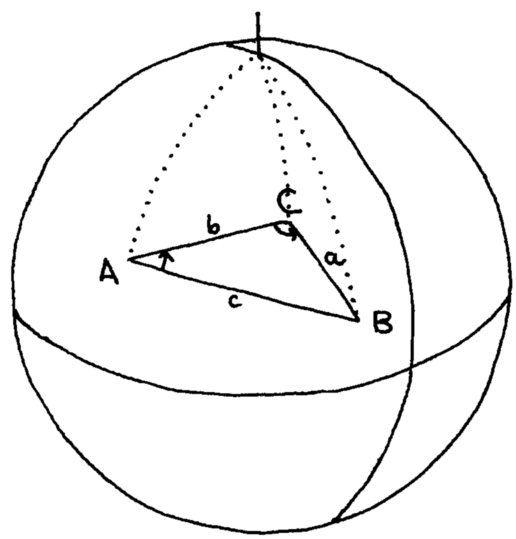



FIGURE 3B

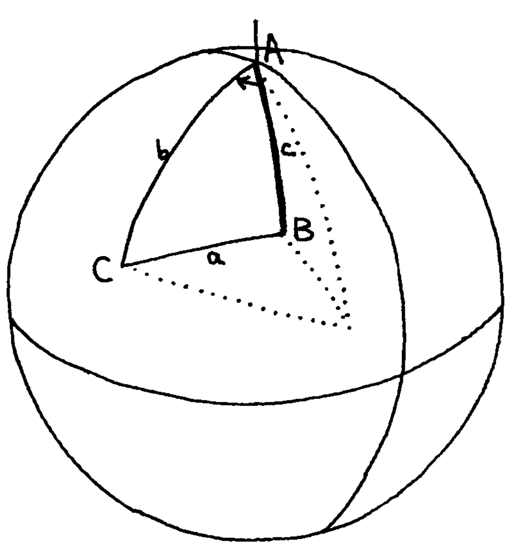



FIGURE 3C

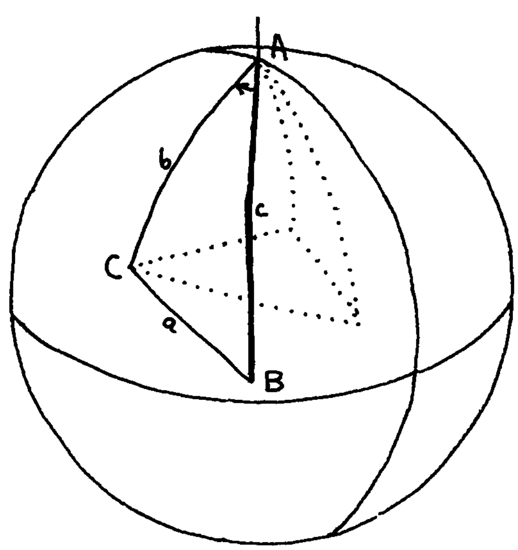



FIGURE 3D

the videotape from the U.S. Naval Institute, 118 Maryland Ave., Annapolis, MD 21402-5031.

An excellent discussion of recent writing and opinion on the Columbus voyages is given by Joanne E. Dumene in the Fall 1992 issue of *Naval History Magazine,* (Vol. 6, No. 3) entitled "Columbus Revealed". In her article Ms. Dumene highlights the works of:

Kirkpatrick Sale - *The Conquest of Paradise: Christopher Columbus and the Columbian Legacy,* Alfred A. Knopf 1990. "It is a critical assessment of Columbus and the effects of what Sale refers to as his disastrous encounter with the New World."

Gianni Granzotto — *Christopher Columbus: The Dream and the Obsession.* Doubleday and Company 1985. "A biography that takes a middle road."

Louis DeSanti — *Columbus and the New World.* Millenium Publishing Co. 1991.

The problem of the first Columbus landfall is also described in her article. The principal points of landfall are mentioned. These include:

1. *Cat Island* — suggested by Washington Irving in the early 19th Century.
2. *Samana Cay* — selected by Gustavus Fox in 1882. (See 5 below).
3. *Mariguana, Watling and Samana Cay* — seiously considered by J. W. Redway in 1894 (NG Vol VI 29 Dec. 1894).
4. *Watling Island* — identified by Samuel Eliot Morison in 1942. *Admiral of the Ocean Sea; A Life of Christopher Columbus.*, Little, Brown and Co., 1942.
5. *Samana Cay* — selected by Joseph Judge (NG Vol 170 No. 5 Nov (1984) (See 2 above).
6. *Concepcion Island* — suggested by Steven Mitchell based on geological research (Naval History, Fall 1988).
7. *Grant Turk Island* — suggested by J. Marvel and R. H. Power, American History Illustrated, Feb. 1991 issue.
8. *East Caicos Island* — advocated by Edwin and Marion Link based on a translation of the Columbus diary (diario) by Armando Alvarez Pedroso.
9. *Egg Island* — suggested by Arne Molander, Journal of the Bahamas Historical Society Vol. 4 No. 1, 1982.

Ms. Dumene emphasizes that all the landfall theories are based on the translation of Las Casas abstract of the Columbus diary (diaro) and also "on trying to duplicate Columbus' track across the Atlantic."

*Note: To reproduce a DR track is a very difficult thing to do under any circumstnce. To exactly duplicate a track today across the Atlantic based on 15th Century estimates of compass heading, compass error, magnetic variation, speed, wind, leeway, etc. is well nigh impossible. An interesting discussion of the general problems involved in DR navigation entitled Dead Reckoning and the Voyages of the Past is found in the Mariner's Mirror magazine (British) issue; Vol. 44 No. 1 of 1958. In their 17-page article, authors C.W. Solver and G. J. Marcus discuss the difficulties of DR navigation and also describe a number of ocean voyages which came to grief because of the complete reliance on dead reckoning methods to fix the vessels position after many days, even weeks, at sea.*

Dumene's article concludes with a selected bibliography. The following works are of special interest:

Bedini, Silvio. Editor, *The Christopher Columbus Encyclopedia.* Simon and Schuster 1992. 2 volumes. 800 pages containing 350 articles and 300 illustrations with maps, drawings and photographs. Very expensive.

DeVorsey, Louis, Jr. *Keys to the Encounter; A Library of Congress Resource Guide to the Study of the Age of Discovery.* Washington, DC U.S. Gov. Print. Office 1992.

Nebenzahl, Kenneth. *Atlas of Columbus and the Great Discoveries,* Rand McNally 1990.

University of S. California. *Repertorium Columbianum.* Projected 8 to 16 volumes will comprise documentary sources bearing on Columbus' career and four voyages. Vol. 1 scheduled to appear 1993.

Sanchez, J.P., Burule, J.L. and Broughton, W.H. *Bibliographia Columbiana 1492-1992.* University of New Mexico, Spanish Colonial Research Center, Pub. #1 1990. A treasure source for researchers.

Taviana, Paolo Emilio. *Christopher Columbus: The Grand Design.* Orbis 1985. Concentrates on the explorer's family background.

Navigation Foundation members who are interested in learning more about the exhibitions, regattas, rallies and festivities celebrating the Columbus Quincentennial should call or write to:

The Christopher Columbus Quincentenary
Jubilee Commission
1801 F Street, NW, 3rd Floor
Washington, DC 20006
Telephone: (202)632-1992

The Jubilee Commission publishes a magazine called *Five Hundred.* Various issues of the magazine explore fact and fiction about Columbus.

The replica Columbus Fleet of Nina, Pinta and Santa Maria will visit the West Coast on the following dates:

San Francisco: October 2 - October 25
San Luis Obispo: October 30 - November 1
Los Angeles: November 6 - November 29
San Juan de Capistrano: December 4 - December 6
San Diego: December 11 - December 20

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 36, Answer.

In Problem No. 36, it was noted that the basic tools of the navigator are: a current-year *Almanac,* a set of sight reduction tables, a sextant, a chronometer (or radio for obtaining time ticks), a set of plotting tools, and a plotting sheet or chart.

The chronometer (or radio) is used to determine the exact second of time (Greenwich Mean Time) when the celestial observation was made. This time information is required to enter the *Almanac*. The *Almanac* is used to determine the exact geographical position (GP) of the celestial body, in terms that are analogous to latitude and longitude at the exact second of time when the observation was made. Remember: it is this GP which is then the "known position" from which the unknown position is determined by means of finding one's distance and direction from it. That GP appears to be moving constantly westward because of the rotation of the Earth, and thus the distance in a westerly direction from the observer to the GP is constantly increasing, which is why time needs to be measured to the second.

The sextant measures the altitude of the body above the sea horizon. That altitude is a value expressed in arc degrees, minutes and tenths, which is translatable into distance that the observer is from the GP at the second in time when the observation is made. The sight reduction tables enable the observer to dispense with spherical trigonometry. When entered with values that correspond to latitude of the observer at an assumed position, declination latitude of the GP, and the difference in longitude between that of the observer and that of the GP, they enable the observer to extract values which give him direction and a correction factor for the distance that needs to be used because the assumed position and actual position are almost never the same.

The plotting tools enable him to plot this direction and corrected distance on his chart. A line drawn perpendicular to the direction line at the corrected distance point on the direction line becomes the observer's "line of position" (LOP). Two intersecting LOPs give him a fix.

Problem 37

In Issue 34, Winter 1991, we began to explore in simple layman's terms the theory of celestial navigation - not in a manner requiring the reader to push a pencil or delve into tables - but in a manner that asked the reader to delve into the recesses of his or her own mind. Thus, problems 34, 35 and 36 asked basic questions about the principle underlying all forms of navigation, the great navigational triangle used in celestial navigation, and what the celestial navigator's tools were really doing for him when used by him. In the brief answers to Problems 34, 35 and 36, there emerged a "theory thread" that, in layman's terms, hopefully unveiled much of the needless mystery of celestial navigation. Tying these answers together, what is a succinct statement of the theory of celestial navigation? (The next Issue will present such a statement).

# NAVIGATION PERSONALITIES

## *Amerigo Vespucci*

*By Roger H. Jones*

Amerigo Vespucci was born to a noble family of Florence in 1454. At an early age he had a keen interest in geography and cosmology, but he was formally trained for a career in business. He settled in Seville in 1491, and was in the employ of a branch of the Bank Medici.

A year later Columbus undertook the first of his four voyages of discovery. With the failure to find the expected riches of Asia, the Spanish and Portuguese rulers began to ask just what lands had Columbus really found. The non-European world was divided between them by the papal Line of Demarcation of 1493, and Vespucci, as a man of sagacious and scientific mind, was sent to answer the questions raised by the early claims of Columbus. Vespucci claimed also to have made four voyages, the second of which was in 1499-1500 in behalf of Spain. The third, in 1501-02 was in behalf of Portugal, and the fourth voyage was reported to have been made in 1503-04, also in behalf of Portugal. The first voyage, in 1497, and the fourth are somewhat in dispute.

He explored 6,000 miles of the coast of a great land which he determined was a continent. He was the first to claim that an unknown continent lay between Europe and Asia, and he was the first to state that to reach Asia by travelling westward, one would have to cross two oceans. In a famous letter of 1504, he explained that he had followed the coast to 50 South, and this could not be Asia, because this was far too southerly a latitude to be Asia.

It is known that he visited what is now Brazil, Venezuela and Hispanola, and that he sailed at least as far south as the Rio de la Plata. In 1507 the German cartographer, Martin Waldseemuller, published an account of Vespucci's voyages along with a map, the Cosmographae Introducio, and he was the first to use the name America for the vast region visited by Vespucci. After this use of the name America, controversy arose, and some charged that since Columbus made four voyages, Vespucci had to claim as many. If, indeed, Vespucci visited the mainland of South America in 1497, it gave him priority over Columbus. Irrespective of his priority, he was clearly the first to recognize that there was a continent theretofore unknown, and to the west of Europe there were two oceans before Asia could be reached.

Vespucci developed a method of celestial navigation which enabled him to calculate the circumference of the Earth to within 50 statute miles of its true value. It is reported that by comparing the hour of the Moon's conjunction with a planet in the "Western Land" and the hour at which this was observed in Spain, he obtained longitude, and this made possible his calculation as to the circumference of the Earth and his claims as to a second ocean to the west. There were certainly no chronometers available to assist in this comparison, and one wonders if he formulated a theory that was one of the precursors of the method of lunar distances instead of one dependent upon time observations.

In 1508 Vespucci was named Pilot Major for Spain. He was the astronomer to the King of Spain and responsible for training and examining pilots and for control of the master map that was a closely guarded royal possession. Vespucci knew Columbus, and visited him when he was sick and in near poverty. He was friendly to Columbus, and the latter regarded him as a man of honor.

Vespucci died in Seville on February 22, 1512. Despite the controversy over the number of his voyages, the name America was one that was widely accepted by the public, and it was applied very early to both the great South and North American land masses. Even on the 500th anniversary of the first voyage of Columbus, this is not altogether unjust, as it was Amerigo who recognized that this was not the continent of Asia, but a new world indeed.

# MARITIME INFORMATION NOTES

*Provided by Ernest Brown*

## Central Pacific Loran-C Chain To Be Terminated

At 2400Z 30 June 1992, the Central Pacific Loran-C Chain 4990 ceased operation permanently. The Loran-C lattices 4990-X and 4990-Y portrayed on some 32 DMA and NOS charts became unusable.

## GPS SATELLITE System

Users of GPS are cautioned that the system is not yet fully operational. Signal availability and accuracy are subject to change due to an incomplete constellation and operational test activities. As of 151800Z JUL: the GPS constellation consists of 18 satellites.

## New DMA Catalog of Hydrographic Products

A new edition of the Defense Mapping Agency Catalog, art 2 Hydrographic Products. Volume I Nautical Charts and Publications, Third Edition - 1 April 1992 is now available. This edition includes a more durable laminated cover and a spiral binding to aid usability. Charts in this edition and future editions will be represented in black color only. Representation of DS, NOS and CHS are still shown in the Price Category on the adjacent page. This is the final edition that will be made available to the civil users.

Future editions of this catalog volume will be available only to the Department of Defense, U.S. Coast Guard, qualified DoD contractors, and U.S. Government agencies supporting DoD functions. The public sale of DMA hydrographic charts and publications will be transferred to NOAA/National Ocean Service (NOS) effective 1 October, 1992. Nine separate Regional Catalogs containing DMA products will be available from NOS in October 1992. Each free Regional Catalog will contain miscellaneous products and ordering instructions. A free quarterly "Dates of Latest Editions" (Nauticals) bulletin will also be available from NOS.

Requests for the new catalogs and bulletins contains DMA charts and publications may be sent to:

NOAA Distribution Branch (N/CG33)
National Ocean Service
Riverdale, MD 20737-1199
Tel: (301)436-6990 / Fax: (301)436-6829

## Vessel Bridge-To-Bridge Radiotelephone Regulations

On August 19, 1992, several changes to the Vessel Bridge-to-Bridge Radiotelephone Regulations became effective. These changes were published in the Federal Register on April 21, 1992 (57 FR 14483) and were published as a change to *Navigation Rules: International-Inland* in August. The following is a summary of the substantive changes:

(a) For power-driven vessels, the minimum size requirement for application of the regulations will change from 300 gross tons to 20 meters (65.5 feet) in length. This means that all power-driven vessels 20 meters in length or greater, passenger vessels of 100 gross tons or greater, towing vessels 25 feet in length or greater, and most dredges will be required to abide by these regulations.

(b) All vessels subject to the regulations must be capable of transmitting and receiving on VHF-FM channel 22A (157.1 MHz) (Coast Guard Marine information Broadcast and Communications Channel). Note: most VHF-FM Marine radios commercially available in the United States are already capable of transmitting and receiving on this channel.

(c) Vessels, subject to these regulations, operating in a designated area on the lower Mississippi River and its approaches, must have equipment capable of transmitting and receiving on channel 67 VHF-FM (156.375 MHz) and are required to monitor this channel instead of channel 13.

## Atlas Moorings In The Equatorial Pacific

The National Oceanic and Atmospheric Administration (NOAA) is in the process of placing buoys called Autonomous Temperature Line Acquisition System (ATLAS) reaching from the Galapagos extending to New Guinea along the Equator.

The ATLAS buoys, orange and white bands, Q(2-3 meter toroid buoy) which make up the array are located in the following positions:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0°00' | 143°00'E | 8°00'N | 165°00E | 1°55'N | 125°05'W | 2°00'S | 155°00'W |
| 0°00' | 154°00'E | | | 2°00'N | 170°00'W | 2°00'S | 139°55'W |
| 0°00' | 160°3°5'E | 2°00'S | 156°00'E | 2°00'N | 155°00'W | 2°00'S | 109°55'W |
| 0°00' | 170°00'E | 2°00'S | 164°41'E | 2°00'N | 140°05'W | 2°05'S | 124°55'W |
| | | 5°00'S | 156°00°E | 2°00'N | 110°05'W | 2°10'S | 170°00'W |
| 2°00'N | 137°00'E | 5°00'S | 165°10'E | 5°00'N | 170°00'W | 5°00'S | 170°00'W |
| 2°00'N | 147°00'E | 8°00'S | 165°00'E | 5°00'N | 154°55'W | 5°00'S | 155°00'W |
| 2°00'N | 156°00'E | | | 5°00'N | 140°00'W | 5°00'S | 140°00'W |
| 2°00'N | 165°00'E | | | 5°05'N | 124°55'W | 5°00'S | 110°00'W |
| 5°00'N | 147°00'E | 0°00' | 170°00'W | 5°00'N | 109°55'W | 5°05'S | 124°50'W |
| 5°00'N | 156°00'E | 0°00' | 155°00'W | 8°00'N | 109°55'W | 8°00'S | 109°00'W |
| 5°00'N | 165°00'E | 0°00' | 124°25'W | 9°00'N | 140°15'W | 8°16'S | 155°00'W |

Mariners are advised to give all mooring positions a nautical mile wide berth.

# BOOK REVIEW

*By Roger H. Jones*

### *Arctic Passage*

By John Bockstoce
Hearst Marine Books (1991), William Morrow & Company, 105 Madison Avenue, New York, NY 10016
256 pages; $22.95

John Bockstoce is an Arctic historian and archaeologist, and he is the author of many articles and several books on the Arctic, including *Whales, Ice and Men, The Archaeology of Cape Nome, Alaska,* and *Steam Whaling in the Western Arctic.* He was educated at Yale and received his doctorate in archaeology from Oxford. Recently, the Royal Cruising Club of Great Britain awarded him its Tilman Medal for twenty years of voyaging in the high latitudes.

In 1988 Bockstoce became the first person to complete a traverse of the Northwest Passage above mainland Canada from the West to the East. *Arctic Passages* is his account of a thirty-five hundred mile voyage through the northern hemisphere's most dangerous and difficult waterway, from the Bering Strait to Baffin Bay.

This is a book that is made even more interesting by the many photographs taken by the author. It is also the beneficiary of a number of well-drawn maps and charts.

Navigating largely without the benefit of a working compass, Bockstoce made his way through thousands of uncharted islands along many stretches of shore that were virtually featureless. His skills were honed over many years working with territorial Eskimo whalers, and he traveled in an umiak, the traditional Eskimo walrus hide canoe.

Summer storms, totally disorienting fog, and incessant bone-chilling cold were his constant companions. The danger of being trapped by the ever shifting ice floes was, however, his greatest obstacle. At one point he arrived within a few hundred miles of his intended destination only to find his well-planned route totally blocked by dense ice. At this point he had already accomplished the longest recorded passage by open boat in the Arctic. He returned to break through a final ice field in a steel-hulled yacht, thus completing a passage that was truly remarkable.

Virtually all of this journey was carried out well above the Arctic Circle, and at times he was forced in northerly directions to points that were scarcely 900 miles from the North Pole. This is a book about navigation, human endurance, finely turned skills that few men other than Eskimo voyagers have acquired, open boat seamanship, geography, and even history. It represents the culmination of the author's many years in the Far North - years that were spent researching history, exploring uncharted territory, and living with and learning from the Eskimo people. It is a book which conveys the beauty and power of the high latitudes. It is essential reading for those with the salt of the Navigator in their bloodstreams.

# ADDENDUM

As mentioned in the Reader's Forum, the following is a letter from Paul Janiczek that may be of interest to readers of a technical persuasion. It is reprinted here in its entirety:

May 19, 1992
CDR John M. Luykz
Infocenter, Inc.
P.O. Box 47175
Forestville, MD 20747

Dear CDR Luykx:

I am embarrassed to realize that it has taken so long to get back to you on the subject of the Concise Tables for sights with large altitude. Here is one way to get around the problem, using an example.

Suppose our assumed position is such that Latitude is N32° and the LHA is 5° for entering the tables. Further, let the declination of the observed object be N30°14'. On first entering the Concise Tables, we find A=4-14, B=57-54 and $Z_1$=87.3 Re-entering the table at A=4° and F=88, we see that adjusting for the minutes part of A and F gives $H_c$=85-24 but not a confident value for $Z_z$.

A variation in use, first proposed by Radler de Aquino a century ago, allows the Table to dictate the assumed position. I'll take part of his method (the remainder can lead to an unacceptable assumed position). At the first entry A=4-14, B=57-54 and $Z_1$=87.3. Force A to the nearest whole degree. This is done by entering the auxiliary table using rounded B instead of F. In the example, B=58. At "P" (really B) = 58, look across the 58 row until the minutes part of A (=14) is found. Then take the number at the top of the column (the horizontal index) and use it as an adjustment to rounded LHA. That is,

LHA rounded = 5-00
adjustment = - 16
one LHA = 4-44

This demands that the longitude of the assumed position be adjusted by a like amount. Then we have,

A = 4-00, B = 57-54, $Z_1$ = 87.3

Although we have not adjusted B or Z, for a change in LHA, those two quantities are changing very slowly and do not introduce appreciable error.

Now enter the main table for the "second" time at A=4. Round F to the nearest tenth of a degree (88.1). Scan the $Z_1/Z_2$ column for the rounded value of F. When found, take Hc from the B/P column on the same line, $H_c$=85-35, and $Z_2$ from the leftmost LHA column (25°).

Certainly users may get a bit mixed up when trying to use this alternate method. It does have compensation owing to the fact that use of the auxiliary table along with the second entry of the main table is obviated.

You may wish to try this scheme for a few examples yourself. I would be interested in having your opinions or any special problems encountered. I have not tried to analyze the scheme for errors. But, in summary of the example, the solution arrived at by the use of the published rules gave computed altitude within error of 2' and no reliable $Z_2$. The alternate method gave computed altitude exactly and a useful value for $Z_2$. Note that there were two entries in the $Z_2$ column with identical numbers - 88.1. I chose the upper one because of the rounding (down) of F.

Thanks for your patience. Thanks also for the material on the Infocenter product line.

Best regards,

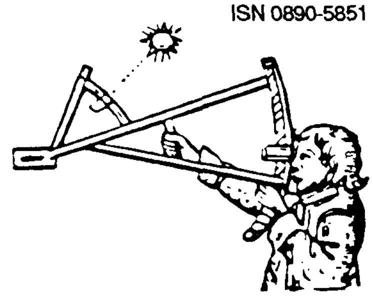
(s) P.M. Janiczek, Director
U.S. Naval Observatory
Astronomical Applications Department
Washington, DC 20392

DO YOU KNOW . . . .

At the end of the nineteenth century ballooning had become popular in both Europe and the United States. The bubble sextant was used by a number of aeronauts, including some who ventured over open water. The device thus pre-dated the arrival of the true airplane in 1903, and it certainly pre-dated the airplanes that became capable of long distance flights over open water in the 1920s.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-EIGHT, WINTER 1992/93

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

With winter approaching and most sailors preparing their boats for storage and winter, there is very little activity to report. Once the boats are winterized I hope the mail volume resumes. We want to hear from our members because others benefit from the experiences detailed in your letters. So, if you have a "have you heard this one" or "you'll never believe what happened on my last voyage" story, please write. Do not be concerned about your prose. Roger Jones is an excellent editor.

This is the second time in the Newsletter that I have had to apologize to our members. Previously it was because of the long delay in getting the Newsletter into your hands. This time it is an apology for not being here in the office to receive your telephone calls. I had a family medical emergency and I was out of the area from October 6 until November 5 and from November 15 until December 15. I hope that I missed nothing of a critical nature during this time. When I returned in November I changed the telephone message, informing callers to contact Director John Luykx if something was urgently needed. Thank you for your patience in helping me cope with the absence from my duty station.

The update on the Peary project appearing in this issue, prepared by Doug Davies, is the best statement of recent activities of the Foundation.

## READERS FORUM

J. F. Zietlow, Jr., of Oak Bluffs, Massachusetts, has written in behalf of the Martha's Vineyard Historical Society requesting that a copy of Issue Thirty-six, containing the profile of Captain Joshua Slocum, be sent to them. We are pleased to provide a copy to them and hope that it may be of interest to the members of their staff and their visitors.

We have received a copy of the news article which appeared in the *Long Island Advance* on August 13, 1992. This article by Susan Kane is about the 26,000 mile voyage by one of the Foundation's members, Eric Forsyth. Two years after setting sail from Patchogue, Long Island, Forsyth and his 42-foot cutter, *Fiona*, returned to the old berth at Week's Boat Yard. Forsyth and his crew voyaged around the continent of South America, and also made interesting side voyages to Tahiti, the Gallapagos, the Gambier and Pitcairn Islands, the Cape Verde Islands off the West Coast of Africa, and many other stops along their nautical way. Forsyth built his vessel by hand. During the eight-year process, his neighbors dubbed it the "world's biggest planter." To say that he was undeterred is perhaps an understatement.

Gregory Rinn of Rockville Centre, New York, forwarded a copy of a very interesting article entitled "The First South Atlantic Crossing by Air." This article is in a format with both Portugese and English text, and it describes the historic flight from Portugal to Brazil in the spring of 1922. Of particular interest is the account of the development of the system of artificial horizons adapted to a naval sextant that was successfully undertaken during the two years prior to the flight. The source in which the article first appeared is not identified. Interested readers may wish to correspond with Rinn at 128 Muirfield Road, Rockville Centre, NY 11570.

Edward Matthews of 154 Burroughs Road, Boxborough, Massachusetts 01719, has written with fur-

DO YOU KNOW . . . ?
*By Roger Jones*

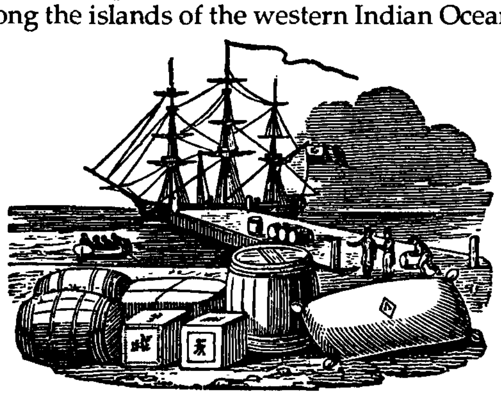
The cross staff was a forerunner of the backstaff. Do you know when it came into use and how it was used?

ther comment on the matter of battery aging and quartz chronometers. Matthews has a Casio Watersport Model 106. He reports that the rate of increase, after about three years, became about .62 seconds per day, and that a battery replacement seemed to have no effect on this rate. He attributes the constant rate to crystal aging. On the last day of each month he resets the watch to WWV, and at any day thereafter he can obtain the error by multiplying the day of the month by .62.

W. J. D. Marshall-Gratrix, of Reno, Nevada, has written regarding several articles he has prepared on the history of astronomy and navigation. The Foundation has replied that it would be interested in seeing these articles. We are always open to articles from any members or readers, and encourage others to furnish us with material that may be suitable for the Newsletter.

Gary LaPook of Moorpark, California, has written inquiring about almanacs available for computers. John Luykx, in his reply, has furnished information which may be of interest to many readers. The only almanac data available for computers from the Naval Observatory is the "Floppy" Almanac for 1992-1993, which is available from The National Audio Visual Center, 8700 Edgeworth Drive, Capitol Heights, Maryland 20743; phone 301-763-1896 ($30). In addition, a superior almanac for use with computers is available from the INFOCENTER, INC., Box 47175, Forestville, Maryland 20747; phone 301-420-2468. The latter is available on 3.5" or 5.25" PC disk, and it contains data from 1900 to 2099. Full ephemeris information is included on the Sun, Moon, Polaris, 59 navigational stars, and the four planets, as well as rising and setting data, for any second of time between March of 1900 and December of 2099. The price is $59.95. This data is also available in a hand-held computer format.

Member Ambassador Claude Nugenia, who has been a frequent contributor to the Newsletter, has written informing the Foundation that in his new post he is representing Switzerland in Tanzania, Mauritias and the Comoros. We shall continue to be interested in his experiments with sun compasses for land navigation, and encourage him to delve into marine navigation among the islands of the western Indian Ocean.



# NAVIGATION BASICS REVIEW

*Editor's Note: In this section of the Newsletter, we normally present several articles. We are saving for Issue Thirty-Nine several that we have received, including one from frequent contributor William Land on Fridtjof Nansen. The following is an update on the Peary project prepared by Doug Davies. Readers may wish to note that there has been a recent new surge of interest in Robert E. Peary, and the finding of the long lost Matthew Henson photographs has caused the Foundation to reevaluate its position respecting a reprinting of the 1990 report on the Peary investigation. The Foundation is looking at the feasibility of printing a new report that will include the original text, a current supplement, and very interesting new findings based upon the Henson photographs.*

## PEARY PROJECT UPDATE

*By Doug Davies*

Most readers will recall the study that the National Geographic Society asked RAdm. Davies and the Foundation to conduct of all of the evidence surrounding RAdm R.E. Peary's controversial claim of having reached the North Pole in 1909. We examined thousands of pages of records and carefully analyzed every possible piece of quantifiable data — including eight ocean depth soundings, two local apparent noon series of sights, one single local apparent noon sight, Peary's thirteen observations of the sun at his final camp, and diary information on wind speed and direction, and hours and distance marched. Although Peary's critics have attempted to explain away this mass of data as a combination of fabrication and lucky guesses, we were impressed by the absence of even a single inconsistency under the most rigorous scrutiny.

Further, we set out to use Peary's photographs, in a way never considered before, to develop affirmative evidence of the location of Peary's final camp. By drawing lines between objects and their shadows, we were able to locate where the sun (or the point diametrically opposite the sun) would be in the plane of the photograph. Based on the distance of this point from the horizon and the focal length of Peary's camera, we could determine the approximate altitude of the sun. Comparing this altitude (after a 9' refraction correction at the altitude in question) to the declination of the sun at the approximate time the photo was taken gives the distance from the pole to Peary's line of position. (At the pole, altitude equals declination.) Since declination, even in early April, changes only about 1' per hour, only a very approximate time is required.

Using these principles, we identified one group of seven photos, taken at approximately the same time, showing solar altitudes of 6°50' (average) compared to 6°43' if Peary had been exactly where he said he was (a few miles from the pole). A second group of four photos taken at a later time were less clear, and in some cases required making reasonable estimates of the location and orientation of the horizon. Again, the average of the solar altitudes determined from these photos was within a few minutes of the right answer. A final photo taken a few hours after Peary left the pole provided a consistent solar altitude at a third time, although again, the location and orientation of the horizon had to be estimated.

Long-time Peary critics claimed that our shadow analysis could not possibly be sufficiently accurate to prove anything and that we had fudged the results to support an alleged pro-Peary bias. Dennis Rawlins, perhaps the most outspoken and persistent Peary critic, did concede publicly that there was one photo that showed the sun at the right altitude, but that this merely established a single line of position. Since it sounded like Rawlins was referring to something other than the photos that we had previously analyzed, we made another search of the archives, and discovered a photo of the same ice pinnacle in Peary's other north pole photos. *(Figure 1)* A large washed out area just to the right of the pinnacle was revealed as the sun whenwe had an extra dark print made. Based on the azimuth of the sun, this photo was taken at about the same time as the group of seven photos

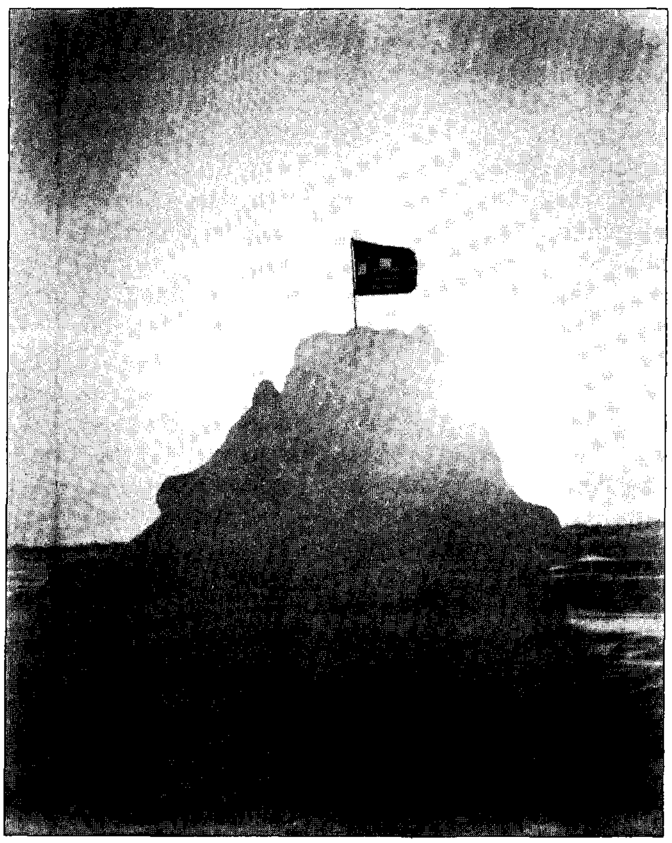


*Figure 1*

analyzed previously.

Analysis of this new photo did not require use of shadows, and three independent measurements by myself, RAdm. Davies and William Hyzer, a certified photogrammetrist, gave very similar values of the sun's altitude: 6°42', 6°43' and 6°45'. These are very similar to the value we determined using shadows and virtually right on the money (6°43') if Peary was at his claimed position.

Since Rawlins has been convinced for over 20 years that Peary did not even come close to the pole, he had to develop an explanation (other than the obvious one) for the admitted fact that the photo showed the correct solar altitude. According to Rawlins' new theory the new photo, showing the sun at the right altitude, proves that Peary was *not* at the pole. The chances of getting the right altitude (within, for example, 10') in a randomly timed photo taken 100 nm from the pole (where Rawlins supposes Peary turned back) are less than one in ten. Thus Rawlins concludes that Peary must have watched the sun's altitude (with his sextant or theodolite) and taken the photo when the sun reached the right altitude.

Having succeed in this effort, why would Peary not exploit this photo to support his claim? According to Rawlins, Peary realized critics would question why he did not have two photos at demonstrably different times (solar azimuths). (Actually, three times would be necessary to remove any possibility of fakery.) Rawlins concludes that, rather than risk criticism that his proof was not complete, Peary decided not to use the photo, and "suppressed" it, since it documented his attempt at fabrication. (Obviously, the photo does not "document" anything of the sort, and there is no evidence that it was "suppressed" other than the fact that, like the vast majority of Peary's photos, including many from the vicinity of the north pole, it was not published in his books.)

Rawlins revealed his convoluted (not to mention unscientific) approach to the Peary controversy when he admitted that he never measured the solar altitude in Figure 1 before announcing that it was the correct value. Rawlins was so convinced that he had found an intentionally "suppressed" document, that the document must have been a fabrication, and that the fabrication must have been successful, that he assumed without ever checking that the solar altitude would be correct.

Boyce Rensberger, who put Rawlins' erroneous and later retracted analysis of some Peary calculations on the front page of the Washington Post, apparently accepted the "suppressed fabrication" theory, and called Hyzer (the photogrammetrist who had provided technical assistance on our report) to suggest that we had similarly attempted to "suppress" the supposedly damaging new photo by intentionally excluding it from our original report.

These arguments came to a head at a Naval Institute symposium at the U.S. Naval Academy in 1991. Rawlins claimed support for his theory in the fact that Figure 1 and the seven photographs most suitable for analysis by photogrammetric methods (of which Peary could not possibly have been aware) were taken at about the same time. He lamented that photos taken by Peary's companion Matt Henson had disappeared; Rawlins speculated they had been destroyed by Peary in order to suppress them. A representative of the American Museum of Natural History in New York made the surprising revelation that the photos were alive and well at the museum.

Terry Carraway tracked down this lead, and within a short time had an entree for us into the archives of the museum. Terry and I traveled to New York and saw over 100 photos taken by Henson on the 1909 trip. The museum made these copies in October 1909, apparently before Peary asked Henson for the photos. (A condition of participating in one of Peary's expeditions was agreement to turn over all diaries and photos, so that Peary could protect the commercial value of his publications and lectures from competition. It is not clear whether Henson ever turned over these photos.)

Most of the Henson photos were clearly not taken at the final north pole camp. A number of others could not be placed even approximately. The few that were definitely taken at the final camp were not usable, because they did not include the horizon (or even clues from which the location of the horizon could be estimated). However, the theory that Peary had to suppress these photos because they were damaging has been laid to rest.

All of this activity renewed my interest in finding at least one more photo taken at a different time from Figure 1 with a clear horizon and clear shadows. In searching through National Geographic records, I found an old print *(Figure 2)* of a photo other copies of which we had previously examined. We had been unable to use the other copies of this photo because, as in the case of many of Peary's photos, the sky was painted out. (The film Peary used tended to give a very dark sky, in the presence of so much snow glare, and black paint was used on the negatives to produce a white "sky".) This painting (which became permanent when the old negatives were copied and destroyed because of fire safety concerns), made it impossible to be sure of the exact location and orientation of the horizon. The orientation of the horizon is particularly critical in photos such as this one, where the "vanishing point" created by the lines connecting objects and their shadows lies far to the side of the photo.

Since the newly discovered print had been made before the sky was painted out, this photo presented an opportunity for analysis. More important, since the camera position and subject of Figure 1 and 2 are virtually identical, but with a difference of roughly 90° in solar azimuth, the potential existed for a cross fix that would conclusively nail down Peary's position (within the inherent accuracy of the measurements).

However, there was another problem with Figure 2. The foreground shadows in Figure 2 are long and easily identifiable, but are so close together that determining the vanishing point from the nearly parallel lines is all but impossible. The small shadow at the top of the pinnacle near the feet of the man holding the flag provides the best separation, but is so small (a little more than 1/8" long) that a new and more accurate method of measurement was required.

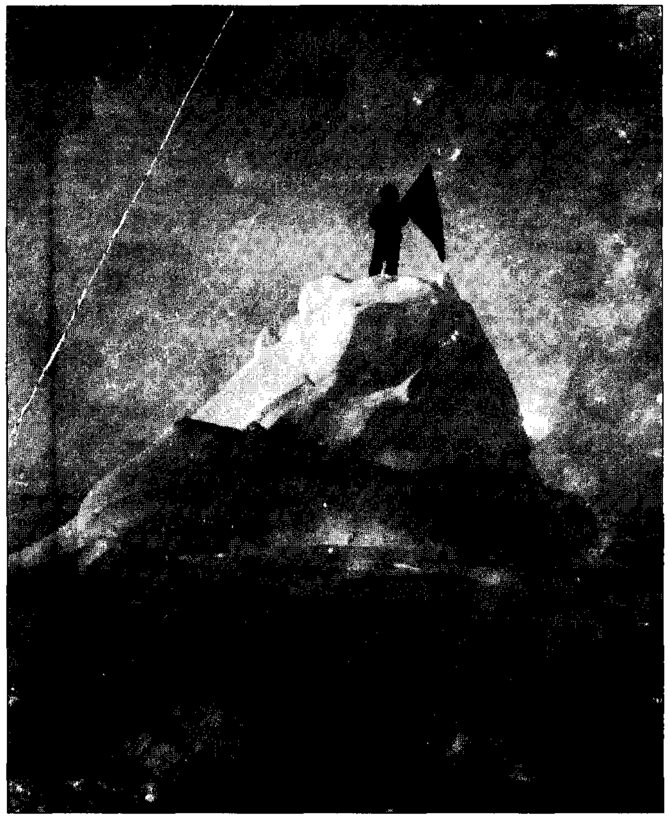


*Figure 2*

Previously, I had used a plastic bar with a fine straight line scribed into the surface facing the photo as a means of lining up objects and their shadows. This scribe line seemed hopelessly wide when I tried to line it up precisely with the edge of the very small shadow referred to above.

I determined that a better approach would be to use a low-power microscope with a cross hair in the internal focal plane. Using two short focal length lenses from door peep holes, I built a small microscope of about 5 power. Initially I used a cat hair stretched across the end of the eye-piece tube (at the focal length of the eyepiece) as a cross hair, but at 5 power, this did not give as fine a line as I desired. With some difficulty, I was able to make the end of the eye-piece tube sticky (dried on Coca-Cola) and place it against a strand of fresh spider web. The resultant cross hair produces a line of infinitesimal width, even at 5 power, and has proven quite durable (still going strong after months).

I built a stand for this microscope that would slide along a six foot aluminum bar and put a pivot at one end of the bar offset by the distance from the bar to the cross hair. The final adjustment was to line up the cross hair parallel to the bar.

Using this arrangement, the pivot point of the bar could be set at an assumed vanishing point, and then the cross hair could be placed over an object and then moved along the bar to check the location of the shadow. (Actually, the sliding feature was necessary only for longer shadows, as discussed below.) I moved the pivot point up, down, left or right as needed to obtain a reasonably good fit with all of the shadows. I repeated the process 11 times, in each case noting whether the resultant vanishing point seemed to err on the side of being too close to the photo (cross hair high with respect to the short shadow) or too far (cross hair low with respect to the short shadow). I tried vanishing points that pushed the limits in both directions.

To avoid any possibility of biasing my results, all of these trials were performed before any measurements or calculations of the solar altitude were performed. The right hand column of Table 1 shows my characterization of each of the trial vanishing points, recorded prior to making any measurements.

Then I used the cross hair to establish the horizon line and measured the normal distances from each vanishing point to the extended horizon and to the vertical centerline of the photo. Raw measurements are shown in Table 1.

These results show considerable uncertainty in the left-right location of the vanishing point. However, as the results below show, these large variations, when combined with the corresponding vertical changes, result in only relatively small variations in the solar altitude determined by this method.

The last two measurements are the distance from the center of the photo to the horizon (0.6") and the focal length of the camera at the scale of the print. Measurement of distances on the print showed that it was a slight enlargement of the negative, and the 6.74" focal length was scaled up to 6.8".

Having made these measurements, it was time to pick up my calculator and compute the solar altitudes. I had no way of knowing how the calculations would come out, and I can truthfully say my hands were shaking, for I knew this was the acid test of our method and our prior work. For each trial the computed results are shown in Table 2. My original characterization of each vanishing point (from Table 1) is repeated in this table.

Discarding trial 5, which I had previously felt was too far, and trial 11, which I was confident was too close, left 9 trials with results ranging from 6°31' to 7°28'. The seven trials in which I had expressed the greatest confidence gave results ranging from 6°40' to 7°19'. The solar altitude at Peary's final camp when this photo was taken would have been 7°0'. Thus these trials covered a range of about plus or minus 20 to 30 minutes from the correct answer.

It is tempting to perform a statistical analysis of the mean and standard deviation of these results; however, that is technically not appropriate, since the process may not have been entirely random. As noted above, I had attempted vanishing points as far away or as close in as possible, consistent with the shadows in order to determine the maximum range of uncertainty. Thus I decided to do a second set of trials on a more random basis.

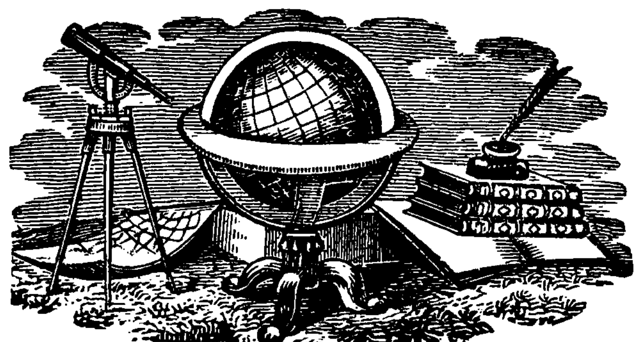
For the second set of trials, I drew a line of best fit (which I will refer to as the base line) through or close to the vanishing points identified above. These points all fell almost exactly along a line determined by the large foreground shadow in Figure 2. Thus the uncertainty in location of the vanishing point is almost exclusively a function of the location and orientation of the line through the small upper shadow.

Next, I did 8 measurements of the upper shadow, using the following method: I loosened the microscope eye-piece tube and rotated it so that it was in no particular orientation to the microscope. I then placed the microscope over the small shadow, and moved it and rotated the eye-piece until the cross hair lined up with the small lump of snow casting the shadow and the end of the shadow. While lining this up, I had no sense of orientation to anything outside the field of view of the microscope, and thus no idea where the line determined by the cross hair would intersect the line established by the foreground shadow.

Once the cross hair was lined up, I put a straight edge under the microscope, lined it up with the cross hair, and drew a line to determine the intersection point with the base line. In order to avoid any feed-back from one trial to the next, I performed no more than one trial per day and, as before, did no calculations until all trials were done. The results of the eight trials are summarized in Table 3.

The mean of these eight trials is 6°57.5', within 3' of the actual altitude of the sun at the location Peary gave for his final camp at the estimated time Figure 2 was taken. The standard deviation is 14.5', meaning that the probability that this result is more than 15' (i.e., 15 miles) off due to random error is very low and the probability of being more than 30 miles off is virtually nil.

Finally, I analyzed sources of error other than the location of the vanishing point. Changing the measured focal length of the camera plus or minus 0.2" (compared



to a nominal 6.8") changed the calculated altitude by only plus or minus 1'. Mislocation of the center of the film by plus or minus 0.2" changed the computed altitude by less than 1'. Mislocation of the horizon line extension by 0.1" would affect the altitude calculation by 14'. A series of independent horizon measurements could be made to determine a standard deviation for this measurement. Since the maximum range of possible positions, based on trying to force the horizon line either direction from the best estimate is about 0.2", the standard deviation is probably less than 14'. Considering all sources of error, the total standard deviation appears to be in the range of 20'.

Performing a larger number of trials can probably reduce the total standard deviation to the range of perhaps 15 miles. Because of nonrandom uncertainties, such as height of eye, height of pressure ridges that make up the horizon, refraction, etc., reducing random error much below 15 miles would probably be meaningless in any event. Photographs cannot provide the accuracy of position measurement provided by Peary's sights. However, if photographic evidence continues to show that he was in the ballpark (30 mi or less) there is no reason not to accept his sights as genuine evidence of his precise location.

Further tests will be conducted before publishing final results. We welcome any comments, and we will keep you informed.

TABLE 1

COMMENTS AND MEASUREMENTS FOR 11 TRIALS

| Trial | Comment (Recorded prior to measurements) | Distance to Vanishing Point in. | |
|---|---|---|---|
| | | Horiz. | Vert. |
| 1 | Maybe too close | 18.85 | 2.33 |
| 2 | Looks good | 20.50 | 2.61 |
| 3 | Looks good | 24.77 | 3.22 |
| 4 | Maybe too far | 29.64 | 3.95 |
| 5 | Seems too far | 35.84 | 4.96 |
| 6 | Seems too far (??) | 31.10 | 4.24 |
| 7 | Looks good, maybe a little too far | 26.55 | 3.57 |
| 8 | Pretty good | 24.03 | 3.13 |
| 9 | Good, maybe too close | 22.27 | 2.90 |
| 10 | Pretty good, possibly too close | 18.00 | 2.29 |
| 11 | Too close (almost certainly) | 13.07 | 1.53 |

TABLE 2

SOLAR ALTITUDES FOR 11 TRIALS

| Trial | Solar Altitude | Comment (Recorded prior to measurements) |
|---|---|---|
| 1 | 6°31' | Maybe too close |
| 2 | 6°47' | Looks good |
| 3 | 7° 2' | Looks good |
| 4 | 7°17' | Maybe too far |
| 5 | 7°37' | Seems too far |
| 6 | 7°28' | Seems too far (??) |
| 7 | 7°19' | Looks good, maybe a little too far |
| 8 | 7° 2' | Pretty good |
| 9 | 6°59' | Good, maybe too close |
| 10 | 6°40' | Pretty good, possibly too close |
| 11 | 5°49' | Too close (almost certainly) |

TABLE 3

MEASUREMENTS AND SOLAR ALTITUDES
(Second Method)

| Trial | Distance to Vanishing Point, in. | | Solar Altitude |
|---|---|---|---|
| | Horiz. | Vert. | |
| 1 | 23.67 | 3.10 | 7° 3' |
| 2 | 24.22 | 3.19 | 7° 7' |
| 3 | 19.89 | 2.53 | 6°45' |
| 4 | 24.27 | 3.20 | 7° 7' |
| 5 | 18.97 | 2.39 | 6°39' |
| 6 | 29.13 | 3.92 | 7°21' |
| 7 | 21.48 | 2.78 | 6°55' |
| 8 | 19.28 | 2.45 | 6°43' |

# HISTORY OF NAVIGATION

*Editor's Note: The fourth in the series of articles by John Luykx that have appeared under this heading will appear in the next issue. That article will deal with Columbus' place among the four great navigator-explorers of the late 15th and 16th Centuries, the other three of whom were Vespucci, Magellan, and Da Gama. (Amerigo Vespucci was the subject of the Navigation Personalities column in the last issue of the Newsletter).*

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 37, Answer

Here is a succinct one-page statement of the theory underlying celestial navigation. In virtually all forms of navigation, an unknown position is determined by means of distance and direction from a known position. In celestial practice, the known position is the GP of the celestial body observed, which is that point on the surface of the Earth that would be intersected by a straight line from the center of the Earth to the center of the body at the second in time when the observation is made. The GP, for every second of time, is determined from the *Almanac*. Hence, one must time his sextant shot to the nearest second of GMT. It is presented in the *Almanac* in terms analogous to latitude and longitude.

The direction and distance from that known GP is, in turn, determined by means of the great navigational triangle. One point of the triangle is always the geographic pole of the hemisphere in which the observer is located when he makes the celestial observation with his sextant. A second point is the GP. The third point is the DR or assumed position of the observer, the more precise coordinates of which must be determined. They can be determined because it is a property of every triangle that if one knows the length of two adjacent sides and the size of their included angle, one can compute the length of the third side and the other two angles. On the surface of the Earth the two known sides are the distances respectively along the meridians of longitude which pass through the GP and the assumed position from those respective points to the Pole. The distance from the GP to the Pole is known precisely. The distance from the assumed position is only approximate, but it is sufficient. The angle at the Pole where the two meridians meet is the difference in longitude. Thus, we have the two sides and the included angle.

The "line" or great circle are on the Earth's surface which connects the assumed position and the GP is the third side. The angle formed where the third side intersects the meridian of the assumed position is the true direction from the assumed position to the GP. The length of the third side is the distance. With that distance and direction from the known GP, the navigator can, using a special technique, draw on a plotting sheet or chart a true direction line through the plotted assumed position in the direction to the GP. Again, that direction is equal to the angle where the third side intersects the assumed position and the meridian of longitude on which the assumed position falls.

The distance is represented by a perpendicular to the direction line, which is drawn through the direction line at a specific point that is either closer towards the GP than the assumed position, or farther away from it than the GP. This "towards" or "away" effect is nothing more than the difference between the distance of the assumed position from the GP and the *actual* distance represented by the value obtained from the sextant shot. The sextant value, when compared to the assumed position value, renders the difference. This difference is used to plot the perpendicular, which in reality is a *line of position* (LOP) on which the observer is located. Two intersecting lines of position from two observations of different bodies constitute a fix.

The sight reduction tables solve the spherical trigonometry problem. The navigator enters the tables with local hour angle (difference in longitude), declination (latitude of the celestial body), and latitude of the assumed position. He looks up an answer expressed in terms of direction and distance (azimuth angle and observed altitude). The difference between the tabulated value for the distance of the assumed position and the actual value from the sextant shot is, again, the offset on the plotted direction line from the assumed position which determines where the perpendicular LOP is drawn. Normally, this offset is relatively minor — perhaps a few nautical miles. In celestial terms it is known as the altitude intercept.

How does one know whether to plot the LOP as the direction line using the offset, closer to the GP than the assumed position or farther away from the GP than the assumed position? Therein lies the great principle of the "circle of equal altitudes" and the special technique that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enables the navigator instantly to know the answer. The next issue will deal with this.

All the rest of the celestial puzzle is nothing more than astronomical terminology and the procedures used in entering the *Almanac* and the sight reduction tables. The puzzle will be far less vexing if the practitioner will keep in mind the basic underlying theory as expressed above. Again, take a sextant shot—it tells you (after certain corrections are made to it) how far you *actually* are from the GP. Use the *Almanac* to determine the precise coordinates of the GP (and also the corrections to the raw sextant shot data). Use the sight reduction tables and a convenient assumed position (near the DR) to determine true direction to the GP from the assumed position and distance. The difference between the tabulated distance and the actual distance as determined by the sextant enables you to make the plot.

# NAVIGATION PERSONALITIES

## Henry Hudson

*By Roger H. Jones*

Henry Hudson, whose date and place of birth are unknown, strode into history on April 19, 1607 when he and the second of his three sons met with the ten members of his crew at the St. Ethelburga's Church on Bishopsgate Street in London. There, four days before they were to set sail on the first of Hudson's four voyages, they received communion and the blessings of friends and supporters.

Hudson was a shipmaster, and one of the boldest of the explorer-navigators at the end of the Elizabethan era. In the small vessel, *Hopewell*, they set out to find the Northwest Passage to Japan and China, and on the first voyage they sailed along the East Coast of Greenland searching vainly for an opening in the ice pack that would take them, they thought, to warmer waters in the Polar regions. Unsuccessful in that quest, they eventually reached Spitsbergen, and were then forced to return to England, arriving in September of 1607.

Hudson was in the employ of the Muscovy Company, and neither he nor his employer were convinced that the passage they sought did not exist. The second voyage was thus organized, and their departure was on April 22, 1608. They skirted the West Coast of Norway, and sighted North Cape. Two of Hudson's men reported seeing a mermaid, and he duly recorded in his log their description of this wondrous creature. Hudson found the passage between Spitsbergen and Novaya Zemla totally blocked by ice, and he searched in vain for an entrance into the Kara Sea. He again returned to England, arriving on August 26th.

Hudson's exploits had gained recognition in the Dutch East India Company, and he was summoned to Holland where a third voyage was commissioned. The departure was again in April (1609) and the crew was a mixed Dutch and English lot. The vessel was the *Half Moon*, and initially she was navigated again towards North Cape. Eventually, she was sailed across the Atlantic, and Hudson and his men visited Virginia before turning north.

On September 2, 1609 they reached the mouth of the great river bearing Hudson's name, which had been first discovered by Verrazano in 1524. (The Verrazano Narrows Bridge, begun in 1959 and completed in 1964, spans the mouth of the Hudson and was named for Giovanni da Verrazano). *Half Moon* sailed up the great river to a point thought to be the head of navigation near present day Albany. The crew observed great natural riches, including the Indian corn and beans. This voyage was completed with the return to Dartmouth in Devonshire on November 7, 1609.

Hudson sent a report to the Dutch detailing his enthusiastic impressions of the great natural riches in the valley of the great river he had visited. In turn they ordered him to Holland. However, the English regarded this as one of their own benefitting a foreign nation, and they ordered him and his crew to remain in England. Eventually, *Half Moon* was returned to Holland with an entirely Dutch crew.

The last voyage, aboard the vessel *Discovery*, departed from England on April 17, 1610. There was a crew of nineteen men, and on July 11th they entered the strait now known as Hudson Strait. Here they were temporarily icebound. They managed to break free and sailed westward, and at the beginning of August they entered what they described as a large sea (Hudson Bay). It was believed they had found the passage they sought. In September they reached James Bay at the southernmost extremity of Hudson Bay.

In November they went into winter quarters, and in June of 1611 they again broke free of the ice and sailed west and north. A bitter feud erupted aboard, and on the night of June 21, Robert Juet and Henry Greene met with certain crew members to plan a mutiny. The next day, Hudson, his son, and eight others were set adrift in a small open shallop. They were left to freeze or starve to death.

Nine members of the mutinous crew survived an attack by Eskimos, and Juet died before they reached England in *Discovery*. Five years later, six of the mutineers were tried for the murder of Hudson and the others. History does not record the outcome of the trial.

Although Hudson did not truly discover some of the great geographical features bearing his name, he certainly paved the opening of them to later commerce of inestimable value. That they bear his name is not unfitting.

# MARITIME INFORMATION NOTES

*By Ernest Brown*

## Metric System Changes in Sailing Directions

Beginning in January of 1993, new editions of Sailing Directions will be fully converted to metric format for heights, depths and temperature scales. Sailing Directions have used a dual system for several years, referring to heights and depths in meters, with the English equivalent (in feet or yards) in parentheses. The English equivalent will be dropped.

Horizontal distances given in miles and fractions of miles or in yards will generally stay the same. The nautical mile of 2,000 yards is in common use, and since marine radars are calibrated at yards/nautical miles, DMA will continue to refer to horizontal distances which might be measured by radar in the same way.

The Defense Mapping Agency will also begin conversion of all Sailing Directions to Celsius instead of Fahrenheit scale for temperature. References to temperature are generally found in the Planning Guides, but selected Enroute Guides may have a temperature reference in any discussion relating to climate, weather, or ocean currents.

## New Safety Satellite Telecommunications Services

As a result of consultations between the International Maritime Organization and the International Maritime Satellite Organization, new safety related tariffs for INMARSAT-A and INMARSAT-C ship earth station users have been implemented by COMSAT and IDB AeroNautical's land earth stations. Ship-originated voice or date messages to the U.S. Coast Guard from INMARSAT-A or INMARSAT-C terminals in the following categories will be handled at no charge through these service providers:

+ Medical Assistance Calls involving grave and imminent danger situations, including MEDICO and MEDIVAC communications with the U.S. Coast Guard. These calls are identified by using Service Code 38.

+ Maritime Assistance Calls involving grave and imminent danger situations, including distress related rescue assistance communications with the U.S. Coast Guard. These calls are identified by using Service Code 39.

+ Navigation, Meteorological and Ice Hazard and Warning Reports. These include observed hazards to ships which to the ship's knowledge had not been included in warnings. Messages will normally report unforecast storm conditions (Beaufort force 10 or greater), ice accretion conditions on superstructures, reports of position and time of all ice sightings to the International Ice Patrol, floating derelicts, major aids to navigation irregularities, and other hazards to shipping such as uncharted shoals, rocks and obstructions. These calls are limited to INMARSAT-A telex or INMARSAT-C, and are identified by using Service Code 42.

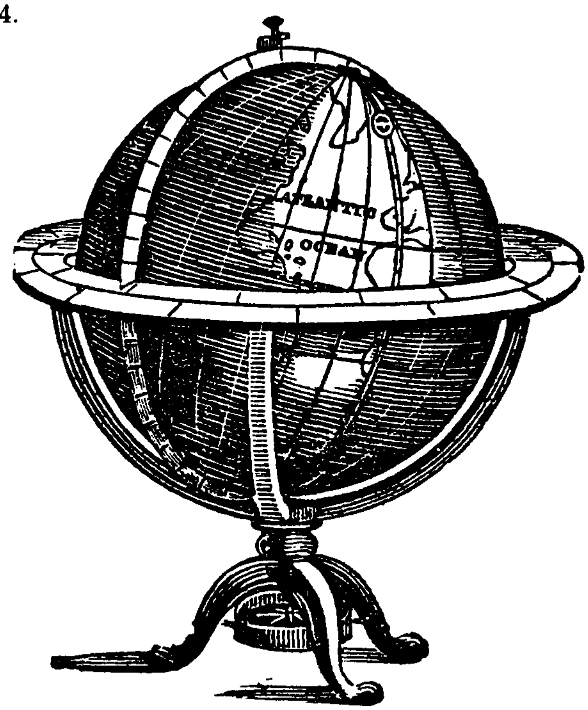
Routing of Priority 3 Distress Alerts remains unaffected by these changes. Messages placed that are not in accordance with the above procedures will be billed at standard tariff charges.

## TOGA COARE International Project Office

TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment) is a large scale oceanographic and atmospheric experiment that is focusing on the western Pacific "warm pool" region and how the interaction of the ocean and atmosphere in this region initiates large scale climate variations such as El Nino.

In order to study this region seven research aircraft, fourteen research vessels, multiple moorings and land sites, and over 800 researchers will be conducting measurements in the area from 1°S to 3°S and 155°E to 157°E during the period November 1, 1992 to February 28, 1993. During this period the research vessels will be conducting both atmospheric and oceanographic measurement runs in coordination with the vessels' operations. Surface and subsurface instrument moorings will also be deployed in this region to make continuous measurements of oceanographic parameters. Some vessels will also be making routine launches of weather balloons.

For additional information contact TOGA COARE International Project Office, P.O. Box 3000, Boulder, CO 80307-3000, telephone (303) 497-8658, FAX (303) 497-8634.



# BOOK REVIEW

*By Roger H. Jones*

## *Polar Passage*

By Jeff MacInnis with Wade Rowland
Ballantine Books, A Division of Random House, Inc.
New York, New York (1989)
115 pages; available in paperback format.

In the last issue the review was of John Bockstoce's *Arctic Passage*, which was his account of his epic voyage, largely in an Eskimo sealskin umiak (open boat of approximately 30 feet in length). The review noted that Bockstoce became in 1988 the first person to complete such a voyage above mainland Canada from the West to the East through the torturous Northwest Passage. The review should have been, as printed, more explicit. Through error, this reviewer somehow sent an earlier draft of the review rather than the final draft. The final draft stated, more correctly, that he was the first to complete the passage in which the trip was made largely by open boat powered by outboard engine and oars or paddles. The final draft also made reference to the fact that another, Jeff MacInnis, was the first to make the passage under sail, and that the MacInnis book would be reviewed in a succeeding issue. Apology is hereby stated for the inadvertent mix-up in drafts.

The fact is that Jeff MacInnis, together with Mike Beedell, also made the West to East passage, and they also completed the trip in late August, 1988. MacInnis and Bockstoce shared a common philosophy—that success would depend upon use of a light vessel capable of being dragged up onto the ice. McInnis chose an 18-foot Hobie Catamaran because of its relatively high speed and its light weight. To compensate for lack of shelter, he and Beedell equipped themselves with Arctic survival gear, including dry-suits and full flotation coveralls and mountaineering tents designed to withstand very high wind forces.

*Perception* was named before she left the factory, and her bright yellow hulls were reinforced with thin strips of almost bullet-proof Kevlar. She also had removable plastic runners to convert her into a sort of haulable sledge. On July 20, 1986, the departure was taken at a point in the MacKenzie River not far from the earlier departure point of Bockstoce, and *Perception* was headed downstream (northwest) towards the Beaufort Sea. The summer seasons of 1987 and 1988 were the second and third "years" of the MacInnis-Beedell voyage, and on August 17, 1988, at 6:50 a.m. *Perception* flashed into Baffin Bay, completing history's first *sail-powered* transit of the Northwest Passage. This was the final chapter in a 400-year-old dream of mankind that began with the great explorers who followed on the heels of Columbus in the Sixteenth Century. From a reading of both the Bockstoce and the MacInnis books, it appears that MacInnis' arrival at Pond Inlet on Baffin Bay occurred about a week and a half before Backstoce's arrival at the same point. Who was "firstest" of the "first"? It is perhaps unimportant. Both accomplished, with nearly identical philosophies of open boat Arctic travel, the more than nearly impossible.

Previous to them there had been a very small number of historic voyages by steel-hulled ice breakers, submarines, and tankers, but even those voyages were accomplished only with the greatest difficulty. They did not begin to test the will, strength and human endurance of mankind in the way that MacInnis and Bockstoce were tested.

The MacInnis route and the enormous obstacles were largely the same as taken and experienced by Bockstoce. *Polar Passage* is an absorbing account of human endurance, encounters with impenetrable ice and polar bears, the solving of crucial navigation problems in areas where there were no landmarks and where fog and poor visibility were constant companions, and the acceptance and dealing with the ever-present freezing cold. In fact, Bockstoce and MacInnis were in contact with each other from time to time, including at least one instance in which Bockstoce flew over *Perception* on an ice reconnaissance flight. Radio contact was established.

They share an understanding that few men could even imagine. From MacInnis: "During a wild, reefed-down ride up the coast and through the rocky channel east of the Tasmania Islands, we counted five polar bears in an hour and a half, and when we found we could no longer cope with the fury of the wind, we had to set up camp just around the corner from them. . . . Our night was an uneasy one, haunted by dreams of marauding animals." That quotation evokes a mild image in comparison with some of the trials described by MacInnis.

On a par with the Bockstoce book, *Polar Passage* is a book which conveys the awesome beauty and the power of the high Arctic latitudes. It, too, is essential reading for those with the salt of the Navigator in their bloodstreams. A "Well done!" to both authors, both navigators, both remarkable men.

# ADDENDUM

*The following figures were accidentally ommitted from the article on* A DR Independent Two Celestial Body Solution, *by R.B. Derickson, in issue Thirty-seven.*

## Mathematical Sight Reduction for Two Bodies

The intersections of two circles of equal altitude are determined analytically, by solving a succession of sides and angles of interrelated spherical triangles (see Figure 1).

*Arguments:*

Greenwich hour angle of first body (GHA1)
Declination of first body (Dec1)
Observed altitude of first body (Ho1)

Greenwich hour angle of second body (GHA2)
Declination of second body (Dec2)
Observed altitude of second body (Ho2)

Time interval between observations
Ship's course
Ship's speed

*Respondents:*

Latitude of Fix (Lat)
Longitude of Fix (Lon)

Latitude of other intersection
Longitude of other intersection

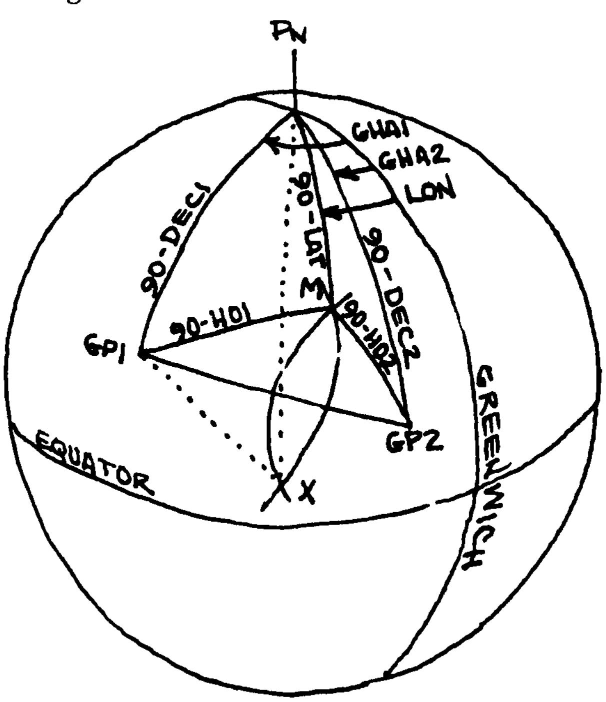



Figure 1.

If GHA1, Dec1, Ho1, GHA2, Dec2, Ho2, are known, then Lat and Lon may be determined by solving a succession of sides and angles.

Pn is North Pole, GP1 is geographic position of body 1, GP2 is geographic position of body 2, and *M* is the position of the observer. The order of solutions follows:

| | | | | |
|---|---|---|---|---|
| side | GP2 | GP1 | | |
| angle | Pn | GP1 | GP2 | |
| angle | *M* | GP1 | GP2 | |
| side | *M* | Pn | | (90 - Lat) |
| angle | GP1 | Pn | *M* | (GHA1 - Lon) |

Another observer located at *X* would have observed the same Ho1 and Ho2. Because of symmetry, angle *X* GP1 GP2 = angle *M* GP1 GP2 but with the opposite sense (angle *X* GP1 GP2 = - angle *M* GP1 GP2).

## Mathematical Solutions for Spherical Triangle

*Arguments:*

side a
side b
angle C (included)

*Respondents*

side c
angle B
angle A

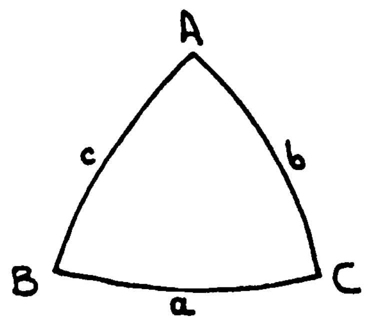



Figure 2.

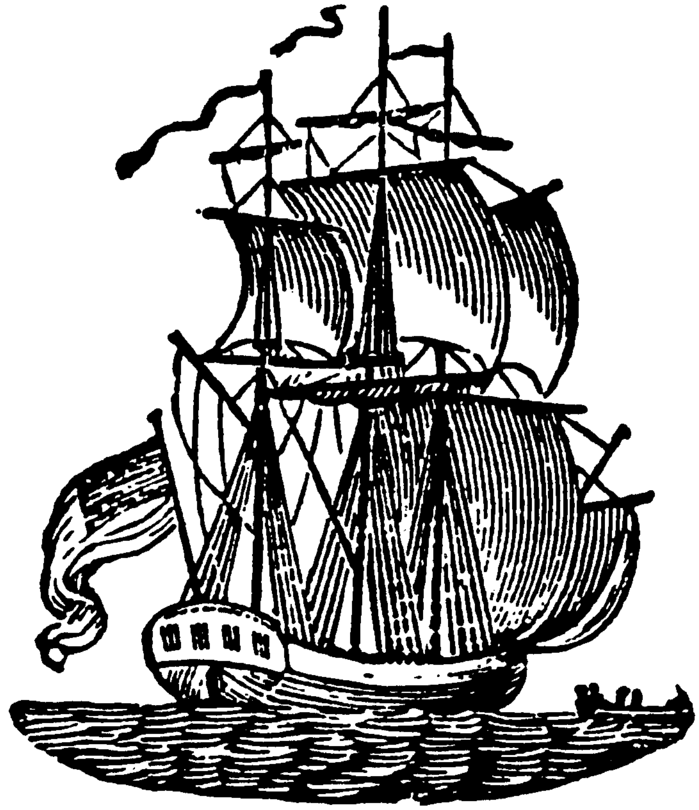
$c = COS^{-1}\ (COS(a\text{-}b)\ \text{-}SINa*SINb*\ (1\text{-}COSC))$
$B = COS^{-1}\ ((COSb\text{-}COSa*COSc)/(SINa*SINc))$
$A = COS^{-1}\ ((COSa\text{-}COSb*COSc)/SINb*SINc))$

The unknown side, c, and angles B and A are found by the equations shown. If only sides a, b, c are known, then angles B and A may still be found.

Sides a, b, c are always considered positive. If angle C is negative then angle B and angle C must also be considered negative.

DO YOU KNOW . . . ?

The cross staff may be traced from a description published in 1328 by the French mathematician and astronomer, Rabbi Levi ben Gerson. His instrument, based upon the principle of similar triangles, was called a Jacob's Staff after the Biblical story in Genesis 32:10. It consisted of a staff of five to six feet in length with a perpendicular vane that was capable of being moved from one position to another along the length. The staff was graduated trigonometrically so that angles could be measured by holding the staff to the eye and moving the vane until its ends coincided with points to be measured. In the 1550s it was introduced into England and developed to measure angles between stars. The typical shipboard use was to find the latitude by measuring the height of Polaris. The sun's altitude could also be found, but this required the observer to look at the sun, and to avoid this, the back staff was devised about 1594. The latter was used in a manner in which the observer's back was to the sun.



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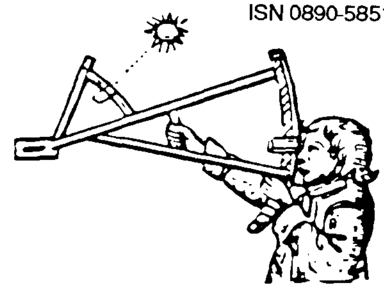


# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE THIRTY-NINE, SPRING 1993

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

During the two and one half months that I was out of the area, the Foundation was forced to revert to a temporary method of preparing the Newsletter for publication. Under normal circumstances the procedure is necessarily complex due to the different locations of all of the principal players who are involved, Directors John Luykx, Roger Jones, Ernest Brown, Meredith Davies, myself, the lady who types the Newsletter to disk, and the person who picks up the Newsletters from the printer, prepares them for mailing and takes them to the Post Office. We live in diverse locations from Maryland to Texas to California.

While I was away and the temporary system in effect, a couple of embarrassing errors occurred. The article by member Dicky Derickson was published in the Fall issue of the Newsletter missing two very important figures and the acknowledgment for the assistance Rick Berg, George Smith and Jill Neidrauer had provided to member Derickson.

The Winter issue of the Newsletter printed the two missing figures but again omitted the acknowledgment. I deeply regret the error and omission and apologize to member Derickson for these errors and omissions.

I also apologize to Ambassador Claude Huguenin for misspelling his name in the Readers Forum in Issue 38. Unfortunately, we are sometimes rushed and do not do as adequate a job of proofreading as we should.

### Latitude and Longitude Adjustments on All NOAA Charts

The Foundation, as a chart dealer, has received the following information on adjustments to NOAA charts. This was not published in the normal Notices format.

Beginning last October 15, 1992 the horizontal referencing system used in all charts and chart products published by NOAA changed from NAD 27, a point in Kansas, to the NAD83, a point based on the center of the earth. The greatest coordinate shift will be in Hawaii and Alaska where latitude will be moved by as much as 2300 feet and longitude by up to 950 feet.

If you use digital data from NOS or the FAA, you must purge your entire data base so that there is no confusion over which referencing system your data is based on. If you use ellipsoidal parameters in your software, they will need to be revised as follows:

a (semi-major axis) = 6,378,137.000 meters

b (semi-minor axis) = 6,356,752.314 meters

i/f = 298.2572221

User questions relating NOS charts and chart products should be directed to 1-800-626-3677. Technical questions on the datum conversion should be referred to Mr. Doyle (National Geodetic Survey) at 1-301-443-8684.

NOAA Nautical Charts Are Going METRIC!

In response to the requirement to convert its suite of nautical charts to metric units, NOAA's Coast and Geodetic Survey will adhere to the following general policies:

1. Safety of navigation will continue to be of primary importance.
2. Every effort will be made to convert charts in logical groupings so that mariners' transits will require minimal shifting between the two measurement systems.

DO YOU KNOW . . . ?

*By Roger Jones*

Special techniques have been used for years by many celestial navigators. Do you know the "Noon Constant" and how it is used? (The answer appears at the back of this issue.)

3. Conversion will be a multi-year effort with implementation expected in 10 to 15 years.

CHECK ALL NEW CHARTS CAREFULLY — THEY MAY BE METRIC!

A catalog of publications has been mailed to all current members. Most, but not all publications that are available are listed. From time to time I will list in the activities column publications that I believe will be of interest to members. This listing will not supersede the book review.

Mid-April is the beginning of this year's work with the underprivileged youth of this area. We are beginning with four classroom sessions, a trip to the boat and then four voyages of one day each. I will keep you informed of our progress.

# READERS FORUM

*Edited by Roger Jones*

Luis Marden, 600 Chain Bridge Road, McLean, VA 22101, has written several long letters regarding the Junghans Mega clock, the apparently diminished Atlantic Ocean range of the WWV Broadcasts from Ft. Collins, Colorado, and the internal clocks in many lap-top computers that are used with sight reduction programs. The Junghans Mega is a radio-controlled clock with a conventional face with second hand and a digital readout of the date. It also indicates the local time zone to which it is set, but does not simultaneously indicate GMT. It is automatically set by the radio signals from WWV, and it has a range of about 2,000 miles. It will run for about three years on a single C cell. Marden reports that it has performed flawlessly in comparison with the WWV radio signals, except for two or three recent occasions when it displayed the wrong date. Other users also reported the date error at the same time, and the unthinkable is suspected — a temporary fault in the WWV long-wave transmission. There have been no repetitions of the date error. The clock may be obtained in the U.S. from J. P. Connor & Co., P.O. Box 305, Devon, PA 19333, at a cost of $195.

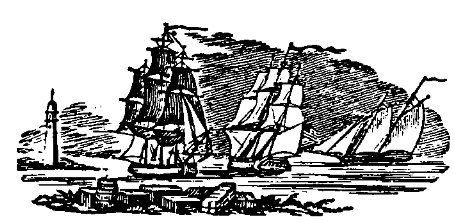
In this same connection, Marden notes that with the move of the Institute of Standards from the East Coast to Colorado, small vessel mariners have found that for most of an Atlantic crossing the BBC's long-wave time signals are much more reliable than those from WWV in Colorado, except when close to the East Coast of the U.S. Notable cruiser authors such as Eric Hiscock have reported this, and Marden has experienced the same problem in his own vessel in the Atlantic. *Editor's Note: John Luykx would be interested in hearing from any reader about the apparent extent of Atlantic coverage of WWV, CHU, and BBC. Please write to him at the Foundation address.*

Finally, Marden has noted that the internal clock in many computers is not particularly accurate, but there is a computer program that is specifically designed to correct the internal clock every time the computer is booted. This is the CLOCKWRIGHT program which permits adjustment of the computer clock to keep time within a second over fairly long periods of time. It is available from Pavel Otavsky, 23 Barberry Hill, Woodstock, Vermont 05091, for $38 plus $5 in postage. For those who are shore-based, there is also a program called TIMESET which, through a modem, dials the U.S. Naval Observatory and automatically sets a computer's clock and calendar. Software dealers will be able to furnish data on this program.

As noted in the ACTIVITIES column (page 1), member Dicky Derickson wrote to us in January with the well-founded complaint that the omission of his Figures 1 and 2 in his Issue 37 article on a DR independent two celestial body solution left the article somewhat incomprehensible. This omission and several other errors were corrected by a special insert in Issue 38. *However, this Editor joins Terry Carraway in further acknowledging that somehow we still failed to identify those who were most helpful in supporting and encouraging Derickson. They were: Rick Berg, George Smith and Jill Neidrauer. We regret the oversight. —Roger H. Jones*

The Derickson article generated comment and interest from a number of readers. Dr. George Bennett of 27 Cabramatta Road, Mosman, N.S.W., Australia 2088, wrote to the Foundation furnishing his comments. He also noted that in the *Journal of the Institute of Navigation*, Vol. 26, No. 4, Winter 1979-80, he published an article entitled "General Conventions and Solutions — Their Use in Celestial Navigation." The Bennett article was a previous study of the subject addressed by Derickson. A copy of the Bennett article, sent by surface mail, arrived at the Foundation address late in March. When this issue of the Newsletter went to press, we had not yet studied it. However, readers of this Newsletter may be interested in the following which was taken from an abstract of the Bennett article.

"It is not realized by many navigators and some astronomers that general solutions exist which do not require a list of auxiliary rules. Before the advent of the calculator, there were good reasons for not using general solutions because the formulae were not amenable to easy solution by logarithms and tabulation. No such barrier exists today, and yet books are still written giving calculator solutions which require one to look up rules when, say, Latitude and Declination are of the same or opposite name. This paper (Bennett's) outlines a set of

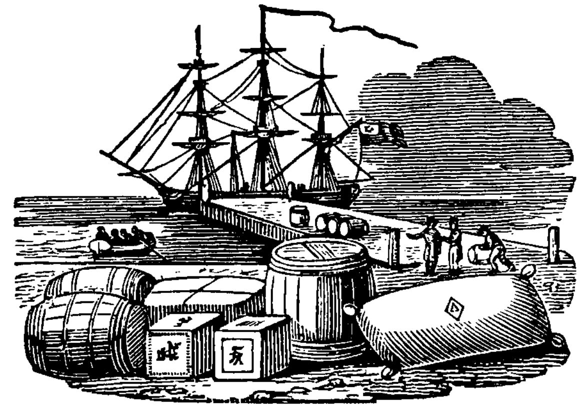


conventions and gives examples which illustrate the simplicity and generality of such conventions when solving celestial navigation problems."

The Derickson article also prompted Mike Pepperday of 115 Kent Street, Rockingham, WA 6168, Australia, to write a later letter to us. He notes that Derickson's piece reminded him of a paper which he had been intending to prepare. The result was his piece entitled *Calculator Tricks and Two-Body Mathematics,* including useful tips that he has taught to survey students, and which are not generally used by those interested in navigation problems. Unlike the Bennett article, Pepperday's has not been previously published, and we are including it below in this issue. We note, however, that Pepperday adds that he did an ocean crossing using the two-body method, and that in the real world practical situation, the method is not always convenient at sea. We'd be interested to hear more about that experience, Mike.

Pepperday's name arises in another connection as well. Matt Morehouse of Paradise Cay Publications, P.O. Box 1351, Middleton, CA, 95461, has written and enclosed copies of two new Paradise Cay publications. One of these is entitled *Celestial Navigation With the S Table — a Complete Sight Reduction Method for All Bodies in Nine pages,* by Mike Pepperday. The second is entitled *100 Problems in Celestial Navigation,* by Leonard Gray. We have been interested in a number of the Paradise Cay offerings in the past, and both of the new ones (and another book) are reviewed in this Issue of the Newsletter. Interested readers should contact Matt at the Paradise Cay address noted above.

Bill Land of Norristown, PA and Stephen Matthews of Port Washington, NY, have each written to us enclosing a copy of the comments of Greg Walsh on the Davies Concise Sight Reduction Tables which are included at the back of the *Nautical Almanac.* The Walsh comments appeared in the January 1993 issue of *Ocean Navigator.* Walsh's experience is that the Concise Tables involve a usage which he finds to be abstract, and that they appear to him to be too far removed from the simple, clean theory of the standard navigational triangle. He finds the instructions to be quite complicated, and he insists that the navigator would still need to have aboard Volume 1 of H.O. 249 and also a regular volume of 249 or 229 for specialty uses such as rapid star solutions, star identification, compass checks, etc. We do not entirely disagree with Mr. Walsh, but we do note that the Concise Tables were intended for what they are—concise. Of necessity, the many concise methods, including the modern revisions of H.O. 211, depend upon rather involved instructions. This is also true in regard to the S Table Sight Computations of Mike Pepperday. While agreeing with Walsh about the Concise Table instructions, we note that he is wrong in several respects. The Concise Tables can be used for such specialty uses as great circle sailing, star identification and compass checks, and Matthews correctly points out that the Concise Tables



are, themselves, derived from the late Admiral Tom Davies' work on the *Assumed Altitude Tables* which were devised principally to permit star sight reduction without first having to identify the star. Finally, it should be noted that David Burch has prepared a truly useful workform for use with the Concise Tables, published by his Starpath Navigation school in Seattle. The answer lies with the teachers of navigation to present the Concise Tables in a logical and coherent manner, and the students should bear in mind that the instructions to H.O. 229 are also complex and confusing in many respects. (Please see the book review in this Issue of A. E. Saunders' new book that specifically teaches the Concise Tables). Certain readers have found Walsh's comments to be more expected from a bar stool than from the pages of a responsible journal such as *Ocean Navigator.* We have refrained from quoting Walsh directly, but we do not entirely disagree with that sentiment as well.

Leslie Finch of Mastic Beach, NY, has written to inform us that he is improving his celestial shots using an artificial horizon inspired by the Peary article. He has constructed this of Plexiglas, and he uses in the pan the blackest used motor oil he can get in order to avoid a secondary reflection from the bottom of the oil pan. We note that the optical quality of his Plexiglas "roof" must be quite good, indeed.

A letter from Captain David Charlwood of West Horsley, Surrey, Great Britain, has been greatly appreciated. He retired as a Captain with British Airways, and he flew 747s as well as DC-3s and other earlier transport aircraft. He used bubble sextants in connection with his earlier flying career, and he has also navigated sailboats since 1952. He states: "With regard to the Navigator's Newsletter, I have found this to be a delightful publication. I am impressed particularly with the relaxed and laid-back approach to the content, and find the balance of technical articles, historical items and reader input to be perfect. I have not seen a nicer or more honest publication anywhere." *This Editor joins the other Directors in thanking you, David.—Roger H. Jones*

Paul Milne of 10 Balmoral Avenue, Grimsby, Ontario, Canada L3M 1G4, is interested in Henry Schufeldt's *The Calculator Afloat.* Any reader who has a copy is urged to contact Milne if he/she would be willing to sell or lend it to Milne.

The Foundation has received letters from Arthur Horning of Great Valley, NY and Jack Tyler of El Paso, TX, expressing interest in used sextants. John Luykx has replied with a list of used sextants that are available. Other readers may wish to contact John at the Foundation's address. He is able to comment on the advantages and features of a variety of sextants, and also to furnish information on sources for new sextants.

Finally, in rounding out the Readers Forum, we note that we've heard form Dicky Derickson in regard to other technical subjects beyond his article on the two-body celestial solution. From 1965 to 1983 he was involved in the design of digital systems, and he proposes a self-regulating digital chronometer. He noted that the resonant frequency of a crystal oscillator is dependent upon the dimensional and electrical properties of the crystal and its components. These properties are affected by temperature, pressure, voltage, etc., and a change of one part per million of the resonant frequency results in an error rate of .0864 seconds per day, or about one second per twelve days. A significant part of the drift from correct time is constant because the crystal is, typically, not exactly the correct size.

Derickson notes there is a way for a watch to determine its own average error rate over a period between settings, and this can be transformed into a compensating adjustment. His letter goes on to present a diagram of the components of a self-regulating watch. He notes that the systems knowledge is present, but thus far no manufacturer has seen fit to build a watch to these specifications. Interested readers may reach him at P.O. Box 8038, Vallejo, CA 94590-8038.

Derickson has also written to the Foundation describing *A Hand Held DR Analyzer* in which he sets forth a group of programs for a shipboard calculator. John Luykx has read the monograph with interest, and John comments that the program described by Derickson appears to be more comprehensive and user friendly than the several that are already available. This article by Derickson may be presented in a future issue.

# NAVIGATION BASICS REVIEW

## The Use of the Calculator in Navigation

*By John Luykx*

In an article entitled "The Use of the Calculator in Navigation" included in a previous issue of the *Navigator's Newsletter* (Issue 37 Fall 1992) a listing was given of many of the typical problems faced by the navigator during the "Day's Work at Sea" which can be solved by a scientific calculator. In the following discussion which is a continuation of the first article, formulae are tabulated for some of the more frequently encountered celestial navigation problems which are capable of solution by calculator. Problems during the "Day's Work" more easily solved *a) using* data in the Nautical Almanac *b)* using tabular data and *c)* using graphic or chart methods are also listed below.

### I. FORMULAE FOR COMMON PROBLEMS READILY SOLVED BY SCIENTIFIC CALCULATOR

1. Plane Sailing

$$l = \cos C \times D$$
$$p = \sin C \times D$$
$$\tan C = p/l$$

2. Middle Latitude Sailing

$$p = DLo \times \cos Lm$$
$$DLo = \frac{p}{\cos Lm}$$
$$\tan C = p/l$$

3. Time of LAN

$$\text{Interval to LAN} = \frac{tE \text{ (minutes of arc)}}{900' \pm \text{ship's hourly longitude change}}$$

*Note: tE = difference between GHA and DR longitude*

4. Noon Latitude

$$\sin L = \cos (Ho \pm d)$$
*(if L and d are same name, the sign is –.)*

5. Sight Reduction

a. Computed altitude:
$$\sin Hc = \sin L \times \sin d + \cos L \times \cos d \times \cos LHA$$

b. Azimuth angle:
$$\sin Z = \frac{\cos d \times \sin LHA}{\cos Hc}$$

6. Time and Altitude on Prime Vertical

$$\cos t = \tan d \times \cos L$$
*Note: meridian angle of a body on the prime vertical*

$$\sin H = \frac{\sin L}{\sin d}$$

7. Time Sight

a. $\cos t = \frac{\sin Ho \pm \sin L \times \sin d}{\cos L \times \cos d}$

*(The sign is + if L and d are contrary.)*

b. Longitide = GHA ± t

*(The sign is + if the sun is east at the time of observation.)*

c. To advance a longitude observation to a latitude observation:

1) $p = \sin C \times D$

2) $DLo = \frac{p}{\cos L}$

d. To advance a latitude observation to a longitude observation:

$1 = \cos C \times D$

8. Star and Planet Identification

a. $\sin d = \sin L \times \sin Ho + \cos L \times \cos Ho \times \cos Z$

*Note: record azimuth of unknown star by hand-bearing compass observation and convert the Zn to Z (azimuth angle).*

b. $\cos t = \frac{\sin Ho \pm \sin L \times \sin d}{\cos L \times \cos d}$

*(The sign is + if L and d are contrary.)*

*Note:* GHA Aries
± Longitude
= LHA Aries
± t of Star
= SHA Star

*Note: A star is identified by its SHA and d.*

9. Amplitude

a. $\sin A = \frac{\sin d}{\cos L}$

b. ZN☉ = 90°t + A AM Fall-Winter
ZN☉ = 90°t - A AM Spring-Summer
ZN☉ = 270°t - A PM Fall-Winter
ZN☉ = 270°t + A PM Spring-Summer

10. Reduction to the Meridian

a. $\tan P = \frac{\tan d}{\cos LHA^*}$

* LHA at the time of observation

b. $\cos Q = \frac{\sin P \times \sin Ho^*}{\sin d}$

* Ho at the time of observation

*Notes: If L and d are contrary; or if L and d are same name and d is greater than L then:*

$L = p \sim Q$

*In all other cases:*

$L = P + Q$

II. ALMANAC DATA

The following computations are best accomplished utilizing data from the Nautical Almanac:

1. Sextant altitude corrections (Front/Back cover)
2. Sun/Moon Rise/Set Twilight (Daily Pages)
3. Latitude by Polaris (Polaris Table)
4. Conversion of arc to time (Arc to Time Table)

III. TABULAR DATA

The following calculations are best accomplished using the formulae and the tables indicated.

1. Mercator Sailing: Bowditch Table 5

Table 5 is used to obtain m, the difference in meridional parts for departure L and arrival L.

$\tan C = \frac{DLo}{m}$

$D = \frac{1}{\cos C}$

$DLo = m \times \tan C$

$p = \frac{1 \times DLo}{m}$

2. Traverse Sailing: Bowditch Table 3

When a series of courses and distances are combined or added the resultant course and distance may be found using Table 3 in Bowditch. the Resultant latitude and longitude is then computed using Mercator Sailing or middle latitude sailing procedures.

## IV. GRAPHIC OR CHART SOLUTIONS

The Complete Great Circle Solution

The most efficient and rapid (although perhaps not the most accurate) method of solving the Complete Great Circle problem is by chart projection. First the initial heading and distance are computed. Then the track is broken down into segments of equal distance and finally the coordinates of intermediate points are computed at which rhumb-line course changes are to be made.

The track from point of departure to point of arrival is plotted directly on an oblique gnomonic projection chart. (Great Circle chart). A number of generally equidistant points along the Great Circle track are then recorded and transferred to a mercator chart or plotting sheet and used as a succession of destinations to be reached by rhumb lines. The true course and distance between each point is then determined directly by measurement on the chart.

Longitude at Noon (LAN)

Longitude at noon may be approximated by the "Equal altitude Method." The times of two or three successive altitudes measured in the morning within an hour of noon are applied to the times for each of two or three equal altitudes measured in the afternoon to obtain mean time. The mean time for the wo or three pairs of observations are then averaged to compute the time of LAN.

Due to ship motion north or south and the change of declination between AM and PM observations, a time correction $\Delta t$ must be applied to the value of LAN computed above to compute the exact (corrected) time of LAN.

Longitude = GHA of sun at the exact time of LAN

Exact time of LAN = Time of highest altitude $\pm \Delta t$

$$\Delta t = .5 \frac{l_1 \sim d_2}{a}$$

$\Delta t$ = time interval or correction in minutes

$l_1$ = vessel motion north or south in knots

$d_1$ = hourly change of sun declination

a = altitude factor (Table 29 Bowditch)

The true correction ($\Delta t$) is plus (+) when the combined value of vessel latitude change and sun declination change is away from the sun's GP and minus (-) when this value is toward the sun's GP.

## V. GLOSSARY

| | |
|---|---|
| l | difference in latitude |
| C | course angle in degrees |
| D | distance in miles |
| p | departure in miles |
| DLo | difference in longitude in arc minutes |
| Lm | middle latitude |
| tE | meridian angle East |
| tW | meridian angle West |
| L | latitude |
| Ho | observed altitude of celestial body (corrected) |
| d | declination |
| Hc | computed altitude of celestial body |
| LHA | local hour angle |
| Z | azimuth angle |
| GHA | Greenwich hour angle |
| A | amplitude |
| p | first auxiliary angle in reduction to the meridian computation |
| Q | second auxiliary angle in reduction to the meridian computation |
| m | difference in meridional parts between point of departure and point of arrival |
| $l_1$ | vessel motion North or South in knots |
| $d_1$ | hourly change in sun declination |
| a | altitude factor (Table 29 Bowditch) |

## Calculator Tricks and Two-Body Mathematics

*By Mike Pepperday*

If the altitudes of two astronomical bodies are observed the fix may be calculaed directly without an estimated position. The recent article *A DR Independent Two Celestial Body Solution* by R. B. Derickson stirs me to take keyboard in hand. The mathematics has actually been set out many times. For example Bowditch gives a procedure by one Charles T. Dozier in 1949 and Bennett[2] set out an elegant general solution with a worked example. Bennett quotes Sadler[3] as remarking in 1977 that this "two-body problem" has been discussed and investigated often. I give a short procedure for a calculator below.

The two-body solution gets repeatedly reinvented. I am the developer of a couple of widely-sold navigation computers, and over the years several people have written to me suggesting two-body as a method for navigation. Some appeared unaware that anyone had thought of it before and in a couple of cases they thought they had invented something which had earning potential. It's understandable. Although it has been well aired in the journals, the navigation textbooks are practically oblivious.

I, too, reinvented it when I was about to make my first ocean crossing in 1982. Why pussyfoot around with intercepts from a DR position when you can compute the fix directly? At the time I presume the reason that the textbooks did not deal with it was because it hadn't been practicable prior to the advent of programmable calculators. I was wrong there: a decade later most texts scarcely even recognize calculators, let alone set out a two-body solution.

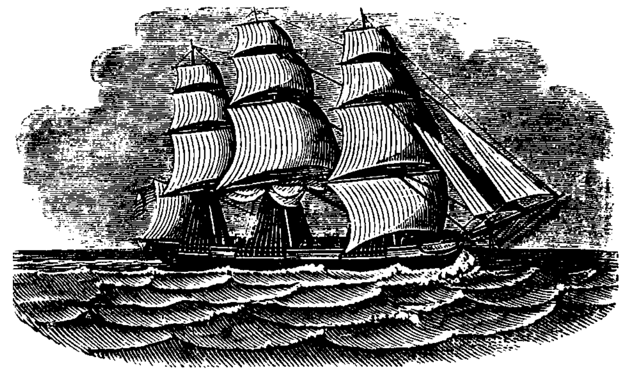
By 1982 it was certainly practicable and, with the help of a Hewlett-Packard HP34E and a makeshift battery charging arrangement, I used it for an eight day crossing of the Coral Sea. Along with noon sights, it was my sole means of position determination. I have not heard of anyone else doing this, so perhaps I am the only person ever to actually navigate by the two-body direct solution. I had thought it would be elegant but it turned out to be inconvenient. Practicable but not practical.

I did discover something new, though. Mathematically there are two solutions for the two-body fix — at the two places where the position circles intersect. As I later found out, everyone says to compute both and discard the one which is obviously wrong. Apart from taking twice as long to compute, this detracts somewhat from the purity of DR independence. It isn't necessary. You only have to say which body was left hand and which was right hand. Apparently no one ever noticed this left/right distinction before —though it does seem astonishing that after hundreds of years of spherical trigonometry, an original insight would still be possible.

A short sequence suitable for a calculator is set out below and shows what the left/right decision affects. In the years since that first passage I have done quite a lot of mathematical massaging, and these formulae can serve to illustrate a few other "wrinkles." There is a select minority of people who have a taste for playing about with the trig and who might appreciate them.

**Advancing an altitude correction.** The advancing or retiring "running up" of a position line by making it an altitude correction calculated from ship's speed and course - as Mr. Dickerson does - is spot on. I have omitted this from the formulae below, but it's good to see it published for there has been much confusion. It is the proper way to do it for short time intervals and all the popular navigation computers have adopted it. Most of the computers automate this altitude correction by having the machine remember the time of first sight and then retiring subsequent altitudes back to it as each sight time is entered.

**Rules.** You don't need 'em. A rule is where you have "if...then..." e.g.: "if lat and dec have different names then add." Rules were needed with tables. If the physical reality provides a unique solution then the mathematics does too and requires no rules. Rules are made redundant by conventions so if you declare south latitudes and declinations to be negative, and designate azimuth and other angles in the corners of spherical triangles as going clockwise positive from some stipulated direction, then there is no mathematical ambiguity - and so no tests or rules. The standard PZX celestial triangle hangs off the



North Pole with sides that are always positive (90°-dec, 90°-lat, 90°-alt), the South Pole is redundant, Napier's rules are a historical curiosity, and messy concepts like "quadrant bearing," "azimuth angle" and "amplitude" are defunct.

**Avoid "if".** Obviating rules is a good thing for another reason: every time you program an "IF" test you introduce the possibility of overlooking some circumstance. Besides, using IFs is intellectually sloppy and such testing tends to consume a lot of computer space. Unambiguous mathematics can enhance the convenience of some low priced calculators which do not have an "if-jump" facility.

**Normalizing.** Don't "normalize" values other than a final result for human consumption. People who should know better do this. For example page 279 of the *Nautical Almanac* tells you to put LHA in the range 0°-360°. Why ever would you want to do such a thing? And when you do normalize a final value (longitude and SHA are the only things that occur to me) don't do what the Almanac says and add or subtract multiples of 360° till it is right. Instead subtract, just once, the correct multiple of 360°. This is given by 360xINT(N/360) where N is the value to be normalized and INT has the BASIC language meaning "the integer value less than." And just subtract it, don't test anything.

**Avoid dividing.** Generally speaking, if you are going to divide you have to make sure that the denominator is not zero or your computer will have convulsions. You can (a) use formulae where no dividing is needed (eg tan formulae as in equations 2 and 6 instead of cos forms), (b) do a cheap trick and add some tiny value to a denominator that might include a precise 0°, 90°, etc. (there are several cases where this can arise; an example is the approximate azimuth when identifying a star) so that it is enough off to avoid a program crash but not enough off to significantly affect the result, (c) as a last resort test for zero - or near zero - and go into an error routine. If you must divide you usually can do (b).

**Arctan.** Don't use the $\tan^{-1}$ key. Use rec→pol instead. In an early lesson on trigonometry we learn that trig functions are ratios — then it seems we forget it. Tangent is opposite over adjacent. In that form there are four possible sign configurations for the ratio numerator denominator corresponding to the four quadrants, viz: +:+, +:-, -:-, -:+. If you divide these ratios the quotient has only two forms, + or -, and the quadrant information is lost. Instead of dividing use both values with the two-function arctan (rec→pol or $r\emptyset$ or P or whatever it's called —it'll be there: (none of the calculator designers forgot their elementary trig) to compute the correct answer.

As a rule you should have the signs of the arctan numerator and denominator reversed which reverses the direction. Then after the arctan you add 180°. An idiosyncrasy of calculators is that they yield arctan between -180° and +180°, so solving for the reverse direction and adding 180° yields the result in the range 0 to 360° — as humans prefer it. No tests, no "normalizing." This reversing trick isn't limited to the tan foumulae— use it wherever trig expression is to yield an answer between 0 and 360°.

**Sexagesimal memories.** All values except azimuth should be in ° ′ (usually ° ′ ″ on calculators) and the navigator shouldn't have to be aware of a "decimal" form. Let the memories hold values in the sexagesimal form (this makes some Casios unsuitable) and if there is room allocate each value a memory. That way entries can be readily checked for correctness and re-used without re-entering. In routine celestial there are only two values to enter: time and altitude (altitude and azimuth in the case of identification). All those other numbers should still be in the calculator from the previous calculation.

**Two-body solution.** To find lat and long from altitudes to two bodies solve in sequence:

1. $-dG = GHA_1 - GHA_2$

2. $\tan(A_{12}-180) = \sin dG/(\cos dG \sin dec_1 - \tan dec_2 \cos dec_1)$

3. $\sin S' = \cos dec_1 \cos dec_2 \cos dG + \sin dec_1 \sin dec_2$

4. $\cos W = \sin alt_2/(\cos alt_1 \cos S') - \tan alt_1 \tan S'$

5. $A' = A_{12} \pm$ or +/- W   Subtract if $body_1$ was right hand

6. $\tan(LHA_1-180) = \sin(-A')/(\cos A' \sin dec_1 - \tan alt_1 \cos dec_1)$

7. $\sin lat = \cos dec_1 \cos alt_1 \cos A' + \sin dec_1 \sin alt_1$

8. $long = LHA_1 - GHA_1$

Where lat and dec are negative south and longitude is negative west, there are no trigonometrical ambiguities; the denominator in formula 4 can never be zero. Where (it isn't essential to know this): $A_{12}$ is the azimuth from $body_1$ to $body_2$, S′ is the complement of the interstellar distance; W is the clockwise angle at $body_1$ from $body_2$ to the observer; A′ is the azimuth to the observer from $body_1$.

Formulae 6 and 7 are the same as 2 and 3 except for the exchange of -A′ for dG and $alt_1$ for $dec_2$ which means that one routine will do both if it includes a couple of memory swaps. The arctangents of fomulae 2 and 6 must be solved rigorously — on a calculator do not execute the division. (On a computer lacking the two-function arctan you can achieve the same result by signing the arctan of the quotient the same as the numerator - ie by multiplying the angle ($A_{12}$-180°) by sign sin dG.)

If GHA Aries is programmed then when both bodies are stars for convenience modify 1 and 8 to:

1a. $-dG = SHA_1 - SHA_2 + 15.041(GMT_1 - GMT_2)$

8a. $long = LHA_1 - SHA_1 -$ GHA Aries at $GMT_1$

Solution by sine rule may be substituted for cosine formulae 3 and 7, viz:

3a. $\cos S' = \cos dec_2 \sin dG/\sin A_{12}$

7a. $\cos lat = alt_1 \sin(-A')/\sin LHA_1$

On a calculator these save space because the sin/sin part of the right hand side is a by-product (the "radius") of the →pol arctangent of formulae 2 or 6. It is getting a bit involved to show why — best just try it and convince yourself; if you figure out the reasons you can exploit the principle at other times. The disadvantage of this is that the sign of S′ (and of latitude through its sign doesn't matter) must be inserted manually. By doing this, I managed to fit the whole task, along with an Aries almanac, on the 128 step Sharp EL 512 calculator.

On Casio, Texas Instruments and Hewlett-Packards, the polar-to rectangular (→rec) function accepts a negative "radius" making possible a very brief program using the unambiguous cosine forms. This is for the fringe dwellers of the calculator twilight zone as it is fairly complicated to reason out.

The reversed tan values aren't actually necessary here since the answers to 2 and 6 are not for human consumption. But programming them this way costs nearly nothing and makes them general solutions, the point being that if the above formulae are programmed to take data from memories, then by storing other numbers in the memories these formulae will solve nearly every spherical problem, prediction, position line, long by chron, star identification and great circles.

I'll leave those as exercises for the reader.

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1. Bowditch, Nathaniel (1977). *American Practical Navigator (page 591).*

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3. Sadler, H. (1977). Comments on the geometry of two-body fixes. *Navigation*, **24**, 281.ION, Washington.

# HISTORY OF NAVIGATION

## Christopher Columbus: A Man of History

*By John M. Luykx*

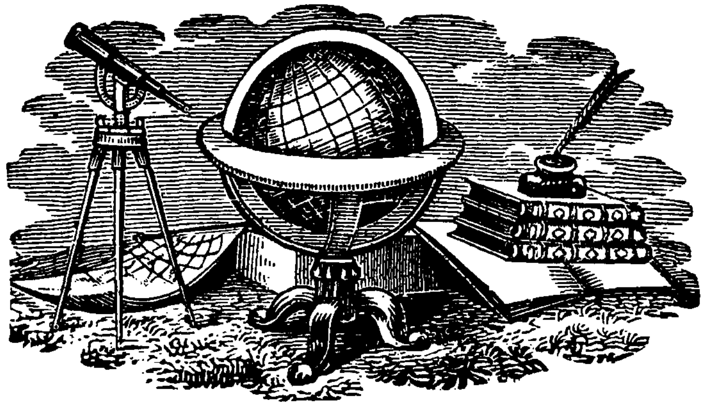
With the passing of the quincentennial anniversary year of Columbus' first voyage to the Western Hemisphere, it would be worthwhile to consider the accomplishments of Columbus, the mariner, as well as those of his principal contemporaries and to review the impact of their voyages on the history of exploration, especially during the early phases of the era of discovery and exploration.

It appears that Columbus first developed the idea of reaching Asia by sailing westward across the Atlantic from Europe after his return from a sea voyage to northern Europe in the mid 1470s. Subsequent correspondence and personal contact with well-known geographers and cosmographers reinforced his ideas for a westward voyage. In the course of his early sea experiences off both the African and West European Coasts, he also gained a knowledge of the prevailing winds; from the east in Latitude 25 north of the equator and from the west in Latitude 40 north of the equator; ideal for his return voyage home.

Extensive study of the history of east-west trade, i.e. trade between Europe (Northern Europe and Mediterranean countries) and the Far East (India, China and the Spice Islands) from Norman times up to the thirteenth and the fourteenth centuries, helped crystallize Columbus' intention to follow a new westward route to the Indies. Columbus knew of the riches of the Far East, for he had read Marco Polo. He also knew about the later break-up of the Mongol power in China, a few decades after Marco Polo's return to Italy. Columbus also understood the effects of both the rise of the Turks in central Asia during the thirteenth century and the failure of the crusades a century before in the Near East. All these events had by the year 1400 effectively brought east-west trade to a near stand-still; what little trade existed was now in the hands of Arab middlemen in Syria, Palestine, Arabia and Egypt, who now controlled the major overland and sea routes between Asia and Europe. The Arab "bottleneck" of Asia-Europe trade was soon to be broken, however, by the discovery of two alternate trade routes form Europe to the east; the one around the tip of Africa, thence to the Indian Ocean and the Far East and the other westward across the Atlantic. To overcome this "bottleneck," it was Portugal on the western edge of Europe with a coast line facing south and west which first initiated explorations toward the discovery of a new trade route to the Far East which would bypass the Arab stranglehold in Europe and the Near East. During the early fifteenth century a large number of intrepid Portuguese seamen under the direction of Prince Henry (The Navigator) and his successors successfully explored the West African coast searching for an eastward route to the Indies. Finally, in 1488, Bartholomew Dias rounded the southern tip of Africa, proving that a passage to the east was possible. It was left to Vasco da gama, one of the greatest of Portuguese navigators and explorers, to lay the foundation for Portugal's eastern empire. This he did during two voyages: the first, between 1497 and 1499; the second, from 1502-1503.

In the meantime, Columbus was to lay the groundwork for the Spanish empire to the west. Although he did not discover the westward route to the Indies (Magellan was to accomplish this three decades later) Columbus' bold adventures: four voyages, the first 1492-3, the second 1493-6, the third, 1498-1500 and the fourth 1502-4, initiated an extensive coordinated plan by Spain to explore and conquer the new continents and islands of the western hemisphere. Although Columbus did not know that they had discovered a new continent (Vespucci was the first to recognize this) his achievements were nonetheless remarkable. As a result, by the nineteenth century the Spanish colonial possessions in the Western Hemisphere encompassed all of Central and South America except Brazil and included many of the islands of the Caribbean; a truly vast and rich empire.

Amerigo Vespucci, during his voyages a decade later, was to establish that the land and islands Columbus had discovered, explored and described during his four voyages, were not the Indies but a new continent barring the way to the Far East. The continuing search for a trade route to the Far East required that the newly discovered continent "America" (named after Vespucci) be rounded either to the north or to the south. Magellan in 1520 successfully navigated around the southern tip of South America and continued on to the Philippines in 1520-21 while the English, Dutch and the French, in their northern voyages during the sixteenth and seventeenth centuries, continued the search for a northwest passage to Asia. The "Northwest Passage" was not finally discovered and traversed until 1941-1944 when the "St. Roch" successfully made the trip in both directions: Halifax to Vancouver.



During the great age of maritime discovery and exploration, which extended from the years 1450 to 1550, five names stand out as remarkable for the standard of their achievements at sea. Many scholars and historians consider Christopher Columbus as perhaps the greatest among them.

Bartholomew Dias, who first rounded the tip of Africa and indicated in 1488 the way to the Far East for Portugal.

Christopher Columbus, who in the service of Spain was the first in 1492 to head west across the Atlantic in order to establish a sea route to the Indies and the first to lay the groundwork for the vast Spanish Empire in the New World.

Vasco de Gama, who conquered the Indian Ocean for Portugal in 1498-1503 and established the foundation for the future Portuguese Empire in the Indian Ocean and the Far East.

Amerigo Vespucci, who in the service of both Portugal and Spain established in 1502 (while in the service of Portugal) that the continent and islands discovered and explored both by Columbus and himself were not the Indies but a new continent or "New World" and that the Far East and Spice Islands lay far beyond to the west.

Ferdinand Magellan, who was the first to plan a voyage around the southern tip of the "New World" to establish a western trade route to the Far East and the first circumnavigation of the earth. In 1521 he passed through the straits that bear his name (near the southern tip of South America) and in early March 1521 he reached the Philippine Islands. Although he died in the Philippines, one of his ships returned to Seville in late December 1521, having circumnavigated the earth for the first time. Magellan had achieved what Columbus had planned: a sea-link to the west between Europe and East Asia.

# NAVIGATION NOTES

## Problem No. 38, Answer

*By Roger H. Jones*

There was a typographical error in the problem as printed. It should have read: "How does one know whether to plot the LOP on the direction line, using the effect, closer to the GP than the assumed position or farther away from the GP than the assumed position?" The answer lies in the concept of the "circle of equal altitude."

Envision a tall flag pole with a long halyard hanging down from the top. If one were to stand ten feet from the base of the pole with the halyard held firmly, and if one were to walk around the pole, he would trace a circle with a radium of 10 feet. Everywhere on the circle, the angle formed by the halyard and the level ground would be the same. As one lengthened the distance from the base of the pole to, say, 40 feet, it would be possible to again trace a circle, but now the angle anywhere on the circle between the halyard and the ground would be less than the angle formed at the 10 foot radius. Conversely, the angle at a 5 foot radius would be greater, and at the base of the pole it would be 90°.

As one measures the angle between the straight-out horizon and the altitude of a celestial body, the same principle applies. The farther you are from the point on the surface of the Earth that is directly beneath the celestial body (the GP), the smaller is the angle. If the body were directly over your head in your zenith, the angle would be 90°. The angle lessens as you move away from the GP, but for any given distance away from the GP the angle is the same at all points on the circle governed by that distance as a radius.

The LOP is nothing more than a minute straight line portion of a circle of equal altitude. For plotting purposes, no attempt is made to draw the LOP with a curve, as the circle is so large that your own small portion of it is, effectively, a straight line. If the altitude as actually measured with the sextant is greater than the altitude that would hold true for the assumed position, then the intercept (altitude difference) would place the observer nearer to the GP than the assumed position. If the sextant altitude, as measured, is less than the computed altitude of the AP, then the actual position is farther away from the GP on the LOP than the assumed position. That insight, in a "nutshell," tells you how to plot the LOP. You are somewhere on that LOP—somewhere on a circle of equal altitude, and your actual circle is either closer to the GP than that of the assumed position, or farther away, depending on your actual distance from the GP. Your actual circle and that passing through the AP are concentric, and unless your sextant shot places you actually at the assumed position (highly unlikely), the two circles will have different radius lengths.

Problem No. 39

*By Roger H. Jones*

One final question seems to remain. Conceptually, why or how does a measurement of the altitude of a body above the visible sea horizon constitute the distance that the observer is from the GP of the celestial body? This will be answered in the next issue.

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# NAVIGATION PERSONALITIES

## Fridtjof Nansen

*By William O. Land*

As recently as only a century ago, oceanographers did not know for sure if there was an Arctic Continent or the exact shoreline of the Arctic Ocean. They knew nothing of the speed or the direction of the flow of the ice that covered the top of the world, or the depths of the sea beneath it. We owe much of our present knowledge of this region to the Norwegian explorer, scientist, diplomat and Nobel Prize winner, Fridtjog Nansen. Born in 1861 near Oslo, he was always drawn to the endless fields of ice and snow of the Arctic regions. At 21 he was a crew member of the sealer "Viking" on a voyage to the east coast of Greenland, and while there he collected a number of specimens of flora and fauna. He obtained his Doctorate at Christiana University, then taught there as Professor of Oceanography.

In 1888, he planned a trip across the Greenland glacier on skis, beginning at Cape Mosting on the east coast and ending 375 miles and 65 days later at Godthaab on the Davis Straight. He stayed a year at Godthaab studying the Eskimos and the wild life, later writing a book, "Eskimo Life" which today is still the best reference book on the subject of Eskimo life of that time. While there, he had a chance meeting with an Eskimo from Frederikshaab, a village a few miles south of Godthaab. The Eskimo had some artifacts that Nansen recognized as belonging to the ill-fated "Jeannette," the vessel of Commander George W. DeLong, which was crushed in the ice in 1881. Nansen wondered how these objects could be discovered on an ice floe in the Davis Strait, when the "Jeannette" sank off the coast of Siberia over 1,000 miles away. Could it be that there was an east to west (clockwise) rotation of the ice pack around the North Pole, and that the Arctic region was entirely ocean and no continent? Further research revealed that the expedition of Sir John Franklin in 1846-47 drifted many miles when their ships, the "Terror" and the "Erebus" were icebound and were eventually crushed and sunk.

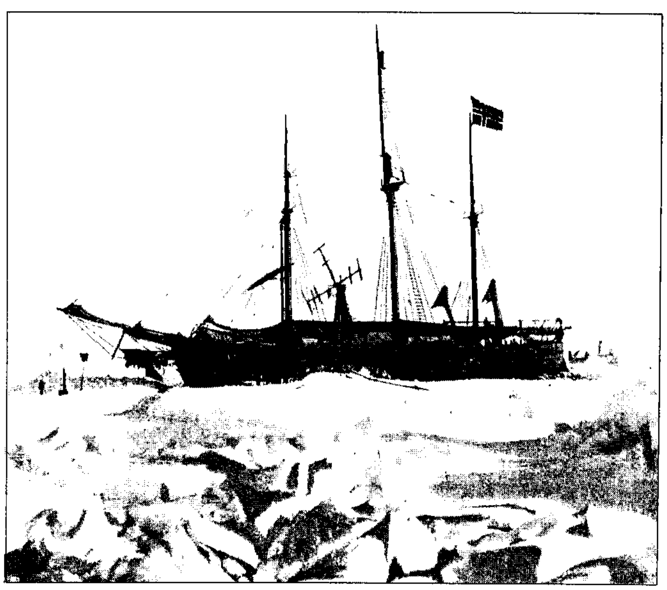
Thus Fridtjof Nansen, still in his twenties, planned an experiment for which he will always be remembered. He planned to build a ship that could not be crushed in the ice, then have it frozen into an ice floe with a crew living aboard. They would then take celestial navigation sights with their sextants every day, determine the position, and thus see whether she drifted with the ice, how fast, how far and in what direction.

He asked Colin Archer, a Norwegian shipbuilder, to build a ship of extremely thick planks, extra strong bracing, and a smooth hull that would not allow the ice any grip on it. The keel and ballast were to be internal. The hull was to be "V" shaped to lift up as the ice squeezed it, then remain upright until the ice melted and the ship was afloat again in the spring. The ship was named "Fram" which translated into English means "Forward". "Fram" was a 3-mast, fore and aft double-end schooner 130 feet long, 30 feet beam with 16 foot draft. Her hull was three feet thick oak. For auxiliary power she had a three cylinder triple-expansion steam engine with a coal-fired boiler. Rated at 220 horse-power, it would drive the "Fram" at six knots with a two-blade cast iron propeller 66 inches in diameter. She had a steam-operated winch on deck to aid in hoisting the sails and the anchor.

The bow was angled to let the ice slip under it, and the deck had a well in the stern which gave access to the rudder and the propeller so they could be easily removed and hoisted to the deck before the pack ice closed in on the hull. Nansen had a crew of only 13 mean, headed by Captain Otto Sverdrup, the man who accompanied him on the 375 mile ski trek across the Greenland glacier a few years earlier. There was a Medical Doctor aboard who was also the expedition biologist. In the crew were a cook, electrician, engineer, meteorologist and sledge dog driver. The remainder of the crew were experienced enough to sail the ship and give assistance to the specialists.

They sailed in 1893 from Norway to a position 78°19'N, 133°19'E, not far from where the"Jeannette" was lost, and waited for the "Fram" to freeze in. As planned, "Fram" lifted out of the ice and remained upright. She bore the pressure of the ice perfectly. In this position she drifted with the ice pack for 36 months. When the ice finally melted, she sailed back to Norway.

It is interesting to note that the "Fram" was so well designed and built that it was used 15 years later by another great Norwegian explorer, Roald Amundsen, to



The *Fram* in the ice, 1895.

take his expedition to Antarctica for the discovery of the South Pole. For the Antarctic expedition the 220 horsepower steam engine was replaced with a 360 horsepower Diesel. The "Fram" has been preserved and at present holds a place of honor in a museum near Oslo.

Once she was fast in the ice, a cloth-covered 4-blade windmill was erected on deck connected to a generator to supply electricity to light the cabins during the long dark winters. "Fram" had two 29-foot life boats aboard with 9-foot beams to be used in case of an unexpected emergency. She also had a launch with a petroleum engine which never worked very well and several times caught fire. The launch was finally dismantled and the wood used to make extra pairs of skis for the 13 crew members.

The instruments aboard for scientific observations were barographs, thermographs, psychrometers, anemometers, sextants, theodolites, chronometers, magnetic inclinometers, spectographs, cameras, and a photographometer for making charts.

During the months adrift, Nansen not only established the fact of the circumpolar drift but also established much scientific data about the Arctic Ocean. He invented the famous "Nansen Bottle" still used today by oceanographers. A series of empty bottles were attached to a long wire at recorded intervals and lowered into the sea. Then a ring called a "messenger" was dropped down the wire.

As it arrived at the first bottle it caused the bottle to close, trapping the sea water sample at that depth, then released another ring that fell to the next lower bottle, and the process was repeated to the end of the wire and the lowest bottle. When the wire was hauled up, the samples of sea water at various depths were available for analysis. There were also thermometers attached to the bottles to record the temperatures at the various depths.

On March 14th, 1895, when "Fram" had drifted to 84°04'N, 102°E, Nansen and one crew member, Commander Hjalmer Johansen, left the ship in an attempt to ski to the North Pole with the aid of dogs and a sledge. They reached 86°14'N on April 8th, about 226 nautical miles from the Pole and then turned back because the ice was too rough to proceed with ski and sledge. This was the closest man had yet come to the Pole. They planned to head back via Franz Joseph Land rather than try to return to the ship, since there was no way to know where she had drifted in the interval. Because of the advanced

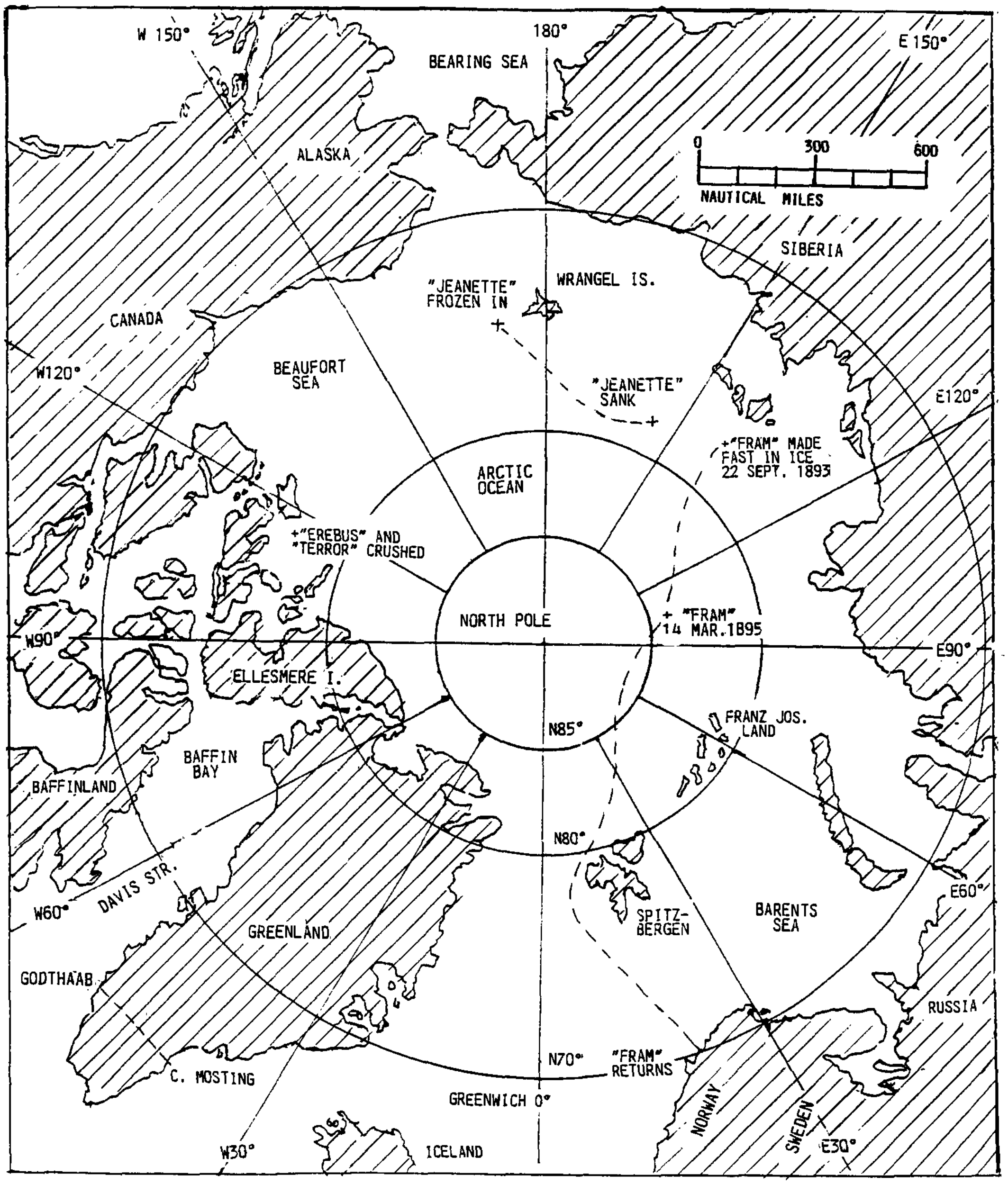


*CHART OF THE NORTH POLAR REGIONS showing the position of the* Jeanette *when she was crushed in the ice, the path of the* Fram *drifting with the ice, and the probable position of the* Erebus *and* Terror *when they were crushed in the ice.*

season they had to winter on a rocky island. They built a hut of stones covered with walrus hides and survived on walrus and polar bear meat, using blubber for fuel. In 15 months they made it to Spitzbergen, where by luck they happened to find the Jackson-Harmsworth expedition from England exploring Capt. Flora Island.

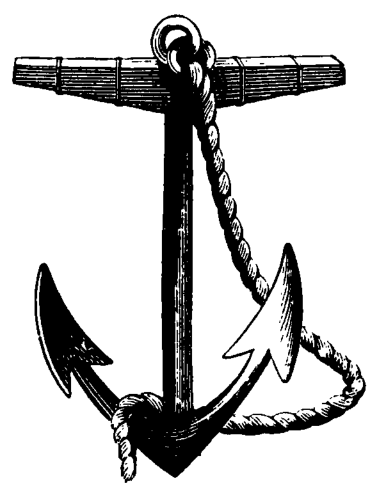
Frederick George Jackson, the leader, offered to drop them off at Norway on the return to England in his ship, the "Winward." By a twist of fate, the "Winward" landed Nansen in Norway within a week of the arrival of the "Fram" after 36 months in the ice pack. During this time not a single life was lost, all hands returning in excellent health, and there were no serious accidents aboard "Fram."

Nansen published a 2 volume book entitled *Fatherest North,* the story of the expedition and the ski trip home. In Oceanography he established the "International Commission for Systematic Study of the Oceans." He taught Oceanography at Christiana University and was awarded a Ph.D. In 1911 he published "In Northern Mists" (2 vol.) and made several scientific expeditions to the northeastern Atlantic Ocean, Barents Sea. Kara Sea and Siberian waters. He also made one scientific trip to the Azores.

He was active in the negotiations obtaining Norway's freedom from Sweden in 1905, and from 1906 to 1908 was Norway's first minister in London. In 1917 he headed a commission to the United States regarding trade imports, and in 1920 headed Norway's delegation to the League of Nations, a position he held the rest of his life. He was described thus: "With his tall and bony frame, his snow-white hair, his flowing mustache, and his broad-brimmed hat at a rakish angle, he made a striking figure at Geneva." He served as head of several commissions for the International Red Cross, one of which repatriated over 400,000 persons from 26 countries after World War I, and another for relief of famine-stricken Russia. In 1922 he was awarded the Nobel Peace Prize. He died at his home in Oslo in 1930 at the age of 69.

# MARINE INFORMATION NOTES

*By Ernest Brown*



## Navigation Information Network Telephone Number Consolidation

Effective 15 November 1992, the telephone numbers to access the Navigation Information Network (NAVINFONET) were consolidated.

NOTE: All 9600 baud modems will automatically match slower baud rates if the slower modems have the proper modulation standard.

All previous telephone numbers not mentioned below were discontinued on 25 November 1992.

TELECOMMUNICATION ACCESS NUMBERS

| MAXIMUM MODEM SPEED | TELEPHONE NUMBER | MODULATION STANDARD(S) |
|---|---|---|
| 1200 BAUD | 301-227-5295 | VADIC 3400,BELL 212A, BELL 103/113 |
| 2400 BAUD | 301-227-4360 | CCITT V.32,22BIS, BELL 212a, BELL 103 |
| 9600 BAUD | 301-227-4424 | CCITT V.32, V.22BIS, BELL 212A, BELL 103 |

## User Outage Reports of Differential Global Positioning System (DGPS) Radiobeacon Prototypes

The U.S. Coast Guard is developing a DGPS service for the harbor and harbor approach phases of maritime navigation. Maritime DGPS will use fixed GPS reference stations which will broadcast satellite pseudo-range corrections using maritime beacons.

The USCG DGPS service goal is to provide radionavigation accuracy better than 10 meters, 2 DRMS, by 1996. In support of this development, the U.S. Coast Guard is operating a DGPS prototype service from select radiobeacon sites. Users may experience service interruptions without advance notice. Coast Guard DGPS broadcasts should not be used under any circumstances where a sudden system failure or inaccuracy could constitute a safety hazard.

To facilitate the evaluation and development of the final DGPS service, reports of prototype system outages are highly beneficial. To ensure timely and complete information, user outage reports are required in the following format:

A. Site (Beacon) Using: ______________________
B. Outage Date: ______________________
Outage Time: ______________________
Outage Duration: ______________________
C. Vessel Position: Lat. ________ Long. ____________
D. WX Conditions:
Wind _________ Sea State ______________
Temp. ________C Vis. ______________
Bearing and Range to Electrical Storm
If Applicable ______________________
E. Number of Satellites tracked on GPS Receiver: ____
F. DGPS Beacon Receiver Signal Strength
(SS) Reading: ______________________
G. DGPS Beacon Receiver Signal to Noise
(SNR) Reading: ______________________
H. Point of Contact:
Name ______________________
Phone No. ______________________
I. Comments: ______________________

This information can be sent the following ways: (1) via mail to Commanding Officer/DGPS, OMEGA NAVSYSCEN, 7323 Telegraph Road, Alexandria, VA 22310-3998; (2) via message to COGARD OMEGA NAV SYSCEN ALEXANDRIA VA//DGPS//; (3) via fax to (703)866-3825; (4) or by calling the GPSIC watchstander at (703)866-3806.

For the current status of prototype DGPS broadcast sites or additional information, contact the GPSIC watchstander at (703)866-3806. The GPSIC computer bulletin board may be accessed at (703)866-3890(300-14400 bps); communication parameters are 8 data bits, 1 stop bit and no parity.

# BOOK REVIEW

*By Roger H. Jones*

*Ed. Note: In this issue we are including three reviews, each of which is somewhat briefer than the normal length in past issues. This is due both to the nature of the books and our desire not to further delay inclusion of reviews on books that have been in our hands for a number of months.*

## Celestial Navigation With the S Table

Complete Sight Reduction Method for All Bodies In Nine Pages, by Mike Pepperday
Paradise Cay Publications, P.O. Box 1351, Middleton, CA 95461 (1992) 22 pages; $7.95

Many readers familiar with *The Almanac* published by Paradise Cay are aware that the so-called S Table was, in 1991 and 1992, included at the back of that Almanac. This is no longer the case, and the S Table is now found in this separate booklet. In his introduction, the author notes that Ageton's H.O. 211 was published in 1931 by the Hydrographic Office in a 36-page format, and that in 1944 this was followed by a version reduced to four pages (by doubling up the headings) published by Hickerson.

Then in 1980 a nine-page version was prepared by Allan Bayless (a director of the Foundation) and was published by Cornell Maritime Press. The S Table is also nine pages, with tabulation to one minute of arc. Ordinary LHA has replaced "meridian angle," and this did away with the lengthy rules for meridian angle, rendered coverage of the full 360 degrees, allowed the "A" and "B" headings to be discarded, and reduced the column headings by one third. A decimal point has been introduced into the numbers in order to enhance readability. The pattern followed in the workform is that used by Ageton in the 211 Tables.

Perhaps the most important feature of the S Table is that it uses the DR position, rather than an assumed position, and thus the intercepts are short, often needing little or no plotting. The table works for all altitudes, and included is a special abridged version and a workform that permits relatively easy star identification. Finally, one of the really intriguing aspects of this little publication is that the author has consciously provided a natural bridge between manual, workform procedures and the procedures utilized by those who have learned to rely on the electronic calculator.

Thus it is that the S Table provides not a list of all possible answers to all possible assumed situations, but a fundamental solution to the observer's particular astronomical triangle. The author helps to provide insight into the underlying mathematics, and provides a natural transition to the substitution of a calculator because the same rules and worksheets apply in calculator use. The S Table gives precisely the same answers as those from a navigation calculator.

Apart from the special star identification instructions, there are nine pages of well written instructions with step-by-step procedures. There is no assumption that the user is already familiar with abbreviations, hour angles, altitude corrections, etc. The prerequisite is simply the ability to read and to add and subtract degrees and minutes of arc. A special section of the instructions deals with using a calculator instead of the S Table.

Pepperday has done an admirable job in furnishing instructions that are not as daunting as those for the Concise Tables at the back of the *Nautical Almanac*. This little book is well worth the price. It's only an eighth of an inch thick. Get it and make your own comparisons. You'll be pleasantly surprised.

## 100 Problems in Celestial Navigation

By Leonard Gray
Paradise Cay Publications (1992)
(See address on page 14) 160 pages; $14.95

One of the unusual features of this new book of practical problems is that the author treats his readers to the full range of celestial navigation problems in a series of 19 voyages. Thus there are sailings from New York to Lisbon, Wellington to Valparaiso, Capetown to Gough Island, and many others that cover virtually all the great expanses of ocean and sea that blanket the Earth.

These nineteen voyages comprise the first 94 pages of this attractive booklet, and then there are six appendices which present: (1) answers to the problems; (2) procedures; (3) *Nautical Almanac* excerpts; (4) H.O. 249 Vol. 1 excerpts; (5) H.O. 249 Vol. 2 excerpts; and (6) a sight reduction form. The problems can be worked either with the Nautical Almanac (or the Yachting equivalent available from Paradise Cay) or the Air Almanac. The problems can be done in any order, but the first one, which deals with planning a round of twilight shots, has a few hints that are not repeated in the others. The problems have been validated with computer programs that are specifically identified at the end of the introduction, and the sight reduction form in Appendix F may be copied for non-commercial use.

Typically, each problem appears, together with all relevant data, on a single page or less. In some cases the problem may overlap onto a second page. The problems are well stated and conceived. The relevant data pertaining to position (DR or last fix, etc.) height of eye, course, speed, index correction, time, and Hs, etc. are presented in bold, easy to read print. There are no long paragraphs of text that are confusing by virtue of their length or inclusion of too many numbers. The text is presented in a manner that reveals that the author has spent considerable time in thinking about logical sequences of events that would befall the navigator at sea.

All of the exercises are quite realistic from the standpoint of navigation, but any political reasons for avoiding certain destinations are ignored. A nice touch is that interspersed throughout the problems are a number of salty sketches of 19th Century mariners and vessels. These catch the eye and tend to relieve the routine of one problem after another.

The answers are succinct—typically stated in a sentence or two. However, the procedures, described in Appendix B, are quite complete and are stated in easy layman terms. It is in the latter section that many valuable insights are revealed in terms of the considerations that the real world navigator must take into account.

This book will be especially helpful to those who are learning celestial navigation, and those who want to delve into the full range of problems. It is an admirable effort at producing a booklet of problems that is not dry and tedious. This reviewer (who has written the problems appearing in the Newsletter) had real fun with it.

## Small Craft Celestial Navigation

By A. E. Saunders
Alzarc Enterprises, Vineland, Ontario, Canada LOR2C0
(1991) 295 pages; price (unstated)

A. E. Saunders began his nautical career in canoes and rowboats on the Detroit River. Subsequently he gained extensive experience in both power and sailing craft, including off-shore passage in the Atlantic and cruising in the Caribbean and the Greek Islands. The examples included in the book are updated and are taken from an actual cruise from Wilmington, North Carolina, to the British Virgin Islands.

Saunders is also the author of *Small Craft Piloting and Coastal Navigation* (now in its third printing), and he has taught coastal and celestial navigation over more than twenty years. He is a past Rear Commodore of the Canadian Power and Sail Squadron and is a retired Captain of the Navigator's Club in Toronto. He is also a member of the Royal Institute of Navigation in London.

This new book is specifically addressed to the recreational boater who would like to venture off-shore. It assumes some experience with coastal piloting, including running fixes and the advancing of lines of position. The primary method of sight reduction used in the book is precomputed tables, in particular the Davies NAO Tables (Concise Tables) that now appear at the back of the *Nautical Almanac*. This is one specific answer to the criticism of the Davies tables that is noted in the Readers Forum portion of this Issue. Saunders addresses the need for teaching of the Davies tables in a logical and coherent manner. In addition, sight reduction by H.O. 249 is also included in *Small Craft Celestial Navigation*.

Saunders starts off with the basic concept of celestial navigation. He loads his pages of clear text with unusually good illustrations and diagrams. His ability to present in picture form what he is also stating in words is excellent, and it is addressed to the layman, not the nautical astronomer. For those who are grappling with the circle of equal altitude and the altitude intercept, these drawings are particularly useful.

Saunders is, if anything, logical. He next deals with the sextant and with time, time diagrams, and time conversions. Again, the drawings are outstanding. This is followed by equally well presented chapters on hour angles, declination, the Almanac, and assumed positions and intercepts. Then, the author launches into a specific treatment of sight reduction by the Davies NAO tables. The latter chapter of eleven pages goes a long way to address the problem of the complex instructions for the NAO Tables that accompany them in the *Almanac*. Again, the illustrations and excerpts from the tables and the workforms are clear and very helpful. An appendix contains the entire NAO Tables.

Saunders is equally committed to clarity in his presentation of sight reduction by H.O. 249. In addition, he deals with the universal plotting sheet, star identification, sextant selection and adjustment, sight reduction by calculator, and many other topics. This is a truly up-to-date book that covers the modern as well as the more traditional approaches to celestial navigation. It is the offering of an experienced teacher and practitioner, and most important — an effective communicator.

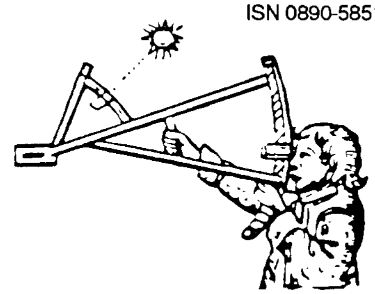
The book comes in a spiral-bound format, and is about three-quarters of an inch thick. It is not bulky, but packed in its pages is a wealth of text, pictures and sound teaching method. Well done, Captain Saunders.

DO YOU KNOW . . .?

In determining latitude by meridian altitude of the Sun, the navigator who uses the "Noon Constant" works much of the problem in reverse. The Noon Constant is a precomputed value based on anticipated declination and altitude corrections, and on the DR latitude. At the end of the procedure, observed Hs and the Noon Constant (computed Hs) are compared. The difference is the difference in latitude between the DR and actual. If the Noon Constant is greater, the difference is applied away from the Sun's bearing, and if lesser, the difference is applied towards the Sun's bearing. The steps are simple:

1. Using the DR and the Almanac, find GMT of meridian passage.
2. From the Almanac find declination of the Sun at that GMT.
3. Combine declination with DR latitude to find computed ZD at LAN. Add together if they are of opposite name; subtract the smaller from the greater if they are of the same name.
4. Subtract computed ZD from 90° to gain computed Ho for the DR latitude.
5. Uncorrect the computed Ho by applying the altitude corrections with signs reversed. The result is computed Hs, or the Noon Constant.
6. Measure the actual Hs at meridian passage, and compare it with the computed Hs. Apply the difference as noted above.

ISN 0890-5851



# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY, SUMMER 1993

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Longitude Symposium

A major international event for those interested in scientific instruments, clockmaking, maritime history, geography, map making and the history of technology will take place at Harvard University from Thursday, November 4th through Saturday, November 6th, 1993. The Longitude Symposium, organized by Harvard's Collection of Historical Scientific Instruments in conjunction with the National Association of Watch and Clock Collectors, will commemorate the 300th anniversary of the birth of John Harrison, inventor of the marine chronometer.

Harrison's timekeepers, for which he eventually won a £20,OOO prize offered by Britain's Parliament in 1713, made possible the first absolute determination of longitude at sea. Thirteen noted authorities from five countries will lecture on the context, history and impact of Harrison's invention, its predecessor methodologies and its successor instruments. Associated events include an exhibition of clocks, watches and other instruments, a reception at Harvard's Fogg Art Museum, and a banquet with guest speaker Alistair Cooke. Information about registration, special airfares and lodging can be obtained from: The Longitude Symposium, Harvard University, Science Center B6, Cambridge, MA 02138, U.S.A., telephone: (617) 495-2779, FAX: (617) 495-3344.

Director John Luykx and Director/Editor Roger Jones are attending the Symposium and will represent the Navigation Foundation. If any members are attending, look for them both and introduce yourself. They will be delighted to meet any and all members, face to face (see page 7 for more details).

### Pilot Charts

Save any old Pilot Charts that you may have in the chart locker. NOS has ceased publishing Pilot Charts and there are no back issues available. Because the data in the Pilot Chart is an average of data collected over the last century, data in the old charts are still useful. I have been unable to locate anyone at NOAA who has any knowledge about the future of Pilot Charts. Any new information will be conveyed by the Newsletter.

### Youth Program

The summer youth program is continuing. The young people are all energetic, eager to learn and interested. The program started with two, two-hour classroom sessions and a one-day, on-board-the-boat learning session. The subject of lines, how to deploy fenders, docking and securing Tandemeer after docking was the thrust of the on-board session.

We have had two day sails with good winds. The youngsters were delighted when beating into the wind, Tandemeer registered 30° heel and the full hull speed of 9.2 knots. On a small sail boat 30° would be hardly noticeable, but with a 17 foot beam and 65 feet of mast, 30° on Tandemeer is impressive.

DO YOU KNOW . . . ?

*By Roger Jones*

A number of well known voyagers and navigators have commented in various published articles and reports that in comparing celestial fixes with GPS fixes and GPS fixes with known locations, all as depicted on a chart, significant discrepancies have been noted. Discounting possible celestial observer error and GPS signal data that may be temporarily unreliable, do you know what a map datum is and the magnitude of positioning errors that may occur if a chart is used that is not based upon the mathematical model of the WGS84 horizontal datum? (The answer appears at the back of this issue.)

Two more day sails are scheduled for this summer and these will conclude the summer youth program until next year.

### Dutton Award

Foundation President Douglas R. Davies presented this year's Dutton Award to Midshipman Brian M. Peterson. The Dutton Award is presented "for excellence in navigation." The ceremony was held at the U.S. Naval Academy in Annapolis, Maryland.

### New Book

Subsequent to the mailing of the latest list of books, publications and charts, a new book is in print and available from the Navigation Foundation.

*Oceanography and Seamanship*, 2nd ed. by William G. Van Dorn is a 456 page hardcover edition which has updated the material in the 1st edition by many new topics. Some of the new topics are: cold water survival techniques; new search and rescue procedures; ship routing for storm avoidance; a reconstruction of the 1979 Fastnet racing disaster; the influence of rating rules upon yacht design, construction, and performance and planing powerboats and open-ocean racing. List price is $44.95.

*My apologies to member C. Huguenin for the massacre of his name in Newsletter #38. An abbreviated version of his letter to the Foundation can be found in the READERS FORUM in this issue.*

# READERS FORUM

*Edited by Roger Jones*

Hon. C. Huguenin, the Swiss Ambassador in Dar es Salaam, has written to us frequently from his various diplomatic postings where he has carried on experimentation in various methods of land navigation. He reports that land navigation by celestial methods remains closest to his heart, but that "there is still hope for the inveterate landlubber, as I have just bought a second hand and modest 85 hp motorboat." He also reports an exhilarating sight of a vertical Southern Cross over the rickety roof shambles of Zanzibar's old stone town, thanks to a total power cut on the island on a particular night.

Dr. J. P. Mudd, Jr., of 222 W. Church St., Jackson, Alabama 36545, has written describing a recent voyage from Mobile, Alabama to the Isla Mujeres, which is just north of Cozumel and immediately south of Isla Contoy. He reports that he and a retired merchant marine captain with many years of seagoing experience struck a reef near the south end of Contoy Island, and that he has been unable to find any large scale chart of this area and is most interested in knowing of any such chart. He also reports that successful repairs were made, enabling a return to Mobile. (Editor's Note: An examination of the DMA Chart Catalog for Region 2 lists Chart No. 28202 as covering Isla Mujeres - Cancun and approaches at a scale of 1 to 30,000. We have not examined that chart, but it may be the only one available from official U.S. sources. If any reader knows of a published cruising guide with a useful chart of the area, please write to Dr. Mudd. — R. H. Jones).

We have had similar letters from David Bishop and Michael Bell regarding the continuing diatribe from Dennis Rawlins directed at Robert Peary and now also at the Foundation officers involved in the Peary Project. They lament the fact that libraries seem to have copies of Rawlins' book, but they do not have the more recent publication of the Foundation, which proves to the satisfaction of credible scientists, historians and navigators in many countries that Peary did indeed reach the North Pole in 1909. They note that the slanders of Rawlins and his colleagues are very hard to dispel, and that it is an unfortunate fact of human nature that when someone is as convinced as Rawlins is and yet is unable to prove his own position with credible evidence, he often resorts to the tactic of calling others liars. Amen! The apparent desperation of Rawlins, if nothing else, may more and more become his own indictment. It fairly shouts to any informed and objective listener that Rawlins is either unwilling or incapable of assessing the significance of cumulative and compelling scientific data.

Paul Dedieu of Haywood, MB, Canada, ROG OWO, has written to ask for help in clarifying instructions and an example in the *Almanac* on page 280. The formula for determining refraction is given, and in the illustrative example for Polaris on page 281 the Ro value of 0.0142 is given. At least one of the mathematically and technically versed members of the Foundation's Board has tried the computation, and cannot come up with the correct answer as given in the *Almanac*. This may well be one case in which an unusually sharp-eyed reader has found an error in the *Almanac*. Other interested readers may wish to follow the lead of Dedieu. Please let us know your results.

Edward Popko of 28 Maverick Road, Woodstock, NY 12498, has written to ask for assistance in locating a copy of "Navigation at Sea Using the HP-41CX Calculator." This manual, when available, was published by Justin Gray, NAS Publications, 33622 B Dana Vista Drive, Dana Point, CA 92629. Any reader who can help Mr. Popko is urged to write to him. *(Editor's note: Being located in Marina Del Rey, CA., I called the information operator for any listing of Justin Gray or NAS Publications in Dana Point and was informed that there is no current listing. — R. H. Jones).*

Bob Chadwick of Beech Hill, 11210 Greensburg Road, Sulphur Well, Kentucky, 42129, has inquired about any "slide rule collector" who might know where one could obtain a 20" slide rule of the accuracy used by the late

Henry Shufeldt in doing the problems presented in his little book, *Slide Rule for the Mariner*. Please write to Mr. Chadwick if you can assist him in his search.

Robert E. Edgar of Box 99411, Louisville, KY 40269, is looking for any book of instructions for the maneuvering board. He notes that the subject is covered in *Dutton*, but that he does not want to add another large volume to his library. (Editor's Note: The principles of vectors and relative motion, whether they be applied to marine or air navigation, are virtually the same. Publication No. 217, "Maneuvering Board Manual," is available from the Defense Mapping Agency Hydrographic/Topographic Center through the NOAA Distribution Branch, N/OG33, National Ocean Service, Riverdale, Maryland 20737-1199. This is specifically addressed to the marine version of the maneuvering board.

There is another possible resource which may not be known to most mariners. Any aviation supply outlet normally has for sale the so-called flight computer, one side of which is a circular slide rule for solving all sorts of time, speed and distance problems and for converting nautical to statute and centigrade to Fahrenheit values. The other side is a maneuvering board for solving relative motion problems, and the "computer" is accompanied by an instruction manual. This manual will cover all the various problems, which are the same in principle in both the marine and the aviation navigation practice. I carry my old flight computer aboard my vessel because of its compact size, and because it is somewhat more versatile than some marine versions that I have seen—R.H. Jones.

Dicky Derickson is aboard the sailing vessel Waimes, and in April of this year wrote to us with a return address of General Delivery, Koror, Republic of Palau, 96940. He and his crew had recently arrived from the Philippines. He notes that on this leg of his voyage he used his calculator to perform a practical planning exercise. In planning a West Channel entrance to Palau, the window of arrival time was 0545 to 1800. At 0000, the GPS indicated that the West entrance was bearing 080 at a distance of 65 NM. The wind direction was 060, and the prevailing conditions allowed the vessel to make good a course of 50 degrees off the true wind at a boat speed of 5 kts. He asked himself, with constant conditions, what was the ETA of the West Channel entrance. He used the formula: Time to Go = Range x COS (Bearing - Wind Direction) / COS Tack Angle / SOG = 19 hours. This is an interesting application of the calculator inasmuch as the GPS would (depending on the model) also give him a quick "Time to Go" calculation based on the 0000 position, the West entrance waypoint, and the 0000 vessel speed. As a prudent skipper, Derickson does not rely entirely on a GPS and external satellites. His calculator and knowledge of formulae were, obviously, a supplement to the GPS, and his sextant was, no doubt, readily at hand also. Finally, in the correction furnished by Derickson for Issue 38, it seems that somehow a parenthesis was omitted from the equation. Any reader who was misled and who would like further clarification is requested to write to the Foundation.

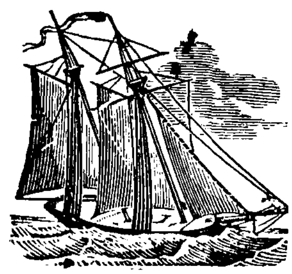
### Correction

Dicky Derickson, author of A DR Independent Two Celestial Body Solution, in Issue Thirty-Seven, wrote to correct an error in the addendum to that article which ran in Issue Thirty-Eight.

Change:
A=COS-1 ((COSa -COSb x COSc) / SINb x SINc))

To:
A=COS-1 ((COSa -COSb x COSc) / (SINb x SINc))

He also adds:
"I would like to acknowledge Rick Berg, Jill Neidrauer and George Smith, who were sources of encouragement and insight for my version of a DR independent two celestial body solution."



# NAVIGATION BASICS REVIEW

## The Use of the American Railroad Watch as a Back-up Time Reference at Sea

*By John M. Luykx*

A number of yachtsmen have asked in recent years whether it would be advisable to carry a spring wound mechanical watch on board as a back-up time reference in the event that the quartz navigation watches, normally carried, should fail or that replacement batteries should become unavailable when these watches run down at sea.

Although full size mechanical 2-day chronometers such as the Hamilton Model 21, the Mercer, the Wempe and the new Russian models (which have recently entered the U.S. market) are available for this purpose, they are a costly item and are expensive to maintain. Most are now considered collectors items. Prices for full size chronometers range from $1500 to $3000 or more.

Gimballed and ungimballed large size (35 to 37 size) deck watches (or chronometer watches) are also available, however, at a lower price. Some fine examples of this type of marine timepiece are the well-known gimballed and ungimballed watches by Hamilton (Mod. 22) Waltham (37 size), Zenith and Longines, all of which regretfully are no longer manufactured. They may, however, be obtained generally without too much difficulty from watch collectors and dealers although they also are costly and becoming collectible. These watches, like full size chronometers, are expensive to obtain and maintain. Purchase prices vary from $800 to $1200 each with outside carrying case.

The least expensive mechanical spring wound watch which may be considered for navigational use as a time reference is the railroad watch, many of which were manufactured in the U.S. between 1890 and 1960 by the well-known watch companies such as Hamilton, Elgin, Waltham, Illinois, and Howard.

The most modern and accurate railroad watches were those manufactured by the Hamilton and Illinois watch companies. In order to reduce the effect of temperature change, the later model RR watches manufactured by these companies incorporated an Elinvar hair spring with an Invar balance wheel. Railroad watches incorporating these two advantageous features are highly desirable and are listed below. They are readily obtainable from watch dealers and collectors at prices ranging from $150 to $400.

Hamilton Model 2974B, size 16, 17 jewels,
50 hour mainspring
Hamilton Model 992B, Size 16, 21 jewels,
56 hour mainspring
Illinois Model 161-161A, Size 16, 21 jewels,
60 hour mainspring

In order to determine the suitability of these watches for navigation the author conducted a test of five such watches taken from his collection. The test was conducted from 1 through 31 May and consisted of the following procedures:

1. During the period 1 May to 9 May each watch was rated to less than two seconds per day.

2. During the period 10 to 17 May the daily and weekly rate of each watch was computed.

3. During the period 17 May to 31 May the daily and weekly rate of the watch was computed. On Monday morning 24 May and 31 May the actual error of each watch was compared with the predicted error of each watch based on the weekly rate computed during the period 10-17 May.

4. During the test all timepieces were located in a room where the ambient temperature was maintained at between 73° and 75° F.

5. All watches were cleaned and oiled within the last 24 months.

6. The Hamilton Model 992 watch, included in the test, is fitted with a bi-metallic balance wheel and a steel hairspring. The four remaining watches are fitted with Invar/Elinvar balance wheel and hairsprings. The results of the test are contained in Tables 1, 2 and 3.

Table 1 shows how the error of prediction for each watch was computed. Table 2 tabulates the mean error of prediction for all 5 watches at the end of the first and second weeks of the test period. Table 3 tabulates the mean daily rate, the mean variation of the daily rate, the maximum variation of the daily rate from the mean as well as the error of prediction of each watch accumulated during the two week period 17 through 31 May.

TABLE 1
Computing the Prediction Error for Each Individual Watch (Seconds)

A. TIMEPIECE: Hamilton Mod. 992

1. Weekly Rate
Error 10 May: +34.0
Error 17 May: +36.7
Weekly Rate: + 2.7

2. Error of Prediction

| Date | Actual Error | Predicted Error | Diff. | Var. |
|---|---|---|---|---|
| 24 May: | +40.8 | +39.4 | -1.4 | |
| 31 May: | +43.0 | +42.1 | -0.9 | +0.5 |

3. Mean Daily Rate
Error 10 May: +34.0
Error 31 May: +43.0
21/ 9.0
MDR: + 0.4

B. TIMEPIECE: Hamilton Mod. 992B

1. Weekly Rate
Error 10 May: +42.7
Error 17 May: +43.0
Weekly Rate: + 0.8

2. Error of Prediction

| Date | Actual Error | Predicted Error | Diff. | Var. |
|---|---|---|---|---|
| 24 May: | +42.2 | +44.3 | +2.1 | |
| 31 May: | +42.0 | +45.1 | +3.1 | +1.0 |

3. Mean Daily Rate
Error 10 May: +42.7
Error 31 May: +42.0
21/- 0.7
MDR: - 0.03

C. TIMEPIECE: Illinois Mod. 161

1. Weekly Rate

| | |
|---|---|
| Error 10 May: | -1.7 |
| Error 17 May: | +1.2 |
| Weekly Rate: | 2.9 |

2. Error of Prediction

| Date | Actual Error | Predicted Error | Diff. | Var. |
|---|---|---|---|---|
| 24 May: | +0.2 | +4.1 | +3.9 | |
| 31 May: | -0.5 | +7.0 | +7.5 | +2.6 |

3. Mean Daily Rate

| | |
|---|---|
| Error 10 May: | -1.7 |
| Error 31 May: | -0.5 |
| | 21/+1.2 |
| MDR: | +0.06 |

D. TIMEPIECE: Hamilton Mod. 2974B (c)

1. Weekly Rate

| | |
|---|---|
| Error 10 May: | +4.5 |
| Error 17 May: | +8.2 |
| Weekly Rate: | +3.7 |

2. Error of Prediction

| Date | Actual Error | Predicted Error | Diff. | Var. |
|---|---|---|---|---|
| 24 May: | +11.5 | +11.9 | +0.4 | |
| 31 May: | +10.5 | +15.6 | +5.1 | +4.7 |

3. Mean Daily Rate

| | |
|---|---|
| Error 10 May: | + 4.5 |
| Error 31 May: | +10.5 |
| | 21/+ 6.0 |
| MDR: | + 0.3 |

E. TIMEPIECE: Hamilton Mod. 2974B (0)

1. Weekly Rate

| | |
|---|---|
| Error 10 May: | +35.5 |
| Error 17 May: | +42.8 |
| Weekly Rate: | + 7.3 |

2. Error of Prediction

| Date | Actual Error | Predicted Error | Diff. | Var. |
|---|---|---|---|---|
| 24 May: | +48.8 | +50.1 | +1.3 | |
| 31 May: | +54.0 | +57.4 | +3.4 | +2.1 |

3. Mean Daily Rate

| | |
|---|---|
| Error 10 May: | +35.5 |
| Error 31 May: | +54.0 |
| | 22/+18.5 |
| MDR: | + 0.9 |

TABLE 2

The Mean Error of Prediction (Seconds)

| Week | Time Period | Mean Err. of Prediction (AllWatches) |
|---|---|---|
| 1 | 17-24 May: | 1.2 |
| 2 | 17-31 May: | 4.0 |

TABLE 3

Watch Rating Results (Seconds)

| Model | Ham. 992 | Ham. 992B | Ill. 161 | Ham. 2974B(C) | Ham. 2974B(0) |
|---|---|---|---|---|---|
| Mean Daily Rate: | +0.4 | -0.03 | +0.06 | +0.3 | +0.9 |
| Mean Variation of Daily Rate: | 0.2 | 0.3 | 0.5 | 0.6 | 0.5 |
| Max.Variation of Daily Rate: | 0.9 | 0.9 | 1.7 | 2.4 | 1.3 |
| Err. of Prediction at end of two week period: | -0.9 | +3.1 | +7.5 | +5.1 | +3.4 |

The test results given in Table 4 (below) indicate that railroad watch performance compares favorably with many of the performance specifications established for the full size Hamilton Model 21 chronometer.*

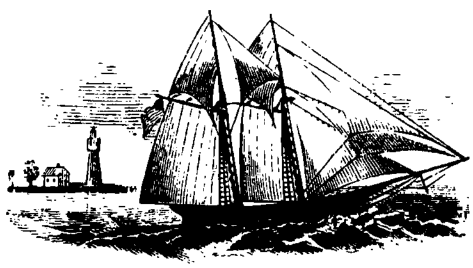
TABLE 4

| | Railroad Watches Tested (Mean of all 5 Watches) (Seconds) | Hamilton Model 21 Chronometer Performance Specifications* (Seconds) |
|---|---|---|
| Mean Daily Rate | 0.34 | ++ 1.55 |
| Mean Variation of Daily Rate | 0.4 | 0.5 |
| Max. Variation of Daily Rate from the Mean Daily Rate | 1.4 | 0.75 |

The mean daily rate of the test watches; 0.34 seconds was well below the 1.55 seconds allowed for the Hamilton Mod. 21 chronometer. The mean variation of daily rate; 0.4 seconds compares favorably for the chronometer specifications; 0.5 seconds. Although the maximum variation of daily rate for the five watches tested was 1.4 seconds, double that of the chronometer specification, it is felt that the Hamilton and Illinois railroad watch can serve adequately as a back-up time reference for navigation at sea. The railroad watch provides accuracy comparable to that specified for the marine chronometer but at only 5% to 10% of the cost of purchase and maintenance.

*See: NAVSHIPS 250-624 Manual for the Overhaul, Repair and Handling of the Hamilton Ship Chronometer with parts catalog, published by the Navy Department, Bureau of Ships, October 1948 (See page 69)

Note: An additional size 16 mechanical watch which may also be considered useful as a mechanical backup time reference at sea is the Hamilton Model 4992B, 22 jewels, 56 hour watch (Invar/Elinvar) used during WWII primarily for aircraft navigation. Four of these watches were tested and results published in Issue 34 of the Navigator's Newsletter. These results show that the error of prediction for the four Model 4992B watches over a two week period were 2.4 seconds, 4.1 seconds, 3.4 seconds and 2.6 seconds. These results are comparable to the railroad watch results in Tables 1 and 2 above.



# HISTORY OF NAVIGATION

## John Harrison: Horologist

*By John M. Luykx*

This year, 1993, is the Tricentennial of the birth of John Harrison, the Yorkshire carpenter and horologist who designed and built the first successful marine timekeeper. Harrison's #1 machine was six years in building, 1729-1735, and was tested successfully on a voyage to Portugal during the spring of 1736 while embarked in HMS CENTURION. It returned to England in May 1736 with its maker in HMS ORFORD. At the end of this voyage the following comment was made by Roger Wills, ORFORD's master:

"When we made the land, the said land, according to my reckoning (and others) ought to have been the Start [South Devon] but before we knew what land it was, John Harrison declared to me and the rest of the ships company that, according to observations with his machine, it ought to be the Lizard [S.W. Cornwall] the which indeed, it was found to be, his observation showing the ship to be more west than my reckoning, above one degree and nearly six miles."

Although the error of Harrison's #1 machine at the time of this landfall in the channel are unknown, it is quite probable that it was only a few seconds: the ship had only been out of sight of land for a few days during the ocean voyage from Lisbon to the mouth of the English channel.

This event, the landfall of HMS ORFORD at the mouth of the channel in May 1736 was the first in which the reckoning of longitude by timekeeper was clearly demonstrated to be superior to contemporary methods of determining longitude. (See note below.) As a result, Harrison was advanced small sums of money by the Board of Longitude (established in 1714) to continue his work. Improved versions of his #1 machine were his #2 and #3 which were completed in 1757. These latter two were not tested at sea.

Harrison's masterpiece is his #4 machine, which is much smaller and more intricate than his first three. It was mounted in a watch case which measured 5.2 inches in diameter and was first tested at sea on a voyage from Spithead to Jamaica via Portland, Plymouth and the Island of Madeira. Over a five month period (including the return voyage to England, November 1761-April 1762) the total error of #4 was 113 seconds or 28 arc minutes of longitude.

A second test of #4 was conducted aboard HMS TARTAR in 1764. TARTAR's voyage to Barbados and return took 156 days. The error of prediction of #4 during this period was 54 seconds. If allowances had been made for changes in rate due to temperature changes, the error of prediction would have been a net loss of 15 seconds in five months or a loss of less than one tenth second per day, a remarkable achievement.

Harrison's last marine timepiece was his #5 built during the period 1767-1770. It was an improved version of #4. #5 was tested at the king's private observatory at Kew in 1772. King George III was personally very interested in the performance of this machine and was present at the daily comparisons during the ten week test. At the end of the test the total error of #5 on mean time was only 4 seconds.

From June 1737 to June 1773 Harrison received a total of £22,550 (passed by Parliament) for his work on his five timekeepers. At his death he left two machines unfinished.

"Longitude Harrison" died on March 24th, 1776, aged eight-three, his life and work a milestone in the history of science. Readers and members who desire to know more about the life of John Harrison and the "Longitude Problem" and its solution by chronometer should refer to:

1. Gould, R.I. *Marine Chronometer, Its History and Development*. The Holland Press, London 1923. (Reprinted 1973). See especially the Introduction and Chapters I through IV.

2. Gould, R.I. *John Harrison and His Timekeepers*. National Maritime Museum, Greenwich, 4th Edition 1978. A reprint from The Mariner's Mirror. Vol. XXI, No. 2 April 1935.

3. Sadler, D. H. *Man is Not Lost* — a Record of Two Hundred Years of Astronomical Navigation with the Nautical Almanac, 1767-1967 HMSO 1968.

4. Howse, Derek . *Greenwich Time and the Discovery of the Longitude*. Oxford University Press, London 1980.

Note: Prior to the development of the chronometer, longitude was determined at sea by a variety of methods, most of which were mathematically cumbersome and not very accurate.

1. A rough estimate of the longitude could be determined by comparing variation of the compass from observations of Polaris with data on an isogonic chart. This method was not accurate and was never popular amongst seamen.

2. Galileo in 1610 discovered four of Jupiter's satellites. Because these satellites are frequently eclipsed, longitude was determined by comparing the local time of eclipse at sea with the local time of eclipse from a reference point such as Greenwich. The time difference between the two converted to arc is the longitude. This method was impractical at sea, however, because ships motion (except in a flat calm) made it practically impossible to use the telescopes of the day with their extremely narrow fields of view to accurately observe the eclipse.

3. Because of its rapid motion across the sky relative to other celestial bodies, the moon can be used for determining longitude. For example:

a. At sea the local time of lunar transit is compared with the Greenwich time of lunar transit. The time difference is converted to longitude difference. Also:

b. At sea the local time of the occultation of a star by the moon is compared with the Greenwich time of occultation tabulated in an almanac. The time difference is converted to longitude difference.

c. At sea the angular distance between the moon and a star, planet or the sun can be measured by a sextant and the local time of observation recorded. The local time of this "lunar distance" is then compared with the Greenwich time of the moon's position in the heavens as forecast by a table. The time difference is converted to longitude difference. With careful observation, accuracy to within less than 1° of longitude was possible. An error of one arc minute in "lunar distance" measurement was equivalent to a 30 arc minute of error in longitude. Accurate moon data was, however, not available to mariners until the 1760s when the astronomer Royal Nevil Maskelyne published the British Mariners Guide in 1763 which gave a general outline of lunar distance principles including Lunar Distance Table. The first Nautical Almanac of 1767 tabulated lunar distances of the sun and seven stars computed for every three hours at Greenwich.

4. Although the lunar distance method found favor among many navigators, it was not a satisfactory method of computing the longitude accurately.

The obvious method to determine accurate longitude at sea was to carry a clock set to the standard time at a known position (such as Greenwich) and to compare the local time of an event with the standard time of the event shown by the clock. The time difference converted to arc is the difference in longitude.

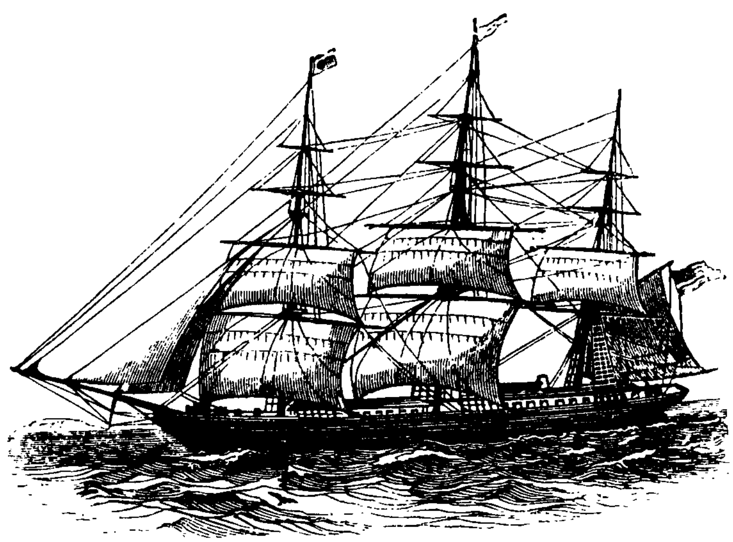
It was left to John Harrison, who himself in 1726 developed a pendulum regulator clock accurate to less than a second a month, to develop the first accurate marine timepiece—a timepiece controlled by two large balances (rather than a pendulum) arranged in such a manner that their motions are always opposed. The effect of ships motion on one balance, therefore, would be corrected by the effect of ships motion on the other.

## 1993 Longitude Symposium

From 4 to 6 November 1993, a Longitude Symposium on the early history of finding longitude at sea will be held at Harvard University, Cambridge, Massachusetts. The symposium is organized in association with the National Association of Watch and Clock Collectors (NAWCC) by the Collection of Historical Scientific Instruments Harvard University. Some of the topics to be discussed by distinguished historians, lecturers and scientists are:

Theories and Practice of Finding Longitude
Early Attempts to Find Longitude
John Harrison
Perfecting the Marine Timekeeper

The Symposium will consist of lectures, panel discussions and receptions in the evening. For more information, contact either the National Association of Watch and Clock Collectors, 514 Poplar Street, Columbia, PA 17512-2130, Phone: 1-717-684-8261 or The Longitude Symposium, Harvard University, Science Center (86), Collection of Historical Scientific Instruments, Cambridge, Massachusetts 02138, Phone 1-617-495-2779; FAX 1-617-495-3344. (Registration Material).



# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 39, Answer

Why does a measurement of the altitude of a body above the visible sea horizon constitute the distance that the observer is from the GP of the celestial body? In the answer there resides the heart and soul of all of the related elements of the theory of celestial navigation. Conceptually, the observer is at the very center of the Earth, rather than on its surface. Thus, a figurative straight line extending vertically from the observer, perched on his slag at the center of the Earth, to that point in space that is directly above him (his Zenith) would form a 90 degree right angle with a figurative horizontal line extending straight out from him to another point in space. At the Earth's surface the very curvature of the Earth would constitute a 90 degree arc (as would any arc between the two sides of this right angle). Now, at the surface of the Earth each minute of arc equals one nautical mile, and this relationship exists because of the distance between the center of the Earth and its surface (the radius). The length of that radius, by simple geometry, translates into the happy fact that along any great circle of arc at the surface of the Earth, one minute of arc equals one nautical mile.

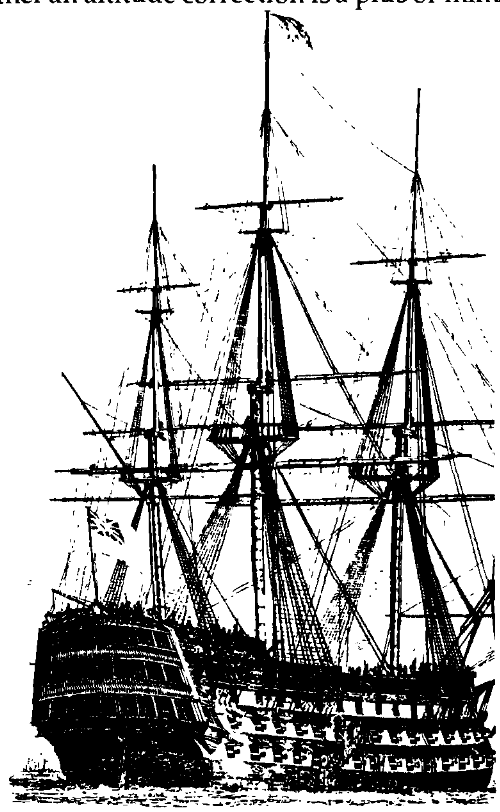
The observer measures the altitude of the body above the horizon because the horizon constitutes the "straight out" horizontal reference for the horizontal leg of the right angle. If an observer at the center of the Earth measured the altitude of a celestial body as 30 degrees, then the angle formed by a straight line from the observer to the body and the straight line to the Zenith would be 60 degrees, and at the surface of the Earth where each minute of arc equals one nautical mile, that 60 degrees translates to 3,600 miles. From the point where the vertical Zenith line of the observer intersects the surface to the point where the line to the body intersects the surface of the Earth it is 3,600 nautical miles.

Hence, an altitude of the body above the horizon, when subtracted from 90 degrees, constitutes the distance on the surface of the Earth from the observer to the GP of the celestial body. The result of the subtraction from 90 degrees of the altitude, when corrected for all altitude corrections, is known as "zenith distance." Zenith distance is not measured directly from "straight up" down to the celestial body because the observer has no reference to tell him by mere observation where that point in space is that is directly above him. But he does have the "straight out" horizontal reference of the horizon, so he measures the altitude of the body above the horizontal reference rather than the direct angle downward from the Zenith to the body.

The fact that the observer is not at the center of the Earth, but is on the surface of the Earth, constitutes a mathematical discrepancy. Altitude of the body needs to be corrected not only for this displacement of the observer, but for a number of other factors as well in order to arrive at true zenith distance. Thus, there is the correction for index error related to the sextant (plus or minus), height of eye of the observer (always a minus value), refraction related to bending of light rays by the Earth's atmosphere (usually a minus value), the semi-diameter of the Sun or the Moon (a plus correction for a lower limb sight and a minus correction for an upper limb sight), and the parallax caused by the fact that the observer is not really at the center of the Earth, but is, instead, 3,438 nautical miles away on the surface of the Earth. The parallax correction is always a plus. Fortunately, these corrections need not be applied piecemeal, as the Almanac combines most of them into aggregate factors. They will be dealt with in a succeeding question.

Problem No. 40

A navigator should be able to picture in his mind the reasons why the various altitude corrections are either a plus or minus value, and he should always remember that true zenith distance is only arrived at after all applicable altitude corrections are made. What picture should be formed in the mind in order to determine instantly whether an altitude correction is a plus or minus value?



# NAVIGATION PERSONALITIES

## James Cook

*By Roger H. Jones*

Born October 27, 1728 in the village of Marton-in-Cleveland, Yorkshire, James Cook spent his boyhood years there. At the age of seventeen, he was apprenticed to a grocer and haberdasher, but he was attracted to the sea and his indenture was transferred in July of 1746 to John Walker, a ship owner and coal dealer at Whitby. Walker sent him to sea at once, and then as winter descended on the East Coast of England, Cook was brought ashore and immersed in the study of mathematics and navigation.

After the indenture was fully served, Cook spent two years before the mast in the Baltic trade, and he then returned to the service of Walker in 1752 as a mate. In 1755 Walker offered him command. However, war with France was looming, and Cook instead volunteered into the British Navy as an able seaman aboard the "Eagle." Within a month, he was promoted to Master's Mate, and after channel service from 1755 to 1757, he was again promoted to Master in the "Pembroke" (64 guns). His experience navigating colliers previously had prepared him well, and was the foundation for his later work.

"Pembroke" crossed the Atlantic in February of 1758, and took part in the operations under Admiral Charles Saunders in the siege of Louisburg and the naval assault on Quebec. Cook played an important role in the charting of the St. Lawrence during this time, and after the fall of Quebec, he was transferred to command the flagship of Lord Colville (successor to Saunders), "Northumberland." While aboard the latter ship, Cook learned surveying from the military engineers, and he continued to gain expertise in mathematics.

In 1763, after brief service in England, Cook was appointed to the Newfoundland survey, commanding the schooner "Grenville." Upon his return to England, he published his charts, at first privately, and later in the North American Pilot. He had become a recognized hydrographer as well as a highly respected navigator and ship's master, and in 1766 he further expanded his expertise through a very careful observation of a solar eclipse permitting calculations of longitude that were published in the transactions of the Royal Society in 1767.

With this background, he was commissioned by the Admiralty as lieutenant in command of HMS "Endeavor" in 1768, with the mission of taking observers to Tahiti to make careful observations of the transit of Venus in order to permit calculation of the distance of the Sun from the Earth. The two observers appointed were Charles Green and Cook, himself.

A second purpose of the voyage was geographical discovery of the great continent that was thought to lie well to the south, and upon leaving Tahiti, he was ordered to proceed to 40 South, and if he did not find the continent, then to proceed westward to New Zealand, which had last been visited by Abel Tasman in 1642-43. While Venus did not permit observations that would fulfill the first purpose, the second purpose was ultimately met with extraordinary success. Tahiti was departed on July 13, 1769, and Cook followed his orders. Not finding the continent, he did turn to the west, and he arrived in New Zealand on October 7th. He circumnavigated the two great islands in a figure of eight, conducting a brilliant survey and charting operation along the way.

On April 1, 1770, Cook left New Zealand and proceeded to explore the east coast of Australia, despite great peril from the Great Barrier Reef. Again, masterful charts were prepared. He rediscovered the Torres Straight, and passed through it to Batavia where the crew fell ill with malaria and dysentery. There were many deaths, but Cook brought his ship home in July of 1771, and was promoted to Commander.

After suggesting a further voyage of circumnavigation as far south as possible in the high latitudes, he was given command of two vessels, "Resolution" and "Adventure." Departure from England was in July of 1772, and three memorable Antarctic cruises took place: the Atlantic-Indian Ocean sector from December of 1772 to March of 1773; the Pacific sector from November of 1773 to February of 1774; and the completing Atlantic sector in January and February of 1775. Cook was thus able to discount completely the old continental theory, but he did believe that land lay to the south beyond the ice pack. His furthest penetration was to 71-10 South, 106-54 West on January 30, 1774.

In between these cruises, he made a great sweep of the Pacific which covered Easter Island, the Marquesas, the Society Islands, Niue, Tonga, the New Hebrides, New Caledonia, and many smaller islands. He discovered and charted South Georgia and the South Sandwich Islands, and was home again in July of 1775. This second of his three great voyages has been described as the single greatest voyage of discovery, and it proved to be very useful in validating the use of the new marine chronometer in enabling calculation of longitude, in the development of Antarctic navigation skills, and in the development of means of preventing scurvy among the crew. For this voyage Cook was elected a fellow of the Royal Society and was awarded its Copley medal. He was also further promoted to Post Captain, and in this capacity he volunteered for a third voyage to explore the Pacific coast of North America and to search for the Northwest Passage.

Again in command of "Resolution" and accompanied by "Discovery" (Captain Charles Clerke), Cook departed on July 12, 1776, and proceeded to the South Pacific. He again visited the Society Islands before turning northeast on December 8, 1777. He discovered the Hawaiian Islands on January 18, 1778 and then went to the coast of North America. Once there, Cook sailed as far north as the Bering Straight and he penetrated to latitude 70-44 before being stopped by the pack ice. Deciding to winter in Hawaii, he returned there and, after a coastal survey, the ships were anchored in Kealakekua Bay from January 17 to February 4, 1779.

Upon departing Hawaii, the ships were forced to return for repairs to a sprung topmast, and it was upon this occasion that Cook was killed by native Hawaiians. Command was assumed by Captain Clerke, who later died of consumption, but the two vessels did return to England on October 4, 1780 under the final command of John Gare.

Cook was survived 50 years by his widow, Elizabeth Batts Cook. Of his six children, three died in infancy, and his three sons (two of whom joined the Navy) were all dead by 1794.

It may accurately be said of him: he was a superb planner and administrator; he was a masterful manager of crew, both officers and seamen; he was perhaps the first of the truly scientific navigators with his master of higher mathematics and celestial mechanics; he was a prolific and skilled hydrographer; he was a discoverer in the age of discovery! In his time no one was more greatly admired by colleagues of his own calling.

# MARINE INFORMATION NOTES

*By Ernest Brown*

## Global Positioning Systems (GPS)

The Global Positioning System (GPS) is a satellite-based radionavigation system with continuous worldwide coverage. It provides navigation, position, and timing information to air, marine and land users. The GPS is being developed and will be operated and controlled by the Department of Defense (DoD) under Air Force management. Although originally intended for military use only, federal radio-navigation policy has established that the GPS Standard Positioning Service will be available for civil use. Current plans call for GPS to meet Initial Operational Capability (IOC) by mid-1993. At IOC, the GPS will have achieved its earliest operational configuration for providing the GPS Standard Positioning Service (SPS). Full Operational Capability (FOC) to meet operational military functionality is expected to occur in 1995. Due to the orbiting nature of the incomplete satellite constellation, GPS coverage currently varies in quality throughout the day from place to place. Computer programs are available from commercial sources so that interested users can determine the quantity and quality of GPS coverage at their particular location.

The USCG is the government interface for civil users of GPS and has established a GPS Information Center (GPSIC) to meet the needs of the civil user. The GPSIC is a Coast Guard facility located in Alexandria, Virginia. It provides voice broadcasts, data broadcasts, and on-line computer-based information service, which are all available 24 hours a day. GPSIC watchstanders are available to handle telephone, fax, and mail inquiries daily from 6:00 AM to 10:00 PM eastern time. The information provided includes planned, current or recent satellite outages and constellation changes, user instructions and tutorials, other GPS-related information, system status and information about other Coast Guard provided radionavigation systems, and general information about federal radionavigation policy and systems.

The GPS system is not yet fully operational. Signal availability and accuracy are subject to change due to an incomplete satellite constellation and operational test activities.

However, whenever possible, advance notice of when the GPS satellites should not be used will be provided by the DoD and made available by the U.S. Coast Guard. Subsequent to IOC, any planned disruption of the SPS in peacetime will be subject to a minimum 48-hour advance notice provided by the DoD to the GPSIC. The GPSIC advisory services are updated only during the time 6:00AM to 10:00 PM eastern time. GPSIC services are described below:

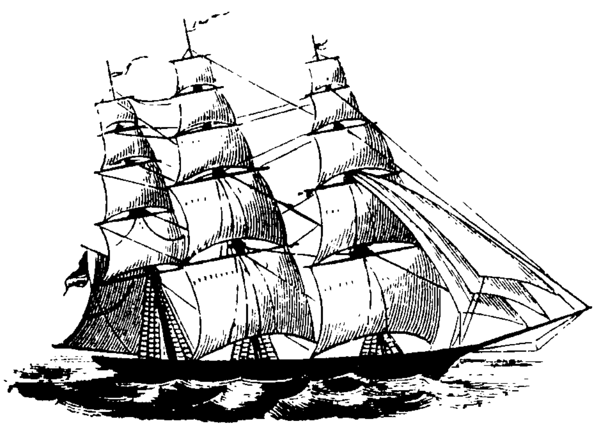
The GPSIC 24 hour voice recording provides access to a 90 second message of the current system status. Forecast outages, historical outages, and other changes in the GPS are included as time permits.

The Department of Commerce transmits recorded information WWV/WWVH 5, 10, 15, and 20 MHz frequencies. During the 40 second interval between time ticks, navigation information is announced by voice. Listen at minute 14 & 15 on WWV and minute 43 & 44 on WWVH for GPS status and current or forecast outages.

The computer bulletin board system (BBS) provides information such as GPS status messages, satellite almanacs, Notice Advisory to Navstar Users (NANU), and post-mission ephemeris data. Also available is status on other CG operated radionavigation systems, federal radionavigation policy, and general radionavigation information. Connections can be made to the BBS either via phone or SprintNet (a public data network). The BBS phone number is (703)866-3890 and handles modem speeds of 300-14,400 bps. Communications parameters are 8 data bits, no parity, 1 stop bit (8N1), asynchronous comms, full duplex. The BBS SprintNet number is 311020201328. (This can be abbreviated to 20201328 if accessing SprintNet via telephone to one of SprintNet's modems.) Users must set up their own accounts to access SprintNet.

The GPSIC disseminates safety GPS Advisory Broadcast Messages through USCG broadcast stations using VHF-FM voice, HF-SSB voice, and NAVTEX broadcasts. The broadcasts provide the GPS user in the marine environment with the current status of the GPS satellite constellation, as well as any planned/unplanned system outages that could affect GPS navigational accuracy.

DMAHTC broadcasts navigation information concerning the "high seas." Information is provided in message format via an established system of message dissemination. GPSIC provides the GPS Operational Advisory Broadcast information to DMA for broadcast in NAVAREA, HYDROLANT, or HYDROPAC messages. These messages are generally geared to the deep draft mariner.



# BOOK REVIEW

*By Roger H. Jones*

## Navigation Rules for International and Inland Waters

Edited by David Burch
*Paradise Cay Publications, P.O. Box 1351*
*Middletown, California 94561 (1993) 79 pages*

David Burch is no stranger to the Newsletter. Readers will recall reviews of a number of his books. He is, in fact, the author of eight books on marine navigation and also the recent Starpath Radar Trainer, a software package that teaches collision avoidance by converting the computer screen into a radar simulator. He is also the recipient of the Institute of Navigation's Superior Achievement Award for outstanding performance as a practicing navigator, and he has taught navigation to many students at his Starpath School of Navigation in Seattle.

This new little booklet fulfills the requirement that there be on board all vessels of twelve meters or more in length (39 feet) a copy of the Inland Rules at all times when upon inland waters. It is more than obviously prudent, however, to have both the Inland and the International Rules on board in all navigable waters. The COLREGS Demarcation Lines specify the official boundaries between U.S. Inland and International Waters, and they are enumerated in detail on pages 35-46 of the book. This reviewer lives aboard in Marina Del Rey, California and thus, for example, one of the demarcation lines is described as: "A line drawn from Marina Del Rey Breakwater South Light 1 to Marina Del Rey Light 4." These lines are, of course, depicted on applicable charts, but for someone not having a full complement of charts aboard, it is nice to have a complete listing of all the demarcation lines in each of the Coast Guard Districts.

Of perhaps greater interest to the practical navigator, however, is the fact that Burch has presented the International Rules in a form in which there are clear bracket lines for each section of rule text where there are differences between the International and the Inland Rules. The International Rules are presented in full, and the Inland Rules are presented in a following section only insofar as they differ from the International Rules. Note: the margin lines or brackets that appear in the official government edition have a different meaning. They indicate rules that have changed since the 1983 edition. Note also that the Inland Rules apply only to U.S. waters. In Canadian waters different regulations apply, which are printed in the Canadian Sailing Directions.

Beyond this very useful format in combining the International and the Inland Rules in a way that emphasizes the difference between the two sets of rules, Burch has also provided "Annotated Contents." There is no index to the government edition of the Rules, and this annotation helps to guide readers to a desired rule. For those who do not have aboard a set of the Rules, this is the edition to purchase. For those whose rules languish in an outdated version on the back of the cabin shelf, this is the update to get. For the format and the index, a well deserved "Thanks!" is due to David Burch.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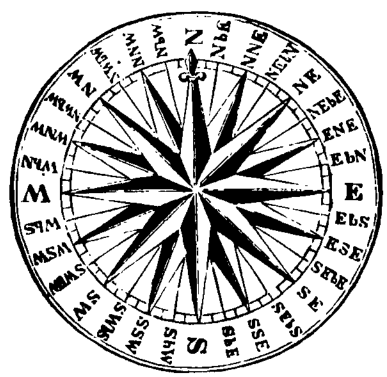
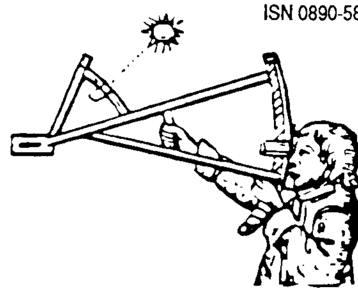
DO YOU KNOW . . . ?

A map datum is a mathematical model of the earth, and the latitude and longitude of a position may vary from one model (datum) to another. There are literally hundreds of map datums in use throughout the world, but only a few are in widespread use. The legend of a chart will usually indicate which datum is the basis for that chart. The National Oceanic and Atmospheric Administration (NOAA) is currently changing its charts to datum NAD83, which, for most purposes, is the same as WGS84. Previous editions of NOAA charts were constructed to the NAD27 datum.

A datum is based upon the ellipsoid or ellipsoidal arc whose shape most closely approximates the actual area of the surface of the earth being described, and each datum is centered at a specific location. A datum may describe a small part of the earth, such as Bermuda (the Bermuda 1957) datum uses the Clarke 1866 ellipsoid), or the entire earth, such as WGS84. The difference in latitude and longitude coordinates from one datum to another may be small or significant. It is therefore important to relate your GPS position information to a chart by knowing which datum the chart is based upon. Positioning errors of up to 600 meters (1,968.5 feet) may occur if this is not borne in mind. Most GPS units report position in terms of the WGS84 datum, but they enable the user to select other datums as well. When cross-checking between a celestial fix and a GPS position, be especially careful to note the datum of the chart in use, and when relying upon GPS alone (which would be counter to the Navigation Foundation's purpose of preserving the celestial art), be equally careful in identifying what datum is in use.



# THE NAVIGATOR'S NEWSLETTER



ISN 0890-5851

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION ISSUE FORTY-ONE-FORTY TWO, FALL/WINTER 1993-94

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Books, Charts, & Bulletin Boards

The 1994 Government Printing Office Nautical Almanac is available from the Foundation. This year the list price has decreased to $20.00. Members still get their 20% discount on publications plus any postage required to mail it to the member.

There are two, no cost, marine bulletin boards available to mariners. The Defense Mapping Agency controls the "Navigation Information Network" (NAVINFONET) and NOAA, NOS and Coast and Geodetic Survey controls the "Marine Information Bulletin Board." A users manual and the request for a Users ID, for the NAVINFONET can be obtained from:

Navigation Division/NAVINFONET Staff
ST D 44
DMA Hydrographic/Topographic Center
4600 Sangamore Road
Bethesda, MD 20816-5003

Information available from NAVINFONET is:
Broadcast Warnings.
Anti-Shipping Activity Messages.
Mobile Offshore Drilling Units.
GPS Daily Status.
Chart Corrections.
Catalog Corrections.
Defense Mapping Agency and U.S.C.G. Lights.

Individuals with computer modems can log onto the NOAA system BBS at 301-443-7637. Baud: 12/24/9600; 8 Bits; No parity; 1 stop bit. The BBS is available 24 hours a day, 7 days a week. The SYSOP is Ruby Becker and she can be reached at 301-443-8635 or FAX 301-881-2665. For more information write:

NOAA, NOS, C&GS (N/CG211)
6001 Executive Boulevard
Rockville, MD 20852

Information available from NOAA is:
Wrecks and Obstructions.
Nautical Chart Locator.
Sediments.
NAD Conversion.
Aerial Photographs available from NOAA.

A new book available from the Foundation is, "Survival Guide for the Mariner," by Robert J. Meurn. Cornell Maritime Press is the publisher.

Anyone who goes to sea knows that he or she is at risk, but being prepared minimizes the risk and makes the mariner—whether aboard a yacht or a containership—a better captain or crew member. Seafarers must be trained to cope with the worst that the marine environment has to offer. Beginning with the preparation one can make before sailing, principally in training oneself, the book proceeds to the steps that must be taken aboard each vessel to ensure the safety of the ship and its human cargo before the emergency situation occurs. Crew overboard, abandon ship procedures, and methods for survival in the water or life raft are thoroughly covered in this text which is essential training for mariners who may someday face extreme hardships on the sea. The possibility of being castaway, the means of survival in such a situation, search and rescue procedures, and needed information about the process of being rescued are also topics for this complete treatment of safety of life at sea.

Since this book can be used as a text for those preparing to be Coast Guard certified lifeboatmen, the appendices contain lifeboat, rescue boat and rigid life raft equipment

DO YOU KNOW . . . ?

*By Roger Jones*

Who invented the first doubly-reflecting octant? When? (The answer appears at the back of this issue.)

descriptions, recommendations, and inspection guidelines; sample Coast Guard examination questions and answers; and a table to lifesaving signals.

Robert J. Meurn, a master mariner and captain in the U.S. Naval Reserve, teaches in the department of marine transportation at the U.S. Merchant Marine Academy at Kings Point, New York. Capt. Meurn is also the author of Watchstanding Guide for the Merchant Officer.

Survival Guide for the Mariner is priced at $25.00, and its 248 pages include photographs, figures, appendices, tables, and an index.

## Orders & Correspondence

Members who use computers with modems and are connected to Compuserve or have a FAX available are requested to provide the FAX telephone or their Compuserve address number when writing to the Foundation. This will, in many cases, decrease the time for receiving a response to their queries.

Reminders: Back issues of *The Navigator's Newsletter* are available for $2.00 each, postpaid.

Both the 1994 yachtsman's ($15.95 list) and Government Printing Office ($20.00 list) issues of the Nautical Almanac are available.

Chart prices have increased to $14.00 (list), effective October 1, 1993.

## Awards

The Foundation has established the RADM Thomas D. Davies, USN award for excellence in navigation at the United States Coast Guard Academy, New London, Connecticut. The plaque is awarded to the Third Class Cadet in his first year at the Academy. The criterion for selection is established by the Coast Guard Academy and includes a recommendation from the Navigation Departments of the ships served on by the Cadet and the Cadet's academic record at the Academy. The first plaque was awarded to 3/C Fabio Zapata, who is an exchange cadet from Columbia. Having met 3/C Zapata, I am impressed with the Coast Guard Academy's selection.

## Organizational Note

You will notice that this issue of The Navigator's Newsletter is twice size of previous editions. Due to the amount of material we wished to include and the delay in getting the copy ready for print, we decided to make this newsletter a double issue. To keep your records in order, this issue is the Fall/Winter 1993-94 Issues Number 41-42. If all goes well the Foundation should be back on schedule with the Spring 1994 issue of The Navigator's Newsletter.

# READERS FORUM

*Edited by Roger Jones*

Open letter to all readers from Roger Jones:

This will be the last issue of the *Newsletter* that I will be able to work on in behalf of the Foundation and all readers. I have been associated with Terry Carraway and Admiral Davies and the members of his family since the outset of the Foundation, and with all of the Directors over the years have always enjoyed my role in the activities of the Foundation and in the publication of the *Newsletter*. During the past ten months, I have been working essentially full time on the many tasks of getting my 43-foot cutter ready to embark upon several years of cruising, and I expect to leave from Marina Del Ray, California on the first leg to Panama in January or February of 1994. ALLIDORO is a Hans Christian (Christina model), and the end of a long series of major projects is in sight. They have included installation of the following: stainless antenna arch, boom gallows, and racks for deck storage of extra fuel containers (6 five-gallon cans); radar, autopilot and GPS; AC/DC inverter; engine and DC refrigerator and freezer; SCUBA compressor; large volume watermaker; engine-driven emergency bilge pump, deck wash and fire hose; 6-man ocean liferaft; automatic Halon fire extinguisher in engine room; vapor sniffer (because there is a propane stove aboard); dual fuel filters for the diesel engine; Ham radio; full dodger and Bimini; 400-foot all chain anchor rode (with a 200-foot nylon line tail) plus three other anchors and rodes; auxiliary generator; more than 100 custom interior projects in teak, including storage racks for nearly 400 charts (world-wide coverage) obtained through the Foundation with the help of Terry Carraway, and a 406 MH EPIRB.

My initial itinerary will probably take me through the Panama Canal to the East Coast. After that - perhaps the Mediterranean and the Red Sea, or the South Pacific via an easterly or a westerly route. All of this is fluid and will depend upon the whims of the crew.

Any Foundation member (man or woman) who might be interested in joining the crew for one or more legs during the next several years should contact me via mail at Box 368, New Hartford, Connecticut 06057. The only prerequisites: an ability to stand watch, freedom from major medical problems, congeniality, willingness to pitch in on your own food and personal expenses, and the freedom to get away for a while. The vessel library has over 300 books, 150 audio tapes, and 80 video tapes. From time to time I will update readers on the current and future itinerary. Until the end of January, you may also reach me by phone at (310)305-0414.

All readers are urged to continue to support the Newsletter and the Foundation. Keep your letters and articles coming. Ernest Brown, who is a former editor of Bowditch and who is a Director of the Foundation, has agreed to take on the duties of editing the Newsletter upon my departure. To all—my fond and best wishes and "May Dolphins Dance Beneath Your Bow!" —*Roger*

Shellamn Brown of Hyde Park, New York has written to us commenting on the recent Bennett and Pepperday contributions to the *Newsletter.* Among his interesting comments are the following:"... the *Almanac For Computers* produced by the Naval Observatory ...(Final printed edition 1991, Ed.)... facilitates noon longitude by curve fit from a moving vessel. See the article in the March, 1991 *Cruising World* which shows possible accuracy of one quarter mile." Brown also notes: "...the Hewlett-Packard Nav Pak contains liberal use of polar-rectangular functions. You don't see trig function in its implementation of the customary formula for altitude."

Edward Matthews of 156 Burroughs Road, Boxborough, Massachusetts 01719, has also joined the ranks of those interested in the Bennett and Pepperday solutions to the two-body fix. In his letter he notes that his paper on "Running Fix By Calculator From An Unknown Position" was presented at the Institute of Navigation's 34th Annual Meeting in St. Louis in June of 1979. The remainder of the Matthews letter is quoted as follows:

"Dozier, who started all this fuss in 1949, did not allow for non-simultaneous observations. My paper addressed this and also resolved the ambiguity problem by observing beforehand on which side of the great circle connecting the two geographic positions of the bodies the observer is located. In practice this is obtained by noting the rough bearing (Zn) of each body. The proper solution depends on whether the difference in the Zns is greater or less than 180_. If the difference is less than 180_ the northernmost solution is the correct one.

"If the vessel is underway, a knowledge of our approximate latitude is required to establish the longitude difference associated with the rhumb line course. We accomplish this by assuming that the sights occurred at the same time, therefore producing an approximate position. Then by using the speed and course of the vessel the GHA and DEC of the first body are altered to designate an imaginary body at the second time. This is then used with the second body for the final solution. The position is that of the time of the last body entered. The approximate Znl can also be determined by the first pass to arrive at an imaginary Ho used by other 'co-inventors'. This value is more precise than Prof. Bennett's RUDE star finder method of determining Znl.

"This procedure has been programmed for both the TI-50 and HP-41CX calculators. I prefer to use my own programs than to use dedicated routines since they can be customized to my liking and it's more fun. The program uses the NAUTICAL ALMANAC hourly data and all corrections are automatically performed. This program has been in use for over 15 years and I disagree with Mike that the process is inconvenient. I prefer its use since it requires no DR position. It is particularly useful in the tropics for high altitude LAN fixes where excellent 'cuts' near 90° can be acquired in a short period." (The Matthews paper is reprinted in this Newsletter as an article.)

As noted in the last issue, Ed Popko of 28 Maverick Road, Woodstock, New York (telephone 914-679-7050) is still interested in obtaining a copy of the *Manual for Navigation at Sea Using the HP-41CX.* This was formerly published by Justin Gray, NAS Publications, in Dana Point, California. Again, any reader who may have a lead to an available copy of this manual, should contact Mr. Popko.

Director John Luykx would like to obtain a Government Printing Office copy of the 1992 Nautical Almanac. If any member has one, please call Director Luykx at 301-420-2468 or write: John Luykx, InfoCenter, Inc., P.O. Box 47175, Forestville, MD 20747.

Member Wayne E. Feely of 1172 Lindsay Lane, Rydal, PA 19046; Tel. 215-884-6540, writes that he wants to purchase slide rules, He states: highest prices paid for quality and unusual slide rules. Please call or write member Feely if you have a slide rule that he may be interested in purchasing.

# NAVIGATION FEATURE

## Peary Update: Local Apparent Noon Sight at High Latitudes

*By Doug Davies*

One of the central questions surrounding Peary's claimed attainment of the North Pole in 1909 is how he was able to determine whether he had drifted off course and make appropriate course corrections. Peary knew how to take celestial observations for longitude, but he stated that such observations were not necessary, and he took none. Unless one assumes that Peary knew that his navigation was inadequate to get him to the Pole, but didn't care, he must have been confident from other observations that he was on track. The question is what methods did he use, and were they sufficiently accurate.

In our report to the National Geographic Society, we identified several ways that Peary and his colleagues (Cornell University Civil Engineering Professor Ross Marvin and ship's master Bob Bartlett) could have determined their left-right drift. In addition, retired USAF polar navigator Bill Mollett identified a method of estimating and comparing the sun's altitude at the times when it should have been on the prime verticals east and west. This method clearly would have worked well during the middle part of Peary's trip, when the sun's declination was between 0° and 3°N, and there is evidence to suggest that Peary used this method at least once, on March 21 and 22.

Peary appears to have relied on his observations of the time of the sun's culmination during local apparent noon latitude sights to give him a rough longitude on his 1906 attempt. On that occasion, savage westerly winds over a period of more thn six days drove Peary far to the east. He used his noon sights at latitudes above 85 to estimate the amount of drift and find his way back to northern Greenland, where he knew he could find game. The fact that Peary was willing to rely on local apparent noon sights in these circumstances in which his life depended on knowing his approximate longitude in our view justified the conclusion, based on our calculations, that adequate longitude information could be obtained in this manner and that it was reasonable to believe Peary used this method in 1909.

The method works like this: At the moment the sun reaches its highest altitude, it is on the meridian (ignoring, for the moment, a small correction for the rate of change of the sun's declination). Since Peary's watches were set to 60th meridian time, every 20 m of time after 12:00 (ignoring, for the moment, the equation of time) corresponded to 5° of longitude west of 60°. At the moment of meridian transit, the sun lay due south, and the way to the Pole lay in exactly the opposite direction.

A number of people, including a few experienced navigators and a few people who I have reason to believe have never taken a sight with a sextant, have questioned whether the time of the sun's culmination could be determined with sufficient accuracy for these purposes. We believed that it could, and that several differences between Peary's situation and that of the sea-going navigator enabled the Peary team to achieve much greater precision in the local apparent noon sight than one might expect.

First, Peary used a mercury artificial horizon that doubled the altitudes of all of his observations. Thus, a 1' change in the sun's true altitude would appear as a 2' change as measured by the sextant.

Second, there is no out-of-vertical error and no need to dip the sun to the horizon by swinging the sextant. When the two images of the sun are lined up one above the other, the instrument is vertical. The two images can be kept in more or less continuous contact. At the low altitude Peary encountered, sextant errors and motion of the images caused by rocking the sextant are minimized.

Third, the comparison of two images of the sun, rather than one image of the sun and the horizon, seems inherently more precise. On an upper limb sight, the smallest overlap between the two images as the sun continues to rise causes a bright spot that is very easy to see. (This can be observed by index correction sights using the sun.)

Fourth, being on land and able to steady the sextant in a prone position with right elbow resting on the ground, Peary and his colleagues would have been able to use a higher power telescope. Sextants in Peary's era typically were provided with two or more telescopes. While the 3x to 4x "star scope" was typically used at sea, the higher power inverting telescope (often refered to as a collimator, since it included cross wires for use in ascertaining proper alignment between the telescope and the frame of the sextant) was used on land. With a little practice, I have had no difficulty using the 12x collimator provided with my post WW II Tamaya to take sun sights with an artificial horizon.

Until recently, our theories seemed doomed to remain untested in practice. The rapid rising and setting of the sun at noon at middle latitudes is so unlike the very gradual rising and setting at latitudes of 85° to 88°, where Marvin's and Bartlett's sights were taken, that any experimentation here seemed almost pointless. On the other hand, the cost of an expedition to such high latitudes to test our theories was clearly prohibitive.

Some time ago, while experimenting with a Freiberger plate glass artificial horizon, I found my free ticket to any latitude I wanted. It occurred to me that if the artificial horizon were tilted about an east-west axis so that its southern end was elevated, it would be exactly parallel to level artificial horizon located on the same meridian, but further north. This is illustrated in Figure 1, where the circle represents the local meridian, Z is the local zenith and the tilt angle between the local vertical and the normal to the artificial horizon is equal to the difference between the local latitude and the simulated latitude. The difference in the parallax of the sun (at most 9" of arc) for different locations on the earth is meaningless for

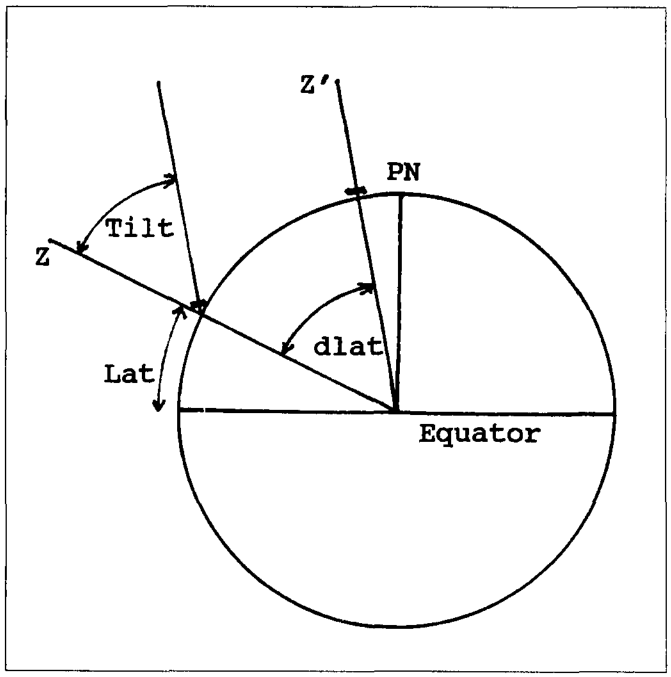



*Figure 1*

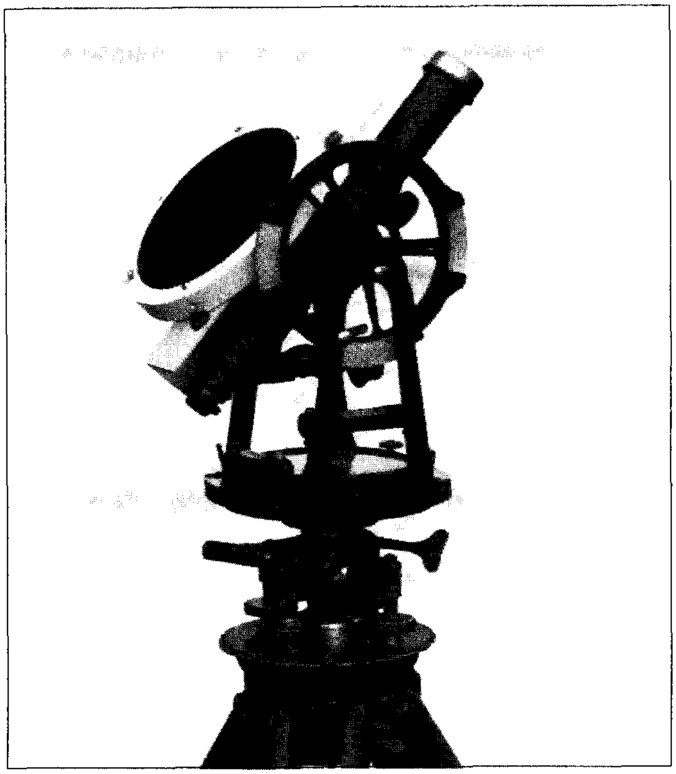


*Figure 2*

present purposes (and, indeed, for navigational purposes generally).

The image seen in the tilted artifical horizon would thus correspond to the image seen in a level artificial horizon located to the north by the number of degrees of latitude corresponding to the tilt of the artifical horizon. (Of course, the refraction corrections would be different, but these are not material to the question of determining local apparent noon.)

I constructed a bracket to mount the Freiberger on the telescope level mounting posts on my theodolite (see Figure 2) and thus had a means of elevating the artificial horizon to precisely the right angle and orientation. I spent the next few weekends performing the usual checks on the theodolite to put the cross wires, levels, and telescope carriages in perfect alignment.

On the first sunny weekend after the sun was above the horizon (at 85°N), I was ready to give it a try. Fearing that city dwellers would look askance at neighbors playing with high-power optical instruments, I went to Tartan Farms in Poolesville, MD on April 3, 1993. The U.S. Geological Survey topographic map for the area shows that the sights were taken at latitude 39°08.75′N, longitude 77°26.5′W.

After setting up and leveling the theodolite, the first step was to get the instrument pointed due south, so that the axis about which the telescope (and thus the artifical horizon) was elevated would be due east-west. This was accomplished by an azimuth observation of the sun checked by a second observation, as follows:

For the first observation I set the upper plate vernier at 0 and used the lower base clamp and tangent screw to observe the azimuth of the centerline of the sun. (Incidentally, the method I use for observing the sun with a theodolite is to focus the eyepiece so as to project an image of the cross hairs and the sun onto a white card held a few inches away from the eyepiece.) The calculations are as follows:

| | | |
|---|---|---|
| Watch time: | 09:35:45 | |
| Corrected time: | 09:35:29 | |
| GMT: | 14:35:29 | |
| | | |
| GHA (from almanmac): | 29-11.4 | (At 1400h) |
| | 8-52.3 | (Corr.for35m29s) |
| | 38-03.7 | |
| LHA: | | |
| Longitude: | 77-26.5 | |
| -GHA | 38-03.7 | |
| | 39-22.8 | |
| Dec. (from almanac): | 5-27.3 | (At 1400h) |
| | .6 | (Corr. for 35 m) |
| | 5-27.9 | |
| Latitude: | 39-08.8 | |

The sun's azimuth is found by first finding the altitude, using the equation:

sin(alt) = cos(lat)*cos(dec)*cos(LHA) + sin(lat)*sin(dec)

This gives altitude = 41.0607

Then azimuth is given by:

cos(az) = (sin(dec) - sin(alt)*sin(lat))/(cos(alt)*cos(lat))

This gives azimuth of 123°07′, or 56°53′ east of due south. I then marked off 56°53′ to the right using the vernier on the theodolite and re-oriented the lower plate so that the vernier was reading 0 with the theodolite oriented due south. I then took a second azimuth observation just to be sure. This time, I left the lower plate clamped and observed the sun as before by rotating the upper plate. At this point, the vernier read 310°52′, corresponding to an observed azimuth of 49°08′ east of south. The calculated azimuth was determined as follows:

| | | |
|---|---|---|
| Watch time: | 10:04:36 | |
| Corrected time: | 10:04:20 | |
| GMT: | 15:04:20 | |
| | | |
| GHA: | 44-11.6 | (At 1500h) |
| | 1-05.0 | (Corr. for 04m20s) |
| | 45-16.6 | |
| LHA: | | |
| Longitude: | 77-26.5 | |
| -GHA: | 45-16.6 | |
| | 32-09.9 | |
| | | |
| Declination: | 5-28.2 | (at 1500) |
| | .1 | (corr. for 04) |
| | 5-28.3 | |

| | |
|---|---|
| Latitude: | 39-08.8 |
| | |
| Sun's altitude | 45.5381 |
| Sun's azimuth | 130.50 |

This correspondes to 49°10' measured from south, or within two minutes of the observed azimuth. This was considered adequate for present purposes, and the upper plate was returned to the zero position.

I then attached the Freiberger horizon to the theodolite telescope and leveled it left and right using the mounting screws and fore and aft using the tangent screw to adjust the elevation of the telscope. When all leveling adjustments were completed and rechecked, I noted the vertical vernier, which read about 20'. I then elevated the telescope (and the artificial horizon) to about 47°00', for an increase of 46°40'. Adding 46°40' to my latitude of 39°08' gave a simulated latitude of 85°48', the approximate latitude of the first series of sights taken by Ross Marvin of the Peary expedition.

I then placed a straight backed chair where I could sit in it backwards and use the back as an elbow rest. This was far from comfortable, but it did permit me to hold the sextant reasonably steady while observing the sun in the artificial horizon.

I began observing the sun about 11:15 a.m., and at that time, the sun's rising was immediately noticeable. I continued to observe it every few minutes, in each case moving the sextant tangent screw to bring the two images of the sun just into contact at the upper limb and then observing long enough to see the two images begin to overlap.

By 12:00, the sun's rising was slowing down, but still definitely discernible. Between 12:00 and 12:09 I observed the sun nearly continuously, nudging the tangent screw on two or three occasions to move the two images back to the point of tangency. At 12:09, the sun went behind a cloud, at a time when I had just reset the images to the point of tangency. At 12:15, the sun emerged from behind the cloud, and the images distinctly overlapped. I reset the tangent screw and continued to observe the sun. After a minute or two, the sun went behind another cloud, and when it emerged at 12:22, the two images looked as if they might finally be pulling apart. By 12:25 the space between the two images was very clear. On the basis of the foregoing obsrvations, I concluded that culmination of the sun occurred at the absolute latest one or two minutes after 12:22 (i.e., 12:24) and at the earliest perhaps slightly before 12:15 (i.e., 12:14). Thus, I was able to identify with confidence a window of plus or minus 5 minutes (centered at 12:19) when culmination appeared to occur. If I had been impatient, I might have declared the sun to have finished rising possibly as early as 12:10, and if I had not kept careful note of the time, I might have estimated culmination as late as 12:24.

When did culmination in fact occur? The sun crossed the meridian at 12:12:58, since the sun's GHA at that time approximately equalled my longitude, as follows:

| | | |
|---|---|---|
| GMT | 17:12:58 | |
| GHA: | 74-11.9 | (At 1700h) |
| | 3-14.5 | (Corr. for 12m58s) |
| | 77-26.4 | |

However, the sun's culmination does not occur exactly at the moment of meridian transit if the sun's declination is increasing or decreasing. On April 3, the sun's declination was increasing by almost 1' per hour. The effect of the rate of change of declination is nominal at mid latitudes, but is significant at high latitudes (including simulated high latitudes). Table 1 shows the computed altitudes at latitude 85°48', longitude 77°26.5' for each minute from 12:05 through 12:25, showing that culmintion occurred at about 12:16:30. This was within 3m of my best estimate of culmination, and within plus or minus 7m of the widest range of times that I think I could possibly have estimated, as noted above.

TABLE 1
SUN'S ALTITUDE AT 85°48N, 77°26.5'W

| Time | Altitude | Rate of Change (" per m) |
|---|---|---|
| 12:05 | 9-42-01.9 | |
| 12:06 | 9-42-05.1 | 3.2 |
| 12.07 | 9-42-08.0 | 2.9 |
| 12:08 | 9-42-10.6 | 2.6 |
| 12:09 | 9-42-12.9 | 2.3 |
| 12:10 | 9-42-14.9 | 2.0 |
| 12:11 | 9-42-16.6 | 1.7 |
| 12:12 | 9-42-18.0 | 1.4 |
| 12:13 | 9-42-19.2 | 1.2 |
| 12:14 | 9-42-20.0 | 0.8 |
| 12:15 | 9-42-20.6 | 0.6 |
| 12:16 | 9-42-20.8 | 0.2 |
| 12.17 | 9-42-20.8 | 0.0 |
| 12.18 | 9-42-20.5 | 0.3 |
| 12.19 | 9-42-19.9 | 0.6 |
| 12:20 | 9-42-19.0 | 0.9 |
| 12:21 | 9-42-17.8 | 1.2 |
| 12:22 | 9-42-16.3 | 1.5 |
| 12:23 | 9-42-14.6 | 1.7 |
| 12:24 | 9-42-12.5 | 2.1 |
| 12:25 | 9-42-10.2 | 2.3 |

Even a plus or minus 8m error in the time of culmination would result in only a plus or minus 2° error in the determination of true north, or a plus or minus 9 n.m. left-right error. Marvin would have been confident that he had established his left right position within this degree of acccuracy.

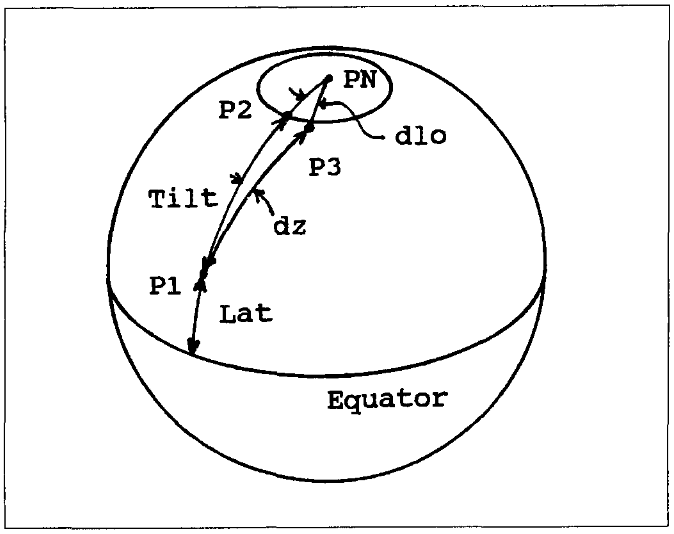



*Figure 3*

Since Marvin probably would not have known to correct for the rate of change of declination, the 3m30s delay in culmination would have caused Marvin to believe that his position was about 3.8 n.m. west of his actual position. Thus at the worst, Marvin's actual position would have ranged between a little more than 5 n.m. west to a little less than 13 n.m. east of his etimated position. Any significant drift - particularly any westward drift - would have been readily detectable by Marvin.

Looking at Table 1 gives an idea of the amount of change that was detectable. For example, the 7.7" change in the sun's altitude between 12:09 and 12:15 (15.4" of double altitude) was quite easy to observe. The 4.3" decrease from 12:15 to 12:22 was discernible, but not with confidence. I would say that a 5" change in altitude over a reasonable period (say 5 minutes) could reliably be observed. This is about double the theoretical value of 2.5", based on resolution of the human eye of about 1', a 12x magnification, and doubling the angle by use of the artificial horizon. Put another way, the time during which the rate of change of altitude is less than about 1" per minute is very difficult to perceive, and shortly after the rate slows to such low rates, rising ends; shortly after the rate picks up above such slow rates, setting is perceived.

My second experiment on April 4, 1993 replicated Bartlett's sight at 87°45'. Since Bartlett's sight was taken on April 1, the sun's altitude for his sight was fairly close to the value in my experiment. However, the sun's altitude is not particularly critical in these experiments; it is not the low altitude that makes these sights difficult (in fact, low altitudes are easier, in my experience). Instead, it is the relatively little rising or setting. This is not greatly affected by the sun's declination (and hence its altitude).

The second experiment was in some ways a learning experience. I set up the apparatus as before and began taking sights about 11:30. This time, I recorded the sextant setting from time to time. Up until about 12:10, the sun's rising was readily apparent. For about the next 10 minutes, the sun's motion was difficult to detect, but appeared to be still rising. This was puzzling, since I knew by that time the sun should be very close to culmination. I became concerned that the way I was steadying the sextant - by resting the bottom of the index arm on my left palm, since only my left elbow was low enough to rest on the chair back - was affecting the readings. By reversing the preload on the index arm I was able to convince myself that the sun was setting around 12:25. However, by 12:30, it was clear that the sun was still rising. Since I knew that this was impossible, I spent the next 20 minutes experimenting with the sextant and unable to ascertain any motion of the sun. By 12:49 it appeared that the sun had begun to set, and I quit.

Upon comparing my recorded sextant observations with calculated values, it was apparent that the sun was rising far too fast during the early phases of the experiment, and I searched for an explanation. I discovered an error in my azimuth measurement calculations that resulted in the theodolite being aimed 15' east of due south. While this did not seem like very much, a little spherical trigonometry showed that even small errors in the azimuth of the theodolite can cause a large shift in the longitude of the simulated point.

The geometry is shown in Figure 3. P1 is my actual position, P2 is the intended simulated position, and P3 is the simulated position that results when the theodolite is out of the meridian by an angle dz. If P1 is thought of as the north pole (at elevation lat1) and PN is thought of as the zenith and P3 is thought of as a subastral point of a body, then the following analogies to the celestial triangle apply: 1. tilt is analogous to the co-decliniation (90-tilt is analogous to declination); 2. dz is analogous to hour angle of the body; 3. the co-latitude of P3 is analogous to the zenith distance, and therefore latitude of P3 (lat3) is analogous to altitude of the body; and 4. the difference in longitude (dlo) between P2 and P3 is analogous to the azimuth of the body. Thus, the familiar equations for sight reduction apply, with analogous terms substituted, as follows:

sin(lat3) = cos(90-tilt)*cos(dz)*cos(lat1) +
sin(90-tilt)*sin(lat1)

cos(dlo) = sin (90-tilt)-sin(lat3)*sin(lat1))
(cos(lat3)*cos(lat1))

Applying these equations for lat1=39.1458, tilt = 48.6 and dz = .25 resulted in a simulated latitude (lat3) of 87°44' (versus 87°45') and an error in the simulated longitude (dlo) of 4.77°W. This meant that, in effect, I had to subtract 19m from all of my observed times.

With the times so corrected, my observations tracked very well against the computed altitudes for this experiment. The last point at which I noted the sun's rising (12:11 as corrected) was about 6m before the sun's actual culmination, and approximately equal to the time of the sun's meridian passage. The earliest point at which a careful observer might have declared culmination to have occurred was perhaps as much as 15 m before meridian passage.

Assuming that Bartlett was about 45 n.m west of the 70th meridian, as Wally Herbert concludes in his critical book about Peary, the time of meridian transit would have been about 1:56 (60th meridian time) on April 1. The earliest that Bartlett could reasonably have concluded that the sun had stopped rising was, in my judgment based on the foregoing, about 1:41. Peary and Bartlett could not have failed to recognize that such a result placed them far to the west of their intended track, and an approximate course correction of at least 15° to the right would be required.

Even if Peary was only about 25 n.m. west of his intended track, meridian transit would have occurred at 1:26, and the earliest that Bartlett could reasonably have concluded that the sun had culminated would have been about 1:11, showing the party to be somewhat west of the 75th meridian, justifying at least a 5° course correction for the final dash to the pole. Even a course correction of only 5° would have recovered about half of the 25 n.m. drift hypothetically assumed, permitting Peary to arrive in the very near vicinity of the pole.

On the basis of the foregoing, it appears that our previous conclusion, that Peary's navigation methods were sufficiently accurate to guide him to the very near vicinity of the pole, where final latitude sights at 6hr intervals could provide any final correction needed, has been experimentally validated. Time and weather permitting, I intend to make further observations to refine my own technique (which is probably not up to Marvin's standard) and obtain more data. In particular, my inadvertent azimuth error suggests that, in the future, I will have an assistant intentionally offset the theodolite by an unknown amount anywhere between plus or minus 15'. This will avoid any possobility of my observations being helped or hindered by knowledge of the actual time of meridian transit. I will keep readers informed.

# NAVIGATION BASICS REVIEW

## Running Fix by Calculator From an Unknown Position

*By Edward I. Matthews*

(First published in the *Proceedings of the Institute of Navigation*, June, 1979)

*The author has a BSEE from Drexel Institute of Technology and is currently engaged in the design of data processing diagnostic procedures. He is also a former member of the U.S. Power Squadrons and taught courses in that organization for six years.*

Abstract

Two celestial altitude observations from an unknown fixed position can define two equal altitude circles intersecting at two locations, one of which is the observer's position. A calculator determination of this precise position requires a six step solution of two spherical triangles. If the observer's position changes between observations, then without knowledge of latitude, the problem becomes so complex that a rigorous calculator solution is not practical. Fortunately, the observer's approximate position can be determined if the equal altitude circles intersect. Using the intersection nearest the observer for a reference, one of the circles of equal altitude is advanced or retired consistent with the course and distance made good. This new equal altitude circle will define a pseudo body whose celestial coordinates can then be determined. The advanced/retired Running Fix may then be calculated as if it were a fixed position from which altitude observations of the pseudo and a second real body were made. Theoretical analysis of the method under conditions of latitude 50 degrees, high altitudes of 88 degrees, and relative azimuths of 90 degrees indicate the error is not likely to exceed 3 miles and will probably be less than one mile for observations made within 50 miles of each other. Similar results were obtained for lower altitudes of less than 70 degrees and distances of 100 miles.

### Introduction

In the strictest sense, a celestial fix is formed at the intersection of circles of equal altitude, usually referred to as circles of position (COPs), obtained from simultaneous altitude observations of two or more celestial bodies. In practice simultaneous observations are very difficult to achieve; therefore, lines of position (LOPs) - infinite radius COPs - are adjusted (advanced or retired) along a course line to a convenient common time. If the time interval between observations does not exceed several minutes, the intersection of the adjusted lines is considered to be a Fix.

Frequently, only a single body is available for observation. At some later time, a section LOP is obtained from an observation of the same or another body. The earlier LOP can then be advanced over the course and distance travelled, allowing for current drift, to produce a running fix (R fix) at its intersection with the second LOP. The accuracy of an R fix depends on the navigator's estimation of the course actually made good. An additional error may be introduced when, for plotting convenience, straight line LOPs are used in place of COPs for higher altitude bodies. In this paper, any fix, no matter how small the time interval, will be considered an R fix.

Some modern navigators have recognized the advantage of hand held calculators in reducing sights compared with the usual sight reduction table method. Both procedures are based on St. Hilaire's altitude method and require a knowledge of the observer's approximate position. The method computes the altitude and azimuth of a body at an assumed position. The difference in the computed (hc) and observed (ho) altitude together with the azimuth (Zn) establishes an LOP. Two spherical equation solutions are required for each LOP.

(1) sin(hc)=cos(d) cos(L) cos(t) +sin(d) sin(L)

(2) $\cos(Zn)=\frac{\sin(d)-\sin(L)\ \sin(hc)}{\cos(L)\ \cos(hc)}$

The cosine form is preferred to the simpler expression

(3) sin(Zn) = cos(d) sin(t)/ cos(hc)

because it eliminates the ambiguity associated with angles greater or less than 90 degrees.

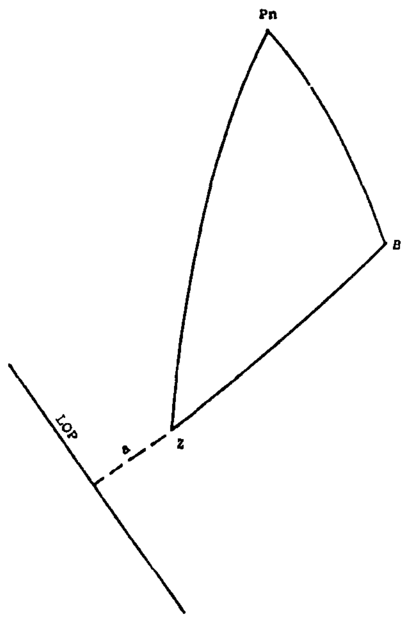



*Fig. 1 - Line of position from an assumed position at Z.*

The celestial triangle in figure 1 is formed by the north celestial pole (Pn), a celestial body B and the observer's assumed zenith (Z). PnB is the co-declination (90-declination), ZB the co-altitude of the body and PnZ is the colatitude of the assumed position. The altitude intercept (a) is the difference between the observed and computed altitudes of B. The LOP is constructed perpendicular to intercept (a). If the assumed position is reasonably close to the observer's true position, the intercept will be small enough to plot on a large scale chart. Where high altitude observations are involved, conversion of the LOP to a COP requires special plotting techniques. A desirable calculator solution would eliminate graphical solutions and require no previous position knowledge.

Numerical Solution of the Running Fix

Dozier proposed a method for a mathematical computation of a fix from simultaneous observations at an unknown position. The accuracy of this method is unaffected by the altitudes of the bodies and requires no position line plotting. The solution mathematically fixes the observer's location at one of the two possible intersections of two COPs. The ambiguity may be resolved by a visual observation of which side of the great circle connecting the bodies the observer's zenith is located relative to (Pn).

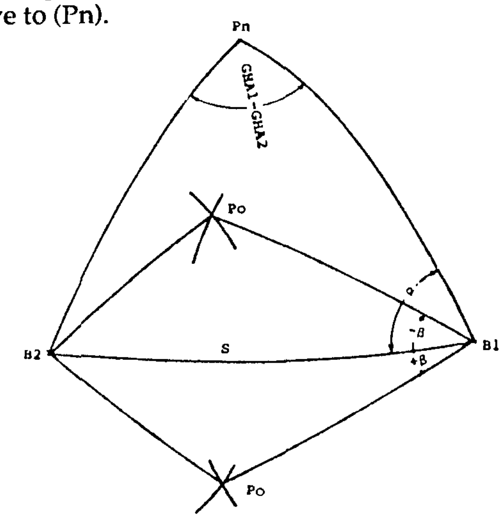



*Fig. 2 - Navigational triangle indicates two possible fixes (Po) from altitude observations of two celestial bodies.*

Referring to figure 2, S is the great circle distance between the two bodies (B1 and B2). The observer's zenith is located at one of the Po positions.

If d1, d2, GHA1 and GHA2 are the declinations and Greenwich (or sidereal) hour angles of B1 and B2, then:

(4) sin(90-S)=cos(d1)cos(d2)cos(GHA1-GHA2) +sin(d1) sin(d2)

(5) $\cos(\alpha) = \frac{\sin(d2)-\sin(d1)\ \sin(90-S)}{\cos(d1)\ \cos(90-S)}$

(6) $\cos(\beta) = \frac{\sin(h2)-\sin(h1)\ \sin(90-S)}{\cos(h1)\ \cos(90-S)}$

where h1 and h2 are the observed altitudes of B1 and B2. The sign of β is (+) if the great circle S is between the observer's zenith and Pn. Otherwise the sign is (-).

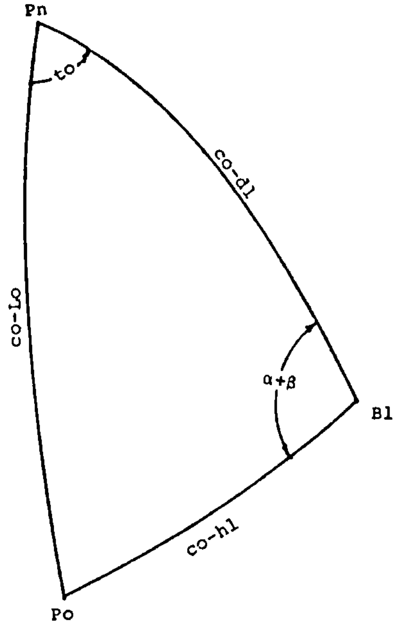



*Fig. 3 - Observer's position Po can be found by solving for Lo and to.*

In figure 3 the observer's latitude (Lo) can be determined from:

$$(7)\ \sin(Lo)=\cos(h1)\cos(d1)\cos(\alpha+\beta) + \sin(h1)\ \sin(d1)$$

and the meridian angle (to) from:

$$(8)\ \sin(to)=\cos(h1)\sin(\alpha+\beta)/\cos(Lo)$$

$$(9)\ \lambda o = GHA1 - to$$

Dozier's method is well suited to calculator solutions establishing a fix by solving six equations using only the three basic trigonometrical equation forms, (1), (2) and (3). Unfortunately, it is limited to the solution of simultaneous or fixed position observations and cannot support an R fix. Any R fix solution requires a knowledge of the observer's approximate latitude to determine the longitude difference (dλ) associated with a rhumb line course. To utilize the method we must develop a facility for accommodating a moving observer.

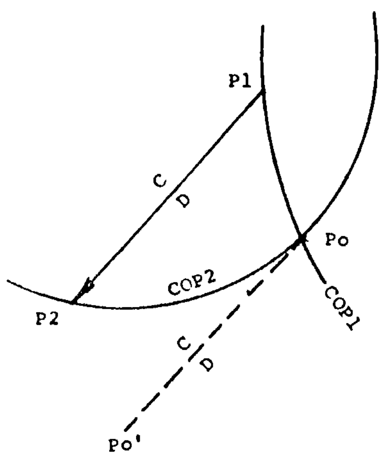



*Fig. 4 - longitude difference for P1 and P2 is approximately that of Po-Po'.*

In figure 4 assume a moving observer travels from an unknown position P1 to P2 along a rhumb line course C for a distance of D miles between observations.

If D is sufficiently small, COP1 and COP2 will intersect at some position Po which is in the general vicinity of p1. Applying Dozier's method we can then accurately determine this common position whose latitude is nearly that of P1. A rhumb line from Po to Po' using the same C and D can then be established which will have approximately the same dλ as that from P1 to P2.

The latitude difference (lo) in degrees between position Po and Po' is:

$$(10)\ lo = (D/60)\cos C$$

and the advanced latitude (Lo') is:

$$(11)\ Lo' = Lo + lo$$

To determine the advanced rhumb line longitude, it is first necessary to calculate the meridional parts for the latitude difference. Because celestial navigation solutions assume a perfectly spherical world, the Mercator meridional parts difference (m) equation for a sphere is in the simplified form:

$$(12)\ m=(180/\pi)\ \ln \frac{\tan 1/2(Lo'+90)}{\tan 1/2(lo+90)}$$

and the advanced longitude (λo') is:

$$(13)\ \lambda o' = \lambda o - m \tan C$$

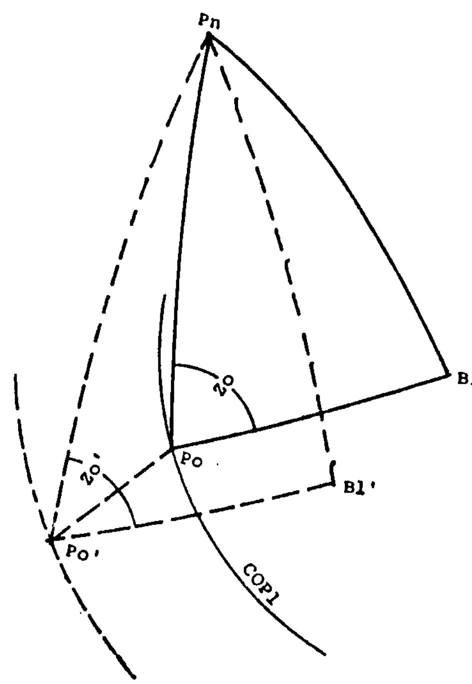



*Fig. 5 - Azimuth and altitude at Po' of pseudo body B1' are identical with those at Po.*

In figure 5, COP1 which passes through P1 and is advanced along the rhumb line to Po'. The geometry of an advanced COP will be preserved if the altitude and azimuth of Po are maintained at Po'. A pseudo celestial body B1' can be created and located so as to preserve these parameters at Po'.

In figure 6 the pseudo navigational triangle is superimposed on the initial triangle at Po. The declination (dl') and meridian angle (to') of the pseudo body can now be determined by solving triangle Pn', B1', Pn.

$$(14)\quad \sin(dl') = \cos(90-lo)\cos(dl)\cos(to) + \sin(90-lo)\sin(dl)$$

$$(15)\quad \cos(to') = \frac{\sin(dl) - \sin(90-lo)\sin(dl')}{\cos(90-lo)\cos(dl')}$$

$$(16)\quad GHA1' = to' + \lambda o'$$

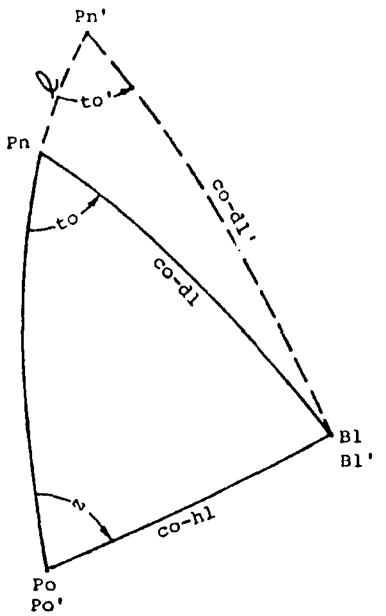



*Fig. 6 - Difference triangle Pn', B1, Pn formed from real and pseudo spherical triangles.*

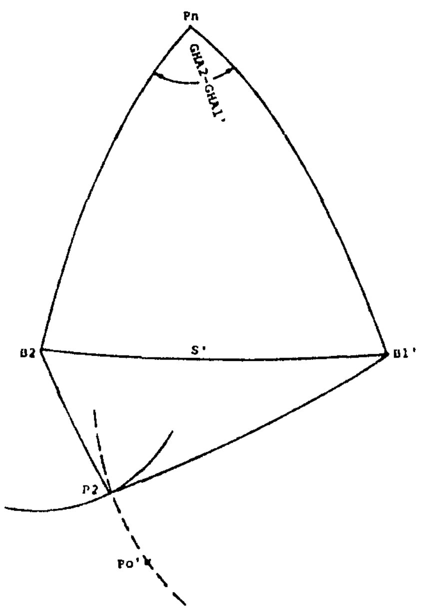



*Fig. 7 - Advanced position P2 determined from pseudo coordinates of B1' and real coordinates of B2.*

Dozier's method can again be invoked using the pseudo parameters of B1 together with the real parameters of B2 to solve for the R fix at P2.

CONCLUSION

Aside from the inherent R fix error of inaccurate course and distance over the ground estimates, the foregoing method has one error source which is attributed to the difference in latitude between the common altitude position Po and P1. If the navigator at P1 is fortunate enough to observe a body either due north or due south, then the resulting E-W COP insures that Po will be close to P1's latitude and the error will be minimal.

Test calculations at latitude 50 degrees involving altitudes of 88 degrees, distance of 50 miles and relative azimuths of 90 degrees indicate that maximum errors are not likely to exceed 3 miles while the average error is less than 1 mile. Similar results were obtained with altitudes of 70 degrees but with the distance increased to 100 miles. The tests also confirm that B1 azimuths of 0 or 180 degrees result in errors less than 0.1 mile. The complete solution requires 19 separate equations, requires no sight reduction tables or plotting and produces numerical coordinates of the adjusted position.

REFERENCES


1. Bowditch, N., "The American Practical Navigator" H.O.9, p548, 1966 Government Printing Office.

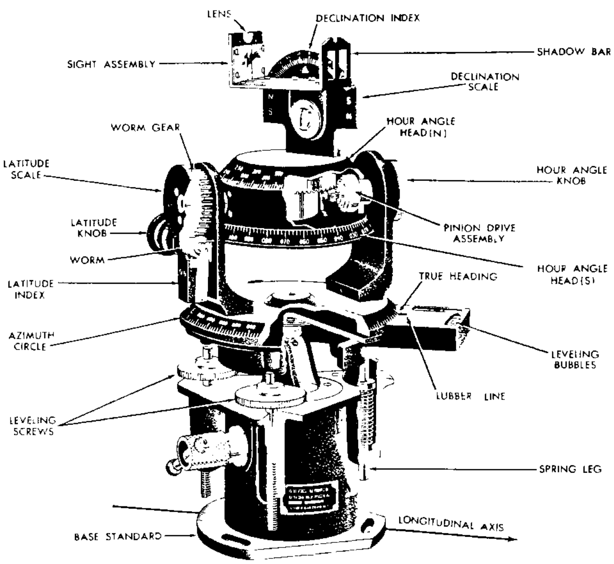

*Editor's Note: Matthews, in furnishing the copy of his article, has noted that since 1979 the calculator program has undergone several revisions. One change eliminates the meridional parts equations to conserve memory space, and also a great circle routine utilizes existing formulae with insignificant effect on the results. — R. H. Jones*

## The Astro-Compass

*By John M. Luykx*

### Introduction

The astrocompass was first developed for use in aircraft navigation to establish the true heading of the aircraft in areas where the magnetic compass was unreliable and/or in circumstances where the deviation of the compass was unknown, in error or variable. The astrocompass is basically a simple mechanical device which incorporates a sight for alignment with a celestial body and various angular scales to set or indicate a) true course or heading; b) true bearing; c) local hour angle; d) declination; and e) latitude. The main body of the compass is mounted on a base which is aligned with the fore and aft axis of the aircraft and is levelled using two spirit levels; the one oriented longitudinally, the other transversely. (See Figure 1)




*The astrocompass*

*Figure 1*

### True Heading Indication

True heading of the aircraft is correctly indicated by the astrocompass when either one of two set-up procedures are followed:

#1 Observer latitude and celestial body LHA and declination are set on the appropriate scales on the astrocompass. With the aircraft in level flight, the main body of the compass is rotated until the sight points to the celestial body. In this position the aircraft true heading is indicated on the true course scale.

#2 Observer latitude is set to 00° and celestial body azimuth and altitude (obtained by sight reduction) are set on the true bearing and declination scales respectively. With the aircraft in level flight, the main body of the compass is rotated until the sight points to the celestial body. In this position the aircraft true heading is indicated on the true course scale.

An alternative method is to set the latitude scale to 00° and to set the declination scale to the value of the observer's latitude. The true bearing scale is then set to the computed azimuth of POLARIS (obtained from the Air or Nautical Almanac) and the main body of the compass rotated until the sight points to the star Polaris. In this position the aircraft true heading is indicated on the true course dial.

### Compass Correction

The procedures described above for determining the true heading of an aircraft can be employed equally well aboard a ship or small vessel for the same purpose, i.e., to establish true heading. Setting the instrument in a gimballed mounting system will improve accuracy and utility when used at sea.

The true heading indication feature of the astrocompass is also invaluable as an aid to compass adjustment. The aircraft or vessel compass heading is compared with the true heading indicated by the astrocompass to obtain the compass error. The local variation is then applied to the compass error to obtain the deviation of the magnetic compass. Thus the astrocompass may be used both in adjusting the magnetic steering compass as well as in computing the residual deviation for inclusion in the deviation table.

### Alignment

Prior to its use in navigation, the astrocompass should be checked for proper alignment. The procedure involved includes:

1. Checking the alignment of the true heading/course scale with the base index (i.e. lubber's line of the vessel or aircraft).
2. Checking the alignment of the true bearing scale with the true heading/course scale.
3. Checking the alignment of the LHA scale with the true bearing scale.
4. Checking parallelism of the equatorial plane (latitude scale) with the horizontal plane of the instrument.
5. Checking parallelism of the declination scale with the equatorial plane (latitude scale). This check determines whether the declination scale is parallel to the latitude scale.

Note: Although there are no mechanical means to adjust for or correct errors of alignment among the various elements and scales on the astrocompass, errors of alignment should be noted and corrections mathematically or mentally applied when the instrument is used for practical navigation.

### The Astrocompass As Pelorus

Finally, the astrocompass may also be used as a pelorus to obtain either true or relative bearings to visual objects and navigation aids to fix the vessel's position in piloting waters.

1. To obtain a relative bearing:

a. The latitude scale is set to 00°.
b. North or 000 on the true heading scale is aligned with the vessel's lubber's line or fore and aft axis.
c. The declination scale is set to 00°.
d. The true bearing scale is then rotated until the sight is aligned with the visual object or navigation aid. The value of relative bearing is then read on the true bearing scale.

2. To obtain a true bearing:
a. The latitude scale is set to 00°.
b. The declination scale is set to 00°.
c. The true heading/course scale is set to the true course being steered.
d. The true bearing scale is then rotated until the sight is aligned with the visual object or navigation aid. Looking down upon the astrocompass, the sight axis will indicate true bearing on the true heading/course scale.

Note: When taking both true and relative bearings, accuracy is improved when the helmsman follows the course accurately and audibly "marks" the heading when exactly on course.

Foundation members who desire to obtain detailed descriptive and operational information on the astrocompass may obtain it by written request to the Foundation.

## The 57 Navigational Stars

*By William O. Land*

When a navigator, sextant in hand, climbs the hatchway steps from his cabin and stands on the cockpit sole to take his twilight shots he looks into the heavens and sees about 6,000 naked-eye stars. He chooses 3 stars, usually from a dozen or so navigational stars he knows so well, old friends he can find easily and confidently, takes his sextant sights and reduces them to make an easy plot and fix.

But how many navigators know anything about stars other than the 57 navigational star names and numbers, where to find them in the sky and where in the Nautical Almanac to get their S.H.A. and Declination?

To an observer the stars seem to be fixed on the inside of a vast black hollow sphere—half of it unseen beneath his feet. The observer, as he is standing on the earth, appears to be in the center of this hollow sphere, and all the stars, en masse, revolve around the earth once each day. They all rise in the east, swing around over the local meridian and then descend toward the west and disappear over the horizon. This is the same way the Sun, Moon and planets rise in the east, swing over the meridian, descend and then set in the west. The axis on which they appear to turn is the north pole - south pole axis. Since the star Polaris (the North Star) is quite near the North Celestial Pole it appears the stars use the North Star as their hub. Actually, some stars never set during the night regardless of the season of the year. These are the stars in the vicinity of the North Star. For example, to an observer at the Earth's latitude North 40°, all the stars with the declination of N50° or more will never set, and are known as the Circumpolar stars. They simply rotate around the North Celestial Pole and never touch the horizon.

The Persian poet, Omar Khayyam, in his "Rubaiyat," called this "The Bowl of Night."

The list of the 57 Navigational Stars including their S.H.A. and Declination is given on each daily page of the Nautical Almanac. This information is for the second date shown on the page, i.e. the center daily listing. Since the S.H.A. and Declination of the stars change very little day to day we can use these figures for all three days listed and still be well within the accuracy limits for sextant celestial navigation. The names of the stars may seem strange since most of them were named by the Arabs many centuries ago, and the names have stuck. In Bowditch, Volume I page 1232 (1984 edition) there is a list of these 57 navigational stars with a guide to pronunciation and the meaning of each name. For example, Deneb, star #53, means "Tail of the Hen", and Deneb is the tail star in the Swan in the constellation Cygnus. Enif, star #54 in the constellation Pegasus (the Flying Horse) means "Nose of the Horse." The star Rigel, star #11 in the constellation Orion, means "Foot."

The magnitude of a star indicates its brightness relative to other stars as seen by the naked eye. It has nothing to do with the actual size, temperature or color of the star in space. On the next to last yellow page of the Nautical Almanac (page xxxiii) the 57 navigational stars are listed both alphabetically and numerically, along with their magnitudes. At the top of each daily page the magnitude of each of the four navigational planets is listed next to their names. The higher the magnitude number, the dimmer the star! Here is how it works: Many years ago, Ptolemey, the ancient mathematician, geographer and astronomer who lived in Alexandria about the time of the reigns of the Roman Emperors Hadrian and Antonius (c.127-151 A.D.) divided the stars into magnitudes. He made all the 20 brightest stars Magnitude #1, or Stars of the First Magnitude. All the dimmest stars he could see he made Magnitude #6. Then he put the remaining stars into groups of magnitudes #2 to #5, but he did not refine it further. Since he had no telescope, these stars were all naked-eye values, and the dimmest star to be seen without a telescope is Magnitude #6. You cannot see a Magnitude #7 star with the naked eye.

In modern times we kept the magnitudes #1 to #6, but we refined it by making it a logarithmic scale. Between magnitudes #1 and #6 there are 5 divisions. We consider a first magnitude star to be 100 times brighter than a 6th magnitude star, so we take the 5th root of 100 which is 2.5118864. For practical purposes we round off the number and say a first magnitude star is 2.5 times brighter than a second magnitude star, and a second magnitude star is 2.5 times brighter than a third magnitude star, etc.

By naked-eye it is difficult to distinguish the exact magnitude of a star. Astronomers use photometers to get the exact magnitude, and for scientific purposes they do not round off the figures.

For our navigational purposes we can get the magnitude in the alphabetical list on yellow page xxxiii in the N.A. It is given to 0.1 of a magnitude. The very brightest star in the sky is Sirius #18, magnitude -1.6. Negative magnitudes are needed because some stars are found to be brighter then mag. 1. These were designated 0(zero) or lower. For example, Arcturus #37 is mag. 0.2, and Procyon #20 is mag. 0.5. Canopus #17 is mag. -0.9. A good rule of thumb to follow is: "The higher the number, the dimmer the star. The lower the number, the brighter the star." This method was introduced by an astronomer named Pogson in 1850 and is now standard all over the world.

Notice that Betelguese #16 is listed as "Variable" magnitude since it is a very large ball of glowing gas 244,000,000 miles is diameter slowly cooling off, and in its death throes pulsates and varies in magnitude from 0.1 to 1.2. But we will not have to worry about it because astronomers assure us it will be countless eons before it explodes or collapses. We are told that the diameter of the orbit of the Earth around the Sun is about 185,000,000 miles, thus the Earth in orbit could be entirely contained within the diameter of Betelgeuse with room to spare!

We can see stars as dim as mag. 22 with the 200 inch telescope at Mt. Palamar. Most sextants have telescopes of about 4-power, with a one inch diameter lens, so we can see stars down to a magnitude of about 9, even though the dimmest navigational star is Acamar #7, with a magnitude of 3.1. The Moon is mag. -12.6, and the Sun is mag. -26.7. On the daily pages of the N.A. the 4 navigational planets are listed and their magnitudes are shown next to their names. These magnitudes vary from day to day and year to year because we see the planets only by the reflected light of the Sun, and sometimes a planet is close to the Earth and sometimes as far away from us as the other side of the Sun. However, planets are very bright compared to the stars, and the four navigational planets, Venus, Mars, Jupiter and Saturn will often have magnitudes in the minus (-) range. Venus is the brightest planet and has phases just like the Moon, and can be crescent or gibbous if you look at it with a telescope of about 30 power or higher. Sometimes Venus can be seen with binoculars in the daytime if you know where to look for it in the sky.

In addition to the 57 navigational stars listed on pages 268 to 274 of the N.A. there is a list of 116 more stars that can be used for sextant sights. The best way to explain this list is to begin at the top of page 268. Let's begin with the second listed. The magnitude is 2.6 and the star is alpha Pegasi, star #57. Now look at the top of page 269, second star from the top. The magnitude is 2.6 and the star is Markab, star #57. What we have here is a duplicate list on two pages. The left-hand page lists the stars by names the astronomers give them, and the right-hand page stars by the name navigators give them. They are the same stars, just different names. To explain how the astronomers names are used, we must first understand that astronomers have divided the entire heavens into 86 areas called constellations, each with a name. The divisions are quite unequal in area, and very irregular in outline. Each constellation contains hundreds, even thousands of stars, but only the half-dozen or so bright stars within the constellation area comprise the picture or diagram for which it is named. Bowditch (1984 Ed.) pages 1233-4 lists all constellations and includes much additional information. One of the best books to explain and chart the outlines of the constellations is "Norton's Star Atlas" published by Sky Publishing Co., 49 Bay State Road, Cambridge MA 02138, ISBN Number: 0-85248-900-5. In addition to a very excellent text, there are 16 full-page maps of all 6,000 naked-eye stars magnitude -1 to 6 inclusive.

For the star Markab #57, the constellation is Pegasus, the Winged Horse of mythology. The constellation Pegasus contains hundreds of stars, but only about 12 of the brightest stars in the Pegasus area make up the outline of the horse with which we are all familiar. The brightest star in Pegasus is Markab #57, mag. 2.6. The astronomers call it alpha Pegasi. The name Pegasus is changed to the Latin Genitive case when we put a Greek letter in front of it. Navigators call it Markab and astronomers call it alpha Pegasi. The next star in the list is beta Pegasi because it is the second brightest star in the constellation Pegasus, but beta Pegasi was not chosen as one of the 57 navigational stars. However, epsilon Pegasi #54 is on the list, and navigators call it Enif. The 57 navigational stars were selected with two objects in mind. First, the brightest were selected. Secondly, the stars selected should be as evenly distributed as possible over the entire expanse of the heavens so that a navigator, no matter he is on the surface of the Earth or what time of year it is, should see at least a dozen or more navigational stars available for him to use. So if it were Spring, Summer, Fall or Winter, Northern, Southern, Eastern or Western Hemispheres, the navigator will have a good choice of stars listed in the daily pages. In some cases a bright star in one area was omitted because another bright star was close to it, and a less bright star chosen in some other part of the heavens where there was a scarcity of stars.

An example are the stars Castor and Polux in the constellation Gemini. Pollux, beta Geminorum, star #21, S.H.A. 243°, mag. 1.2 is a navigational star. Castor, alpha Geminorum, S.H.A. 256, mag. 1.2 is not because they are so close together.

If you go down the list of stars beginning on page 269 you will find all 57 navigational stars listed by name and number, with additional stars listed in between them.

The S.H.A. and Declination values for all 173 stars are given for each month across both pages to and including page 273. In celestial navigation it is not necessary to limit ourselves to only the 57 stars for our sextant shots. We may use any star if we know the S.H.A. and Declination.

We in the Northern Hemisphere are very lucky to have the North Star, Polaris, almost, but not quite directly over the Celestial North Pole. It is at S.H.A. 323° and Declination N89°-14.0', only 000°46.0' south of the Celestial North Pole. It is possible for a navigator to take a sextant shot of Polaris and read his North Latitude directly from the sextant scale, and after making the apparent altitude, I.C. and dip corrections he would not be more than a maximum of 46 miles in error North or South of his correct Northern Latitude. There are correction tables in the N.A., pages 274 to 276 to remove the 000°46.0' error. The North Star is not one of the 57 navigational stars. However, if the navigator takes a sextant shot of it and reduces it to get his latitude, he can draw an L.O.P. of Polaris at the latitude on the VPOS Universal Plotting Sheet, and make this latitude one of the L.O.P.'s for a three-star fix. Unfortunately, there is no star bright enough or close enough to the Geographic South Pole to be called the "South Star."

Astronomers have a term "Absolute Magnitude." This is the relative brightness or magnitude of each star if all stars were the same equal distance from us. Another way to say it would be the actual brightness of a star with no other factors considered. But some dim stars are close to us and look bright, and some bright stars are far away from us and look dim, so we can be fooled as to their absolute magnitude. But magnitude to the sailor or navigator means star brightness relative to the brightness of the other visible stars as seen by the naked eye. So we as navigators do not bother with absolute brightness. Even the largest telescopes cannot resolve a star into a disc. All stars appear simply as points of light regardless of the amount of magnification with our present telescopes. This is because the stars are so very far away from us. Planets can be resolved into discs and then enlarged to actually see their features. But stars continue to be simply points of light, some brighter than others. Astronomers can determine the elements contained in these points of light by the use of spectral analysis, and have been doing so for years. They determine the diameter of stars by studying the mass of the star and its gravitational pull on other stars. Double stars, or binaries, are two stars so close together that their gravities attract each other, and as a result they revolve around each other at a common center of gravity. To the naked eye they appear as a single star, but with a telescope of sufficient magnification they can be resolved into separate stars, and over a long period of time determine their angular velocity as they revolve around each other. About a third of all stars in the heavens are double stars. This means that when seen with a telescope the single naked-eye star appears to be two stars relatively close to each other. This is explained because one of the stars is farther out into space and seems to be almost behind the closer one. This is not a true binary, only a double star. Since a pair of binaries are usually of different sizes and mass, or density, their gravities are different, and the star with the greater gravity pulls some of the mass or materials from the star of lesser gravity. Thus the greater increases its own density or mass at the expense of the lesser one. Some of the 57 navigational stars known to be binaries or double stars are Rigil Kentaurus #38, Vega #49, Antares #42.

The Milky Way looks the way it does because we are inside a flat disc. This disc is called a galaxy, and it contains so many uncountable stars, and they are so far away that it looks like a milky cloud, hence the name, Milky Way. The individual stars we see in the heavens are just the closer ones. It wasn't until Galileo pointed his telescope at the Milky Way that he discovered that it is made up of millions upon millions of individual stars like our Sun, but so far away they simply blend into a white haze to our eyes. It wasn't until early this century that astronomers could prove that the Milky Way was a galaxy and that the Earth was a satellite of a rather minor star called the Sun, located about 2/3 of the way out from the center. The center of the galaxy is located about 30,000 light years from the Sun in the direction of a point located about 7° north of the star Shaula, #45 in the constellation Scorpius. The Center of the plane of the Milky Way is right through the center of the densest part. If you follow the path of the Milky Way in the sky as it winds through the stars you will find it makes a complete circle in the sky, but you must follow it through all 4 seasons of the year.

What about the Zodiac? The term is related to our word "Zoo", a place where they keep wild animals for the public to visit. "Zodiac" means "Parade of the Animals," and seemingly like a parade around the Ecliptic (the apparent path of the Sun through the heavens) are the twelve constellations of the Zodiac. Eleven are animals. Only one, Libra the Scales (or the Balances) is not animal. But if you imagine a lady is holding the scales then they are all animal. Some of the navigational stars are in it, but the Zodiac has no meaning to navigation or astronomy, as such. It was devised by the ancients and still is with us today even though it is not used in navigation. We find, for example, Pollux #21 in Gemini, Aldebaran #10 in Taurus, Hamal #6 in Aries, Antares #42 in Scorpius, Zubenelgenubi #39 in Libra, Spica #33 in Virgo, Regulus #26 in Leo. Each of the 12 Zodiac constellations are approximately 15° apart on the Ecliptic, and twelve times 15° equals 360° which completes the circle.

Sometimes the question arises, "There is a constellation named 'Aries' the Ram. There is also a term "Aries", also known as the 'First Point of Aries', but the First Point of

Aries is in the constellation Pisces, the Fish. Explain it." Yes. Many years ago, 2,000 or more, the ancient star gazers needed a "0" point in the sky from which all stars and planets could be measured in the East-West direction. They decided that the point on the celestial equator where the ecliptic (the path of the Sun) crossed is in the spring of the year would be the "0" or zero point. Two thousand years ago the Sun crossed the equator from the southern hemisphere to the northern hemisphere around the 21st of March, and the point where it crossed was within the boundaries of the constellation Aries the Ram. So it was called "The First Point of Aries," and a meridian drawn from the North Pole to the South Pole through this First Point of Aries is called the "Equinoctial Colure." It is the 000°00.0' line in the sky, just as the Greenwich meridian is the 000°00.0' point on the surface of the earth. For the East-West measurements it determines the Sidereal Hour Angle (S.H.A.) for navigators and the Right Ascension for astronomers. Once each day, every 24 hours, the Equinoctial Colure passes over the Greenwich Meridian because the earth turns on its axis. But the star gazers of 2,000 years ago did not know of something called "Precession", in which all the stars in the sky, as a unit, make one revolution around the earth once every 25,800 years. This means the First Point of Aries moves westward on the ecliptic 17/th of a second of arc every day. And so in a couple of thousand years the First Point of Aries moved out of the constellation Aries and into the constellation Pisces, the Fish. In a few more centuries it will move from Pisces into the constellation Aquarius, the Water Bearer. However, it is still called The First Point of Aries no matter what constellation it happens to be in. But we must not concern ourselves with this movement because astronomers and the people at the U.S. Naval Observatory who prepare the Nautical Almanac constantly adjust the S.H.A. and the Declination figures of the navigational stars for us.

To check on this, let us see how much a star has moved in one year. Let us take the star Denebola #28 and check it out in the 1994 N.A. In the January 1, 1994 daily page, in the star column Denebola reads: January 1, 1994 Denebola S.H.A. 182°48.4, Declination N14°36.1. A year later, December 31, 1994 S.H.A.

| | | |
|---|---|---|
| | 182°47.7, | Declination N14°35.8 |
| Motion in 1 year: | 0°00.7' | 00°00.3' |

This isn't much, but it has moved, and the correction is not only for precession but for any other movement the star makes relative to the First Point of Aries and the Celestial Equator.

The term "Fixed Stars" as we see above if not exactly true. They move, but ever so slowly, so that in a person's lifetime we never notice the difference. But as navigators, isn't it comforting to know that even the smallest iota of a correction is made for us in the Almanac tables?

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

DISCONTINUE WATCHKEEPING OF DISTRESS FREQUENCY 500 KHZ

Effective August 1, 1992, all United States Coast Guard communication stations and cutters will discontinue watchkeeping on the distress frequency 500 kHz, and will cease all morse code services in the medium frequency radiotelegraphy band. More efficient telecommunication systems are now available to provide the mariner with options for initiating or relaying distress alerts, and passing and receiving maritime safety information. These options include INMARSAT, radio telex (SITOR), MF/HF single sideband and VHF radiotelephone, satellite EPIRBs (for distress alerts and telecommunications), and INMARSAT Safetynet, NAVTEX and HF NAVTEX (SITOR) (for maritime safety information broadcasts). NAVTEX broadcasts include the same Notice to Mariners, weather, search and rescue and fixed fishing gear location products that have been provided by the MF morse broadcasts. Distress and other calls to any U.S. Coast Guard communication station can also be made on any of the following HF single sideband radiotelephone channels: 424(4134kHz), 601(6200 kHz), 816(8240 kHz), or 1205(12242 kHz). Meteorological broadcasts are also made on these channels. We believe these options provide sufficient redundancy to ensure that adequate distress and safety communication capabilities are available. Questions or comments regarding this discontinuance of MF morse telegraphy services can be sent to any Coast Guard communications station or direct to U.S. Coast Guard Headquarters:

COMMANDANT(G-TTM)
U.S. Coast Guard
Washington, DC 20593
TELEX 892427 (COASTGUARDWSH)
TELEFAX:(202)267-4106 or 267-4662

NAVTEX COMMENCEMENT

Commencing 1 August 1993, NAVTEX service of Maritime Safety Information (MSI) broadcasts under the Worldwide Navigational Warning Service will be operational worldwide. For a listing of stations, schedule times and types of information provided consult DMA Publication 117, Radio Navigational Aids. These internationally coordinated broadcasts on medium frequency 518 kHz will provide mariners with distress, urgent and safety messages, and weather forecasts and warnings.

The coverage of NAVTEX will be reasonably continuous out to 200 nautical miles from the transmitting station. In the U.S., the Coast Guard is the responsible Agency for NAVTEX operation.

The U.S. NAVTEX area of coverage will reduce the number of NAVAREA IV and XII messages sent out by DMA, since most of these warnings fall within the 200 nautical mile limit. It is estimated that NAVAREA IV and XII traffic will be reduced by more than half. NAVAREA IV and XII traffic will also be used to cover gaps in U.S. NAVTEX coverage and to allow for messages that traverse the 200 nautical mile border so as to provide full MSI coverage in these two areas. In addition, the Coast Guard will forward to DMA those NAVTEX messages that are within the 200 nautical mile limit, but which are significant enough that they should be sent by NAVAREA broadcast as well (as an example, a closure of a port).

# HISTORY OF NAVIGATION

## The Fleuriais Gyroscopic Sextant

*By John M. Luykx*

In an article in Issue #26 of the *Navigator's Newsletter* (Fall issue 1990), mention was made of the gyro-stabilized artificial horizon sextant designed by Captain G. E. Fleuriais of the French Navy in 1886. The article entitled "The Artificial Horizon Sextant" contained a discussion of the early history of artificial horizon instruments and included a brief description of the unusual Fleuriais design. This sextant was the first gyro type artificial horizon design developed for practical navigational use at sea since John Sersoin's "Whirling Top" with horizontal speculum developed almost a century and a half previously. (See Figure 1)

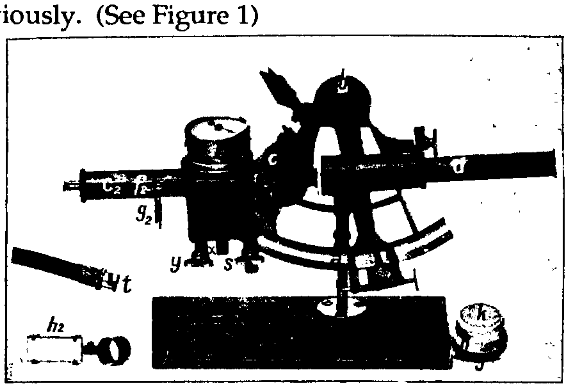


*Figure 1*

A small air-driven gyro designed by Captain Fleuriais was installed forward of the horizon mirror of the sextant and was activated by a hand-operated air pump similar to the modern bicycle pump. From the time of initial "blow-up" it took about five or six minutes for the gyro to erect and level off. During this operation the observer was required to hold the sextant upright and relatively steady. At the outset the gyro rotated at about 2500 rpm in an evacuated chamber and "coasted" (wound down) for a period of twenty to thirty minutes.

It was during the first ten to fifteen minutes after settling down that the gyro was usable as an artificial horizon and that accurate observations could be made with the sextant.

In August 1886 sea-borne accuracy tests of the sextant were conducted in Toulon harbor and in the Mediterranean by the French Navy. Initial results were poor because the observers selected to conduct the test were completely unfamiliar with the Fleuriais instrument. The mean range of observation error during initial tests was in the order of 15' to 30'. After a week of further testing in Toulon harbor, the range of observational error fell to about 0' to 10' for a series of six observations of the sun. Further improvement was experienced during the following weeks. By the end of September, with increased observational experience, the range of error of observations taken at Toulon of both Polaris and the sun was reduced to as low as 2' to 3' for a series of eight observations.

Although tests of the Fleuriais gyroscopic horizon in heavy seas were not as successful as those conducted at Toulon that year (again due primarily to observer inexperience) further sea tests were scheduled on board French naval vessels enroute from the Mediterranean to the Orient. Many hundreds of official government tests were conducted by the French Navy between 1890 and 1905.

During the last decade of the nineteenth century a number of improvements to the design of the sextant were incorporated by the various manufacturers of the sextant and literally thousands of observations were taken with Fleuriais instruments during this period. The results of these observations taken by merchant navy observers on board vessels of the Compagnie Generale Transatlantique (CGT) as well as those taken by naval officers, indicate that significant improvements in accuracy were achieved; the mean error of all observations recorded being less than 4 minutes of arc. These results demonstrated the accuracy of this sextant and highlighted the quality and efficiency of this instrument for navigation at night and during periods when the natural sea horizon is not visible.

In April 1907 an unusual although unofficial test of the Fleuriais sextant was conducted in the air in a balloon during a night ascension and flight from Brussels to Mezieres in Belgium. Five observations were taken during the night between 9 PM and 4:15 AM by two observers embarked in the balloon "Aero Club IV" of the

Belgian Areo Club on the night of 27-28 April. To fix position in flight observations were taken of Polaris to obtain the latitude and of another star to determine longitude. During the night five two star observations were made using Polaris and either Arcturus or Regulus. The mean error of position from the five sets of observations was approximately seven miles.

The Fleuriais sextant (especially models manufactured after the turn of the century by the firm Ponthus et Therrode) enjoyed wide popularity, especially in Europe. Admiral Sims, Chief of U.S. Naval forces in Europe during the first World War, personally tested one of the Fleuriais sextants while in France and collected data on this instrument as a possible source of information for the U.S. development of a similar instrument.

In 1928 LCDR (later Captain) P.V.H. Weems serving in USS Cuyama, became interested in the Fleuriais sextant and obtained a copy of the data collected by Admiral Sims. In a letter to the U.S. Navy Bureau of Navigation dated 10 August 1928, LCDR Weems wrote:

"Since the principle of the Fleuriais sextant gets away from the bubble principle altogether, it is believed that this principle might be used to advantage in the development of a sextant for night observations aboard ship and under some conditions for aerial navigation. This data is submitted with the hope that it will aid in the development of an accurate sextant for night use."

Captain Weems' letter of 1928 was prophetic. It would be not until thirty years later in 1960 that Mr. G. D. Dunlap, then President of Weems System of Navigation, would design a sextant based on the Fleuriais principle and submit it to the U.S. Navy for testing.

However, in the meantime, it was the firm C. Plath of Hamburg which realized the significance of Captain Fleuriais' sextant and gyroscopic artificial horizon for night navigation. It was the Fleuriais sextant design which the Plath firm used as the basis for its famous SOLD gyro sextant used with success aboard German submarines in the later years, 1944-45, of World War II.

The C. Plath modification to the Fleuriais sextant lay primarily in the addition of a unique roller integrator averager mechanism whereby continuous night observations of stars and planets taken from a submarine conning tower could be averaged over a period of one to three minutes.

# NAVIGATION NOTES

## A Navigation Problem

*By Roger H. Jones*

Problem No. 40, Answer

Altitude correction number one, for index error, is individual. It varies with the sextant used, and its current state of adjustment. It will be a plus or minus value. If, upon setting the instrument index to zero exactly, a further small setting adjustment of the micrometer drum screw is necessary in order to make the horizon appear as an uninterrupted straight line, the direction of that further adjustment away from the exact zero setting will determine if the index error correction is plus or minus. If the screw must be turned to a setting of, say, 2.5 minutes of altitude in order to make the horizon appear as a straight line, the error is said to be "on the arc" and it must be subtracted as a minus value for all bodies then observed. Why - because the observation starts not from a reference of zero, but from plus 2.5 minutes. Thus, a body whose altitude measures as 48-2.5, has an altitude of 48-00.0 when the index error correction is made. Conversely, if the error is "off the arc" and the starting reference is zero less 2.5 minutes, it must be added to all observations.

Correction number two, for height of eye, is the so-called dip correction. The navigator's eye is always some distance above the surface of the water; perhaps four feet in a row boat, and 40 feet on the bridge of a freighter. Thus, he observes the horizon from an elevation above sea level, and he is therefore looking "down" beyond the true horizon he would see if his eye was at sea level. The horizon has appeared to "dip" with the curvature of the Earth, and thus the dip correction is always a negative value for all bodies. It must be subtracted from the observed value, and the higher the eye is above the sea level, the greater will be the negative dip correction.

Corrections three, four and five are for refraction, semidiameter, and parallax respectively. They are combined in the Almanac into one correction. Refraction is always a negative correction. Ignoring the precision of science, a ray of light speeding through space encounters no deviating influences until it enters the Earth's atmosphere. The Earth's atmosphere is curved, just as is the Earth's surface, and thus if one conceives of a ray of light as having a thickness, the lower edge hits the curve of the atmosphere before he upper edge does. For an instant in time, the upper edge appears to wheel around the lower edge until it too enters the atmosphere, and thus the direction of the ray appears to be changed. To a person within the atmosphere, the celestial body will appear to be higher than it is, and the lower the altitude the greater the refraction. For all bodies a minus correction is applied.

Semi-diameter is the big one. For stars and planets there is no appreciable difference between the center, the top, and the bottom of the point of light. For the sun and moon there is a very appreciable difference. It is impractical to visually pinpoint the center of the disc, so the observer measures the altitude of either the bottom or the top of the disc above the horizon. If he observes the lower limb of the sun or moon, the resultant altitude is lower than it would have been had the center of the disc been observed. Thus, for lower limbs the observation must be corrected by adding back the value of the semi-diameter or radius of the disc, and for upper limb shots it must be corrected by a minus value of the semi-diameter.

Finally, there is the correction for parallax which applies to the Moon, the Sun, Mars and Venus. These are the bodies that are relatively close to the Earth, and in terms of which the apparent altitude as seen from the ideal center of the Earth would be different from the altitude as measured from the surface of the Earth. The surface of the Earth is some 3,438 nautical miles from the center. To an observer on the surface, a Moon which appeared to split the horizon would have an altitude of zero. To one sweltering on a slag at the center of the Earth, it would appear to have appreciable altitude, since he, too, is looking straight out horizontally from the center of the Earth. Thus, when applicable, the parallax correction is always a plus value.

To recap: index error depends on the sextant used and involves either a plus or minus correction; height of eye involves a negative correction for all bodies; refraction involves a negative or minus correction for all bodies; for the Sun and Moon a lower limb sight involves a plus correction and a minus correction for an upper limb sight; and for the Sun, Moon, Venus and Mars, there is, when applicable, always a plus correction.

Question No. 41.

With this question we come to the natural end of the series of questions that have dealt with the theory of celestial navigation expressed in layman's common sense terms, and which have focused upon a process of the reader simply forming a mental image in his or her own mind as opposed to the earlier questions that required, most often, use of the *Almanac* and sight reduction tables to work up the solution to a hypothetical problem. In the course of the many preceding issues, we have taken a journey around the world and we have investigated many problems in emergency navigation techniques as well as the routine procedure for the many different types of celestial problems. This more recent series of problems illustrating the underlying theory in layman's terms may, in a future issue, be restated in an integrated, concise article format. Meanwhile, the one remaining question is:

Can you form your own mental image that will easily resolve for you the question, when crossing the International Date Line, of whether you lose a day or gain a day?

# NAVIGATION PERSONALITIES

## Abel Janszoon Tasman

*By Roger H. Jones*

Abel Tasman was born in the Dutch village of Lutjegast in 1603, although there is some question as to the exact date of his birth. He was the greatest of the Dutch navigators and explorers, and his discoveries included Van Diemen's Land (so named by Tasman, and now known as Tasmania), New Zealand, Tonga, and the Fiji Islands.

He entered the service of the Dutch East India Company in 1632 and made his first voyage in the company's behalf to Ceram Island in Indonesia as captain of the "Mocha" in 1634. He sailed again in 1639 under the command of Mathijs Hendickszoon Quast on an expedition in search of the "islands of gold and silver" in the seas east of Japan.

After a series of trading voyages to Japan, Formosa, Cambodia and Sumatra, he was chosen by the Governor General of the Dutch East India Company to command the most ambitious of all the Dutch voyages for exploration of the Southern Hemisphere. By 1642 Dutch navigators had sailed along discontinuous stretches of the western coast of Australia, but whether this land was connected to the hypothetical Southern Continent remained unknown. Tasman was to resolve the mystery.

Leaving Batavia (Jakarta) on August 14, 1642 with two ships, "Heemskerk" and "Zeehaen", Tasman sailed to Mauritius, then southward and eastward, reaching latitude 49 South at about longitude 94 East. He turned north and discovered Van Diemen's Land on November 24th and he skirted its southern shores. A council of officers decided against further investigation, so Tasman failed to discover the Bass Strait between Tasmania and Australia.

He turned eastward, and on December 13th sighted the coast of the South Island of New Zealand. Sailing northward, he explored its western coast, and he entered the strait between the North and the South Island, supposing it to be a vast bay. He then left New Zealand waters on January 4, 1643, at North Cap under the impression that he had probably discovered the west coast of the great Southern Continent, which was envisioned as possibly being connected to Staten Land (his name for New Zealand). While on the coast of New Zealand, a landing was attempted at Golden Bay (called Massacre Bay by Tasman), and four of the men were killed by Maoris. Only six others died of illness during his ten-month voyage.

After leaving New Zealand, Tasman turned to the northeast with the notion that a passage to Chile could be discovered. Instead, he discovered Tonga on January 21, 1643, and the Fiji Islands on February 6th. Then, turning to the northwest, the ships reached New Guinea on April 1st, and Batavia on June 14th. Without himself realizing it, Tasman had circumnavigated Australia, proving that it was not a part of the great Southern Polar Continent. He did not then know that New Zealand was also not connected to the Southern Continent.

Despite his great discoveries, the East India Company felt he had been less than diligent. The Company sent him again in 1644 to try to establish the connections or relationships between New Guinea, western Australia (which was then the "Great Known South Land"), Van Diemen's Land, and the unknown South Land. He sailed from Batavia on February 29, 1644 and entered he Torres Strait. He mistook this for a great bay. It had earlier been discovered in 1606 by the Spaniard, Luis Vaez de Torres, but its existence was kept secret until 1674. Ultimately, he sailed to a point at 22 South, but he had still failed to establish the true configuration of the Southern Continent. Nevertheless he was made a member of the Council of Justice of Batavia, and in 1647 he commanded a trading fleet to Siam. Then, in 1648 he led a war fleet against the Spanish in the Philippines, and shortly thereafter he left the Dutch East India Company.

The circumstances and date of his death at Batavia are not known with full certainty. It is believed that he died early in 1659, while some scholars have settled on a time of his death in the summer or early fall of 1661.

That Tasman was a superb navigator and seaman is without question. Without charts and any reliably fast method of sounding depths, he managed his command in a safe and yet bold manner. Based upon his findings, later navigators realized that other than Australia itself and the Polar Continent there was no great Southern Continent "balancing" the land mass in the more widely known northern hemisphere. He sailed some of the roughest and most hazardous waters of the Indian and Pacific Oceans. When it is realized that Cook was only the second European to navigate the Torres Strait, knowing what it truly was, many years later, the failure of Tasman to realize the stupendous truth about New Zealand and Australia can be put in its proper light. Like his predecessors, Columbus, Vespucci, Magellan and others, Tasman was a truly great navigator who opened the way to many followers of no less courage and imagination.

# BOOK REVIEW

*By Roger H. Jones*

## Learn to Navigate by the Tutorial System Developed at Harvard

By Charles A. Whitney and
Frances W. Wright
Cornell Maritime Press, Inc.
Centreville, Maryland 21617 (1992)
317 pages; $24.95

While this new book was first published in October of 1992, the review copy did not reach this reviewer until very recently, just before, but not in time for inclusion in, the last issue of the *Newsletter*. We are once again indebted to and very glad to have from the Cornell Maritime Press this latest and very interesting contribution to the important educational texts on navigation. Indeed, this is a full compendium of navigation topics, including coastwise navigation topics in eleven initial chapters, followed by a most complete section on celestial navigation presented in Chapters 12 through 23. There are also seven appendices, several of which are unusual in the sense that most other texts do not present the information which they contain. They will be mentioned in due course.

In 1942 the Harvard College Observatory offered to provide in-depth training in navigation to the branches of the united States armed forces. Professor of Astronomy Bart Bok gave the lectures, and Frances Wright ran laboratory sections in which the students applied the ideas developed in the lectures. More than one subsequent letter attested to the lives saved by the techniques that had been learned from Bok and Wright, whose book, *Basic Marine Navigation,* was first published in 1944, followed by a second edition in 1952.

After the War, Wright continued to offer courses to Harvard students, and she published three books of her own: *Celestial Navigation* (1969), *Particularized Navigation* (1973) on emergency techniques, and *Coastwise Navigation* (1980) on piloting techniques. In 1988, after more than 45 years of teaching, Dr. Wright turned the teaching of the course over to Charles A. Whitney, who carried on until his retirement from Harvard two years later. Dr. Wright passed away while this book was in preparation, and proceeds from its sale will go to the Frances W. Wright Navigation Fund at Harvard University.

*Learn to Navigate* thus has a solid background of more than fifty years of academic and also practical development underscored by the urgency of global warfare. It is more than a compendium of what has come before, however. It retains the flavor of the earlier books, with their emphasis on practice and on eternal vigilance, and it adds many new exercises and illustrations, improved sight-reduction forms, and information on useful shortcuts for performing various navigational tasks. In short, it is a thoroughly up-to-date and most complete text, by seasoned experts, the core of which has been tested by United States servicemen ad women under real conditions where accurate navigation was an absolute necessity. In a single inch-thick format, this is a virtual encyclopedia. There is not space here to adequately describe each chapter. Suffice it to say that before launching into celestial topics, it deals with every conceivable building block of knowledge from estimating distances and angles to practical understanding of charts to true and relative bearings, and to a host of other coastwise topics, including use of the sextant in piloting, and over thirty other sub-chapter topics. The mariner who has room for but one text aboard would do well indeed to consider this book, not only for its completeness but also for its clarity and its anticipation of the needs of the student, from novice to master.

In recent years the new publications have taken much of the confusion out of the earlier diagrams and illustrations of *Bowditch* and *Duttons*. This new book builds on the teaching lessons learned, and its illustrations are among the most useful and easy to grasp of any seen by this reviewer (who has read and reviewed more than 75 books on every aspect of navigation). They are numerous, but they are presented in a series, each of which seems to foster understanding of the next. They are not cluttered with too much information crammed into any one illustration.

The celestial section is itself most complete and up-to-date. Again, there are topics and sub-topics covered that are not found in many of the classic texts, including reducing a noon sight with an Analemma and Polynesian steering by the risings and settings of the stars. One who has never studied celestial could realistically undertake that purpose by himself using this Harvard tutorial text.

Among the appendices are several which are uncommon, either in terms of format or in terms of the fact that they are included to begin with. Thus, there is a Running Fix Table, which in half a page will present much of the information contained in several pages of the Bowditch Distance Off tables. There is a unique, single-page chart-like table of all of the navigational coordinates, their symbols, the reference from which measurements are made, the units of measurement, the practical precision, and many other bits of information. There is even a comparative description of the *Nautical Almanac*, *Reed's Nautical Almanac and Coast Pilot*, and *Eldridge's Almanac*. The complete listing and description of the various sections of each of these three publications is presented.

Finally, there is a section that presents the answers to the many text questions, and these questions are more than esoteric. These are the teaching exercises that are practical, fun, and aimed at the real-world student, and many of the questions call for answers in layman's terms rather than tedious end-results of mathematical procedures.

All in all, it is a remarkable book. It is a remarkable addition to the long shelves of previous books on the subject of navigation. It finds the interesting and more relevant ways to present the basic theory. It is obviously the effort of teachers who have spent years observing the responses of students and their needs for understandable information. It is indeed a fine testament to the late Dr. Wright, to Charles Whitney, and also to the many teaching and laboratory assistants whose more silent hands have seasoned and nurtured this end-product in the halls of Harvard and the Hayden Planetarium of the Boston Museum of Science.

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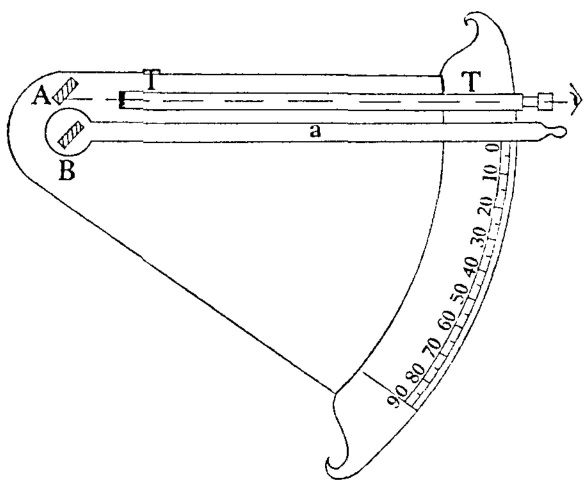
Answer to DO YOU KNOW . . . ?
(from page 1)

Sir Isaac Newton. Although his instrument was probably devised some years before, he presented a paper and the instrument to the Royal Society in 1699. It was designed for lunar distances and consequently was unequipped with shade glasses. The instrument and paper were forgotten as tables for lunar distances weren't sufficiently accurate until Maskelyne's were published in the first Nautical Almanac in 1767. Hadley (Eng.) and Godfrey (USA) designed their famous doubly-reflecting instruments in 1731 and were jointly credited with the discovery. Newton's earlier discovery only came to light when his paper was found among the effects of the former secretary of the Royal Society, Edmund Halley, at the time of his death in 1742.




*Newton's Octant*

*Address all correspondence to:*
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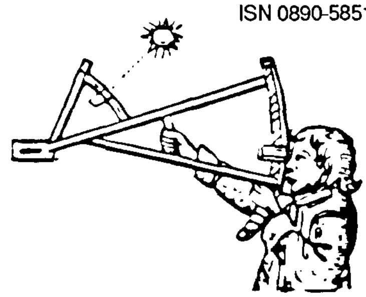
ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-THREE, SPRING 1994

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

Good news for sailors!!! The Defense Mapping Agency is again publishing the Atlas of Pilot Charts. Currently available are Atlas NAVPUB106, thirty-seven pages in three sections: North Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Atlas NAVPUB109, six pages printed front and back, each page one month, for the Indian Ocean. The third Atlas, for the Pacific Ocean, is the same format as Atlas NAVPUB109. The current price for each Atlas is $26.25 (list) and takes about 4 weeks to arrive.

We are saying "good-bye" to our editor of the last three years, Roger Jones, and "hello" to our new editor, Ernest Brown. Roger is off on the first leg of his around-the-world cruise and has promised to keep us informed of his progress and any navigational techniques he thinks will be of interest to you. Ernest Brown has been a director since the founding of The Navigation Foundation and the contributor of Marine Information Notes to the Newsletter. His background is very impressive. He was the editor of "The American Practical Navigator," BOWDITCH, for a number of years so he brings years of experience to his new task. Director Bill Land has agreed to do Navigation Personalities for the Newsletter, another task that was so admirably performed by Roger Jones.

### Slide Rules

Member Wayne E. Feely, 1172 Lindsy Lane, Rydal, PA 19046, Telephone 215-884-5640, is looking for quality slide rules. He is willing to pay top prices. Call or write him if you have any good old usable slide rules that you want to have put back into use.

### Books And Charts

The Foundation has been experiencing some difficulty with orders for charts, books and publications. Because of the severe winter, with considerable ice and snow, 4th class mail has been delayed for several weeks or even months. Publishers who have shipped book orders have been besieged with calls about non-receipt of their orders. Nautical Almanacs, that I have personally mailed, have not arrived in over two months. First Class mail has been delivered in a timely manner. If you receive two shipments of your order, please let me know and The Foundation will reimburse you for mailing them back to The Foundation.

A related problem has been the reorganization of The Naval Institute Press. They have a new computer and ordering system and we have had difficulty receiving orders promptly. In several cases the orders have been shipped to The Foundation months after the order was placed. I hope we now have that problem under control.

Several times orders placed with NOS have been delayed. When inquiries were made, we were told that the chart or publication was no longer being printed. A call several days later would elicit a completely different response, that the chart of publication was available. I hope that problem is also settled.

I want to thank member Malcolm Baker for challenging me to keep after NOS about Pilot Charts. We made several calls to our sales agent at NOS and were told that there would be no more Pilot Charts and the Atlas would no longer be published. Member Baker ordered a copy of the Atlas from the NOS retail store and received it in a short time. He kept insisting that the Atlas was available. Due to his insistence, I kept badgering our NOS sales agent until we finally got the correct story. The Atlas is now available.

Looking to build your own "Chinese Sailing Rig"? Paradise Cay Publications has a book on how to design and build your own. ($15.95 (list).

DO YOU KNOW . . . ?

*By Ernest Brown*

What is the year of the oldest extant isogonic chart? (The answer appears at the back of this issue.)

# READERS FORUM

*Edited by Ernest Brown*

Dr. R. T. Callaghan, Department of Archaeology, The University of Calgary, has written to us with respect to the source of the Pilot Chart data, following our announcement — now rescinded — that the Atlas of Pilot Charts would no longer be published:

"The data that the Atlases of Pilot Charts is based on is available on CD disk from the National Climatic Data Center, Asheville NC 28801-2733, ph. (704)271-4800 or (704)259-0682. The title is *Marine Climatic Atlas of the World* and the price is $50.00 plus $11.00 shipping and handling. It includes air and water temperature, scalar wind speed, dew point temperature, sea-level pressure, wave height, wind and current roses, and probability of superstructure icing and gale force winds. These data can be selected by month in either 1° or 5° grid areas. You also can select any size area of the globe and get a pretty decent display on screen. There seem to be many more features but I don't have a CD drive installed in my own computer yet and I've only had a quick look on a friend's. This program appears to be quite impressive overall and could be useful in place of Pilot Chart Atlases, assuming that you own a computer with a CD drive."

In a following letter:

"I just thought I should warn you about the U.S. Navy Marine Climatic Atlas now that I have had the opportunity to play with it a bit more. Although the CD has more information than an Atlas of Pilot Charts, it is to my mind set up rather strangely. You can only get a wind or current rose for one 1° or 5° sq. at a time — this of course makes it difficult to follow currents over an area. You can get a numerical printout of all the climatic data for each sq. very easily and printout the data for an area consecutively. There are isopleths for wave heights, wind speed, etc. over large areas that can be printed but nothing graphic for currents. If you don't already have a pretty good idea where a current should be it seems to be a hit and miss affair to find the sq. with the current rose. It would be nice if you could print out a sheet similar to the hard copy Atlases but it is not possible unless there is something I haven't yet discovered. The program "as is" is very useful to me since I need the numerical data but not necessarily a graphic representation of it. I think it would be a good idea for someone with more general needs than I to write a review of the program. Perhaps the U.S. Navy will consider a second version of the program in a format that is capable of giving a graphic display that conveys more of the information quicker to a user — the data base itself is very good."

*Editor's note: Each Planning Guide of Sailing Directions published by DMAHTC covers the ocean basin environment for its respective basin. The environmental information is superior to that of the Pilot Chart.*

Anthony Whitman writes from Tokyo, Japan: "I would be interested to learn if you or the Navigation Foundation is aware of any perpetual almanac computer program (IBM compatible) that can be called by another program along with the UT time and body and receive back GHA, declination and SHA, if appropriate, so that it can be directly processed by the calling program. I have seen many almanac programs offered, but all only advertise that they support input from the keyboard and display of the parameters to the CRT."

*Editor's Note: If the membership can help, we will forward the information to Mr. Whitman in Japan.*

Dan M. Rau of 204 E. 6th Street, Duluth, MN 55805 has written: "For your information I am enclosing the notice for a class I organized and offered for the first time last year. The class was well received by the participants and I look forward to teaching it again this year. I used a University of Rhode Island Sea Grant text, *Chartwork for Fishermen and Boat Operators*, as the main text but was not completely satisfied with it. Are you aware of any other public domain basic navigation texts (or, next best, copyrighted inexpensive nav texts which the students could purchase) which would be appropriate for a basic course for, essentially, non-sailors? I would appreciate any suggestions. There is another problem you may be able to help me with. I have been trying for almost two years to procure a sextant through the State of Wisconsin's surplus federal property program, for use on the University's research vessel, the *L.L. Smith Jr.*, which vessel is actually used almost exclusively for educational trips for mostly high school students. So far I have had no luck obtaining a sextant. If you have any suggestions for possible sources I would be grateful to hear of them. The University of Wisconsin-Superior is an eligible recipient of surplus federal property. It is probably obvious form the above requests that the research vessel operates on a limited budget. Actually, our educational program is almost entirely self-supporting, with the fees paid by the schools for our programs."

*Editor's note: We find that for navigation courses addressing limited or specialized needs it is usually best for the instructor to prepare his own instructional materials, which may include excerpts form texts in the public domain. Are there any suggestions from the membership? On making a call to Defense Surplus, we were advised that they had never had a sextant that was usable or repairable. Perhaps Mr. Rau should look at one of the relatively low-cost plastic sextants.*

Edward S. Popko of 28 Maverick Road, Woodstock, NY 12498 has written that Bill Land of Norristown, PA responded to his request for assistance in locating a copy of "Navigation at Sea Using the HP-41 CX Calculator" by sending him a generous set of notes.

*Editor's note: See* Issue 40, Summer 1993.

# NAVIGATION BASICS REVIEW

## The Accuracy of the Hand-Bearing Compass at Sea: Allowing for Systematic Error and Minimizing the Effects of Deviation

*By John M. Luykx*

I. INTRODUCTION

A. The hand-bearing compass has largely replaced the pelorus aboard small pleasure vessels for taking bearings of objects at sea. The modern hand-bearing compass is a small, portable, lightweight, practical instrument which may be used to take a bearing from almost any point aboard a pleasure vessel or small boat with general accuracy to within a few degrees. The accuracy of bearings obtained with the hand-bearing compass may be improved, however, by determining the systematic error of the instrument, where it exists, and then applying a correction to obtain a magnetic bearing with little or no error.

B. Hand-bearing compasses are offered commercially in varying sizes and grades of quality. Some can only be used during the day, others are provided with illumination and may be used both during the day and at night.

C. The hand-bearing compass is affected by systematic error, variation and deviation in the same manner as the magnetic steering compass. Because the hand-bearing compass is not fixed at any one particular location aboard the vessel and may be carried about anywhere on board, no provision is made to adjust it. Under these conditions the effect of systematic error and deviation on the hand-bearing compass remains unknown which limits its use in accurate bearing measurement.

D. The purpose of this short article is to a) describe methods to determine the systematic error of the hand-bearing compass and b) to describe a procedure whereby bearings may be obtained by hand-bearing compass aboard a vessel with minimum or no error caused by deviation.

II. SYSTEMATIC ERROR

A. Systematic Error in the hand-bearing compass may be caused by:

1. The compass dial not being centered about the pivot point of the compass card and,

2. The compass card magnets not being correctly aligned with the North/South axis of the compass card.

B. To test for systematic error in a hand-bearing compass, the following procedures are recommended.

1. Several successful low altitude bearing observations of the sun should be taken ashore with the compass from a position free from magnetic influence. The mean time and the mean observed bearings are then recorded and compared with a pre-computed curve of magnetic azimuths of the sun to determine the mean compass bearing error.

2. Several successive bearing observations of a range ashore of known magnetic bearing should be taken with the hand-bearing compass from opposite directions. The mean value of compass bearing error using this procedure is then computed.

The mean bearing error determined from each of the above two procedures should be of similar magnitude and direction. The mean bearing error of all observations is then the systematic error of the compass. Once this error has been determined the compass itself should be marked with the correction value; if the systematic error is west the correction is subtracted; if the error is east the correction is added to obtain the correct magnetic bearing.

Some years ago the author conducted an accuracy test of thirteen popular hand-bearing compasses in his collection. Seven bearing observations, as described above, were taken with each compass during the test. The results are listed below to show how systematic bearing error may vary among hand-bearing compasses of differing quality.

TABLE I

HAND-BEARING COMPASS SYSTEMATIC ERROR

| Compass Error | Mean Bearing | Range of Error to Observed Bearing | Correction |
|---|---|---|---|
| # 1 | 2.5° W | 0.8° | -2.5° |
| 2 | 2.2° W | 0.7° | -2.2° |
| 3 | 1.2° W | 5.2° | -1.2° |
| 4 | 0.5° E | 1.6° | +0.5° |
| 5 | 0.7° E | 4.6° | +0.7° |
| 6 | 1.5° W | 0.9° | -1.5° |
| 7 | 2.2° W | 1.7° | -2.2° |
| 8 | 1.0° E | 3.2° | +0.6° |
| 9 | 0.3° E | 0.5° | +0.3° |
| 10 | 3.8° W | 9.6° | -3.8° |
| 11 | 0.8° W | 4.3° | -0.8° |
| 12 | 0.2° W | 4.2° | -0.2° |
| 13 | 1.1° W | 0.6° | -1.1° |

Note: Compass #9 was an Opti-Compass (The Hockey Puck)

III. DEVIATION

To minimize the effects of deviation on the hand-bearing compass a position or point somewhere on the vessel should be located where deviation is minimum or even non-existent. The following general procedure may be employed to determine this position or point on the vessel.

1. Select a small area near the vessel's home port at the center of which is located a day beacon or other small fixed navigation structure or aid which is marked on the chart. This point is designated Point A.

2. From the chart, select a navigation aid or mark or other prominent fixed object in the water or ashore (designated Point B) which is marked on the chart and visible to an observer at Point A and also which is at least 3 to 5 miles distant from Point A. The two points form a range which then becomes the directional reference for the test of the hand-bearing compass. The magnetic bearing of the range is obtained as follows:

T True bearing of range from Pt. A to Pt. B.
± V Variation
= Magnetic bearing of the range from Pt. A to Pt. B.

3. As the vessel slowly circles Point A (within 50 yards) an observer takes continuous bearings of Point B with the hand-bearing compass (mentally correcting for systematic error) from a selected position on the vessel comparing the observed bearings with the magnetic bearing of the range. When the vessel has completed a full circle about Point A, the observer records the average value of error of the series of observed bearings. A different position on the vessel is then selected and the test repeated. This procedure is continued, each time changing the point of observation on the vessel until a position is found where the magnetic influence of the vessel has minimum or no effect on the hand-bearing compass.

4. It is then only from this position on the vessel that the most accurate bearings by hand-bearing compass can be observed.

## IV. CONCLUSION

Some hand-bearing compasses can be read to greater precision than others depending on the size and graduation of the compass dial. When corrected for systematic error bearing observations taken from a position ashore using a high quality precision instrument should provide bearing accuracy within 1/2 degree. The same instrument at sea should provide accuracy to within 1 degree.

Accuracy can even be further improved by taking a *series* of observations with the compass. The mean value of bearing is then used to more accurately fix the vessel's position.

## V. RECOMMENDATIONS

Prior to using a hand-bearing compass at sea:

1. Compute the systematic error of the compass and correct all observed bearings for this error.

2. Take bearings at sea only from a point on the vessel which is free from deviation producing magnetic forces.

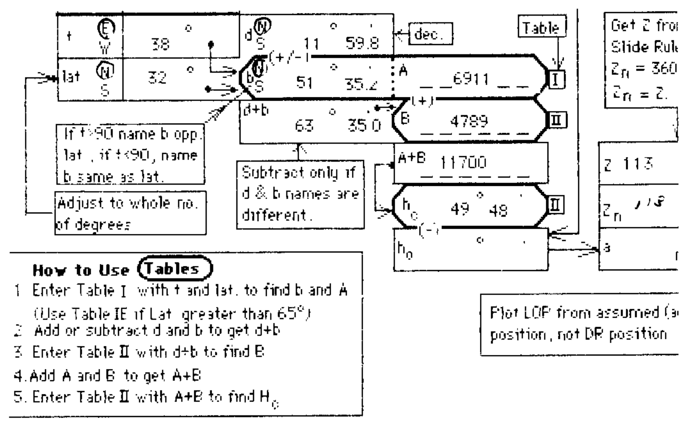
3. When extreme accuracy is required, take a series of bearing observations and only employ the mean value of bearing for navigation.

## Celestial Slide Rule-Assisted Sight Reduction Method

*By Robert M. Girdler, Omnitronics, Inc.*

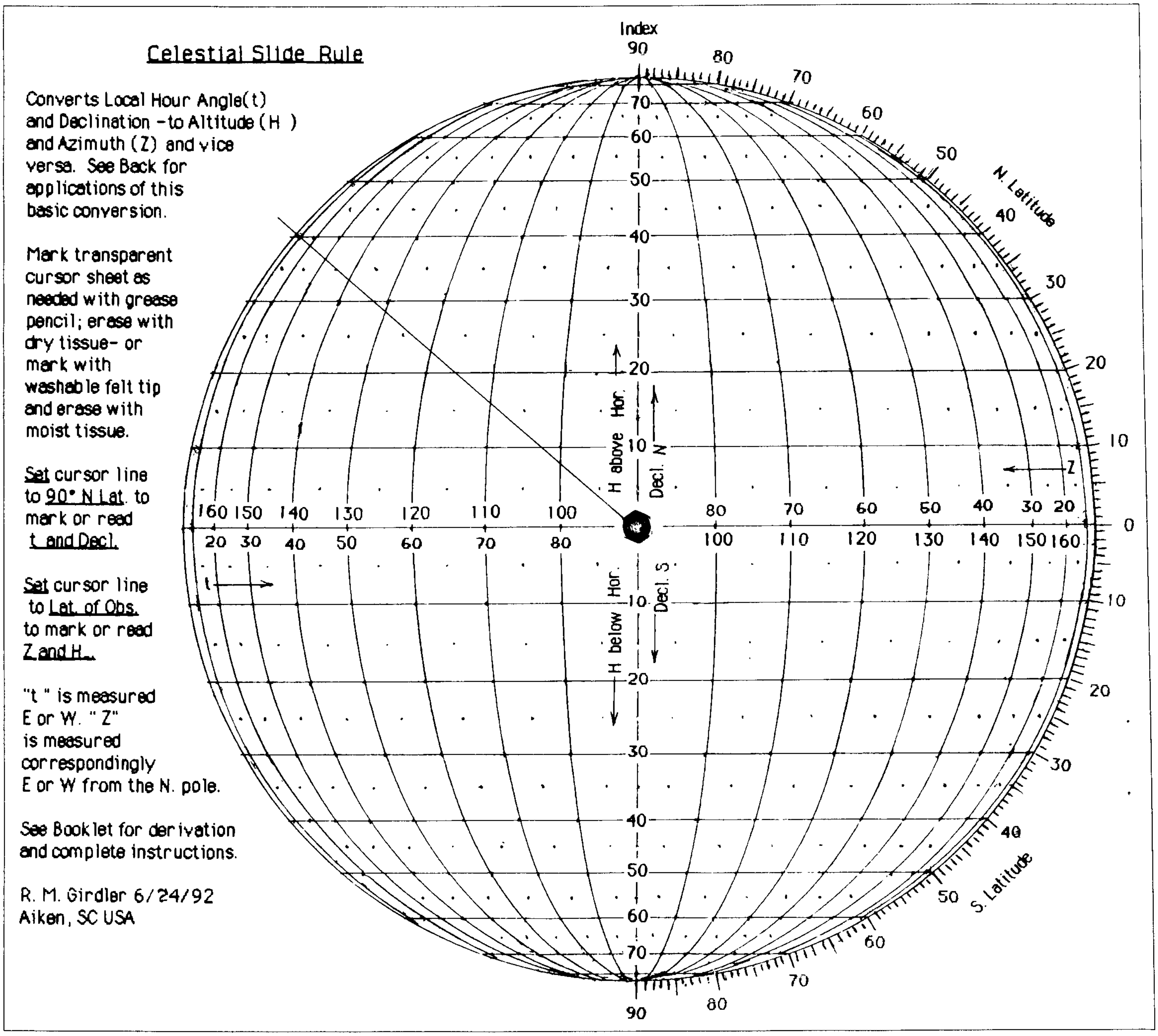
The Quik-Dri Sight Reduction Method is based on Dreisonstok's HO 208 Tables, but reduced 50% in bulk, and more than 50% reduced in reduction work and time. This is made possible by eliminating all of the tabular data from the tables that pertain only to securing the azimuth. Instead, the azimuth is secured independently in a few seconds by manipulation of the "Celestial Slide Rule", a rapid graphical method of solving the Navigation Triangle.

Starting with the assumed latitude and LHA (in integer degrees), together with the declination, the operational steps involve only three table extractions and two summings to yield the calculated altitude. This is illustrated by example in the partial view of the Quik-Dri reduction form, shown below. The other operations, standard for any pencil method, are not shown.




These operations can be accomplished in less than a minute; the manipulation of the Celestial Slide to get the azimuth, adds an additional 5 to 10 seconds, and at the same time yields an approximate Hc for checking the tabular solution. This method is much faster than HO 211 and its derivates, and is almost as fast as HO 229. A series of reductions, made with no interpolations and compared to hand calculator solutions, revealed no errors greater than one minute in Hc, even at LHA of 90° where HO 211 has a problem. The Azimuth will be accurate to 1° except near the North and South points and at high calculated altitude.

The Quik-Dri tables I and II, including instructions, are contained on both sides of eight 8½" by 11" sheets and cover all latitudes through 65° (the range of the original HO 208 tables). Latitudes from 66° to 80° are covered separately by Table IE, recently computer-generated and printed out on three additional sheets. Several Sight Reduction Forms, The Celestial Slide Rule and the manual describing its many other applications, are all included in the *Quik-Dri Navigation Kit.*




*Celestial Slide Rule*

*Note: If members require additional information, they should contact: Mr. John M. Luykx at Infocenter, Inc.,Box 47175, Forestville, MD 20747 Telephone (301)420-2468.*

*The Celestial Slide Rule and Quick-Dri Sight Reduction Table are available for $15, including shipping.*

## A Navigation Problem

*by Douglas Davies*

One of the questions surrounding the Peary controversy that we have been studying is why Peary did not make a longitude observation when camped at 87°45′N (shown by his latitude sight taken at the time of local apparent noon on the 70 W meridian). Part of the answer could be that, being unfamiliar with modern position line methods, he did not know how easy such a sign would be at that latitude.Using only arithmetic and normal plotting instruments, determine Peary's position if a second sight taken at 22:12:40 GMT had an observed altitude (after applying all corrections) of 5°15′30". Assume that from the almanac, the sun's declination at midnight GMT is 4°50′48" and the hourly change in declination was plus 56". The GMT of meridian passage was given in the almanac as 12:04:32.

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## Vessel Squat in Shallow Water

In August 1992, a 950-foot passenger liner ran aground in an area where the charted depth was 7 feet greater than the vessel's draft. One major contributing factor was that neither the master nor the pilot adequately judged the considerable squatting effect caused by high speeds in shallow water. This accident highlighted the fact that, while most mariners understand the general concept of vessel squat, the pronounced effect of squat in shallow water is often underestimated.

*Vessel Squat:* As a vessel increases speed the buoyancy distribution along the hull changes due to wave formation (e.g. the bow and stern wave system). Consequently the vessel squats, increasing the navigation draft of the vessel. The term "squat" generically describes the combination of sinkage (overall sinking of the hull) and trim (the bow up/down rotation of the hull affected by wave formation as well as normal weight distribution).

*Shallow Water Effects*: Because the formation of the bow wave is affected by the proximity of the bottom, the effects of squat become more pronounced in shallow water. The vessel may appear to ride up on the bow wave and the vessel's wake will be high and steep. The vessel will require substantially more revolutions to maintain the same speed. During sea trials with a 270 foot destroyer drawing 8 feet of water, the ship required 400 rpm to reach 22 kts in 100 feet of water, but nearly 500 rpm to maintain the same speed in 45 feet of water. As speed increases, most vessels squat by the stern, with the amount of squat increasing in a fairly linear manner with speed; however, at excessive speeds in shallow water, a vessel may reach critical wave conditions (also called a critical Froude number). Here the bow wave formed may appear as a steep breaking wave extending nearly perpendicular to the ship from admidships or even further aft. Under these conditions, the ship may trim radically by the bow or stern. Where underkeel clearance is minimal, the movement of the hull form through the water forces the water between the hull and the bottom to increase velocity, in effect "sucking" the ship down closer to the bottom. This suction effect is accentuated at high speeds. In addition to squat and suction, the mariner should be aware that shallow water may increase turning diameter. Modeling of tankers has shown an increase in turning diameter of 60-100% in water less than 1.25 times the ship's draft. Hydrodynamic effects such as yawing and sheering should also be taken into account when determining a ship's speed in shallow and restricted waters.

*Warning Signs of Excessive Squat:*

—Vessel appears to be riding up on large bow wave extending nearly perpendicular from ship.

—High, steep stern wave, may be above level of fantail.

—Excessive turns required to maintain speed.

Note: Many ships have fathometers mounted forward where clearance may be considerably greater than at the stern where maximum squat is likely.

*Regulations:* The code of federal regulations requires that the person directing the movement of the vessel set the vessel's speed with consideration for the tendency of the vessel underway to squat and suffer impairment of maneuverability when there is small underkeel clearance [33 CFR 164.11(p.)(3)]. In addition, the International Maritime Organization recommends that ships keep a maneuvering booklet on the bridge, which includes diagrams showing maximum squat at various speeds, and water depth/draft ratios for that particular vessel [Navigation Safety Inspection Circular 7-89].

## 1869 Notice to Mariners 1994

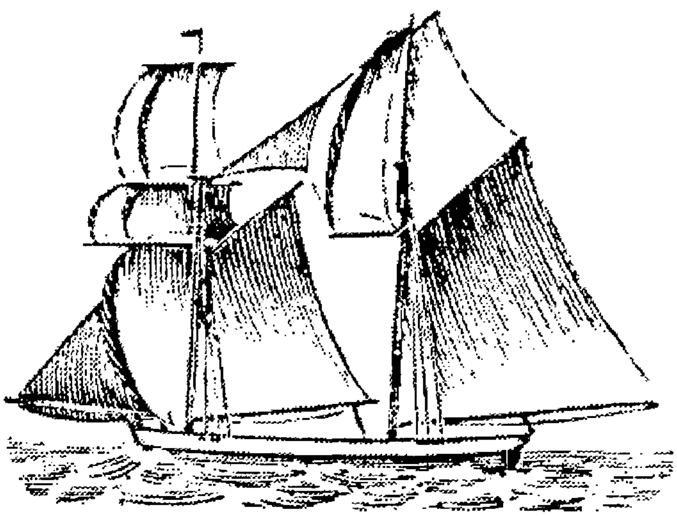
This most visible and widely known product within the seagoing community, Notice to Mariners, is celebrating 125 years of continuous service to the mariner. Under the authority of the Bureau of Navigation, Department of the Navy, the first issue of the Notice to Mariners appeared in 1869, containing updated hydrographic information not yet appearing on charts. Over the years the Notice has adapted to the influx of new information caused by advancing hydrographic surveys, changes to navigational aids, computer technology, and world-events. In recognition of this year's observance our covers throughout the year will display the seals and corresponding dates of the four publishing organizations.

In its evolution, distribution of the Notice was handled by special mail, telegraph, cable, wireless communication, and direct contact with mariners through the central office or the 17 branch offices. Today, for mariners receiving printed copies of the Notices, the Automatic Distribution List can reflect address changes up to the moment the address labels are printed by computer. Also the mariner can instantly receive selected weekly Notice corrections via phone modem and PC link through satellite, cellular or land line communications by a system called the Navigation Information Network (NAVINFONET).

In the early part of this century, 5,450 copies of the Notice to Mariners were printed weekly, which corrected up to 2,706 charts of foreign waters and 672 charts of U.S. waters and territories. A system of mutually exchanged information began with 24 other countries during this period. Today, 56 contributing countries and a host of individual mariners provide the vital information that goes into the weekly Notice. Last year up to 13,000 copies of Notice to Mariners were printed weekly which updated a portfolio of 4,000 charts of foreign waters and 1,000 domestic charts. There are currently over 50,000 active corrections in existence for the 5,000 charts that are maintained by Notice to Mariners. The Notice also maintains data on 80,000 lights found in either DMA's seven volumes of List of Lights, or the U.S. Coast Guard's seven volumes of the Light List.

During our anniversary year, you will be seeing changes that will further enhance the Notice to Mariners. These changes are being brought about to better serve you, the valued user. Beginning with this issue, a restructuring of the Notice to Mariners Contents Sections has taken place and is reflected in the cover format. Later this year, a double column format will be introduced for chart corrections. This will reduce the unused space, bringing the correcting position closer to the action verb. We will also be expanding the paper size to 8½"x11". Another feature to be added weekly will be a "List of Charts Affected by Notice to Mariners." NAVINFONET will be providing additional menu items such as the latest edition of all charts and pubs, world-wide radiobeacons, and a list of DMA's Navigation Division fax and phone numbers.

This publication is for you and could not have flourished in its first 125 years without your active participation. We at Notice to Mariners render our sincere thanks to all contributors and pledge to continue striving to improve our services in the interest of your navigational safety.



# HISTORY OF NAVIGATION

## Determining the Longitude of a Place by Chronometer

*By John M. Luykx*

I. INTRODUCTION

THE LONGITUDE SYMPOSIUM held at Harvard University from 3 to 6 November 1993 (see Navigator's Newsletter issue 40) was very comprehensive and covered in great detail the historical aspects of the longitude problem. Little time, however, was devoted to the actual detailed procedures employed during the 18th and 19th centuries to determine the longitude at sea or of a place ashore. It is felt, therefore, that a brief description of this procedure would be of interest to members who attended the Symposium or who would like to know more about how the longitude of places around the world were first determined during the fifty to hundred years following the trials of Harrison's most successful chronometer, his H4, in the 1760s.

II. GENERAL

A. Although in 1530, Gemma Frisius first suggested using a timekeeper for finding the longitude at sea, it was not until 1736, during a voyage from Lisbon to the English Channel, that John Harrison, using his first timekeeper H1, proved that longitude determination by chronometer was actually possible.

B. The Greenwich Observatory was established in 1675. By 1736, when Harrison's H1 was first tested, the Greenwich Observatory had already been in existence for over sixty years and many thousands of sun, moon, planet and star observations had been made. In 1676 under John Flamsteed, the first Astronomer Royal, the two "Great Clocks" by Thomas Tompion were installed at the Observatory. Using these clocks, Greenwich Mean Time (GMT) was first measured and as a result the first equation of time (Eqt) tables were published to distinguish between apparent solar (sundial) time and mean solar (clock) time. Some time later, around 1720, regulator clocks with George Graham escapements and mercurial pendulums were installed at the Observatory. These clocks were accurate to within 0.5 seconds per day. It was these famous regulators, in continuous use for over 150 years which were employed to "rate" the early chronometers submitted to the Observatory for use in ships of the Royal Navy. The "going" of the regulator clocks was checked daily, weather permitting, by observation of the stars using the observatory's meridian transit telescope. This procedure provided sidereal time which was converted mathematically to mean solar time as a reference for checking the chronometers. An alternate method for checking chronometers during this time was to apply the equation of time (Eqt) to Local Apparent Noon (LAN) to obtain the mean time of the sun's meridian passage. The mean time of LAN was then compared with the chronometer time of LAN to obtain chronometer error.

C. The first chronometers were offered for trial at the Greenwich Observatory in 1766 and consisted of Harrison's four timekeepers; H1 through H4. Early trials of chronometers submitted to the observatory consisted of determining the error of prediction of each machine over a period of six months based on its rate determined during the month immediately preceding that six month period. Data concerning the rate of each machine over the seven month trial period was then recorded and issued with each chronometer as it went to sea.

III. DETERMINING THE LONGITUDE

A. During the latter half of the eighteenth century, the primary procedures for determining the longitude of a place or a position at sea, by chronometer were, either a) the chronometer time sight method or b) the equal altitude method. Both of these procedures are described or mentioned in previous issues of the Navigator's Newsletter, especially issues 14, 15, 16, 27, 30 and 33.

1. The Chronometer Time Sight

General: Basically, in the chronometer time sight procedure, an altitude observation of a celestial body is made when the body is East or West of the observer. The sight is then reduced to obtain meridian angle t which is then applied to the GHA of the body to obtain the observer's longitude. The procedure is as follows:

Step One: The latitude is computed from a meridian observation of a celestial body.

Step Two: A sextant altitude is observed (and the chronometer time of the observation recorded) of a celestial body bearing well to the east or well to the west of the observer.

Step Three: The meridian angle t is then computed using the formula:

$\cos t = (\sin Ho + \sin L \times \sin d)/(\cos L \times \cos d)$

t is either east or west according to the azimuth of the celestial body.

Step Four: The longitude of the observer is computed by applying the value of t to the Greenwich Hour Angle (GHA) of the body at the time of observation:

$\lambda =$ GHA - tW*

$\lambda =$ GHA + tE *

**Note: Early Nautical Almanacs used the term Sun's Longitude rather than the term Greenwich Hour Angle (GHA).*

2. The Equal Altitude Method

General: In this method altitude observations of a single celestial body are taken at sea or ashore using an artificial horizon, first east and then west of the meridian. The two altitudes must be equal and the chronometer time for each observation must be recorded in order to compute the chronometer time of meridian passage. The chronometer time is corrected for daily rate to obtain the GMT of the observation. The GHA of the body for the time of observation; i.e., the longitude is then obtained using data from the Nautical Almanac.

Step One: A sextant altitude is taken of a celestial body east of the meridian and the chronometer time is recorded. An artificial horizon is used ashore.

Step Two: A second sextant altitude using an artificial horizon is taken when the body is west of the meridian and the chronometer time is recorded. The second altitude measurement must be made when the second altitude is exactly equal to the first.

Step Three: The mid-time or chronometer time of meridian passage is computed by obtaining the mean of the two observation times.

Step Four: The Greenwich Mean Time (GMT) of the celestial body's meridian passage is computed by applying a correction for accumulated chronometer error to the chronometer time of meridian passage found in Step Three.

Step Five: The GMT of Meridian Passage computed in Step Four is corrected for the effect of celestial body declination change (if any) during the period between the first (AM) and second (PM) observations. For at sea observations, a correction must also be applied for vessel motion north or south during the period of the two observations.

Step Six: The Greenwich Hour Angle (GHA) of the body determined from the corrected GMT of meridian passage (Step Five) is equal to the longitude of the place or observer.

IV. SAMPLE SOLUTIONS TO PROBLEMS

A. To assist in describing both the *Chronometer Time Sight* and the *Equal Altitude* methods of determining longitude by chronometer the following sample solutions describing these procedures are given below. In order to inject some realism to these solutions a deck watch which has been running continuously over three months was selected from the author's collection to provide an actual time reference for the solutions. From the daily rate record, the error of the watch for December 20, 1993, 27 December 1993 and January 1994 was recorded to compute the daily rate of the watch for the period 20 December through 3 January. The daily rate thus obtained was then used to predict the error of the watch on 21 January 1994; the date selected for the sample longitude determining procedures described in the following paragraphs.

1. BASIC CHRONOMETER DATA

The deck watch used for the sample problems described below is taken from the author's collection of precision navigation watches.

The timepiece is an Elgin master navigation watch, GCT, 16 size, Grade 581, 22 jewels, B.W. Raymond, 12 hour dial with sweep second hand. The dial has the British government's broad arrow ordnance property symbol beneath the numeral 12. Rate data is as follows:

| Date | Error | Rate |
|---|---|---|
| 1993 12/20 | +20.5s | |
| 12/27 | +24.0 | +3.5s per week; +0.5s per day |
| 1994 1/3 | +28.7 | +4.7s per week; +0.7s per day |

Mean Rate: +4.1s per week; +0.59s per day

2. CHRONOMETER TIME SIGHT SAMPLE SOLUTION

A. Problem
Given: Date 21 January 1994
Body: SUN (center)
IC: 0.0
Dip: 0.0
Chron. Time (CT): 21 - 05 - 55
Sun Hs 11°06.9'

B. Find:
Longitude, given Latitude 38°52'N, sun's declination 19°50.4'

C. Solution:
1. Hs: 11° 06.9'
-Ref: -4.8'
Ho: 11° 02.1'

2. $\cos t = \dfrac{\sin Ho + \sin L \times \sin d}{\cos L \times \cos d}$

$= \dfrac{.19141 + .21258}{.73257}$

cos t = .55147
tw = 56° 32.0'

3. Chron. error, on 3 Jan 1994: +29s
Chron. gain, 3-21 Jan 1994 +11s
Chron. error, 21 Jan 1994: +40s

4. Chron. time of observation: 21-05-55
Chron. Correction: -40s
GMT of Observation: 21-05-15
GHA : 133° 27.4'
-tw: -56° 32.0'
Longitude (λ): 076° 55.4'W

3. EQUAL ALTITUDE METHOD (SAMPLE SOLUTION)

A. Problem
1. Given:
Body: Sun (Center)
Date: 21 January 1994
IC: 0.0
Dip: 0.0
First observation: CT: 16-53-17, Hs:31° 01.0'
Noon observation: Hs:31° 19.2'
Second observation: CT: 17-46-36, Hs:31° 01.0'
2. Find:
Latitude
Longitude

B. Solution
1. Latitude (from noon observation for use with Time Sight method)
a. Hs: 31° 19.2'
-Ref: -1.6'
=Ho: 31° 17.6'
b. Zenith: 90° 00.0'
- Ho: 31° 17.6'
= Zenith Dist: 58° 42.4'
- Dec: 19° 50.4'
= Latitude: 38° 52.0'N

2. Longitude
Chron.Time First Observation: 16-53-17
Chron.Time Second Observation: +17-46-36
2/34 39 53
Chron.time of Meridian Passage: 17-19-57
Correction for chron.rate:
+0.59s x 18 days: -11s
Correction for chron.error on 3 January: -29s
GMT of Meridian Passage: 17-19-17
GHA of sun: 076° 58.6'
Long. Corr. for sun's dec change: $\dfrac{15}{4} \times \dfrac{p}{\cos 31° 01'}$ -4.4'
Longitude: 076° 54.2'W

The actual altitude observations were made at the author's office with an R.A.E. (English) Mark IX aircraft sextant. Although the 21 January predicted error of the Elgin Deck watch used in the sample solutions was +40 second; the actual error of the watch from the daily record book was +34 seconds. This error of time prediction resulted in an error of 1.3 arc minutes in the computation of longitude.

The exact location of the point of observation was:
Latitude: 38° 51.8' N
Longitude: 076° 55.1' W

# NAVIGATION PERSONALITIES

## Captain Matthew Flinders
*By William O. Land*

Captain Matthew Flinders, the English navigator, is remembered today for two great contributions to navigation: the charting of the coastline of Australia and the invention of possibly the first method of adjusting the magnetic compass for deviation, the "Flinders bar".

Matthew Flinders was born March 16, 1774, in Donington, Lincolnshire, England, a little town near an inlet of the North Sea known as "The Wash". (He was one year younger than another great navigator, Nathaniel Bowditch, who was born in Salem, Massachusetts in 1773).

Flinders may have been of Dutch heritage, for the name "Flinders" in the Dutch language translates to "Splinters", and the area around Donington is Lincolnshire is known as "Holland". There is a possibility his family came from Holland with William, the Prince of Orange, when the English invited William to be their king in 1689 after Charles I lost his throne. Matthew Flinders certainly was an ambitious boy, for he studied geometry and navigation on his own and in 1789, at the age of 15, entered the Royal Navy as a midshipman. He served the next five years in European waters and the West Indies.

In England in 1795, Flinders was assigned to *Reliance* and ordered to sail to Australia and carry as a passenger the Governor of New South Wales, one Captain Hunter. Flinders spent the next five years in Australian waters exploring the Australian coast and circumnavigating Tasmania in a small sloop believed to be *Norfolk*. His instructions were to make detailed charts of all the shoreline, including rivers and inlets.

In 1798 Flinders was promoted to lieutenant. On his return to England, Flinders was given command of the sloop *Investigator*, leaving Spithead in July of 1801 with orders to return to New Holland, as Australia was called in those days, and completely chart the coast. A small scientific party, which included an astronomer, a botanist, a miner, two artists, and a gardener to care for plants collected, was aboard *Investigator*. Flinders' orders read: "Examine the south coast, the northwest coast, the Gulf of Carpentaria, Torres Strait and the northeast coast that Captain Cook had not charted. Seek harbors, creeks and rivers or openings likely to lead into the interior." (Earlier in 1770 Captain Cook charted the east coast but was unable to chart details of the creeks and rivers because of the hostility of the natives).

Leaving England, Matthew Flinders sailed *Investigator* south in the Atlantic Ocean, across the equator to the Cape of Good Hope, and then east across the Indian Ocean, making landfall in December 1801 at Cape Leeuwin (34°22'S, 115°08'E) the southwest point of the Australian continent and about 100 miles south of what is today the city of Perth. This passage of over 9800 miles took 6 months.

Cape Leeuwin had been discovered by Dutch explorers and means Cape Lion in English. Flinders Bay, later to be named in honor Matthew Flinders, lay just east of Cape Leeuwin.

From Cape Leeuwin Flinders began charting the south coast, going eastward until he came to Encounter Bay (36°S, 139°E) where he unexpectedly met the French ship *LaGeographie* on April 8, 1802. (Encounter Bay had been discovered in 1770 by Captain Cook and is just south of the modern city of Adelaide). The French informed him that they claimed all land to the west of the bay (virtually 75% of the continent of Australia; this matter was not resolved between Britain and France until 1814). Flinders continued his eastward charting assignment to the Bass Strait. During this period south of the continent, Flinders observed dipping of his magnetic compass needle.

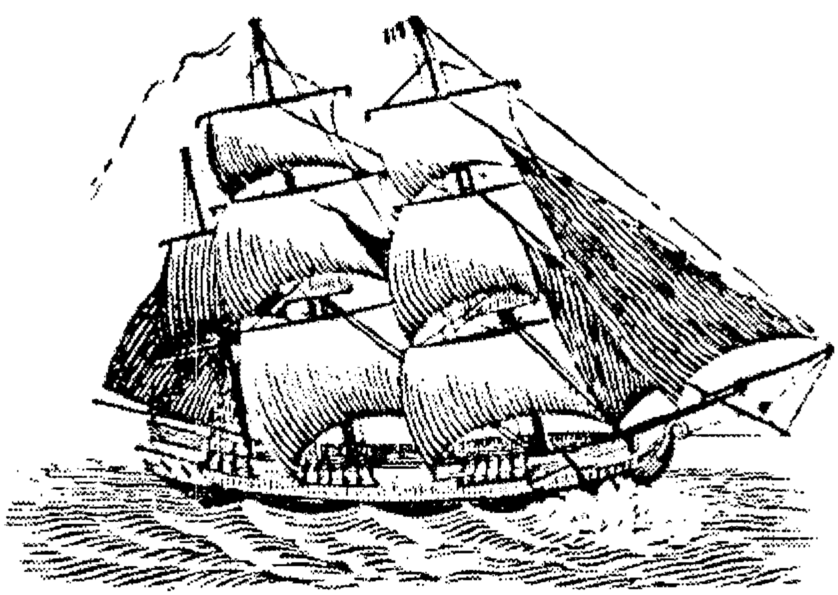
After passing through Bass Strait and sailing northward in the Pacific Ocean off the east coast of Australia, Flinders arrived at Port Jackson (34°S, 151°E) on May 9, 1802. (Port Jackson was later renamed Sydney). Leaving Port Jackson and continuing his northward charting assignment, Flinders charted the Great Barrier Reef which begins about 23°S and runs northward about 1250 miles along the greater part of the northeast coast, and consists of about 3000 coral reefs, islands and coral cays.

During the charting of the Great Barrier Reef, Flinders conducted a number of experiments in an attempt to correct the dipping problem. He found that if he mounted vertical iron rods on the side of the binnacle, he could correct the problem. Today these iron rods are known as "Flinders bars" and are now used for correcting for induced magnetism in vertical soft iron.

Following the 1802 magnetic compass discovery, the life of Matthew Flinders seems to be steeped in bad luck and tragedy. After finally arriving in the Gulf of Carpentria (15°S, 140°E) on the north coast, Flinders now had a ship in such poor condition that the crew was unable to contain all the leaks. Flinders decided to make a run for Port Jackson for repairs. He returned via the west and south coasts, thus completing the first circumnavigation of the continent. In doing so, Flinders proved that Australia was a single landmass. After much suffering and with most of his crew in poor condition from scurvy, Flinders arrived at Port Jackson on June 9, 1803. *Investigator* was found to be beyond repair, so Flinders with his crew headed back to England in two small ships, *Porpoise* and *Cato*, which the British Admiralty assigned to him. On August 17, 1803, 800 miles east of Port Jackson, both ships were wrecked on a sunken coral reef. The officers and men camped on a small sandbank while Flinders and a small crew sailed back to Port Jackson in a six-oared life boat to obtain relief. There he obtained the use of the *Cumberland* and returned to the sandbank two months later, October 8th, to rescue the crew.

With his crew together once again, and on the way to England, Flinders stopped at the island of Mauritius (20°S, 58°E) to replenish supplies after crossing the Indian Ocean. To his surprise, he found Mauritius in French hands, and that England and France were at war. He and his crew were interned, his ship seized along with all his charts and records of the exploration of Australia, and his calculations on the Flinders bars. Fortunately, much of this information had been sent to England in duplicate ahead of time on other ships. But the French used this material to enhance their own charts, and Flinders and his crew were imprisoned for seven years. It was not until 1810 that he and his crew were released and his charts and records were returned to him. He finally reached England in October of 1810, but he was broken in health. He was promoted to the rank of captain on his return to England, but he had to conserve what little strength he had left to write his report on the exploration of the Australian coasts and the results of his experiments with the Flinders Bars and the compass. He supervised the correction of the charts of Australia, and this survey is still the basis of Australian charts to this day. His report was published July 10, 1814, the day Flinders died, tired, sick and completely exhausted at the age of only 40.

The Australians have not forgotten him. Today on the map of Australia (the name for New Holland suggested by Matthew Flinders) is a Flinders Bay, (east of Cape Leeuwin), Flinders Island (34°S, 135°E), Flinders Mountain, Flinders River and Flinders County. A number of native Australian trees and plants have been named in his honor: Flindersia, a genus of trees of the family of Rutaceae, one species, Flindersia Australis yields a heavy, hard dark timber somewhat like mahogany, grows to heights of 100 to 150 feet, and four to six feet in diameter. It is popularly known as Flindosa ash. Flindersia Oxylana, a tree 150 feet high, produces a yellow wood, one of the finest in Australian hard woods for cabinet making. It is also used in the preparation of dyestuffs. Flindersia Maculosa called leopard tree is a smaller species which is used for shingles and barrel staves. The gum which extrudes from this tree resembles gum arabic and makes good mucilage. Many of the streets and towns of Australia are lined with the Flinders ash. The name of Captain Flinders is also kept alive in his grandson, through his daughter, Anne, Sir William Matthew Flinders Petrie (1853-1942), the famous British archaeologist (better known as Flinders Petrie), investigator of Egyptian antiquities, and who, among other honors and explorations, held the Chair of Egyptology at the University College, London.



Answer to DO YOU KNOW . . .?
(from page 1)

The year of the oldest extant isogonic chart is 1701. If reproducible copy can be obtained, the chart will be illustrated in a later issue.

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126
Rockville, MD 20850
Telephone 301-622-6448

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-FOUR, FALL 1994

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Newsletters

It seems I have to apologize to our members in every issue for the tardiness of each previous issue of the Newsletter. The entire publication process of the Spring Issue, which was mailed in July, was a disaster. All of the difficulties can be attributed to me.

This year my wife and I decided to catch up on our world travel. In preparation, I gathered the material for the Spring Issue of the Newsletter early and sent it to the Editor, Ernest Brown, before departing on a trip. Upon returning I received the material from Ernest and gave it to our publisher. Everything was on schedule, I thought. The day before I returned from this trip we had a family medical emergency and only stopped at home to empty our suitcases and proceed to another destination.

When I returned I found that I had not provided all of the material for the Newsletter to the Publisher. Without this very important material, she was not able to complete the layout for printing.

### Awards

Midshipman 3/C James L. Marsh was the recipient of the annual "Dutton's" award at the U.S. Naval Academy this spring. Foundation President Douglas Davies presented the award at the Academy's graduation "family day" ceremonies. A certificate was presented in lieu of the actual award. The award was completed and presented at a later date.

### Marine Information

Coast and Geodetic Survey hosted a marine information users meeting in Seattle, Washington in July 1994. Both traditional and non-traditional users of NOAA's nautical products were invited for discussions on present and future surveying plans, C&GS' surveying and charting policies, tides, currents, and the PORTS system. Future meetings are scheduled in New York, NY in September and Boston, MA in November. For more information call CDR Marlene Mozgala (301)713-2729.

C&GS has initiated efforts for a joint NOAA - Tulane University sponsored International Law Conference to be held in New Orleans, LA on March 20-22, 1995, to address the legal issues related to electronic charts. Inquiries to: Fred Gajon (301)713-2698.

DMA is now folding its new edition nautical charts and has extended this initiative to include current edition charts stocked in their inventory. Folded format has been made to meet military requirements. DMA also notes that folded charts can be handled with greater efficiency and less cost than flat charts. In addition, folded chart shipments are significantly less vulnerable to damage while in transit.

### Summer Youth Program

The Summer Youth Program, operated in conjunction with the KIWANIS, did not materialize this summer. This can be viewed as a positive sign since the youth who were interested in sailing found jobs or selected another activity that did not have the potential of conflict with their summer schedule. It is difficult to arrange a training schedule when the schedule has to accommodate a large number of people.

### Warning

The Foundation has recently received mail that had been opened with an automatic letter opener. In each case the mail was from members who did not live in the United States and had a foreign return address. Fortunately, the letters received contained checks that could

> DO YOU KNOW . . . ?
>
> *By Ernest Brown*
>
> Why mariners were once charged not to eat onions or garlic?
>
> (The answer appears in the History of Navigation section)

only be cashed by the Navigation Foundation, without difficulty, by other than the payee. Please be wary of sending cash through the mails; it may not arrive at its destination. I recommend whenever possible that our foreign members try to locate a local bank that has an affiliation with a bank in the United States. This saves the excessive $12.00 fee charged by U.S. Banks for the transfer of funds internationally. Canadian Postal Money Orders made out in U.S. Dollars are accepted by the U.S. Postal Service.

### Books

The new 1995 Nautical Almanac, Commercial Edition, will cover 14 months. Coverage includes November and December 1994 and all of 1995.

For those who are traveling to foreign ports, two books just printed may be of interest, "Landfall Legalese, Vol. 1" The Pacific, and Volume II, the Caribbean. They are a compendium of the Legal Requirements and Protocols for entering and clearing the majority of popular cruising ports throughout Oceania. They contain many forms required by Customs and Immigration Officials, Documentation Forms, a crew contract and other information valuable to the Blue Water Sailor. Vol. 1 lists for $29.95 and Vol. II lists for $24.95. (Members discounts apply)

### Renewals

In July I mailed out an inordinate number of "Final Notices" for renewals. I have received renewals from most of the "Final Notices" sent. Most stated that the "Final Notice" was the first notice they had received. I cannot explain why the two previous notices did not reach our members. I have had practically no problems with the Foundation computer that carries the member lists. Because I send "Renewals" to our members on the anniversary of their membership, a "Second Notice" three months later if a member has not renewed, and a "Final Notice" six months after the anniversary date on the label, there are three chances for the member to receive a notice. The only reason that I can give that so many members did not receive their renewal notices, and this is not a certainty, is that somehow mail is being lost. I do know that about 5% of our publications sent by book rate never arrive; however, that should not apply to First Class Mail. To our members who receive a "Final Notice" as their first reminder, I apologize. Please do not be concerned about being dropped. We are very patient about hearing from members on renewals because some members are on "Around the World Cruises"

### Lt. V. Cardashuan, N, Wins Chapman Award

We are pleased to bring to the attention of the membership the presentation of the Chapman Award for 1992 to Navigation Foundation member Lt Van S. Cardashian, N, United States Power Squadrons. The Charles F. Chapman Award for Excellence in Teaching is sponsored by Hearst Marine Books and USPS. Each year USPS honors three of its teachers nationwide for their skill in teaching classes at the squadron level.

Van Cardashian, a member of Minnetonka Power Squadron since 1982, has been teaching navigation courses for the squadron since 1983. He completed in two years the 10 courses required for full certification in the organization. He has a B.A. in education from American University in Cairo, Egypt and an M.S. in physics from the University of Missouri in Columbia, MO. Additionally, he was Senior Principal Research Scientist for the Honeywell Corp. Van Cardashian has published papers in scientific journals and participated in a manual space flight project funded by NASA. Recently he earned his 17th patent certificate.

The award consists of a framed certificate and a C. Plath sextant for the squadron in Van Cardashian's name..

## READERS FORUM

*Edited by Ernest Brown*

Dear Navigation Foundation:

I am sorry to inform you that Richard (Dicky) Derickson died in Palau on January 4th. He was buried at sea, 12 miles west of the islands. He was 57 years old.

His love of navigation and the sea came naturally, as both of his grandfathers served in the U.S. Coast and Geodetic Survey; each served for 2 years in the Philippine Islands as commanders of *their* Coast Survey and also extensively in the Philippines and Alaska.

Dicky attended the U.S. Naval Academy and graduated with the Class of '59. After serving in the Navy, he spent a successful career as a logic designer. He enjoyed this intellectually stimulating work, and his projects included Project Apollo, video games for Atari and a digital tape recorder for Ampex.

In 1986, we left the west coast of the U.S. to cruise the Pacific. He then had time to devote to one of his first loves, the art and science of navigation. He was very pleased to discover the existence of your organization — fellow "nav nerds!"

Sincerely, (Mrs.) Jill Derickson

The Owner/Master of S.V. *Allidoro*, Director Roger Jones writes on May 29, 1994 from Titusville, Florida, (Lat. 28 56.8 N. Long. 80 47.7 W):

"It is now six days short of three months since I left

**Richard Barnett Derickson**

1936-1994

It is with sorrow that we announce the passing of Richard Barnett Derickson on January 4, 1994.

California on February 26 at thirty minutes past midnight (in deference to the old sailor's superstition that one does not begin a sea voyage on a Friday). In that time ALLIDORO and her crew have traveled over 5,000 miles. The first stop was in San Diego at Shelter Island, and then there was again a midnight departure in order to arrive at Ensenada, Mexico at dawn. We cleared into Mexico in Ensenada, spent a day and a half there, and then departed for Cabo San Lucas, 800 miles south at the tip of the Baja Peninsula.

"Two delightful days were spent at anchor in Cabo anchored off the beach, with dingy trips into the inner harbor. From Cabo the route was southeast directly to Acapulco. We entered the harbor at sunset, anchored for the night, and in the morning on March 15th we moved to the dock at the Acapulco Yacht Club. The crew aboard for the trip south from Marina Del Rey, in addition to myself, were: Paul Carlton (an old friend) and two young Englishmen, Ed Hartgill and Nick Hesley. (Nick and Ed were aboard to reach Panama, where they initially hoped to find positions on a sailing vessel going to the South Pacific. In Panama they made a dramatic change in plans — more about that below.) Paul, Ed, Nick and I went to see the cliff divers in Acapulco. They made three night dives (spot- lighted), and they were truly awesome.

"From Acapulco we set a course southeast across the Gulf of Tehauntepec, bound for Costa Rica. As with the legs to Cabo and Acapulco, this was again a long leg of over 800 miles. However, we encountered very light winds, and I became concerned about our fuel supply, and we made an unscheduled stop in Corinto, Nicaragua. They don't see many yachts in Corinto, and we were the object of much curiosity. We obtained 135 gallons of diesel via the means of three trips to a local automobile filling station with eleven jerry jugs in the back of a local man's jeep. (In Nicaragua most of the trucks and many cars operate on diesel rather than gasoline). This stop on the West Coast of Nicaragua was carried out because of the fuel problem. We were all conscious of the reported problems with a stop in Nicaragua on the eastern side due to the resentment of many locals lingering from the recent times when the U.S. was involved in military operations. The people in Corinto were all very friendly, however, including the man with the jeep, whose oldest son was a casualty of a U.S. mine emplaced in a Nicaraguan harbor on the east coast.

"In departing Corinto, we went seriously aground on a sand bar, but with a strong ocean surge pushing us towards a stone breakwater. Despite a serious language problem over the radio, we managed to get a tow from the harbor pilot vessel. We had to cut our stern anchor rods, but the loss of the anchor was a small price to pay. In any event there was no time to put a buoy on the rods before we cut it. Needless to say, the entrance to Corinto is a tricky one.

"From Corinto we cleared out to Puntarenas, Costa Rica, but bypassed it and proceeded directly to Balboa, Panama. We entered Balboa on a pitch-black night, but with the help of very accurate radar in conjunction with equally accurate GPS and depth sounder, we managed to tuck into a cove of Taboga Island, with the intent of entering the Panama Canal channel in the morning of March 25. We thus achieved our goal of reaching Panama by the 25th of March — three thousand miles from Marina Del Rey. It was a fast passage, and I am sorry we could not linger in Mexico and in Costa Rica.

"After several days at the Balboa Yacht Club just off the Canal Channel on the Pacific side, we transited the Canal on March 30. Meanwhile, Nigel Gale had arrived via plane from L.A., as had Toni, and they both were aboard for the Canal transit. The transit was quite interesting. Locking up through the three locks at Balboa, we were rafted up with two other yachts and no other vessels in the locks ahead of us or behind us. We were lucky. Usually there is a large ship ahead, and its props create a surge upon leaving the lock that can be a serious problem for a small vessel behind it. During the 50 miles of the lake portion of the Canal we were under power by ourselves (with a Pilot-Advisor aboard). The lake scenery was very pretty. We averaged over 8 knots, and made it to Colon in time to complete the transit in one day. Locking down we were placed center lock by ourselves, but there was a very large tug with an eight hundred foot tow behind us. We had no mishaps, and arrived at the Panama Canal Yacht Club in Colon late in the afternoon of March 30th.

"Paul Carlton and Toni both departed from Colon to fly back to L.A. Nick and Ed also departed there, but instead of finding positions on another yacht, they equipped themselves with jungle gear. They were last seen heading off for a foot journey down into Columbia, despite our warnings that they were undertaking a very dangerous trip. I shall write to Ed's parents in England to inquire as to the news from them.

"My son, Steve, joined Nigel and me in Colon for the passage to Montego Bay, Jamaica, and we three departed at 2:45 p.m. on April 2nd. We knew this would be directly into a stiff wind and it was. After a rough passage, we arrived in Montego Bay at the northwest end of Jamaica on April 7th — some 600 miles north of Colon, Panama. Steve had to catch a plane back to the U.S. on April 10th, so we lingered in Montego Bay for several days on a delightful beach.

"Nigel and I then departed on the 11th, headed east along the north shore of Jamaica (120 miles) to the Windward Passage between Cuba and Haiti, and then northeast to Great Inagua in the Bahamas. This was a passage of 350 miles and it, too, was extremely rough. We arrived in the Bahamas on April 14th. We then island hopped up through the Bahamas to Nassau, after stopping in Georgetown and other places in the Exumas. We arrived in Nassau on the 19th, and Nigel caught a plane back to L.A. on the 20th.

"On the 25th Jessica Spitek joined me in Nassau. We departed on the 27th for Chubb Bay in the Berry Islands, and thereafter we wound our way up to Great Harbor Cay where we spent several days in a very secure harbor just unwinding a bit. We had a memorable Bahamian dinner with new friends, cooked especially for us by Michelle, a local woman. Jess and I then left on May 5th for Freeport on the west end of Grand Bahama Island, where we spent a stormy night tucked into the harbor.

"On May 6th we departed for Ft. Lauderdale, arriving late in the afternoon. Old sailing friends, Ted and Arline Raab, and other friends, Peter and Marty Mamunes, were very helpful to us there, and we spent several days at a private condominium dock awaiting an electrician. (No serious problem — just the pesky type.) Jess and I then went outside and reentered at Lake Worth on May 16th. From there, we stayed in the Intracoastal Waterway with successive stops in Ft. Pierce, Vera Beach, and now Titusville in the Cape Canaveral area, where we are anchored awaiting the passage of a storm front. On that note, I'll end for now. Warm regards and best wishes! (From here it's on up the waterway to points north).
— *Roger*

Director Alan E. Bayless of 116 Gardens Drive #201, Pompano Beach, FL 33069 writes: "I have been dissatisfied with the sign schedule for the *Auxiliary Table* used in conjunction with the *Sight Reduction Tables* which are presently found in the *Nautical Almanac*. These tables, as I'm sure you know, were the result of the collaboration of the late Admiral Davies and Paul Janiczek. I got into the act later and suggested the present marginal *rubrics* for the signs involved. However, the sign schedule for the altitude corrections, particularly the corrections for F, are too bloody difficult. They have proven to be a prime source of error in the use of the table by USPS students. So, after some fruitless attempts to enunciate the rules in a simpler fashion, I came up with a minimal modification of the *Auxiliary Table* itself....

"Anyway, for your amusement, I've enclosed a copy of the modified *Auxiliary Table*. As you will note, the signs for the corrections are found directly from the table and the need to reverse the sign of *corr*, when F > 90° is all that remains. Incidentally, I find it interesting, if unimportant, that "F > 90°," which occurs only when the body is poleward of the foot of the perpendicular from zenith to hour circle and t < 90° is not! It is actually (B + D) that is greater than 90°and not F. B + D=co-F+90° = 180°- F and F is never > 90°!

"Anyway, here I am. Maybe *this* will be my final address?

"Incidentally, I am currently co-chairing a committee to abridge the USPS courses in celestial navigation ... and would love to get in touch with the two guys who are currently abridging *Bowditch*. I don't want to heckle or advise, but I'd sure like to know what they're doing. Do you know who is involved or how I can get in touch with them? ...

"I had the pleasure of seeing Roger Jones when he reached Fort Lauderdale. I had decided not to accompany him in his voyage via the Panama Canal in view of my relative physical fragility (I sure did give it a lot of careful consideration, though). He obviously did very well without me! But I think I made the right decision, nevertheless.

"In any case, I continue to be somewhat involved in things nautical. I have presently undertaken the instruction of a good friend of mine (also a past Chairman of the Navigation Course for USPS) in great circle calculation *a la* Edward Willis, and all his marvelous observations on gnomonic charts generally. Remarkable guy, Willis. I know absolutely nothing about him except his books, do you? Alton Moody first acquainted me with his work and sent me the first edition of his book (1925) as well as a couple of 'appendices' published separately. I subsequently found a copy of his much enlarged 1935 version in the UCLA library of which I made a Xerox copy. A startlingly different approach to celestial navigation calculations and concepts!

"I hope this note finds you in the best of health and enjoying life. And I hope all is well with the Navigation Foundation, too." — *Allan*

"A few PS's:

"Oh! I forgot to mention the revised *Auxiliary Table* has found favor with the "commercial edition" of the *Nautical Almanac* published by Paradise Cay/Celestaire and it may be included therein *in addition* to the government version.

"Incidentally, Admiral Davies never answered me directly as to where he found the inspiration for his *Concise Tables*, but I have assumed they are a modification of Admiral Radler de Aquino's tables; do you know if this was his source?

"Another afterthought: Also revised in the enclosed version of the Auxiliary Table are the tabulated values for P 30°/$Z_2$60°. The tabular values on this row should represent the minutes increment times the sin of the angle [sinP30°=cos(90°-P)=cos$Z_2$60°], this is true for all other tabulated values, all of which are rounded *up*. But on this line, the value for Pi/6 was apparently calculated as minimally less than 0.5(sin 30° - sin Pi/6 = 0.5, *exactly*) and the tabulated values rounded *down* instead of *up*, as they should have been. This error has been corrected in the enclosed revision. It makes no difference whatever to the pencil-and-paper navigator for whom this table is intended, but it makes it impossible to reproduce the values with a calculator unless a subroutine is added for this row only. Janiczek and I had decided the differential equation (H'=F'sinP-A'cos $Z_2$) should be the basis for this table, rather than as published in Davies' version so it would be reproducible by calculator...."

Member George P. Leonnig, Owner/Master S/V *Moctobi*, mailing address 8125 SW 54th, Portland, Oregon 97219, writes that he is preparing to set out on a 3-

year adventure and is looking forward to exercising the art of traditional navigation extensively. Mr. Leonnig, a former quartermaster in the U.S. Navy, also writes that he hopes that through his experiences during the next 3 years he can contribute to the Foundation and the art of navigation.

The Honorable C. Huguenin, Switzerland's ambassador to Tanzania, wrote to us from Dar es Salaam on January 10, 1944:

"Between X-mas and the New Year, I at last managed to indulge in my favorite hobbies of hunting and navigation and took to the vast expanses of uninhabited Tanzanian bush with my family.

"It was my first go with the sun compass again since I left Libya 1½ years ago and I was initially in quite a shock! . . . My shadow angle tables were all haywire!

"I first corrected my tables and formulae empirically and later back home did my homework correctly: I had forgotten that in southern latitudes, when LHA is greater than 180, Zn does not equal Z but 180-Z!

"Serves me right for not having read the script in the Air Navigation Sight Reduction Tables!

"Here's wishing you both, your families and the Foundation all the very best for 1994. — *S. Huguenin*

# NAVIGATION FEATURES

## The 'Two Body Fix' Re-visited

*By George G. Bennett*

In issues 37 to 42 of the *Navigator's Newsletter*, considerable attention has been focussed on what has come to be known as the "two body fix". In my view, the problem, including the case when sights are not made simultaneously, is capable of a simple and practical solution that does not require anything other than the application of standard spherical trignometrical formulae, some simple convention for the variables and the normal definitions of circular functions (sine, cosine and tangent). If these latter precautions are not taken then it will be found, as most authors have discovered, that in addition to the basic data of GHA, declination and altitude for each star, information is required on the position or inter-relationship of the two bodies. For example, in the solution offered by Matthews (Issue 41/42 p.9) one must know where the observer's zenith lies in relation to the great circle connecting the two bodies. Solution by Dozier, Derickson, A'Hearn & Rossano, Pepperday, Keys *et al* fall into this category.

In May 1979 I submitted an article to the Navigation journal entitled "General Conventions and Solutions - Their Use in Celestial Navigation" which was published in Issue No. 4, Vol. 26, Winter 1979/80. In that article I promoted the advantages of adopting general conventions and illustrated it with examples, one of which was the two body fix. I claim no priority in my exposition of general conventions, which rightly belongs to the German mathematician C. F. Gauss and the American astronomer W. Chauvenet. Unlike Matthews (Issue 41/42 p.3) I do not consider myself a 'co-inventor' but rather a 'disciple' furthering the work of Gauss & Chauvenet.

When such a generalized system is adopted all problems of celestial navigation are amenable to unambiguous solutions which do not require the navigator to memorize or look up rules when, say, "Latitude and Declination are of the same or opposite name". The system is admirably suited to solutions by calculator/computer.

E.g. Sight Reduction

$$\sin Hc = \sin Lat \sin Dec + \cos Lat \cos Dec \cos LHA \quad (1)$$

$$\tan Z = \frac{-\sin LHA}{\tan Dec \cos Lat - \sin Lat \cos LHA}$$

Where Hc is the calculated altitude (negative below the horizon), Lat and Dec are the latitude and declination respectively (+N, -S), LHA is the local hour angle (measured from the local meridian 0° - 360° and Z is the azimuth measured clockwise from north 0° - 360°). These symbols and conventions, including those used later in this article, are identical to those adopted in the Nautical Almanac.

The solution of azimuth as given by formula (2) may be unfamiliar to navigators. The azimuth is placed in its correct quadrant by considering the signs of the numerator and denominator. The calculator user does not have to concern himself with the problem as the 'to polar' and 'to rect' functions are designed for this purpose, as was stated in my original article and repeated by Pepperday in Issue 39 p.7.

General Solution of the Two Body Fix

The following is a synopsis of the solution given in my 1979 article. Given the GHA, declination and altitude of each of two bodies the latitude and longitude of the observer can be deduced as follows,

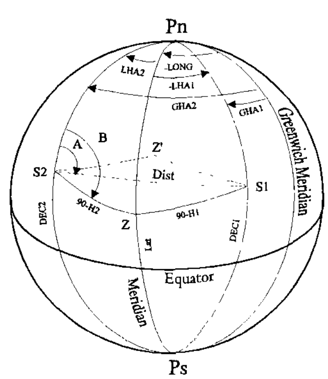



DIAGRAM 1

From Diagram 1

$$\cos Dist = \sin Dec1 \sin Dec2 + \cos Dec1 \cos Dec2 \cos(DGHA) \quad (3)$$

$$\tan A = \frac{\sin(DGHA)}{\tan Dec1 \cos Dec2 - \sin Dec2 \cos(DGHA)} \quad (4)$$

where DGHA=GHA2-GHA1

$$\cos(B-A) = \frac{\sin H1 - \sin H2 \cos Dec1 \cos Dist}{\cos H2 \sin Dist} \quad (5)$$

The solution for (B-A) is ambiguous because of the two possible positions of the zenith Z and Z'. Therefore the two values of (B-A) which result will give two values for B.

$$\sin Lat = \sin H2 \sin Dec2 + \cos H2 \cos Dec2 \cos B \quad (6)$$

Two values of Lat result from the two values of B.

$$\tan LHA2 = \frac{\sin B}{\tan H2 \cos Dec2 - \sin Dec2 \cos B} \quad (7)$$

Two values of LHA2 result from the two values of B as before.

The longitude of the observer's position is the found from

$$Long = LHA2 - GHA2 \quad (8)$$

Likewise two values of Long result from the two values of GHA2.

The aforegoing solution is completely general and it is immaterial in which order the bodies are considered for the solution and their disposition on the celestial sphere.

As was seen, two positions result from the data and the decision as to which of the two is correct only presents a difficulty when the bodies are nearly in line (sliding fix).

Non-simultaneous Sights

When the two observations have not been made at the same instant, which is usually the case, the basic data must be modified before the solution can be effected in order to take into account the possibility of a change in the observer's position. This is not a problem peculiar to the two body fix. When one uses the Marcq St Hilaire technique non-simultaneous sights are usually treated in one of two ways.

(1) If the time interval is short or the vessel has only moved over a short distance the observed altitude may be corrected as follows,

$$Hf = Ho - t(V/60)\cos(Z-T) \quad (9)$$

Note that t is the time interval from the time of fix to the time of observation.

By correcting the observed altitude in this way we assume (a) that we are dealing with a first order effect (higher order terms are negligible) and (b) there is no significant difference between the vessel's rhumb line course and a great circle path. It is for these reasons that the application of this formula should be restricted. I even suggested in the original article that the azimuth could be obtained from a star finder - this being simple and of sufficient accuracy for the illustrative example (2.6 miles between sights). Your correspondent, E. Matthews (Issue 41/42 p.3) criticizes the application of this method by making an incorrect comparison with formulae that are more appropriate to long runs between sights. One should not condemn a technique when it is used out of context.

(2) If the distance covered between sights is long, then other techniques should be considered. The standard method in sight reduction is to use transferred observations (British nomenclature - double sights). A new DR position based on the vessel's run between sights and the fix obtained from consideration of the second sight and the transferred azimuth and intercept of the first. This technique is easy to apply both numerically and graphically, the details of which may be found in standard text books on navigation.

Method A

For the two body fix, and this also applies to the Marcq St Hilaire method, a derivation of an altitude correction, from which the simple altitude correction described previously can be made as follows,

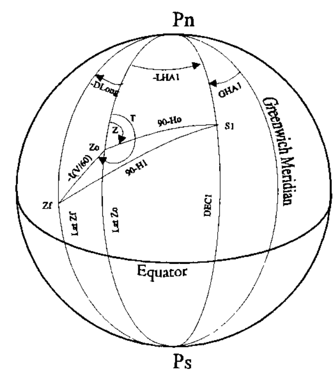



DIAGRAM 2

Zo and Zf show the position of the observer at the times of the first and second sights respectively. If the values of GHA1 and Decl, obtained at the time of the first observation are retained then all that is required is a new value for Hl to effect the two body fix solution previously given.

In order to treat triangle Zo,Z,Sl as a spherical triangle the rhumb line course T must be corrected to a great circle course. This may be done either using Table l in Bowditch Vol II or numerically as follows,

$$\text{Conversion Angle } CA = \frac{-DLong \sin MeanLat}{2}$$

$$\text{but } Dlong = \frac{-t(V/60)\sin T}{\cos MeanLat} \quad (10)$$

$$\therefore CA = t(V/60)\sin T \tan MeanLat \quad (11)$$

Where Dlong is LongZf-LongZo and the average of the latitudes of Zo and Zf is taken for Mean Lat.

The formula is a very close approximation to the rigorous one which involves meridional parts. It has also been assumed that the great circle and rhumb line lengths are the same and the conversion angle at either end of the course are equal.

From the cosine formula in triangle Zo,Zf,Sl we obtain

$$\sin Hl = \sin Ho \cos(t(V/60)) - \cos Ho \sin(tV/60))\cos(T+CA-Z) \quad (12)$$

where Z can be calculated from either formula (2) unambiguously or from

$$\cos Z = \frac{\sin Decl - \sin LatZo \sin Ho}{\cos LatZo \cos Ho} \qquad (13)$$

or from

$$\sin Z = \frac{-\cos Decl \sin LHA}{\cos Ho} \qquad (14)$$

The ambiguity in the solution of Z from its cosine in formula (13) is resolved by considering the size of (GHAl - Long Zo) i.e. the value of the approximate LHA. Although formula (14) is the simplest of the three, the ambiguity in the solution of Z from its sine is not easily resolved. For ways of accomplishing this the reader is referred to discussions related to the Rust diagram in navigational texts.

After Hl has been found, formulae (3) to (8) can be applied to find the observer's position.

Method B

An alternative solution which is also simple to derive and apply is as follows. If in diagram (2) we shift the observer's zenith Zo to the meridian of Zf through an angle -DLong, see formula (10), and also the star's GHA by the same amount so that

$$GHAl = GHA + DGHA = GHA + \frac{t(V/60)\sin T}{\cos MeanLat} \qquad (15)$$

the resulting situation will be shown in Diagram 3.

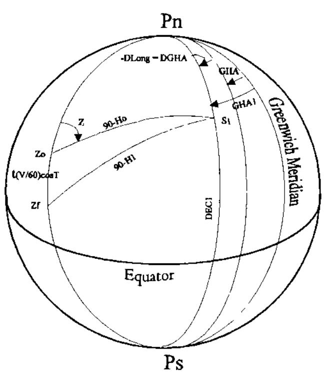



DIAGRAM 3

From the cosine formula in triangle Zf,Zo,Sl

$$\sin H1 = \sin Ho \cos(t(V/60)\cos T) - \cos Ho \sin(t(V/60)\cos T)\cos Z \qquad (16)$$

Z may be calculated from either formula (2) or (13). Alternatively, if one substitutes the expression for cosZ from formula (13) in formula (16), then

$$\sin H1 = \sin Ho \cos(t(V/60)\cos T) - \frac{\sin(t(V/60)\cos T)(\sin Decl - \sin LatZo \sin Ho)}{\cos LatZo} \qquad (17)$$

Illustrative Example

Approximate position at the time of the first observation N54°, W46°. Based on a course of 205° and a speed of 20 knots the position at the time of the second observation is N52°27', W47° 12'.

| Body | GMT of obs'n | Altitude* | GHA | Dec. |
|---|---|---|---|---|
| 1 | OH 10M 50S | 62°24.5' | 39°17.6' | N26°44.2' |
| 2 | 5 17 26 | 69°24.7' | 80°38.4' | N51°29.4' |

*Corrected for index, dip and refraction.

Find the observer's position at the time of the second observation.

Method A

| | |
|---|---|
| Z(formula (2)) with LHA=353°17.6' | 167.038° |
| Mean Latitude | N53°14' |
| CA (formula (11)) | 0.963° |
| Hl (formula (12)) | 63°42.8' |
| Position of fix (formulae ((3) to (9)) | N52°23.0' |
| | W46°58.3' |

Method B

| | |
|---|---|
| GHA(formula(15))** | 40°29.8' |
| Hl(formula(17)) | 63°55.3' |
| Position of fix (formulae(3) to (9)) | N52°21.4' |
| | W46°58.9' |

**Mean latitude as before

Small variations in the value of Z will be obtained depending upon which of formulae (2), (13) or (14) is used. This will result in small variations in the position of fix. If high accuracy is sought the solution may be repeated using the improved estimates of the position of fix in the solution.

Conclusion

It has been shown that the two body fix, including an allowance for run between sights, can be solved in a relatively straightforward way. The solutions offered involve some minor approximations which would be masked by uncertainties in the observed data, when one considers unknown errors of helming, current, leeway, windage, to name but a few that would be present after a long run.

In extreme circumstances, altitudes of 88° etc as cited by your correspondent E. Matthews in Issue 41/42 p.8, most methods will exhibit inaccuracies in position brought about slight differences between the values of the true and estimated positions. However, an iteration of the solution should rectify this problem when the refined values of position are used in the solution.

I consider the technique inferior to that of the Marcq St Hilaire method, which has been almost universally adopted. Any number of bodies can be considered simultaneously, even a single position line may be of invaluable assistance in certain circumstances. The number of reduction methods that has been devised using logarithms, calculator/computer, tabular and graphical methods attest to its popularity. If one chooses to navigate using the two body fix technique, then my view is that there is no logical justification for this self-imposed restriction.

My interest in the method stemmed from a desire to popularize general conventions and the two body fix readily demonstrated their advantages. I have heard it argued that with the two body fix a navigator need not know his position at all. This surely is a proposition that any self-respecting navigator will reject. It would be absurd to suggest that one could be in such a situation. In an extreme case two applications of the Marcq St Hilaire technique will converge to give an acceptable fix.

## Longitude by Maximum Sun Altitude

*By Edward I. Matthews*

By definition Local Apparent Noon (LAN) occurs at the instant the sun bears due north or south at meridian transit. At this time the navigational triangle reduces to a straight line with the meridian angle (t) equal to zero. Finding latitude (L) then becomes a simple operation involving the Sun's declination (D) and the observed altitude (Ho).

$L=D\pm(Ho-90)$

To maintain the practice of signifying north and west with the + sign and south and east as negative (with apologies to our 'down under' friends), we use the term (Ho-90). Then + is used if the Sun bears north of the observer. The timing is not critical since Ho is nearly constant at this time.

Longitude (Lo) can also be determined at LAN, it being equal to the GHA of the Sun when west of Greenwich and (GHA-360) when east. Note that east Lo will always be negative. The problem however is to determine the exact time of LAN with Ho almost at standstill. A few navigators assume that LAN occurs at maximum observed altitude. This is only true when the vessel is steaming due east or west at the time of the solstice or if the noon Sun is directly overhead.

Two factors influence the time difference between LAN and maximum Ho(Tmax). The first condition is due to the relative north/south movement of the Sun and the observer at LAN. The hourly rate of change of the Sun's declination (d) is considered positive when increasing northward. If d is advancing toward the observer, Ho will still be increasing after LAN. Therefore Tmax will occur later than LAN. If the vessel has a northerly component of speed (S) on course (C), maximum Ho will occur earlier than LAN since the observer is proceeding away from the Sun. This effect can be expressed mathematically by (d-ScosC).

The second condition effecting Tmax is due to the seasonal altitude of the noon Sun. It establishes the magnitude of the time difference and is determined by the latitude difference of the observer and the Sun. This effect can be denoted by (tanL-tanD).

The total effect is represented by:

$\sin t=(d-S\cos C)(\tan L-\tan D)/900$

$LAN=Tmax-t/15$

then at LAN:

$Lo=GHA-t$

The equation for sin t is a simplification of my original derivation which appeared in the winter 1984 edition (#7) of the Newsletter.

John Luykx in the spring edition (#39) of the Newsletter takes a different approach for determining LAN that uses an altitude factor from Bowditch Table 29. The formula given had an obvious typo error and should be:

$\Delta t=(t_1-d_1)\ /2a$

The problem of determining Tmax remains. Several observations of the Sun are made some time earlier than meridian transit, when the altitude is changing more rapidly. A second series of observations are made during transit. Sometime after LAN when Ho returns to one of the AM altitudes the time is recorded. Tmax will occur half way between the times of two equal altitude sights. This is only true if the speed and course are maintained constant. This may be difficult with sail powered vessels unless the Sun is high enough for a short period between the sights to occur.

Another problem with the equal altitude method is the unpredictability of cloud conditions obscuring the Sun at a critical time. This problem may be avoided by the use of a statistical least squares polynomial routine. By this means a series of sights taken around LAN can be provided with a best fit approximation of the actual altitudes. Obscured Sun sights can be approximated to obtain both Tmax and maximum Ho. An important feature of this method is the 'smoothing' of observation errors. A mathematical description of this routine may be found in Milne's 1949 edition of *Numerical Calculus*.

To illustrate the maximum altitude method, consider a ship steaming at 19 knots on a course of 228° in time zone +9. The date is Jan. 17, 1993 and the maximum Ho was 42°14.6'. The AM and PM sights need to be changing at least 0.1' per second to be useful. This required the AM sights to be acquired at least 1½ hours before LAN at this time of year. Tmax was determined to be 12:27:52.

$L=-20.6028-(42.2435-90)$
$=27.1537°$ or 27°09.2N

$\sin t=(.5-19\cos 228°)(\tan 27.1537°-\tan -20.6028°)/900$
$=.0130$
$t=.7477°$

$t/15=.0498$ or 2 min 59 secs after LAN

LAN=12:27:52-2.59=12:24:53

$Lo=139.3933°-.7477°$
$=138.6456°$ or 138°38.7W

To illustrate the seasonal effect, consider the same ship under the same conditions but on July 19,1993. Tmax occurred at 12:21:12 with Ho of 83°32.9. The rate of change of the high altitude Sun of 0.1' per second is now only about ¼ of an hour either side of Tmax and the time difference between Tmax and LAN is only 25 secs.

# NAVIGATION BASICS REVIEW

## Checking the Deviation of Your Compass

*By John M. Luykx*

The author has often been asked by boatmen to describe a simple procedure for determining boat compass deviations. The following procedure is suggested for those who may wish to quickly check the accuracy of a boat compass.

The accuracy of a boat compass can easily and rapidly be checked by noting the compass course between a set of beacons or other navigation aids in the local operating area and comparing this compass course to the magnetic course between the beacons obtained from the chart. The difference between the compass course and the magnetic course is the deviation of the compass. The deviation is *West* if the compass course is *greater* than the magnetic course. The deviation is *East* if the compass course is *less*. The procedure is as follows:

First: In your local operating area, select two beacons (they are better than buoys for this purpose since they are fixed to the bottom) and determine the true course back and forth between the beacons.

Second: From the compass rose on the chart determine the variation and apply it to the true course to obtain the magnetic course between the beacons. If the variation is *West, add* the variation to the true course to obtain the magnetic course. If the variation is *East, subtract* the variation.

Third: Steer a course between the beacons and compare the course steered by compass with the magnetic course to determine the deviation of the compass.

Fourth: Record the deviation and keep this information in the vicinity of the compass for ready reference.

Note: Repeat this procedure for several additional sets of beacons in your area which will provide data on different headings.

Example:

A. To demonstrate this procedure, beacons in the St. Mary's River in Southern Maryland were selected to show how a deviation table for the boat compass is computed. The variation in this area is 10°W. The following data shows the true courses between each of the four selected sets of beacons, the magnetic courses, the courses steered by the boat and the deviation for each course.

1. Lighted beacon "1" to

| | | |
|---|---|---|
| lighted beacon "2": | 035°T | 215°T |
| Variation: | 10°W | 10°W |
| Magnetic Course: | 045° | 225° |
| Compass Course Steered: | 053° | 220° |
| Deviation: | 8°W | 5°E |

2. Lighted beacon "2" to

| | | |
|---|---|---|
| lighted beacon "3": | 350°T | 170°T |
| Variation: | 10° | 10°W |
| Magnetic Course: | 000° | 180° |
| Compass Course Steered: | 005° | 177° |
| Deviation: | 5°W | 3°E |

3. Lighted beacon "3" to

lighted beacon "2":

| | | |
|---|---|---|
| (St. Inigoes Creek): | 088° | 268° |
| Variation: | 10°W | 10°W |
| Magnetic Course: | 098° | 278° |
| Compass Course Steered: | 105° | 273° |
| Deviation: | 7°W | 5°E |

4. Lighted beacon "A" to

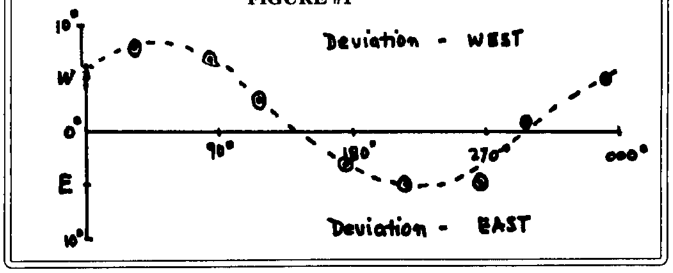
lighted beacon "2":

| | | |
|---|---|---|
| (St. George Creek): | 295°T | 115°T |
| Variation: | 10°W | 10°W |
| Magnetic Course: | 305° | 125° |
| Compass Course Steered: | 306° | 138° |
| Deviation: | 1°W | 3°W |

5. Deviation Curve

The Deviation curve derived from the above data is as shown below:

FIGURE #1




C. The Deviation Table derived from the Deviation Curve is shown below:

| TRUE COURSE | MAGNETIC COURSE | DEVIATION |
|---|---|---|
| 000° | 010° | 6°W |
| 030° | 040° | 8°W |
| 060° | 070° | 8°W |
| 090° | 100° | 6°W |
| 120° | 130° | 3°W |
| 150° | 160° | 1°E |
| 180° | 190° | 2°E |
| 210° | 220° | 4°E |
| 240° | 250° | 4°E |
| 270° | 280° | 4°E |
| 300° | 310° | 2°E |
| 330° | 340° | 1°W |

# NAVIGATION NOTES

## A Navigation Problem: Three Star Fix by H.O. 229

*By William O. Land*

Returning from Bermuda to Norfolk we wish to get a fix on the morning of the 4th of July 1994. We made a precomp the night before using the No. 2102-D Star Finder and found the morning twilight to be about 3:30 A.M. Local Time and the stars Capella, Fomalhaut and Vega to be in good positions roughly about 120° apart.

As we entered the cockpit of our 52-foot ketch we looked around and found Fomalhaut almost due south with the planet Saturn several degrees above it, higher in the sky. It would be a good planet for a fix, but we will stick to our three stars. On the east we found Capella with Mars and the Moon slightly to the south above the eastern horizon. The Moon is waning with only a sliver showing. Its last quarter was June 30th and the date of the New Moon will be July 8th, so the Moon isn't going to be bright enough to cause any trouble with the sextant shots.

Our dead reckoning position is 35°01.7'N, 71°21.8'W, date 4 July 1994, Eye Height 10', Chrometer Error 7 seconds fast, Index Error +0.2', and the sextant shots as follows, all Local Zone Time:

(#12) Capella, Hs 20°52.4', @ 3h, 49m, 19s.
(#56) Fomalhaut, Hs 25°11.9' @3h, 53m, 51s.
(#49) Vega, Hs 38°35.5' @ 3h, 57m, 10s.

We did a sight reduction using H.O.229 and made a plot using the V.P.O.S. Universal Plotting Sheet. We determined our fix to be 35°14.0'N and 71°28.0'W. The complete sight reduction and plot will be printed in the next issue of The Navigator's Newsletter, but if you want the solution sooner, please write or phone William O. Land, 1521 W. Main St.(E-1) Norristown, PA 19403. (610) 539-0790.

## Answer to Last Issue's Problem

What Peary did not know is that a "longitude" observation 150 miles (or even further) from the north pole can be worked out without any trigonometry by simply using an assumed position of the pole itself. The line of azimuth from the assumed position to the sun is simply its GHA, and the intercept is readily determined by noting that the computed altitude of the sun (using the pole as the assumed position) is simply its declination.

In this example, the time difference between the time of the observation and the time of the sun's meridian passage at Greenwich (reported in the almanacs of Peary's time) gives the GHA (if one ignores the change in the equation of time over the relatively short period). Thus the time difference of 10 hours, eight minutes and eight seconds corresponds to 150 degrees plus two degrees plus 2 minutes( minutes can be ignored). The sun's GHA is thus 152 degrees, and the line of position (90 degrees to the "azimuth") is a line parallel to the 62nd west meridian.

The distance from the line of position to the 62nd meridian is, as in normal slight reduction, one mile for each minute of difference between the computed and observed (corrected) altitudes. The sun's declination of 4 50' 48" is reduced by about 1'52" for two hours before midnight GMT (1'42" for 1 hour 50 minutes, if one wants to be precise) giving about 4 49'. This is about 26' less than the observed altitude, meaning the intercept is 26 miles from the 62nd meridian toward the sun (i.e., toward the 70th meridian in this example).

This line of position can be plotted on polar paper or used to determine a longitude directly where, as here, the meridian parallel to the line of position is not too far from the dead reckoning position, i.e., sight taken when sun assumed to be close to due west or east. Using the direct method, one would note that at Peary's latitude, one degree of longitude is about 2.36 miles (using trig tables to look up one cosine or, alternatively, a protractor and scale. Thus 26 miles would equate a longitude of about 11 degrees west of the 62nd meridian, or about 73 degrees west.

Although the earliest scholarly reference to this method of which I am aware dates to about 1905, it is apparent that Peary was not aware of the method in 1909. In fact, Peary did not use any of the line of position methods that began to be available after the "new navigation" of Marcq St. Hilaire was published in the 1870s. All of Peary's longitude sights used the "time sight" method, where the sun's altitude and declination and the observer's latitude are used with spherical trigonometry to derive the sun's local hour angle. This is then added to (or subtracted from) the sun's Greenwich hour angle to give longitude.

For a time sight, local hour angle is found from the equation:

```
sin (t/2) = sec L cosec p cos s sin (s-h),

where:

L=latitude
p=polar distance
h= altitude
s= (h+L+p)/2
```

The calculation would look like this:

```
   90  00  00
-   4  49  06  Declination (determined as above)
   85  10  54  Polar distance "p"

    5  15  30  h
   87  45  00  L      log secL      = 11.40605
   85  10  54  p      log cosec p   = 10.00154

  178  11  24  (h+L+p)
   89   5  42  s      log cos s     =  8.19849
    5  15  30  h
   83  50  12  (s-h)  log sin (s-h) =  9.99748
                                    2)39.60356
                                      19.80178
                      log sin (t/2) =  9.80178
                                t/2 = 39-18-45
                                  t = 78-37-30

Sun's GHA (determined as above) = 152-02-00
     -t                            78-37-30
Longitude                          73-25-30
```

Not only is this method, which requires five look-ups and interpolations in the confusing and easily misread log-trigonometric function tables, tedious and full of opportunities to make mistakes, but in addition Peary was concerned that the small rate of change in the sun's altitude At high latitudes meant that a local hour angle developed from the sun's altitude and an earlier determined ( and potentially inaccurate) latitude would be unreliable. Whether such concerns were entirely justified will be the subject of a future article.

# HISTORY OF NAVIGATION

## Origins of Geomagnetic Science

*A Revision by David G. Knapp*

Medieval lore surrounding the mariner's compass, with its seeming evidence of fearful unseen powers and influences, must have been colored with a superstitious awe that can scarcely be appreciated by the present-day student. Such primitive attitudes may well account for the meagerness of contemporary references to the beginnings of compass art, and the unfortunate resulting obscurities in later writings. The labors of a host of scholars have erected a considerable body of literature on which to draw, though discrimination is needed in handling a number of unsettled points. In the predecessor to this publication, Hazard has this to say concerning his sources:

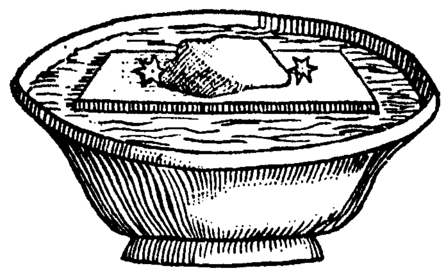
Much of the historical material has been taken from the 1902 publication. Detailed reference to original sources of information is not considered necessary. Benjamin's "Intellectual Rise in Electricity," published in London in 1895 and republished in New York in 1898 under the title "History of Electricity," was used freely by Bauer, and the writer has found the "Bibliographical History of Electricity and Magnetism" by P. Fleury Mottelay (London, 1922) of great assistance. Mottelay's English translation of Gilbert's "De Magnete" and Dr. G. Hellmann's reproduction in 1898 of the very rare writings on the earth's magnetism prior to 1600 have made it possible to get first-hand information regarding these important documents. Additional information regarding the early history of the compass was obtained from the investigation of G. Hellmann, A. Wolkenhauer, P. Timoteo Bertelli, and W. van Bemmelen.

More recently, the literature of some phases of the subject has been critically reviewed by Dr. A. Crichton Mitchell of Edinburgh, Scotland, an outstanding scholar and magnetician.[1] His findings illumine some of the obscurities remarked by Hazard in his historical discussion, which itself embodied substantial departures from its 1902 predecessor, and is further revised in the ensuing pages.

THE LODESTONE AND ITS PROPERTIES

At what date the properties of the lodestone first became known to man has not been definitely determined. Its property of attracting iron was certainly known to the Greeks toward the close of the seventh century B.C., as it is mentioned by Thales, who lived from 640 to 546 B.C. The origin of the word "magnet" is not well established, but it probably came from the place where the lodestone was first found (in the hills of Magnesia).

The names given to the lodestone, magnet, and compass form an interesting study and afford important clues to the diffusion of the concepts involved. Crighton Mitchell cites several writings in which this topic is explored. The terms for "magnet" in various languages are suggested, as a rule, by one of its properties, as attraction for iron (French, aimant; Spanish, iman); directive property (English, lodestone; Icelandic, leidersteen; Swedish, segelsteen; German, siegelstein); hardness (Roman, adamas; Old English, adamant). The Italian form, calamita, may be derived from the method of supporting the magnet in the early form of compass, namely, on a bit of reed (calamo) floating in a vessel of water. One kind of medieval floating compass is illustrated in figure 30.



The nature of the attraction for iron by the magnet was variously explained by the early Greek writers: "Iron gives it life and nourishes it"; "A certain appetite or desire of nutriment that makes the lodestone snatch the iron"; "Humidity in iron which the dryness of the magnet feeds upon"; "On the surface of the magnet there are hooks and on the surface of the iron little rings."

In addition to the physical properties of the lodestone recognized at the present day, curative properties for all sorts of maladies were ascribed to it in the Middle Ages, just as such properties were later ascribed to electricity. Toothache, gout, dropsy, hemorrhage, and convulsions were among the many complaints which it was said to relieve, and even disputes between husband and wife came within the scope of its magic powers.

On the other hand, a common belief which prevailed for many centuries was that a magnet would lose its directive property if rubbed with garlic, and mariners were charged not to eat onions or garlic lest the odor "deprive the stone of its virtue by weakening it and prevent them from perceiving their correct course."

The ancient myths about magnetic rocks and hills, typified by the fatal mountain of lodestone that broke up ships by drawing the nails out (in *The Arabian Nights*), were the precursors of equally fantastic ideas in later times, attributing the action of the compass to a supposed magnetic mountain or island in the Arctic regions.

Some writers have credited the Greeks with the use of the lodestone to direct navigation at the time of the siege of Troy, on the basis of a passage in Homer's Odyssey, but this interpretation seems not at all warranted by the wording of the original passage. According to Bertelli, a careful examination of the writings of more than 70 Greek and Latin authors, covering the period from the sixth century B.C. to the tenth century A.D., failed to disclose any mention of the directive property of the lodestone, or any suggestion from which one might conclude that this directive property found any use whatever in navigation, astronomy, or surveying during that long period of time, though there are numerous descriptions of voyages and storms at sea where mention of the compass would be expected, if it had been in general use at the time. Apparently the only facts about the lodestone which were known at that time were its property of attracting iron and of communicating that attractive power to iron. That the property of polarity was unknown before the tenth century is indicated by the fact that Pliny and subsequent writers explained the phenomena of attraction, repulsion, and neutralization of magnetic action by ascribing them to three supposedly different minerals, magnete, teamede, and adamas.

CHINESE APPLICATION DOUBTFUL

There has been a persistent belief that the directive property of the magnet was known to the Chinese before the beginning of the Christian era. Some writers go so far as to say that it was known as early as 2634 B.C. According to Klaproth a quaint legend relates that in the reign of Huang-ti the Emperor's troops attacked some rebels led by Thi-yeou, on the plains of Tchou-lou. Finding that he was getting the worst of the conflict, Tchi-yeou raised a great smoke in order to throw the ranks of his adversary into confusion. Huang-ti was equal to the occasion, however, and constructed a chariot which indicated the south and thus was enabled to pursue the rebels and take Tchi-yeou prisoner. Modern scholars consider this legend as clearly mythical. Huang-ti was probably the outstanding figure of Chinese antiquity, the legendary founder of the Chinese Empire, and it would not be surprising if knowledge and acts were ascribed to him which really belonged to a much later epoch.

The chih-nan-ch'ê or so-called south-pointing cart, a recurrent curiosity in Oriental literature since the third or fourth century, has been claimed to have been in use in China as late as the fifteenth century and to have been introduced into Japan in the seventh century. (See fig. 31) A pivoted figure with outstretched arm was mounted in front of the cart. Certain seventeenth-century missionaries supposed that a magnet had actuated the figure to keep it pointing south. It is now considered more likely that the cart was set in a place where the directions were known and that the figure was connected to the two wheels so that on rounding a bend the differential effect kept the figure pointing in the original direction. 2

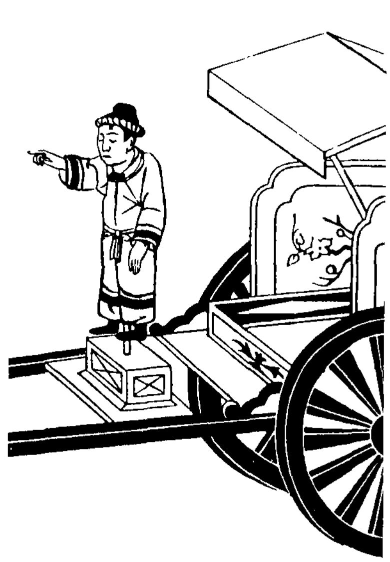


*Figure 31*

It must be recognized that a knowledge of the directive property of magnetized needles may have preceded by a long interval the embodiment of the principle in the form of a useful instrument, particularly if the secret was known only to a select class and carefully guarded. A remarkable passage in a work entitled "Mêng-ch'i-pi-t'an," which appeared toward the end of the eleventh century A.D., seems to establish that the directive property was known in China at that period. This passage is as follows:

A geomancer rubs the point of a needle with the lodestone to make it point to the south, but it will always deviate a little to the east, and not show the south: that to use the needle, it may be put on water, but it would not be steady; and also it may be put on the nail of a finger or on the lip of a bowl, but it is too apt to drop, because its motion is very brisk; that the best method is to hang it by a thread, and to prepare the contrivance, one has to single out a fine thread from a new skein of floss silk and fix it with a piece of beeswax on the middle of the needle, the latter to be hung up where there is no wind; that the needle would then always point to the south; that, on rubbing a needle with a lodestone, it may happen by chance to point to the north, and he (the author) owned needles of both sorts, and that no one could as yet find the principle of it. 3

This passage was repeated in several later Chinese works without essential revision, but we have no trustworthy evidence of any application of this knowledge for many centuries to come.

## MEDIEVAL ORIGIN OF THE MAGNETIC COMPASS

The earliest definite mention of the use of the compass in Europe occurs in a Latin treatise entitled "De Utensilibus," written about 1187 A.D. by an English monk, Alexander of Neckam. In another book, "De Naturis Rerum," he writes: "Mariners at sea, when through cloudy weather in the day, which hides the sun, or through the darkness of the night they lose knowledge of the quarter of the world to which they are sailing, touch a needle with a magnet which will turn around until, on its own motion ceasing, its point will be directed toward the north." [4]

At about the same date Guyot de Provins, minstrel at the French court, in a politico-satirical poem entitled "La Bible," refers to the use by sailors of the compass with floating needle. Other writers of the thirteenth century who speak of the use of the compass are Jacobus de Vitry, Cardinal of Ptolemais in Syria; Raymond Lully, of Majorca; Vincent de Beauvais, a crusader; Roger Bacon, the English philosopher (p.61); Brunetto Latini, a celebrated Florentine encyclopedist; and the poet Dante. Brunetto supposes that the lodestone directs the needle toward the mariner's star. He dwells on the distinction between the polarities of the opposite faces of the stone, and the effect each part has on the needle.

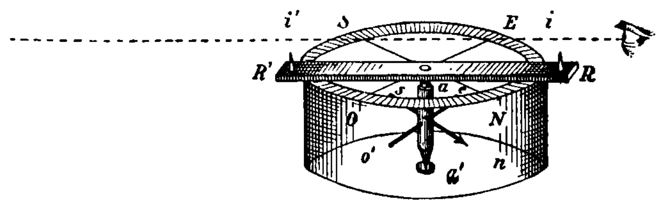
References to the compass in Chinese literature are fairly well authenticated after the eleventh or twelfth century, with some indication that Arabian navigators were the first to use a compass in Chinese waters. Klaproth, who made a special study of the early history of the compass, found "no indubitable use" of the compass in navigation by the Chinese until toward the end of the thirteenth century. A primitive floating needle seems to have been in use in China in the sixteenth century. [5]

## PETRUS PEREGRINUS AND THE PIVOTED COMPASS

It is to Pierre Pelerin de Maricourt, usually referred to as Petrus Peregrinus, that we owe what is probably the first European treatise on the magnet and the earliest known work on experimental physics. Pierre was a native of Maricourt, a little village in Picardy, France, and his appellation Peregrinus indicates that he had taken part in the Crusades. He was a partisan of Charles of Anjou and was with him at the siege of Lucera in southern Italy at the time (August, 1269) of writing his famous letter to his friend and neighbor, Sygerus de Foucaucourt — "Epistola Petri Peregini de Maricourt ad Sygerum de Foucaucourt, Miletem, de Magnete."

In this epistle he gave a clear and concise statement about what was then known regarding the magnet and its properties, which he had evidently tested experimentally. He conceived and made use of a spherical lodestone "in the likeness of the heavens," the precursor of Gilbert's terrella. He devised methods for locating the axis of such a magnet, finding that at the axis poles a short piece of a needle would stand perpendicular to the surface of the stone. He must also be credited with discovering the fact that when a magnet is broken into a number of pieces each piece will be a magnet, and with devising the methods of touch and rubbing for reversing the polarity of a needle (p.3)

In the second part of the discourse he described important improvements of the compass, which were attained (1) by floating the lodestone in a circular bowl with graduated rim, (2) by replacing the floating lodestone with a pivoted needle, turning between upper and lower bearings, and (3) by supplying an azimuth bar, having sighting pins, so that the azimuth of an object in any part of the horizon might be measured (fig. 32).




It will be noticed that Peregrinus had in his improved compass the features needed to ascertain whether or not the magnetic needle pointed precisely to the north. He noted (Part I, Chapter X) that the direction of the magnet is not toward the mariner's star, for that star is always out of the meridian except twice in each complete evolution of the firmament. Since he reached the conclusion that the poles of the magnet receive their power from the poles of the heavens, it seems safe to assume that the needle did not at that time point far from true north at the place where he made his experiments.

His work has further significance as a rare exemplar, for medieval times, of the experimental approach to Nature's laws. Small wonder, then, that he was hailed with the greatest enthusiasm by his advocate, the philosopher Roger Bacon, whose bold attack on the prevailing authoritarian basis of physical knowledge was a harbinger for the teachings of Copernicus, Galileo, Francis Bacon, Gilbert, and Newton, with their varying contributions to the emergence of experimental science. Roger Bacon characterized Peregrinus as the only man, besides Master John of London, who at that period could be deemed a perfect mathematician; and as one who understood the business of experimenting in natural philosophy, alchemy, and medicine better than anyone else in western Europe.

THE AMALFI TRADITION

With only a few manuscript copies of the letter of Peregrinus in existence, knowledge of its contents could hardly have diffused very rapidly, and some of the facts which it contained about the magnet may have been later discovered independently by others. Up to modern times there was a persistent tradition that the mariner's compass was invented by one Flavio Gioja, of Amalfi, Italy, about the year 1302. Bertelli made a very thorough investigation of the origin of this tradition and found nothing to indicate that it was founded on fact. The first writer to attribute a special knowledge of the compass to the Amalfians was Flavio Biondo, who, about 1450, made a first attempt at a history of Italy. The passage was quoted, with Flavio credited as its author, in a later work, whence it was carelessly re-quoted with the invention itself attributed to Flavio, who finally acquired the fictitious surname Gioja and the associated date.

It may be that the Amalfians should be credited with improving the compass by the substitution of a pivoted needle for the floating one and by the addition of the graduated compass card or "rose of the winds" attached to the needle and moving with it.

EUROPEAN ORIGIN NOW ACCEPTED

In the words of Crichton Mitchell, the present position with respect to the invention of the compass may be stated as follows:

"(I) That while it is possible that the Chinese were acquainted with the directive property of a magnet by 1093 A.D., they made no further use of that property for a least two hundred years thereafter.

"(II) That there is no evidence of the origin of any such knowledge among the Arabs, and it is improbable that they transmitted any information on the matter to Europe, their earliest mention of the compass being nearly half a century after its first mention in Europe.

"(III) That the compass was in use in western Europe by 1187 A.D., and taking into consideration the fact that the directive property must have been discovered much earlier, it is most probable that a knowledge of that property and its application in western Europe were of independent origin and as early as, if not earlier than, [the same developments] in China."

*Editor's Note:*

*Origins of Geomagnetic Science* is taken from chapter VI of the Coast and Geodetic Survey Serial 663, *Magnetism of the Earth* by Albert K. Ludy and H. Herbert Howe, published in 1945. The remainder of this chapter on the history of magnetism will appear in one or more issues of the Newsletter to follow.

1 A. Crighton Mitchell, Chapters in the history of terrestrial magnetism—Chapter I, On the directive property of a magnet in the earth's field and the origin of the nautical compass; Chapter II, The discovery of the magnetic delineation, and Chapter III, The discovery of the magnetic inclination. *Terr. Mag.*, 37, 105-146, 1932; **42**, 241-280, 1937; **44**, 77-80, 1939. Quoted extensively in the final chapter of reference [2].

2 M. Hashmoto, Origin of the compass, in *Memoirs of the Research Department of the Toyo Bunko* (the Oriental Library), Tokyo, 1926, No. 1, pp. 69-92. For an excellent description of geared mechanisms for accomplishing the result stated above without resorting to differential gears, are A. C. Moule, The Chinese South-pointing Carriage in T'oung Pao, Leyden, **23**, 83, 1924. Note, however, that the device there described would not maintain a true indication unless the inside wheel were locked for each turn. Gradual turns would not register at all.

3 Discussed by FRIEDRICH HIRTH, Ancient History of China, New York, 1908, p. 132. The translation above is that given by Crichton Mitchell.

4 The parallel passage from "De Utensilibus" contains the words "acum jaculo suppositam" which have been variously translated as "needle mounted on a pivot" or "needle placed on a reed" as in the floating compass. Some authorities accept the former rendition as proof that the pivoted compass was in use in Neckam's time.

5 Some of the Chinese references are reviewed in the article "Compass" in the eleventh and subsequent editions of the Encyclopaedia Britannica. The article likewise quotes the passages from Cardinal de Vitry and from the "Livres dou Trêsor" of Brunetto Latini. Other writers give a statement hitherto called Brunetto's, to the effect that the needle was commonly supposed to be guided by infernal spirits. Some such notion may have prevailed at some time in the distant past, but the statement in question (which is quoted in the 1925 predecessor to this publication) had its origin in a "letter" (fabricated in 1802, recording the pretended visit of Brunetto to Roger Bacon. (See Crichton Mitchell's Chapter 1, p.126, cited in footnote 1 of this chapter.)

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## Marad Advisories

MARAD ADVISORIES rapidly disseminate information on government policy, danger and safety issues pertaining to vessel operations, and other timely maritime matters.

MARAD ADVISORIES are periodically issued by the U.S. Maritime Administration (MARAD) to vessel masters, operators and other U.S. maritime interests.

Text of all in force MARAD ADVISORIES may be received by accessing the Defense Mapping Agency NAVINFONET system, or by contacting the Maritime Administration, Office of Ship Operations, Code MAR-745, Room 2123, 400 Seventh Street S.W., Washington DC 20590, Telephone (202)366-5735, Facsimile (202)366-3954, TLX II 710-822-9426 (MARAD DOT WSH).

MARAD ADVISORY NO. 94-1 (161331Z Feb 94)
Subject: Piracy in the South and East China Seas (161300Z FEB 94)
To: All Operators of U.S. Flag and Effective U.S. Controlled Vessels

1. An increased number of piracy incidents, some involving the use of armed force, have been reported in the South and East China Seas over the

past year. The International Maritime Bureau's Regional Piracy Center reported that out of 82 piracy attacks world wide in 1992, 60 have occurred in this region. The DMA Anti-Shipping Activity Message (ASAM) file contains almost 90 reports of attacks on vessels world wide in 1993 of which half are from the South and East China Seas.

2. Pirate attacks have occurred frequently in the South China Sea between Hong Kong, Hainan, and Luzon, and also have been reported in the East China Sea between Taiwan, The Sakishima Islands, and the southern archipelago of Okinawa. Japanese fishing vessels and Vietnamese flag vessels have been most often targeted, but numerous attacks have been made on vessels from other nations. Smugglers operating off the Chinese coast appear to be responsible for many of the attacks.
3. Mariners should exercise caution and vigilance when operating in these areas, and should obtain and evaluate current warning information broadcast by the Defense Mapping Agency (DMA) via hydropac broadcasts.
4. Mariners should review and have available for use the procedures for the "Ship Hostile Action Reports" (SHAR) and "Requests for U.S. Navy Assistance in Emergency Situations" found in Chapter 4 of the current edition of DMA Publication 117, Radio Navigational Aids, when operating in those areas.
5. Mariners should report all piracy, hostile actions, and related incidents while at sea, anchor or in port to the DMA, Anti-Shipping Activity Message (ASAM) file of the Navigational Information Network. (NAVINFONET).
6. Countermeasures have been effectively used by vessels to deter piracy boardings. Piracy countermeasures should be included in the ship's security plan, exercised and utilized when approaching dangerous waters. Some general precautions include the following:
   - A. Be vigilant. Anticipate trouble.
   - B. Provide a general alarm signal to alert all crew members.
   - C. Have water hoses under pressure with nozzles ready at likely boarding places when at sea and in port.
   - D. Illuminate sides, bows, and quarters while running in threat areas and in dangerous ports.
   - E. Keep a hood radar and visual lookout, including lookout aft.
   - F. Have searchlights available to illuminate suspected boarding parties.
   - G. Have signalling equipment available for immediate use.
   - H. Maintain or increase speed and use maneuver as navigational safety allows.
   - I. Don't be heroic if boarders are armed.

### Merchant Fleet Reporting of Alien Smuggling

1. Maritime smuggling of undocumented aliens has dramatically increased. Vessels involved in this type of activity are not equipped for the safe transport of passengers and pose a grave danger to the safety of life at sea. Often they are overcrowded and unsanitary without adequate food, ventilation, berthing and safety equipment. Recognizing the danger to life at sea arising from the unsafe practices of these vessels, the International Maritime Organization adopted an alien smuggling resolution urging governments to cooperate and increase efforts to suppress and prevent unsafe practices associhowever, that any vessel can be used to smuggle aliens.

2. Profile vessels: (A) General ocean going dry cargo vessels (150 to 500 feet in length) and (B) Former high seas drift net vessels (80 to 150 feet in length) with a superstructure amidships, rigging or heavy fishing gear aft and possibly a well deck forward. Typical crew size of the profile vessels is less than 25. Any vessel that is not designed for passenger travel but has an unusually large number of persons on board should be reported.

3. Merchant vessels underway within 500 miles of the US coast and noticing a potential smuggling situation are requested to contact the U.S. Coast Guard using the following procedures:

Contact a USCG Communication Station via HF radio telephone, radio telegraphy, or HF radio telex. (USCO Communications Stations are located in Kodiak, Alaska; San Francisco, California; Honolulu, Hawaii; Boston, Massachusetts; Portsmouth, Virginia; Miami, Florida; and New Orleans, Louisiana).

Vessels with INMARSAT can contact the USCG Atlantic Area Operations Center at 212-668-7055 or the USCG Pacific Area Operations Center at 510-437-3700.

Vessels in port may call Pacific Area Operations Center at 510-437-3700, Atlantic Area Operations Center at 212-668-7055.

Merchant vessels beyond 500 miles of the US coast should report to their flag state.

DMAHTC Representative Address/Telephone Number Changed

Defense Mapping Agency Hydrographic/Topographic Center West Coast Representative Mr. Gary Rogan, 11 Golden Shoe Drive, Suite 410, Long Beach CA 90802, Phone (310)980-4471.

# BOOK REVIEW

*By Terry Spence*

### *An Ocean Navigation Exercise: Bermuda to the Azores: 236 Navigation Problems*

By: Thomas M. Stout, Cornell Maritime Press, Inc. Centreville, Maryland 21617 (1985)

I recently completed a cruise as the skipper and navigator from Bermuda to the Azores in the comfort and ease of my home. It was both an enjoyable and educational exercise. Two or three days into the cruise there is an interesting Search and Rescue side trip necessary to help a stranded sailboat. The reader is Master and Navigator of the M/V *Peregrine*, an approximately 100' power driven vessel. "Except for a radio time signal receiver, a shallow-water depth sounder and 36-mile radar, no electronic aids to navigate are available."

There are three main divisions to this book; Part I - The Voyage; Part II - The Calculations; Part II - The Plots. All necessary excerpts from the Nautical Almanac, Bowditch and H.O. Pub. No. 229, plus other necessary tables are included in the appendices.

There are 236 navigational problems presented in Part I. You are required to determine during the course of the cruise initial great circle courses; determine azimuths for compass deviation; establish DR positions on a regular basis, and solve celestial fixes. You will determine set and drift necessary for determining the compass course to steer plus many, many more of the required duties normally associated with a 'navigator's work day'. The use of single LOPs to assist in checking on speed determination; arriving at the best times to shoot the stars, i.e. sunrise, twilight, sunset, etc. are all part of the problems posed.

Part II comprise the calculations to provide answers to the questions. The format is as follows:

Questions 1-2: You plan a great circle track from a departure point three miles due East of St. David's light to Ponta Comprida Light (The coordinates of both locations are given). What is the departure position?

In the calculations this is answered by the statement: "This is a parallel sailing problem", so you are led into the solution. Mid-latitude sailing principles are frequently employed to provide DR positions. The great circle sailing problems utilize H.O. Pub. No. 229 to arrive at the initial course. This reviewer used several other procedures to arrive at these answers - so expand your abilities. Celestial navigation solutions use the Nautical Almanac and H.O. Pub. No. 229.

The Plots (Part III) were developed on Position Plotting Sheets; DMA Stock numbers WOXZP 5960, 5961,5963 and 5965 which covers the necessary latitude ranges for the voyage. So, if you complete the 'voyage' by plotting only, you can check your plots against those provided.

This reviewer performed the calculations as well as plotting the cruise on Universal Plotting Sheets and kept a log of differences for future review.

Of interest to this reviewer was a 'Traverse Board' which provides the figures to arrive at 'l' for difference in latitude and "p" for departure, both figures that are necessary to solve mid-latitude sailing equations, most of which include changes of course and speed.

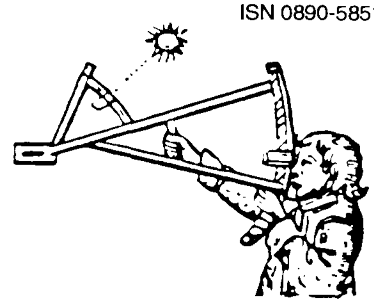
It is the kind of 'cruise' that can be re-taken several times to 'cement' the principles involved and to a self-taught navigator like me (Bowditch and Dutton primarily) a confidence booster.

So enjoy and Bon Voyage!

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126
Rockville, MD 20850
Telephone 301-622-6448

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-FIVE, FALL 1994

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Newsletters

The schedule for publishing the Newsletter has been a disaster. As soon as we think we have everything under control, a new problem surfaces. It took so long to get the Summer Issue printed that the publisher mistook issue 44 for the Fall Issue. For record purposes, Issue 44 is the Summer Issue of the Newsletter. This Issue of the Newsletter is Number 45, Fall 1994.

### Nautical Almanacs

The U.S. Government publication of the 1995 Nautical Almanac is available from The Foundation. The list price is $20.00 (members discount of 20% applies) and postage is $1.78 within the United States. The 1995 Nautical Almanac (Commercial Edition) is also available at a list price of $15.95 plus shipping of $1.98. (Members discounts apply).

Charts

DMA and NOAA Nautical and Aeronautical Charts are also available from The Foundation. The list price of current nautical charts is $14.90 and aeronautical sectional charts are $7.00. Other aeronautical charts are available at varying prices. Members receive a 20% discount on all chart orders up to $50.00 and a 25% discount of orders over $50.00. All orders are plus UPS or postage charges as appropriate.

### Celestial Navigation Classes

Member George E. Lear is starting a class in celestial navigation, with the emphasis on fundamentals. The class commences on February 28, 1995 at the Waldorf School in Bethesda, Maryland. If you are interested please call Member Lear at 301-986-0314.

## READERS FORUM

*Edited by Ernest Brown*

Mrs. Terris Moore of 123 Brattle Street, Cambridge, MA 02138 wrote on August 9, 1994, to inform us of the death of her husband: "Gentlemen: Terris Moore died on November 7, 1993. I must therefore ask you to remove his name from your mailing list. He very much enjoyed your Newsletter and other publications. *Sincerely yours, Mrs. Terris Moore.*"

Mary Chibnall, Assistant Librarian, Burlington House, Royal Astronomical Society, wrote on July 14, 1994: "Over the last few years, you have been very kindly sending us Navigator's Newsletter, which we have found very useful in our library.

We now have a complete run of it from No. 4, but are lacking issues 1-3. Do you still have any of these in stock? If so, we would be delighted if you could send them to us. *Yours faithfully, Mary Chibnall.*"

Member Carrie L. Watkins, P.O. Box 477, Sandia Park, NM 87047 (505)281-4677 wrote on August 5, 1994: "It was quite a surprise to read of Anthony Whitman's request for information about an IBM-compatible almanac program in the last issue of he newsletter. It sounds like we are trying to do the same thing.

I've enclosed a copy of the letter I wrote to the Naval Observatory after playing around with their I.C.E. software. If I get any kind of solution from them, I will certainly make sure to let Mr. Whitman know. Also, I would appreciate any information Mr. Whitman receives on the subject in case there's a better solution to the problem.

Thank you for providing the Reader's Forum for this kind of exchange. *Sincerely, Carrie L. Watkins.*

*Editor's Note: Member Anthony Whitman's request appears in Issue Forty-Three, Spring 1994.*

DO YOU KNOW . . .?

*By Ernest Brown*

When the Mercator chart came into general use among navigators?

(The answer appears at the back of this Issue)

Member Dan Hogan, 1622 S. Willow Ave., West Covina, CA 91790-5621 wrote on June 27, 1994: "The *Newsletter* is outstanding; every issue is interesting and informative.

"I currently sail a Catalina 27 out of Marina Del Ray, I use a pair of HP 32S11 pocket calculators for navigation. One is programmed with Mercator Sailing and Traverse Table calculations for dead reckoning. The other is used for celestial navigation using the Dozier formula and bits and pieces picked up from various navigation books that do the mathematics to solve for altitude, GHA, intercept and azimuth. In one issue of the Newsletter I found all the formulas that I searched through several navigation books for. *Most happily, Dan Hogan.*"

Allan D. Pratt, Registrar of Dials, North American Sundial Society, 1936 E. Belmont Drive, Tempe, AZ 85284 has written: "One familiar with your organization has suggested to me that your members might like to know of the establishment of the North American Sundial Society.

"The Society was formed early this year, with the objective of promoting interest in both existing dials, and in the design and creation of new ones. We have a quarterly journal, published both in paper and digital form, with articles ranging from the simply descriptive to the fairly technical.

"One of our objectives is to compile a registry of fixed dials (and collections of portable ones) in North America. In the hope that you are willing to assist us in this, and our other endeavors, I have enclosed a number of membership applications for the Society, and a number of copies of our dial registration form.

"If you or any of your members are interested in joining the Society, please fill out the application and mail it to Mr. Terwilliger, as directed in the application itself. If you care to contribute some information about existing dials to our registry, please fill out the registration form as completely as possible and send it to me. *Sincerely, Allan D. Pratt*"

*Editor's Note: The following information is taken from the membership application form of the North American Sundial Society:*

When you join, you will receive a subscription to *Compendium, the Journal of the North American Sundial Society* which is available in either conventional printed form or as a 3.5" MS-DOS compatible diskette. The quarterly *Compendium* contains articles describing both old and new dials, articles on construction and design, and on related topics. Photos of noteworthy dials are also featured. The diskette version also contains computer programs to solve a number of different problems related to dialing. Some issues also contain bibliographies or other data files too extensive for publication in the paper version.

In addition, you will receive a copy of the dial registration form for your use when recording information about dials you learn of, and *Guide for Dial Hunters*, our set of guidelines on what to look for when you go searching, and a list of the modest equipment you need for recording.

NORTH AMERICAN SUNDIAL SOCIETY
Membership Application

Name ______________________

Address ______________________

City/St/Zip ______________________

E-mail address (if any): ______________________

Choose the type of membership you wish from the options below:

❑ With *Compendium* print edition: $25
or
❑ With *Compendium* digital edition $25
or
❑ With both editions: $35

Air Mail (outside No. Am.) $10

TOTAL: $ ______

*(Note: The digital edition requires an IBM compatible computer with 640K RAM, MS DOS 3.1 or higher, EGA/CGA hard disk and Logtech or Microsoft compatible mouse. Available only in 3.5" disk format)*

Please make your check out to:
Robert Terwilliger, Treasurer, NASS
and mail it to him at 2398 SW 22nd Ave.
Miami FL 33145

*Editor's Note: See the History of Navigation section of this issue for the contribution of old sundials to the study of the history of geomagnetism.*

Mr. George G. Bennett of 27 Cabramatta Road, Mosman, N.S.W. Australia wrote on 1 December 1994:

"Dear sir, I received Issue No. 44 of The Navigator's Newsletter yesterday in which my article that I sent to you in March of this year appears. I anticipate that some of your readers may have some difficulty with the diagrams which have been reproduced at about half the size of the originals. In addition there are a number of typographical errors which may cause some problems. The latter have been compounded by some errors of my own.

"I enclose a manuscript in which my errors have been corrected and I would be grateful if you have any correspondence with, or submissions from, readers in respect of this article you would furnish them with a copy of this manuscript. *Sincerely, G. G. Bennett*"

### Terris Moore

It is with sorrow that we announce the passing of Terris Moore on November 7, 1993.

*Editor's Note: Mr. Bennett, the author of* The 'Two Body' Fix Revisited *submitted to us not only superb manuscript copy and additional high quality illustrations but also provided a disk for reproduction of the article. Unfortunately we could not use the disk because it was not IBM or Macintosh. We sincerely regret that the article was reproduced with the defects as pointed out by Mr. Bennett. We will certainly provide readers with corrected copies of his manuscript in accordance with his wishes as stated above.*

Mr. John G. Hocking of 4205 Meridian Road, Okemos, Michigan 48864 (a retired professor of mathematics at Michigan State University and a former member of the Navigation Course Committee of the United States Power Squadron) has written to us with respect to the formula for meridional parts (table 5 of Bowditch):

"...The second reason for writing this is to present you with a new formula for meridional parts. The one we always see in Bowditch involves an infinite series which forms the slight correction needed to account for the ellipticity of the earth's meridians. I have come up with a single term to replace that series. It is merely

$$\frac{ae}{2} \ln \left(\frac{1 + e \sin L}{1 - e \sin L}\right)$$

Of course, a = 21,600/2$\pi$ and e = 0.0818188, as in Bowditch.

I got this differentiating the series term by term to arrive at the series

$$e^2 \cos L(1 + e^2\sin^2 L + e^4\sin^4 L + ...)$$

Inside the parentheses we see a series form of the fraction

$$\frac{1}{1 - e^2\sin^2 L}$$

Then, by substituting u = e sin L, and du = e cos L dL, the rest is an easy integration. Why this was never done before, you will have to tell me. Or is it actually very well-known? If, as Allan believes, this is the first time this formulation has come to light, would you want to publish it in the Newsletter of which you are the editor?

Allan tells me to tell you that isogonic lines were, perhaps, first found on a published map by Sir Edmund Halley in 1701. It was a chart of the world "shewing the Variations of the Compass in the Western & Southern Oceans as observed in ye year 1700 by his Maj[ties] Command Edm. Halley when Captain of the *Paramour*.

What can you tell me about the derivation of the meridional parts formula? Where can I find such? Who first did it? I surmise that it was done after Newton because it surely incorporates an integral, right?"

*Editor's Note: As to who first did it, we note that the 1938 edition of Volume III of the Admiralty Manual of Navigation states that the first complete description of the Mercator graticule did not arrive until 1645 when Bond published the logarithmic formula. But the logarithmic formula in use now comes from an integral. We expect that the geodesy component at DMA HTC will be of help in this matter.*

*Dr. Hocking has derived a new formula since bringing the modified formula above to our attention.*

*The new formula*

$$y=a\left[\ln \frac{1 + \sin\phi}{\cos\phi} + \frac{e}{2} \ln \left(\frac{1 - e\sin\phi}{1 + e\sin\phi}\right)\right.$$

*is more convenient for use with the modern scientific calculator.*

# NAVIGATION FEATURE

## Another Discussion of the Line of Azimuth Method

*Reprinted from Proceedings with permission; copyright*



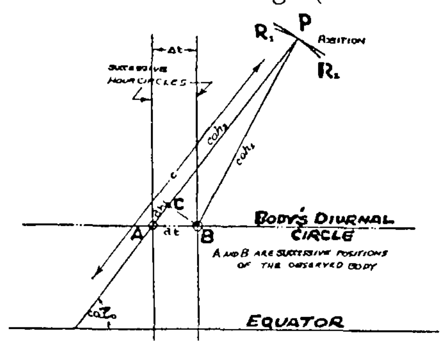
*Midshipman T. D. Davies, U.S. Navy*

*(See page 848, June, 1936, Proceedings)*

In this article the author advanced a method for finding position, independent of dead reckoning, by using H.O. 211 to obtain a solution of formulas based on E. J. Willis' line of azimuth method. This system involves the determination of the body's rate of change of altitude, from which $Z_0$, the azimuth measured at the equator, from the elevated pole, is computed. The relation used is:

$$\text{CSC } Z_0 = \frac{\text{time int. in secs. time/4}}{\text{altitude int. in mins. arc}} = \frac{dt}{dh}$$

This azimuth is used to facilitate the solution of the equinoctial triangles, to obtain expressions for the latitude and for the local hour angle (from which the longitude may be found by combination with the Greenwich hour angle).




The exact position is then found without the tedium of dead-reckoning computations and without chart work. This, naturally, should attract air navigators for whom dead reckoning presents particularly discouraging difficulties.

After a demonstration of the derivation of the formulas by the ordinary methods of spherical trigonometry, the author proceeds to work out a problem, in which the observer takes a sight of the sun at sunset, by timing the passage of the disk below the horizon.

In reading this paper it occurred to me that the method might be susceptible to considerable error, by virtue of irremovable errors encountered in practice. In addition to the fact that the problem worked out was a special case, there was also the consideration that two sights such as here used to such advantage, would, if worked out as two lines of position, be practically useless. It seemed improbable to me that such widely varying degrees of accuracy as to results could be obtained from the same set of data, simply by varying the method of computation. Suspecting that there was some practical consideration that the author had overlooked, I proceeded to investigate the methods, both theoretically and practically.

The diagram of the figure shows the general set-up of the problem. In this figure the known data are the two zenith distances, $coh_1$ and $coh_2$. The diurnal circle shown is that of the body, projected on the earth. Hence the actual determination of the position can be represented graphically by swinging the two arcs, $R_1$ and $R_2$, and using their intersection as the fix. Of course this actually occurs on the surface of a sphere, but for the purpose of simplification it can be assumed that the distances are small and thus can be represented on the plane. However it can be readily seen that the intersecting of these arcs, or the determination of the location of their intersection, using only the two positions of the body and the two altitudes, requires a high degree of accuracy of the lengths $coh_1$ and $coh_2$, no matter what method is used to arrive at the point, *P* The author uses the increments, $\Delta h$ and $\Delta t$, to solve the small triangle, *ABC* (which he assumes to be infinitesimal) and determine the angle $Z_0$. Using this angle and the distance *c*, he locates the fix, *P*. It appears that the accuracy of this fix can be but little better than that obtained by intersecting the two lines of position if the sights are worked by dead reckoning.

It also appears that the problem used is a very special case, inasmuch as the diameter of the sun's disk, and therefore the altitude increment, is used to hundredths of a minute. Although, in this case such accuracy may be obtained, there is some doubt as to the accuracy of the determination of the instant that the limb cuts the horizon. I considered it improbable that the eye could determine this point with the same accuracy that the diameter of the disk was given in the *Almanac*. Certainly in the case of a star sight, where a sextant must be used, such significant figures could not be used. According to the opinion of experts the average accuracy of the sextant, in the hands of a competent observer, is about one minute of arc.

Of the elements concerned in the computation, the only one which can actually be measured with a high degree of accuracy is the time increment. With an ordinary stop watch time can be measured to about .1 seconds, although most stop watches read only to .2 seconds. When the fact is also considered that in this system the time is divided by four, further reducing the error, it appears that a fair degree of accuracy can be expected and hence little inaccuracy in the final result from this source.

After a consideration of the theoretical aspects of the method, an actual test was made to check the accuracy of the foregoing deductions. First, to check the effect of errors in both time and altitude determinations, the original problem was reworked, introducing fair errors in the various data. The effect of the time element was checked by introducing an error of .2 seconds. The results were as follows (time interval changed from 205.6 to 205.8, other data unchanged):

| | |
|---|---|
| latitude change | 0°-3' |
| longitude change | 0°-1' |

This indicated that the measurement of the time element could, at least theoretically, be determined with sufficient accuracy.

Next the altitude interval was changed from 31.56' to 32.56'. This change produced the following results:

| | |
|---|---|
| latitude change | 1°-23' |
| longitude change | 1°-12.5' |

These results seemed to indicate that the altitude increment must be measured to a degree of accuracy impossible with the sextant, a conclusion I suspected from the theoretical consideration. If the method were no more accurate than these tests indicated it must be regarded as worthless, except that a fix might be obtained at sunrise and sunset, which would be of considerable value. It was also suggested that the moon might be used, which possibility is removed by a little consideration, inasmuch as the upper and lower limbs are very seldom visible at the same time.

As I stated before, I doubted that the sunset sight would be of value, due, not only to the inaccuracy of the eye, but also to the fact that considerable distortion exists at the times of such sights. Hence I resolved to include such a sight in a test of the method.

The test of the system was its actual use in a series of sights. First a sight was taken of Vega, in the prescribed manner. At the same time four other stars were taken and a fix obtained by H.O. 211. The conditions were average, a good horizon and a clear sky. The interval between sights was 242 seconds, which compares favorably with the 205.6 seconds used by Mr. Hinkle. The altitude interval was 34 minutes, and the two sights when worked individually by H.O. 211 gave closely corresponding lines. The ship, the U.S.S. *Arkansas*, was well off the coast of France, and was not rolling excessively. The results of these sights are tabulated below.

| | Fix by H.O. 211 | Fix by Line of Azimuth | Difference |
|---|---|---|---|
| L | 51°-36.0' | 55°-42.0' | 4°-06' |
| $l_0$ | 11 -43.0 | 10 -56.2 | 0 -46.8 |

The actual distance apart of the two fixes was over 200 miles. It would appear from this sight that the formulas do not permit of sufficient accuracy, at least when the sights are taken with the sextant.

Although he formulas broke down when applied to star sights, on account of the inherent inaccuracy of the human eye, I considered it still possible that a satisfactory position might be obtained by the sunsight. Hence I attempted to take a sight at sunset as Mr. Willis had done. To prepare for the sight I obtained a mounted long glass of about 4-inch aperture, of variable power (up to 45) and equipped with suitable colored filters. This glass was of excellent quality and enabled me to observe very carefully the passage of the sun below the horizon. After being held up by cloudy weather for several days, a clear sky finally obtained, and it appeared that a sight would be available. However, when the sun was an extremely small distance above the horizon it revealed a small group of low lying clouds, which completely prevented taking the observation. However I was able to observe the extreme distortion of the sun at setting.

From my observation of this distortion, and the apparent rarity of conditions permitting this sight, I decided that the sight must be taken by some other method. To obtain the sight I caused the sun to dip by means of the sextant, and actually observed an artificial sunrise. The sight was obtained at about 0815 when the sun was practically on the prime vertical. This observation was subject to none of the usual distortion, and should have been even more accurate than the sight given in the article. Again there was good visibility and a clearly defined horizon. The stop watch was of better than usual accuracy, and had been carefully checked against the chronometer. The point of coincidence of the upper and lower limbs with the horizon were observed with the greatest possible care and accuracy. The sight was taken at GCT 08-17-32, of July 15, 1936, and gave a time interval of 203.2 seconds. The diameter of the sun at this time, according to the *Nautical Almanac*, was 31.53'. The average altitude was 30°-02.5'. The results of the sight were as follows:

| | Fix by H.O. 211 | Fix by Line of Azimuth | Difference |
|---|---|---|---|
| L | 50°-58' | 51°-35' | 0°-37' |
| $l_0$ | 11 -42 | 11 -19.6 | 0 -22.4 |

The error in distance was about 41 miles. Here again my original deductions were borne out, in that the formulas, even though used with a very accurate altitude interval, were rendered useless by the inaccuracy of the eye.

The foregoing tests indicated that the formulas are of little or no practical value. As mentioned before, it appears from theoretical considerations that the accuracy of the method would be about the same as that of the sight worked by H.O. 211, which would be relatively low. There is, perhaps, one other point of interest of the method. If we consider the fix obtained from an average altitude and a rate of change of altitude, and investigate the variable position of this fix with the varying of the rate of change of altitude, it is obvious that the fix will move along what would ordinarily be the line of position resultant from using the average altitude in the usual way. Thus the fix is on a line of position, the azimuth of which may be determined, as will be shown. Actually this line is the line obtained from the average altitude, while if the first and last altitudes were worked out they would each give a line through this fix, the fix therefore being at their intersection (which we would expect from our previous considerations). The direction of this mean line of position is easily obtained, by inverting the formula

$$\sin Z_n = \sin Z_0 \sec L$$

to

$$\csc Z_n = \frac{\csc Z_0}{\sec L}$$

By calling $\csc Z_n$, $\sec (Z_n\text{-}90)$, we have the direction of the line. Using this direction and the fix obtained by the line of azimuth method, we can draw the usual line of position without recourse to dead reckoning. While it is of interest to note that such a line of position can be obtained, this is actually of slight value, inasmuch as the assumed position methods require little or no dead reckoning and are much faster to use. The method requires chart work, which eliminates the advantage.

The above discussion shows, I believe that, although the line of azimuth formulas are fundamentally sound, they are so limited as to accuracy that they are worthless as a method of navigation. This is merely another case of the so-called human element creeping in to an academically beautiful set-up.

*Editor's Note: The founder of the Navigation Foundation, the late Rear Admiral Thomas D. Davies, U.S. Navy, published the above in the February 1937 issue of the Proceedings when a midshipman at the U.S. Naval Academy.*

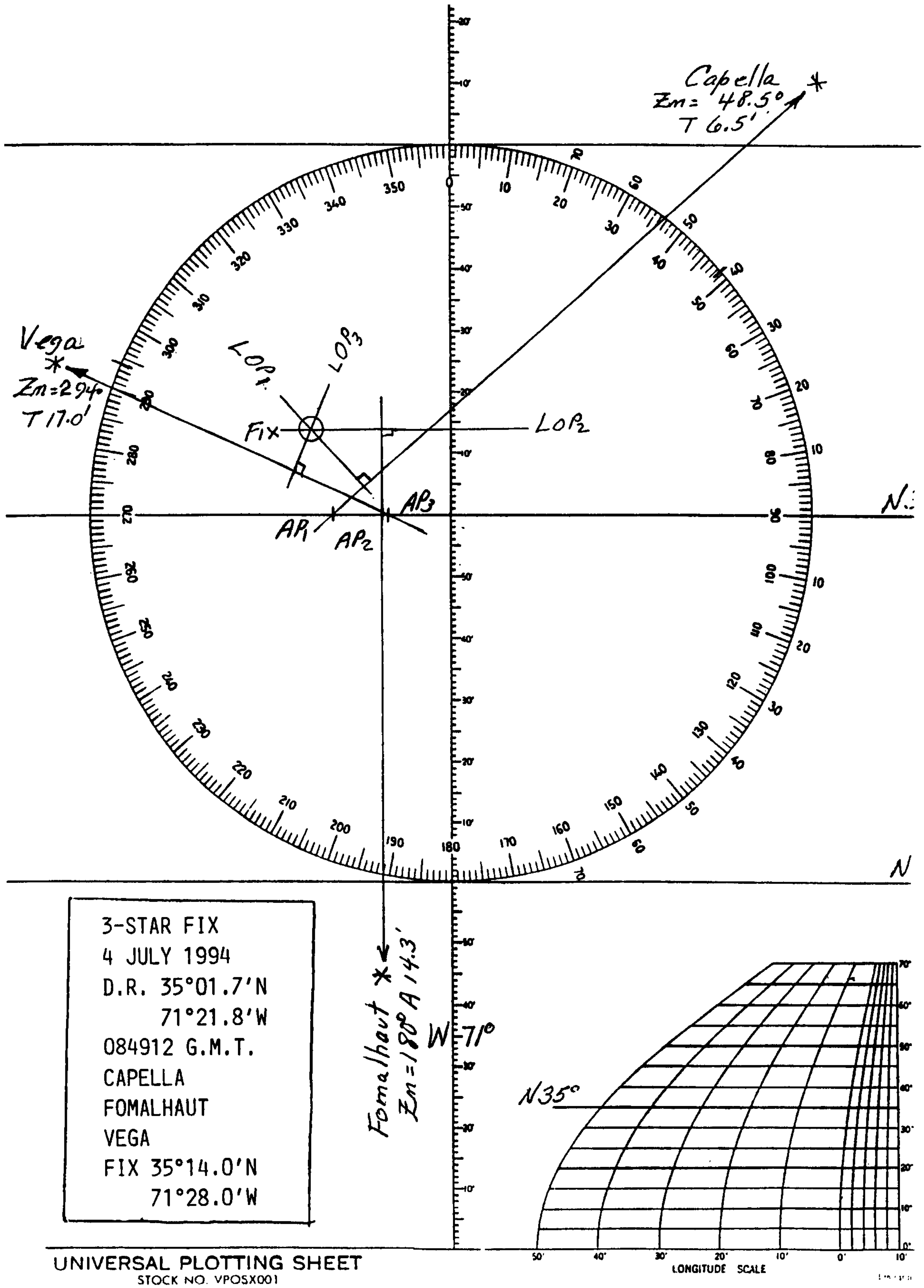
# NAVIGATION NOTES

## A Navigation Problem: Initial Great Circle Course and Distance by H.O. 211.

*By William O. Land*

What is the initial great circle course and distance from Atlantic City, NJ 39°21.0'N, 74°24.6'W (the Absecon Inlet buoy) to Gibraltar, 36°06.0'N, 5°21.0'W (the Atlantic Light)? The answer is 070°.2, and 3200.9 nautical miles.

ANSWER TO LAST ISSUE'S PROBLEM:



STAR SIGHT REDUCTION
H.O. 229

GIVEN: Lines #1,2,3,4,5,6,7,8.
FIND: Lines #37, 39.
ENTER H.O.229 with lines #26, 27 and 28.

| | | | | | |
|---|---|---|---|---|---|
| STAR | 1 | Capella #12 | Fomalhaut #56 | Vega #49 | |
| Local Date | 2 | 4 July 1994 | 4 July 1994 | 4 July 1994 | |
| D.R. Lat. N/S | 3 | N 35° 01.7' | N 35° 01.7' | N 35° 01.7' | North or South? |
| D.R.Long. E/W | 4 | W 71° 21.8' | W 71° 21.8' | W 71° 21.8' | East or West? |
| Eye Ht. F/M | 5 | 10' | 10' | 10' | Feet or Meters? |
| Chr. Err.F/S | 6 | 7 Sec. F. | 7 Sec. F. | 7 Sec. F | Fast or Slow? |
| Hs | 7 | 20° 52.4' | 25° 11.9' | 38° 35.5' | Sextant Reading |
| Local Time | 8 | 3 h 49 m 19 s | 3 h 53 m 51 s | 3 h 57 m 10 s | Use Standard Time |
| Z.D. ± | 9 | +5 h | +5 h | +5 h | (E=-) (W=+) Fr. Ln.4 |
| Chr. Err. ± | 10 | m -7 s | m -7 s | m -7 s | (Fast = -)(Slow = +). |
| G.M.T. | 11 | 8 h 49 m 12 s | 8 h 53 m 44 s | 8 h 57 m 03 s | Add lines 8±9±10 |
| Correction | 12 | h | h | h | Need ± 24 hrs.? |
| Correction | 13 | m s | m s | m s | Need ± 60 secs.? |
| G.M.T. | 14 | 8 h 49 m 12 s | 8 h 53 m 44 s | 8 h 57 m 03 s | Add lines 11±12±13 |
| G.M.T. Date | 15 | 4 July '94 | 4 July '94 | 4 July '94 | Need new Date? |
| G.H.A. T hr. | 16 | 42° 06.3' | 42° 06.3' | 42° 06.3' | Fm.Ln.14.AlsoGet 18,27. |
| Incr. T m,s | 17 | 12° 20.0' | 13° 28.2' | 14° 18.1' | From Line 14, m,s. |
| S.H.A. ☆ | 18 | 280° 55.9' | 15° 39.4' | 80° 48.1' | From Lines 1, 15 and N.A. |
| G.H.A. ☆ | 19 | 334° 82.2' | 70° 73.9' | 136° 72.5' | Add 16 + 17 + 18 |
| Correction | 20 | ° | ° | ° | Need -360°? |
| Correction | 21 | +1° -60.0' | +1° -60.0' | +1° -60.0' | Need ±60.0'? |
| G.H.A. ☆ | 22 | 335° 22.2' | 71° 13.9' | 137° 12.5' | Add 19 ± 20 ± 21. |
| Ass'd.Long ± | 23 | -71° 22.2' | -71° 13.9' | -71° 12.5' | (W = -)(E = +) |
| L.H.A. ☆ | 24 | 264° 00.0' | 000° 00.0' | 66° 00.0' | On Ln.23 Sub. MM.m |
| Correction | 25 | ° 00.0' | ° 00.0' | ° 00.0' | Need ±360°? |
| L.H.A ☆ | 26 | 264° 00.0' | 000° 00.0' | 66° 00.0' | Add Lines 24 ± 25. |
| Dec. ☆ N/S | 27 | N 45° 59.4' | S 29° 38.8' | N 38° 46.8' | Same or Contrary? |
| Ass'd.Lat.N/S | 28 | N 35° 00.0' | N 35° 00.0' | N 35° 00.0' | Nearest Whole ° |
| Hc | 29 | 20° 11.0' | 26° 00.0' | 38° 00.1' | Also get Lns.30,38,39 |
| (d) Tens ± | 30 | (+29.7) +19.8' | (-60.0) -32.4' | (+18.4) +7.8' | From Line 27 MM.m . |
| (d) Units ± | 31 | + 9.6' | - 6.4' | + 6.5' | From Line 27 MM.m. |
| Dbl.2nd.Diff. | 32 | ( 0.0) + 0.0' | ( 0.0) + 0.0' | ( 0.0) + 0.0' | Use only for d˙ |
| Hc | 33 | 20° 40.4' | 26° -38.8' | 38° 14.4' | Add 29±30±31+32. |
| Correction | 34 | ° . ' | ° . ' | ° . ' | Need ±60.0'? |
| Hc | 35 | 20° 40.4' | 25° 21.2' | 38° 14.4' | Add 33 ± 34. |
| Ho | 36 | 20° 47.0' | 25° 06.9' | 38° 31.4' | Line 37 = 35 ~ 36 |
| Intercept(a)A/T | 37 | T 6.6' | A 14.3' | T 17.0' | A or T? Ho Larger = T |
| Z | 38 | 48.5° | 180.0° | 66.0° | |
| Zn | 39 | 48.5° | 180.0° | 294.0° | Z = Zn or need Corr'n? |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 | SEXTANT CORRECTION | | | | | | |
| | 41 | + | - | + | - | + | - | |
| Dip | 42 | XXX | 3.1' | XXX | 3.1' | XXX | 3.1' | Line 5 and Page A2 N.A. |
| I.C. | 43 | 0.2' | 0.0' | 0.2' | 0.0' | 0.2' | 0.0' | (On = -)(Off = +). |
| + and - Totals | 44 | 2.1' | 3.1' | 0.2' | 3.1' | 0.2' | 3.1' | Add Lines 42 ± 43. |
| Diff. +/- | 45 | - 2.9' | | - 2.9' | | - 2.9' | | Diff. =/- Line 44 |
| Hs ☆ | 46 | 20° 52.4' | | 25° 11.9' | | 38° 35.5' | | From Line 7 |
| App. Alt. ☆ | 47 | 20° 49.5' | | 25° 09.0' | | 38° 32.6' | | Line 46 ± Line 45 |
| A2 Alt.Corr'n. | 48 | - 2.5' | | - 2.1' | | - 1.2' | | ☆ Table Page A2 N.A. |
| Ho ☆ | 49 | 20° 47.0' | | 25° 06.9' | | 38° 31.4' | | Add Lines 46 + 47. |
| | | | | | | | | Enter into Line 36 |

# HISTORY OF NAVIGATION

## Origins of Geomagnetic Science

*A Revision by David G. Knapp*

*Editor's Note:* Origins of Geomagnetic Science *is taken from chapter VI of the Coast and Geodetic Survey serial 663,* Magnetism of the Earth *by Albert K. Ludy and H. Herbert Howe, the first part of which was published in issue 44 (Summer 1994). The remainder is being printed in this issue and two other issues of the Newsletter to follow. The writer uses the term magnetic declination, as used in geophysics, for what navigators commonly call magnetic variation.*

### THE MARINER'S COMPASS AFTER PEREGRINUS

**Cap-and-Pivot Suspension**

The arrangement outlined by Peregrinus, with a needle on a staff confined between upper and lower bearings, did not afford the best solution to the difficulties imposed by the weakly magnetized needles then available, since the effects of friction in such a mounting are so largely dependent on dynamic conditions that are difficult to control. The introduction of the cap-and-pivot design constitutes another of the lost milestones in the evolution of the compass[7]. In the modern version of this mounting, a very hard metallic pivot is solidly supported from below, and the movable card with its needles hangs from a jeweled cap which turns on the pivot. In this type of bearing the friction is small and uniform if the surfaces are properly shaped.

It has been conjectured that the Amalfians introduced the movable "fly" or card attached to the needle; at all events, we are told by Da Buti, writing in about 1380, that the sailors of his day used a compass at the middle of which was pivoted a wheel of light paper—an indication that this feature was developed within a century of the time when Peregrinus wrote.

**Compass Cards and the Rose of the Winds**

The remarkably accurate early charts of the Mediterranean Sea, contained in "Portolani" or handbooks of sailing directions, were usually embellished with an eight-pointed star or "rose," the same figure which served for the fly of the early compasses (possibly at first a by-product of the pattern of rhumb-lines that crisscrossed the charts). Initials at the several vertices of the figure stood for the Italian names of the eight principal winds. An alternative system of marking the cardinal points utilized the Latin names of the corresponding quarters of the heavens—*septentriones, oriens, meridies,* and *occidens* (see fig. 33). Both systems ultimately fell out of use, though a vestige of the former is said to survive in the fleur-de-lis at the north point (supposedly derived as a combination of a spear-head with a "T" for *tramontano,* the north wind).[8]

The demands of accuracy led to the subdivision of each of the eight "winds" into four "quarters of the wind" (points) separated by 11¼°; this 32-point division is still in wide use, and it was mentioned by Chaucer as early as 1391. In modern times, the improved accuracy with which steam-powered vessels can be steered has resulted in the addition of a scale of degrees, and curiously enough the ensuing subordination of the older pattern of points has led in some cases to a reversion to the eight-point division, like the ancient wind roses, the intermediate points being then superseded by the degree markings.

**Other Early Developments**

**Multiple Needles.**—In connection with the introduction of a movable card, trouble must have been experienced so long as only a single straight needle was used, for the motions of the ship would be apt to impart to the card a "wobbling" motion of its unweighted east and west edges. It is interesting to note that the early compasses often had an assembly of two needles, joined at their ends and spread apart in the middle; this tended to mitigate the difficulty just mentioned, as did the later use of an arrangement of parallel needles. It was finally shown that an arrangement should be used which would result in a card having approximately equal moments of inertia about all diameters, and such an arrangement is one feature of the Kelvin compass.[9]

**Gimbal rings.**—It was an obvious desideratum to provide a special mounting for the compass so that the bowl as well as the card would remain horizontal despite the rolling and pitching of the ship. This was the purpose of the gimbal rings or so-called cardan suspension; this form of universal joint, now in such general use, made possible greater accuracy in measuring the compass bearing on any object, whether terrestrial or celestial, and paved the way for the introduction of the azimuth circle and other aids to the use of the compass.

Summarizing the four chief improvements applied to Peregrinus' compass in late medieval times were: the movable fly, the cap-and-pivot support, the divided needle, and the gimbal suspension. All these were apparently in use by 1551, the date of a treatise on navigation by Martin Cortes, in which a compass having these features is described.[10]

**Modern Improvements**

The development of the compass in modern times has proceeded hand in hand with the treatment of the troublesome deviations caused by the ship's magnetism (p. 53). It is likely that from the first beginnings of compass navigation there have been unexplained errors from the effects of iron fittings near the compass. However, the deviation as a systematic phenomenon first came to light in the course of Captain James Cook's explorations in the southern oceans, during the period 1772-79, illustrating the general principle that deviations become more pronounced in high latitudes, where the horizontal intensity of the earth's field is small and the compass is more readily influenced by extraneous forces. With the increasing use of iron in shipbuilding, accelerated by the introduction of steam, the problem of compensating the compass came to the fore and engaged the attention of some of the ablest scientific minds of the nineteenth century. The basic theory of Poisson came to fruition in the mathematical achievements of Archibald Smith, and finally Kelvin showed how to construct a compass to which the theory could be applied with complete satisfaction.

During rough weather, violent motions of the ship may cause the compass card to oscillate severely despite careful design of the card and the use of gimbals. In the time when Cortes wrote his treatise on navigation, he could only counsel blunting the pivot if the card was too unsteady. In modern practice, two methods of damping have proved useful. One is to use heavy copper for the compass bowl, so that rapid oscillations of the card will be restrained through the agency of the Foucault currents generated in the copper by the magnetic field of the moving needles. The other and older method (proposed in 1813) is to fill the compass bowl with liquid; this has the further advantage of reducing the weight on the pivot. It is said that the idea of using liquid in the bowl originated when a heavy sea, breaking over a vessel during a storm, accidentally filled the compass bowl with sea water, whereupon the violent swinging of the card ceased, yet the card continued to show directions correctly. For war vessels, the stability of the liquid compass under the shock of gunfire proved to be a decided advantage, though it did not afford a solution to all the problems involved (see p. 53).

## EARLY KNOWLEDGE OF THE MAGNETIC DECLINATION

### Discovery of the Effect

**Possibly a Chinese discovery.**—The isolated passage from "Mêng-ch'i-pi-t'an" quoted on page 60 has often been cited as indicating that the Chinese were aware of the magnetic declination before its discovery in Europe. The words "will always deviate a little to the east" certainly suggest such an interpretation to the modern reader. However, the passage contains the further statement that when suspended by the "best" method the needle would "always point to the south." Translators are not agreed as to the proper rendering of the passage, and the version given above is not altogether clear on this point, so that some doubt remains as to the original author's meaning. Furthermore, there is no elaboration of the matter; the whole emphasis is on the remarkable fact of the directional behavior, rather than on any precise measure of the phenomenon.

If the Chinese had known of the magnetic declination as early as the twelfth century, it is reasonable to presume (as Bertelli points out) that the knowledge would have been handed down from generation to generation. However, at the beginning of the seventeenth century, when the Jesuit mathematician and astronomer Matteo Ricci and some of his fellow missionaries were allowed by the Emperor of China to take part in the Tribunal of Mathematicians, it was with great difficulty and only by ocular demonstration that they were able to convince the Chinese scientists that the magnetic and astronomic meridians were not coincident. At that time the declination at Peking was about 2° W., as determined by Ricci. Nearly two centuries later Amiot found that the Chinese still used that value of declination in placing their sundials, indicating that the knowledge of the fact was preserved for two centuries after its demonstration by Ricci.

**Observations by Columbus not significant here.**—Columbus is frequently credited with the discovery of the fact that the compass needle does not in general point true to the pole and that it changes its direction as it is carried from place to place. This viewpoint (which is presented more fully in the predecessors of this publication) is based on certain obscure statements found in the journal kept by Columbus, or rather in documents prepared by subsequent writers who made abstracts of his journal. One passage, however, shows that one of the compasses carried on the second voyage was constructed with the needles set away from the north point of the card, so as to allow for the declination prevailing at some place (presumably the locality where the compass was made). Columbus appears to have been troubled by the diurnal revolution of Polaris, a confusing factor in the method he followed by checking the indications of the compass.[11] Furthermore, all his epochal voyages were made in regions where the magnetic declination and its space changes were relatively small (see fig. 37). The whole matter has been further obscured by errors of long standing in various editions and translations of the relevant documents. While the discoverer probably had no opportunity to gain a comprehensive view of the space changes in declination, nevertheless he seems to have been the first navigator of Western civilization to penetrate a region of west declination and to remark on the behavior of the compass therein. In any event, the chief reliance of Columbus, as of all navigators of that day, was on dead reckoning, not on celestial observation; and the successful completion of his voyages, with all their consequences to civilization, must be credited in no small degree to a phenomenal skill in that art, completely overshadowing any defects that might be singled out from his speculations on the behavior of the compass.

**Evidence of compass charts**—Returning now to an earlier day, we find that the compass played an important role in the medieval phases of cartographic development. This instrument came into use during an era when geographic knowledge was at a low ebb, but as soon as compasses of the requisite precision became generally available, so that mariners might determine with reasonable accuracy the direction from one port to another, chart construction was established on a much surer footing.

The early charts of the Mediterranean coasts of the fourteenth and fifteenth centuries were thus oriented by compass, in disregard of the (perhaps unrecognized) fact that the compass needle does not in general point true to the pole. The earliest of these charts were by Marino Sanuto, between 1306 and 1324; the best, however, are those in the atlas of Andrea Bianco of Venice, which bears the date 1436. This atlas was subjected to a critical comparison with modern charts by Oscar Peschel. He found that in spite of the crude appliances in use at that date, the distances from place to place harmonized in a most remarkable manner with later, more accurate, determinations; but the places were not always in their proper relations as regards latitude and longitude, the departures therefrom being quite systematic. This was more noticeable in the latitudes because of the greater distances involved, places at the west end of the Mediterranean being shown too far south with reference to those at the east end.

As the charts were based on compasss directions, this systematic departure from the true directions indicates that the direction shown by the compass at that time differed by an appreciable amount from true north. By measuring the angle through which one of these charts had to be turned (about Rome as a center) in order that the places would fall in their proper geographic relations, Bauer found that the magnetic declination at Rome was 5° E. in 1436 (or more probably before that date, as the charts were undoubtedly constructed from data obtained during many years prior to the date of publication).

In later years, after the fact of the magnetic declination came to be generally known, it became the practice in some localities to place the needles at such an angle to the compass card that the compass would give true bearings instead of magnetic bearings in the particular locality in which it was to be used. Thus Norman, in his book, "The Newe Attractive," published in London in 1581, says that he finds in Europe five sorts of compasses, depending upon the locality in which they were used. Those made in Italy gave the correct magnetic bearings, as a rule, presumably because the magnetic declination was small in the Mediterranean; in Holland and Denmark the wires were set three-quarters of a point or sometimes a whole point "to the eastward of the north of the compass." (See p. 62 regarding "points"). In compasses for use in France, Spain, Portugal, and England, the wires were most commonly set at half a point; these compasses were used in charting the coasts of those countries and the East and West Indies as well. In Russia still another angle was used.

Norman goes on to say:

> ...And the Mayster or Maryner Sayling by these Compasses of sundry sorts may thereby fall into great perill, and the reason is, because that of long time these Compasses haue been used, and by them the Marine Plats haue bene described of sundry sortes, every one according to the Compasse of that Countrey.
>
> If then he take not the Compasse of the same setts or making that the Plat was made by, then his Carde or Plat will shewe him one Course and the Compasse when he thinketh he goeth well, will carry him another way."

This difficulty is discussed at length by the Dutch cartographer Willem Barentsz in a navigators' atlas published in 1595. Overlapping sets of convergent rhumb lines were provided on some of his charts to facilitate their use with either Flemish or Italian compasses as desired. As Heathcote points out, these lines show that in that period the Flemish compasses were set to allow for 6 degrees of east declination. A discrepancy between Dutch and Genoese compasses was also noted by Columbus (see p. 64).

The earliest known maps on which magnetic declination was graphically depicted are probably certain German road maps by Etzlaub, dating from about the time of Columbus' first voyage. On these maps there appears a figure of a compass with its needle pointing about 11¼° east of north. Again, a map of the coast of Palestine, which was included in a work published in 1532, contained a figure which similarly seems to represent the declination as 25° west (apparently an excessive value).[12] Such maps were the precursors of the isogonic charts discussed on pages 10-14 and 72.

**Evidence in sundial compasses of first knowledge of the declination.**—The investigations of Hellmann indicate that it was the construction of sundials that first required a definite recognition of the magnetic declination, so far as can be established from the available records. Besides fixed sundials, the use of which may be traced back into the Babylonian-Chaldean period, there were also in olden times portable sundials for travelers, the distinctive feature being a small compass, to be used no doubt for the purpose of orientation. Samples of these portable sundials are preserved in many of the museums of Europe. The majority of them are of German origin, and it appears that as early as the middle of the fifteenth century Nuremberg was a recognized center for the manufacture of sundials provided with magnetic needles.

Thanks to the searching investigations of A. Wolkenhauer there have been brought to light three compass sundials constructed prior to 1500. The most important of these was preserved in the Museum Ferdinandeum at Innsbruck. This is a pocket sundial not much larger than a watch. It bears the date 1451, and is made of copper (or bronze), gilded and decorated with a black enameled imperial eagle. According to Hellmann, there appears to be no question that this sundial was made in Nuremberg, probably for Emperor Frederick III.

The cardinal points are indicated on the rim of the compass box. Across the bottom of the box there is a heavily engraved line, forked at one end, which it is believed indicates the direction of the compass needle at Nuremberg at the time the instrument was made—about 11° east of true north.

Hellmann has found that still another specimen, in the Bavarian National Museum, dating from the year 1456, and very probably by the same maker, likewise has engraved on the compass a line making an angle of about 11° with the true north-south line. As the making of compass sundials had evidently reached a high state of perfection in the middle of the fifteenth century, Hellmann argues that this angle of 11° E. may refer to an earlier date than 1451, as it is known that the same angle was used by Nuremberg compass makers well into the sixteenth century. However, it has recently been suggested that the endeavor may have been simply to allow one point as a sufficiently close approximation to the prevailing declination; one point of the nautical compass equals 11¼ degrees.[13] The same amount of east declination is indicated on the early German road maps already mentioned.

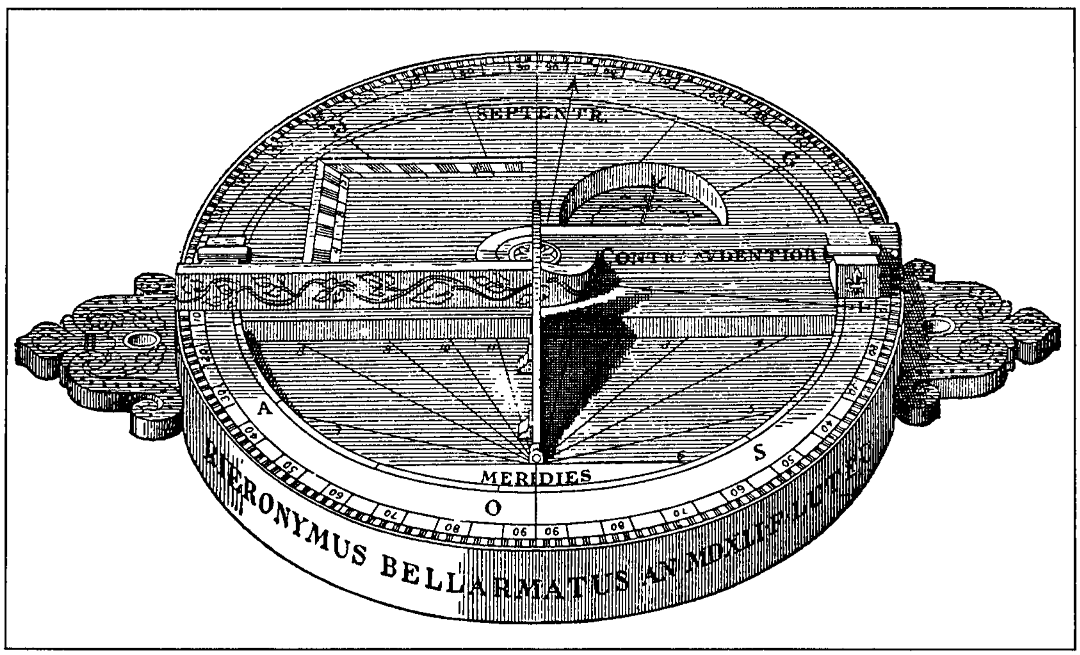



*FIGURE 33—A traveller's sundial with compass, made about 1541 and marked to show the magnetic declination. From G. Hellmann, "Die Anfänge der Magnetischen Beobachtungen."*

One of the most famous of the compass makers, as they were called, was Georg Hartmann, who lived in Nuremberg from 1518 until his death, serving as vicar of the church of St. Sebaldus. He constructed such sundials in great numbers for persons of high rank, among others Duke Albert of Prussia, with whom he corresponded. In one letter Hartmann speaks of making eight compass sundials of ivory and four smaller ones of boxwood most of them designed for used in latitude 55°.

We have no means of determining at what date the makers or users of compasses became convinced that the failure of the compass needle to point exactly north was not due to imperfection of construction or to the peculiarity of the lodestone with which the needle was rubbed, but it is to Hartmann that we owe the first recorded determination of the magnetic declination on land. Under date of March 4, 1544, he wrote to Duke Albert of Prussia that from his own observations he had found the declination to be about 6° E. at Rome and 10° E. at Nuremberg and more or less at other places.[14] As Hartmann was living in Rome in 1510, his observation must refer to that date.

Even before that date, as we have seen, the compass makers adopted the practice of placing a line on the sundial to indicate the angle between true north and the direction taken by the compass needle, and Wolkenhauer gives a valuable summary of the angles of the early compass sundials according to the country or place from which they originated. Thus it has been possible, from some of the old sundials which have been preserved, to derive values of the magnetic declination for the date of their construction. From the one shown in figure 33, for example, an ivory sundial made by Hieronymus Bellarmatus in 1541 and found in the collection of the Prince de Conti, it is concluded that the declination was about 7° E. in Paris in 1541.

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7 See footnote 4 on page 60 concerning Neckam's first mention of the compass.

8 SYLVANUS P. THOMPSON, The Rose of the Winds: The Origin and Development of the Compass-card. *Proceedings of the British Academy*, **6**, 179-209, 1914. Other authorities have advanced different and equally plausible explanations.

9 See W. J. Peters: The distribution of mass in marine compasses. *Terr. Mag.*, 37, 317-320, 1932.

10 "Breve compendio de la sphera y de la arte de navegar" (Seville). The portion germane to the present discussion is translated by H. D. Harradon [11], **48**, 79.

11 For a good discussion on this point see "Columbus and Polaris" by Samuel Eliot Morison, in *The American Neptune* I (1941). The polar distance of Polaris in 1492 was nearly 3_ degrees, considerably greater than at present. It will reach a minimum of less than half a degree at about the end of the twenty-first century.

12 G. HELLMANN: The beginnings of Magnetic Observations, *Terr. Mag.*, **4**, 73, 1899, p.79. See also *Terr. Mag.*, 13, 97, 1908.

13 N. H. de VAUDREY HEATHCOTE, Early Nautical Charts, *Annals of Science*, I (1936). The suggestion adds its weight to the idea that knowledge of the declination originated with pre-Columbian navigators.

14 See item (11) of Bibliography on p. 76. The story that one Peter Adsiger determined the declination in 1269 was discredited by Wenckebach in 1836; it arose from a spurious passage in one of the manuscripts derived from the Peregrinus letter.

## Correction

*Editor's Note: Captions for figures 30, 31 and 32 missing from part of chapter in Issue 44:*

FIGURE 30—Medieval floating compass, as shown by Athanasius Kircher, "Magnus sive de arte Magnetica" (1643)

FIGURE 31—A version of the "south-pointing chariot," believed to be of Chinese origin. The principle of its operation is obscure. From Urbanitzky, "Electricität und Magnetismus im Alterthume," (Original was in the Japanese encyclopedia *Wa zi si*, compiled by Kal bara Tok sin.)

FIGURE 32—Peregrinus' compass with a pivoted needle and a graduated rim (after Bertelli).

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## New Navigation Information Network Menu Options

The Defense Mapping Agency's Navigation Information Network (NAVINFONET) has the following new menu options available:

1) Menu Option Number 13: Points of Contact for User Inquiries.

Access to a listing of the DMA Navigation Division branches, the U.S. Coast Guard and the National Ocean Service for specific product questions, by telephone and fax number.

2) Menu Option Number 14: Current Edition Dates for Charts and Publications.

Access to a listing of current edition numbers and dates for DMA and National Ocean Service (NOS) charts and DMA, NOS and U.S. Coast Guard nautical publications.

## New Changes to DMA's Nautical Products and Services

As mentioned in Notice to Mariners 1/94, DMA is changing the format and contents of the Notice to Mariners and the Navigational Publications. Additionally, the Navigation Information Network (NAVINFONET) menu options will be expanded to provide greater user access to marine safety data files. DMA hopes these changes will enhance the products and services with ease of use and, in some cases, save taxpayer dollars on printing expenses.

Commencing with Notice to Mariners 13/94, the following changes will be in effect for the Notice:

- expanded paper size of 8.5 x 11 inches
- double column format for the chart corrections
- weekly List of Charts Affected by Notice to Mariners
- quarterly listing of the text of navigational warnings for the previous 13 weeks
- Notice 52 of each year to contain the text of all navigational warnings in force

Also, during 1994 the following changes will occur:

- expanded paper size of 8.5 x 11 inches
- double column format for the Summary of Corrections
- Summary of Corrections to be issued annually vice semi-annually

Additions to the Navigation Information Network-NAVINFONET-menu:

- listing of chart and publication current edition number and date
- listing of radiobeacons world-wide
- listing of DMA'S Navigation Division fax and phone numbers.

Useful Addresses:

NAVIGATION DIVISION
ST D 44
DMA HYDROGRAPHIC/
TOPOGRAPHIC CENTER
4600 SANGAMORE ROAD
BETHESDA, MD 20816-5003
*Information Affecting:* Charts and publications produced by DMA Hydrographic/Topographic Center for foreign coasts & waters

COMMANDANT
G NSR 3 14
US COAST GUARD HEADQUARTERS
2100 2ND ST SW
WASHINGTON DC 20593-0001
*Information Affecting:* Aids to navigation in U.S. waters

COAST AND GEODETIC SURVEY
N CG22
SSMC3 STATION 7362
1315 EAST WEST HIGHWAY
SILVER SPRING, MD 20910-3282
*Information Affecting:* Charts and publications produced by National Ocean Service for U.S. coasts and waters, includingU.S. territories.

*Editor's Note: The author of the following article, Mr. Spivak, is currently a member of the South Shore Power Squadron in Long Island, New York, where he is currently taking Junior Navigator (Celestial Navigation 1). Mr. Spivak is President of SBA * Consulting, a firm specializing in small business accounting and computer systems. Mr. Spivak is the Sysop of the Power Squadrons Mailing List.*

## The Internet and the Navigator

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To, with the increase in communications, Navigators and boaters have several new sources of information.

These sources are contained in the Information Superhighway — The Internet.

WHAT IS THE INTERNET?

The Internet is a world wide computer system, consisting of thousands of host computers. These computers are owned by Governments, Educational Institutions and Commercial ventures. Users of the Internet have the opportunity to utilize information contained on these Host computers (known as servers). Two major aspects of the Internet are Electronic Mail (Email) and the UseNet.

Electronic Mail (Email) provides the ability to write a letter to anyone on the Internet, regardless of location and "mail" them the message. You could have a conversation with anybody in the world, for the cost of a local call (plus your provider fee — the cost of maintaining the Internet connection). The UseNet is a gigantic discussion area, with topics ranging from jobs in the UK to computer topics, to Boats, Dogs, and yes even Sex. Multiple discussions can be ongoing at one time. There are some specialized Newsgroups and Mailing Lists geared for Boaters and Navigators.

MAILING LISTS OF SPECIAL INTEREST:

The first Mailing List is called the Navigation Mailing List. The list can be subscribed to by sending Email to majordomo@ronin.com and in the body of the message typing subscribe navigation [your Internet account]. Topics on this Mailing List include any non-electronic navigation issue. To date, most conversations center around celestial navigation.

A Power Squadrons Mailing List has also been formed. This Mailing List is limited to members of the United States Power Squadron and Canadian Power and Sail Squadron. Members can use the Mailing List for discussion on topics ranging from the many educational courses the Power Squadrons give to internal items of interest. To subscribe to the Power Squadrons Mailing List, send Email to waynes@netcom.com, please include your squadron affiliation. At press time, this mailing list was being upgraded to a list server ( specialized Internet Program). Mr. Spivak will Email back current instructions for joining.

NEWSGROUPS OF SPECIAL INTEREST:

There are currently three Newsgroups concerned with Boating. They are Rec.Boats, Rec.Boats.Racing and Rec.Boats.Building. Rec.Boats has conversations dealing with all matters of the boating industry. From opinions on a specific make of boat, to how to fix a broken prop. Rec.Boats.Racing is geared for those who race their boats. Current discussions are centering on the BOC race. Rec.Boats.Building discusses naval architecture and building your own boats, from canoes on up in size.

Other Newsgroups that can be found deal with weather, marine sciences, etc. If there is an area you're interested in, you're sure to find a discussion topic on it.

Another benefit of an account on the Internet is access to a large pool of free information. Let's say you have a problem with your boat, and your immediate circle of knowledge is stymied. All you have to do is post a message in the Boating newsgroup and wait for an answer. Most times you'll receive at least one reply, sometimes hundreds! Want to get the Local Notice for Mariners from a different Coast Guard District, no problem, access the USCG BBS over the Internet and get all the LNMs issued.

HOW DO I JOIN THE MAILING LIST OR NEWSGROUP?

First you need an account. There are many commercial providers who will sell you access to the Internet. Some of the most popular vendors are CompuServe, Delphi, America On Line, GEnie and Prodigy. Other services are Netcom, PSI and local Universities.

Each of these providers charge for services differently, so it is wise to price them. Most services will bill your credit card directly each month. Below are the costs for some of the more popular services. Make sure you check how you will access their service. Are the phone lines a local, medium distance, or long distance phone call. Remember, the telephone company is going to bill you for using your phone in addition to whatever the Provider charges!

Here are the charges for some of the services listed:
CIS (CompuServe costs $8.95 per month plus additional fees for access to non-basic areas (most areas are non-basic). Access to the Internet is $4.80 per hour up to 2400 Baud (speed of modem -higher the number, the faster information flows). $9.60 for 14400 Baud. Internet access is limited.

AOL is $9.95 per month including 5 hours connect time to everything. As of January 1, 1995 $2.95 per hour over the first 5. Most areas have 9600 Baud access, some only 2400 Baud. Internet access is fair with an expansion planned for next year.

Delphi is $10.00 per month basic which includes 4 hours unlimited access and full Internet. $4.00 per hour thereafter. They also have other plans, such as 20/20: $20 per month, 20 hours free, $1.80 per hour thereafter. 9600 Baud is available in most areas. Delphi has excellent Internet Access.

# NAVIGATION PERSONALITIES

## Robert FitzRoy, Captain of H.M.S. *Beagle*

*By William O. Land*

Almost everyone knows who Charles Darwin was and many know he sailed aboard a ship named the *Beagle*. But a good $64,000 question would be, "Name the captain of the Beagle." He was Robert FitzRoy, Royal Navy, a very remarkable person, born at Hampton Hall, Suffolk, England, on July 5, 1805.

FitzRoy came from the aristocracy as his father, Lord Charles FitzRoy, was the son of the third Duke of Grafton and his mother was descended from the first Marquis of Londonderry. In 1819 at age 14, he entered the Royal Naval College. He then saw service in the Mediterranean and South American waters.

While on the South American station and only 23 years of age, FitzRoy was promoted to the command of the *Beagle,* a brig of 240 tons, one of two ships then being employed in a survey of the coasts of Patagonia and Tierra del Fuego. Even in consideration of an age of rapid advancement for exceptional men with high connections, this promotion reflected highly on the young officer's ability.

The other ship, the *Adventure,* 350 tons, was commanded by Captain Philip Parker King, Royal Navy (1793-1856), the commander of the survey. (Captain King had previously spent five years charting the Torres Strait between New Guinea and Cape York Peninsula of Australia). The two ships had sailed from Plymouth Sound in 1826 and for the next four years made charts of the east and west coasts of South America from Montevideo, Uruguay to Valparaiso, Chile. The charts included details not only of the shoreline, terrain, depths, harbors, rivers and bays, but their notes contained information of the inhabitants and customs of the citizens of the various ports and countries. They charted the Strait of Magellan and also Cape Horn. Returning to England in 1830, Captain King said of FitzRoy, "I was fortunate to have as my colleague in command of the *Beagle,* Commander FitzRoy, upon whose qualifications alone he was selected. In 1828 I detached the *Beagle* and the tender of the *Adventure* to complete the survey of portions of the Strait of Magellan. The difficulties under which this service was performed, from the tempestuous weather, exposed nature of the coast, fatigue and privation endured by the crew, and the cheerful and meritorious conduct of Commander FitzRoy can only be mentioned in terms of highest appreciation. I want to express in the strongest manner the service Commander FitzRoy has rendered, and also the zealous and perfect manner he rendered it."

FitzRoy brought back with him aboard the *Beagle* four native Fuegians with whom he made friends while exploring their shores. With their help on the voyage home he made a vocabulary of Fuegian words equivalents to English words. The Fuegians were cared for while in England by several missionary society churches.

FitzRoy was reappointed captain of the *Beagle* and ordered to continue the survey, sailing from Plymouth December 27, 1831, carrying aboard a supernumerary Charles Darwin, the expedition naturalist, who was only 23 years of age at the beginning of the voyage. He also had aboard three of the four Fuegians in order to return them to their homeland; the fourth one unfortunately died in England. The *Beagle* was gone for five years, returning home in 1836 after exploring the Strait of Magellan, Tierra del Fuego, the Galapagos Islands and running a chronometric line around the world.

Anyone with a globe or a chart of the world can follow the route of this voyage of exploration. Captain FitzRoy charted the waters in the Atlantic Ocean around the Western Islands (today known as the Azores), Madeira, Canary Islands, Cape Verde Islands and St. Paul's Rocks, finally reaching South America at Rio de Janeiro. He sailed down the east coast of South America charting waters not included in Captain King's survey and corrected errors found in previous surveys. He surveyed waters around the Falkland Islands and then headed for Staten Island, just east of Cape Horn. On arrival at Tierra del Fuego, he delivered the three Fuegians to their homeland and left with them seeds, plants and other vegetation along with agricultural hand tools and fertilizers, hoping the Fuegians could raise vegetables and fruits even though their summer growing season was short.

FitzRoy sailed north along the west coast of South America making stops along the way for Charles Darwin to collect specimens which allowed him to take soundings of the ports and coast line surveys. The next stop was the Galapagos Islands, which today figure so highly in Darwin's writings. Darwin wanted to remain for an extended stay but FitzRoy could not give him that much time. They agreed to leave Darwin and his aides on the island, and have FitzRoy pick them up five weeks later.

With Darwin back on board, the *Beagle* then crossed the Pacific Ocean, sailing through the "Dangerous Islands", later to be named the Carolines and the Marianas. It is obvious why the old time sailors named them the "Dangerous Islands" since most of the uncounted atolls had only a foot or two of elevation at low tide. FizRoy charted the waters around Tahiti while Darwin made an extensive excursion into the interior mountains. From here the *Beagle* sailed to New Zealand, stopping at Bay of the Islands on the northeast coast of North Island. The next stop was Sidney, Australia, and then on to Hobart, Tasmania.

FitzRoy then sailed along the south coast of Australia and anchored at King George Sound near the present city of Albany. There was a period of rain and cloudy weather here, and finally on the 14th of March, 1836, the *Beagle* weighed anchor for the venture into the Indian Ocean. FizRoy set course for the Keeling Islands, and then for Mauritius. Mauritius is where, in 1803, Captain Matthew Flinders, R.N., when he stopped on his return from Australia to England to replenish supplies was surprised to find the island in French hands, and that England and France were at war. (Flinders and his crew were interned for seven years. See "Navigation Personalities" issue #43, Spring 1994). Captain FitzRoy left Mauritius for Cape Colony, Cape of good Hope, and then before returning to England sailed to Bahia, Brazil, near the modern town of Salvadore.

FitzRoy arrived at Greenwich, England October 28th, 1836, where his chronometer rates were checked at the Greenwich Observatory, and then he sailed to Woolwich on the 17th of November where the crew was paid off.

A voyage of almost five years with virtually the same crew can cause some differences of opinion among crew members, but Charles Darwin wrote this of Captain FitzRoy, "He gave up part of his own accommodations that I and two of my aides could carry on scientific work. During the five years we were together I always received from him the most cordial and steady assistance."

FitzRoy published in four volumes the *Narrative of the Voyage of H.M.S.S. Adventure and Beagle*. In 1843 he became a member of parliament and later was appointed Governor and Commander-in-Chief of New Zealand. During his stay there he was instrumental in improving the living conditions of the natives and the settlers. Returning to England, he became Superintendent of Woolwich Dockyard and was given command of the *Arrogant*, an experimental screw frigate fitted out under his supervision. In 1850 he was retired with half pay with the rank of vice-admiral. He then was appointed Chief of a new department of the Board of Trade dealing with all phases of the weather, devoting full time and efforts to practical meteorology. In 1863 he published his *Weather Book* (a publication far advanced for its time) establishing a system of storm warnings which became the basis of the Storm Warning System we use to this day. He also revised certain wind and current charts of Lieutenant Matthew Fontaine Maury, U.S.N., to a more practical and useful system.

Admiral FitzRoy's last years were devoted to the Lifeboat Association, whose aims were to design and develop lifeboats and surf boats that possess extra buoyancy, stability, self-bailing and self-righting qualities. This included contributions to the better, faster and safer rescue methods for rescue crews. FitzRoy no doubt knew George William Manby, the famous English inventor of life-saving apparatus. Even though Manby was by 40 years FitzRoy's senior, it may have been Manby who influenced the younger FitzRoy to carry on this life-saving work. Much of FitzRoy's research information was offered to the United States to add to its own development program of lifeboat and rescue methods. The Lifeboat Association still exists in the British Isles under the name of "The Royal National Life-Boat Institution.."

He was a person who gave his full effort to every endeavor, today possibly being called a "workaholic." As a result he overworked himself into poor health and depression, and unfortunately took his own life April 39, 1865, at the age of 60.

Other publications of FitzRoy are *Remarks on New Zealand*, London 1846; *Sailing Directions for South America*, London 1848; ***Barometer and Weather Guide***, **1858;** ***Barometer Manual***, **1861;** articles in the *Journal of the R.G.S.*; *Symom's Monthly Meteorological Magazine* and the *Marine Observer*.

# BOOK REVIEW

*By Terry Spence*

*Reviewer's Note: The first review covered a voyage from Bermuda to the Azores. In this issue two books are reviewed: The first is Celestial Navigation Planning that covers work that can be done in advance, in comfort and under the best of conditions. The second book deals with various legal requirements for Ports of Entry in the Pacific. We have therefore planned our voyage, completed the cruise and upon arrival complied with necessary legal matters allowing us to "drop the hook" and savor our trip.*

## Celestial Navigation Planning

*By Leonard Gray,* Cornell Maritime Press, Inc.
Centreville, Maryland 21617 (1984) 133 pages, $12.95

In the opening chapter a brief comparison is drawn between an unprepared and a prepared navigator when the electronic equipment failed or did not operate to capacity thus laying the groundwork for the book. The navigator's job is sketched out with a suggested schedule for a typical day. This is followed by a discussion on Sight Reduction Methods and such related items as determining the Height of Eye, and HE problems when encountering high waves.

Discussing weather planning in Chapter 3 an interesting point is made. If you have ever listened to weather broadcasts on WWV or other weather channels you are aware of how quickly it is stated. A prepared form with headings such as "storm warnings etc." in the same sequence as forecast makes it easier to record the message. There are some interesting observations on timekeeping at sea. For example: "...some days may be 23 hours long (easterly direction) while others 25 (westerly direction). A celestial navigation program for the Hewlitt Packard HR 33C & 33E calculators is provided together with an example. There is a caution concerning errors by the statement that "celestial navigation is intricate but its individual steps are simple" thus many chances for error. There is also a formula for determining boat speed (if a shark has eaten your log rotator).

Chapters 6 & 7 provide the heart of this book - the route planning. Using pilot charts the best route and time of departure are reached together with set and drift for the currents along the course. While the text is slanted towards a sail boat the principles involved would apply equally to a motor boat. Chapter 7 "Preparing the Worksheets" details actually laying out the course on a Mercator or plotting sheet and then pre-determining the times of such celestial events as LAN, Moonrise and Moonset; Planet sighting times; AM & PM Civil & Nautical twilight together with suitable stars by use of the Rude Star Finder, and much more. It is readily apparent that all this pre-planning can be a real time saver.

There is a short chapter devoted to the Assumed Altitude Method by use of the tables developed by our own Tom Davies, followed by some appendices.

### Landfall Legalese (The Pacific)

*By Alan E. Spears, Esq.*, Paradise Cay Publications
PO Box 1351, Middletown, CA 95461
185 Pages (1994) $29.95 Phone 1-800-736-4509

This second of the two book reviews is not exactly navigation nor is it easy reading; however if you are contemplating a trip to say (I just opened the book at random) VANUATU (Republic of Vanuatu) this book provides the necessary information and forms required to clear entry into port. Addresses of Medical services and Tourist offices are provided.

As stated in the Foreword: "Landfall Legalese is not a cruising guide. Rather it is a summary of the legal requirements, procedures and protocols required upon entering and leaving popular cruising areas in Oceana (the Pacific)." A clarification of frequently used terms is both helpful and enlightening, i.e. PRATIQUE, relates the Webster's definition followed by a practical definition, to wit "as a practical matter the term connotes the act of sailing into port, hoisting the yellow Quarantine (Q) flag from the starboard spreader and awaiting the arrival of Government Officials."

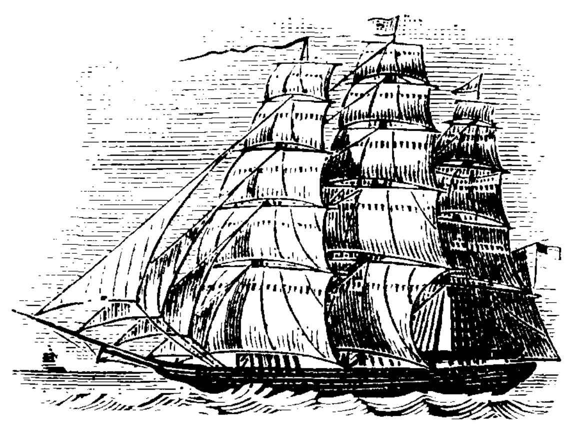
Let us look at FIJI as an example of the contents: there are eight pages devoted to this archipelago. Listed are conditions upon which certain islands may be visited. Ports of Entry (the only) are provided and the rules of Pratique (see above) are spelled out. Much valuable information follows outlining Customs, Passports and Visas. Visitor's Bureau and importantly a Medical Facility. A special prohibition outlines the problems of the village water.

Following all this vital information are copies of forms required to enter Port that may be copied ahead of time and filled in. Of interest is a letter to the author Alan Spears dated 12/16/1993 from the Director of Immigration, Suva, Fiji, authenticating how current the information is.

The Table of Contents is a guide in itself: Part I - Polynesia; Part II - Melanesia; Part III - Micronesia; Part IV - Down Under; Part V - Other Common Pacific Cruising Areas. There are five appendices at the end of the book.

All in all, a handy reference guide to have.

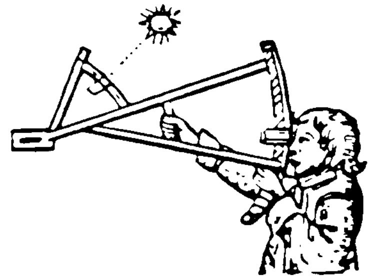
*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126
Rockville, MD 20850
Telephone 301-622-6448



Answer to **DO YOU KNOW?** (Page 1)
The Mercator chart came into general use among navigators about 1630.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-SIX, WINTER 1994-1995

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Postal Information

When renewing your membership in The Navigation Foundation, it is requested that you check your ZIP Code. If the ZIP Code on the renewal card does not include the full 9 digits, please add the additional numbers, if known. This will assist us in complying with Postal Directives for bulk mailings in the future.

For many members The Foundation has a Post Office box as the only address. When placing orders for charts, books and publications, please provide us with a street address. Many items that are shipped by The Foundation are sent via United Parcel Service as being more economical. UPS will not ship to a Post Office Box but requires street address. Having a street address will expedite your order, in many cases.

### Charts

A reminder - The Foundation can provide charts for all of your travels by both air and sea. In most cases orders for charts are filled in 2 to 4 weeks. In cases of emergencies, where charts are required for a transit and time is a requirement, you can receive charts in under 10 days. The process for rapid processing of emergency orders is: for FAX orders, call me at my home telephone number 301-622-1296. I can then turn on the computer that can receive your FAXed order; if you elect to order by mail, send your order to The Navigation Foundation, 12509 White Drive, Silver Spring, Maryland 20904. We use the emergency request sparingly in order to keep our ability to receive charts expeditiously from the charting agencies. Please use the urgent request only when really needed. The Foundation has provided charts to members who were in distant foreign ports. In these cases a long lead time is required due to the amount of time for mail to transit to and from these countries.

> DO YOU KNOW . . .?
> *By Ernest Brown*
> When the North Magnetic Pole was first located?
> (The answer appears at the back of this Issue)

### Circumnavigating

To our knowledge there are three Foundation Members currently circumnavigating. Director and past Editor Roger Jones on S/V *Allidoro*, in the Caribbean as of this publication. Member George and Ginny Leonnig on S/V *Moctobi*, in Puerto Vallaria but heading south after 15 February. Member E. B. Forsyth, who is departing Long Island, New York. We do not have his vessel's name or itinerary. However, if we receive any information, we will include it in the Activities Column. If there are other members who are on long voyages or contemplating such voyages, The Foundation will include a short itinerary in the Newsletter. Having information that another member of The Foundation is in one's area will allow members to exchange "hails".

### Nautical Charts

The Defense Mapping Agency has issued a "Material Safety Data Sheet", MSDS. Hydrographic Charts (Nautical Charts) printed prior to 1 August 1993 may off-gas low levels of formaldehyde from formaldehyde resins that were used in manufacturing the paper. Formaldehyde that off-gasses from a single chart is not expected to exceed a time-weighted average concentration of 0.1 part per million. Low concentrations (up to 2.0 parts per million) may irritate the throat, nose, and eyes of some individuals. Copies of this MSDS will be included with all future chart orders. If more information is desired, please call the DMA at 703-285-9161. This MSDS is dated 9 December 1993.

### Tabor Academy

The Foundation for the Promotion of the Art of Navigation, "The Navigation Foundation", is pleased to announce that TABOR ACADEMY of Marion, Massachusetts will be awarding "THE THOMAS D. DAVIES

AWARD" for excellence in navigation to a student selected by the Academy.

Tabor Academy has an outstanding academic program including an impressive Nautical Science program, chaired by Captain James E. Geil. There are six Nautical Science courses offered. They are: Seamanship, Piloting, Celestial Navigation, Maritime History, Marine Architecture and Lifeboatman. Tabor Academy also offers special sail training aboard its 92-foot schooner *Tabor Boy*. Satisfactory completion of any two of the six courses entitles the graduate to an Honor Naval Certificate, recognized by the United States Armed Forces as part of the candidate's permanent record, and qualifying him/her for the school's nomination to a service academy.

# READERS FORUM

*Edited by Ernest Brown*

John G. Hocking of 4205 Meridian Road, Okemos, Michigan 48864 wrote to us on January 30, 1995:

"Here at last is a copy of the derivation I have spent so much time getting. I thank you for the material you sent to me. It was of value in my struggles. I do not offer this for publication for fairly obvious reasons. It is all too well-known to geodesists and surely doesn't interest most navigators. I simply had to do it for my own peace of mind."— *Sincerely, John G. Hocking.*

Birgit Jacobsson of 502 65 BORAS, Sweden on October 16, 1994 wrote to us:

"This is to thank you for your letter of October 3, 1994. I found it very interesting to read your analyses of Peary's reaction towards the Henson photographs. It seems to me very up to the point. I also want to thank you for the copies of "The Navigator's Newsletter". It was really exciting to read about the finding of the Henson photographs.

"In National Geographic, January 1990, there is an account of the Peary report. I must say it has convinced me that Peary really reached the North Pole. Before, I was very doubtful, having read Wally Herbert ("The Noose of Laurels") among other doubters.

"I also want to refer to the Swedish professor Tore Frångsmgr who says the Peary report is the final solution of this old dispute.

"I am looking forward to reading the full report." — *Sincerely, Birgit Kristina Jacobsson.*

Member Jack R. Tyler of 10635 Islerock Drive, El Paso, Texas 79935-1539 wrote on November 12, 1994:

"...I have enjoyed another year of celestial navigation with a R.A.E. Mark IX bubble sextant (RAF 1940). I used it with good accuracy during a cruise on a four masted brigantine (200+ feet) in the Caribbean this last summer. Upon being discovered taking a sun shot (behind the wheelhouse) I was given a VIP tour of the chart/radio room and granted 24-hour access to the charts, radio, computer, library, a marine sextant and the coffee pot! The ship's officer's enthusiasm was overwhelming!" — *Jack R. Tyler.*

Member Donald A. D'Alessandro of 643 Bridgewood Drive, Rochester, New York 14612-3713 wrote to us on December 8, 1994:

"...Thank you for the prompt execution. I have read the latest 'Navigator's Newsletter' and was particularly delighted with your friend Roger Jones' last letter. As usual the "Newsletter" doesn't disappoint!" — *Sincerely, Don.*

Wayne Spivak of SBA Consulting wrote to us on November 24, 1994:

"I received a copy of your Newsletter from Anthony Kelley, a member of your Foundation and my instructor in the USPS-JN course.

"He suggested I join the Foundation. In addition, I should write an article about the Internet and Navigation. Enclosed please find an article on just that topic.

"Please send me information about your Foundation." — *Yours truly, Wayne Spivak.*

*Editor's Note: Mr. Spivak is now a member. His paper, "The Internet and the Navigator" was printed in the Marine Information Notes section of issue 45.*

The Owner/Master of S. V. *Allidoro*, Director Roger Jones, wrote on December 21, 1994:

"After Allison's marriage to Bill Lundeen on July 3, 1994, and following the reception at the Sweden Point Marina on the upper Potomac near Washington, D.C., *Allidoro's* next point of call was St. Michaels on the Eastern Shore of Maryland's long sweep on the Chesapeake Bay, and then it was on to Annapolis where we remained for the Summer and Fall months, refitting after nearly 7,000 miles since leaving Marina Del Rey, California.

"Cornell classmate, Judge Peter Wolf, and I then departed Annapolis on November 29, 1994, and made a fast overnight passage to Norfolk, arriving at 0430 on the 30th. Hampton Roads and the Norfolk Harbor were negotiated in rain and fog, but by 0630 we were anchored just off of Hospital Point across the Elizabeth River from the downtown Norfolk Waterside complex. Due to the fact that a key railroad bridge over the south fork of the Elizabeth was closed for replacement of the electric motors that operate its opening machinery, we were then unable to leave Norfolk until 0600 on December 5th. However, Norfolk is very rich in museums and places of interest, and we made good use of the time there. We were also the guests of Pete's parents in Virginia Beach.

"Continuing on the 5th, our route took us through the lock at Great Bridge, Virginia, and then to Coinjock, N.C. From Coinjock, the Alligator River, the Carolina Albemarle and Pamilico Sounds, and the Neuse River took us to a point near Oriental, N.C., when the unexpected happened. Pete went below for a few minutes, and he reported some water on the cabin floor. Needless to say, I was below in a flash, systematically inspecting each through-hull fitting. The problem was that the shaft coupling safety had failed, and the shaft and prop backed out, leaving a nice round hole for water to pour in. Pour in it did at an alarming rate, but I got a wooden plug into the shaft log immediately, and the flow was completely stopped. We pumped the bilges and then sailed the vessel 12 miles down a narrow system of creeks and canals to Bock Marine, and right into the travel lift slip. We were out of the water within a half hour of arriving there, and *Allidoro* is up on land in a steel cradle while repairs are performed. Losing the shaft is the last thing I would have expected, but I carry wooden plugs for all sorts of problems, and we stopped the "leak" within ten minutes and 800 gallons of the time it started. We'll resume a passage to the Bahamas in a month or two, and all is well that ends well! "— *Again, Best Wishes and Warmest Regards to you, Roger.*

Director William O. Land advises us that member Ed Papko, 28 Maverick Road, Woodstock, N.Y. 12498 has just been awarded his Navigator's "N" by the United States Power Squadrons. Ed is an architect by profession and is employed by I.B.M. to develop software for High-Tech industrial buildings, chemical plants and ships. For his own use he writes navigation programs for the H.P.41CX and the H.P. 48GX.

Member Leslie J. Finch of 261 Madison Street, Mastic Beach, New York 11951 wrote to us on November 25, 1994:

"I am pleased with the 1995 Almanac and charts that arrived so quickly.

"The Aeronautical Charts are just right for plotting positions worked out from sights with my sextant and oil pan artificial horizon. I find strange and wonderful places in New York State as part of National Guard training. Places like Binghamton, Utica and Watertown (Ft. Drum). The first line of position that I worked out was in the field at Ft. Drum. I plotted it on an Army map and found that the LOP ran along the center of a road about 400 meters from our camp. I could look over at it. This was quite a moment, but I had no one to share it with. Since then I have worked out my position in this way when I have been away a number of times.

"I am looking forward to the Newsletter." — *Thank you again, Leslie J. Finch.*

The owner/master of S. V. *Windfall*, Lee Pliscou, wrote to us on December 6, 1994, from P.O. Box 644, Oxnard, CA 93032:

"I am a new member and just got my first issue of the Newsletter (Issue 44, Fall 1994). The article by Mr. Edward I. Matthews, 'Longitude by Maximum Sun Altitude' prompts me to write.

"My wife and I recently sailed our 28-foot sailboat from California to Australia (November 1993-November 1994). We're not using any electronic, position-indicating device such as GPS, rather we rely exclusively on the sextant. Reduced about 430 sights, including sun, moon, stars, planets.

"I felt I couldn't rely on my LAN observations. I'd generally take 3 or 4 sights beginning half hour to 45 minutes before LAN and match with sights of equal altitude after LAN, and split the difference in GMT to determine the time of LAN. A couple questions:

"1) Am I right in my reading of the article that I should make sure that Ho is changing at least 0.1' per second, and that if it isn't, my calculation of LAN won't be reliable?

"2) What's a good method for figuring out rate of change of Ho on a given day at a given D.R., to know in advance how early one needs to begin taking sights for an L.A.N. calculation? (Using Nautical Almanac and Sight Reduction Tables for Air Navigation, but no computer. I have a calculator but don't like to use it.)

Thank you very much." — *Sincerely, Lee Pliscou.*

*Editor's Note: For the calculation of LAN for finding longitude the answer to your first question is yes. As for the second question, the rate of change of the altitude of a body for a stationary observer, declination being constant, is*

15' cos L sin Z (minutes of arc per minute of time)

$\frac{\cos L \sin Z}{4'}$ (minutes of arc per second of time)

*In latitude 30° the rate is only 0.'1 per second when the azimuth is 150°. In higher latitudes, or when the body is nearer the meridian, it is less. The limiting azimuth is thus about 160°. This limiting azimuth is helpful when examining an inspection type table to find the hour angle argument which provides the appropriate rate of change of altitude. The difference between this argument and zero in degrees multiplied by four gives the time interval in minutes to LAN needed for sight-planning purposes.*

Member Edward I. Matthews of 156 Burroughs Road, Boxborough, MA 01719 wrote on January 13, 1995:

"G. Bennett's excellent article on the 2-body running fix referred to the part of my article in issue 41/42 concerning high altitude observations. He mentions inaccuracies in extremely high altitude solutions due to differences between true and estimated positions. By estimated position, I assume he is referring to the first phase of my routine which establishes an approximate position if underway and true position if not. The second phase repeats the process and obtains a running fix. A running fix includes drift (speed, course, current, etc.) errors which increase with distance. My method requires that the COPs of the two bodies intersect at a reasonable angle both at the initial and final positions. The small COP of both at the initial and final positions. The small COP of a high altitude body limits the run to a short distance to maintain good intersecting angles and therefore reduces the drift error. The relative difficulty of high altitude observations may introduce other errors.

"Going back over my old logs, I preserved a rare occasion (for me) of the Sun directly overhead on a voyage off the South American coast in calm seas on March 26, 1989. We were proceeding at 17 knots on course 118° true, height of eye was 50 feet, watch error was 3 second fast in ZD+3 and there was no sextant error. I managed to take 8 sights in about 10 minutes during which time the

```
                                 TIME
22:16:44
                                  RUN
3/26/89
                          XEQ "RFIX"
WT?
                  12.1219         RUN
WE=-0.0003?
                                  RUN
ZD=3.00?
                                  RUN
GMT-H=15.00
BDY? *=1,S=2,P=3,M=4
                     2.00         RUN
GHA-H=43.356?
                                  RUN
DEC-H=2.213?
                                  RUN
d=1.0?
                                  RUN
SD=16.1?
                                  RUN
HS?
                   88.334         RUN
IC=0.0?
                                  RUN
HE?50.
                                  RUN
U/L? U=1,L=0
                       0.         RUN
HO=88.426
ZN1?
                   90.000         RUN
WT?
                  12.1737         RUN
WE=-0.0003?
                                  RUN
ZD=3.00?
                                  RUN
GMT-H=15.00
BDY? *=1,S=2,P=3,M=4
                     2.00         RUN
GHA-H=43.356?
                                  RUN
DEC-H=2.213?
                                  RUN
d=1.0?
                                  RUN
SD=16.1?
                                  RUN
HS?
                   89.259         RUN
IC=0.0?
                                  RUN
HE?50.
                                  RUN
U/L? U=1,L=0
                       0.         RUN
HO=89.351
ZN2?
                  180.000         RUN
S?
                   17.000         RUN
TC?
                  118.000         RUN
L=2.453
LO=47.517
                                 TIME
22:22:12
```

Sun's bearing "zipped" from East through South to West. I was able to get a LAN position fix within 2 miles of the NAVSAT plot.

"After reading Mr. Bennett's article I decided to apply some of this data to my 2-body "RFIX" calculator program.

| | WT | Hs. | Bearing |
|---|---|---|---|
| (1) | 12:12:19 | 88°33.4' | E |
| (2) | 12:17:37 | 89°25.9' | S |
| (3) | 12:21:58 | 88°33.3' | W |

"Sights (1) and (2) plus the hourly entries from the NAUTICAL ALMANAC are the only information required for the running fix. The approximate bearing (within 45°) resolves any position ambiguity. The resulting position was 2°45.3' N Lat. 47°51.7' W. Long. The attached calculator printout includes the 1989 almanac data. If speed is made zero the solution requires only one pass resulting in a position of 2°45.7'N and 47°53.2W. or a difference of only 1.5 nm.

"Now this is a case of using a blow torch to light a birthday candle. My article on LAN sights in issue 44 states that when the Sun is directly overhead the maximum altitude and LAN occur at the same time. The rapid change in altitude prevented an observation at the time of maximum altitude.

"The mid-time between sights (1) and (3) provided a simple solution for longitude, it being identical to the Sun's GHA at that time. Similarly the latitude is provided by 90°-Ho+DEC.

"Mid-time was 15:17:06 at which time the GHA and therefore the longitude was 47°52.1'W. The DEC was 2°21.6'N and Ho was 89°35.1' giving a latitude of 2°46.5'N. This position is 1.3 nm from the 2-Body solution. Some of this difference is due to using an altitude occurring 28 seconds after LAN. — *Edward I. Matthews*

# NAVIGATION FEATURE

## Night Sextant Observations

*By John M. Luykx*

### Sextant and Astigmatizer

On a clear night at sea with no moon, it is often possible to obtain accurate star, planet and moon observations although the horizon may appear dim and hardly distinguishable. If the observer's eyes have become adapted to darkness, the line of the distant, faint horizon can be distinguished with sufficient clarity through a sextant telescope to observe altitudes to within 1 or 2 minutes of the correct value. In addition, the use of an "astigmatizer" or "elongating" lens will assist in improving accuracy because the astigmatizer lens will elongate the star or planet image into a fine line in the field of view of the telescope. Experience has shown that when the "point" image of a star, as seen in the sextant telescope, is elongated into a fine line, it is easier to collimate the elongated line with the faint night horizon rather than to align the point image with the horizon.

When the horizon, in the dead of night, is not so clear and even hazy, it is often advisable to remove the telescope from the sextant and to observe stars and planets with the naked, unaided eye. In this circumstance the full sweep of the apparently dim, almost invisible, horizon is distinguishable both to the right and to the left of the point on the horizon directly below the star or planet.

During observations under these conditions, the image of the star, enhanced and elongated by the astigmatizer (if installed on the sextant), is aligned at the same level as the faint horizon seen in the corner of the eye extending from the left to the right of the star.

To further improve accuracy a series of 5 to 10 observations should be made and the mean value of time and altitude reduced to obtain the line of position.

No matter how dark the night or how overcast the sky at night, it is frequently possible (with eyes well adapted to darkness) to distinguish the horizon in the distance with sufficient clarity to obtain reasonably accurate sextant observations. This horizon may not be sufficiently distinguishable when seen through a sextant telescope because of its narrow field of view, but if the telescope is removed and a series of observations is taken with the naked eye, accurate results are often possible.

Preliminary night observation tests conducted by the author on Chesapeake Bay on 30 August 1994 using an ARIES 40 sextant without telescope provided results which indicate that night observations are practical and should be employed as a regular procedure during the navigator's "Day's Work at Sea". A series of twenty-five observations of the planet Saturn was taken in five groups of five observations each from a point of Chesapeake Beach, south of Annapolis located at N38°41'.7 W076°32'.0 The height of the eye was 13 ft; the sextant I.C. was 0.'0 and the weather was warm and cloudy with a bit of haze. Time of Sunset was 19-38 (+4).

The results were as follows:

| Group | Mean GMT | Mean Hs | Mean Error |
|---|---|---|---|
| A | 02-21-30 | 26°46'.8 | +2'.6 |
| B | 02-26-27 | 27°28'.6 | +0'.7 |
| C | 02-31-44 | 28°12'.4 | -1'.3 |
| D | 02-36-59 | 29°02'.9 | +4'.5 |
| E | 02-42-20 | 29°45'.2 | +2'.1 |

Mean Error of observation for the series: +1'.7

**Sextant and Night Vision Telescope**

In addition to the astigmatizer, night sextant altitude observations of the moon, stars and planets are also improved by the use of a light enhancing telescope attached to the sextant in lieu of the standard 4x40 galilean or 6x30 and 7x35 prismatic sextant telescope.

In April of this year, the author conducted a preliminary accuracy test with a telescope of this type attached to an ARIES 40 sextant. The telescope with bracket weighed 27 oz. and was 7" long, 2_" wide and 3_" high with a magnification of 1.5x, enhancement of 1400x and a field of view of 18. On 21 April on a dark night on the western shore of Chesapeake Bay, with no moon, two hours after sunset, the author took a total of 25 altitude observations of Jupiter (15 observations) and Spica (10 observations) in 5 groups of 5 observations each. The sextant used was an ARIES 40 fitted with the light enhancing telescope described above with the Chesapeake Bay horizon as a reference. The mean of the first five observations of Jupiter was used to compute the I.C. of the telescope. This I.C. was then applied to the remaining 20 observations.

The results of the test were as shown in Table 1.

TABLE 1

| 1<br>Group | 2<br>Observations | 3<br>Body | 4<br>Uncorrected Error | 5<br>I.C. | 6<br>Corrected Error |
|---|---|---|---|---|---|
| 1 | 5 | Jupiter | -9'.7 | +9'.7 | — |
| 2 | 5 | Jupiter | -8'.4 | +9'.7 | +1'.3 |
| 3 | 5 | Jupiter | -7'.7 | +9'.7 | +2'.0 |
| 4 | 5 | Spica | -9'.2 | +9'.7 | +0'.5 |
| 5 | 5 | Spica | -10'.5 | +9'.7 | -0'.8 |
| | | | 5/45'.5 | | 4/+3'.0 |
| | | Mean Error: | -9'.1 | | |
| | | | Mean Corrected Error: | | +0'.8 |

The uncorrected error (in minutes of arc) shown in Column 1 is the error caused by the inability of the light enhancing telescope used in the test to produce a visual acuity comparable to the standard optical telescope. In other words, it could not be focused to provide the same clarity as a normal telescope. This resulted in both Jupiter and Spica appearing to have a small semi-diameter when seen through the light enhancing telescope and the horizon appearing to be somewhat "fuzzy" rather than appearing as a clear distinct line across the field of view. As a result, an I.C. had to be computed and applied when using the light enhancing telescope for night observations. When using the light enhancing telescope, the amount of the I.C. will vary with the quality and capability of the scope: i.e., the greater the clarity of objects in the field of view of the scope, the less the I.C. and vice versa. The I.C. will also have a small variation from observer to observer due to personal bias.

**Summary**

For observers who wish to significantly improve the accuracy of night sextant observations, it appears from the preliminary testing, that the use of an *astigmatizer* lens and/or *light enhancing telescope* fitted to the sextant is helpful and promising. The author is in the process of conducting further tests of instruments and methods to improve the accuracy and reduce the costs of equipment for night sextant observations. As results are obtained, they will be published.

# NAVIGATION BASICS REVIEW

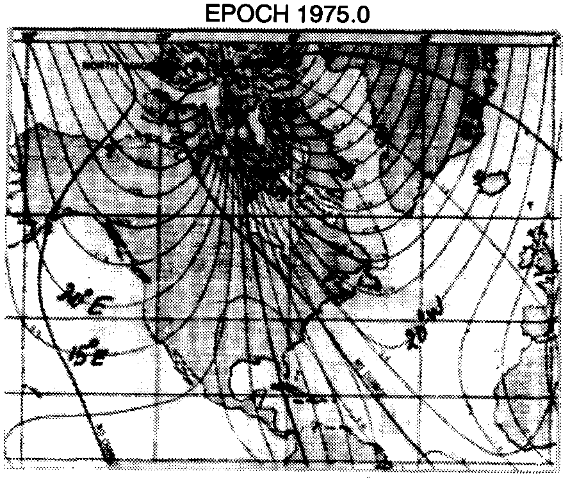
## A Navigation Instruction Hint

*By Ernest Brown*

For Epoch 1975.0 The North Magnetic Pole was located at 76°.1 N, 100°.0 W, approximately to the northward of Prince of Wales Island. Looking at Figure 1, Magnetic Variation Chart, along the meridian (100 W) which passes through both the North Magnetic Pole and the geographic North Pole, one sees values of magnetic variation which contradict the widely held notion that the magnetic compass needle points at or seeks the North Magnetic Pole. No doubt a part of this notion is an erroneous concept of magnetic variation as the difference in the directions to the magnetic and geographic poles from a place. According to this erroneous concept, the variation along the meridian through the North Magnetic Pole would be zero.

At this point the instructor would be well advised to have the student examine the definition of the magnetic meridian at any point as the vertical plane fixed by the direction of the lines of force of the earth's magnetic field, i.e., by the direction taken by a perfect compass needle.

MAGNETIC VARIATION
EPOCH 1975.0



# NAVIGATION NOTES

## A Navigation Problem: Three Star Fix by H.O. 229

*By William O. Land*

Preparing for the cold East Coast winter season we stowed several weeks worth of food and other supplies aboard our 52-foot ketch and headed south down the Chesapeake, destination: St. Thomas for the winter! We left Annapolis Thanksgiving, November 24th, 1994, which is normally late enough in the season to escape any hurricanes, and said "good-bye" to land as we entered the Atlantic just north of Cape Henry.

We took sextant sights every morning, noon and evening, and on the morning of Thursday, December 1st we had the following information: Our dead reckoning position was 25°20.0'N, 69°05.0'W. The moon rose about 4:40 A.M. but since it was approaching New Moon, it was barely a crescent and the moonlight did not interfere with the sextant sights. Mars was almost at meridian passage, high in the sky.

Our sextant shots were as follows, all data Local Zone Time:

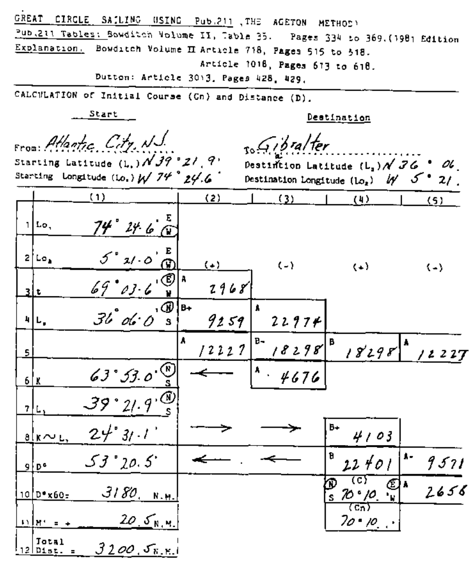
Arcturus, #37 Hs 33°12.3' at 05h 05m 40s.
Alphard, #25 Hs 55°20.9' at 05h 08m 01s.
Capella #12 Hs 28°29.4' at 05h 11m 20s.

The chronometer error was 16 seconds fast, eye height 11 feet and the Instrument Correction 0.8' off the scale. What was our fix?

Answer: 25°26.0'N, 69°10.0'W.

ANSWER TO LAST ISSUE'S PROBLEM

A step by step explanation of the solution will be provided on request.



GREAT CIRCLE SAILING USING Pub.211 (THE AGETON METHOD)
Pub.211 Tables: Bowditch Volume II, Table 35. Pages 334 to 369.(1981 Edition
Explanation. Bowditch Volume II Article 718, Pages 515 to 518.
Article 1018, Pages 613 to 618.
Dutton: Article 3013. Pages 428, 429.

CALCULATION of Initial Course (Cn) and Distance (D).

Start — From: Atlantic City, N.J.
Starting Latitude ($L_1$) N 39°21.9'
Starting Longitude ($Lo_1$) W 74°24.6'

Destination — To: Gibralter
Destination Latitude ($L_2$) N 36°06.
Destination Longitude ($Lo_2$) W 5°21.

| | | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| 1 | $Lo_1$ | 74°24.6' E (W) | | | | |
| 2 | $Lo_2$ | 5°21.0' E (W) | (+) | (-) | (+) | (-) |
| 3 | t | 69°03.6' (E) W | A 2968 | | | |
| 4 | $L_2$ | 36°06.0' (N) S | B+ 9259 | A 22974 | | |
| 5 | | | A 12227 | B- 18298 | B 18298 | A 12227 |
| 6 | K | 63°53.0' (N) S | ← | A 4676 | | |
| 7 | $L_1$ | 39°21.9' (N) S | | | | |
| 8 | K~$L_1$ | 24°31.1' | → | → | B+ 4103 | |
| 9 | D° | 53°20.5' | ← | ← | B 22401 | A- 9571 |
| 10 | D°x60= | 3180. N.M. | | | (C) (N) S 70°10.' (E) W | A 2656 |
| 11 | M' = + | 20.5 N.M. | | | (Cn) 70°10.' | |
| 12 | Total Dist. = | 3200.5 N.M. | | | | |

# HISTORY OF NAVIGATION

## Origins of Geomagnetic Science

*A Revision by David G. Knapp*

*Editor's Note:* Origins of Geomagnetic Science *is taken from chapter VI of the Coast and Geodetic Survey serial 663,* Magnetism of the Earth *by Albert K. Ludy and H. Herbert*

*Howe, the first parts of which were published in issue 44 (Summer 1994) and issue 45 (Fall 1994). The remainder is being printed in this issue and one other issue of the Newsletter to follow. The writer uses the term magnetic declination, as used in geophysics, for what navigators commonly call magnetic variation.*

### Early Methods of Determining the Magnetic Declination

The first method was no doubt that of noting the magnetic bearing of the pole star (in practice, of a point beneath it on the horizon), and this was probably the one employed by Columbus. That no great accuracy could be attained in this way is self-evident, and it is doubtful whether at first the motion of the pole star about the pole was recognized and taken into account, though such motion was clearly explained by Peregrinus in 1269 (see p. 61).

Felipe Guillen, a Sevillian apothecary, devised an instrument for a more accurate determination of the declination, which he called *brujula de variacion* and which he presented to the King of Portugal in 1525. With this instrument the magnetic bearing of the sun was noted at equal altitudes before and after noon, with the aid of the shadow from a stylus. Half the difference of the bearings was the declination.

The first book giving directions for determining the declination appears to be one by Francisco Falero, published at Seville in 1535. He gave three methods, all making use of the sun: (1) magnetic bearing of the sun at apparent noon, when the shadow of the stylus falls to the north, (2) Guillen's method of equal altitudes, and (3) magnetic bearing of the sun at sunrise and sunset.

In 1537 Pedro Nunes improved Guillen's instrument by adding a device for measuring the sun's altitude and invented a new method for the determination of latitude at any time of day. Infante Dom Luis of Portugal, who had received instruction in mathematics and astronomy from Nunes and had shown great interest in all nautical problems, presented such an instrument to João de Castro, commander of one of the 11 ships that sailed to the East Indies in 1538, and charged him to give it and the new methods a thorough test. How completely Castro carried out his instructions is shown by the very full journals or log books in which he recorded all his nautical, magnetic, meteorologic, and hydrographic observations and notes on allied phenomena from 1538 to 1541. They include 43 determinations of the magnetic declination, notes regarding the instruments and methods, the deviation of the compass, magnetism of rocks, etc. After reading the journals, Hellmann did not hesitate to pronounce João de Castro to be the most noteworthy representative of scientific marine investigations up to the close of the epoch of discoveries. It is of interest that, on one occasion, the journal recorded serious errors owing to the proximity of the ship's armament. (See ref. [11].)

The methods thus given such a thorough trial gradually came into general use among navigators, and we find them described by writers in Spain, England, and Holland as late as the end of the sixteenth century, but without mention of Guillen, Falero, or Nunes.

### Norman and the Magnetic Inclination

Although Hartmann, the Nuremberg maker of sundials, had noticed in 1544 that the north end of the compass needle tends to dip below the horizon, it was left for Robert Norman, of London, to devise an apparatus with a needle supported on a horizontal axis and actually measure the amount of dip. In his book "The Newe Attractive," published in 1581, Norman tells "by what means the rare and strange declining of the needle from the plane of the horizon was first found." Norman was an instrument maker who had had 18 to 20 years of practical experience as a seaman. In making compasses he noticed that it was always necessary to put small pieces of wax on the south end of the needle in order to balance it, although it had been perfectly balanced before magnetization. He paid little heed to this fact, however, until he had occasion to make an instrument with a needle 6 inches long and was constrained to cut away some of the north end to secure a balance. In doing this he cut it too short and spoiled the needle.

Vexed by the necessity of doing his work over again ("hereby being stroken in some choller" as he says), Norman devised an instrument to determine how much the needle touched with the stone would decline, or what greatest angle it would make with the plane of the horizon. With this instrument he measured the dip at London in 1576 and found it to be 71°50'. The general character of the instrument is indicated by the sketch in figure 34, copied from Norman's book.

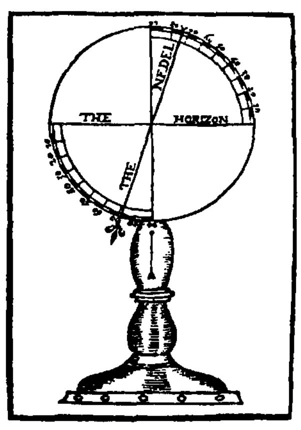



FIGURE 34.—First dip circle (after Norman, 1576).

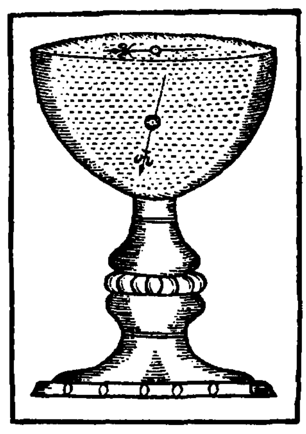


FIGURE 35.—Norman's experiment to show the absence of net force on a magnetized needle.

Norman continued his investigations and proved experimentally that the force exerted on the needle by the earth's magnetism does not produce motion of translation but simply that of rotation. To do this he first stuck a steel wire through a piece of cork of such size as to support the needle on the surface of a vessel of water. Then he cut away the cork bit by bit until it would float the wire well beneath the surface. At the same time he adjusted the position of the cork with respect to the wire so that the wire would lie horizontal. After being rubbed by the stone, the north end of the wire dipped below the horizon as the needle had done in the dip circle, but the supporting cork still held it in equilibrium, neither sinking nor rising to the surface. (See fig. 35.)

He also weighed several pieces of steel wire before and after magnetization, using a "fine gold balance," and showed that no change of weight occurred, thus disproving the assertion made by some that the act of rubbing one end of the needle by the stone added to its weight.

It should be remarked that the prevailing opinion of Norman's day regarded the compass as being drawn toward a "point attractive" usually identified with the celestial pole or with a supposed magnetic mountain or island (p. 59). Norman refuted this false idea, maintaining as a result of his experiments (a) that the supposed point toward which the north end of the needle tended to direct itself was not above the horizon but below it, and (b) that it was not a "point attractive" but a "point respective" — or in modern terms, that the needle was not attracted but merely directed toward the point, which he believed lay somewhere in the continuation of the line through the dipping needle, so that dip observations in other places would serve to fix the position of the point by intersections. He ventured the opinion that the angle of dip would be found to change according to the distance from the "point respective." The actual behavior of the dip needle at various distances from the earth's north magnetic pole is not at all in accord with Norman's hypothesis of a "point respective," yet his experiments and deductions constituted a large forward step and an undoubted stimulus to the next great advance in the science.

In his book Norman called attention to the common practice of adjusting the compass card to correspond with the declination in the region where it was to be used, and to the confusion which had resulted from the use of such compasses in making maps. (See p. 65.)

Annexed to later editions of Norman's book (if not to the first) appeared "A discourse of the variation of the compasse, or magneticall needle," by William Borough, which explained several methods of determining the magnetic declination and gave directions for its use in navigation. Borough called attention to the irregular distribution of the earth's magnetism, borne out by his own experience as a navigator, and showed that the observed compass variations cannot be explained by a magnetic north pole toward which the needle is directed, thereby refuting a widespread belief which nevertheless persists in some quarters to the present time (see p. 9).

### The Work of William Gilbert

The year 1600 is a memorable one in the history of the sciences of magnetism and electricity, for in that year appeared Dr. William Gilbert's famous work "De Magnete," giving the most complete summary of the properties of magnetic bodies up to that time, and containing his theory that the earth itself is a great magnet.

Gilbert was born at Colchester, England, in 1540, and after graduating at St. Johns College and serving there as mathematical examiner, he took up the study of medicine and received his degree in 1569. He is said to have practiced as a physician with great success and applause. His skill attracted the attention of Queen Elizabeth, by whom he was appointed physician in ordinary, and who showed him many marks of her favor, besides settling upon him an annual pension to aid him in the prosecution of his philosophical studies.

Gilbert's early investigations were directed to the study of chemistry, but later he turned his attention to electricity and magnetism, his interest aroused perhaps by Norman's discovery of the magnetic dip and the publication of "The Newe Attractive" in 1581; for it is stated that Gilbert had been actively engaged in the study of magnetism for nearly 18 years before the appearance of "De Magnete" in 1600, so that he must have begun about 1582.

Gilbert went about his investigations in a thorough and systematic manner. The many citations in the book attest his familiarity with previous writings on the subject, and it is said that he spent £5,000 on his experiments, "examining very many matters taken out of lofty mountains or the depths of seas, or deepest caverns, or hidden mines, in order to discover the true substance of the earth and of magnetic forces." He evidently had a collection of lodestones of various kinds coming from a number of different localities. Gilbert, like Norman, was a thorough believer in the importance of experimentation, and he had no patience with the "conjectures and opinions of philosophical speculators of the common sort." Nearly every conclusion drawn rests on experiments made over and over under slightly varying conditions; in this lies the great value of Gilbert's work on the properties of magnetic bodies. He was not willing to accept the statements of others until he had satisfied himself experimentally that they were correct.

In connection with his conception of the earth as a great magnet, Gilbert paid particular attention to experiments with a terrella, or spherical lodestone, and a very small pivoted magnetized needle (versorium) as long as a barleycorn. His description of one terrella gives its diameter as 6 or 7 fingerbreadths, but he evidently had several terrellas.

"De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure," as the title indicates, was written in Latin, but an English translation by P. Fleury Mottelay was published in 1893, and it is from that translation that the information here given has been derived.[15] Unfortunately Gilbert frequently made use of what he terms "words new and unheard-of," besides attaching to many others a significance far different from that generally accepted at this day, so that the translator had difficulty in determining the exact meaning of some passages in the book.

## The Earth a Great Magnet

Gilbert first discusses the sources and characteristics of various kinds of lodestone and iron ore, and their fundamental similarity. He then urges a comprehensive theory to the effect that the lodestone is the fundamental form of matter; that lodestone constitutes all but the outer shell of the earth and that the various forms of matter with which we are familiar are derived from lodestone by disintegration; that the earth, being a great lodestone, has poles and a magnetic equator, just as the terrella has its magnetic poles and a neutral line between. And the earth takes a definite direction in space, just as the terrella takes a definite direction with reference to the earth; it rotates daily about its axis, thereby defining (so he believed) the direction in which a rotating terrella always tended to come to rest. Although most of Gilbert's reasons for considering the earth a great lodestone have since been discarded (see p. 20), his idea that the earth acts in much the same way as a spherical magnet was the starting point for the future development of the science of terrestrial magnetism. The renowned Galileo was captivated by Gilbert's treatise, which supported the Copernican view that the earth rotates about an axis.

According to Gilbert's theory the compass needle should everywhere point in the direction of the true meridian. Though he gave no table of values of the magnetic declination in "De Magnete," he was familiar with what was known of its distribution at that time and recognized the errors inherent in the instruments and methods then in use. He explained the fact that the needle does not in general point true north by saying that the north end of the needle is drawn toward the land in the northern hemisphere (the south end in the southern hemisphere) because of the greater amount of lodestone in the more elevated portions of the earth's crust. He supported this statement by experiments with a terrella on which irregular masses projected above the spherical surface. At that time the declination was small in the interior of Europe and he was able to find a spot near the center of the raised mass on the terrella where the versorium showed no variation. From this he concluded that declination was greatest near the borders of the land and decreased to zero in mid-ocean and also in the middle of continents. Later observations showed the error of his conclusions. He was evidently familiar with the fact that the force directing the compass needle, the horizontal force, is greatest at the magnetic equator and decreases toward the magnetic poles, as he gives that as the reason why the observed declinations are greater in higher latitudes than near the equator, the needle being more susceptible to disturbing causes near the surface as the directive force becomes less.

Although Gilbert probably had no observed value of dip except the one determined by Norman at London, he was able with his terrella to obtain a very good idea of the distribution of dip on a uniformly magnetized sphere (fig. 36). Note that his diagram correctly shows how the dip on such a sphere would change from zero at the equator to 90° at either pole, the change being most rapid in crossing the equator. He devised an ingenious graphical method of finding the dip for any latitude, based on the assumption that the axis of magnetization coincided with the axis of rotation. This assumption would lead to a different construction in terms of modern theory (see p. 8), but Gilbert's was a remarkably close approximation and a radical improvement over Norman's "point respective." It yielded for the latitude of London approximately the value observed by Norman. A prompt confirmation of Gilbert's bold prediction regarding increase of dip with latitude was afforded by Hudson, on his voyage across the Barents Sea in 1608, when he made many dip observations giving values in excess of 84°.

Gilbert proposed to use dip observations as a means of determining latitude; he designed an instrument for measuring the dip, and showed how it might be mounted on board ship for the purpose. At the same time, he disparaged the analogous notion of finding longitude from the declination (a favorite project since the time of Columbus), holding that the needle "does not follow the rule of any meridian" and that the declination is "in diverse ways ever uncertain." He anticipated that similar irregularities of dip might impair the usefulness of his method of finding latitude, and cautioned against relying on the method until the distribution of dip should be charted, though he seemed to think the irregularities would be small. It may be noted that the existence of a considerable discrepancy between the earth's geographic and magnetic axes (of which he was skeptical or unaware) is an important factor in both propositions.

In Book II an explanation is given of the difference between the attraction exerted by electrified bodies, particularly amber, and that exerted by the lodestone and other magnetized bodies. The mutual action between lodestone and iron is examined in great detail.

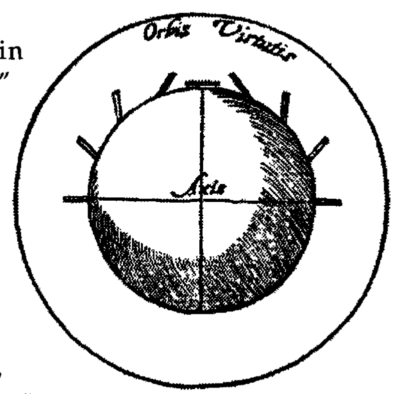


FIGURE 36.—Gilbert's representation of the field about a spherical magnet such as the Earth.

Gilbert discusses in Book III the "verticity" or directive property of the lodestone. He notes that a bar of iron may be magnetized without being rubbed by the lodestone; that, for example, heated iron that is hammered while cooling acquires "verticity" dependent upon the direction in which it is held; also that an iron bar fixed in a north-and-south direction for many years will become magnetized. This latter fact was discovered on January 6, 1586. A piece of iron which for a long time had supported a terracotta ornament on the tower of the church of San Agostino at Rimini was bent by the force of the winds and so remained for 10 years. The friars, wishing to have it restored to its original shape, took it to a blacksmith, and in the smithy it was discovered that it resembled lodestone and attracted iron.

Impressed with the fact that the earth as well as the lodestone exerts an influence at a distance, in spite of intervening bodies, Gilbert used the term "orbis virtutis" (fig. 36) to denote the magnetic field of a magnet — the space surrounding a magnet through which its influence extends — apparently getting the idea from Norman, who spoke of the "vertue extending rounde about the stone in great compasse."

An interesting sidelight on the times in which Gilbert lived is afforded by the following statement in his book: "...and as the planets and other heavenly bodies, according to their positions in the universe and according to their configuration with the horizon and the earth, do then impart to the newcomer (newborn infant) special and peculiar qualities, so a piece of iron, while it is being wrought and lengthened, is affected by the general cause, the earth." Evidently Gilbert accepted some of the currently essential tenets of the astrologers at the same time that he was subjecting the properties of the lodestone to repeated experiments.

**Discovery of the Secular Change**

The next noteworthy contribution to the science of terrestrial magnetism was Gellibrand's discovery in 1634 of the change of the magnetic declination with time. Up to that time it had been supposed that the declination, though different at different places, was fixed and invariable at any one place, except that it might suffer a change "by the break up of a continent," as Gilbert put it.

Henry Gellibrand was a professor of mathematics at Gresham College. He made a careful determination of the magnetic declination at Diepford, about 3 miles southeast of London Bridge, on June 12, 1634, and got the value 4°06'E. Now Edmund Gunter, another mathematician of Gresham College, had found it to be 5°56_'E. on June 13, 1622, and Borough and Norman had found 11°15'E. about 1580. Gellibrand repeated his observations and then examined carefully the published observations of Borough, without finding any material error. Clearly, therefore, the magnetic declination had changed by a considerable amount between 1580 and 1634.

Gellibrand announced his discovery in a book entitled "A Discourse Mathematical on the Variation of the Magneticall Needle, together with its Admirable Diminution Lately Discovered." He refrained from speculating as to the source of the change, "whether it may be imputed to the magnet or the earth, or both," saying that it must all be left to future times to discover.

Gellibrand's discovery was of the greatest importance to all users of the compass. No longer could the mariner feel confident that on visiting a distant port he would find the same value of declination as had been observed by previous navigators, nor could the land surveyor retrace the lines of an old compass survey without first finding out how much the declination had changed in the meantime.

Since Gellibrand's time, observations have shown that the dip and intensity of the earth's magnetic field also are changing with lapse of time, but the cause of the change is still a mystery. The idea has been advanced repeatedly that the secular changes were due to shifting of the magnetic pole, but it has been long since established that they are too complex to be described in that simple fashion. (See p. 9.)

15 Mottelay translates the full title of Gilbert's work as follows: "On the lodestone and magnetic bodies and on the great magnet the earth, a new physiology, demonstrated with many arguments and experiments."

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## Special Warning No. 95

**Nicaragua**

1. Mariners operating small vessels such as yachts and fishing boats are advised to avoid both the Caribbean and Pacific ports and waters of Nicaragua until further notice. The government of Nicaragua has adopted a new law that mandates the payment of a fine equal to 200 percent the value of any boat caught fishing illegally within Nicaragua's Exclusive Economic Zone (EEZ). There have been several cases of foreign-flagged fishing and other vessels being seized off the Nicaraguan coast by Nicaraguan authorities.

2. While in all cases passengers and crew have been released within a period of several weeks, in some cases the ships have been searched, personal gear and navigational equipment have been stolen, and there have been excessive delays in releasing vessels. Prompt U.S. Embassy consular access to detained U.S. citizens may not be possible due to non-notification of the Embassy by the Nicaraguan government.

3. It should also be noted that there have been recent incidents of piracy in Caribbean and Pacific waters off the coast of Nicaragua.

## NAVAREA VII Safety Net Service

The Republic of South Africa Hydrographic Office has announced plans to transmit all NAVAREA VII Radionavigational Warnings via the INMARSAT Safety net Service commencing 1 January 1995.

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126 • Rockville, MD 20850
Telephone 301-622-6448

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By William O. Land*

Roald Amundsen (rō'äl ä mo͞onsən), 1872-1926, was a giant among giants in the closing era of polar exploration but will be best remembered as the discoverer of the South Pole on December 14, 1911. But he had many other accomplishments. During 1903-06 he was the first to transit the whole of the Northwest Passage in a single ship. During this period he made scientifically significant observations of the North Magnetic Pole first located by James Clark Ross in 1831 while accompanying the Second Arctic expedition of John Ross. In 1918, his transit of the Northeast Passage by sailing along the whole of the northern coast of Europe and Asia was the first such transit since the first passage in 1876-79 by Nils A. E. Nordenskjöld (nīls no͞or' dənshöld). He was a pioneer in the exploration of the Arctic Ocean by air.

Amundsen was born on July 16, 1872, in Borge, Norway. After receiving his B.A. at Christiana University, he began graduate work in medicine but gave it up in 1894 to enter the naval service. In 1897 the Navy gave him permission to join the Belgian Antarctic Expedition aboard the *Belgica* as first officer under Captain Adrien de Gerlache. They explored the Palmer Peninsula, now known as Graham's Land (73°S, 60°W). Because of poor health and other reasons Captain Gerlache made a navigational error which caused the *Belgica* to become icebound for 13 months. It was under these conditions that Amundsen assumed command of the vessel and returned her safely to her home port. It is interesting to note that the ship's physician on this Antarctic expedition was Dr. Frederick A. Cook, who later gained notoriety as the arctic explorer who challenged Admiral Peary as the discoverer of the North Pole.

Back in Norway Amundsen planned an expedition to transit the Northwest Passage through the Canadian Archipelago. He purchased the *Gjoa*, a small 27-year-old sloop of 47 tons, 70 feet long with six-foot draft which had served as a fishing vessel in the North Atlantic. As he was short of funds he worked on his ship himself for two years to put it in condition. To support himself he held a job as a waiter in a nearby waterfront restaurant and induced many of his friends to work without pay to restore the *Gjoa*. But he could not get financial backing and in 1902 his creditors served him with a Bailiff's Bill which would have discouraged any ordinary man. Amundsen found new sources of gear and provisions, equipped his ship for sea, got his crew of seven together and in a frightful rainstorm slipped out of the harbor the night of June 17, 1903, without saying goodbye to anyone. Thus began the 3-year voyage of exploration to the Northwest Passage and the hunt for the North Magnetic Pole. They sailed across the Atlantic, south of Greenland and into Davis Strait, then north to Baffin Bay. If you have a chart of the Arctic regions you can easily follow his route. Leaving Baffin Bay he sailed west into Lancaster Strait and Barrow Strait, then south through Franklin Strait. Boothia Peninsula was to his east, and it was here that James Clark Ross, in 1831, determined the North Magnetic Pole to be at a point at 70°05'N, 96°46'W. Amundsen continued to sail south to the Strait of James Ross, entered the Wellington Strait and then into Barrow Strait, finally anchoring off the southeast shore of King william Island, at the Neumeyer Peninsula in what was a small unnamed bay. He named the bay Gjoa Haven.

From here three land bases were established on King William Island at considerable distances and different directions from Gjoa Haven. From these three bases magnetic compass triangulations were established to correct or confirm Ross' position of the North Magnetic Pole. Using the best instruments of the time which he had borrowed from Christiana University he confirmed Ross' position, and also found that the North Magnetic Pole was not a "point" but rather an "area" and that the "point", if there was one, actually moved around in this area of several hundred square miles of western Boothia Peninsula. He explored the area personally by dog sledge and skis, confirming findings with dipping needles, and concluding that the magnetic pole was possibly an area 50 miles north and south by 25 miles east and west.

From Amundsen's observations, scientists were able to estimate the pole's position as 71°N,96°W (James Clark Ross gave its position as 70°05'N, 96°46'W). Although the difference in the two positions does not represent the actual change during the interval, the old theory that the magnetic pole circles around the geographic pole in a few hundred years was disproved, for that would have required a change of longitude of perhaps 60° in 70 years.

In 1905 the *Gjoa* continued on her voyage, sailing west around Victoria Island and Banks Island, entering the Beaufort Sea, where, near Herschel Island he found whalers that had entered the Beaufort Sea from the Pacific Ocean. He returned to Norway via San Francisco where he sold the *Gjoa*. Amundsen was the first man and *Gjoa* was the first ship to transit the whole of the Northwest Passage.

He now had enough money to pay his creditors, but now that he was famous many of them refused to take payment. He was now free to plan another expedition. (To Be Continued)

Answer to **DO YOU KNOW?** (Page 1)
The North Magnetic Pole was first located by James Clark Ross on June 1, 1831. Ross was later knighted and advanced to the grade of rear admiral.

# BOOK REVIEW

*By Terry Spence*

***Formulae for the Manner*** (Second Edition)
*By Richard M. Plant,* Cornell Maritime Press, Inc.
Centreville, Maryland 21617 (Fourth Printing (1994)

This is essentially a reference book for the many formulae that are needed and used by mariners. In addition to the formulas used primarily by the navigator, there are chapters covering formulas for Seamanship, Tanker Operations, Ship Handling, Stability and Trim and Electricity. These latter chapters while strictly not germane to navigation may be of interest to the reader and certainly provide knowledge and fun reviewing them and working some of the formulas.

Let us turn our thoughts to the areas that pertain more to navigation: i.e. the Chapters on Mathematics & Navigation. In the Introduction the author spends several pages explaining the value of, and uses of the Polar to Rectangular Conversion and its reverse application Rectangular to Polar conversion capabilities when using a scientific calculator to perform these functions. Throughout the section on navigation formulae there is reference to the use of this system. The author provides a clear explanation of P>R and R>P with diagrams and examples. Some of the applications of he P/R are Set and Drift: Mid-Latitude and Mercator Sailing: Azimuth and Bearing Problems. Traverse Sailing is made easy by the ready determination of "l" and "p" which when individually added provide a composite "l" and "p" for the applicable sailing period.

A complete explanation of the key functions of a Scientific Calculator opens the Chapter on Formulae for the Mariner followed by diagrams and explanation of the Laws of Sine;Cosine and Tangent. We then meet our old friend from school days "SOH;CAH;TOA" of the right angle triangle followed by solutions of an oblique triangle. We begin our review of the formulae by calculating the course and distance between two points. By use of diagrams of right angled triangles we are led into the development of the necessary formula for the solution of the problem. A simplified formula is provided for the determination of Meridional parts (useful when Bowditch Table 5 not available) that is accurate to within 0.1 of said tables. I checked and verified this claim. As can be expected there follows the formula for Mercator Sailing which uses meridional parts.

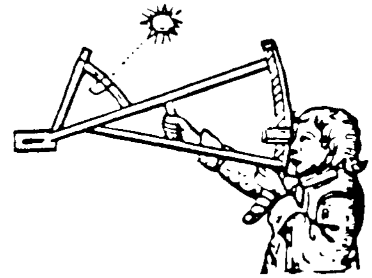
Great Circle Sailing formulae are next presented. When checking these out I had difficulty with those formulae dealing with the determination of the Latitude and Longitude of the vertex and points along the great circle. The Initial Course (IC) and Distance were a breeze however. More review required. There are formulae presented for the calculator solution of altitude and azimuth as well as solving amplitude.

The Greenwich Hour Angle (GHA) of both the Sun and Aries may be found by use of formulae that were taken from "The Calculator Afloat" and would be helpful if an almanac was not available. The positions of the planets and stars are not included in any formula so this would provide a limited use. The means of determining "course to steer" and "speed made good" can be solved by the formulae next presented. We are next provided with an interesting determination of the course made good by use of a three bearing fix on a single object. Carrying this illustration a little further, if you know the distance off at the time of the first bearing you can determine your speed made good on this course and then by rectangular/polar conversion set and drift can be found. A course to steer to intercept a vessel and bearing problems i.e. doubling the angle etc. close out the portion of this book as it applies to navigation. With the exception of some paragraphs covering visibility of lights which has navigation application the rest of the chapters are designed for the merchant seaman and other mariners but are nevertheless interesting to review.

All in all I found the book interesting and informative though at times somewhat heavy going.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-SEVEN, SPRING 1995

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Newsletters

I have heard that there have been some complaints voiced on INTERNET about not having received the quarterly *Newsletter* on time. The Foundation is working hard to get the *Newsletter* back on schedule. Our new Editor, Ernest Brown, is an experienced editor, having been the editor of Bowditch for years. He is striving to collect the material for publication sufficiently far enough ahead as to have material on hand for at least one additional *Newsletter*. This will provide enough material to print the *Newsletter* on time even if current material is delayed.

### Service Options

As mentioned in an earlier *Newsletter*, NOAA has introduced two service options for handling both aeronautical and nautical charts. These service options were placed in effect on 20 March 1995. They are:

*Standard Service*:

Standard service is the regular level of service that we have been using in the past. With Standard Service there is no charge for normal handling. Orders are filled and shipped on a first-in, first-out basis and normally delivered in less than 2 weeks from the date that the order is received in the Distribution Branch. All orders will be given Standard Service unless Expedited Service is specified.

*Expedited Service:*

Expedited Service is available, for a handling charge, to meet the urgent needs of agents. With Expedited Service, orders received by 2:00 p.m., local Washington, D.C. time, Monday through Friday (except holidays), are put on the fast track and normally delivered to the agent in 2 business days. Delivery time for re-shipments to members, depending on the address, i.e. Post Office Box, APO, FPO, and foreign destination takes longer.

Expedited Service handling charges are determined by the total weight of the order and will be billed to the agent's account.

Members requesting this service should make their order **EXPEDITED SERVICE** on any written orders or simply state Expedited Service if a message is left on the answering machine.

Please note that the Expedited Service charge is in addition to cost of shipping materials from The Foundation Offices.

Samples of the additional cost for Expedited Service is as follows: 0-3 lbs., $3.99; 5 lbs., $5.61; 10 lbs., $9.66; 15 lbs., $13.71. Service charges are subject to change without notice.

## READERS FORUM

*Edited by Ernest Brown*

Member Captain David Charlwood of York House Officers Mess, Royal Air Force Cranwell, Lincolnshire NG34 8HB, Great Britain, wrote on 5 February 1995:

"With regard to the letter from Director Alan E. Bayless in issue 44 (Summer 1994) who wrote about the confusion amongst students using the Auxiliary Table published in the Nautical Almanac, please add my concern.

"Personally, for 'back-up' use, I have always been very happy with Myerscough & Hamiltons *Rapid Navigation Tables* (Pitman, 2nd Edition of 1950), and use them in preference to the tables published in the Nautical Almanac.

"Call me old-fashioned, but I have only just got round

DO YOU KNOW . . .?

*By Ernest Brown*

Who invented the isogram (isoline) used to display on a map or chart a constant valve such as a pressure, temperature, magnetic variation, etc.?

(The answer appears at the back of this Issue)

to taking a long look at the *Star Sight Reduction Tables for 42 Stars -Assumed Altitude Method of Celestial Navigation* by the late Rear Admiral Thomas D. Davies. Now this is really something of a breakthrough method and I deeply regret that the 2nd Edition valid 1986-1992 has not (to my knowledge) been re-published - are there any plans at all to update both this volume and its companion that deals with the Sun, Moon and Planets?

"Congratulations on maintaining the very high standards of the Navigators Newsletter."— *Kind regards, Captain David Charlwood.*

Director Alan E. Bayless wrote on March 12, 1995:

"I ran across some interesting things about meridional parts during the ongoing discussion with Hocking prior to the final article he sent you. Maybe you know all about it already. In case you don't...

"According to Eva Taylor in *The Haven-Finding Art*, Chapter X, The True Chart: During the last decade of the sixteenth century,

> *Both men (Thomas Hariot and Edward Wright) constructed the tables of meridional parts...by a continuous addition of secants at 1' intervals.*
>
> *(Later, Thomas Hariot) had begun the calculation of meridional parts (M) by the equivalent of the modern formula*
>
> $$M = K \log \tan (45° + 1/2ø)$$
>
> *although the integral calculus had not been introduced or logarithms invented.*

"In this post Newton/Leibniz/Napier era, we can write this as:

"$M = \int \sec ø \, dø = k \ln \tan(\pi/4 + ø/2)$ where ø=latitude and $k = 21{,}600/2\pi$=radius of the earth in minutes of arc = nautical miles. Thus, the meridional parts for a spherical earth. The integral can also be written (substituting the *Bowditch*/Hocking *a* for *k*):

"$\int \sec ø \, dø = a \ln(\sec ø + \tan ø) = a \ln (1/\cos ø + \sin ø/\cos ø) = a \ln[(1 + \sin ø)/\cos ø]$.

"This is the first part of Hocking's final equation, the meridional parts for a spherical earth. The last part of Hocking's equation accounts for the difference between geocentric and geodetic latitude and may be regarded as a correction for ellipticity where the complete equation represents meridional parts for an ellipsoid.

"Hocking is very aware of all this, but I think the origin of the equation for meridional parts for a spherical earth is a little historical gem in itself." — *Cordially, Alan.*

Mr. Robert Loran Smith of 803 E. Palmaire Avenue, Phoenix, AZ 85020-5335 wrote on March 17, 1995:

"In issue #44, there was a fascinating article by David C. Knapp on the history of the magnetic compass. There was a discussion of the early European use of the compass. We have some documentation of that. The Danes were the early Northmen who ranged along the southern coasts of the North Sea and the English Channel, eventually attacking the Southern coast of England. They were limited by the distance and the seasons from doing extensive damage, as there was not enough time to raid along the coasts, then get to England and get back before winter set in. Eventually, reportedly using a magnetic compass, someone set sail across the North Sea directly, and reached England. This developed into an invasion and resulted in the north of England, for example Yorkshire, becoming a Scandinavian colony. According to legend, the first to accomplish this was Ragnar Lothbrok, or Lodbrok, also known as Ragnar Hairybreeches. As Ragnar was a historical as well as a legendary figure, we should be able to document an early use of the compass with some pretty reliable dates.

"This was considered an interesting topic. A novel was written on the incident, and a movie was made, starring Kirk Douglas. An after effect of the Danish invasion was the effect on the English language. According to Otto Jesspersen, Danish became the largest donor of words to the English language. There are so many Danish words in English that we do not recognize their foreign origin.

"It would be appreciated if this could be communicated to Mr. Knapp." — *Thank you. Bob Smith*

Member George R. Leonnig, Owner/Master of S. V. *Moctobi*, of 8125 S.W. 54th, Portland, OR 97219 has made available to us, with rights reserved for publication elsewhere, the *"Log of Moctobi"*:

*"Moctobi"* left Portland, Oregon on September 4th (1994) bound for the Caribbean and east coast of the United States on a 3 year cruise. The first leg of the trip was to the Sea of Cortez for the winter. *Moctobi* is a 36 foot Cabo Rico sailboat crewed by myself and wife, Ginny. Going to sea in a small boat and shorthanded crew is quite an experience.

"The trip to San Diego entailed a lot of motorsailing. We found that most of the cruising people do the same with the amount of sailing increasing after rounding Point Conception. Shorthanded husband and wife crews, with the always present weather threat want as quick a passage off the Pacific Northwest coast as possible.

"We had an excellent weather forecast to cross the Columbia River bar, known for its well earned reputation for rough conditions. Once over the bar we motorsailed all night to Newport, Oregon, timing our arrival for sunrise, which is a practice we follow for safety. But we had not counted on heavy fog. This was a tricky approach in fog, and charter fishing boats. We stood 2 hour watches to Newport. That was not enough time to get any real rest. We have since changed to a 3 hour watch schedule at night which works much better.

"Navigation fixes are taken hourly. Fixes are taken primarily with GPS and cross-checked to Loran. The radar is used at night if we are within 5 miles of land, closing on any land masses or in inclement weather. We often "buddy boat" with other cruisers. What this means is you stay in radio contact every few hours and are usually within a few miles of each other in case of a problem.

"*Moctobi* left Newport, Oregon on September 10th in heavy Oregon rain and a flat sea bound for Crescent City, California. That took us around the first of the dreaded three capes of the west coast, Cape Blanco. Cape Blanco is the furthest point west in the continental United States. We rounded the cape early the next morning in good weather, heaving a sigh of relief. The sigh was a little premature. Having passed the Oregon border into California during the late morning, the wind began to blow hard. It blew 40 knots behind us with a large following sea. We could see Crescent City ahead, but it took us 6 hours to get there, clawing our way west to get around the dangerous St. George's reef. Fishing boats were headed for safety with us. The only one having fun was a gray whale about a mile away breaching in the sea.

"Arriving in Crescent City we looked for somewhere to tie up for the night, when our engine died. We were 30 yards from shore and the wind was blowing us toward it. We performed an emergency anchoring. After determining that *Moctobi* was out of immediate danger, I called the Coast Guard to see if they could assist us in moving to deeper water or to a dock. We had only 9 feet of water under the boat. *Moctobi* needs 5 feet and the tide was just beginning to ebb. The Coast Guard sent a work skiff over and towed us to a dock in the fishing basin for the night. The harbor was filled with fishing boats. The weather had forced the tuna Fleet of California into Crescent City.

"The next morning I took a look at the engine and found that the fuel filter was leaking. The entire engine compartment was covered with diesel. I corrected the problem and the engine started. My class on diesel maintenance had just paid for itself. Using a bucket and the bilge pump we took 12 gallons of diesel out of the bilge and scrubbed the engine compartment.

"The weather improved after two days. Listening to the weather forecast and talking to the fishermen we decided to leave at sunset. That night was beautiful and we rounded the second cape, Cape Mendicino, at sunrise without incident. *Moctobi* arrived at Fort Bragg, California just before dark.

"On September 18th, we were at most 2 days from San Francisco. As we headed to sea, at the last turn out of the Noyo River and under the bridge, a fog bank awaited us 1/8 of mile ahead. There is a range to enter the harbor. With the radar on and aligning *Moctobi* up on the range we headed into the fog. We knew that once reaching the first channel buoy the narrow channel opens wide to the sea. Entering the fog all seemed in order. I glanced to port and was surprised to see that we had entered the edge of a kelp bed, maybe 10 feet into it. I swung hard to port, at the same instant we were at the bottom of a trough. We hit a rock on the keel, rising on the next swell and back into the channel. Not more than 15 yards ahead was the buoy we were looking for. My first instinct was to turn back towards the entrance and head into the harbor. That would have been a mistake. We would never have found the entrance. Continuing to sea and reaching open water, I had Ginny steer and I went below. First to clean out my underwear and second to check the bilge for water and the hull for damage. All was O.K. Luckily we hit the rock dead on the keel and not the hull.

"We motorsailed through dense fog the entire way to San Francisco. I did a complete workup of navigation to enter San Francisco Bay. Then after dinner we reviewed the plan. *Moctobi* rounded Point Reyes about midnight, which is where you start to see shipping heading to and from San Francisco. The fog was so thick we couldn't even see a glow from the lighthouse (25 mile light) 2 miles away.

"About 3 a.m. King Neptune took pity on us and decided we had 'paid our dues' for at least this part of the trip and raised the fog from the ocean. We could see the navigational lights and even the lights of San Francisco. Then through the fog, there it was —the Golden Gate. The roadway was just visible in the fog. Ginny went below and made a pot of fresh coffee. I told her to make mine 'stiff' with a shot of brandy. She returned with a cup for each of us. I turned the wheel over to her. This was her first trip under the bridge and she had earned the privilege to take *Moctobi* under the Golden Gate after a 640 mile trip down one of the fiercest coasts in the world. *Moctobi* stopped rolling for the first time in 13 days as we headed across the bay. We both had a huge feeling of accomplishment. It just can't be accurately described, only experienced.

"We spent 10 days in the San Francisco area. This included a tour of the Corps of Engineers bay model. This is a huge detailed model of the entire San Francisco bay and delta. They can create different scenarios of what will happen to the bay if certain man made or natural changes occur to water flow and silting. These changes have a direct impact on navigation in the bay and the delta region. It was a fascinating exhibit to see.

"September 29th started with a high overcast and no fog so we were on our way to Half Moon Bay. This was a short hop of 20 miles south of the Golden Gate. Two days later the foggy weather was replaced by sunshine. *Moctobi* headed for Monterey 60 miles further south. It was at this point that our GPS failed. Latitude and Longitude agreed with the Loran, but speed and course were in error. As it turned out, there was a software error in the GPS giving the erroneous data. This error affected all the vendors' models of GPS throughout the world.

Electronics fail, and traditional methods are necessary as a backup to today's technology.

"The trip to Monterey was great. The sea conditions made it easy to spot seals, sea lions, huge floats of jellyfish, and even a whale. Late in the day we did get some good downwind sailing. Entering Monterey harbor two sea otters escorted us to our dock slip, swimming along on their backs eating shell fish. In Monterey we met more than a dozen other crews on their way to Mexico. It is an incredible community of vagabonds out here with varying degrees of experience.

"We had intended to spend 3 or 4 days in Monterey, but Mother Nature had other plans. This is when we began using the SSB radio to talk to other boats, getting first hand information about weather and navigational conditions ahead. Sort of a home grown Notice to Mariners."

Member A. E. Saunders of 4119 Cherry Blossom Lane, Vineland, Ontario, LOR 2CO, Canada wrote on November 29, 1994:

"I am astounded at how such an article (Checking the Deviation of Your Compass by John M. Luykx) could appear in such a prestigious publication as the *Navigator's Newsletter*.

"The method of checking deviation or establishing a deviation table as described is totally erroneous.

"Firstly, if one is going to use the 'Run the Range' process, one does not sail between the two aids 'Steer a course between the beacons'. This, of course, is in any event impossible if both 'beacons' are ashore. The reason for that is: it is extremely difficult and totally impractical to ensure that the vessel is actually following a track between the two objects. In fact, if there is any leeway or drift of the vessel it will either be 'crabbing' (not headed in the direction of the beacon ahead) or it will be moving 'off-line' (will not be following a track between the two objects). In either of these cases, the results will be incorrect!

"Secondly, if one properly follows the 'Run the Range' process by heading in a direction to keep the two objects in line, the results will only be correct if there is no leeway or drift of the vessel. Otherwise either you will not be following the True Course laid out or you will not be headed (pointing) in the True direction that you desire. You will be 'crabbing' to maintain the desired course and have a false heading.

"CAVEAT: The conditions must be ideal - no wind or current to affect the vessel!

"To use the 'Run the Range' under less than these ideal conditions means that one must use a pelorus to determine the relative bearing on one of the two objects at the instant that they are in line and the Compass Course must be simultaneously noted. Of course if the vessel's head is 'swinging' due to even slight wave conditions or unsteady helmsmanship, the Compass Course must be noted after the compass movement has been sufficiently 'damped' to result in a satisfactory reading (and the beacons still in line).

"If one uses a pelorus to obtain the relative bearing, the need for a range is totally eliminated if one follows the procedure as outlined in this author's book 'Small Craft Piloting and Coastal Navigation'. The helmsman has no interest in the location of the beacon and need not line up two objects at the same time as concentrating on steering a steady course and reading the compass at the appropriate time.

"A further advantage of this author's process is that leeway and current have no effect on the results! It is, of course, important to have sufficiently calm conditions as to allow a reasonably steady course.

"'Running a Range' is still useful for the occasional 'quick and dirty' check of gross errors in the deviation table.

"It is interesting to note that, in the example, the maximum deviation West is 8°, whereas the maximum deviation East is 4°. Since the points of maximum deviation are separated by approximately 180° and the null points of deviation are separated by approximately 180°, it would appear that the compass is well compensated. However, this aberration would lead one to believe that the compass card rotation point and lubber line are not parallel to the keel. The compass case should be rotated on its mount 2° counter-clockwise to correct this condition.

"Regardless of the process used - IT IS IMPERATIVE THAT SOMEONE IS MINDING THE STORE! Someone aboard must have the sole responsibility for look-out and be in command of the vessel. This person must have no other responsibilities to divert his / her attention!!" — *Yours very truly, A. E. Saunders.*

*Editor's Note: Director John M. Luykx's response is as follows:*

*"The method I described in The Navigator's Newsletter to determine boat compass deviations is a practical one and is predicated on the inherent idea that the boat operator will have his boat correctly aligned between the two beacons when recording the compass course between them, i.e., the bow pointed to the beacon ahead and the stern pointed to the beacon astern. For the boat operator to accomplish this is not, I believe, as serious a problem as you suggest.*

*"You are correct in stating that from your examination of the deviation curve, there may be error in the alignment of the compass to the fore and aft axis of the boat. However, the purpose of the article was to describe a simple method of determining or checking boat compass deviation and not to describe compass alignment or adjusting procedures."*

*Member Saunder's book,* Small Craft Piloting and Coastal Navigation, *is reviewed in this issue.*

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# NAVIGATION FEATURE

## The Accuracy of Small Sextants

**Including Miniature and Box Sextants in Navigation**

*By John M. Luykx*

### General

Small handy lightweight sextants have been in use since the late 18th Century for taking celestial observations at sea. Some of the earliest models were based on the "Snuff Box" sextants of English design first developed in the last decades of the 18th Century for use primarily in surveying. This box sextant 2½ to 3 inches in diameter and weighing only 8 to 10 oz. could be easily carried in the pocket. The typical box sextant is shown in Figure 1.

During the 19th Century, the English also built small sextants of traditional design which were fitted in a small leather case or pouch and carried in the pocket. Such sextants including the box type have intrigued navigators over the years but surprisingly little has been written or documented concerning them as navigation instruments (although the English "box" sextant is well known as a surveying instrument). Many were manufactured by such famous makers as Stanley, Barker, Elliot and Troughton and Simms.

### Description

In order to determine the order of accuracy of some typical small sextants for navigation, the author, using instruments from his collection, recently conducted some preliminary accuracy tests from land on the western shore of Chesapeake Bay. Having determined the height of eye as well as the exact observer position at a spot at Chesapeake Beach, Maryland, sixteen miles south of Annapolis, sixty observations were taken with the six instruments, ten observations with each. Each observation was reduced, using a CN-2000 computer, and the error of the observation recorded. The mean error for the ten shot series for each instrument was then computed. The results are tabulated in Table 1 (following page).

The instruments used in the test were: (See Characteristics, Table 2.)

1. Brass box sextant by F. Barker (English 1932) *(Figure 1)*
2. Modern (1993) reproduction of an English brass box sextant (unsigned) *(Figure 2)*
3. Modern box sextant by F. Barker (English 1970) labelled "Small Craft Precision Sextant", aluminum. *(Figure 3)*
4. ILON Mark III brass micrometer sextant (US 1962) *(Figure 4)*
5. A-10 air sextant by Fairchild Camera Co. modified for marine navigation (US 1943) *(Figure 5)*
6. Bendix Mark 5 air sextant without averager (US 1942) *(Figure 6)*

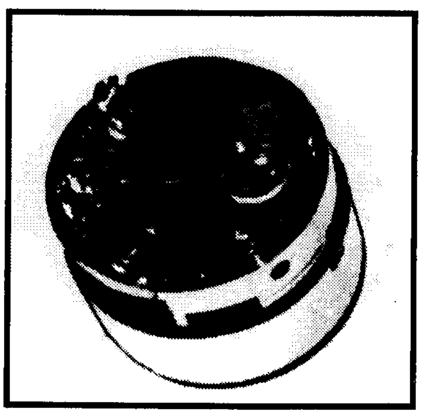


Figure 1

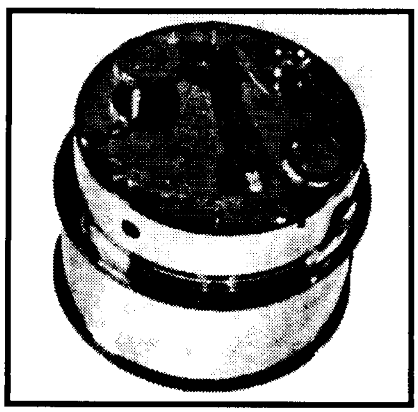


Figure 2

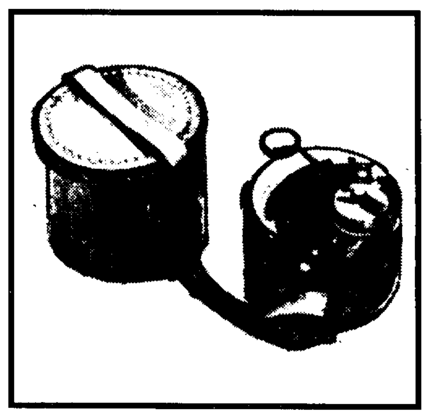


Figure 3

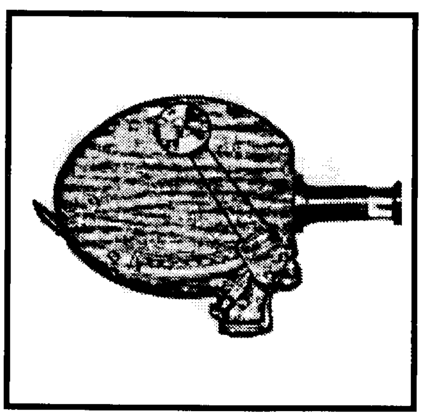


Figure 4

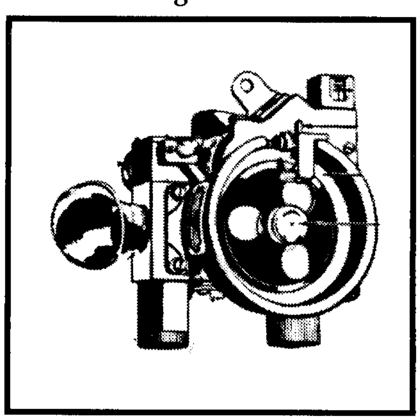


Figure 5

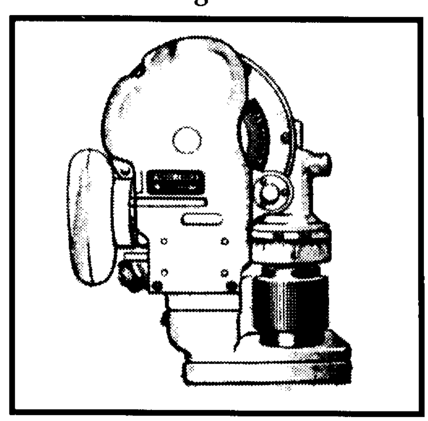


Figure 6

**Results**

See tables 1 & 2

**Summary**

During the test, it was found that the easiest sextant to use was the Mark 5 (#6) because of the very wide field of view of its telescope. Also very handy and accurate was the Fairchild A-10 (#5). The small ILON (#4) sextant with its micrometer and higher power telescope simplifies sighting to a large extent, except that the field of view is rather narrow. It is felt that the box sextants would be more difficult to use by the uninitiated due to their miniature size and their small optics. In addition, the reading of the vernier in poor lighting conditions may cause error. The small size of the field of view of the box sextant is the greatest disadvantage of these small instruments. However, although the original design was primarily for surveying, the addition of a sun filter (or filters) converts the box sextant to an effective instrument for observing celestial bodies where absolute accuracy is not the primary consideration.

In general, it is felt that the smaller the instrument, the greater the skill required by an observer to obtain accurate celestial observations.

The mean error of observation tabulated for sextants #2 through #6 indicate that these instruments appear to be suitable for use at sea. The relatively large error 7.8 shown for sextant #1 may be attributable not only to the instrument but also to the want of skill of the observer who has not had much experience in using such small instruments for altitude observations of celestial bodies. It was also the first instrument of the six to be tested, which is generally a disadvantage.

**TABLE 1**

Small Sextant Accuracy Test Results

Date of Test: 9 Nov 1994
Observer Posit: N38 41.7 W76 32.0
Body Observed: Sun (LL)
Height of Eye: 14.5 feet
Weather: Clear

Mean Error: in minutes of arc for 10 observations
Range of Error: in minutes of arc

| SEXTANT | OBSERVATIONS | MEAN ERROR | RANGE OF ERROR | |
|---|---|---|---|---|
| #1 (BARKER) | 10 | -7'.8 | -6'.7 to -10'.2 | (3'.5) |
| #2 (BRASS/BOX) | 10 | -3'.7 | -0'.2 to +12'.3 | (12'.5) |
| #3 (BARKER/ALUM) | 10 | -0'.7 | +2'.6 to -3'.8 | (6'.4) |
| #4 (ILON) | 10 | +0'.8 | -1'.2 to +2'.2 | (3'.4) |
| #5 (A-10) | 10 | -1'.2 | +0'.5 to -1'.9 | (2'.4) |
| #6 (MK 5) | 10 | -3'.2 | +1'.3 to -4'.9 | (6'.4) |

**TABLE 2**

Instrument Characteristics

| | #1 | #2 | #3 | #4 | #5 | #6 |
|---|---|---|---|---|---|---|
| Inst. | Barker | Box (Repro) | Barker (Alum) | ILON | A-10 | MK-5 |
| Lgth: | 2.5" | 3.3" | 3.2" | 6.0" | 6.7" | 5.0" |
| Wdth: | 2.5" | 3.3" | 3.2" | 5.0" | 5.5" | 5.3" |
| Hgt: | 1.5" | 1.7" | 2.8" | 2.7" | 3-1/2" | 6.0" |
| Wgt: | 10 oz. | 18 oz. | 8 oz. | 20 oz. | 30 oz. | 50 oz. |
| Arc: | 0 to 140 | 0 to 140 | 0 to 150 | 0 to 120 | 0 to 90 | -10 to 100 |
| Scope: | No | 2x | No | 5x | 2x | 2x |
| Radius: | 1.5" | 1.8" | 1.8" | 2.5" | 1-1/2" | 1.7" |
| Filters: | 2 index | 1 index | 2 eyepiece | 3 index 2 horizon | 2 index | 4 index |
| Const: | Brass | Brass | Aluminum | Brass | Aluminum | Aluminum |
| Case: | No | No | Leather | Leather | Vinyl | Vinyl |
| Accur | 1'vernier | 1'vernier | 1'vernier | 1'micrmtr | 1'micrmtr | 2'micrmtr |
| Illum: | No | No | No | NO | Yes | Yes |

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By William O. Land*
*(Continued from Winter 1994-95 Issue #46)*

Roald Amundsen's good friend and fellow Norwegian, Fridtjof Nansen, (see Issue 39, Spring 1993) during the years 1893-96 drifted in a large arc around the North Pole in the schooner *Fram* and established the fact of the clockwise polar drift of the Arctic ice. On March 14, 1895, when the *Fram* had drifted to 84°04"N, 102°E, Nansen and Commander Hjalmer Johansen left the ship in an attempt to ski to the North Pole with the aid of dogs and a sledge. They reached 86°14'N on April 8, 1895, about 226 nautical miles from the North Pole but had to turn back because the ice was too rough to proceed.

Amundsen thought that he could reach the North Pole by using a modification of Nansen's plan. By starting from the Bering Strait instead of Siberia as Nansen did, the polar ice drift would carry his ice-bound ship farther north, and thus close enough to the pole that he could reach it by dog sledge. For this coming expedition he was able to secure the *Fram* which was designed to avoid the crushing effect of the polar ice. He planned to drift for 5 years. But he still had the problem of raising funds and backing. Public interest waned after Robert E. Peary reached the North Pole on April 6, 1909.

By 1910 Amundsen was still interested but lacked the $40,000 needed to complete his plans. So, on August 9, 1910, he sailed in spite of this. In his own mind he had secretly decided to sail to Antarctica instead and make a dash to the South Pole using dogs and sledges just as Peary did the year earlier to the North Pole. He sailed to Madeira where he stopped for final supplies and then told the crew that it was not a 5-year drift in the Arctic, but a 2-year trip to Antarctica to discover the South Pole. The crew agreed 100%. Amundsen said he kept this change of plans secret. He did not want Robert Falcon Scott to accelerate his plans and thus beat him to the South Pole.

Amundsen arrived at the Bay of Whales, Antarctica on January 3, 1911, where he sent up a base camp some 60 miles farther south than Scott's. Attention to detail and foresight were to be the keys to his success. For example, on a preparatory trip he deposited stores of food along the route he intended to follow out and back.

Amundsen set out for the South Pole on October 20, 1911, with four companions, 52 dogs and four sledges carrying provisions for four months. Fortunately, he encountered favorable weather. Following confirmation by celestial observations on December 14, 1911, the Norwegian flag was raised at the South Pole, in a level region that Amundsen named King Haakon VII Plateau. Amundsen and companions remained there until December 17 while making studies and observations. They arrived at their base camp at the Bay of Whales on January 25, 1912. The Robert Falcon Scott party reached the South Pole 35 days after Amundsen and perished during their return to their base camp. *(To be continued)*

# NAVIGATION NOTES

## A Navigation Problem: Great Circle Vertex

*By William O. Land*

What is the latitude and longitude and distance to the vertex of the great circle from Atlantic City, NJ 39"21.0'N, 74°24.6'W (the Absecon Inlet buoy) to Gibraltar, 36°06.0'N, 5°21.0'W (the Atlantic Light)? The answer is 43°20'.7N, 44°47'1.W and 1,348 nautical miles.

Answer to last issue's problem on pp.8-9

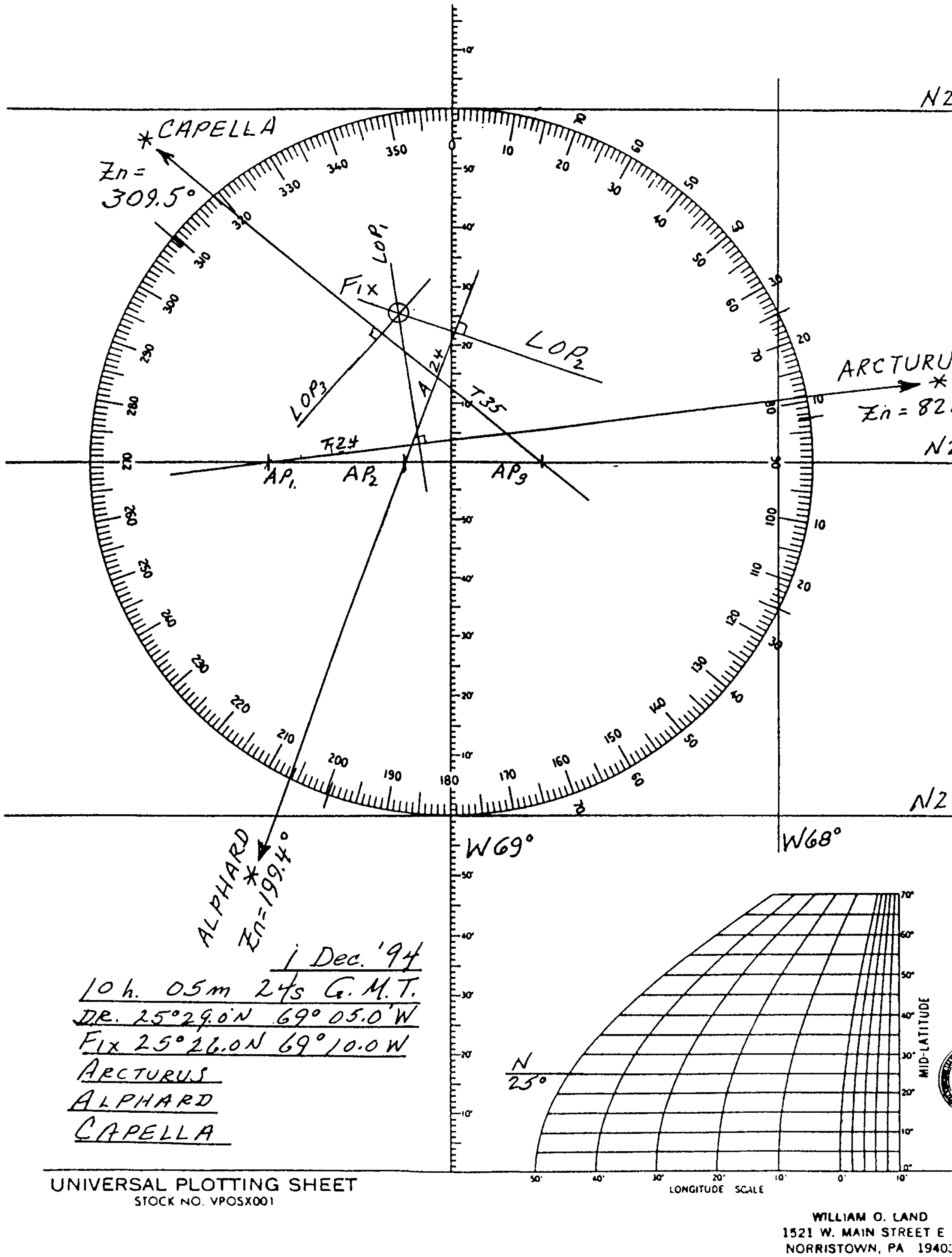
ANSWER TO LAST ISSUE'S PROBLEM:

STAR SIGHT REDUCTION
H.O. 229

GIVEN: Lines #1,2,3,4,5,6,7,8,43.
FIND: Lines #37, 39.
ENTER H.O.229 with lines #26, 27 and 28.

| | | | | | |
|---|---|---|---|---|---|
| STAR | 1 | ARCTURUS #37 | ALPHARD #25 | CAPELLA #12 | |
| Local Date | 2 | 1 DEC. '94 | 1 DEC.'94 | 1 DEC.'94 | |
| D.R. Lat. N/S | 3 | N 25° 29.0' | N 25° 29.0' | N 25° 29.0' | North or South? |
| D.R.Long. E/W | 4 | W 69° 05.0' | W 69° 05.0' | W 69° 05.0' | East or West? |
| Eye Ht. F/M | 5 | 11' | 11' | 11' | Feet or Meters? |
| Chr. Err.F/S | 6 | 16 sec. F | 16 Sec. F | 16 Sec. F | Fast or Slow? |
| Hs | 7 | 33° 12.3' | 54° 20.9' | 28° 29.4' | Sextant Reading |
| Local Time | 8 | 05 h 05 m 40 s | 05 h 08 m 01 s | 05 h 11 m 20 s | Use Standard Time |
| Z.D. ± | 9 | +5 h | +5 h | +5 h | (E=-) (W=+) Fr. Ln.4 |
| Chr. Err. ± | 10 | m -16 s | m -16 s | m -16 s | (Fast = -)(Slow = +). |
| G.M.T. | 11 | 10 h 05 m 24 s | 10 h 07 m 45 s | 10 h 11 m 04 s | Add lines 8±9±10 |
| Correction | 12 | h | h | h | Need ± 24 hrs.? |
| Correction | 13 | m s | m s | m s | Need ± 60 secs.? |
| G.M.T. | 14 | 10 h 05 m 24 s | 10 h 07 m 45 s | 10 h 11 m 04 s | Add lines 11±12±13 |
| G.M.T. Date | 15 | 1 Dec. '94 | 1 Dec. '94 | 1 Dec.'94 | Need new Date? |
| G.H.A. ♈ hr. | 16 | 220° 02.1' | 220° 02.1' | 220° 02.1' | Fm.Ln.14.AlsoGet 18,27. |
| Incr. ♈ m,s | 17 | 1° 21.2' | 1° 56.6' | 2° 46.5' | From Line 14, m,s. |
| S.H.A. ☆ | 18 | 146° 08.7' | 218° 09.6' | 280° 54.6' | From Lines 1, 15 and N.A. |
| G.H.A. ☆ | 19 | 367° 32.0' | 439° 68.3' | 502° 103.2' | Add 16 + 17 + 18 |
| Correction | 20 | ° | -360° | -360° | Need -360°? |
| Correction | 21 | ° . ' | +1° -60.0' | +1° -60.0' | Need ±60.0'? |
| G.H.A. ☆ | 22 | ° . ' | 80° 08.3' | 143° 43.2' | Add 19 ± 20 ± 21. |
| Ass'd.Long ± | 23 | -69° 32.0' | -69° 08.3' | -68° 43.2' | (W = -)(E = +) |
| L.H.A. ☆ | 24 | 298° 00.0' | 11° 00.0' | 75° 00.0' | On Ln.23 Sub. MM.m |
| Correction | 25 | ° 00.0' | ° 00.0' | ° 00.0' | Need ±360°? |
| L.H.A ☆ | (26) | 298° 00.0' | 11° 00.0' | 75° 00.0' | Add Lines 24 ± 25. |
| Dec. ☆ N/S | (27) | (N) 19° 12.5' | (S) 8° 38.2' | (N) 45° 59.5' | Same or Contrary? |
| Ass'd.Lat.N/S | (28) | (N) 25° 00.0' | (N) 25° 00.0' | (N) 25° 00.0' | Nearest Whole ° |
| Hc | 29 | 32° 40.6' | 55° 18.2' | 27° 41.5' | Also get Lns.30,38,39 |
| (d) Tens ± | 30 | (+18.3) +2.1' | (-57.2) -31.8' | (+8.7) 0.0' | From Line 27 MM.m . |
| (d) Units ± | 31 | +1.7' | -4.6' | +8.7' | From Line 27 MM.m. |
| Dbl.2nd.Diff. | 32 | (0.0) + 0.0' | (0.0) + 0.0' | (0.0) + 0.0' | Use only for d' |
| Hc | 33 | 32° 44.4' | 54° 41.8' | 27° 50.2' | Add 29±30±31+32. |
| Correction | 34 | ° . ' | ° . ' | ° . ' | Need ±60.0'? |
| Hc | 35 | 32° 44.4' | 54° 41.8' | 27° 50.2' | Add 33 ± 34. |
| Ho | 36 | 33° 08.4' | 54° 17.8' | 28° 25.2' | Line 37 = 35 ~ 36 |
| Intercept(a)A/T | 37 | T 24.0' | A 24.0' | T 35.0' | A or T? Ho Larger = T |
| Z | 38 | 82.7° | 160.6° | 50.5° | |
| Zn | 39 | 82.7° | 199.4° | 309.5° | Z = Zn or need Corr'n? |

| | 40 | SEXTANT CORRECTION | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 41 | + | - | + | - | + | - | |
| Dip | 42 | XXX | 3.2' | XXX | 3.2' | XXX | 3.2' | Line 5 and Page A2 N.A. |
| I.C. | 43 | 0.8' | 0.0' | 0.8' | 0.0' | 0.8' | 0.0' | (On = -)(Off = +). |
| + and - Totals | 44 | 0.8' | 3.2' | 0.8' | 3.2' | 0.8' | 3.2' | Add Lines 42 ± 43. |
| Diff. +/- | 45 | -2.4' | | -2.4' | | -2.4' | | Diff. =/- Line 44 |
| Hs ☆ | 46 | 33° 12.3' | | 54° 20.9' | | 28° 29.4' | | From Line 7 |
| App. Alt. ☆ | 47 | 33° 09.9' | | 54° 18.5' | | 28° 27.0' | | Line 46 ± Line 45 |
| A2 Alt.Corr'n. | 48 | -1.5' | | -0.7' | | -1.8' | | ☆ Table Page A2 N.A. |
| Ho ☆ | 49 | 33° 08.4' | | 54° 17.8' | | 28° 25.2' | | Add Lines 46 + 47. Enter into Line 36 |


CAPELLA
Zn = 309.5°
ARCTURUS
Zn = 82.
ALPHARD
Zn=199.4°
Fix
LOP1
LOP2
LOP3
AP1
AP2
AP3
W69°
W68°
1 Dec. '94
10 h. 05 m 24 s G.M.T.
DR. 25°29.0'N 69° 05.0'W
Fix 25°26.0'N 69° 10.0'W
ARCTURUS
ALPHARD
CAPELLA
N 25°
MID-LATITUDE
LONGITUDE SCALE
UNIVERSAL PLOTTING SHEET
STOCK NO. VPOSX001
WILLIAM O. LAND
1521 W. MAIN STREET E
NORRISTOWN, PA 1940

# NAVIGATION BASICS REVIEW

## Use of H.O. 229 for Check Solution

*By Ernest Brown*

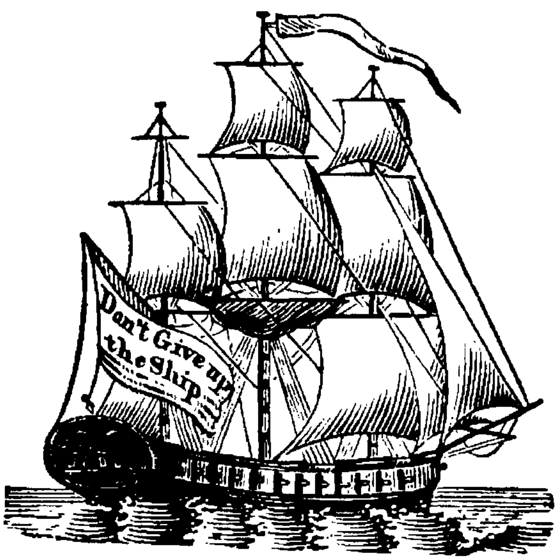
The answer to the initial great circle course and distance problem by H.O. 211 in issue forty-five, Fall 1994, is 70°10' and 3200.9 nautical miles. In this issue the problem is extended to finding the latitude and longitude and distance of the vertex of the same great circle.

The solution by H.O. 211 (table 35 of Bowditch) can be checked rapidly for gross error or blunder by inspection of H.O. 229. For the problem stated, the latitude and longitude and distance of the vertex are: 43°20'.7N, 44°47'.1W and 1,348 nautical miles.

Entering H.O. 229 with the latitude of departure (39°) — always enter with SAME NAME — and initial course angle (70°) as LHA, and 90° minus distance to a desired point on the great circle as declination argument, one finds as respondents tabular altitude and azimuth angle which are with these substitutions, respectively, the latitude of a point on the great circle and its difference of longitude from the point of departure.

Since we are looking for the vertex, we note that the highest latitude (43°05'.4) corresponds to declination 67° and Z30°.2. These values (not interpolated) give 43°05'.4N, 44°12'.6 W and 1,280 nautical miles. They look close enough to insure that gross errors or blunders have not been made.

*Note*: If the respondents are extracted from across the C-S line, the DLo is the supplement of the tabular azimuth angle; the tabular altitudes correspond to latitudes on the side of the equator opposite from the latitude of departure.




# HISTORY OF NAVIGATION

## Origins of Geomagnetic Science

*A Revision by David G. Knapp*

*Editor's Note:* Origins of Geomagnetic Science *is taken from chapter VI of the Coast and Geodetic Survey serial 663,* Magnetism of the Earth *by Albert K. Ludy and H. Herbert Howe, the first parts of which were published in Issue 44 (Summer 1994), Issue 45 (Fall 1994) and Issue 46 (Winter 1994-95). This is the last part. The writer uses the term magnetic declination, as used in geophysics, for what navigators commonly call magnetic variation.*

### Historic Magnetic Charts

Methods of showing the value of the magnetic declination by means of compass roses, as on some of the medieval charts (p. 65), were ill adapted for use on general charts of the oceans and continents because of the changes of the declination from place to place. We are told that "magnetic charts" were prepared by Santa Cruz about 1536; it is not known what his mode of delineation was. As the record stands, however, it was not until the next century that a suitable method was devised—a method destined to find wide application in meteorology, topographic mapping, and other branches of physical geography. This invention was disclosed for the first time in a Latin work published in 1641 by Athanasius Kircher, who credits it to the Jesuit mathematician Christopher Borrus. The earliest extant example of the type, and probably the first such chart to have a firm foundation in observed data, was the work of the astronomer Edmond Halley, who published in 1701 a chart (fig. 38) showing lines of equal magnetic declination over the Atlantic Ocean, based upon his observations made between 1698 and 1701 on a "pink," the *Paramour*, at the expense of the British Government. His second chart, probably published a year later, gave the lines of equal variation over the Indian Ocean and the extreme western part of the Pacific as well as over the Atlantic. The name "isogonic lines" was applied to Halley's curves after they came into general use.

Van Bemmelen gives[16] an extensive collection of early values of the magnetic declination and a series of isogonic charts which he prepared for the years 1500, 1550, 1600, 1650, and 1700. The one for1500 is shown in figure 37. Although any charts for these early epochs are necessarily only rough approximations because of the limited number of observations available, the series in question nevertheless brings out well the change in the distribution of the magnetic declination over the earth's surface from century to century.

Halley's example soon led the way to other uses of the scheme, and was the inspiration for the first dip chart, published in 1721 by William Whiston. Many of the early magnetic charts were prepared with the avowed objective of enabling the mariner to find his longitude by means of magnetic observations (see p. 70). Whiston expressed the hope that this might be accomplished with dip observations. His chart, however, was restricted to southeastern England, and it was not until 1768 that a world chart of inclination was published, the work of Johann Carl Wilcke of Sweden. This chart attested the general confirmation of Gilbert's prediction concerning the distribution of dip. The corresponding relation for intensity was discovered by Lamanon in 1787, and independently by Humboldt on his travels in America (1798-1803). The voyages of Duperrey in 1822-25 afforded further elucidation of the pattern of the earth's magnetism, particularly with regard to the magnetic equator.

**Discovery of the Daily Variation of Declination**

For a long period after the existence of secular change was well established, it was supposed that this was the only time-change that occurred. However, in 1685 a party of French missionaries, guests of the Siamese king, recorded on December 9 and 10 a succession of determinations of the declination which failed to agree; the reported results[17] of seven observations showed a spread from 0°16′W. to 0°38′W. As all the observations were made at the same place (at Louvo, now Lop-buri, Thailand) they may be regarded as the pattern of early observations containing an intimation of the occurrence of transient changes in the direction of the compass needle.

The credit for the discovery of the daily variation must properly be given, however, to a London mechanician and clock maker named Graham, who, after many hundreds of observations of the declination at various times of the day, made in 1722 a definite announcement of his discovery. A few years later, with the aid of a needle made expressly for the purpose, the discovery was verified and amplified by the Swedish astronomer Anders Celsius (whose name is perhaps better known in connection with the Centigrade temperature scale). He was followed in this by a host of other investigators; in fact, the daily variation, because of its complexity and periodic character, has afforded a fruitful and well-tilled field of investigation. Celsius, with his colleague and successor Hiorter, is likewise credited with discovering (1747) the relation between magnetic disturbance and the aurora. The seasonal change in the daily variation of declination was brought to light by Canton in 1759, and its inversion in southern latitudes by John MacDonald in 1795.

**Developments Culminating in the Work of Gauss**

Graham was probably the first to suggest that relative values of the intensity of the earth's magnetism might be obtained by noting the time of vibration of a compass needle, but there is no record of observations by him. Frederick Mallet was the first one to make such observations, and he found, in 1769, the times of vibration to be the same at St. Petersburg and a place in China. In 1776 Jean Charles Borda, a French mathematician and astronomer, improved upon the work of Mallet and made observations with the needle of a dip circle mounted in the magnetic meridian, during an expedition to the Canary Islands. With the dip needle so mounted, relative values of the total intensity may be obtained, whereas the vibration of the compass needle would give relative values of the horizontal intensity. Considering the limitations of the instruments then in use, it is probable that greater accuracy was obtainable with the dip needle than with the compass. Upon the development of an instrument with a magnet supported by a silk fiber, much greater accuracy was possible with the horizontal magnet.

Poisson was no doubt the first (1828) to conceive a method for making absolute determinations of the intensity, but it was left for Gauss to devise the practical details of a complete procedure, the one in general use today

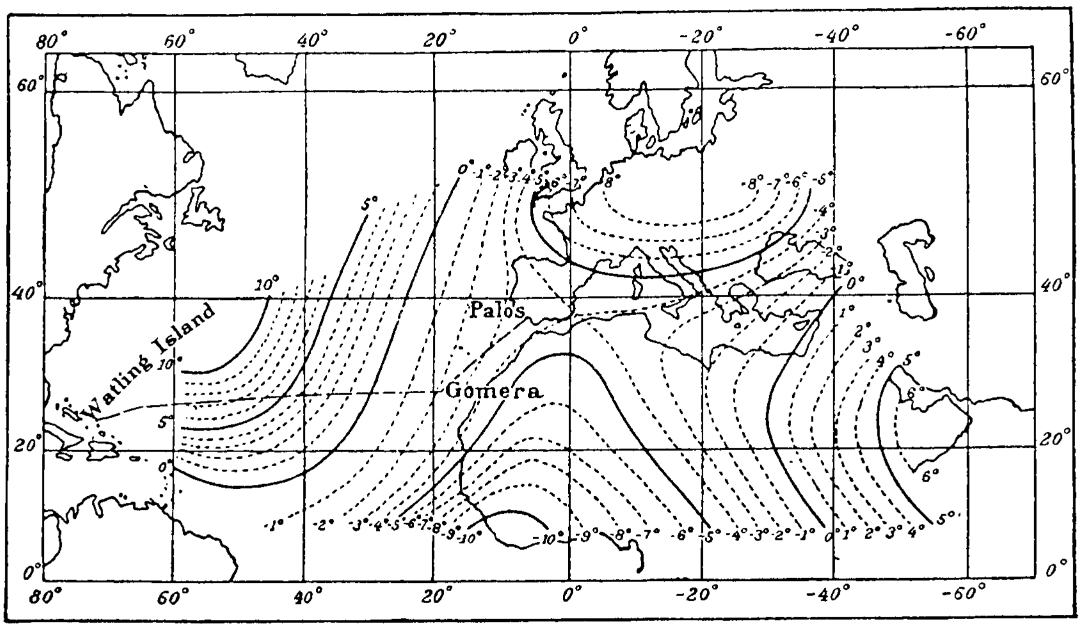



FIGURE 37.—Van Bemmelen's isogonic chart for 1500. Scale at equator, 1: 130,000,000. (Published in 1899. East declination shown with negative sign.) The approximate track of Columbus' Atlantic crossing of 1492 has been added.

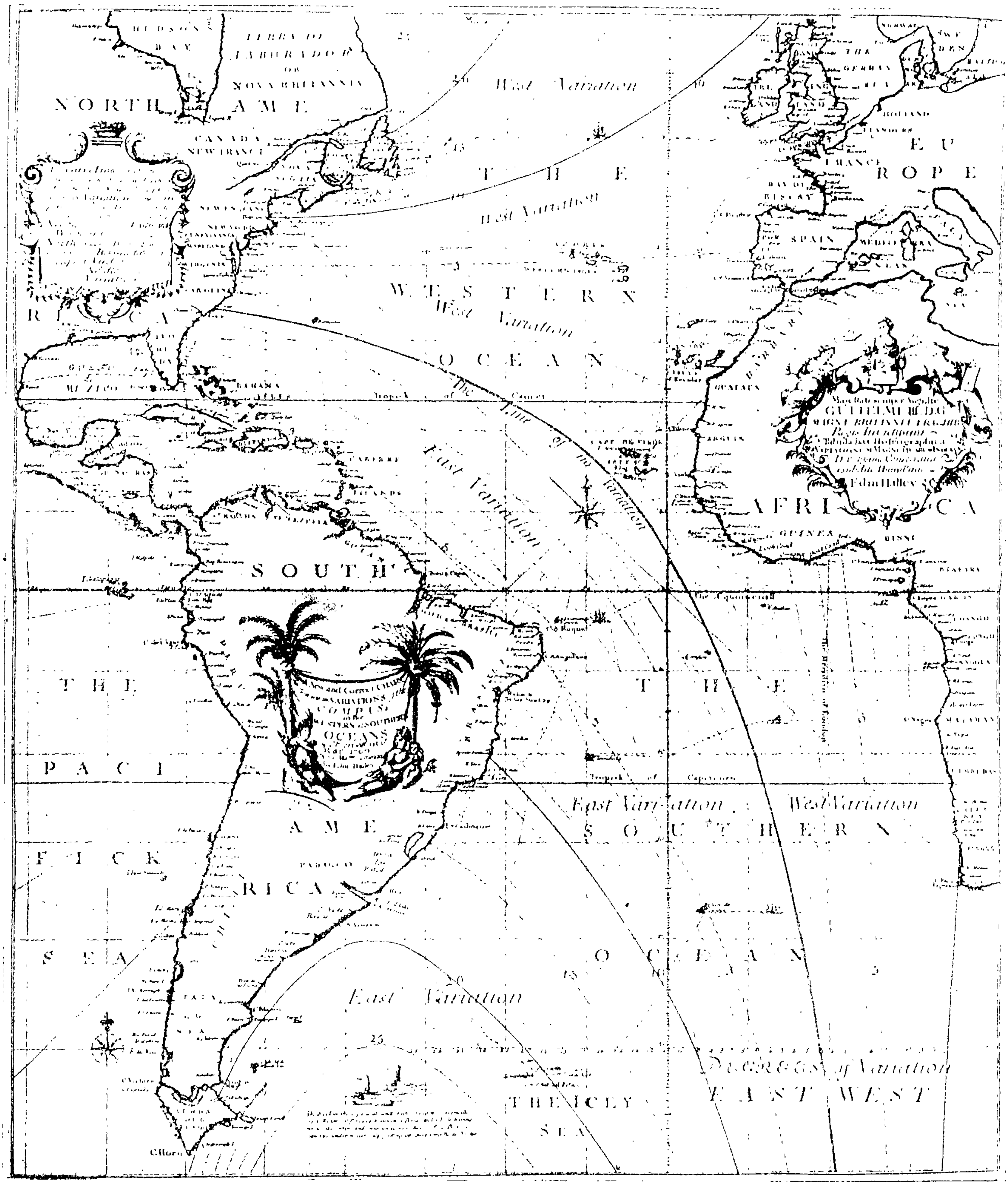



FIGURE 38.—Halley's "Atlantic chart," the oldest extant isogonic chart (1701).

(p. 52). His first paper on magnetism, published in 1832, was devoted to this subject, and a few months later, working with Weber at Göttingen, he developed a magnetometer with fiber suspension, for declination and absolute intensity observations. In the same year he established a magnetic observatory at Göttingen and later developed suitable instruments for measuring the variations of declination and horizontal intensity. It is interesting to compare Gauss' bifilar variometer, having a magnet more than 3 feet long that weighed 25 pounds, on a suspension 17 feet long, with a modern instrument having a magnet no longer than a carpet tack, suspended on a filament of quartz less than 6 inches long.

In 1838 Gauss published his famous paper "Allgemeine Theorie des Erdmagnetismus," in which he developed a potential formula in terms of spherical harmonics to represent the facts of the earth's magnetism as known at that time. This method has formed the basis for most of the mathematical discussions regarding the distribution of the system of forces required to produce the earth's magnetism (see p. 9 and ref. [7]).

This study of the earth's magnetism as a whole directed attention to the need for more accurate and more extended information regarding the distribution of the earth's magnetism over the surface. With the assistance of Humboldt, Gauss succeeded in arousing the interest of scientists in other countries and developed one of the earliest examples of international cooperation for the study of a world-embracing natural phenomenon. Magnetic surveys were undertaken and observers were sent to regions where magnetic observations had not previously been made. One of the best known outgrowths of the interest then aroused was the expedition of Ross to the vicinity of the magnetic south pole. Soon after 1840, magnetic observatories were established at widely separated points to secure simultaneous data regarding the variations of the earth's magnetism (see p. 40). Some of them were discontinued at the close of the limited period for which international cooperation had been arranged, but others continued in operation much longer, some (as the one at Toronto, Canada) even to the present day. It is of interest to note that, thanks to the zeal of Alexander Dallas Bache, later superintendent of the Coast Survey, a magnetic observatory was operated at Girard College, Philadelphia, from 1840 to 1845, and that variation observations were made in Washington from 1840 to 1842. One of the meteorological and magnetic observatories established by Russia was at Sitka, Alaska, and was in operation from 1842 to 1867. In spite of the inferior instruments then available, the operation of these observatories served to establish the principal features of the short-period variations of the earth's magnetism.

**Growth of magnetic surveys.**—From that time onward the importance of a knowledge of the earth's magnetism was recognized more and more, and one after another the several nations instituted magnetic surveys of their own possessions. Great Britain took the lead with a survey of the British Isles between 1836 and 1838. The work was later repeated and extended to India, Canada, Australia, New Zealand, Egypt, and South Africa. Nearly all European countries have now been surveyed magnetically in more or less detail, and the same is true of large regions in Asia and in the Western Hemisphere.

In the United States there were scattered observations by Long (1819), Nicollet (1832-36), Locke (1838-43), and Loomis (1838-41). The last named made the first general collection of results of magnetic observations in this country and prepared the first magnetic maps, covering the eastern part of the United States. Outstanding in this period was the magnetic survey of Pennsylvania and of part of adjacent States by Bache in 1840-43.

When the Coast Survey was reorganized in 1843, the making of magnetic observations was included in its regular functions; and from that time forward many magnetic observations were made, at first confined to the coasts (to supply the necessary compass data for its charts) but later extended to the interior States.

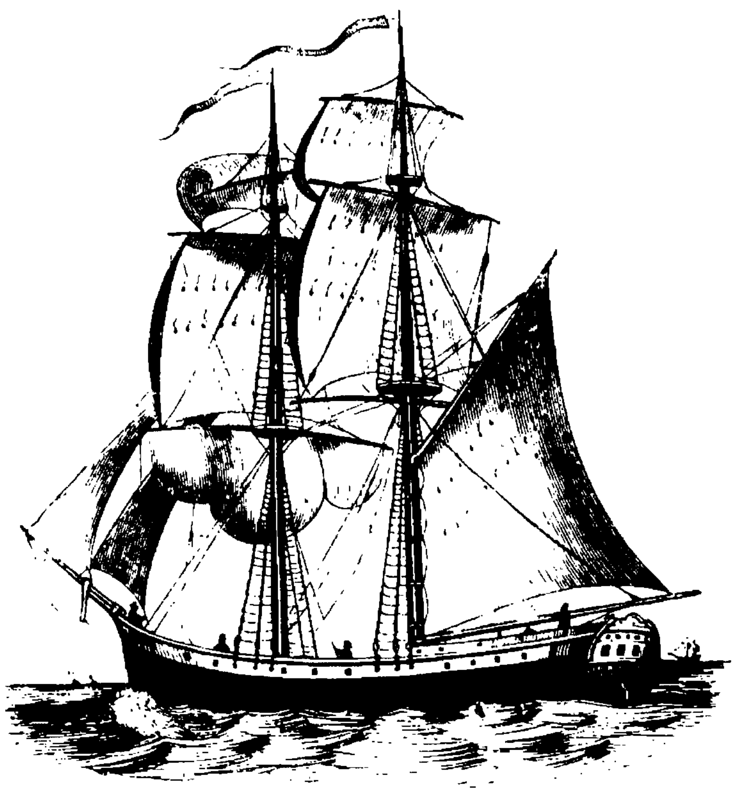
### Conclusion

Without endeavoring to relate the numerous and rapid advances in geomagnetism since the time of Gauss, it should be pointed out that they have been the fruit of a remarkable program of international cooperation that has suffered only brief interruptions, as by the present conflict. Especially to be noted are the two official bodies which have materially advanced the magnetic survey of the earth and the investigation of the many problems involved. One of these, the International Meteorological Organization, has been active in this field since its founding in 1872. This body, for example, sponsored both the First and Second Polar Year Commissions (p. 39), and has had a commission on terrestrial magnetism since 1896. The International Union of Geodesy and Geophysics, organized after World War I, had a Section (now called the Association) of Terrestrial Magnetism and Electricity. The two organizations have cooperated well.

Summarizing briefly the early history of terrestrial magnetism, we note that it had its beginnings in the ancient lore of the lodestone, for many centuries a curiosity or mystery with no practical application. Eventually we find the mariner provided with a crude floating compass, suitable only as an expedient of last resort when other methods of finding direction failed. It nevertheless served to demonstrate the incalculable value of the basic principle in the service of a growing sea trade, and soon gave place to improved forms, leading to the discovery in succession of magnetic declination, of inclination or dip, of secular change, of the daily variation, and of other short-time changes; and to the invention of isogonic charts. This account has been closed with the researches of Gauss and his contemporaries, which mark the culmination of all the older discoveries and the inception of the modern science of geomagnetism.

16 "Die Abweichung der Magnetnadel," in *Observations made at the Royal Magnetical and Meteorological Observatory at Batavia*, 21, supplement, 1899. Some of the charts of van Bemmelen, as well as those of Halley, are reproduced and discussed in S. Chapman's "Edmond Halley as physical geographer, and the story of his charts," *Roy. Astr. Soc., Occas. Notes*, No. 9, London, 1941.

17 "A relation of the voyage to Siam performed by six Jesuits sent by the French King to the Indies and China in the year 1685, with their astrological observations and their remarks of natural philosophy, geography, hydrography, and history." [By Father Gui Tachard] London 1688, pp. 231-2. (The usual account of these observations, as derived from Pieter van Musschenbroek's "Physicae Experimentales et Geometricae Dissertationes," 1729, p. 156, diverges in several particulars from the one by Tachard.) Tachard's results are noteworthy for the impetus they lent to further studies (see ref. [6] p. 407). They were scrutinized successively by Musschenbroek, by Emmanual Swedenborg, and by Anders Celsius, in their consideration of the evidence for transient fluctuations.



# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## NAVINFONET Menu Option 13

The following telephone and FAX numbers were obtained by accessing NAVINFONET Option 13:

DMAHTC NAVIGATION DIVISION
(Phone) 301-227-3371 (FAX) 301-227-4211
SAILING DIRECTIONS BRANCH
(Phone) 301-227-3183 (FAX) 301-227-4211
NOTICE TO MARINERS BRANCH
(Phone) 301-227-3146 (FAX) 301-227-4211
SUMMARY OF CORRECTIONS AND LIST OF LIGHTS BRANCH
(Phone) 301-227-1961 (FAX) 301-227-4211
ELECTRONIC NAVIGATION SYSTEMS AND BOWDITCH BRANCH
(Phone) 301-227-3173 (FAX) 301-227-4211
BROADCAST WATCHDESK
(Phone) 301-227-3147 (FAX) 301-227-3731
NAVINFONET HELP
(Phone) 301-227-3296 (FAX) 301-227-4211
DMA CUSTOMER ASSISTANCE TO ORDER DMA PRODUCTS
(Phone) 800-826-0342 (FAX) NONE
COAST GUARD LIGHT LIST
(Phone) 202-267-1550 (FAX) 202-267-4222

**Reporting of Dangers to Navigation**

Mariners will occasionally discover uncharted shoals, malfunctions of important navigational aids, or other dangerous situations which should be made known to other navigators. In addition to broadcasting a safety message address CQ (to all ships), those items which can be classified as urgent should be reported via radio to the closest responsible charting authority. DMAHTC additionally requests the reporting of such urgent navigational data directly to its Washington, D.C. office via any U.S. Government radio station. General criteria for important data is "that information, without which, a mariner might expose his vessel to unnecessary danger." Follow-up letter reports are encouraged to provide DMAHTC additional evaluation background. The initial report should be broadcast on 500 kHz prefixed by the safety signal, "three repetitions of the group TTT". It should be brief, but must contain:

What — description of danger
When — GMT and date
Where — Latitude and Longitude
(Reference chart in use)
Who — Reporting vessel and observer

Additional guidance in preparing a report of navigational information is contained in Pub. 606 (Guide to Marine Observing and Reporting) and Pub. 117 (Radio Navigational Aids).

Answer to DO YOU KNOW (P.1)

The invention of the isogram was disclosed for the first time in a Latin work published in 1641 by Athanasius Kircher, who credits it to the Jesuit mathematician Christopher Borrus. (See Origins of Geomagnetic Science in this issue.)

# BOOK REVIEW

*By Terry Spence*

***Small Craft Piloting and Coastal Navigation***
*By A. E. Saunders,* RTP Sales
1585 Bloor Street W., Unit 314,
Toronto, Ontario M6P IA6

In the previous reviews we crossed the ocean from Bermuda to the Azores, planned our voyage, met the legal needs upon entering port and reviewed the various formulae that are used in navigation. However, before we leave port and begin our transit of the open seas and upon landfall when we will switch from sailing charts to coastal and harbor charts we need to rely on piloting (also referred to as coastal piloting) to leave port safely and to arrive at our anchorage or dock without mishap. The book under review covers this important aspect of navigation.

Mr. Saunders is well qualified to present his subject. He spent 10 years as a coxswain on a rescue cutter. He has taught Seamanship, Advanced Piloting and Celestial Navigation, and is currently teaching the Canadian Yachting Association Celestial Navigation Course. (Taken from the resume in the book). Sprinkled throughout the book are truisms and Saunders' Laws of Navigation. As an example and perhaps my favorite (or should I spell it favourite) "A really good navigator can always prove that he was going to where he got to."

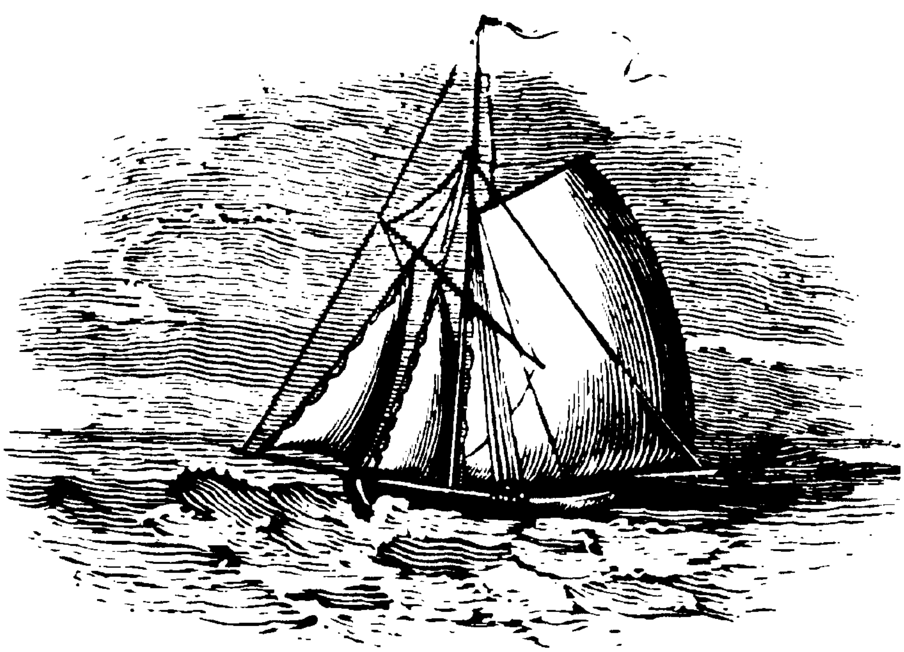
The book opens with a brief review of the basic Rules of the Road and the Buoyage Systems. There is also a chart (courtesy of the Canadian Coast Guard) of the Buoys and International Buoyage System. Very necessary to know this. There are two chapters devoted to the compass: one covering compass basics and the other delving into the mysteries of variation and deviation. There are numerous diagrams and chart illustrations to help understand the problems. The use of Charts, Plotting Tools and the ever needed Time, Speed and Distance calculations is easily understood.

We have now reached the heart of the piloting needs - the Plotting. We begin with elementary plotting followed by how to maintain a log and how to take and plot bearings and fixes. Again numerous drawings make understanding easy. We are next taught about circular LOPs and distance off methods. To emphasize what you have learned to this point in the book a Practice Cruise is provided. You can follow along with the illustrated charts provided in the text or you may actually plot the cruise on a chartlet provided. As there is a final cruise 5 to be taken later using the same chartlet you will have to erase the lines of this cruise.

Now we are ready to move to the advanced areas of piloting. Running Fixes are explained and shown as well as plotting a running fix with course changed included. Necessary Log entries are also provided to remind us how important it is to maintain a log. Leeway and drift, danger bearings, the effects of tides and currents all so necessary to the safe passage are covered in detail. There is a chapter devoted to the use of a sextant in piloting.

The fun part of the book is completing a Final Cruise encompassing all the principles that we have covered in the text. Again the chartlet mentioned above is used for the exercise.

Appendix A details compensating a compass and interestingly provides for the construction of a sun compass which he names Devi-Sun. This Appendix is naturally followed by instructions on preparing a deviation table. This is a neat book, spirally bound such that it lies flat when open to any page and very readable.



ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-EIGHT, SUMMER 1995

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Navigation Awards

The Navigation Foundation has presented awards for excellence in navigation to the following persons:

The Radm. Thomas D. Davies, U.S.N. Award for excellence in Navigation to Daniel C. Varisco, Gould Academy, Bethel, Maine and Jonathan Baron, Tabor Academy, Marion, Massachusetts.

The Dutton Award for excellence in Navigation to Midn. 3/C James J. Bae,USN, United States Naval Academy, Annapolis, Maryland.

### Digital Nautical Chart Available

In August 1994, the Nautical Charting Division (NCD) signed a public/private "partnership" called a Cooperative Research and Development (CRADA) to perform research and development (R&D) on electronic charts. CRADAs are used to promote technology transfer and the commercialization of federally developed technology. NOS' private-sector partner is BSB Electronic Charts, a joint venture of the Better Boating Association (BBA), Rockland, Massachusetts; J.W. Sewell Company, Old Town, Maine; and Blue Marble Geographics, Gardiner, Maine.

The R&D being performed is targeted on technology necessary to produce raster nautical charts. Raster nautical charts are electronic files that contain an exact image of the paper chart and which are usable on computers with electronic navigation software. The result will be a commercially available raster chart product from NOAA's private sector partner. NOAA will be providing the original, high resolution raster files and will stand behind their correctness. BSB Electronic Charts will receive these files, apply the results of the R&D, and will manufacture and distribute the resulting raster nautical charts. They will be available on floppy diskettes and on CD-ROMs. NOAA expects to have its entire 1000 chart suite available by the end of 1995.

The Navigation Foundation is currently negotiating to become an agent for Digital Nautical Charts. If successful, Digital Nautical Charts will be available through The Foundation with discounts to be determined after an agreement is reached with the producing company.

### Flat DMA Nautical Charts

Effective January 23, 1995, all DMA hydrographic charts will be produced, stocked, and issued in a *flat* configuration. This should resolve the approximately 2-year long controversy over whether DMA's public sale customers, who are serviced through NOS, will receive flat or folded hydrographic charts. DMA will *not* reprint to replace those hydrographic charts that were folded within the past 2 years. When the folded stock is depleted it will be replaced with flat stock.

### Circumnavigating

Navigation Foundation members Mike and Yvonne LeMay are departing Oregon in S.V. *Drifter* around the first of July. They will transit south along the coast of California into Mexico and on into the Caribbean. Give them a "hail" if you see them.

### New Edition of Bowditch

The new edition of Bowditch is a single volume printed on an enlarged page size and is listed at $22.00.

DO YOU KNOW...?

Who first introduced English speaking navigators to the sight reduction method of using the pole as the assumed position?

# READERS FORUM

*Edited by Ernest Brown*

Member Dr. G. G. Bennett of 27 Cabramatta Rd, Mosman, N.S.W. Australia wrote on April 30, 1995:

"Thank you for publishing the letter I sent on the 1st December 1994 with reference to "the two body fix" article. I am puzzled by the statement you made (page 3) that the disk I sent was not IBM or MacIntosh. The disk, as I said in my original letter of the 30th March 1994, was IBM compatible.

"I also read with interest the contribution of J. G. Hocking in the same issue regarding the formula for meridional parts. To answer the question concerning its origin may be difficult but it has been known for some considerable time. I have a standard text book on geodesy by G. Bomford published in 1952 by Oxford University Press which sets out both the concise formula and the series version. A more modern reference, which your readers may have better access to, is *Map Projections Theory and Application* by F. Pearson II published by CRC Press Inc., 1990, Boca Raton, Florida, ISBN 08493 6888. The above are but two of a long series of references.

"The reason for putting the meridional parts formula in the form of a series was common practice before the advent of computers. Those formulae that were not amenable to a logarithmic solution, i.e. not composed of products and/or divisions were expanded in a series, where possible. The simpler dominant first term could be calculated by logarithms and subsequent terms evaluated by tables or a slide rule.

"I trust that this may shed a little light on the subject" — *Yours sincerely, G. G. Bennett.*

In reply to Dr. Bennett, Executive Director Terry F. Carraway wrote on May 8, 1995:

"I apologize for the inaccuracy of the statement in Issue 45, Fall 1994, of The Navigator's Newsletter, concerning your computer disk. The misunderstanding was between the editor, Ernest Brown, and myself. I told Mr. Brown that I had tried several conversion programs to convert to one of my DOS word processing programs but was unable to convert. I also mentioned that I had sent the disk to our publisher, who uses a MacIntosh Desk Top Publisher. She was unable to convert to any of her programs. Neither she nor I have Corel Draw (?) so were unable to reproduce the drawings. The error occurred when I told Mr. Brown about our attempts to use DOS and MAC software. I did not elaborate on the methods which caused the confusion.

"I did not try to use DOS print to attempt to reproduce the article on my printer. I was in error in not attempting that route to print your article.

"I have sent your letter to the editor along with a copy of this note." — *Sincerely, Terry F. Carraway.*

Member Phillip H. Sherrod of 4410 Gerald Place, Nashville, TN 37205-3806, U.S.A., Internet: phil@sandh.com wrote on April 21, 1995:

"I want to thank you for the excellent job you do in producing *The Navigator's Newsletter*. It and *Ocean Navigator* magazine are my two favorite publications. There is an elegance to celestial navigation that is hard to explain to those who do not share the interest. I am an "arm chair" navigator who has never lifted a sextant on board a vessel, but I greatly enjoy studying the art and science of navigation.

"In Issue 45 I read a letter by Mr. George G. Bennett of Australia regarding an article by him titled "The 'Two Body Fix' Revisted" that was published in Issue 44. According to the editor's note, 'We will certainly provide readers with corrected copies of his manuscript in accordance with his wishes.'
I would appreciate receiving a corrected copy of his manuscript. If there is any charge for it just let me know and I will send you a check to cover the cost.

"Thank you again, and keep up the good work." — *Yours truly, Phillip H. Sherrod.*

Mr. Allan D. Pratt, Registrar of Dials, North American Sundial Society of 1936 E. Belmont Drive, Tempe, AZ 85284, wrote on May 6, 1995:

"Thank you very much for sending me a copy of the *Navigator's Newsletter* which contained my letter to your organization. I appreciated getting it, as did the other members of our board. Since it coincidentally contained a brief article about sundials, it was especially welcome.

"Please extend my thanks to the editor of the *Newsletter* as well. We have received at least half a dozen new members since the publication of that issue." — *Regards, Allan D. Pratt.*

Owner/Master of S.V. *Allidoro* Director Roger H. Jones wrote from 100 Isle of Venice, Ft. Lauderdale, Florida on May 9, 1995:

"*Allidoro* was in Beaufort, NC during the period December 8, 1994 - March 2, 1995. There were extensive repairs to be done as a result of losing the shaft and prop when the shaft coupling safety failed, and we took on a large quantity of water before I got the shaft gland plugged. However, we departed Beaufort on March 2nd and proceeded south down the ICW, stopping in Southport, NC, Charleston, SC, Beaufort, SC, Cumberland and Jeckyll Islands, GA, Savannah, GA, St. Augustine, Florida and many other lesser ports of call. We arrived in Ft. Lauderdale early in April, and then it was off to the Bahamas where the crew and I wound our way along the south shore of Grand Bahama Island, through the Berry chain, to Nassau, and then over to the northern Exuma Islands. A voltage regulator problem in the Exumas required a return to Nassau and then to Ft. Lauderdale, and I am now at the above address for the summer and fall.

"Son Steve is getting married in Naples, Florida on May 28, and after that I'll go to Connecticut during a good portion of June to check upon my mother's situation. Then in the fall, I'll cruise the Florida Keys, and maybe the West Coast of Florida, and will spend the winter in the Bahamas. Meanwhile the above address is a good one through September, and perhaps October. When you have a moment please let me hear from you.

"My original plan of going to the Mediterranean or to the South Pacific as a next stage is still in the works. However, I am sticking close to the East Coast until my mother's situation is clarified. She is getting on in years, with all the usual age-related problems, and I've committed myself to the only sensible course of action for the time being - that of remaining within reasonable hailing distance in U.S. waters.

"Old friends Ted and Arline Raab are here at the same dock in Ft. Lauderdale, and I also see Peter Mamunes from our Cornell Class and his wife Marty. I'm also meeting a lot of new friends and acquaintances - especially fellow members of the Seven Seas Cruising Association, which is headquartered here in Ft. Lauderdale.

"Sir Henry Pigott came aboard for a visit while we were in Lucaya, Grand Bahama. He is in the record book for a circumnavigation of the world in the smallest vessel, his 19 foot, 8 inch Junk-rigged sloop. He was about to start his seventh Atlantic crossing. He left Poole, England, in June of 1983 and returned to Poole in February of 1986. He's a legendary solo sailor and voyager, and we were glad to give him some charts and a large container of packages of freeze-dried soup. Bon voyage, Henry!

"My best wishes to you along with the hope that all is well." — *Warm regards, Roger.*

Member F. Sennett Duttenhofer of the Florida Station Membership Committee, The Cruising Club of America, wrote on May 16, 1995:

"I wish to enter a subscription for: Archibald Baldocchi, Apt. 900, Commodore East, 177 Ocean Drive, Key Biscayne, Florida 33149.

"Although Arch is not a mariner per se, he is, or was in his younger days, an aerial navigator for Pan American Airways when they were pioneering the Pacific routes during the second World War. Later he was an instructor for the company as well as designing and patenting a navigation watch with a bezel ring marked in circles of longitude - similar to the one developed by Lindbergh. He also developed a computer-like apparatus attached to the bubble quadrant to speed working up a three star fix. At a later date he owned and flew several P-51s and was qualified to fly a helicopter. He belongs to and regularly attends annual meetings of an aerial navigators association. I'm sure he will be interested in The Newsletter." — *Sincerely, F. Sennet Duttenhofer.*

Member Alan L. Olson of P.O. Box 383, Dollar Bay, MI 49922 wrote on February 22, 1995:

"First, I haven't received a renewal notice in recent memory and my membership card is looking rather tattered. Are you still there?
If so, please confirm my membership status.

"Secondly, I wish to solicit your assistance. I'm working on computer navigation problems and writing them myself in Basic. To complete the set I need math solutions to two final programs and I'm having great difficulty in finding written material about them. Can you help me with the following or guide me in the right direction?

"1. The three LOP six. The two LOP fix is quite common and easily programmed (Schufeldt, Harris, et al), but all texts and references I have checked neatly sidestep the three. By solution I mean entering the three intercepts and returning the altitude and longitude of the fix.

"2. Latitude by Polaris. I would like to procure the mathematical algorithms used to prepare the Polaris tables in the Nautical Almanac (AO,A1,A2). Or, better than that, is there a math model that may be used to determine latitude directly from GHA, Declination, and Azimuth of Polaris.

"I certainly hope you can help me with this - I've been working a long time on this project and would like to wrap it up." — *Thank you, CSM Alan L. Olson.*

*Editor's note: We have requested assistance from the Nautical Almanac Office, U.S. Naval Observatory, Washington, DC in this matter.*

Member George R. Leonnig, Owner/Master of S.V. *Moctobi*, of 8125 S.W. 54th, Portland, OR 97219 has made available to us, with rights reserved for publication elsewhere, the *"Log of Moctobi":*

"On the morning of October 4th (1994), we left with other boats for Morrow Bay about 100 miles south. The weather was beautiful leaving the harbor. There was a nice breeze blowing and we set the sails, looking forward to a good day of sailing. There was a big dark storm cloud hanging over Pebble Beach golf course. I felt that the sudden increase of wind and sea must be a local weather pattern, to end shortly. The seas continued to build and the wind was now 30 knots. This was a chance to see how *Moctobi* would handle pounding into heavy seas and wind. The starboard deck was awash and spray was flying as *Moctobi* pounded to windward. *Moctobi* took it like 'no big deal', although our course was not even close to where we wanted to go, south.

"The fun and excitement disappeared after three hours when the winds hit 40 knots. The thought of beating ourselves up for 24 hours in these conditions made the next decision an easy one. I turned *Moctobi* around and we headed back to Monterey to wait for better weather.

We covered the distance in 20 minutes that had taken us 1 hour to gain. Surfing down the waves and back around Point Pinos. Along with us came six other boats also giving up the southerly trek for the day. We slid back into the dock we had left and watched as the weather continued to deteriorate.

"In the morning we turned the radio on to listen to the latest weather forecast. This was when we heard of the earthquake in Japan and that a tsunami warning was in effect for the entire west coast of the U.S. The harbormaster told one cruiser that once the entire boat basin was dried by a tsunami. This was the same tsunami that wiped out Crescent City, California. I remembered seeing on the wall of the harbormaster's office in Crescent City the painted line of how far up the sea had risen during the tidal wave.

"I poured myself a cup of coffee and got my oceanography book out to take a crash course on tsunami. The estimated time the wave would reach us was 4:20 in the afternoon. The only safe place to be in
tsunami is at sea, where the wave is only a couple of feet in height. We only needed to be in about 60 feet of water and all would be fine according to the book. The cruisers began to compare knowledge and agreed that if the tsunami was imminent then we also would head to sea about 3:30 and ride it out. Reports started coming over the weather radio of the tsunami hitting Pacific islands such as Midway, Wake, Hawaii and the heights were in inches not feet. But tsunamis are unpredictable, so it was still possible that the "big wave" could still hit the coast. At 3:15 the tsunami watch was called off by the Coast Guard. At 4:30 the weather really turned nasty. Rain, lightning, thunder, hail, and high winds hit. Had we gone to sea for the tsunami the weather would have been worse than the wave. It stormed all night.

"The tsunami did hit Monterey. One of the more scientific cruisers measured the water level on a dock piling at 4:20. Within several minutes the level dropped by 8 inches. Several minutes later it rose by 5 inches. So among all our other experiences and adventures we had now SURVIVED a tsunami.

"On October 6th we headed south in much improved conditions. Having lost several days in our trek south we decided to bypass Morrow Bay and head to San Luis Obispo before taking on the Point Conception. We arrived in San Luis Obispo at dawn after more than 6 hours of escort by dolphins. We had never seen dolphins at night before. This was quite an experience. They came along side the boat with their wake shining of phosphorescence. They looked like runaway torpedoes coming at the boat. It was an incredible show to watch.

"In San Luis we picked up a mooring buoy in a much welcomed flat, calm harbor. We slept until late afternoon and then prepared for a sunset departure to Point Conception. Another boat wished to buddy boat with us around the last cape. At 1:00 a.m. the light at Point Conception came into view. The sea and wind conditions were calm. It looked to be an easy passage around the point and finally be in southern California. As *Moctobi* approached Conception the wind began to blow from the shore. It was like someone had thrown on the wind switch. The wind speed went from 0 to 20 knots in a blink of an eye. I checked in on the radio with our buddy boat a mile away on my beam. He was peeling his coat, sweater, and tee-shirt off it got so hot. I was freezing and ready to put foul weather gear on to stay warm. By the time I went back up to the cockpit, maybe 3 minutes, the heat hit and I was pulling clothes off. This effect of hot and cold air is what causes the terrible conditions of wind and seas that Point Conception is noted for. Turning into Santa Barbara channel the wind died again and the channel was calm. Six hours later we eased into Santa Barbara.

"*Moctobi* harbor-hopped from Santa Barbara to San Diego arriving October 25th 7½ weeks and 1,173 miles from Portland. We spent a month in San Diego. During this time we did maintenance and repairs to the boat, reprovisioned, and made preparations to enter Mexico and spend 16 months outside the United States enroute to Florida via the Panama Canal. We added 2 pieces of equipment to the boat. The first being roller furling for the head sail and the other an autopilot. We found both to be essential for shorthanded sailing.

"November 23rd we said our good-byes to friends. As the sun set we headed to sea bound for Ensenada 60 miles south. This would be our port of entry into Mexico. We arrived at dawn and celebrated Thanksgiving with a small turkey and all the trimmings that evening. At Ensenada we were introduced to pangas. Pangas are the type of boat the Mexican fishermen use. These are open boats looking like a cross between an oversized rowboat and driftboat. Very seaworthy and powered by outboard engines. You find the fishermen miles offshore in pangas. They navigate with local knowledge alone. Pangas are a constant concern at night, as they have no running lights and make poor radar targets.

"*Moctobi* left Ensenada November 28th. The stay again longer than planned, weather being the delay. Charts for Mexican waters are not necessarily accurate. Many charts are no longer printed. We found waves breaking on rocks two miles offshore 10 miles south of Ensenada, that do not appear on the chart. That put the 'fear of God' in all our navigation. Always being alert and giving a wide berth to any suspicious looking coastline.

"We sailed to San Quintin anchoring *Moctobi* behind a large rock right off the beach. A lot of the anchorages are like this. Right on the ocean behind some little outcropping of rock. In Mexico this is what is called a 'safe' anchorage. Most anchorages along the coast are open to the south. We stayed at San Quintin overnight for some rest. In the morning we set sail for Cedros Island 150 miles away. During the night we broke a shackle on the mainsheet. This required a repair in darkness and rough sea conditions.

"By daybreak Cedros Island came into view. Cedros is the word for cedar in Spanish. At one time this island was covered with cedar forests. Today, other than a few scrub trees at the very top, the island is bare. The Mexicans have stripped it of the rare resource in this barren land.

"The entire coastline of Baja is fascinating. It is desolate yet beautiful. The terrain changes continuously. There are areas where high rugged mountains drop to the ocean's edge. The next area may be deep canyons leading from inland, while a little further along there might be long flat sandy beaches with dunes as far as the eye can see. The colors and rock formations must hold an amazing geological story.

"*Moctobi* anchored in 50 feet of water in a small indent named Bahia del Sur on the southwest corner of Cedros Island. We had a dinner of Mexican Bonita which I had caught earlier in the day. Our next stop was Turtle Bay. It is one of only three places on the entire Baja coast where you can get fuel and water. It is about 1/3rd of the way down the coastline and almost every boat passes through the little village located on a large enclosed bay. We arrived just before dark after a wonderful day at sea. Joining 20 other boats resting at anchor just off the village.

"The village has a rickety old pier used by a fish processing plant and as a fuel dock for large tuna boats. Cruising boats tie their dinghies to a single ladder and climb up 20 feet to the top of the pier. The village's boys, 8 to 10 years old, help you tie up, hoist your jerry cans for water and fuel to the top of the pier and watch your dinghy for candy.

"The sight is bizarre with these boys jockeying for position, hanging onto the ladder with one hand and tying knots with the other. Below 20 dinghies, and a couple of pangas for good measure, bob tethered in a ball of mooring lines resembling spaghetti. The real fun begins when you try to load 60-lb. jerry cans into the right dinghy. How anything ever ends up with the right dinghy is a miracle.

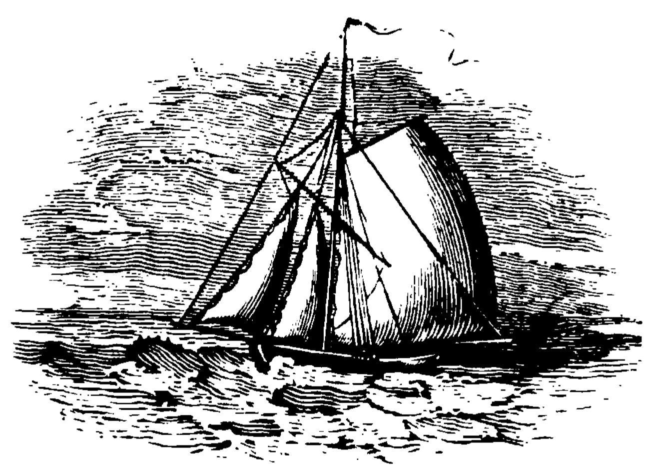
"And while all this is going on, a vintage John Deere tractor rolls down the pier, pulling trailers stacked with steel pallet boxes full of tuna to the processing plant. Just about then a wheel from a trailer rolls off the pier and several pallet boxes go crashing into the water. All the Mexicans laugh, cheer, and clap. What fun and chaos. Welcome to rural Mexico!
We loved it.

"We went into the village in quest of ice, because *Moctobi* does not have refrigeration. The village looks like something out of a spaghetti western. Dirt streets, little shacks, and mangy dogs. The horses had been replaced by 4-wheel drive trucks. We found a little store to buy fresh vegetables and beer. Ice we bought from an elderly woman who made it in her house using mixing bowls and storing the ice in a big chest freezer. I always wondered where all those old chest freezers went. Here they are, along with the Maytag wringer washer machines.

"Departing Turtle Bay on the morning of December 4th we listened as usual to the weather report on the Ham net and with the forecast favorable we headed to Bahia Santa Maria further down the coast. As darkness fell, the wind began to blow to 25 knots and a few light rain showers fell. *Moctobi* flew south at 7½ knots. As my watch ended, the winds had died to a comfortable 10 knots but the rain continued. An hour later the winds had rebuilt to 30 knots. We reduced sail and continued on.

"A half hour later the autopilot sounded an alarm. The seas had gotten too wild for it to steer. So we hand steered *Moctobi*. Both of us were getting a little concerned about the weather about this time. The seas were getting bigger, rougher and more confused. The wind was now gusting to 40 knots and the rain was pelting. I decided to look for a place we might be able to slip *Moctobi* into and anchor. But there was no place. I decided to head in close to shore in hopes of getting some relief from the seas, as the winds were blowing offshore. By daybreak we were within 2 miles of the beach and the seas were no better. Concerned about getting too close, since the coastline is poorly charted, we turned back out to sea.

"We stood 1-hour watches now, as after an hour steering you are exhausted. Ginny went down to rest once, peeled a banana to eat, but fell asleep holding the banana in her hand, for an entire hour. We were soaked to the bone from the rain and the waves which crashed across *Moctobi*. The winds were topping out at 50 knots and the seas, although only 10 to 12 feet, were so confused the ride was like being on a bucking bronco. These conditions continued for 16 hours, before the wind and rain began to let up. We arrived at Bahia Santa Maria late in the afternoon of December 6th".



# NAVIGATION FEATURE

## H.O. 214

*By Ernest Brown*

H.O. Pub. No. 214, *Tables of Computed Altitude and Azimuth,* was a major step in providing adequate and accurate solutions of the navigational triangle in such form that by inspection the navigator could also readily note quantitative changes in the navigational triangle with varying arguments of latitude, declination, and hour angle (meridian angle). The simplicity of the Marcq St. Hilaire, or altitude intercept, method of basic sight reduction was further extended to its solution. Prior to introduction of H.O. 214, the navigator was prone to lose sight of the basic simplicity of the altitude intercept method while handling logarithms or such while tediously reducing his sights to a fix position. This is not to say that tables similar in form and use to H.O. 214 did not exist aforehand. But tables such as Davis' *Alt-Azimuth Tables* of 1921 vintage were limited in scope as pertains to latitude and declination entries. The tables of Percy L. H. Davis, F.R.A.S., were quite similar to H.O. 214 in format, although the hour angle was presented in apparent time units as is the case with the Red Azimuth Tables. The main feature of H.O. 214 was the scope of coverage of latitude, declination, and hour angles.

"H.O. 214 did not just provide comprehensive solutions for the altitude intercept method. The tables provided the means for quite rapid sight reduction with reduced chances for mistakes. A multiplication table was provided to facilitate linear interpolation for declination difference in the most common application. These tables served for air navigation purposes until the introduction of H.O. 218, especially designed for the needs of air navigation and subsequently superseded by H.O. 249.

"An interesting historical aspect of H.O. 214 is that during the severe economic depression of the thirties and extending into the early forties, the computation of the tables was a W.P.A. (Works Progress Administration - later Works Projects Administration) project after some initial work at the U.S. Navy Hydrographic Office. Mathematicians and other white collar workers were assembled in Philadelphia to solve over a million spherical triangles. (The latitude band 0° to 59° required approximately 6,500,000 computations, including check computations. The altitudes were computed using seven place logarithm tables while the azimuth angles were computed using five place tables and an azimuth formula independent of altitude.)

"By 1941 all computations had been completed. As the computations were completed, the tables were issued in volumes covering a latitude belt of 10 degrees. But the latitude belt 80° to 89°, Volume IX, was not published until 1946 because of the cost and the very limited demand for navigational tables in the immediate vicinity of the pole until that time. In 1942 a Spanish language supplement was published by the Hydrographic Office for use with the tables.

"Over the years computational and typographical errors remaining in H.O. 214 were corrected. For a quarter of a century these tables provided for the navigator and other users solutions for altitude and azimuth angles, but limited to those solutions where the calculated altitude is above about 5 degrees. For each latitude and declination entering argument, the meridian angle entering argument is cut off at that point where the altitude will be below about 5 degrees. For each degree of latitude, the declination entering arguments were limited to 96 selected same name and contrary name declinations. The declinations were selected in integral and half degrees in such a way that the entering argument declination will always be within 30 minutes of the declination of every star generally used in navigation. This includes all the 57 navigational stars. An examination of The Nautical Almanac will reveal that of the 173 stars for which declination and sidereal hour angle are presented in that almanac, only 8 of these stars are not suitable for use with H.O. 214. And one of these stars is Polaris which can be most easily reduced by other simple means.

"Since the declination intervals in H.O. 214 are for intervals of every 30 minutes up to 20°, H.O. 214 provided a more accurate azimuth table than H.O. Pub. No. 260, *Azimuths of the Sun* (Red Azimuth Tables). While the tabulated aziumuths (azimuth angles) in H.O. 260 are in minutes of arc as opposed to tenths of degrees of arc as in H.O. 214, where interpolation is required (the usual case or almost always) the shorter declination intervals for a given latitude in H.O. 214 provide greater accuracy because linear interpolation used is only approximate for both cases.

"Recognition of H.O. 214 in the maritime world was exemplified by the British Admiralty's Hydrographic Department publishing the tables as H.D. 486, identical to H.O. 214 except for latitude coverage in the various volumes and explanatory material according to their needs. Also the Italian and Spanish Hydrographic Institutes reproduced the tables in their respective languages and in latitude belts of 15 degrees as in the British version. Other nations published explanatory supplements for use with the English language versions.

"The H.O. 214 tables had reasonably wide application beyond the maritime sphere, in the solution of spherical trigonometry problems and determination of great circles and distances. Hydrographic surveyors used the tables for rough astronomical work, including those surveyors who "navigated" the arctic ice stations. The designed cut-off at altitudes of about 5° above the horizon because of severe refraction problems at low altitudes in marine application has somewhat restricted the general use of the tables for purposes other than that for which the tables were designed.

"The computation of H.O. 214 was a formidable task of slow, tedious calculations performed by men with formulas of spherical trigonometry and logarithm tables. Today with high speed electronic computers, the job could be done in a very few hours.

First Edition Dates of H.O.214:

| | | |
|---|---|---|
| Volume I | 0° to 9° | 1939 |
| Volume II | 10° to 19° | 1939 |
| Volume III | 20° to 29° | 1939 |
| Volume IV | 30° to 39° | 1936 |
| Volume IV | 30° to 39° | 1937 |
| (Altitude correction for DR Latitude) | | |
| Volume V | 40° to 49° | 1940 |
| Volume VI | 50° to 59° | 1940 |
| Volume VII | 60° to 69° | 1940 |
| Volume VIII | 70° to 79° | 1941 |
| Volume XI | 80° to 89° | 1946 |

*Editor's note — Mr. John H. Blythe, a former Director of the Navigational Science Division component of the U.S. Navy Hydrographic Office and U.S. Naval Oceanographic Office, in speaking of the H.O. 214 project, in which he participated, pointed out that they did not use the then available mechanical calculators because of the "make work" requirement of the project.*

*Address all correspondence to:*
The Navigation Foundation
P.O. Box 1126 • Rockville, MD 20850
Telephone 301-622-6448

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By William O. Land*

The conclusion of this article will appear in Issue fifty, Winter 1995-96.

# NAVIGATION NOTES

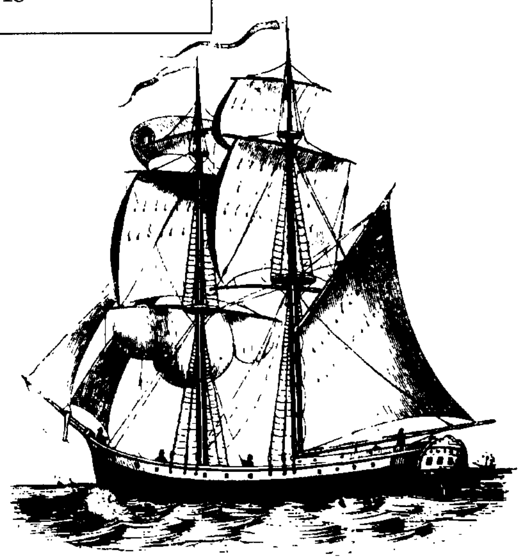
## A Navigation Problem: Three-Star Fix by H.O. 229

*By William O. Land*

We have received a commission to deliver a 74' Ring Anderson Schooner from Melbourne to Tahiti. A few days out we estimate our evening D.R. to be 35°12.0'S, 165°43.0'W. The local date is 7 January 1995. The Eye Height is 11', the Chronometer Error is 16 seconds fast, and the I.C. is 0.0. Do a Sight Reduction and make a plot using these three stars, all times L.Z.T.

Sirius, Hs 36°35.5' @ 19h 51 m 10 s.
Achernar, Hs 63°44.2' @ 19h 55m 30s.
Alpheratz, Hs 13°29.1' @ 19h 59m 01s.
What is our position?

Answer: 35°07.0'S, 165°36.0'W.



## Answer to Last Issue's Problem:

Answer: 35°07.0'S, 165°36.0'W.

GREAT CIRCLE VERTEX USING Pub. 211 (THE AGETON METHOD)
Pub. 211 Tables: Bowditch Volume II, Table 35. Pages 334 to 369.
Explanation: Bowditch Volume II, Article 718, Pages 515 to 518.
Article 1018, Pages 613 to 618.
Dutton: Article 3013, Pages 428, 429.

CALCULATION of Vertex Latitude (Lv) and Longitude (Lov) of a Great Circle Route.

Start — Destination

From: ATLANTIC CITY, N.J. To: GIBRALTER
Starting Latitude ($L_1$) 39°21.9'N — Destination Lat. ($L_2$) 36°06.0'N
Starting Longitude ($Lo_1$) 74°24.6'W — Destination Long. ($Lo_2$) 5°21.0'W
Course (C) N70°10.0'E

| | | (1) | | (2) | (3) |
|---|---|---|---|---|---|
| | | | | + | - |
| 1 | $L_1$ | Starting Latitude | 39°21.9' | B 11175 | |
| 2 | C | Course | N70°10.0'E | A 2656 | B 46943 |
| 3 | Lv | Vertex Latitude | 43°20.0'N | B 13831 | A 16345 |
| 4 | tv | | -29°37.5' | | A 30598 |
| 5 | $Lo_1$ | Starting Longitude | 74°24.6'W | | |
| 6 | Lov | Vertex Longitude | 44°47.1'W | | |

Start — Destination

DISTANCE TO VERTEX
From: ATLANTIC CITY NJ To: VERTEX
Starting Latitude ($L_1$) 39°21.9'N — ~~Destintion~~ Latitude ($L_2$) 43°20.7'N
Starting Longitude ($Lo_1$) 74°24.6'W — ~~Destination~~ Longitude ($Lo_2$) 44°47.1'W

| | | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| 1 | $Lo_1$ | 74°24.6' E (W) | | | | |
| 2 | $Lo_2$ | 44°47.1' E (W) | (+) | (-) | (+) | (-) |
| 3 | t | 29°37.5' (E) W | A 30599 | | | |
| 4 | $L_2$ | 43°20.7' (N) S | B+ 13832 | A 16343 | | |
| 5 | | | A 44431 | B- 3005 | B 3005 | A |
| 6 | K | 47°21.3' (N) S | ← | A 13338 | | |
| 7 | $L_1$ | 39°21.9' (N) S | | | | |
| 8 | K~$L_1$ | 7°59.4' | → | → | B+ 423 | |
| 9 | D° | 22°28.0 | ← | ← | B 3428 | A- |
| 10 | D°x60= | 1320.0 N.M. | | | N (C) E<br>S ° . ' W | A |
| 11 | M' = + | 28.[illegible] N.M. | | | (Cn)<br>° . ' | |
| 12 | Total Dist. = | 1348.[illegible] N.M. | | | | |

# HISTORY OF NAVIGATION

## Navigation as it Pertains to Shore Bombardment During Naval Amphibious Operations

*By John M. Luykx*

The recent celebration of the 50th Anniversary of the D-Day landings in Normandy brings to mind the part played by allied naval vessels in conducting the bombardment of the Normandy coastal and inland areas prior to and during the actual landing of troops on 6 June 1944 and which continued on for a period of almost three more weeks.

Accurate gunnery in shore bombardment operations depends upon accurate navigation. Quite often targets assigned to firing ships are not visible to them because of target location, weather and intervening topography. Under these circumstances, targets are assigned to fire support ships as coordinates on a map or chart. The range and true bearing to the target from the firing ship can only then be determined when the ship's position on the chart is known. The more accurately the ship's position is determined, the more accurate will be the initial and succeeding gun salvos.

When a fire support ship is assigned a target by map or chart coordinate (i.e., a target which cannot be observed directly from a ship) during the shore bombardment phase of an amphibious landing, the ship's navigator, using standard chart plotting equipment, determines the range and true bearing to the target directly from the ship's position as fixed or plotted on the bombardment map or chart. The navigation plot is maintained on the bridge of the ship. The ship's navigation position is fixed either by multiple simultaneous visual gyro bearings to prominent points ashore or by sextant angles observed between known objects ashore and plotted on the map or chart by a station pointer or three arm protractor. Based on the ship's course and speed (usually about five (5) knots when in a fire support area), the navigator predicts the ship's future position along the projected track at regular intervals; for example, every sixty (60) seconds. A preliminary Dead Reckoning (DR) Track is then run up for five (5) minutes at 1 minute intervals and plotted on the chart. For each DR Position of the ship thus obtained, the range and true bearing to the target is determined. As the vessel passes through each successive DR position, the navigator transmits, via the ship's internal communication system, the value of target range and true bearing, at that instant, to the Gun Firing Control Plotting room for insertion into the tracking section of the Gun Fire Control computer. Combined with inputs of ship's course and speed from the ship's gyro and ship's log respectively and from values of target range and true bearing, the computer generates a continuous solution of present target range and true bearing. A check of the accuracy of computer generated values is made every minute in the plotting room by comparing the computer solution of present range and true bearing to the target with the navigator's determination from the ship's actual or DR position plotted on the map or chart on the bridge. The computer solution for range and bearing will normally match or coincide with the navigation solution after one or two comparison checks of this type and when minor adjustments to the computed values, if required, are made.

If the navigator discovers during plotting that the ship is being "set" due to wind and current which is normal when steaming at slow speeds, the drift is computed and plotting room personnel notified. The ship's set and drift is then inserted in the computer, as target course and speed with the course inserted as the reverse of the set. When a correct and accurate tracking solution is achieved, the computer is ready to solve the ballistic problem which is to position the guns in train and elevation to hit the target.

The tracking section of the computer also determines the values of range rate (rate of change of range) and true bearing rate (rate of change of true bearing). These are multiplied by the time of flight from the ballistic section to determine the change of range and change of true bearing to the target during the predicted period of time the projectile is in the air on its way to the target. The present range and true bearing to the target as maintained by the computer combined with the computed values of change of range and change of true bearing result in the values of *predicted range* and *predicted true bearing* to the target. It is these continuously computed values (predicted range and predicted true bearing to the target) which form the reference for the application of ballistic inputs and corrections which continuously aim the guns, i.e., train and elevate the guns so that the projectiles fired from the guns will hit the target.

When a fire support mission is assigned to a ship, the navigator of that ship and the Gun Fire Control computer operators must work very closely to insure that the Gun Fire Control computer correctly and continuously "keeps" the range and true bearing to the target during the entire fire support mission.

During World War II, gun fire control computers used with the main battery of a battleship or cruiser were known as Range Keepers. Associated with the range keeper was a (gyro stabilized) stable vertical element which indicated the true vertical and thus, also, the true horizontal. When the ship rolled, pitched and yawed due to the motion of the sea, train and elevation signals from the computer to the guns were continually "stabilized" by signals from the stable vertical so that the guns were kept pointing to the target no matter how the ship moved "in" and "across" the line of fire.

The type of naval gunfire described briefly above is known as "indirect" fire. The target is not visible to the ship, and, therefore, an observer aboard the ship cannot correct for errors in the fall of shot. Observation of the fall of shot in indirect fire, however, is assigned to a fire control party away from the ship in radio communication with the ship. The fire control party is either airborne or located at a point on shore where the target is visible to the observer or spotter.

In order to insure the accuracy of the navigation plot on the bridge of a fire support ship, the ship's gyros are regularly checked for gyro error. Bearings taken to objects ashore are observed to the nearest tenth of a degree and corrected for gyro error. In addition, bearing and azimuth circles as well as telescopic alidades used with gyro repeaters on the bridge to take bearings are each checked for error in the alignment of their optical elements. Where error exists, the observed bearing is further corrected for instrument error. It is not surprising to see notes or labels attached to each such instrument to indicate its error in tenths of degrees. Observed bearings, then, are often corrected twice before plotting on the chart to determine a fix; first, for gyro error and second for instrument error.

Extremely accurate positions can also be obtained by taking two simultaneous sextant angles between three (3) objects ashore. The two angles are "set" on to a station pointer (three arm protractor) and the fix then plotted on a chart. This procedure is commonly used in hydrographic surveying and is the most accurate method of optical/visual position determination available.

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## Discontinuance of Coast Guard High Frequency Morse Radiotelegraphy Services

More effective means of communication are now in use, and vessels in maritime areas over which the United States exercises responsibility for search and rescue no longer rely on high frequency Morse (HFCW) radiotelegraphy as a primary means of communication.

The Global Maritime Distress and Safety System (GMDSS) amendments to the Safety of Life at sea (SOLAS) Convention were adopted in 1988 and initial provisions entered into force in February, 1992. GMDSS methods provide the mariner with improved means for initiating or relaying distress alerts, and receiving safety information pertinent to its area of operation.

Effective 1 April 1995, the Coast Guard will cease all high frequency Morse (HFCW) radiotelegraphy services currently operated from Coast Guard Communication Stations Kodiak, Honolulu and Guam and Communication Area Master Stations San Francisco and Portsmouth.

The U.S. Coast Guard will continue to provide HF SITOR service from Communication Stations Kodiak (NOJ), Honolulu (NMO) and Guam (NRV) and Communications Area Master Stations San Francisco (NMC) and Portsmouth (NMN).

More information concerning Coast Guard distress and safety radio circuits can be obtained from the Coast Guard Navigation Information Service computer bulletin board,, accessible by modem at (703)313-5910, or by Internet from Telnet fedworld.gov'. (FED REG 1/27/95)

## New 24 Hour Toll-Free Telephone Number For Defense Mapping Agency Nautical Products And Services Information

New telephone access to DMA is now available. This number is for customers with questions regarding quality and utility of DMA nautical products and services: 1-800-DMA-NAVY or 1-800-362-6289

U.S. Government users with questions and comments regarding requisition, distribution and availability of DMA nautical products should continue to be referred to DMA's Customer Assistance Branch at:
1-800-826-0342.

Civil users desiring information regarding requisition and availability of public sale DMA products should continue to use National Oceanic and Atmospheric Administration/National Ocean Service (NOAA/NOS) Sales Agents, or call the NOAA Distribution Branch at: 301-436-6990.

The 1-800-DMA-NAVY line is staffed 24 hours a day. If questions cannot be answered over the phone, your concern will be forwarded to the appropriate DMA employee for quick resolution.

(NM 21/95)

## Unannounced Hydrographic Products

New editions and new DMA products are not to be used until their availability is announced in the Notice to Mariners. Consult DMA catalog of maps, charts and related products Part 2, Volume I Hydrographic products and the Notice to Mariners Section II catalog corrections.

All products should be promptly annotated with the Notice to Mariner's number that authorized their use. This will ensure that only valid products are used.

## BOOK REVIEW

*By Terry Spence*

**The Star Finder Book**
*By David Burch,* Paradise Cay Publications
P.O. Box 1351 Middletown, CA 95461 (1984) $12.95
Telephone Order: 1-800-736-4509

This little book, as stated on the cover: "A complete guide to the many uses of the 2102-D Star Finder", certainly provides complete assistance in the use of the Star Finder.

Have you ever gone into your back yard at night, spotted a star and wondered "what star is that?"
Well, now with this book and the Star Finder you can get your answer. There is one other item that will help you in this quest, namely a small compass to assist you in determining the bearing of the star (I have a compass that is used when hiking through the woods - orient the compass and read the compass bearing of the star).

Following a brief introduction there is a description of the 2102-D Star Finder followed by a chapter covering general information, i.e. time and time keeping in navigation, which all leads us to the real heart of the book, namely identifying stars after the sight and predicting altitudes and azimuths of stars for a fix.

Application I provides four examples of unknown star identification. In Star 2 of the examples there is a variation given that makes identification of this second star much quicker (building on the first set of steps). The first two stars were among the 57 navigational stars but the third star is not. However, the author shows us how to solve this problem. As we know, any identified star can be used for navigating purposes. The fourth star is a planet and the solution is provided.

Application 2 illustrates the prediction of heights and bearings for a star fix. There is an interesting comparison on the accuracy of the predictions of three methods of precomputing the Stars and a table showing a worst case scenario with the Star Finder being the most incorrect due to latitude differences. Combinations of planets and stars for sights are explained and a diagram showing how to achieve a suitable "spread" for a good fix. Sun-Moon and Sun-Venus sights are also covered.

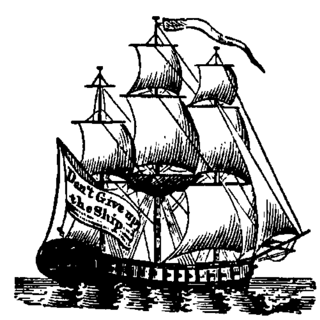
A thoroughly useful little manual to have around.

**Practical Celestial Navigation**
*By Susan P. Howell*
Published by Mystic Seaport Museum Stores, Inc.
Mystic, CT 06355
(to be used with H.O. 229)

If you are planning to or considering attending a formal navigation class, many times one of the qualifications required is the ability to reduce a sight without a form. When I first started studying Celestial Navigation I used the forms by Davis and those in Duttons. I learned them but, with apologies to both, I had a dickens of a time with them and they certainly did not help me to really understand the principles of sight reduction or to produce a sight without them. The sequence of teaching in this book and the culmination of the final sight form allowed me to be able to reduce sights without a form. There are some excellent exercises provided in the manual and were very helpful to me. Towards the end of the book a chapter is devoted to sight reduction by H.O. 211.

This is followed by a chapter on Mercator Sailing which provides an additional formula for the solution of this sailing as well as the standard formulae generally in use. The chapter on Great Circle Sailing gives us an interesting set of formulae for arriving at a solution using predetermined longitude, and completing the exercise with Mercator solutions.

After presentation of calculator sight reduction methods, two other uses of the calculator are provided. By use of one set of formula, two points of longitude can be derived which lie on a Line of Position, and by joining these two points a LOP is obtained. Two of these LOPS, if properly determined, can provide a fix - an example is given. I found this a very useful set of instructions but would add one additional item, namely a compass bearing of the celestial object, thus facilitating the determination of the required latitude used in the formula. The second formula yields latitude and longitude directly from two simultaneous sights. I found this difficult and I am not sure it is too practical. All necessary tables are provided, as well as the answers to problems given at the end of chapters. If you are new to celestial navigation or having trouble completing a sight, this book will certainly assist you.



ANSWER TO DO YOU KNOW...?
(P.1) The sight reduction method of using the pole as the assumed position was first brought to the attention of English speaking navigators by Professor Emeritus Harry Fielding Reid of Johns Hopkins University in 1910.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FORTY-NINE, FALL 1995

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Charts

Canada and the United States have been engaged in a cooperative nautical charting program of boundary waters for the past 20 years. During this time, chart standards, chart coverage and chart databases have been brought into agreement for many common areas. In order to continue to provide the highest level of safety of navigation, yet respond to the realities of diminishing resources and reduced funding levels, the Canadian Hydrographic Service (CHS) and the United States National Ocean Service (NOS) are taking the next logical step: "Single Agency Cooperative Charting (SACC)."

Under SACC there will be minimal duplicate chart coverage. Official chart coverage of particular boundary areas will be provided by one agency, either CHS or NOS. SACC will eliminate duplication and inefficiencies created by the availability of two official, same-scale chart services in a given area. For example, chart coverage of the St. Lawrence River will be provided solely by CHS. NOS will cancel its duplicate chart coverage of the St. Lawrence River. In other areas, boundary waters will be covered only by NOS charts and the same-scale Canadian chart coverage will be canceled.

SACC charts are currently intended to be distributed by existing procedures—Canadian charts are distributed through the CHS chart agent network and U.S. Charts through the NOS chart agent network. (For members of The Navigation Foundation NOS and DMA charts will continue to be available through The Foundation.)

### Chart Errors

Member George Leonnig, S.V. *Moctobi* provided the following information concerning chart errors he discovered along the Pacific Coast.

Puerto Vallaria, Mexico is over a mile in error. Chart #21543, Bahia Potrero and Bahia Carrillo, in Costa Rica (surveyed by the U.S. Navy in 1885) is almost two miles in error. In all cases the error could result in running aground or worse. The basis for this information was Member Leonnig's GPS. Note that observations such as this should be reported using the Notice to Mariners Marine Information Report and Suggestion Sheeet, a copy of which is shown in the issue.

### Tide and Tidal Current Tables

Tide and Tidal Current Tables will no longer be available through NOAA. NOAA has stated that it wanted to become less of a publishing agency and more of an information-gathering agency. As of this newsletter, International Marine Publishing Company (IM) will be the source of these tables.

All of the tidal predictions, times and speeds of currents, and other vital information included in the books will be compiled, as always, by NOAA. The data will be supplied to IM, which will publish the material, unaltered and unabridged, in the same four volumes mariners have come to know and trust.

To our current knowledge, The Navigation Foundation will be able to continue to provide these publications to its members at the usual 20% discounted price, plus the cost of postage. Members can order as usual. Tide Tables $13.95 (List Price), Tidal Current Tables $12.95 (List Price).

DO YOU KNOW...?
*By Ernest Brown*

what the base plate and latitude templates of No. 2102-D, Star Finder and Identifier, are?
(The answer appears at the back of this issue)

## New Books

*Advanced First Aid Afloat*, by Peter F. Eastman, 4th Edition. More than 25,000 bluewater sailors have looked to this book when injury or illness struck at sea. Virtually every accident or ailment that might happen when professional medical care is unavailable is dealt with, using layman's language and step-by-step instructions that calmly take the reader from diagnosis, through treatment, to follow-up care. This fourth edition includes the latest methods of treatment and the most appropriate drugs and dosages. There are separate chapters devoted to preparing a crew and the boat's medical chest for long cruises, including lists of drugs for which you will need a prescription. A number of chapters deal with children whose needs are often unique. 224 pp. Illustrations, Tables Glossary, Paperback $14.95 (List Price).

*Storm Tactics Handbook*, by Lin & Larry Pardy. Modern methods of heaving-to for survival in extreme conditions. Paperback $19.95 (List Price).

*Care and Feeding of the Sailing Crew*, by Lin & Larry Pardy. This book tells not only how to buy, provision and store food for local cruising and extended voyages, but also how to take care of the other aspects of crew comfort. Hardcover, 388 pages, $35.00 (List Price).

## Circumnavigating

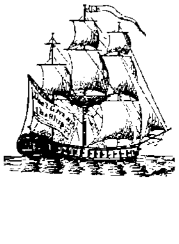
As promised in Issue 46, Winter 1994-95, we are updating the list and known whereabouts of members who are circumnavigating.

Members Mike and Yvonne LeMay departed Oregon aboard the sailing vessel *Drifter* about 1 July 1995. Their initial trek was to take them down the west coast into Mexico.

Members George and Ginny Leonnig aboard S.V. *Moctobi* arrived in Balboa Panama on the first of August. They will be heading toward Florida in November. (The third issue of the "*Log of Moctobi*" can be found in this issue of The Navigator's Newsletter.)

Director Roger Jones aboard S.V. *Allidoro* is currently docked at Isle of Venice, Ft. Lauderdale, FL. Roger has been elected Commodore of the Seven Seas Cruising Association. He is also active in teaching a course in "Celestial Navigation—An Armchair Perspective". The first three lessons appear in this issue of The Navigator's Newsletter.

Member E. B. Forsyth, who departed Long Island, New York has not provided the Activities Column with his vessel's name or his anticipated cruising route. If he provides this information, it will be included in this Column.



# READERS FORUM

*Edited by Ernest Brown*

Member Edward I. Matthews of 156 Burroughs Road, Boxborough, MA 01719 wrote on May 22, 1995:

"G. G. Bennett's learned paper (Issue 44) criticizes me for using the term 'co-inventors'. Pepperday (who coined the term), Dickerson and I were included (Gauss and Chauvenet are excluded) in this frivolous category, since we all had submitted to the Newsletter independent versions of the Dozier's two-body solution at different locations without using dead reckoning (DR). I am sorry if Bennett took offense. Dicky Dickerson and I exchanged letters discussing ideas on this subject and I'll sadly miss his technical savvy and good humor.

"Mr. Bennett also categorically states that this technique is inferior to the Marc St. Hilaire method which by definition requires a DR. The merits of any process should be judged on its performance, such as accuracy, simplicity of use, speed, etc.

"I used the parameters, less the DR, from his article with the Sun bearing south for the 1st position and west for the second. A Great Circle track was used in place of the Rhumb line with insignificant effect. The resulting position of Lat 52° 21.6'N, Long 46° 58.8'W was 0.2 nm from the results of his method B. The Accuracy is independent of distance (other than drift errors) if the intersection angle of COP 1 and COP 2 is at least approximately 45°. Using this position as the DR for the Marc St. Hilaire method, the resulting intercept was zero (actually it works out to be .0000006 nm away and bearing ZN 281.5°)

Any self-respecting navigator will appreciate the absence of a DR requirement if on a passage from Newport, R.I.to Bermuda he encounters a two or three-day overcast while coping with the meanderings of the Gulf Stream. The inputs to the program are identical to usual methods except that the approximate azimuth of the body must be used rather than a DR. The system makes all decisions by the user unnecessary resulting in fewer errors. Total run-time for the complete solution is about 5 min. on a HP41CX using the Nautical Almanac and 8 min. with the NAV-PAC Perpetual Almanac." —*Edward I. Matthews*

Member James E. Moore of 331 Philip Drive, #107, Daly City, CA 94015 wrote on May 17, 1995:

"I would appreciate any information you could send me, having to do with Captain Sumner's solving the LOP in 1837. This would be in addition to the procedure outlined in Chapter 1, Bowditch 1984.

"May I thank you in advance for any assistance."—*James E. Moore*

*Editor's Note: In the Navigation Personalities section of Issue Fifteen (Winter 1986), reference is made to A New and Accurate Method of Finding a Ship's Position at Sea, published by Sumner in 1843.*

Director John M. Luykx of 2021 Brooks Drive, Apt. #319, Forestville, MD 20747 wrote:

"This summer is the Fiftieth Anniversary of the end of World War II, symbolized by the surrender of Japan. Having served in the Navy for 24 years, I feel it worthwhile at this time to consider for a moment the trials as well as the accomplishments of the Navy, especially during the last months of the war in the Pacific. The concept of naval operations was revolutionized by the Pacific Fleet during this final period of the war.

The operational requirement of conducting continuous offensive operations against the enemy employing large fleets of combatant, amphibious and support vessels and thousands of aircraft was unheard of up to this time.

"Conducting offensive operations from February to August 1945 from the Philippines to the Northern Islands of Japan via Iwo Jima and Okinawa with task forces including over 20 battleships, 35 cruisers, 180 destroyers and over 30 carriers with 1500 aircraft supporting an amphibious force of over 200 large vessels and continually replenished at sea by a fleet of 100 deep draft supply vessels including over 50 oil tankers, is an accomplishment which is almost beyond comprehension.

"That large numbers of these ships, especially the battleships, cruisers, destroyers and carriers with their aircraft were able to remain at sea on offensive operations for periods of 60 to 90 days at a time, fighting off enemy ships, aircraft, Kamikazes and the effects of a typhoon, is a high tribute to the supply and service fleets and is an accomplishment of which even the professional can hardly conceive.

"In the summer of 1945, 50 years ago, the U.S. Pacific Fleet, the most powerful naval force ever assembled, established itself as the "Engine of War" unique in history." — *John M. Luykx*

Member George R. Leonnig, Owner/Master of S.V. *Moctobi*, of 8125 S.W. 54th, Portland, OR 97219 has made available to us, with rights reserved for publication elsewhere, the *"Log of Moctobi"*:

"Once anchored we started to dry the boat out and survey our damage. The mainsail had torn out 2 track slides, the autopilot was dead, and our bedding and cushions were soaked from water coming through the anchor locker as the bow buried in the waves. We were among the fortunate. Three boats were lost in the storm, but luckily no lives. The 3 boats were all within 20 miles of us. This description of the storm isn't very good. I am not sure it can be accurately described. We learned a lot from the storm. And also know that there are other storms awaiting us during our cruise.

"After 2 days drying out in Bahia Santa Maria we headed to Bahia Magdelana. A boat there had a sail mending supply needed to repair our mainsail. That's the way cruisers are. Everyone helps everyone. We anchored and were told of a potluck beach party that evening. There were 17 boats in the anchorage. Half of them also had been through the storm. We were all licking our wounds and feeling an additional sense of bonding after the ordeal. Two other boats' autopilots died during the storm. They found water had gotten inside the control box. I opened ours up and found the same. Using a Q-tip I dried and cleaned the salt off the circuit board. The operation was a SUCCESS, the autopilot was alive again!

"We spent 3 days at Bahia Magdelana. As all the boat crews were, so were we, gun shy of the weather. Leaving Magdelana there is no place to stop until Cabo San Lucus another 150 miles. Each boat's crew regained their courage and headed out. We got our courage up on December 11th, pulling the anchor up along with two other boats just before dawn. Once underway and back into the ocean our comfort level returned.

"The morning of December 12th Mo*ctobi* stuck her bow around the tip of Baja California and into the Sea of Cortez. We entered Cabo San Lucus just before noon now with 2,000 miles transited. We spent 10 days in Cabo replenishing our fuel, water, fresh food supply, and doing maintenance. *Moctobi* was the 179th boat to pass through Cabo in the annual quest for winter warmth.

"There were more boats than normal in Cabo. The reason again the weather. When high pressure builds over the southwestern United States, cold winds blow down the Sea of Cortez to mix with the warm tropical air and traveling north becomes next to impossible. These winds are called Northers and usually last about 3 days. However, this time the Northers had already been blowing for a week. Each morning several boats would venture out thinking they could go north. And each evening, most of the boats returned with battered and bruised crews. Those boats which did not return got trapped 40 miles north at a place called Los Frailes.

"December 21st the weather forecast showed a 2-day window to head north, we made our run for La Paz. We left with 3 other boats. One boat turned back less than 5 miles from Cabo. Mo*ctobi* pounded north. The further we went the worse it got. The winds blew 25 knots on our nose, but the seas were the problem. They were short and steep. About every 5th wave would be like hitting a brick wall. A 12-ton boat going 4 knots, stopped in her wake. The final 6 miles into Los Frailes took us 4 hours. This anchorage was a welcome relief from the pounding.

"The next morning the seas had settled down and again we weighed anchor. One boat had left early and kept us informed of the weather ahead via the VHF radio. At 3:00 p.m. the lead boat called and said he was making a run for Los Muertos as the conditions were getting as bad as the previous days. We headed for Los Muertos arriving at dusk in rain and a howling wind.

"I awoke just before midnight. It had stopped raining and the sea was like a lake. It is incredible how the conditions can change so quickly. It was now or never to make La Paz. We hoisted the anchor and with the radar aglow *Moctobi* began a 60-mile sprint to make Christmas in La Paz with friends. Within 2 hours the rain returned, but luckily not the winds. Watching the radar screen we could see rain squalls coming at us. Sweeping across the screen blotting out the land masses with torrents of rain. *Moctobi* raced north at 7_ knots through Cerralvo channel.

"Before sunrise we were at the tricky Lorenzo channel. Here one must pass between 2 dangerous reefs. Then 20 miles ahead is La Paz. As *Moctobi* approached the point to turn into the narrow channel, along came another squall at us. It obscured the land on the radar screen and the 2 navigational lights disappeared in the heavy rain. It was too dangerous to pilot through the channel in these conditions, relying only on the GPS navigation system. The previous year a ferry sank in bad weather on the northern reef. So we turned to the east and open water heading away from our destination frustrated, tired, wet and cold. As the squall finally passed *Moctobi*, we turned back towards the channel once again. We lined up in the channel using all our navigational aids we had and shot through the gap. It rained harder and harder. I yelled at the heavens 'Go ahead, how about some thunder and lightning, but we are going to make La Paz today!' And I swear on the bible, there was a crash of thunder and lightning at that very instant. The only time the entire stormy trip.

"It rained solidly the next 3 hours as we headed into the anchorage at La Paz. As the anchor hit the sandy bottom of Bahia La Paz, some blue sky appeared overhead. I can only speculate that some almighty power was letting us know that we again had earned the right to be where we were. A bucket left on the deck of *Moctobi* by accident had worked as a rain guage. There was 8 inches of rain in the bucket. We found that in La Paz entire streets had been washed away in the storm.

"On Christmas morning, we exchanged small gifts amongst our cruising friends. Packages of gourmet hot chocolate, candy, ginger bread cookies, even Xmas tree shaped pasta. Small tokens of celebration and friendship.

"*Moctobi* is now sailing the waters of the Sea of Cortez until March. Then she will head to mainland Mexico to cruise south to Costa Rica, Panama, and then through the canal into the Caribbean Sea."

# NAVIGATION FEATURE

## The Accuracy of the Artificial Horizon

*By John M. Luykx*

**General**

The purpose of this short article is to publish the results of accuracy tests conducted by the author with two of the principal types of artificial horizon which surveyors, scientists and student navigators use to determine an observer's position on the earth's surface by observations of a celestial body. The two artificial horizon types are the liquid and the precision horizontal glass type. Other types though not discussed herein are the pendulum, the spirit level and the gyro. The method of observation using the liquid and the horizontal glass artificial horizons is shown in Figures 1 and 2.

Figure 1

Figure 2

The instruments used during the tests were:

1. A Davis plastic trough artificial horizon filled with water. The trough which measured 6" in length by 4.25" in width and .75" in depth was protected from the wind

by a glass cover placed at each end of the trough and inclined at 45°. See Figures 3 and 4.

2. A C. Plath circular, darkened mirror artificial horizon 4.75" in diameter supported in a circular housing which is adjusted horizontally by three levelling screws. Levelling is accomplished by either a sensitive elongated tubular spirit level 3.5" in length or a precision circular level .75" in diameter placed on the horizontal glass surface and then removed during observations. See Figures 3, 4 and 5. (See Note below.)

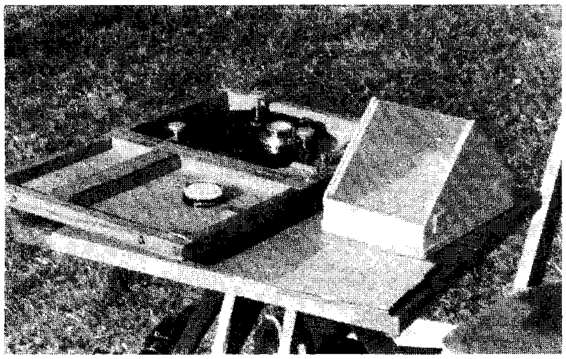


Figure 3

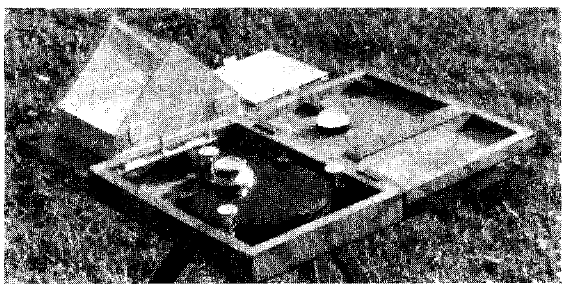


Figure 4

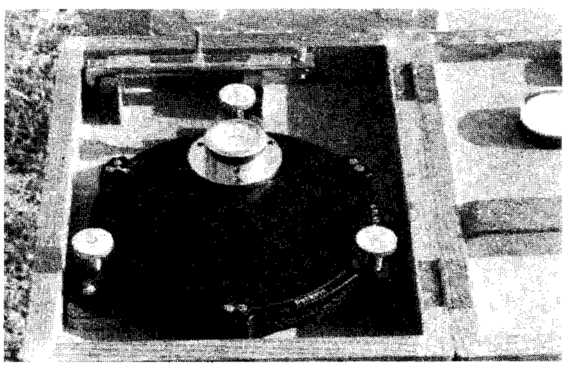


Figure 5

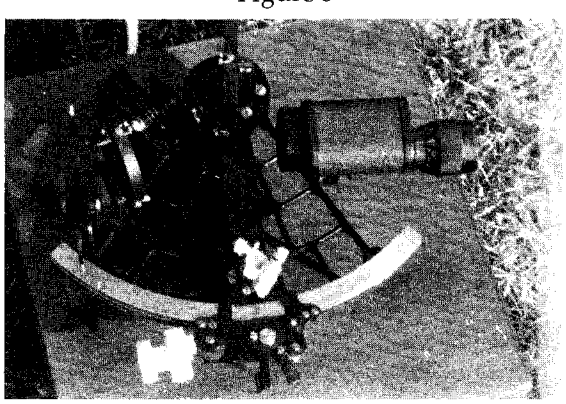


Figure 6

3. The observing instrument was a C. Plath marine sextant with a 6 x 30 prismatic monocular with an Index Correction of +0'.1. See Figure 6.

4. During observations the artificial horizon was placed on a surveyor's plane table and the observer remained seated in a portable chair.

**Procedure**

The observations were conducted as follows:

1. Thirty sextant observations of the sun were taken with each artificial horizon in the vicinity of Forestville, Maryland. The mean watch time and the mean altitude for each of three ten-shot groups were then computed, recorded and reduced. A Tamaya NC2 calculator was employed to reduce the observations.

2. All observations were made by bringing both images of the sun into coincidence. The sextant I.C. was applied to the measured angle and the measured angle was divided by two to obtain the apparent altitude (Ha). The refraction correction was then applied to Ha to obtain the observed altitude (Ho). There is no dip correction.

3. The error for each group of ten observations was the difference in minutes of arc between the mean observed altitude (mean Ho) and the computed altitude (Hc).

**Test Results**

The results of the tests were as follows:

| Test No. | Instrument Used | Group #1 Error | Group #2 Error | Group #3 Error | Mean Error |
|---|---|---|---|---|---|
| 1 | Davis (Liquid) | -1'3 | -1'2 | +0'4 | -0'7 |
| 2 | Plath (Glass) | -0'1 | -0'7 | -0'1 | -0'3 |

**Conclusion**

Of the two artificial horizons tested, the liquid trough type (with water) was the more difficult to use.

1. The water under the heat of the sun would evaporate rapidly and would condense on the interior glass surfaces of the covers. The glass covers, therefore, had to be removed at regular intervals to permit the condensation to evaporate.

2. The wind, at velocities over ten knots, would cause the surveyor's plane table to vibrate resulting in a distortion of the reflected image of the sun on the water surface. Under these circumstances the observation was delayed until the wind velocity died down.

Because the elongated spirit level measures inclination along one axis only it is less satisfactory than the precision circular level in levelling the Plath circular mirror artificial horizon. Using the precision circular level, the levelling procedure can be completed in just a few seconds of time.

The accuracy of the two instruments is comparable.

The advantages and disadvantages of each instrument are as follows:

1. Davis Liquid Trough

| a. Advantages | Disadvantages |
|---|---|
| 1) Inexpensive | 1) Affected by wind |
| 2) Easy to transport | 2) Affected by temperature |
| 3) Self-levelling | 3) Messy if oil, mercury or liquid other than water is used as a liquid |

2. Plath Circular Glass

| a. Advantages | Disadvantages |
|---|---|
| 1) Not affected by wind | 1) Expensive |
| 2) Not affected by temperature | 2) Requires levelling |
| 3) Easy to transport | 3) Levelling must be checked periodically during observations. |

**Note:**

A darkened glass circular artificial horizon similar in design to the C. Plath artificial horizon is currently manufactured by Freiberger, a division of Carl Zeiss Jena. This device is 125mm in diameter and is provided with two levels. To accurately level this artificial horizon, one of the levels is aligned on the glass surface parallel to two of the three levelling screws and the other is placed perpendicular to the first. The levelling screws are then rotated until each of the two bubbles is centered. C. Plath no longer manufactures a glass artificial horizon as described above.

**Summary**

The liquid and glass types of artificial horizon are used when the true horizon is not visible and are employed only on shore where a firm steady supporting platform is available.

A lower limb observation is made by bringing the lower limb of the upper image of the sun into coincidence with the upper limb of the lower (reflected) image.
The altitude corrections are as follows:

1. Apply I.C. to the measured angle.
2. Divide the measured angle (corrected for I.C.) by two (2).
3. Apply corrections for refraction, parallax and semidiameter.

An upper limb observation is made by bringing the upper limb of the upper image of the sun in coincidence with the lower limb of the lower (reflected) image.
The altitude corrections are:

1. Apply I.C. to the measured angle.
2. Divide the measured angle (corrected for I.C.) by two (2).
3. Apply corrections for refraction, parallax and semidiameter.

A center observation is made by bringing both the upper and lower images into complete coincidence.
The altitude corrections are:

1. Apply I.C. to the measured angle.
2. Divide the measured angle (corrected for I.C.) by two (2).
3. Apply corrections for refraction and parallax.

Celestial bodies with altitude less than 10° or greater than 60° are generally difficult to measure using an artificial horizon. The lower altitudes are difficult because of larger refraction errors and increased restriction of the field of view. Higher altitudes are more difficult to observe because of the limitations of the sextant arc. For example, altitudes greater than 70° cannot be measured by a sextant with an arc graduated to only 135°. As a result it is impossible, for example, to take noon observations of the sun using the artificial horizon with the standard sextant during the spring and summer months in many areas of the southern United States.

With the exception of dividing the measured angle by two and ignoring the dip correction, observations using the artificial horizon are taken in the normal manner including the timing and averaging of sights.

An example of the sextant altitude corrections for a lower limb observation of the sun is given below:

| | | |
|---|---|---|
| Given: | Body: | The Sun (LL) |
| | Date: | 1 June 1995 |
| | Angle: | LL of upper image of sun in coincidence with UL of lower image: 76°42'.0 |
| | I.C.: | -2'.0 |
| Solution: | Angle: | 76° 42'.0 |
| | I.C.: | -02'.0 |
| | Angle: | 76° 40'.0 / 2 |
| | Ha: | 38° 20'.0 |
| Sun (Ref&SD): | | +14'.8 |
| | Ho: | 38° 34'.8 |

# NAVIGATION BASICS REVIEW

## Celestial Navigation - An Armchair Perspective

*By Roger H. Jones* Copyright © 1995, Used With Permission

Editor's Note: *Beginning with this issue, Director Roger H. Jones will be furnishing a series of articles on celestial navigation, written in layman's terms and addressed to those mem-*

*bers who have nursed ambitions towards the celestial art, but who have been understandably daunted by the common perception of the difficulty of the subject. This first article will present an overview of the basic theory, which, in reality, is quite simple. It will be followed by shorter successive articles dealing with each of the essential elements of the celestial theory and practice mentioned in the overview.*

**Article Number 1**

In the great era of exploration under sail, the Captain was usually the principal navigator as well. Quite often he was the only person aboard fully capable of using the navigation instruments and of performing the calculations required to obtain a useful line of position from observations of a celestial body such as the Sun. If he was the only man aboard who knew fairly well where he was and how to get to the destination and home again, the often frightened and superstitious crew members were less likely to rebel and put him down. Thus, it was understandable that he often sought to create an aura of mystery as he strode upon the deck each noon with his backstaff or perhaps his quadrant. Reportedly, this was true of Columbus and many noteworthy explorers who followed in his wake. Today, however, virtually any person can acquire the understanding and skill to navigate by the Sun, the Moon, any of our planets, and a small number of stars using a modern sextant. It takes only the ability to add and subtract ordinary numbers, a laymen's grasp of basic theory, and access to the tools of the navigator. The purpose of these articles will be to delve into celestial theory and practice from the comfort of an armchair or sea berth, without reference to scary stuff such as spherical trigonometry equations and far-out nautical astronomy of an esoteric nature.

We'll start with the most basic concept of *navigation* and with the *tools of the navigator* that give meaning to that concept. All navigation rests upon one basic notion: *one may determine an unknown position and make it known by means of distance and direction from a known position.* This is true of dead reckoning, navigation by radio, Loran or GPS, and it is true of celestial navigation. Consider a simple case of dead reckoning. If, by dead reckoning log you have sailed on a true course of 270° for four hours at six knots from the known and *fixed* position of the northern tip of Bimini in the Bahamas, then by direction and a distance of 24 nautical miles from that known position you can pencil in your now "known" position. Fix this concept of distance and direction from a known position firmly in your mind.

In celestial navigation you determine and plot a useful Line of Position (LOP) by means of distance and direction from a precise known location. That known location is called the Geographical Position (GP) of the celestial body that is the object of your sextant observation. There is only one real difference - in celestial navigation the known position (GP) is <u>not a fixed</u> position. It is a position on the surface of the Earth that is constantly moving westward at a predictable rate. Why? The GP is simply that precise point on the Earth's surface that would be intersected at any given instant in time by a straight line from the center of the Earth passing through the surface of the Earth to the center of the celestial body out in space. For purposes of simplicity, we will hereinafter refer to that body as the Sun. Stated another way, the GP is that point on Earth that is directly "beneath" the Sun at any given instant in time.

The Earth's motion in revolving about its own axis results in the point that is directly beneath the Sun, the GP, being constantly on the move in a westerly direction the Earth's surface revolves from the west towards the east in its 24-hour daily cycle. This rate of movement averages over a year's time to be 15 degrees of longitude per hour, and 360 degrees in 24 hours. Hence, we have what is known as Greenwich Mean Time (GMT) in celestial and many other applications. It is also known as Coordinated Universal Time. The fastest time for the Sun to complete one trip around the Earth in its apparent motion is 23 hours, 44 minutes, and the slowest is about 24 hours, 16 minutes. (With respect to the Moon, the time is an inconstant 24 hours 50 minutes, and for the stars it is a nearly fixed 23 hours, 56 minutes, 10 seconds).

Well, navigators if you seek to find your distance from a known position that is moving westward at a predictable rate, then you must obviously know the precise time that you measure that distance. And that is why the celestial navigator must time the sextant shot to the nearest second of GMT. It is a happy fact that on the surface of the Earth one minute of arc (Great Circle Arc) which will be defined later, also equals one nautical mile. And if a GP moves westward at a rate of 15 degrees of longitude per hour, then at least at the Equator the GP is moving at a rate of 900 nautical miles per hour, or one nautical mile every 4 seconds in time. Thus, if a navigator makes a mistake of 4 seconds in the timing of his sextant shot, his measurement of distance may be off by up to one mile.

The logical question is this: what in the world does a sextant have to do with this? Let's pause and list the too<u>ls</u> of the navigator mentioned at the outset. They are: a chronometer, a sextant, a <u>Nautical Almanac</u>, a set of sight reduction tables, a chart or plotting sheet, and personal dividers and plotting instruments. What the chronometer does for the navigator is now easy to see. It enables him to time his sextant shot. The sextant enables him to measure <u>distance</u>. Take that on faith for the moment. The <u>Almanac</u>, for every second of every minute of every hour of every day of the year, lists the precise coordinates of the GP, expressed as Greenwich Hour Angle (GHA), which is equivalent to longitude, and Declination (Dec), which is equivalent to latitude. The sight reduction tables list the precomputed solutions to the spherical trigonometry problem involved in the great navigational triangle that is present in every sextant shot and the information ultimately derived therefrom. The chart is what that information is plotted on, and the plotting tools simply enable the plot to be drawn in by hand.

We've talked about distance, what about direction? It is the sight reduction tables which give to the navigator direction, and they also enable a critical adjustment to distance that makes the final plot of the LOP possible. They do that via the great navigational triangle.

Now, without knowing anything about spherical trigonometry equations, just accept a truth. If you have a triangle of any size or shape on the surface of the Earth, and: (1) if you know the length of any two sides, and (2) if you know the size of the angle formed where those two sides meet, then (3) you can determine the length of the third side and the size of the other two angles. Let's take that truth to the surface of the Earth. You are out in the ocean southwest of the Canary Islands, and you have at least a rough idea of your position from your DR log. Let's say your DR position is 25N-20W. A figurative line from that DR to the North Pole is one side of the triangle, and its length is 65 arc degrees (25 plus 65 equals 90, and the Pole is at 90N). Those 65 degrees of arc are equal to 3,900 nautical miles. Let's say also that the Sun's GP at the fleeting moment of your sextant shot is 14N-58W. The second side of the triangle runs from the GP to the Pole, and its length is 75 arc degrees, or 4,500 nautical miles. This puts the Sun's GP just to the east of Martinique. The 20 degree and 58 degree meridians of west longitude meet at the Pole, and the angle between them is simply the difference in longitude, or 38 degrees.

You have two sides of the triangle and the included angle. Armed with that, the tables tell you the exact arc length of the third side running from your position all the way across the Atlantic to the GP of the Sun, and the tables give you the true direction or bearing of the GP at the fleeting moment in time of your sextant shot. That direction is nothing more than the angle between the third side from you to the GP, and the first side from you to the Pole. What you actually do is enter the tables with an Assumed Position (AP) based upon your DR, but the AP is near your DR, and your DR, even if many miles from your position, will not prevent establishment of a line of position that is quite accurate. The AP simply makes table format and entry easier, as it does away with the need for time-consuming interpolation, and it reduces to a manageable size what would be an otherwise unwieldy set of tables of enormous volume. You also enter with the Declination of the Sun and the difference in longitude between the AP and the GP. You extract simple numbers that enable you to plot the LOP. You don't ever plot the large triangle or any of its sides, except for a small portion of the third side, which is the bearing line running through the AP towards the GP. The LOP is a short line that is perpendicular to the GP's bearing, and you are somewhere on that LOP. Two or more intersecting LOPs render a nice fix, but often only a single LOP reveals very useful information.

The final protocol that tells you exactly where on the bearing line to place the perpendicular of the LOP is known as the Altitude Intercept. It will be dealt with later. It is simple. For now, navigators, you have it! You have the basic theory of celestial navigation. Your LOP is plotted by means of distance and direction from the known position of the GP. Keep coming back to that fundamental concept. You are well on your way.

**Article Number 2**

*By Roger H. Jones*

The convention in books and articles on celestial navigation is to start with nautical astronomy and concepts of Greenwich Mean Time and Local Time, and then to work laboriously through the theory of the sextant altitude, the altitude corrections, the use of the Almanac, and then the use of the sight reduction tables. Along the way, the reader is introduced to the concept of the Altitude Intercept (which enables the final adjustment to distance), and towards the end there finally emerges the line of position (LOP). This, more or less, follows the sequence of events that the seasoned navigator brings into play as he starts with his sextant shot, carefully records the time, and then proceeds to use the Almanac and the tables to arrive at his ultimate goal - a useful LOP to be drawn on the chart of plotting sheet.

The problem is that many readers are not seasoned navigators. Therefore, in the interest of more immediate clarity we have started with that ultimate goal. We have seen that we seek an LOP that is plotted by means of distance and direction from the known coordinates of the GP of the celestial body. Our target in this second article is to understand why the LOP is plotted perpendicular to the line that represents the true bearing from the Assumed Position (AP) to the far off GP. (The GP is, of course, normally well beyond the borders of the chart and well beyond the navigator's visible horizon.) Our logical question is what does the LOP really represent, and how are we using it in conjunction with the line of direction that runs through the AP towards the GP? As a relatively short straight line, plotted at a right angle to the bearing line, the LOP is, in reality, a very small segment of the curved arc of the rim of a normally very large circle on the surface of the Earth that figuratively surrounds the GP. The GP is the center of that circle. In the preceding article's example, the DR was southwest of the Canary Islands at 25N-20W, and the GP was to the east of Martinique at 15N-58W. Taking the difference in longitude of the DR and the GP (38 degrees) in combination with the latitudes of the two positions, one could quickly enter the tables and determine that the arc length or distance from the DR all the way across the Atlantic to the GP was 36°57.0' (equivalent to 2,217 nautical miles), and that the direction from the DR to the GP was 262° True. The exact same procedure would apply when entering the tables with the AP rather than the DR, which is the normal procedure. In any case, the LOP represents how far the navigator is from the GP at the fleeting moment in time of the sextant shot!

That distance is thus the radius of a circle that surrounds the GP, and the circle is known as the "Circle of Equal Altitude". The name derives from the fact that from any place on the rim of that circle the navigator would at the same fleeting moment in time, measure with his sextant the exact same altitude of the Sun above the sea horizon. The sextant altitude is an indirect but mathematically accurate measurement of the arc distance along the curvature of the Earth's surface from the navigator to the GP. On a globe, a string stretched form the GP to the navigator's position would represent the same thing, and this string would be the third side of the great navigational triangle. If a pin secured the string to the GP, the taut string could then be used to inscribe a circle around the GP.

The simple logic that the sextant altitude represents a measurement of arc distance will be explored later. For the moment, if you are curious about the full size of the circle in our example, note that the rim would pass near Rio De Janeiro, Puerto Vallarta (Mexico) and the Canadian wilds north of Lake Superior, as well as the spot southwest of the Canaries.

Thus with a given sextant altitude, the navigator has placed himself at a certain precise distance from the GP on the rim of a circle surrounding the GP. All he has to do is construct a nice line of direction from his own position to the GP, and at or near the point of intersection of that line and the circle's rim is where he is!

Alas, direction is not as precise as distance. It cannot be determined as a bearing using the ship's compass because the GP is normally well below the horizon, and in any case it is an invisible figurative spot on the Earth's surface that is moving westward at a rapid rate. The solution lies in the precomputed trigonometry answers that appear in the sight reduction tables. The bearing plotted on the chart is a "best case" line of direction from the AP to the GP that is computed for the particular circumstances of the AP and GP. At this point, navigators, you will say "Yes, but the AP used to enter the tables and the actual position rarely coincide, so how useful is a line of direction from the AP?" Consider this: if you were standing on a straight beach trending north and south, looking out over the ocean in an easterly direction toward a point 2,217 nautical miles away, and if somehow you could get a bearing on that spot, the bearing would not change if you moved ten or even forty miles to a new location on the beach. The distance is so great that a change in your position would result in a bearing change too small to measure and work with effectively on a chart.

Thus it is that with a single LOP crossing a true bearing at a right angle you have distance and direction. You are somewhere on that LOP near or perhaps at the point of intersection of the two plotted lines. With two or more intersecting LOPs the navigator has a "fix", but as noted earlier, often a single LOP provides a great deal of useful information.

**Article Number 3**

*By Roger H. Jones*

Settle again into your sea berth or armchair and contemplate your wake. It stretches back over your mental sea lanes to our point of departure - distance and direction from the known coordinates of the westward moving GP of the Sun (or other celestial body) are used to plot the Line of Position (LOP). The LOP, representing the distance that the navigator is from the GP at the fleeting moment of the sextant shot, is really a small segment of the rim of a figurative circle surrounding the GP, and the radius of that circle is thus also that distance. Distance is measured with the sextant. Direction is the True Bearing from the navigator to the GP at the fleeting moment of the shot, and it is obtained from the sight reduction tables for an Assumed Position. On the chart the bearing is plotted through the AP, which is in the general vicinity of, but rarely coincides with the actual position or with the DR. Thus, the bearing also represents a portion of the radius of the circle, and the LOP represents a portion of its rim, plotted perpendicular to the bearing. The navigator must be somewhere on the LOP, and, depending on how closely the true bearing from the actual position to the GP matches the true bearing from the AP to the GP, the navigator is reasonably close to the point of intersection of the LOP and the bearing. You should be asking (1)Why is the sextant altitude a measurement of distance? (2)How do we know where to plot the intersection of the LOP and the bearing? The straight forward answers will come in due course.

Meanwhile, it is time to begin to put the emerging theory to use. Let's follow a seasoned navigator through the initial steps of his practical application of the theory.

Using the Sun, our navigator will first select a time when it is visible above the horizon and not too low in the sky. A Sun too low will present extra problems with abnormal refraction. Refraction can be resolved easily, but in normal circumstances why bother. (Refraction is the deflection of straight light rays as they pass through the atmosphere). Any time from several hours after sunrise to several before sunset will do nicely. Next he'll look quickly to ascertain that the horizon is not obscured by fog or haze, and that the Sun is not obscured by clouds. He'll also perform a quick mental check on the time and date at Greenwich. Depending on his own longitude, the date at Greenwich could be different from his local date. He wants to enter the Almanac after his sextant shot with the Greenwich date and time. For example, on October 1st at 150° West Longitude (in the Pacific his local time is 10 hours behind Greenwich time. At 1600 local time on the 1st, it is 0200 on the 2nd at Greenwich. Conversely, on October 1st at 45° West Longitude at 1000 (in the Atlantic), local time is only 3 hours behind the time at

Greenwich, which would be 1300. If our navigator is in East Longitude, local time will be ahead of GMT. The difference in longitude of any two places on the Earth's surface is also the difference in time between those two places. The *Almanac* again comes to our assistance, as it tabulates for any precise longitude difference the corresponding precise time difference in its table for Conversion of Arc to Time, and also in the Increments and Corrections tables. Time, you will remember, is based upon the fact that the Sun's apparent movement around the Earth is at a mean rate of 15 degrees of longitude per hour, .25 degrees per minute of time, and .25 minutes of arc per second of time.

Next, the navigator will assure that he has at hand an accurate time reference. Today, this is simple. He wears a quartz-driven watch with an hour, minute and second read-out, and he compares it with a radio time tick, usually just before the sextant shot. He thus knows how fast or slow his watch is.

Together with his watch and sextant he'll go on deck to a position that is secure and for which he has previously determined his Height of Eye above the water. His goal is the altitude of the Sun above the sea horizon as viewed from water level. If his eye is above the water level, he'll measure an altitude greater than a true water level measurement because the visible horizon will "dip" below the horizon as viewed from the water level, due to the fact that it is farther away on the surface of the spherical Earth.

Thus, the Height of Eye (HE) correction is always a minus one, taken directly from the Almanac's "DIP" table which appears with the other Altitude Corrections at the very front of the volume. In the real world, he'll always use the same spot on deck for observations, and thus his HE correction will be consistent. Even on a small boat the HE correction is not to be ignored.

The first thing the navigator will do with the sextant itself is to check it for Index Error (IE). He'll set his sextant to zero on the arc and micrometer drum, and will then look at the horizon through its optics. The horizon should appear as a straight line. If not - if it has a "stepped" appearance - he'll turn the micrometer drum until a straight line horizon appears. He'll then read the value on the drum, and if it is positive (above zero) he must subtract that value from his raw sextant altitude of the Sun. If it is a negative value (less than zero he must add it to the sextant altitude. IE is normally slight, but it is also normally present, and it can change due to expansion and contraction of sextant parts and other factors. Always check it for every sextant shot, and make a record of IE and HE. IE is the second of the several altitude corrections applied after the shot. Starting with the raw sextant altitude (HS), our navigator will subtract the HE correction, and then add or subtract the IE correction, and the result will be Apparent Altitude (HA).

# NAVIGATION NOTES

## Comments on the 1995 Edition of Bowditch

*By Ernest Brown*

The 1995 edition of Pub. No. 9, The American Practical Navigator (Bowditch), is a single volume which incorporates the canceled Pub. No. 226, Handbook of Magnetic Compass Adjustment, and Pub. 606, Guide to Marine Observing and Reporting. The new edition does not include the following tables of the 1981 edition of volume II, of Bowditch:

Table 1, Conversion Angle
Table 2, Conversion of Compass Points to Degrees
Table 34, Haversines
Table 35, The Ageton Method (H.O. 211)
Table 36, Compact Traverse Table

The remaining tables have been renumbered and grouped according to category. For example, the celestial navigation tables are tables 19 through 28; the meteorological tables are tables 29 through 36.

The new Bowditch, which again includes "The" in the title, is printed on an enlarged page, the standard page size now being used by the Defense Mapping Agency (DMA). What were two pages of a multi-page Bowditch table are printed side by side on the enlarged page, except for a last page which may be printed separately. Overall, the larger page size serves to enhance the clarity of presentation of the text and associated graphics.

The following is from the preface (emphasis added):

> This 1995 edition of the *American Practical Navigator* incorporates extensive changes in organization, format, and content. Recent advances in navigational electronics, communications, positioning, and other technologies have transformed the way navigation is practiced at sea, and it is clear that even more changes are forthcoming. The changes to this edition of BOWDITCH are *intended to ensure that this publication remains the premier reference work* for practical marine navigation. Concerned efforts were made to return to Nathaniel Bowditch's original intention "to put down in the book nothing I can't teach the crew." *To this end, many complex formulas and equations have been eliminated, and emphasis placed on the capabilities and limitations of various navigation systems and how to use them, instead of explaining complex technical and theoretical details.* This edition replaces but does not cancel former editions, which may be retained and consulted as to navigation methods not discussed herein.

The editors say that this publication remains the premier reference work for practical marine navigation. But it is clear from what the editors say and what a cursory examination of the book reveals - the book is no longer a reference work like the 1958 through 1984 editions. Even more certainly it is not a premier reference work.

The editors say that the new edition replaces but does not cancel former [sic] editions. Although a similar statement may be sometimes used for other hydrographic products, the clear meaning here is that the 1995 edition does not stand alone as a reference work, even within the usual limitations of a general reference work.

The following is also from the Preface:

The former Volume II has been incorporated into this volume to save space and production cost. A larger page size has also been chosen for similar reasons. These two changes allow us to present a single, comprehensive navigation science reference which explains modern navigational methods while respecting traditional ones. The goal of the changes is to put as much useful information before the navigator as possible in the most understandable and readable format.

TAB 1. FUNDAMENTALS, has been reorganized to include an overview of the types and phases of marine navigation and the organizations which support and regulate it. It includes chapters relating to the structure, use and limitations of nautical charts; chart datums and their importance; and other material of a basic nature. The former chapter on the history of navigation has been largely removed. Historical facts are included in the text where necessary to explain present practices or conventions.

TAB 2, PILOTING, now emphasizes the practical aspects of navigating a vessel in restricted waters.

TAB 3, ELECTRONIC NAVIGATION, returns to the position it held in the 1958 edition. Electronic systems are now the primary means of positioning of the modern navigator. Chapters deal with each of the several electronic methods of navigation, organized by type.

TAB 4, CELESTIAL NAVIGATION, has been streamlined and updated. The text in this section contains updated examples and problems and a completely re-edited sight reduction chapter. Extracts from necessary tables have been added to the body of the text for easier reference.

TAB 5, NAVIGATIONAL MATHEMATICS, includes chapters relating to such topics as basic navigational mathematics and computer use in the solution of navigation problems.

TAB 6, NAVIGATIONAL SAFETY, discusses aspects of the new distress and safety communications systems now in place or being implemented in the next several years, as well as navigation regulations, emergency navigation procedures, and distress communications.

TAB 7, OCEANOGRAPHY, is updated and consolidated, but largely unchanged from the former edition.

TAB 8, MARINE METEOROLOGY, (formerly WEATHER) incorporates new weather routing and forecasting methods and material from former appendices. Included are new color plates of the Beaufort Sea States (Courtesy of Environment Canada).

The Glossary has been extensively edited and updated with modern navigational terms, including computer terminology.

In TAB 1, FUNDAMENTALS, the editors could have benefitted from a study of *Origins of Geomagnetic Science* (see issues 44-46) in their presentation of historical facts. In chapter 1 they carelessly say that the earth is an oblate spheroid. An excellent presentation of geodesy for the navigator follows in chapter 2. Respect for chapter 2 should have dictated the insertion of "approximately" in chapter 1.

The editors state that TAB 2, PILOTING, now emphasizes the practical aspects of navigating a vessel in restricted waters. But the editors removed an excellent method for the rapid determination of constant error in a cross-bearing plot, a means of avoiding the hazardous delays associated with the trial and error method retained. This appears to be a very poor judgment call. The removal of horizontal sextant angles is another significant mistake.

The editors also state that TAB 3, ELECTRONIC NAVIGATION, returns to the position it held in the 1958 edition. Apparently, this means no more than the order of presentation of the several parts of the book. If the editors feel so strongly about both the order of presentation and the 1958 edition, one might wonder why they did not include the theory of tides and currents as a separate chapter apart from tide and current predictions in the OCEANOGRAPHY part as in the 1958 edition. But it is obvious that the principal concern of the editors is to put celestial navigation in what they consider to be an inferior position.

In the preface the editors fail to mention a very significant fact. Unlike most formal navigation texts, the glossary is the only place where a substantial part of the fundamental information is presented. The glossary is the core of the book. For example, for gyrocompass the index refers the reader to page 3. On page 3 one finds:

The gyrocompass was made necessary by iron and steel ships. Leon Foucalt developed the basic gyroscope in 1852. An American (Elmer Sperry) and a German (Anshutz Kampfe) both developed electrical gyrocompasses in the early years of the 20th century.

One must refer to the Glossary of Marine Navigation for more information on gyroscopes, gyrocompasses, associated equipment, errors, and modes of operation. I certainly cannot criticize this other than for its not being mentioned in the preface because my ideal navigation book would be a well illustrated glossary with certain appendices of text used to integrate material in the glossary or to present those subjects not suitable for the glossary approach.

I had hoped that the use of graphics would have been expanded in the Glossary of Marine Navigation. In this edition there are no graphics in the glossary.

The editors' use of Nathaniel Bowditch's original intention to justify their actions does not stand up to cursory inspection, never mind close scrutiny. They are so wrong in this that it is difficult to find a place to start. In the interest of brevity here, one could give consideration to what a person like Bowditch could teach another person of very limited education.

Although I found certain omissions to be very disconcerting, my expectations are that the book will be well received. The price ($22) is very attractive. As I look at the book, it appears to be worth considerably more.

Answer to last issues problem on pp. 13-14

# BOOK REVIEW

*By Terry Spence*

***Celestial Navigation with the S Table***
*By Mike Pepperday*, Paradise Cay Publications
P.O. Box 1351, Middletown, CA 95451 (1922), 22 pages, $9.95
Telephone Order: 1-800-736-4509

As stated on the back cover of this booklet "A state of the art revision of a century old method, the S Table is the only sight computation designed to back up a celestial computer". Instead of using an assumed position as in so many sight reduction procedures it utilizes the D.R. position for calculations. Yet a further advantage: by using a scientific calculator and the same format the solution is arrived at, thus eliminating the use of a different form or procedure (sines and cosines replace the tabular values of the Tables).

I experimented extensively with the tables and with the use of a calculator using examples in various books (answers provided) and came to trust the answers provided by the S Tables. Plotting the LOPs was in my opinion considerably easier; however do not forget to "advance or retard" the LOP as necessary - if enough time exists between the shots. You are allowed to copy the work forms for your own use and I would recommend that you do. They are concise, and carry the necessary rules right on the work paper. I was able to fit two of the worksheets on a standard letter size sheet (double sided if you wish) and have them made up in pads of 50.

I did run into difficulty reducing a Polaris sight to a standard LOP (as opposed to the usual latitude reduction) by use of the tables; however, it did work out when I used the calculator version. Help or comments on this would be welcome. I did feel that practice was necessary before I fully understood the way the tables are arranged and thus cut down on my blunders.

A secondary benefit of these tables is the star determination factor. A slightly modified form and an abridged S table is used to identify stars and planets by arriving at their sidereal hour angle and declination. Using these figures and an almanac - presto there is your star. You then proceed with the standard sight reduction.

This booklet coupled with a scientific calculator and an almanac could constitute a compact and concise sight reduction system, taking up little space.

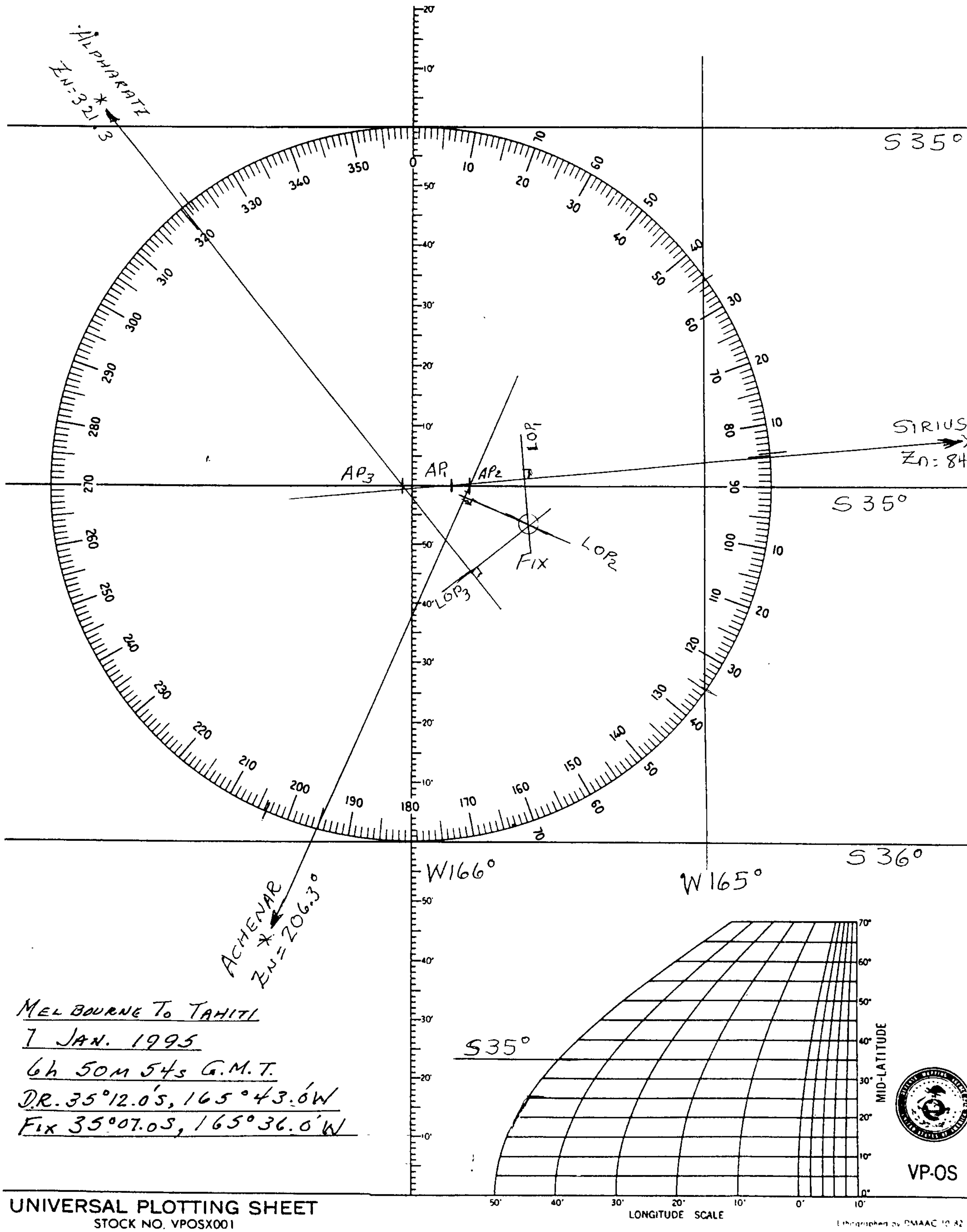
***Taking Terrapin Home***
*By Mathew Wilson*, Paradise Cay Publications
P.O. Box 1351, Middletown, CA 9546
230 pages (1994) $14.95. Phone 1-800-736-4509

This is the story of a man obviously "in love" with his new purchase - a 26-foot Catamaran, built in Cornwall, England. The author intends to berth his boat in Florida and must somehow get to this berth. The final decision is the story of this journey from Chicester, England (point of departure) across the English Channel to France thence down the length of France by canal to the Mediterranean. From here the track is to Cadiz to the Canaries to the Barbados via Cape Verdes Islands. He then departs for Jupiter, Florida by way of the Caribbean and the Bahamas. The journey takes two years - many delays and leaving the boat stored at different locations while conducting personal matters. The total distance is just about 7,267 n.m.

Murphy (that renowned trouble-maker) must surely have been aboard. If the weather forecast called for light winds, yes you guessed it, it blew a minor gale. There were numerous times when plastic wrapped itself around the prop through the French canals and ports in the Mediterranean requiring a dive many times in filthy water. However, after many trials and tribulations, a refit in the Virgins and some great times, *Terrapin* finally reached its home in Jupiter, Florida.

At the end of the book there are several chapters with such headings as Refits and Rethinks, Commissioning Lists and *Terrapin's* specifications. It is a thoroughly enjoyable tale and covers, as stated on the back of the cover "the book is a look at one of the great sailing routes of the world through fresh eyes. Enjoy.

Answer to Last Issues Problem:



STAR SIGHT REDUCTION
H.O. 229
*Melbourne to Tahiti*

GIVEN: Lines #1,2,3,4,5,6,7,8.
FIND: Lines #37, 39.
ENTER H.O.229 with lines #26, 27 and 28.

| | | | | | |
|---|---|---|---|---|---|
| STAR | 1 | SIRIUS (18) | ACHERNAR (5) | ALPHERATZ (1) | |
| Local Date | 2 | 7 JAN. 1995 | 7 JAN. 1995 | 7 JAN. 1995 | |
| D.R. Lat. N/S | 3 | S 35° 12.0' | S 35° 12.0' | S 35° 12.0' | North or South? |
| D.R.Long. E/W | 4 | W 165° 43.0' | W 165° 43.0' | W 165° 43.0' | East or West? |
| Eye Ht. F/M | 5 | 11' | 11' | 11' | Feet or Meters? |
| Chr. Err.F/S | 6 | 16 Sec. F. | 16 Sec. F. | 16 Sec. F. | Fast or Slow? |
| Hs | 7 | 36° 35.5' | 63° 44.2' | 13° 29.1' | Sextant Reading |
| Local Time | 8 | 19 h 51 m 10 s | 19 h 55 m 30 s | 19 h 59 m 01 s | Use Standard Time |
| Z.D. ± | 9 | +11 h | +11 h | +11 h | (E=-) (W=+) Fr. Ln.4 |
| Chr. Err. ± | 10 | m -16 s | m -16 s | m -16 s | (Fast = -)(Slow = +). |
| G.M.T. | 11 | 30 h 51 m -06 s | 30 h 55 m 14 s | 30 h 59 m -15 s | Add lines 8±9±10 |
| Correction | 12 | -24 h | -24 h | -24 h | Need ± 24 hrs.? |
| Correction | 13 | -1 m +60 s | m s | -1 m +60 s | Need ± 60 secs.? |
| G.M.T. | 14 | 06 h 50 m 54 s | 06 h 55 m 14 s | 06 h 58 m 45 s | Add lines 11±12±13 |
| G.M.T. Date | 15 | 8 JAN. '95 | 8 JAN. '95 | 8 JAN. 95 | Need new Date? |
| G.H.A. ♈ hr. | 16 | 197° 19.5' | 197° 19.5' | 197° 19.5' | Fm.Ln.14.AlsoGet 18,27. |
| Incr. ♈ m,s | 17 | 12° 45.6' | 13° 50.8' | 14° 43.7' | From Line 14, m,s. |
| S.H.A. ☆ | 18 | 258° 45.5' | 335° 37.0' | 357° 57.9' | From Lines 1, 15 and N.A. |
| G.H.A. ☆ | 19 | 467° 110.6' | 545° 107.3' | 568° 121.1' | Add 16 + 17 + 18 |
| Correction | 20 | -360° | -360° | -360° | Need -360°? |
| Correction | 21 | +1° -60.0' | +1° -60.0' | +2° -120.0' | Need ±60.0'? |
| G.H.A. ☆ | 22 | 108° 50.6' | 186° 47.3' | 210° 01.1' | Add 19 ± 20 ± 21. |
| Ass'd.Long ± | 23 | -165° 50.6' | -165° 47.3' | 166° 01.1' | (W = -)(E = +) |
| L.H.A. ☆ | 24 | -57° 00.0' | 021° 00.0' | 044° 00.0' | On Ln.23 Sub. MM.m |
| Correction | 25 | +360° 00.0' | ° 00.0' | ° 00.0' | Need ±360°? |
| L.H.A ☆ | 26 | 303° 00.0' | 021° 00.0' | 044° 00.0' | Add Lines 24 ± 25. |
| Dec. ☆ N/S | 27 | S 16° 42.7' | S 57° 16.0' | N 29° 04.0' | Same or Contrary? |
| Ass'd.Lat.N/S | 28 | S 35° 00.0' | S 35° 00.0' | S 35° 00.0' | Nearest Whole ° |
| Hc | 29 | 35° 56.5' | 63° 50.3' | 13° 43.6' | Also get Lns.30,38,39 |
| (d) Tens ± | 30 | (+31.5) 21.4' | (-45.2) -10.6' | (-48.7) -2.6' | From Line 27 MM.m . |
| (d) Units ± | 31 | + 1.1' | - 1.4' | - 0.7' | From Line 27 MM.m. |
| Dbl.2nd.Diff. | 32 | (0.0) + 0.0' | (0.0) + 0.0' | (0.0) + 0.0' | Use only for d· |
| Hc | 33 | 35° 79.0' | 63° 38.3' | 13° 40.3' | Add 29±30±31+32. |
| Correction | 34 | +1° -60.0' | ° ' | ° ' | Need ±60.0'? |
| Hc | 35 | 36° 19.0' | 63° 38.3' | 13° 40.3' | Add 33 ± 34. |
| Ho | 36 | 36° 31.0' | 63° 40.5' | 13° 21.9' | Line 37 = 35 ~ 36 |
| Intercept(a)A/T | 37 | T 12.0' | T 2.2' | A 18.4' | A or T? Ho Larger = T |
| Z | 38 | 95.3° | 26.3° | 141.3° | |
| Zn | 39 | 84.7° | 206.3° | 321.3° | Z = Zn or need Corr'n? |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 | SEXTANT CORRECTION | | | | | | |
| | 41 | + | - | + | - | + | - | |
| Dip | 42 | XXX | 3.2' | XXX | 3.2' | XXX | 3.2' | Line 5 and Page A2 N.A. |
| I.C. | 43 | 0.0' | 0.0' | 0.0' | 0.0' | 0.0' | 0.0' | (On = -)(Off = +). |
| + and - Totals | 44 | 0.0' | 3.2' | 0.0' | 3.2' | 0.0' | 3.2' | Add Lines 42 ± 43. |
| Diff. +/- | 45 | -3.2' | | -3.2' | | -3.2' | | Diff. +/- Line 44 |
| Hs ☆ | 46 | 36° 35.5' | | 63° 44.2' | | 13° 29.1' | | From Line 7 |
| App. Alt. ☆ | 47 | 36° 32.3' | | 63° 41.0' | | 13° 25.9' | | Line 46 ± Line 45 |
| A2 Alt.Corr'n. | 48 | - 1.3' | | - 0.5' | | - 4.0' | | ☆ Table Page A2 N.A. |
| Ho ☆ | 49 | 36° 31.0' | | 63° 40.5' | | 13° 21.9' | | Add Lines 46 + 47. |
| | | | | | | | | Enter into Line 36 |

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## New Menus on the Navigation Information Network

Two new features have been added to NAVINFONET. First off, new option number 44, provides access to the radiobeacons listed in DMA List of Lights volumes 110 through 116 by radiobeacon number. Secondly, existing menu option 14 has been expanded to list the next due date of the subsequent edition of DMA List of Lights, U.S. Coast Guard Light Lists, Radio Navigational Aids, Summaries of Corrections, and the DMA Hydrographic Catalog.

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By William O. Land*

The conclusion of this article will appear in Issue fifty, Winter 1995-96.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**NOTICE TO MARINERS MARINE INFORMATION REPORT AND SUGGESTION SHEET**

Observer_______________________ Ship's Name_______________________________

Mailing Address______________________________________________________

______________________________________________________________________

Date of Observation ____________________ Time of Observation (GMT)____________________

Lat.______________ Long.________________ Nav System ______________________________

Double-checked by Navigator? Yes______No______

Charts/Publications affected (Nationality)___________________________ Ed. No.________________

Latest correction applied N.M.___________of 19___

When reporting depths, please provide an annotated echogram for depth verification. Depth sensor or method used_________________________________________Depth(s) corrected for draft? Yes_____ No_____

Details of Information Reported. Continue on reverse side or use additional sheets if necessary.

Navigator Signature________________________________

This space provided for user feedback and suggestions for improving navigational publications, charts and services. Questions to consider are: Is DMA meeting your needs for maritime information? What other types of information would be useful? How might DMA better serve the maritime community?


**For mailing instructions and other pertinent details, please see pages ii and iv.**

ANSWER TO DO YOU KNOW ... ?
(from page 1)

Each side of the white base plate of No. 2102-D, Star Finder and Identifier, is a polar azimuthal equidistant projection of the celestial equator (equinoctial) system of coordinates. For each side, the plane or projection is tangent to the above system of coordinates on the celestial sphere at the elevated pole, north or south. For clarity most of the projection has been removed, leaving only the elevated pole, celestial equator, and short segments of the celestial meridians near the periphery. The 57 navigational stars are placed according to their coordinates of declination and right ascension. All of this is made possible by the fact that the azimuthal equidistant projection can project almost all of the sphere.

Each latitude template is an *oblique* azimuthal equidistant projection of the horizon system of coordinates. For each template, the plane of projection is tangent to the combined coordinate systems on the celestial sphere at the elevated pole on the principal vertical circle. The display of the zenith, vertical circles and circles of equal altitude on each template, is a family of altitude and azimuth curves limited to the region on the celestial sphere above the celestial horizon. The radial extension of the principal vertical circle indicates the observer's celestial meridain. Note that with this radial set at LHA of Aries on the base plate, the observer's celstial meridian is set at its right ascension, or at its proper place among the stars.

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# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY, WINTER 1995-1996

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Nautical Almanac

Both the government publication and the commercial version of the 1996 Nautical Almanac are available from the Foundation. The commercial edition, published by Paradise Cay Publications, lists for $15.95 and the government publication lists for $22.00. Postage for mailing is $1.74 for the government publication. Shipping and handling for the commercial edition is $3.50. Your member's 20% discount applies to both issues.

### Computer Disks

Members frequently send computer disks, along with their letters, articles, navigation problems and programs that they have developed. The Foundation's normal word processor is WordPerfect 5.1/6.0. We can convert to Ami Pro 1.2a to Ami Pro 3.0; ASCII Text; Bitmap Graphics; CGM Graphics; DisplayWrite 4.0/5.0; Excel 2.1 to 4.0; IBM DCA FFT, RFT; Lotus.pic Graphs; Lotus 123 versions 1A to 3.1; MS Word versions 5.0/5.5; MS Word for Windows versions 1.0 through 2.0b; PC Paintbrush Graphics; PlanPerfect 5.0/5.1; Quattro Pro 3.0/4.0; WordPerfect versions 4.2/5.1/6.0' WordPerfect Graphics 1.0/2.0; WordStar versions 3.3 through 5.5 and WordPerfect 2.0 (Macintosh). It would be very helpful to include with the disk, the method used to record the disk, whether a DOS or other base system, and the program used to develop the data.

### Circumnavigating

We have received a newsletter from Member E. B. Forsyth who left Block Island on July 7th aboard the Yacht *Fiona*. As of 2 October he was in Georgetown, Guyana. He plans to depart to arrive in St. Martin in mid November. His future plans are to transit the Panama Canal in February and then on to Polynesia. His newsletter will be published at some later date.

### Matching Gifts

Many members have most graciously offered matching gifts along with their contributions. The following letter from Morgan Guaranty Trust Company of New York shows a problem that an organization such as ours can have:

August 9, 1995
Captain Terry F. Carraway
Executive Director
Foundation for the Promotion of
the Art of Navigation
P.O. Box 1126
Rockville, MD 20850

Dear Captain Carraway:

With reference to your request for a matching gift, we regret to inform you that gifts to your institution are not eligible for matching. It is our policy not to match gifts to organizations that do not employ a full-time paid management.

We are sorry that we are not able to be more helpful.
With kind regards.
Sincerely,
(s)Gloria P. Turner
Vice President

So much for all volunteer organizations.

DO YOU KNOW...?
*By Ernest Brown*

The phase-out dates for the Loran-C and Omega Radio-navigation Systems?
*(The answer appears on page 13 of this issue.)*

### Internet Address

The Foundation has long been a member of the Sailing Forum on Compuserve and receives E-Mail at The Navigation Foundation, 76476,1165. We can also be reached on the Internet at 76476.1165 @ COMPUSERVE.COM, and check out the Navigation Foundation's web page at www.olyc.com. Do not be surprised if E-Mail is not answered with the speed of electronics. I am barely keeping up with the mail. Some may say that I am not keeping up. They are also correct. My family does most of its traveling during the late fall and early spring. Last year we went to Russia in February. It was great. We are off in December to Turkey for the third time. If you have not tried Turkey, consider doing so.

### FAX

The Foundation can receive and send FAXes. To send a FAX to the Foundation you must call 301-622-1296 to let me know personally that you want to send a FAX. I will then set the computer to receive. It is a complicated system, I know, but it is necessary to follow this routine.

# READERS FORUM

*Edited by Ernest Brown*

Mrs. Phyllis Levine of 803 E. Palmaire, Phoenix, AZ 85020, wrote on September 24, 1995:

"Please be advised that ROBERT LORAN SMITH died on August 14, 1995. Enclosed please find a copy of his mailing label for further information.

"I was looking through the last issue (Summer 1995) and noticed a letter by Alan L. Olson of Michigan. My husband was also writing a book about navigation using the sextant and a hand-held calculator. Coincidentally, this was also written in the Basic language because of a number of calculation problems he had.

"The book was 95% complete when he died. I am interested in completing it and having it published. Is there someone in the Foundation that could review it for me and help with the calculations? I can do the word processing sections, but the others are beyond my expertise. I am sending a copy of this letter to Mr. Olson to see if he can help me.

"Thank you for your consideration of this request."

— *Sincerely, Phyllis Levine (widow)*

ROBERT LORAN SMITH

It is with sorrow we announce the passing of Robert Loran Smith on August 14, 1995

Our Executive Director wrote to Mrs. Levine on October 2, 1995:

"I was saddened to hear about Robert's death. Because the Navigation Foundation is such a small unique group of individuals, I feel as though I know each member personally. The loss of a member is like losing a friend. I extend my most heartfelt condolences to you on your loss.

"You have probably received a telephone call from Member Dan Hogan concerning the book you are trying to complete. I called Dan because he is an expert navigator, is computer literate, conducting a navigation problem on Internet and most reliable. If he is unable to help you I will contact some of the Directors of the Foundation. They also have expertise and contacts that may be able to assist you in completing Robert's work.

"When you complete your manuscript there are three publishers that may be interested in a work on celestial navigation: Paradise Cay Maritime Publications, Cornell Maritime Publications and The Naval Institute Press. The Navigation Foundation is an agent for each of the three publishers and I would be honored to call my contacts concerning publication.

"If I can be of any assistance please do not hesitate to call on me. The officials of the Foundation are all volunteers and we contribute our time and resources to further the art of celestial navigation. We are here to serve our members."

— *Sincerely, Terry F. Carraway, Captain, U.S. Navy (Retired), Executive Director.*

Director Allan Bayless of 116 Gardens Drive #201, Pompano Beach, FL 33069-0946 wrote on September 29, 1995:

"I suspect you, like most Editors, would like to have something useful for the Navigation Foundations Newsletter. I've been fussing with horizon sights recently and dreamed up the little problem I've enclosed. You're welcome to use it in the Newsletter if you think it's appropriate...

"I saw Roger Jones a week or so ago and had dinner with him. He's holed up in Fort Lauderdale with a leak in his boat from God knows where and has half his teak deck torn up to fill all the screw holes which he thinks the likely source. Unenviable job! The water comes in under the deck in the neighborhood of the chain plates, but he swears those apertures are sealed to a fare-thee-well. Mine developed a leak a few months ago from below, but it turned out well; the 20-year-old caulking around the fathometer through-hull transducer fitting was weeping about a hundred gallons a week. A little under-water epoxy and a swim fixed it.

"A friend of mine with whom I have been collaborating on a version of Dreisonstok's tables sent me a copy of *From Sails to Satellites* by J.E.D. Williams. Fascinating book; it has a reproduction of Halley's isogonic world chart (p. 89) of which you had earlier sent me a copy of a portion.

"Hope this finds you in the best of health and proceeding at flank speed!"

— *Cordially, Allan*

Director Allan Bayless wrote on October 2, 1995:

"... I was very interested in your comments on the new *Bowditch*. I knew celestial navigation was being abridged and wasn't too surprised at all the omissions. I haven't looked it over in great detail, and don't intend to, but I would guess most everything in Volume II went down the drain except for the surviving tables. I was interested to find the description of the dip short formula corrected to which Obe Ellis and I had called attention about 10 years ago. One thing for sure, I don't plan on throwing away the previous edition."

*— Cordially, Allan*

Director Allan Bayless wrote on December 3, 1995:

"Enclosed is an item that may very well be of no interest to either you or the readers of the Newsletter, but then again, it might interest someone. You may certainly give it the deep six. I've given upon The Ensign for things like this - anything remotely technical and they founder, totally. I wrote it principally to document it before it passes completely from memory. A sort of memorial to a close friend with a high curiosity quotient.

"However, I always thought it ingenious. Charles dreamed this up in the early years of hand-held electronic calculators when every step saved was money in the bank; I vividly remember squashing this reduction into a one-memory HP-35! It took a lot of judicious stack manipulation and a hell of a lot of button-pushing. I certainly appreciated programmable instruments when they became available.

"Incidentally, I had nothing whatever to do with its conception, its adoption by USPS, nor its abandonment. But Bowles was a close friend and I remember well when he dreamed it up.

"The example on page 2 shows an interesting example of rounding. 134.4990 rounds to one decimal as 134.5, but to the integral degree 134. This was done on Lotus and I had to check the calculation to be sure it knew what it was doing. Actually, Lotus is pretty clever; it'll round either up or down if you tell it to. Its default is up, like most calculator/computers. Of course, if you want it to do something fancy, like considering whether to round to an odd or even number (something else no longer mentioned in Bowditch), then some programming is in order. Admittedly, it isn't too vital considering all the decimals calculators/computers use.

"I'm a part-time medical transcriptionist these days, but my computer at work broke down, so my computer at home has been busy! The hospital loaned me a Fax for urgent stuff. Unless they want it back soon (doubtful as it has been unused in a storeroom for a year and a half), you can Fax me should you feel the urge. I don't have a dedicated line for it, so call my number (954) 977-7299, if you want to send something and Ill turn it on to receive it. New area code for Broward County. It was 305.

"The weather here has been superb for the last week or so: Cool! Marvelous! I don't really care for the Florida heat and my wife and I are here only because this is where my daughter lives."

*— Cordially, Allan*

Member Daniel R. Kerner wrote on August 29, 1995:

"I am an avid reader of your columns appearing in "The Navigation Newsletter." Enclosed with this letter you will find a brief paper that I wrote which was motivated by a navigation problem that you (William O. Land) raised in the Fall 1994 issue. I would be interested to read your derivation of the solution to the Initial Great Circle Course and Distance by H.O. 211.

"You might find the MLAB program on which the enclosed article is based of interest for navigational problems. I can send you further information about it if you would like."

*— Sincerely, Daniel Kerner*

*Editor's note: The enclosed article, "Great Circle Routes on a Mercator Projection of the World" by Daniel Kerner, Ph.D., of Civilized Software, Inc., 7735 Old Georgetown Road, Suite 410, Bethesda, MD 20814 (E-Mail: kerner@civilized.com) presents a script for the MLAB mathematical modeling program to compute and draw the great circle route between two arbitrary points on a Mercator projection of the world.*

Member Vanildo Maldi of Av Anhguera 7.206 Goiania Goias, Zip 74546- 010 Brasil, wrote on September 27, 1995:

"I am in receipt of the Newsletter No. 1 to 31. I thank you very much for your kind attention. The whole set, I mean the complete collection, is an invaluable source of knowledge for those who love the art of celestial navigation.

"I am enclosing my check amount U.S.$80.00 (namely, 60.00 for the back issues and 18.00 - which I suppose to be enough - for the following:) One copy of the corrected manuscript of member G. G. Bennett's article "THE TWO BODY FIX RE-VISITED", published in issue 44.

"I read about a diskette concerning the subject. If such a diskette is free of problems and my remittance is enough, one copy could be sent instead, which option is less bothersome for you.

"Once again, Capt. Carraway, please accept my words of gratitude."

*— Very Sincerely, Vanildo Maldi.*

Member Peter Ifland of 8560 Wyoming Club Drive, Cincinnati, OH 45215-4243, Phone and FAX (513)761-0952, E Mail PWIFLAND@ix.- netcom.com wrote on October 9, 1995:

"Attached please find a review of Willem Mörser Bruyns' book, *The Cross-Staff*, that I would like to submit for publication in The Navigator's Newsletter. I found the book to be informative, well written and a very useful addition to the literature on navigation instruments. I am also enclosing a floppy with the article in WORD6 which I hope will save you some typing if you decide to publish the piece.

"Although I am not a practicing navigator, I read your

Newsletter with great interest. I've learned a lot from it.

"If I can be of any help in editing my submission, please let me know."

— *Very truly yours, Peter Ifland*

Dr. Herrold E. Headley of 66 Girard Avenue, #317, Newport, RI 02840 wrote on 29 October 1995:

"In the 1991 winter edition of your Newsletter there was an article "Navigation Personalities" by Roger H. Jones on George W. Mixter. Little did he know at that time that I was in the process of updating and editing this outstanding contribution to navigation. I have taught many courses in Celestial Navigation in the last dozen or so years using that book and missed it greatly when it was no longer available.

"The project has been completed, and the Seventh Edition of the PRIMER OF NAVIGATION was published by W. W. Norton in June of this year. I asked that they send you a copy of the book, hoping that you might review it. It will have been the classic book on the subject for over half a century and I hope continues to be so. Did you receive a copy, and will you be reviewing it? If so, might I be sent a copy of the review?

"I would also appreciate an address and perhaps a phone number for Roger Jones. Also, how does one arrange to receive the Newsletter? Does one become a member of the Foundation?

"I teach courses in Celestial Navigation at least twice a year during the fall and late winter, as well as privately, and I am presently doing so through the auspices of the Museum of Yachting here in Newport. Seeing that you announce such in the Newsletter, how might it be arranged to have the courses here announced? I get students from this general area often including Naval officers taking a refresher course while at the Naval War College of NETC. I have a Naval Lieutenant in the present class. I am even willing to offer the course anyplace within perhaps a hundred miles from here for any group of half a dozen students or more. I can be reached either at the above address, or by phone at 401-849-1264, or through the Museum of Yachting, P.O. Box 129, Newport, RI 02840."

— *Sincerely, Herrold E. Headley*

*Editor's note: The Seventh Edition is reviewed in this issue.*

Member Frank Bailey of 415 Shady Drive, Grove City, PA 16127 (412-458-8306) wrote on October 8, 1995:

"I have been reading and enjoying immensely "The Navigator's Newsletter" unfortunately only since issue No. 26 and two questions have presented themselves to me which may have been covered previously or elsewhere. They are as follows:

"1. I have seen nowhere a discussion of the difference in sextant design between first surface mirrors and the mirrors with the silvering on the back surface. All diagrams trace the rays as if from a first surface mirror and one can approximate the ray tracing from a rear silvered mirror and see what happens to the ray geometry but are these "displacements" a factor in the sextant design, layout and construction? Gross mis-parallelism of the glass could be a factor introducing errors but I assume this is minimal. Also, a first surface mirror would be almost impossible to maintain.

"2. I have a Link A-12 bubble sextant. Is it possible that at some angles there is interference to the light rays as a result of the mechanical construction of the assembly? I have not used this instrument for a few years but I recall difficulty in sighting a body at certain angles and assumed it was because of the support for the shade glasses. Am I in error?

"As a final word, it is interesting to note that the mirroring on my John Bliss & Co. sextant is in excellent shape whereas the horizon glass on my Hezzanith has deteriorated to the point of no use, the repairing of which has brought to my mind question No. 1."

— *Sincerely, Frank Bailey*

*Editor's note: It takes much less than gross mis-parallelism to cause prismatic error. From the 1938 edition of Bowditch: "Mirrors having a greater angle than 2" between their faces are rejected for use in the United States Navy. Index mirrors may be roughly tested by noting if there is an elongated image of a well-defined point at large angles. Since the error due to a prismatic horizon mirror is included in the index correction, and consequently, applied alike to all angles, it may be neglected."*

On November 5, 1995 Member Frank Bailey wrote:

"I received your communication on the above subject (front vs. rear surface mirrors) and wish to thank you profusely for the effort which went into it. I inadvertently assumed a very brief note on the subject would suffice but I see that you and Mr. Luykx very kindly gave the subject some thought. Again, many thanks. I expect you might get many "hairbrained" letters and no doubt mine had the proper makings for one. I have read your communication several times and found some new insights into that instrument, the sextant. I will read it at least several more times to fully mine the information contained therein....

"However, I am off to Florida this coming Thursday and I just wanted to thank you for so kindly answering my letter, and taking the time to research it. I am busy packing and will certainly take your letter along with me and a few navigation books (among a bunch of other books). Packing for Florida is very onerous.

"One final note. I have been getting the newsletters since about 1990 and surely enjoy each and every one of them. The more I study this subject, it seems more and more interesting aspects turn up. It is needless to say: keep up the good work."

— *Sincerely, Frank Bailey.*

*Editor's note: Re any "displacement," the fact of parallel rays from a single star apparently has been overlooked.*

Member Michael Allen of 850 Pago Street, San Francisco, CA 94117 wrote on July 12, 1995:

"I've been messing around with celestial navigation for the past few years. Up until recently I was using a plastic beginner sextant, Davis MKIII, taking sights from a beach or using an artificial horizon. I've been doing the sight reduction and LOP determining using the Vol. 229 tables, or a programmable calculator and now using a spread sheet program (Excel) on my Mac that I set up to input all the data and which then calculates Hc, altitude intercept, position fix and plots the LOP's. The spread sheet resembles the Davis celestial navigation work forms.

"A couple of months ago, I went to the other extreme and bought a new C. Plath Classic model sextant from BC Navigation in Sausalito, California. It's a beautiful instrument and taking sights with it is a whole new experience. I have a boat, an older 42' cabin cruiser that we use up in the Sacramento River Delta region but in that location I obviously have no need for the sextant. Sometime in the future we want to charter a boat or maybe take a Windjammer cruise in the Caribbean where I could put my sextant to better use having an unobstructed horizon to work with.

"Here is my question or questions. I would like to be able to take accurate sights from land or up in the delta but that seems impossible without an unobstructed horizon. I have been using my Davis artificial horizon, the type that uses water or other liquid like oil, to reflect the image resulting in doubling of the sextant altitude. With a little practice I've been able to take fairly consistent sights but all of the altitudes I measure when using the artificial horizon appear to be too large by 4 to 6 minutes which translates to a 2 to 3 mile error in my altitude intercept position. I only seem to get this error when using the artificial horizon, the sights I've taken at the beach using the real horizon are giving me positions within a few tenths accuracy limited by my ability to take accurate sights. I've taken sights of the sun and moon both upper and lower limb and also Jupiter. In every case the altitudes are too large by 4 to 6 minutes. One interesting thing is that my left eye seems to work better than my right eye, i.e., when I line up the two images using my left eye, the error is about half that when using my right eye. Do you know if there is any inherent reason why the artificial horizon would give this error? Is it a consistent error I can include in the calculations like dip? Do you have any advice on taking accurate sights with an obstructed horizon? What about an artificial horizon bubble sight attachment? C. Plath offers one for about $1700.00 but that's out of the question. Any advice you can give me on using an artificial horizon as well as helpful hints on using the sextant with a clear horizon would be greatly appreciated. You can send information to the above address or fax or E-mail me using the following: michael.allen@eng.sun.com (E-mail address); 408-774-2099 (fax); "

— *Michael Allen*

*Editor's note: The article "The Accuracy of the Artificial Horizon" by John M. Luykx in issue 49, Fall 1995, should be helpful in this matter.*

Mr. Gary Scott of 12215 Tildenwood Drive, Rockville, MD 20852 wrote on October 13, 1995:

"I read with great interest about your organization which, to my surprise, has an address very close to my home.

"I have always held that traditional navigation is a special magic performed by revered persons. My 10 years sailing experience has been mostly in the Chesapeake Bay, plus three offshore trips. While I do not currently own a boat, I wish to learn the respectable skill of celestial navigation and to participate in activities pertaining to such navigation. My ultimate goal is to travel offshore and utilize such skills.

"Some years ago I purchased a mail order course, but failed to complete it. I believe I would do better in the company of others. I am about to buy the Mary Blewitt book, 'Celestial Navigation for Yachtsmen', and try again.

"Please pass on to me any suggestions or guidance on this issue of learning celestial and information regarding activities that I might participate. Thank you."

— *Very truly yours, Gary Scott*

*Editor's note: "Celestial Navigation - An armchair Perspective," a series of articles now being published in this newsletter, should be very helpful to the beginner.*

Member Raphael C. Marshall of 14802 Tabor Avenue, Maple Heights, Ohio 44137 wrote on November 1, 1995:

"Congratulations for all you are doing to promote the Art of Navigation.

"After teaching Celestial Navigation for the Cleveland Power Squadron for fifty years, I had to give it up. I still am interested and work a line of position problem now and then.

"I am sending you a check for $55.00, which I hope will cover the cost of a 1996 Nautical Almanac and my 1996 dues to the Foundation."

— *Sincerely yours, Raphael C. Marshall*

Mr. George H. Kaplan of the Astonomical Applications Department, U.S. Naval Observatory, 3450 Massachusetts Avenue NW, Washington D.C. 20392-5420, wrote on January 2, 1996,

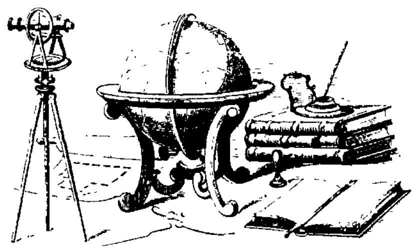
"The enclosed manuscript, "The Motion of the Observer in Celestial Navigation", is submittted for your consideration for publication in *The Navigator's Newsletter.*"

"This paper is part of a series of technical reports that have grown out of a project of our department to provide standard celestial navigational software to the Navy. This software is scheduled to become a module in the Navy's integrated navigation system, NAVSSI. Because NAVSSI is a system that analyzes data from a variety of sensors, we decided to anticipate the possibility that at some time in the future automated shipboard star trackers might provide the basic observational data. Since these devices are capable of arcsecond-level measurement precision, our software was designed with one arcsecond (30 meter) or better precision as a specification."

"This specification lead us to re-examine the basic techniques and algorithms used in celestial navigation. In several cases, we had to design our own high-precision algorithms. Our oblate-earth sailing formulas were just published in the latest edition of *Navigation*, and another paper on our basic navigation solution in in press. The enclosed manuscript, on the methods used to account for the motion of the observer during a series of observations, is more of a review and is less mathematical than our other reports, and may be of interest to a wider readership. I hope you will consider it for publication in your newsletter. It has not been published, or submitted for publication, elsewhere."

"Thank you for your consideration."

—*Sincerely yours, George Kaplan*



# NAVIGATION NOTES

## Sign Conventions for Sight Reduction

*By Allan Bayless*

From the time calculator sight reduction was adopted by the United States Power Squadrons' Navigation course until the 1993 revision, a period of more than 10 years, the course used a sign convention for the cosine law equations devised by the late Charles Bowles, a dedicated member of the Navigation Committee until his death.

sin Hc=sin L sin d+cos L cos d cos LHA
cos Z=(sin d-sin L sin Hc)/cos L cos Hc

**Figure 1. The equations**

Bowles' sign convention is direct and unconditional.

| Conventional | Bowles |
|---|---|
| L always (+) | L or d(-)if S |
| d(-) if contrary name to L | |

**Figure 2. Sign conventions for initial data**

The negative value for south latitude results in a negative value for its sine in the altitude azimuth equation. As a result, the cosine of Z is negative and the arc cosine is the supplement of Z. Consequently, there are two additional cases for south latitude.

In the N course, the supplement was called Zc to distinguish it from Z. Z in Bowles' north latitude cases was also called Zc, whence Zc = Z when latitude is north, 180° - Z when latitude is south.

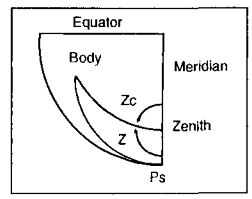



**Figure 3. Zc = 180° - Z**

In Bowles' south latitude cases, Zc is returned directly and is the same as the conventional SE case, Zc=(180°-Z) = Zn. The SW case is obtained by the additional calculation (360°-Zc) = (180°- Z) = Zn.

**CONVENTIONAL**

| L and d same name | |
|---|---|
| LHA or t | 25°46.8' |
| L | 39°50.6' |
| d | 11°01.3' |
| Hc | 53°14.2' |
| Z | 134.5° |
| NE: Zn = Z | 134° |
| NW: Zn = 360°-Z | 226° |
| SE: Zn = 180°-Z | 46° |
| SW: Zn = 180°+Z | 314° |

| L & d contrary name | |
|---|---|
| LHA or t | 25°46.8' |
| L | 39°50.6' |
| d | -11°01.3' |
| Hc | 33°47.4' |
| Z | 149.1° |
| NE: Zn = Z | 149° |
| NW: Zn = 360°-Z | 211° |
| SE: Zn = 180°-Z | 31° |
| SW: Zn = 180°+Z | 329° |

**BOWLES**

| L and d north | | L and d south | |
|---|---|---|---|
| LHA or t | 25°46.8' | LHA or t | 25°46.8' |
| L | 39°50.6' | L | -39°50.6' |
| d | 11°01.3' | d | -11°01.3' |
| Hc | 53°14.2' | Hc | 53°14.2' |
| Zc | 134.5° | Zc | 45.5° |
| E: Zn = Zc | 134° | E: Zn = Zc | 46° |
| W: Zn = 360°- Zc | 226° | W: Zn = 360°-Zc | 314° |

| L north and d south | | L south and d north | |
|---|---|---|---|
| LHA or t | 25°46.8' | LHA or t | 25°46.8' |
| L | 39°50.6' | L | -39°50.6' |
| d | -11°01.3' | d | 11°01.3' |
| Hc | 33°47.4' | Hc | 33°47.4' |
| Zc | 149.1° | Zc | 30.9° |
| E: Zn = Zc | 149° | E: Zn = Zc | 31° |
| W: Zn = 360°-Zc | 211° | W" Zn = 360°-Zc | 329° |

**Figure 4. The two techniques**

His north latitude cases duplicate the conventional cases and in these, Zc=Z=Zn for the NE case and (360°-Zc) = (360°-Z) = Zn for the NW case.

### Summary:

Bowles'sign convention simplifies the calculation of Zn, the result of doubling the number of cases: Zn is either the direct solution of the altitude azimuth equation or its separately-calculated explement, depending only on whether the body is east or west and regardless of whether latitude is north or south. In any given sight reduction, the conventional sign rules require additional calculation for three of the four possible values for Zn. Bowles' rules require additional calculation of only one of two possible values.

### Additional Note:

The cosine law equations are also used to find great circle distance and initial course. Using Bowles' sign convention, the same considerations apply to C and Cn as to Z and Zn.

## A Navigation Problem: Horizon Sight Without a Sextant

*By Allan E. Bayless*

PROBLEM

During a severe storm in the Atlantic, the navigator's vessel suffered a violent knockdown and no electronic gear survived. After the storm, when the sky cleared and the seas moderated sufficiently to permit a sorely needed sun sight, the navigator went on deck with his sextant. However, he tripped over some of the debris on deck and damaged his sextant so it was unusable. Intrepid navigator that he was, he decided to take an observation of the sun at sunset, without a sextant.

He was 0°00', of course, but when corrected, HO was (-)54'. He reduced his sight for his doubtful DR and determined Hc(+)54'.

What was his intercept?

SOLUTION

The "usual rule" for finding the intercept, "Hc>Ho, a is A" doesn't apply to negative or mixed altitudes, but the navigator knew another rule that *always* applies, no matter whether the altitudes are positive, negative or mixed: *If Ho is Higher (in the sky), a is Toward* (a good mnemonic is HOT). In this instance, Hc is *Higher* as it is above the horizon, so the intercept is Away.

It is apparent the navigator is farther from the body than the DR as the altitude can only be positive where the sun has not yet set, i.e., west of the navigator's horizon. As the intercept is drawn from DR (from which Hc is calculated) to LOP (the navigator's position, whence Ho), it must be Away from the body.

The magnitude of the intercept is always the difference between the altitudes. In this instance, a=54'-(-54')=108 mi. Actually, the navigator also remembered the corollary to the first rule: *Add if Ho and Hc have different signs. So,*

a = 108 mi Away

# NAVIGATION BASICS REVIEW

## Celestial Navigation - An Armchair Perspective

*By Roger H. Jones* Copyright © 1995, Used With Permission

*Editor's note: Beginning with Issue 49, Fall 1995, Director Roger H. Jones is presenting a series of articles on celestial navigation, written in layman's terms and addressed to those members who have nursed ambitions towards the celestial art, but who have been understandably daunted by the common perception of the difficulty of the subject.*

### Article Number 4

*By Roger H. Jones*

In the first and second articles the celestial theory in almost its entirety was presented in simple layman's terms. Only a few "fine points" were left for later digestion. More than enough was revealed to get our navigator out of his sea berth and up on deck with his sextant and chronometer. In the third article we followed him as he made a quick mental check of the Greenwich time and date relative to his own local time and date. We watched him check the atmospheric conditions and note his height of eye (HE) above the water level and the index error (IE) of his sextant. We saw that to the raw sextant altitude (HS) the negative HE correction must first be made, and then the plus or minus correction for IE, resulting in Apparent Altitude (HA). For example, with a height of eye of 12 feet the *Almanac* tabulates a correction of minus 3.4 minutes of arc. If a positive IE of 2.2 minutes of arc exists, there would be a further minus correction of 2.2, or a total subtraction of 5.6 minutes of arc from the HS. With a negative IE of 2.2, the *net* correction would be minus 1.2 thus far. Simple!

After determining the IE, the navigator will proceed directly to the Sun altitude, HS. He'll flip down the appropriate sun shades on the sextant, and, holding the sextant *vertical*, will orient its telescope and mirrors in the direction of the glare on the horizon beneath the Sun. He'll move the arm outward along the arc until the sun appears as a disk just above the horizon through the clear portion of the glass. Then, using the micrometer drum, he'll bring either the Lower Limb or Upper Limb (bottom or top rim) of the Sun down so that it just barely kisses the horizon. It is sometimes possible to use one limb when the other may be obscured by clouds. At the precise moment when the curved rim to the Sun is just tangent to the horizon, the navigator will note the GMT, or call out "Mark" with someone else noting the nearest second of time. If he does it himself, he can use a stop watch or mentally count five seconds as he glances at his watch, and then subtract five seconds from the watch time. In order to be sure that the sextant is held vertical, the navigator may rock it left and right in the hand holding it, and the disk will appear as a pendulum in an arc above the horizon. At the lowest part of the swing, the sextant will be vertical. The vertical edge of the horizon glass can also be used to judge perpendicularity to the horizon.

Being careful not to move the arm or drum, the navigator will then read the sextant. Whole degrees will be read on the sextant arc, and minutes and tenths will be read on the drum. At this point, our navigator has HS. The corrections for HE and IE will take him quickly to Apparent Altitude (HA), and then a further simple Main Correction will result in Observed Altitude (HO). Assume a raw HS of 47-32.6 for the Lower Limb of the Sun on November 1st at a certain GMT. With an HE of 12 feet and a positive IE of 2.2, the first two corrections (totalling 5.6') would result in an HA of 47-27.0. Taking into account height of eye and index error, the Sun's LL was a vertical angle above the horizon equal to that magnitude of Great Circle Arc. But wait! Can this be true?

It is time to delve into the Great Circle Arc. It is simply an arc on the surface of the Earth, or one that also extends out into infinite space, *whose center is the center of the Earth.* Since our navigator was on the surface of the Earth, rather than at its molten center, when the sextant shot was made, the point of origin of the angle and the resultant arc were at the surface and not the center of the Earth. In Celestial theory and practice we are interested in Great Circle Arcs, and we must therefore move our navigator some 3,438 nautical miles down to the center of the Earth. Depending on the altitude of the Sun from low above the horizon to high above the observer's head, the angle measured at the Earth's surface will be less than one measured from the vantage point of the Earth's center, and the lower the altitude the greater the difference will be. The value of this difference is called Horizontal Parallax (HP), and the problem of HP is resolved by the third or Main Correction.

This main correction is tabulated at the front of the Almanac to include the correction for HP. Parallax varies not only with the altitude of the celestial body (in our immediate case, the Sun), but also with the time of year and the distance of the body. The closer the body, the greater the parallax. (Thus for the Moon parallax is even greater). In January the Earth is closest to the Sun in its orbit around the Sun, and in July it is the farthest away. The upshot is that in the Altitude Correction Tables, our navigator enters for the Sun in either a column headed "Oct. - Mar." or one headed "Apr. - Sept.", and he enters on the correct line for Apparent Altitude. He extracts a main correction which is either a plus one for a Lower Limb sextant shot or a minus one for an Upper Limb shot.

Thus, the pre-computed Main Correction includes the parallax correction together with one related to the fact that what our navigator really wants is the altitude of the exact center of the Sun above the horizon and not its lower or upper rim. The Main Correction also includes the factor for the semi-diameter of the Sun because a LL shot will be less than the altitude of the Sun's center and a UL shot will be greater than the altitude of the center. Again, the time of the year affects the apparent size of the Sun and hence its semi-diameter. The altitude of the center cannot be measured directly, only the Sun's rim gives a sufficiently precise reference for the naked eye and a sextant telescope. Finally, the Main Correction combines a correction for normal refraction, based on an assumed temperature and atmospheric pressure, but in practical terms the average navigator does not even stop to think about the elements of the overall correction. He just looks it up and uses it.

In the example above, the HA on November 1st for a lower limb shot was 47-27.0'. The Main Correction from the Almanac would be plus 15.4', and the resultant final Observed Altitude (HO) would be 47-42.4' of Great Circle Arc as measured by a navigator perched on a molten slag at the center of the Earth. To be continued.

## Article Number 5

*By Roger H. Jones*

In the preceding article the navigator observed the Lower Limb of the Sun on November 1st at a certain GMT. He applied Height of Eye and Index Error corrections to this raw Sextant Altitude, HS, and the *intermediate* result was Apparent Altitude, HA. He then applied a Main Correction, taken from the *Almanac*'s Altitude Correction Tables, and arrived at the *ultimate* Observed Altitude, HO. HO emerged after no more than two minutes of effort. While the altitude of the bottom rim of the Sun above the horizon was measured, *HO was the mathematically corrected altitude of the center of the Sun* because the semi-diameter of the Sun (from its rim to its center) was a plus component of the Main Correction for the Lower Limb shot. Moreover, the "straight out" horizontal plane of the navigator's horizon was, of course, parallel to a horizontal plane running from the center of the Earth through its surface out into space, and the horizontal plane at the surface was, in effect, moved to the center of the Earth by the parallax component of the Main Correction. With the component for refraction taking care of the bending of the Sun's light rays as they passed through the Earth's atmosphere, HO was thus the altitude of the *center of the Sun* as measured from the vantage point of the *center of the Earth. HO was also an indirect measurement of the arc distance on the surface of the Earth from the navigator's actual position to the GP of the Sun.*

Navigators, envision this. You are standing on the horizontal flat surface of a large frozen lake. Your arm is held out horizontally parallel to the lake's surface, and that, in turn, is parallel to a horizontal plane passing through the Earth's center. You raise your straight arm until it points vertically straight up to a point in the sky directly over your head. As you raise your arm, your finger tips inscribe the arc of a 90 degree angle from the horizontal up to the vertical. Take it one step further. A straight line from the Earth's center passing through your body in a vertical plane would run into space to a point directly over your head, and that point in space, irrespective of its distance from you, is called your Zenith. Your Earth position is where the figurative line to your Zenith intersects the Earth's surface. Similarly, a line from the center of the Earth to the center of the Sun passes through the Sun's GP on the surface of the Earth. A simple geometric truth is this: *the arc distance out in space from your Zenith to the center of the Sun is exactly the same as the arc distance from your Earth position to the Sun's Earth position, its GP.*

You cannot measure the arc distance from your Z directly to the center of the Sun because you have no precise visible reference in the heavens over your head to pinpoint your Z. Also, as the Earth rotates on its axis, your Z in the vastness of space constantly changes. *However, you can measure the arc from your horizontal plane up to the center of the Sun because you have the visible reference of your sea horizon.* The arc distance from your horizontal to your Z is 90 degrees. The arc distance from your horizontal plane to the center of the Sun is *included within* the overall arc of 90 degrees. Thus, the arc distance from your Z to the center of the Sun, known as Zenith Distance (ZD), must be 90 degrees minus HO. ZD is the complement of HO. In the preceding example, where HO was 47-42.4', ZD would be 89-60.0 minus 47-42.4, where minutes and tenths are subtracted from 60.0' and whole degrees are subtracted from 89 degrees. The resultant ZD would be 42-17.6'. That is the arc distance from the navigator to the GP, and it is equal to 2,537.6 nautical miles.

In the real world the navigator never even has to bother with doing the subtraction to arrive at ZD. In effect, it is done for him by the sight reduction tables. They tabulate not only the direction from the Assumed Position (AP) to the GP at the fleeting moment of the sextant shot but also the altitude of the center of the Sun that would have been measured if the navigator had been at the AP rather than at his actual position. A comparison of the altitude computed for the AP with the navigator's HO results in a difference of minutes and tenths of arc where the smaller value is subtracted from the larger. If HO were smaller than the altitude computed for the AP, it would be subtracted from the tabulated value and vice versa. That leads to the so-called Altitude Intercept which is quite simple, but which will be discussed in a later article.

Meanwhile, return to your sea berths, navigators, and commence a well earned rest. You have just journeyed to the center of the Earth to take a sextant shot of the Sun. Relax and contemplate what you have done, but always keep it simple. In celestial navigation we are interested in Great Circle Arcs because they and the angles which define them originate at the center of the Earth.

The arc distance between two points out in space is the same as the arc distance between two points on the surface of the Earth that lie, respectively, directly beneath the points in space. The arc out in space is the same as the arc at the Earth's surface, because the two sides of the angle meet and begin at the exact center of the Earth. By virtue of the distance of the surface of the Earth from its center, one minute of Great Circle Arc at the surface equals one nautical mile. Thus arc distance at the surface of the Earth can be converted to nautical miles and vice versa. To accommodate the necessity of the Great Circle Arc where this interrelationship holds true, the navigator, in measuring angles and arcs is, by virtue of the altitude corrections, moved to the center of the Earth for the fleeting moment in time of his sextant shot.

Congratulations! You have just drawn in your mind the diagram of the 90 degree Great Circle Arc from the horizontal to the vertical and the *included arc of the altitude of the center of the Sun above the horizontal. The complement of the included angle is the ZD, which is your real goal.* Countless texts have presented this in a drawing of often bewildering detail. One aim of these articles is to avoid complex diagrams and equations, and this author is confident that the picture you have drawn in your own mind is worth far more than one drawn by someone else upon a page. We'll visit this again. Take heart. By far, the most difficult is already behind you. We have only to cover the actual use of the *Almanac* to determine the exact GP of the Sun, the use of the sight reduction tables, and the Altitude Intercept to plot the LOP perpendicular to the True Bearing of the Sun's GP. To be continued.

## Article Number 6

*By Roger H. Jones*

Navigators, your armchair journey started with the basic theory of celestial navigation: the concept of the Line of Position plotted by means of distance and direction from the known Earth coordinates of the center of the Sun at any given second of time, the Sun's GP. The *Almanac* reveals those coordinates, the sextant measures the distance that the navigator's LOP is from the GP, and the sight reduction tables reveal the true direction and a final adjustment to distance. You journeyed to the center of the Earth, by virtue of the altitude corrections, in order to discover the altitude of the center of the Sun above a horizontal plane passing through the Earth's center, and along the way you passed the procedural milestones for the actual use of the sextant. You have arrived at an intermediate destination known as HO - the Observed Altitude of the Sun. You are ready to discover the precise coordinates of the GP as your journey continues.

Having obtained HO by correction of the raw HS value, we must now re-enter the *Almanac* with the exact GMT and Greenwich date in search of the exact coordinates of the GP for the fleeting moment in time of the sextant shot. The first thing to do is to devise a work form that will organize the elements of our data. We'll use a single vertical column for each separate sextant shot, and *starting at the top* we'll fill in the data in a logical, real-world sequence.

| | | |
|---|---|---|
| OBSERVATION OF: | ____________ | Describe it i.e., "Sun-LL"(Lower Limb,etc. |
| LOCAL DATE: | ____________ | Date at your own location. |
| DR POSITION: | ____________ | DR Latitude<br>DR Longitude |
| COURSE/SPEED: | ____________ | Such as "246 True/6.8kts", etc. Normally not needed for most celestial problems. |
| HEIGHT OF EYE: | ____________ | Feet above sea level. |
| INDEX ERROR: | ____________ | Describe it such as "On arc 2.2" or "Off arc 1.7", etc. "On arc" means it is a positive value above zero on the sextant arc; "Off arc" means a negative value less than zero. "On arc" values are subtracted from HS; "Off arc" values are added to HS. |
| GMT: | ____________ | Hours, minutes and seconds, i.e. "17-37-09". |
| TEMP./PRESS.: | ____________ | Usually ignored, but unusual temperature or barometric pressure should be noted, i.e. "10F/30.3 inches". See Almanac instructions. |
| HS: | ____________ | As read on sextant, i.e. "38-12.7" |
| HE CORR'N: | ____________ | From Almanac "DIP" table - subtract. |
| IE CORR'N: | ____________ | Add or subtract as appropriate. |
| HA: | ____________ | HS corrected for HE and IE. |
| MAIN CORR'N: | ____________ | From Almanac for the specific HA. Sometimes there is even a 2nd or 3rd value for the Main Correction, but usually, not necessary, and a single value suffices. |
| REFRACT.: | ____________ | Additional refraction - usually ignored. |
| HO: | ____________ | HA plus or minus the Main Correction. |
| G DATE: | ____________ | Greenwich Date - either the same as or different from the Local Date. |
| GHA - HOUR: | ____________ | From the Almanac - Greenwich Hour Angle for the whole hour of time, i.e. "83-21.6". |

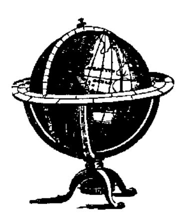
At this point, apart from the few minutes it may take to make the actual sextant shot, it will have taken you only a very few additional minutes to record your data and arrive at HO for the GMT of the shot.

You'll turn to the Daily Pages of the *Almanac* where each page spans three consecutive days of the year and presents GHA values for each celestial body for each *whole hour* of GMT for each of the three days. In the Sun column for each whole hour of any given day the GHA value listed is the *longitude arc* distance of the center of *the Sun* measured *westward* from the Greenwich Meridian. This is a continuous westward measurement through the full 360 degrees covered in 24 hours. Thus, GHA values from zero to 180 degrees will describe GP locations in West Longitude, and those from 180 to 360 will describe GP locations in East Longitude. For each whole hour the Declination listed is simply the latitude of the GP north or south of the Equator, and the "d" value at the bottom of the page is the average Declination change from one hour to the next over the three day period. Declination changes much more slowly than GHA.

Extract the value of GHA for the whole hour. Enter it on your work form (GHA - Hour). Now turn to the Increments and Corrections pages. Your GMT was stated as hours, minutes and seconds, i.e. "17-37-09". For the 37th minute and 9th second you will find that the GP moved on westward another 9 degrees and 17.3 minutes of arc beyond the GHA for the 17th hour. Add this to the value for the full hour. Thus, your continuing work form would appear as follows:

| | | |
|---|---|---|
| GHA - HOUR: | ____________ | GHA for the whole hour, i.e. 17th. |
| MIN/SEC.: | ____________ | Increment, i.e. "9-17.3". |
| GHA: | ____________ | GHA for the Sun at the hour, minute and second of the sextant shot. |
| DEC. - HOUR: | ____________ | Declination at the whole hour, i.e. "23-09.1" |
| INCR. - MIN.: | ____________ | Declination increment for the minutes in time beyond the whole hour. On the Daily Page note the "d" value. On the Increments and Corrections page go down the "v" or "d" column to the "d" value from the Daily Page and note the correction. Add or subtract it according to whether the DEC. is increasing or decreasing from one hour to the next on the Daily Page. Declination changes so slowly that no increment for seconds of time is used. |
| DEC.: | ____________ | Declination for the full hour and minutes of GMT. |

Now take your *Almanac* and make up your own example, filling in the blanks above. Use the HE that would apply on your own boat. Use an arbitrary IE of one or two minutes both "on" and "off" the sextant arc. Use an arbitrary HS. Select a GMT and date and determine GHA and declination. (To be continued.)



# NAVIGATION PERSONALITIES

## Roald Amundsen

*By William O. Land*

(Continued from Issue #47, Spring 1995)

Roald Amundsen returned to Norway in 1913 from Antarctica and, being never content, immediately began plans to revive the 5-year arctic drift using the Fram. However, in 1914 World War I broke out in Europe and his plans were temporarily delayed again. He had his usual trouble raising money, so he organized a shipbuilding company in hopes of financing the expedition himself. By 1918 Amundsen had earned enough money to build a ship named the Maud, 120-foot length and 40-foot beam. He also purchased a Farman biplane and learned to fly it. On July 15, 1918, he had the Maud ready, equipped and fully loaded with food for the 5-year drift in the Arctic. His aim was to drift from the North Siberian Islands across the North Pole. To reach his starting point he had to transit the Northeast Passage.

In negotiating the passage in the course of two winters, Amundsen was the first to sail along the whole of the northern coast of Europe and Asia since the first transit by Nils A. E. Nordenskjöld in 1878-79. Otherwise, things went badly for Amundsen. The landing gear of the Farman biplane was so badly damaged during a test flight that the plane was of no further use. The insurmountable problem was inadequate knowledge of the polar currents which were to take the Maud over the North Pole. After three years and when the ice had melted enough to free him from the ice, Amundsen returned to Norway and planned a 7-year trip in the Maud again, but even with some government backing he did not have enough capital to properly equip the expedition and suddenly found himself in personal bankruptcy. He thought he could raise enough money to cover his financial troubles by lecturing in the United States in the autumn of 1924. But he soon found the lecture circuit did not draw large enough audiences to finance his plans. By chance he met an American, Lincoln Ellsworth.

At the time of this meeting, Ellsworth was about to leave for a second tour with a geologic survey of the Peruvian Andes. Earlier he had volunteered to join polar explorations without success. Having rejected his wealthy father's offers to join him in the world of business and associated luxuries, Ellsworth had led a life which prepared him both mentally and physically for arctic exploration. In France in World War I he had learned to fly but at age 37 was considered too old for combat. He was 44 years of age when he met Amundsen in his hotel room in New York City in the autumn of 1924.

With Ellsworth indicating that he might be able to help finance a polar exploration, their talk soon turned from a 7-year drift in the ice to an aerial survey of the Arctic with Spitsbergen as the base of operations. However, if Ellsworth was to help financially, he would have to get the money from his somewhat estranged father. In due course, and with some help from Lincoln Ellsworth's sister, Clare, the father provided $85,000, about equivalent to $500,000 today, for the exploration.

To carry out their plans, Amundsen and Ellsworth purchased two Dornier-Wal flying boats built in Pisa, Italy. The planes were high wing open cockpit monoplanes of aluminum construction with the main body of the plane acting as a single pontoon. Mounted centrally above the wing were two 750 horse-power Rolls Royce engines in tandem, each with a 4-bladed propeller. The forward engine was a tractor, and the rear engine was a pusher. The cruising speed at full load was about 90 miles per hour. These planes could take off or land only on open water, and usually needed almost a one-mile run to lift off the water and become airborne.

Amundsen's plans called for six persons to crew the two planes. Each plane accommodated three crew members for sleeping as well as living aboard, and had provisions for surviving a long period of time in the event the planes were forced down. Two steamships were chartered for the expedition, the *Farm* and the *Hobby*. The airplanes were disassembled in Norway, stowed aboard the decks of the ships, taken to King's Bay, Spitsbergen and reassembled there.

Kings Bay, (Kongs B.) at about 79° N on the western shore of Spitsbergen, is in the path of a weak meandering current of the Gulf Stream, and as a result there is a short but relatively warm spell for several weeks each summer. It was here the exploration began. The two planes flew together and made several exploratory flights toward the North Pole, and several flights east of Spitsbergen, charting the terrain and the open passages of the sea north of Russia and Siberia. Even though the planes were the best available at the time, they had their problems. The engines gave them trouble, and navigating in fog was always hazardous. They had trouble with ice-pans in the water during take-offs and landings, and the aluminum hulls were leaky.

The most notable flight was that of May 21, 1925. In the article by Donald Dale Jackson, "Lincoln Ellsworth, the forgotten hero of polar exploration" published in the October 1990 (volume 21, number 7) issue of the *Smithsonian*, we are told that the stated goal of the flight was to make a dash to the Pole and return. If a landing at the Pole proved to be possible, it was secretly planned to transfer all fuel to one plane and fly to Alaska while searching for unknown land enroute.

In *First Crossing of the Polar Sea* by Roald Amundsen and Lincoln Ellsworth, we are told by the authors that in their meeting with the Royal Norwegian Navy First Lieutenants Hjalmar Riiser-Larsen and Lief Dietrichsen, at Svalbard (the archipelago) in May 1925, the possibility of a flight from continent to continent, via the North Pole, was *thoroughly* (emphasis added) discussed for the first time. The first venture (May 21, 1925) was to be considered merely as a reconnoitering expedition for the later intended flight over the Polar Sea.

At this meeting Riiser-Larsen drew attention to the Italian airship N1 as being the craft best fitted for the polar sea flight.

A few days later on May 21, 1925, two twin-engine Dornier Wal open cockpit seaplanes, N24 and N25, took off from Kings Bay, Spitsbergen, some 600 miles north of the northern coast of Norway. Amundsen, pilot Riiser-Larsen, and German mechanic Karl Feucht crewed N25. Ellsworth as navigator, Lief Dietrichsen as pilot, and Norwegian mechanic Oskar Omdhal crewed N24.

After two hours Ellsworth observed the white ice cap streaked with ribbons of water. Five hours later when they believed they were close to the North Pole, they landed in an area of narrow leads among huge bergs and hummocky mounds of ice. In the landing, N24 was damaged beyond repair and N25 was locked in the ice. The planes were 3 miles apart with the crews unable to reach each other. Position was established as 87°44′N.

After several days the wind pushed the floes the crews were on closer together until they were just a half-mile apart. On May 26, Ellsworth, Dietrichsen and Omdhal, knowing their only hope was to reach N25, set off on skis across the thin ice. As described in Jackson's article in *Smithsonian*, Dietrichsen behind Ellsworth suddenly cried out and fell through the ice. Omdhal screamed as he also fell. Ellsworth started to slide, dropped to his stomach and extended his skis to Dietrichsen, who grabbed hold and pulled himself out. Ellsworth then crawled to Omdhal, poked a ski within reach of the floundering man and held on until a revived Dietrichsen helped him get Omdhal's pack off so they could pull him out. The three then stumbled on to their reunion with Amundsen.

In his journal on May 31, Ellsworth wrote, "I don't think six men ever found themselves in a more hopeless position. The leads won't open up and the ice is too thin to run the plane onto them. We are marooned on an ice cake 250 yards square." The six men, then on half ration of biscuits, hot chocolate and pemmican, agreed that if they couldn't get the plane into the air by June 15, they would decide individually whether to stay there or attempt a trek to Greenland.

After finding a floe large enough for a runway, the six men worked hard for a week in bridging two crevasses to get the plane onto the floe and in hacking and packing the ice smooth enough to enable take-off of the seaplane. On the morning of the 15th of June, N25 with the six men on board, lifted off the "crisp as tile pavement" runway after a bumpy run. Eight hours later N25 landed off Spitsbergen where the men were picked up by a sealing vessel. (To be continued)

# MARINE INFORMATION NOTES

*Forwarded by Ernest Brown*

## Internet Mailboxes

The Defense Mapping Agency announces two Internet addresses which mariners can use to send in data and/or request information. They are:

a. for information to update the Sailing Directions, Fleet Guides and other navigational publications SDPUBS@dma.gov

b. for information on the DMA electronic bulletin service Navigation Information Network (NAVINFONET) NAVINFONET@dma.gov

Please provide a name, mailing address, telephone number and ship's call sign.

## DMA Office Consolidations

DMA has closed its Marine Representative Offices in Long Beach, CA and New Orleans, LA effective 5 August 1995. Consolidated functions of these offices will be coordinated by Mr. Tom Hunter, Fleet Liaison Officer, Bethesda, MD 227-3370.

## New Chart Correction Template

The Chart Correction Template (DMA Stock No. WOXZP9998) has been extensively revised. The new instructions, particularly the Guide to Symbols, should be reviewed before using the template.

# BOOK REVIEWS

*By Terry Spence*

## PRIMER OF NAVIGATION

By George W. Mixter, CELESTAIRE (Seventh Edition)
416 S. Pershing, Wichita, Kansas 67218 (1995) $35
Telephone Order: 1-800-727-9785

When I first started out on my learning and pursuit of the Art of Navigation several names kept cropping up—Bowditch, Duttons, Squire Lecky and Mixter's were among the more frequent. I was able to acquire the first two books mentioned but quickly found out that the latter two were "out of print." Despite searching at used book stores (not many in Las Vegas and none dealing with navigation) neither turned up. I was very happy when a review of the 1995 Celestaire catalogue showed Mixters for sale. The fact that this is the seventh issue of this navigation text testifies to its value and acceptance.

This book was first published in 1940 and was widely used to teach navigation for use in World War II (according to the preface to the seventh edition.) Following this preface there is a biographical sketch of Geo. W. Mixter. The interesting beginning to this preface (and I quote) "for a man whose career began in the farm machine industry, who was later an industrial and consulting engineer, served his country in the Army Air Force rather than the Navy ... to have produced the outstanding book of his time on nautical piloting and celestial navigation may seem surprising." (Chapman's of course is included in this list; however I have had a copy of this invaluable text for years.)

My first review of the book was a little disappointing as it did not match my thoughts of what the book would be. However, upon subsequent reading and study I became convinced that I would use the book a great deal. The text follows the accepted pattern of describing tools of the trade currently in use, publications, compasses and its necessary corrections, buoyage systems, dead reckoning and celestial navigation. There is a chapter on electronic navigation systems up to and including GPS. The chapter on Sumner Lines was, to me, very interesting and helped me understand the theory of the LOP. The illustration showing Captain Sumner's actual plotting of his LOPs and thus discovering the Sumner lines was enlightening and historically interesting.

Different sight reduction methods are discussed with the author leaning towards the HO211 method. To this end a complete set of the tables is provided in the Appendices (as it is in volume 2 of Bowditch) and a sample work sheet is illustrated in the chapter on "solutions for lines of position". I, however prefer the lay-out depicted in Duttons and Bowditch (vol. 2) when using this method. Use of pocket calculators and the formulae for sight reduction round out this chapter.

Starting on page 399 a series of star charts for North latitude 40 degrees are presented beginning at 0 degrees LHA Aries through 330 degrees in increments of 30 degrees — a total of 12 such chartlets. There are instructions on their use and it was fun to experiment with them.

Radar plotting is extensively covered in Appendix III. There are some very useful and interesting tables provided in Appendix VIII dealing with such items as LHA Aries: LMT of Noon: Suns declination at 12h GMT for any year and the approximate Equation of time under the same restrictions. As in all navigation books the questions and answers provided are most beneficial in learning so also is this true in Mixters. A worthwhile addition to any navigation library to a serious student of the Art of Navigation.

## BOOK REVIEWS (continued)

*By Peter Ifland*

The Cross-Staff

By Willem F. J. Mörzer Bruyns

Walburg Instituut in association with the Vereeniging Nederlandsch Historisch Scheepvaart Museum and Rijksmuseum Nederlands Scheepvaart Museum. 1994. 127 pp.

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*Available in the U.S. from Tesseract, Box 151, Hastings-on-Hudson, New York 10706. Telephone (914)478-2594*

It is not often that we get the definitive works on the history, methods of production and a world wide inventory of existing pieces of a specific navigation instrument. Alan Simson's *The Mariner's Astrolabe* is one such treatise. Now comes Willem Mörzer Bruyns' authoritative and exhaustive survey of *The Cross-staff.*

The cross-staff, or Jacob's staff, is an unusually historic navigation instrument. It was used extensively by Western navigators for over 300 years up to the end of the eighteenth century to measure the altitude of Polaris and the zenith distance of the noonday sun to find latitude or to measure lunar distances in the early attempts to find longitude. It was a simple instrument consisting of a square staff about one meter long and fitted with a selection of one of four transoms or cross pieces that corresponded to the four scales engraved on the staff. It could be used as a fore-staff to look directly at the celestial object or as a back-staff to measure the zenith distance of the sun.

Mörzer Bruyns places the cross-staff in historic perspective with a very useful overview of navigation instruments and techniques used during the years from 1500 to 1800. He cites the sources of available information about the origins of the cross-staff and its subsequent development. Later chapters describe where and how the instrument was produced, how the scales were divided and how the instrument was used for navigational observations. In the final section of the book, he provides an invaluable inventory and detailed "Checklist" of all the 95 authenticated cross-staves in the world. Seven Appendices provide information on makers, contemporary prices, purchases by The Dutch East India Company and details of dimensions and markings.

Mörzer Bruyns is uniquely qualified to write about the cross-staff. He is Senior Curator of Navigation at the Scheepvaart Museum in Amsterdam — one of the outstanding maritime museums of the world. Furthermore, more than 75% of the known cross-staves are Dutch. The book is impeccably scholarly, yet informative and easy to read by anyone with even a casual interest in the history of navigation and navigation instruments.

ANSWER TO DO YOU KNOW? (From page 1)

The Loran-C phase-out has been accelerated to 2000 from 2015; the Omega phase-out has been accelerated to September 30, 1997 from 2005.

# THE NAVIGATOR'S NEWSLETTER

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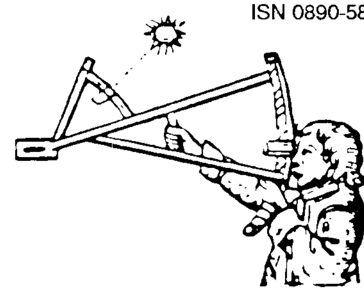


FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-ONE, SPRING 1996

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Navigator's Newsletter

The Foundation had another difficult episode of delivering The Navigator's Newsletter to you on time. The person who did the lay-out for printing departed the area and was unavailable to prepare the Winter Issue. We located a professional who seems to be willing to prepare the Newsletter. We believe this arrangement will improve our publishing time and get us back on schedule.

### Contest

Member CSM Alan L. Olson donated a number of outstandingly high quality navigation instruments and publications to The Foundation. He requested that the items be awarded to youthful persons deeply interested in celestial navigation. In keeping with Member Olson's desires, The Foundation is contemplating sponsoring a contest. One contest will be held for each of the equipments and for different publications. The tentative plan is to have members nominate a candidate, detailing his nominee's interest in celestial navigation, ability and reasons that his nominee should be selected. In conjunction with the member's letter, a letter from the nominee should be included telling us about themselves, their interest in celestial navigation and what they believe they will gain from knowing and practicing this art.

We would appreciate members' views, recommendations or ideas concerning an approach to awarding this excellent equipment to deserving youthful navigators. Please make your ideas and views known by writing to The Navigation Foundation.

### Help

The membership in The Navigation Foundation is slowly decreasing. There are a number of reasons: One, our only advertisements are those donated by Paradise Cay Publications and Starpath School of Navigation; Two, the age of our members is taking its toll and most of the people interested in celestial navigation are seniors; Three, when Admiral Davies founded The Navigation Foundation he expressly stated that he would take no advertisements nor pay to have The Foundation advertised. Today, young navigators consider themselves to be safely covered by the myriad of hi-tech electronic navigational aids available to the navigator. While this may be a satisfactory method of navigation while navigating in the vicinity of industrialized countries where spares, batteries and technical assistance is available, it is not safe to navigate in most parts of the world without an alternative form of navigation. Admiral Davies, who was the Chief of Navy Development, realized that if the United States were to get involved in a conflict with an enemy who had access to missiles, all electronic aids to navigation would have to be shut down. This would be necessary to prevent the enemy from using our own navigation system to target our cities. This was one of the many reasons for founding this Foundation. Another reason was to provide a vehicle for maintaining a data base of people who could still use the traditional methods of navigation, to try and encourage others to learn celestial navigation and maintain proficiency. These are still our goals. We solicit your assistance in increasing our membership. Talk to a friend, write, call or E-Mail us the name and address of potential members so we may send them information about The Foundation. WE NEED AN INFLUX OF NEW MEMBERS.

DO YOU KNOW . . .?
*By John M. Luykx*

The advantage front-coated sextant mirrors have over the back-coated mirrors in common usage?
*(The answer appears at the back of this issue)*

### E-Mail

If you are a member of Compuserve or have access to the Internet, drop us a note so we can record your E-Mail address for future reference. The Foundation E-Mail address for Compuserve is 76476, 1165, for the Internet it is 76476.1165@compuserve.com. You will receive a response faster than "Snail Mail".

# NEW PRODUCTS

*By Terry Carraway*

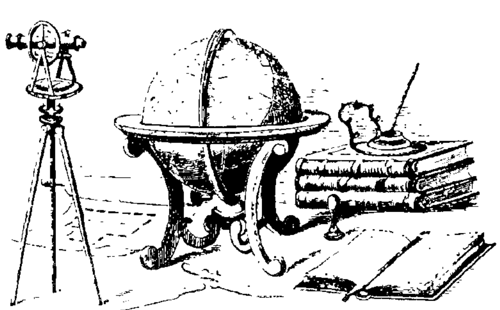
### New Section

This new section is being added to The Navigator's Newsletter in the interest of providing members with information on the latest products available in navigation. Products that come to the attention of The Foundation will be reviewed and those which we think will be of benefit to our members will be critiqued. Many will not be available through The Foundation and will have to be purchased directly from the supplier. Those that are available through The Foundation will be so noted and the price stated. Unfortunately, the price stated cannot be further discounted.

### New Items

There are two new items available to the boater through The Foundation: First, is **The Starpath Radar Trainer** for DOS (Windows) and Macintosh (any system 6.0.5 or newer). List prices are: $79.00 for the DOS/ Windows version and $89.00 for the MAC version. A 20% discount applies for all members; the second is **The Starpath Weather Trainer** 2.0 for Windows (minimum system requirements are 386 with 4Mb, 640X480, 256 colors, with 14 Mb of hard disk space. Recommend a 486 with 8 Meg memory). Also at a 20% discount.

Two new books are available. The first, titled *Shipping Out* is the abridged bible of afloat employment. It addresses both commercial and recreational shipboard jobs. The book can be used as a practical reference for job-seeking mariners because it describes various methods of finding work in the industry. (List $12.95). The second book is the third edition of *Dangerous Marine Animals*, list price $24.95. Discounts apply.



# READERS FORUM

*Edited by Ernest Brown*

Member Robert W. Greaves of 3713 Frazier Road, Endwell, NY 13760-2512 (607) 748-1169 wrote on April 16, 1996:

"Subject: Newsletter Issue 49, Fall 1995. Roger H. Jones Celestial Navigation, Article Number 1, paragraph 4.

"The elapsed time interval between successive meridian transits of the sun does not range between 23 hours, 44 minutes and 24 hours, 16 minutes as stated in the subject article. That conclusion may have been based on an inappropriate application of the equation of time. A more accurate set of values is 24 hours, 30 seconds in mid-December for the longest interval and 23 hours, 59 minutes, 40 seconds in early September for the shortest. A check of the Nautical Almanac for those dates will readily yield 24 hour rates for the GHA of the sun. In December it is about 7.5 minutes of arc less than 360 degrees and in September it is about 5.0 minutes of arc greater. These are the limits for the year.

"Values for the equation of time result from a cumulative process and represent instantaneous phase differences between the apparent and mean suns. While cumulative values may range between +16 min. 26 sec. and -14 min. 15 sec., there are *no* days during the year when they change more than 32 seconds. Consequently, no single day's trip around the earth for the apparent sun can vary more than 32 seconds from 24 hours of mean time. Hourly Nautical Almanac GHA values reflect this, and for purposes of navigation precision, the hourly rate for both bodies can be assigned a value of exactly 15 degrees.

"Readers who have a good understanding of time may dismiss the errant statement with a shrug but the less sophisticated audience that the author was aiming at is apt to swallow it whole. This can create challenging future problems for teachers, like me, who often have to straighten out firmly accepted myths. It should be corrected."

— *Sincerely, Robert W. Greaves*

*Editor's note: Member Greaves' point is well taken.*

Member Richard Cummings of 200 B Hilltop Lane #206, Annapolis, Maryland 21403 wrote on February 22, 1996:

"I read John Luykx' article on artificial horizons with great interest (Navigator's Newsletter, issue forty-nine, fall, 1995) and would like to submit a few ideas which might help overcome some of the problems he encountered with the device.

"1. To prevent fogging, try filling the device with glycerine instead of water. Glycerine is available at most pharmacies, is non-toxic and water soluble, and has good viscosity and reflective properties. I keep a small plastic funnel and a cleaned-out pint milk bottle in my kit and store the glycerine after each session. The artificial horizon gets rinsed out at the kitchen sink and dried in the dishrack.

"2. A large part of the vibration Mr. Luykx experienced from wind may be eliminated by eliminating the surveyor's table. I use a Leitz Tiltall tripod equipped with a center post and a pan head; I put 'sticky-back' Velcro on top of the pan head and the matching elements on the underside of the artificial horizon. I have never encountered a wind strong enough to disturb it, and have a portable, stable base which traverses through 360° and can vary in height to accommodate altitudes from 10° to the limits of my sextant's arc.

"3. Part of the errors Mr. Luykx found with the liquid-filled device may be the result of superimposing the direct and reflected images in it. As a high-power rifle competitor and coach I found that superimposing the top of a post front sight on the center of a bullseye 600 yards away almost always resulted in vertically dispersed shot groups on the target, and that putting the target on top of the sight post (a 'six o'clock hold') reduced this problem if it did not eliminate it. Similarly, in my work with an artificial horizon I have never attempted superimposition, but have invariably used an upper or lower limb shot with appropriate corrections for semidiameter. Using my Bendix-Pioneer Mk II sextant (1945) I have taken 36 sun sights from a known position and have calculated the standard deviation of the differences between Ho and Hc. That standard deviation is .33 nautical mile.

"4. The artificial horizon's versatility can be extended to star sights by lining the pan with black electrician's tape and painting the exterior with luminous material available from Edmund Scientific Co. This material is non-toxic and cleans up with water. Thus one can find the device in the sextant's telescope in the extremely dark places one must go to in order to see stars of the second and third magnitudes. I avoid spoiling my night vision by using a flashlight with a red lens to read the sextant and stopwatch; I prevent the brighter image from the index and horizon mirrors from 'wiping out' the dimmer image from the artificial horizon by swinging the lightest shade into the index path. This equalizes somewhat the two images and makes superimposition possible.

"5. I take my own time with a stopwatch 'velcroed' to the inside of the sextant handle; I start it on WWV and use the lap times to 'nail' my shots. I store the stopwatch inside the sextant box on more Velcro[R], which allows me to use the clamp to properly secure the sextant.

"6. Finally, I would like to report an odd occurrence which happened to a student of mine. He realized he needed a sextant, and being a novice, inquired for one at a local sporting goods store. After a ten minute wait the clerk returned and said: 'Sir, we have all sort of tents for sale in this store, but what you do with it after you've bought it is your business.'"

— *Sincerely, Richard Cummings*

Director John M. Luykx, responding to Member Cummings' letter above wrote on March 19, 1996:

"Your letter of 22 February 1996 to the Navigation Foundation was referred to me. Your comments on my article on liquid and glass artificial horizons are most interesting and valuable. I hope sometime this summer to take additional observations with the liquid artificial horizon, and I will try to incorporate all your recommendations when I do so.

"Long ago I got into the habit of superimposing the direct and reflected images of the sun when aligning the horizon mirror of the sextant (using the sun) and checking for side and index error. When five or six 'averaged' observations for index error are taken by superimposing images, I find little difference in index error calculation with the method you describe. I suppose the procedure for checking sextant accuracy carried on to the procedure I described in the article for artificial horizon observations where no calculation is required.

"Also, I feel that better accuracy is attainable by using a sextant fitted with a 6x30 or 7x35 scope rather than a lower powered scope. Accuracy is further increased when observations are taken at LAN where the sun's rate of change of altitude is minimum, although this procedure would be restricted to the higher latitudes in summertime (N. Hemisphere).

"In summary, I believe the principal cause of error in my observations when using the liquid artificial horizon was vibration caused by the wind. As you suggest, a more stable platform would assist in solving that problem.

"Again, thank you for your comments."

— *Sincerely, John M. Luykx.*

"P.S. For timing sights, I have found the SIGHT TIME device (which fits on the sextant handle and is operated by a trigger) extremely helpful."

*Editor's note: For additional information on SIGHT TIME, contact: INFOCENTER, INC., P.O. Box 47175, Forestville, Maryland USA 20747, Tel: (301)420-2468.*

*Editor's note: In Readers Forum, Issue #50, Winter 1995-96, Member Frank Bailey inquired about the possibility of interference to the light rays in a Link A-12 bubble sextant. Director John M. Luykx responded as follows:*

"I tested the A-12 sextant in my collection and found there was no interference in the line of sight of either sun or star observations in both *direct* and *indirect* modes of operation. The filters, of course, have to be correctly positioned and as altitude changes the filters have to be repositioned to be effective. For example: as altitudes increase, the filters have to be moved higher and higher above the horizontal axis of the sextant. To insure that there is no interference, the index mirror frame has been cut out in a circular manner to accommodate the circular field of the bubble assembly where observing *indirectly* at high altitudes.

"If Mr. Bailey has difficulty or experiences interference in his sextant, he should try repositioning the filters — this I believe will solve the problem."

The president of **JANUS**, Mr. James E. Morrison, of 9 Bigelow Rd., New Fairfield, CT 06812 USA (203) 746-6716, Fax: (203) 746-0815 wrote on March 8, 1996:

"One of our customers recently sent me several issues of 'The Navigator's Newsletter' which I have read with interest, particularly the articles dealing with the history of navigation and prominent navigation personalities. It occurs to me that your readers would be interested in our inexpensive astrolabe reproductions. Even though the planispheric astrolabe is not a navigation instrument *per se*, it illustrates many principles of positional astronomy and played a prominent role in the education of virtually all medieval mariners. A number of our customers have told us that they are involved in celestial navigation and I believe your readers would appreciate knowing about our offerings.

"I have enclosed a description of our astrolabes."

— *Best regards, James E. Morrison.*

Member James M. Furlong of P.O. Box 116, Fulton, Texas 78358-0116 wrote on December 11, 1995:

"I trust the enclosed letter to Mr. A. E. Saunders and the 'Lifeboat Compass Correction' method are self-explanatory.

"As a result of some of Mr. Luykx's inaccuracies and inane presentations, coupled to his unconscionable charges/prices, I was prepared to withdraw my membership. However, after reconsideration, please find my check in the amount $30 for another year's dues.

"I shall welcome any comments anyone might wish to convey.

"Meanwhile, please accept my best wishes for a most pleasant holiday season."

— *Sincerely yours, James M. Furlong.*

Director John M. Luykx of P.O. Box 47175, Forestville, Maryland 20753 responded on January 22, 1996 to Member Furlong's letter of December 11, 1995:

"With regard to Mr. Furlong's letter, and its enclosure, I'm not quite sure that it is serious or purposeful. I'm quite certain, however, that if my articles in The Navigators Newsletter were inane and inaccurate, The Navigation Foundation would not continue to print them. In addition an examination of our INFOCENTER, INC. catalogue of navigation equipment and services would show that our prices are generally lower than those of most of our competitors and could not be and are not considered unconsionable. Mr. Furlong also complains about the cost of re-silvering sextant mirrors. This type of work is complicated and consists of a) the disassembly of the mirror from the sextant, b) the shipment of the mirror to an optical repair shop, c) the return shipment of the mirror, d) the re-assembly of the mirror ot the sextant, e) the re-alignment of the sextant mirrors to the sextant frame and to each other and, finally, f) the collimation of the sextant and the preparation of a calibration report for the customer.

"Mr. Furlong is mistaken if he believes this type of service is available for $10 per mirror."

—*Best regards John M. Luykx*

Member George P. Leonnig of s.v. *Moctobi* wrote on January 6, 1996:

"*Moctobi* is now in Belize and I finally have time to send you the next installment of 'The Log of the Moctobi'. Our PC had died back in Acapulco Mexico, so my correspondence is way behind. Had to buy a new PC.

"I am sending not only a hard copy of the Log, but also a diskette of it. The format of the diskette is a print file placed on the diskette with a 'Copy' command. This should be suitable for any word processing software to reformat and work with.

"We are pretty much on schedule to arrive in Florida this winter. And we plan to be in the Baltimore area sometime in May or June.

"Hope the Foundation is still interested in our adventure cruise. There is not as much in the Log about navigation as I had planned, as we continue to stay close to shore and use the GPS as our primary navigational aid. But it might make interesting reading to members."

— *Sincerely, George P. Leonnig.*

*Editor's note: We intend to publish more from "The Log of Moctobi" later.*

Member Robert Eno of Box 1213, Iqaluit, Northwest Territories XOA OHO Canada wrote on December 15, 1995:

"Please find enclosed, my membership dues. Sorry for the delay. I'm a chronic procrastinator, especially when it comes to parting with money!

"I still thoroughly enjoy the *Navigator's Newsletter* and I look forward to receiving my issues for there is always something of interest. It never ceases to amaze me that so many different contributors can find so many topics — some fairly obscure but nonetheless interesting — to cover.

"With that in mind, would it not be a good idea to have an annual convention/meeting of the membership? The meeting could be held in an appropriate location — say in Annapolis — where guest speakers would present papers on various topics for the interest of those in attendance. I think that it would be a good opportunity for the membership to meet, exchange information, learn a few things and reinforce our common interests and goals. It would also be a lot of fun. Judging by the letters that are published in the newsletters, I think that we have a very interesting bunch of people out there. Personally, I would welcome an opportunity to meet with them and spend a few days immersed in one of my favourite pastimes. How about it? Perhaps you might want to run this idea by the Executive and the general membership to see what they think. I have already spoken to John Luykx and he thinks it is a great idea. Anyway, let me know what you think.

"Winter has arrived to the Arctic and after a long summer pause, I have resumed my weekly practice of star shots with my *C Plath* sextant and bubble attachment. Frozen fingers, toes and other extremities notwithstanding (it has been a steady -30°C) I'm having a great time of it!"

— *Keep up the good work! Robert Eno.*

Member Captain Stephen Miller of 2 Murdock Street, Carver, MA 02330 wrote on November 20, 1995:

"Thank you for the package of information enclosed with my welcome as a new member.

"While in the Navy (in the Sixties), I was a Quartermaster attaining the rank of 2nd Class. It was during my Navy time that I became fascinated with Navigation, especially Celestial. Since my ship had all the various Sight Reduction Tables available, I was able to teach myself all the methods of Sight Reduction. Included were the methods using 211, 214, 229 and 249, as well as the Cosine Haverstine Method as described in Bowditch.

"As a coastal cruising yachtsman in the intervening years, I have not had much of an opportunity to use my Celestial training. I obtained my 25 ton Masters License from the Coast Guard 6 years ago and have been teaching for Sea School here in the Northeast for the last 6 years. With Sea School I teach a Captains' License Prep Course. My job circumstances are apparently going to allow my wife and myself to leave on an extended cruise in the Spring. I have recently gotten back to restudying Celestial Navigation in preparation for our departure in 5 months.

"I noted in the information you sent to me that you can provide information on Navigation courses (I expect that that includes Celestial). I would appreciate it very much if you would send me information on, specifically, any Celestial Courses that you know about. I have already received information from the International Navigation School, Toronto, Canada on their Home Study Celestial Course. If there are any courses that lead to a Certification Document would be most welcome."

— *Very truly yours, Capt. Stephen Miller.*

Our Executive Director responded on January 15, 1996 to Member Stephen Miller's letter of November 20, 1995:

"I apologize for the long delay in answering your letter of 20 November 1995. Trying to administer The Navigation Foundation can be overwhelming at times, especially when my family wants to travel.

"I received your letter just before departing with my wife, son and daughter-in-law for a trip to Turkey. Upon returning, the holiday was starting and the 'Honey Dew' projects took precedence. I had just removed the Christmas decorations when the snow storm hit and the rest has been typical: shovel snow, shovel snow, shovel snow.

"I want to thank you for your service to our country. I have spent many mid-watches with the Quartermasters and found all of them to be intelligent, dedicated and a real pleasure to spend the long lonely hours of the mid-watch with.

"With your background and experience I would recommend just using the book, *Learning to Navigate by the Tutorial System Developed at Harvard*, by Whitney & Wright. You only need a review to get you back on track. However, the Starpath School of Navigation has an excellent home study course. A note to David Burch, Director Starpath School of Navigation, 311 Fulton Street, Seattle, Washington 98109-1740 will get you started. The closest taught course, that lists with us, is taught by Dr. Harry H. Dresser, Jr., P.O. Box 562, Bethel, ME 04217. Dresser is the head of the Navigation Department at Gould Academy.

"I would also recommend that you start very early collecting your charts and publications for your cruise. I assure you that responding to your chart, publication and information needs will not be delayed as long as this answer. If you need catalogs for your cruise area, please let me know and I will photocopy the pertinent sections and mail them to you.

"Many of our members, who are circumnavigating, cannot find the unanticipated charts they need once they leave the United States. They arrange with a relative or friend to receive and tranship charts to their distant ports. They provide me with the address of the contact and order charts with letters direct to me. I bill the chart orders to the contact after I have shipped the charts. If it is an urgent request I will drive to the NOAA chart depository and pick up the chart. In this case there is no discount because we do not receive a discount on over-the-counter purchases.

"I would be pleased to work to supply all of your chart and publication needs prior to your departure. Call the Foundation telephone number and leave your name and number on the answering machine and I will return the call, saving you the telephone charge.

"Thank you for your interest in the Navigation Foundation. We hope that we can supply you with the information, interest and assistance that you expect."

— *Best regards, Terry F. Carraway, Captain, U.S. Navy (Retired), Executive Director.*

Member William C. Rose of 28 Kenwick Road, Hockessin, DE 19707-1208 wrote on June 30, 1995:

"It was a pleasure to speak with you on the phone recently. I enjoyed learning about the flying experiences of you and your colleagues, including the crew of the Truculent Turtle. The idea of flying off of and onto a boat is amazing. You certainly flew in a wide range of airplanes. If you haven't already read it, I'm sure you would enjoy, and understand better than I, the book 'Twilight of the Gods' by Ernest Gann.

"Thank you for sending information about the Navigation Foundation. My membership fee is enclosed. I enjoyed reading in Newsletter #46 about the Thomas D. Davies award for navigation at Tabor Academy. I learned celestial navigation as a sophomore at Tabor and had a summer job as navigator aboard the school's flagship, the 92' schooner *Tabor Boy*. At that time GPS didn't exist, and the ship lacked Loran, so when we sailed to Bermuda it was the sextant that got us there.

"My knowledge of CN came in handy in college —in an unusual way. I applied for the job of student instructor at the undergraduate teaching telescope — running 'public viewing sessions' in the evenings and teaching students how to use the scope. The professor quickly determined that I knew nothing about astronomy per se, having never studied it or pursued it as a hobby. But I explained that my CN experience made up for that, even though I have never used a telescope. He agreed, and so I got the job. Thus proving that CN is a useful skill, even when ashore!

"Thanks to you and the other directors for creating and maintaining the Navigation Foundation."

— *Sincerely, Bill.*

Member Jack R. Tyler of 10635 Islerock Drive, El Paso, TX 79935-1539, Phone/FAX line (915)594-1903, wrote on January 18, 1996:

"Also I would like a copy of Mike Pepperday's 'Celestial Navigation with the S-Table' (Paradise Cay). Another check for $9.95 is attached. (I figure that the 20% discount will just about cover the shipping costs!)

"I wish to thank you for your time and effort in compiling a list of available charts for my trip through the Bahamas, Turks and Caicos, British Virgin Islands, and the Lesser Antilles, Freeport to Port of Spain, Trinidad and Tobago, that we discussed about two weeks ago. I am scheduled, as a passenger, to sail these areas this coming summer for the second time — I went on this trip last June-July (1995), a 26 day round trip of island hopping on a small passenger freighter that was servicing a fleet of five 'tall' ships. About ten minutes after my wife and I had boarded the M/V *Amazing Grace*, the First Officer caught me lowering our travel clothes line over the side to determine He, Hgt of eye. I was immediately escorted up two ladders to the bridge, introduced to the captain, who gave me a place to stow my Aries 40 (Astra IIIb) and other gear, and 24 hour access to the bridge and all of its equipment, even to the point of plotting my shots on the ships's charts - mark lightly with a #2 pencil only! The enthusiastic support I received from the officers and crew was overwhelming.

"At the beginning of the trip, my intercepts were ranging about 15-18 nautical miles — I was learning to compensate for the ship's movement (pitch, yaw and roll), plus gusting winds. Near the end of the trip, I had improved to an average of 5 nautical mile intercepts. I had learned to use the splash board to reduce wind effect and to lean back on the covered telegraph to get the 'feel' of the ship. This was my first experience with a marine sextant and it was so much fun that I'm going to repeat the trip!!

"Looking forward to talking with you again in the near future, I am sincerely yours,"

— *Jack R. Tyler.*

Director Roger H. Jones, Owner/Master of S. V. *Allidoro*, wrote to us from Fort Lauderdale, Florida on December 18, 1995:

"The Best O' the Season to You, and O' All the Seasons To come! My vessel and I have been at Isle of Venice in Ft. Lauderdale since May, refitting, visiting old friends (Ted and Arline Raab and Pete and Marty Mamunes) and getting ready to go voyaging again in 1996. While here, I taught a class in Celestial Navigation at the Seven Seas Cruising Association, published a series of ten articles on the subject, installed a new battery and charging system, and undertook many other projects, including removal of the deck teak and refinishing of the decks.

"In January I'll be off to the Bahamas for winter cruising, golf and SCUBA with crew Saul Arvedon and Les Callaway. In the Spring -to the lower Caribbean and Venezuela, or possibly to the Med or South Pacific with other crew.

"Last Winter crew member and Cornell Classmate Peter Wolf and I dealt with a major problem when the prop shaft coupling safety failed, resulting in our taking in about 1,000 gallons of North Carolina sea water in the ten minutes it took us to locate and plug the source of the flood. Thus, *Allidoro* was in Beaufort, N.C. for the fussin' and fixin' from early December of 1994 until early March this year. All's well that ends well, however, and the vessel is now even more seaworthy than when we left California last year for the 7,500 mile voyage to the East Coast. The episode in North Carolina's Neuse River did throw us off schedule for the rest of 1995, but such is the whim of Lord Salt Water to teach humility at unsuspecting moments.

"After the stay in Beaufort, crew Birgit Ball-Eisner and I sailed *Allidoro* on to Florida where we picked up Dom Rendinell and then proceeded to Lucaya, the Berry Islands, and Nassau. Dom was aboard for two weeks, and then he returned to California. Jane Phillips came aboard in Nassau for a short cruise in the Exumas. After returning her to Nassau, Birgit and I sailed back to Ft. Lauderdale to attend to a minor but vexing voltage regulator problem. By now it was early May, and Birgit's business in Carmel, California required her return to the world ashore.

"Peter Wolf may come aboard again in the Spring of 1996. Meanwhile, there is a growing possibility that I may go to France in April to assist in the shake-down of a new blue water catamaran in the Med, followed by a return under sail to the U.S. via the Cape Verde and Canary Islands. Meanwhile, for the Holiday Season I'm off to Washington, New York, Hartford, and Oak Park and Springfield, Illinois to visit Roger, Mike, Steve and Allison and their respective families. My four young adults and my five grandchildren are all very well, and I wish the same for you and yours.

"Warmest regards and best wishes. Please note my new mailing address: P.O. Box 2430-867, Pensacola, Florida 32513. MAY DOLPHINS DANCE BENEATH YOUR BOW!"

— *Roger.*

Member Louis K. Mantell, Lt N USPS, San Antonio Power Squadron of the United States Power Squadrons of 817 Canterbury Hill Street, San Antonio, TX 78209-6038 wrote on January 23, 1996:

"Thank you for notifying me of the shortfall in my recent order and am enclosing payment of $1.86 + your letter postage.

"I commend you for your beyond the call of duty efforts in so effectively keeping your many, privileged members actively pursuing your world class leadership toward the preservation of the Art of Navigation."

— *Sincerely, Louis K. Mantell.*

Member James M. Lehrer of 2244 Walnut Grove Avenue, Suite 331, Rosemead, CA 91770, Phone: (818)302-3252 wrote:

"I have a sextant I would like to sell, and it occurred to me that you might know of someone interested in purchasing it. If so, I would appreciate your help in passing along the following information.

"The instrument is a C. Plath sextant, full size, manufactured in 1968, with the original fitted plastic case, original 6x30 monocular and new 4x40 telescope (both Plath). The original certificate which accompanies the sextant indicates that the factory certified the instrument to be free of errors for practical use. It still is, having been kept in excellent condition.

"Also included is a Celestaire artificial horizon scope, and a Davis artificial horizon, the three volumes of H.O. 249, four volumes of H.O. 229, and a handful of celestial-related books, all in a new condition. I am asking $800.00 for the above (not including shipping or insurance costs). For $100.00 more, I will include a like-new Hewlettt-Packard CX-41 with math and stat packs, manuals and case, and a set of Admiralty emergency boat charts.

"I am selling these items because I am likely to be much too busy with work for the foreseeable future to be able to enjoy using them.

"I would be happy to send a Polaroid photograph of the sextant to a prospective purchaser.

"Your help in finding a worthy home for this wonderful and complete package would be greatly appreciated, Terry. If you or a prospective purchaser have any questions, I can be reached at the telephone number or address on the letterhead, or at FAX (310)276-2901."

— *Many thanks and warmest regards, Jim Lehrer.*

Member Russell A. Jorgenson of 3590 Lone Lookout Road, Traverse City, Michigan wrote on January 13, 1996:

"Could you please furnish me with the mathematical method of computing the precise time of the equinoxes and solstices. I have enclosed a method that I have devised, but I really cannot explain the logic of my reasoning. This is particularly true since the 1996 Farmer's Almanac proves me to be off some 2 to 4 minutes. I suppose if I were able to obtain an astronomical almanac or ephemeris I might also receive some insight into my question; however, our local book stores do not carry these. In any event I really would not know what to ask for as I am neither mathematician nor astronomer.

"I am an "N" in the U.S. Power Squadron and assist in teaching introductory celestial navigation (CN). I certainly would appreciate your help."

— *Russell A. Jorgenson.*

*Editor's note: Assistance from the Nautical Almanac Office. U.S. Naval Observatory, has been requested.*

Member John D. Johnston of 9092 Eclipse Drive, Suffolk, Virginia 23433 wrote in response to Director John M. Luykx's letter in Issue #49:

"It may be enlightening for readers of the newsletter to see what Admiral Nimitz, Supreme Allied Commander Pacific, during WWII, wrote concerning the execution of the war.

"The Maritime Commission and the War Shipping Administration built the merchant ships, trained crews to sail them, and sent them to be loaded with war materials to be carried overseas in convoys. They delivered the goods necessary to defeat the Axis.

"U.S. merchant ships manned by U.S. merchant sailors were the vital lifeline for Mr. Luykx's 'Engine of War'. Merchant Marine veterans can be justly proud of their service."

— *John D. Johnston.*

Introduction by Admiral Nimitz to *Ships of the U.S. Merchant Marine* by S. Kip Farrington, E. P. Dutton, New York, 1947:

"From the start of our offensive movement in the Pacific in the summer of 1942 to the surrender of Japan three years later, the never ending plea of our armed forces was for the 'beans,' 'bullets' and 'avgas,' so essential for the success of their missions. The thin trickle of those supplies which could be furnished in answer to the first anguished appeals of our embattled Marines on Guadalcanal grew in volume and adequacy as the war progressed, in direct proportion to the increasing size and capability of our Merchant Marine.

"Not one of us who fought in the late war can forget--nor should any citizen be allowed to forget--that the national resource which enabled us to carry the war to the enemy and fight in his territory and not our own was our Merchant Marine. The fighting fleets and Marines of our Navy, the ground forces of our Army, and the aircraft of both would have been helpless to pound the enemy into defeat overseas, had it not been for the steady stream of personnel, equipment and supplies of every character brought into the rear of the combat areas, and often directly into those areas, by the ships of our own Merchant Marine and those of our allies.

"Twice in our history have we prevented a possible invasion of our shores by the ability and capability of our armed forces to wage offensive and containing actions against the enemy overseas. While we cannot discount the changes which every new war brings, or fail to appreciate the tremendous influence which air transport may have on the future, we must not lose sight of the fact that for overseas military movement we are now, and will be for the foreseeable future, largely dependent upon our shipping resources.

"It is well to remember that a professional Army and Navy are merely nuclei of the armed forces needed to wage war. The all encompassing deadliness of another conflict and the suddenness with which it might be initiated make it imperative that no vital national asset such as shipping be allowed to atrophy during times of peace. To do so is merely to invite a repetition of the impotent situation with respect to shipping in which we found ourselves between the two world wars.

"Since ships cannot pass by our front doors or come under the same public observation as the trains, trucks and motor cars, which daily impress themselves upon our consciousness, there is a natural tendency to forget the vital relationship which the Merchant Marine bears to our individual and collective welfare, in peace as well as war. It is my sincere wish that Mr. Farrington's informative and interesting story of the ships of our Merchant Marine will serve to focus the attention of all Americans on a subject which it is perilous to neglect and a matter of pride to remember."

—Chester W. Nimitz, Fleet Admiral, U.S. Navy, Chief of Naval Operations, Washington, D.C., June 25, 1947.

*Editor's note: During World War II, Admiral Nimitz was Commander-in-Chief, U.S. Pacific Fleet and Commander-in-Chief, Pacific Ocean Areas (North Pacific, Central Pacific, and South Pacific). General MacArthur's theatre was the Southwest Pacific. Admiral Nimitz was promoted to Fleet Admiral (5 stars) in December 1944.*

Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona*, wrote to us from Georgetown, Guyana on 2 October 1995:

"Dear Friends, I am going to call my first newsletter 'You Can't Get There from Here,' for reasons that will soon be apparent. Evgeny, Walter and myself took our departure from Block Island on July 7th. We arrived in Bermuda on the 12th, the only major problem being that I forgot the ship's teapot. Apart from one hideous monstrosity on sale in Block Island, I couldn't find a replacement, but we were able to buy a traditional English teapot in Hamilton, Bermuda. Bermuda has gotten very noisy — two cruise ships pulled into St. Georges during the summer weeks and the passenger are wooed to the bars and nightclubs by loud disco music until the small hours. The 'White Horse Tavern' used to be a matey publike place that sold drinks and fish and chips. Now the electronic music emanating from the White Horse can be heard a mile away. We anchored on the west side of the islands and did a little skindiving on the old sunken gunboat *Vixen*. We left on July 17th and dropped anchor in Marigot Bay, St. Martin on the 23rd, experiencing nothing worse than the usual squalls on the way down. I wanted to see Kay and Dudley Pope again, old friends who lived aboard *Ramage* in the Caribbean for many years. I also wanted to lay in a good stock of Mount Gay rum, as St. Martin has probably the lowest prices in the world for this lubricant of the seven seas. We bought eight cases, two less than when we were here in 1990 - we are cutting back on the drinking! Leaving St. Martin on July 31st we fueled up on the Dutch side and set sail for Barbados. About two days out we encountered a vicious tropical wave when we were east of St. Lucia. The local radio stations were full of stories of massive flooding, we had winds to 50 kts in gusts and had 3 reefs in the main. We tied up for customs clearance in Barbados on August 4th and discovered the same storm had caused damage there too. A popular calypso singer called 'The Great Carew' had been swept out to sea sitting on the roof of his house and we later saw the local coast guard bringing his body back. We stayed four days in Barbados, one more than planned because August 7th was 'Crop Over' day, a traditional celebration for the harvesting of the sugar crops. A main street out of town was full of booths selling everything and there were parades with floats. When I was a young lad I used to read stories of intrepid explorers in the jungle who at some state usually said 'The drums, the drums!' Well they didn't know nothing - only when you had experienced drum music relayed by banks of 20 inch speakers have you heard drums. These pockets of sonic energy were spotted all along the road and must have consumed kilowatts of power.

"We left Barbados on August 8th heading Southeast with the intention of rounding the eastern bulge of Brazil. This huge cape sticks out into the Atlantic Ocean to about 35°W; halfway between New York and London. When we left Barbados we were at 12°N and 59 °W, our destination was Natal, Brazil, at about 6°S and 35°W, a distance of about 2000 nautical miles. When I planned the trip I knew the wind and current would be against us but I was obviously suffering from hubris; Mother Nature was about to teach me a lesson. After we left Barbados we had very light and variable winds, mostly from the Southeast. Due to the equatorial current, which ran at 3 knots to the Northwest we made little progress. Fortunately there is a counter current which we were able to find with the help of the GPS receiver, which shows course and speed over the bottom. During this period gear began to fail. The jib roller furling stuck and I had to go up to the mast head to free it, once in the middle of the night. The jib halyard broke - another trip to the mast head. We got to the equator on August 25th at 42°W, having crossed the Doldrums at about 6°N with the help of the counter current, but it then faded. The pilot chart shows it going to the North. After the Doldrums we had heavy winds in the 30 - 40 kt range from ESE. After the roller furling was fixed so at least it would furl, the lower bearing was obviously unhappy. Shortly after crossing the equator the mounting bracket of the Aries self-steering broke and we decided we needed a little time in port to fix things. The only port was Sao Luis, lying 120 nautical miles downwind on the North coast of Brazil. We entered this port using our offshore chart, fortunately in daylight, on August 29th. The currents in Sao Luis are heavy, due to the tidal range which is 18 ft when the moon is new or full. In the 1970's it was abandoned as a major port due to shoaling of the bay. At full tide there is a full, wide bay, and at low tide immense sand banks with serpentine channels of deep water. The problem with the roller furling was that one half of a plastic insert forming the lower bearing had disappeared. At this point we met Sami Wassonf, polyglot and local fixer. He suggested a very typically Brazilian solution - use the half bearing that was left as a pattern and have new ones cast in aluminum. Amazingly enough this worked fine and a day later I had two aluminum bearing inserts at a cost of about ten dollars each.

"Sao Luis is an old colonial city of about 1 million people. Local fruits are delicious and cheap. However other services are hard to find. We heard about a person living near our anchorage who was familiar with the laundry situation, but it turned out when we got there he simply let you use a sink in his garden. So Walter and I set to using the built-in scrubbing board. All the family thought this was very funny, and brought chairs so they could watch our performance in comfort. In the meanwhile a large Doberman, that prowled the compound at night, eyed us viciously from his cage and howled continuously in frustration.

"With our stores replenished and gear fixed we left Sao Luis on September 2nd, and after beating out of the bay headed east. We stayed within 30 miles of the coast, which meant the current against us was a little less but because it was so shallow the waves were steeper. Typically the sea is only 100 ft deep 30 miles offshore. The winds were high, 30 to 40 kts and we had 2 and 3 reefs in the main. At midnight on the night of September 4th I was just entering data in the log prior to changing watches when where was a loud report like a gun shot followed by wild flogging of the jib; the headstay had snapped. At the time the jib was fully reefed. We got the mess down to deck level but the roller furling extrusions were either bent or broken. The jib was torn due to the rig swinging violently against the forestay in the heavy seas. I really don't know why the stay snapped at a point just under the upper tang - it was new in 1993. We braced up the mast with the spare halyard and jib halyards once we had the stay and sail lashed to the port lifeline. I was reluctant to give up our mileage to windward, so for a day we tried motor sailing in the hope of reaching Fortaleza, the next port east of Sao Luis. Although we struggled on for twenty-four hours it was clear we couldn't make Fortaleza with the fuel on board, without the jib we couldn't get to windward in the teeth of the heavy winds and seas, so we turned back once again to Sao Luis. This time it was dark when we arrived on September 8th. But this time we had local knowledge.

"When we got back we removed the sail from the shattered profurl - not as easy as it sounds - and rigged the spare stay. While Evgeny stitched a wire rope to the luff of the storm jib, Walter and I rounded up Sami and his battered car. We went on a search for hanks or shackles so we could attach the storm jib to the stay. We eventually located 25 small steel shackles - when we returned to the boat *Fiona* was hard aground. It was a spring tide and the current had swept *Fiona* to one side of the channel which then dried out. The problem came when the tide reversed, for a couple of 60 ft ferries moored to the west of *Fiona* swung down in the flood current while *Fiona* was still stuck fast. We had a frantic hour keeping the ferries from damaging the self steering gear but we lost a stanchion and I bent the stern pulpit. The next day, Sunday, we bent on the storm jib, reeved a new jib halyard as the old one had been damaged by strain caused by supporting the jib stay and roller furling gear. We tidied up the bent pulpit and then drank a little(?) of the Mount Gay rum. Monday we left and soon encountered the familiar conditions of heavy winds and seas. On Tuesday, September 12th, the main sail, which was double reefed, began to go. We lowered it and stitched in a patch and redid a seam. But an hour or two later it split from luff to leach. Somehow the cloth just seemed to have given up. At this point we had lost our two working sails, we had used all the spare halyards and stays and we were low on fuel. According to the log we had sailed 3216 nm since leaving Barbados, most of it to windward, making good about 1500 miles, but we were still 500 nm from Natal. With a heavy heart I realized we had punished the boat enough and we were not going to round the Cape this year. We needed major repairs to the stays, sails and furling gear. I decided to run off downwind, bide our time until the hurricane season was over in the Caribbean and then return there to make repairs. Georgetown, Guyana, looked like a good spot to head for, so we bent on the storm main, the only sail left and slowly made our way back through the Doldrums, and we pulled into the Demerara River on

September 21st. Here in Georgetown we are tied up next to a rusting tugboat and the rotting pilings left when the Customs House burnt down thirty years ago. Very few yachts call here, so far four this year. The river is very muddy and foul. Thieves are rife in the dock area and we have hired a watch man who sleeps on the foredeck by day. Despite this, one of our screwdrivers was stolen when Walter and I were working on deck. We both went below for a moment and it was gone. We entered into Byzantine negotiations with a middle man and ultimately got it back for about US $5.00. There are also lots of pretty young women around the dock who smile a lot and giggle and suggest they 'might be your wife'. As you may have deduced, people are very poor in Guyana, but there is a festive and exuberant air in the market with lots of smiles and banter. The market is very active with every conceivable item for sale; the local fruit is very cheap. Five year old rum is US$2.00 a bottle. The Guyanese have no coins, only paper money with a dollar worth 7/10th of a cent! I enclose a few as a souvenir. The public phones are free for local calls. We have been able to get some repairs done, including restitching the main sail. This was done by an old gentleman, entirely by hand, who used to make sails decades ago for the vanished fishing sail boats. We also managed to refill our tanks with diesel.

"We will leave soon and slowly make our way North, planning to be in St. Martin in mid November. In view of the tremendous hurricane damage suffered since we were there I don't know if we can get the stays and sails repaired there. One way or another we will try to be fully shipshape for a passage through the Panama Canal in February and then on to French Polynesia. Until the next time."

— *Best wishes from Eric.*

# NAVIGATION FEATURE

## The Motion of the Observer in Celestial Navigation

*By George H. Kaplan, U.S. Naval Observatory*

Abstract Conventional approaches to celestial navigation are based on the geometry of a stationary observer. Any motion of the observer during the time observations are taken must be compensated for before a fix can be determined. Several methods have been developed that account for the observer's motion and allow a fix to be determined. These methods are summarized and reviewed.

Key Words celestial navigation, celestial fix, motion of observer

### Introduction

The object of celestial navigation is the determination of the latitude and longitude of a vessel at a specific time, through the use of observations of the altitudes of celestial bodies. Each observation defines a circle of position on the surface of the Earth, and the small segment of the circle that passes near the observer's estimated position is represented as a line of position (LOP). A position fix is located at the intersection of two or more LOPs. This construction works for a fixed observer or simultaneous observations. However, if the observer is moving, the LOPs from two consecutive observations do not necessarily intersect at a point corresponding to the observer's position at any time; if three or more observations are involved, there may be no common intersection. Since celestial navigation normally involves a single observer on a moving ship, something has to be done to account for the change in the observer's position during the time required to take a series of observations. This report reviews the methods used to deal with the observer's motion. A basic familiarity with the procedures, terminology, and notation of celestial navigation is assumed.

The fundamental principle involved is that each point on an LOP represents a possible true location of the vessel at the time of the observation, and should therefore move with the vessel's course and speed (Bowditch [1], pp. 129-130). Since the estimated position of the vessel also moves with the vessel's course and speed, an equivalent principle is that the difference between a vessel's true position and its estimated position--the error in position--remains constant, in two coordinates, as the vessel moves. The two coordinates are usually taken to be azimuth and distance. We have not distinguished here between the vessel's actual course and speed and its assumed course and speed. For the present, we will consider the vessel's course and speed to be known exactly, or at least well enough that any resulting errors are negligible compared to the errors of observation.

### Chart-Based Approach

In the chart-based approach to celestial navigation, the principle that an LOP moves with the vessel's course and speed can be directly applied. The procedure is called *advancing* an LOP (to a later time) or *retiring* an LOP (to an earlier time). The plotting is done on a Mercator chart, where rhumb-line tracks are straight lines.

Consider a single celestial observation consisting of a sextant altitude, hs, of a known body made at time $t$ from estimated position $p$. We assume that hs is appropriately corrected for instrumental error, dip, refraction, etc., yielding the observed altitude Ho. The observed body's computed altitude and azimuth, Hc and Zn, are obtained in the usual way for time $t$ and position $p$, the altitude intercept $a$=Ho-Hc evaluated, and the LOP drawn.

Now suppose we have a group of such observations, taken from a moving vessel, each made at a different time and position. A fix is to be determined from these observations for some time $t_0$ when the vessel is at estimated position $p_0$. We will assume that $t_0$ is within the period of time spanned by the observations (often, $t_0$ will be the time of one of the observations). For each observation, the interval between the time of observation and the time of the fix is $\Delta t = t_0 - t$. If the vessel's course, $C$ and speed, $S$, are constant, in the interval between a given observation and the time of the fix the vessel's track is a rhumb line of length $S\Delta t$ in the direction $C$, a line that connects points $p$ and $p_0$. (We are assuming that $C$ and $S$ have been adjusted for the current's set and drift.) In the chart-based approach to celestial navigation, each observation is advanced (if $\Delta t$ is positive) or retired (if $\Delta t$ is negative) to the time of the fix by simply moving its LOP on a Mercator chart by the amount $S\Delta t$ in the direction $C$. Each LOP's azimuth is held constant during this process, that is, the relocated LOP is drawn parallel to the original LOP. The distance of the relocated LOP from point $p_0$ is the same as the distance of the original LOP from point $p$. For details of the plotting procedure, see Bowditch [1], pp. 129-132.

If each observation's LOP is properly advanced (or retired) in this way, the LOPs should intersect (to within observational error) at a point near $p_0$. This intersection defines the fix for time $t_0$.

## Mathematical Approaches

For mathematical approaches to sight reduction, there are several algorithms that account for the change in the observer's position. These are all based on the principle that the difference between the true and estimated positions does not change significantly as the vessel moves. That is, the error in position remains essentially constant in two coordinates.

**Linearized LOPs** A mathematical approach to celestial navigation is presented in [2] that is based on the plane geometry and straight lines formed by LOPs near the estimated position. A least-squares solution for the fix is used. The method is a direct mathematical translation of chart-based navigation. It was developed independently at the Royal Greenwich Observatory (RGO) and is described in RGO's publication *Compact Data for Navigation and Astronomy* [3]. The algorithm is also briefly presented on page 282 of the *Nautical Almanac*, in the section titled "Position from intercept and azimuth using a calculator." In this method, the equation for each straight-line LOP is developed with respect to the estimated position $p$ at the time $t$ of the observation. In rectangular coordinates (nautical miles east-west and north-south) any point $(x,y)$ on the LOP satisfies

$$a = x \sin Z_n + y \cos Zn \qquad (1)$$

where $a$ is the altitude intercept (in arcminutes). The estimated position $p$ at the time of the observation is used as the basis for the computations as well as the origin of the rectangular coordinate system used. In this construction, advancing or retiring an LOP amounts to simply a change of origin, and the origin can be any point along the vessel's estimated track. Thus, to advance the LOPs to the time of the fix we simply consider that the equations (1) for all the LOPs refer to a common origin at $p_0$, the estimated position of the vessel at the time of the fix. Then the equations can be solved, using a least-squares procedure, for $x$ and $y$ (in nautical miles). The point $(x,y)$ represents the best estimate (in a least-squares sense) of the intersection point of all the LOPs with respect to $p_0$. After the solution is computed, the resulting $x$ and $y$ values are converted to corrections to longitude and latitude and applied to point $p_0$ to form the fix.

This procedure thus uses equation (1) as a conditional equation for a least-squares solution for the error in position. Each conditional equation that enters the solution is computed for the time and estimated position of an individual observation, yet the positional parameters solves for ($x$ and $y$) are assumed to be constant offsets that apply to every estimated position in the problem. This is simply a restatement of the principle of constant error described above, with the linear coordinates $x$ and $y$ substituting for azimuth and distance.

For the sight-reduction algorithm described in [4], a nearly identical strategy is suggested to deal with the motion of the observer. This algorithm uses a different conditional equation, which allows the least-squares solution to directly yield corrections to estimated latitude and longitude. Applied to a moving observer, this procedure depends on the assumption that there is a constant error in latitude and a constant error in longitude. This assumption is somewhat different from the principle of constant error that we have been using.

**Motion-of-Observer Formula** Another way to account for the observer's motion, commonly used, is to adjust each observed altitude for the change in the position of the observer during the time $\Delta t$. This motion-of-observer correction, in arcminutes, is

$$\Delta \text{Ho} = \frac{S\Delta t}{60} \cos(\text{Zn} - \text{C}) \qquad (2)$$

where $S$ is in knots and $\Delta t$ is in minutes of time; then $\Delta$Ho, which is in arcminutes, is added to the observed altitude. The quantity Ho+$\Delta$Ho represents the altitude that the observed body would have if it were observed at the same time $t$ but from a different position--a position $S\Delta t$ further along the vessel's track, which is $p_0$. Essentially, use of this formula holds the geographical position (GP) of the observed body fixed (the GP for time $t$), but defines a new circle of position for the observation; for positive $\Delta t$, the circle has a larger radius if the vessel's course is away from the body or a smaller radius if the vessel's course is toward the body. For the small area on the surface of the Earth near the vessel's track, this is essentially equivalent to advancing (or retiring) the observation's LOP.

Applied to all observations, each with a different $\Delta t$, equation (2) yields a set of LOPs that intersect near $p_0$, defining the fix for time $t_0$. When equation (2) is used, the Hc and Zn values are computed for the individual observation times $t$ but for the common position $p_0$. Equation (2) is an approximation, of course, but it works quite well for observations taken within a few minutes of each other. Even out to distances $S\Delta t$ of 25 nmi (typically 1-2 hours of sailing) the error in the formula itself is usually only a few tenths of an arcminute.

**Adjustment of Celestial Coordinates** Equation (2) adjusts the observed altitudes, but alternatively, one can make the corresponding adjustments in the celestial equatorial coordinates — hour angle and declination — of the observed body. An exact solution for a two-body fix is presented in [5], and the paper also contains a thorough explanation and development of formulas for adjusting celestial coordinates for both a change in time and a change in the observer's position. These formulas are meant to be applied over relatively short periods of time (an hour or less) and relatively small changes of position (10 nmi or less). Equation (8) in [5] provides for the change in declination of one body and equation (9) in [5] provides for the change in the difference between the local hour angles of two bodies.

More generally, advancing (or retiring) an LOP in the conventional manner can be accomplished by advancing (or retiring) the position of the object observed (Bowditch [1], p. 130). For celestial LOPs, this is accomplished mathematically by changing the GP of the observed body, which, of course, means adjusting its celestial coordinates. How can the Greenwich hour angle and declination of the observed body be adjusted to correctly advance its LOP? In the chart-based procedure, a section of each observation's LOP is moved by an amount $S\Delta t$ in the direction C. However, this is not, in general, the shift that should be applied to the GP. We want to move the GP in such a way that the error in position--the vector between a vessel's true position and its estimated position--remains constant, in both length and orientation, as the vessel moves. So if we have an altitude observation made from estimated position $p$, and we want to use that observation to correct an estimated position $p_0$, then we assume that the altitude intercept and azimuth computed for position $p$ also apply to $p_0$. Essentially, we imagine a celestial body, observed from position $p_0$, with the same altitude and azimuth as the real celestial body observed from position $p$. For this construction, Ho is left unadjusted; and to maintain the same Hc and Zn, the Greenwich hour angle and declination of the imaginary body must be

$$\mathrm{GHA} = -\lambda_0 \pm \arccos\left(\frac{\sin \mathrm{Hc} - \sin\varnothing_0 \sin d}{\cos\varnothing_0 \cos d}\right) \quad \begin{cases} + \text{ if } 180^\circ \le \mathrm{Zn} \le 360^\circ \\ - \text{ otherwise} \end{cases}$$

$$\mathrm{Dec} = \arctan\left(\frac{\sin d}{\cos d}\right) \qquad (3)$$

where $\sin d = \sin\varnothing_0 \sin \mathrm{Hc} + \cos\varnothing_0 \cos \mathrm{Hc} \cos \mathrm{Zn}$

$\cos d = \sqrt{1 - \sin^2 d}$

and where $\varnothing_0$ and $\lambda_0$ are the latitude (north positive) and longitude (east positive) of position $p_0$, and Hc and Zn are the computed altitude and azimuth of the real body observed from position $p$ at time $t$. Note that in the equation for GHA, arccos(...) will always be positive, leaving a sign ambiguity that is resolved using the azimuth Zn. Equations (3) are simply a reversal of the usual altitude-azimuth formulas, applied to point $p_0$. Once GHA and Dec have been obtained using these equations, the entire sight reduction process (whatever process is used) can proceed as if the observation were taken from position $p_0$, with Ho, Hc and Zn unchanged. The effect is to properly advance the LOP from near $p$ to near $p_0$.

Note that equations (3) do not involve $C$. $S$, or $\Delta t$; no assumptions have been made about how the vessel gets from $p$ to $p_0$, or how long it takes. In this sense this procedure is similar to the linearized LOP scheme, and can, in principle, be applied over extended lengths of time or multiple voyage legs.

**Equivalence of the procedures** The three mathematical procedures outlined above should yield virtually identical results for an ordinary round of sights, given the same input data and the same sailing formulas. For example, when applied to the sight-reduction sample case on pp. 282-283 of the 1995 *Nautical Almanac*, the linearized LOP algorithm and the procedure of adjusting celestial coordinates give identical fixes. Use of the motion-of-observer formula, yields a fix that is different by only 0.05 arcminute.

When combining observations taken over a longer span of time, it is important to remember that the motion-of-observer formula is an approximation that degrades as the length of the track over which the observations have been taken increases. The other two procedures do not suffer the same kind of degradation and remain correct and equivalent (given the validity of the basic principles) regardless of the observation span. In any event, the degree of equivalence among these procedures indicates only mathematical precision and should not be mistaken for navigational accuracy.

## Limitations of the Procedures

The fundamental principle that is the basis of the chart-based procedure of advancing or retiring LOPs is that each point on an LOP represents a possible location for the vessel at the time of the observation, and should therefore move with the vessel's course and speed. The equivalent principle that is the basis of the mathematical procedures is that the error in the observer's estimated position, in two coordinates, does not significantly change as the vessel moves. These principles and the way they are applied deserve some closer scrutiny.

First, a celestial LOP is actually a circle, and if it is advanced so that each point on it follows a rhumb line defined by the vessel's course and speed, it will not precisely retain its shape. Even a short LOP segment, represented as a straight line, will not, in general, maintain a constant azimuth during such a transformation. Therefore, the usual chart-based construction, in which the advanced LOP is held parallel to the original, is not rigorously correct. One way to visualize the situation is to note that the scale on a Mercator chart is a function of latitude. (At mid latitudes, the scale changes by 1-2% per degree of latitude.) Different points on the original LOP, at different latitudes, should therefore advance different amounts *on the chart* because the scale is slightly different at each point. This means that the advanced LOP should not be drawn precisely parallel to the original LOP. At mid latitudes, the change in the azimuth of the LOP will typically amount to a few tenths of a degree for an advance of 50 nmi.

A similar difficulty arises with the principle of constant error. The notion that the positional error does not change as the vessel moves is contradicted by the mathematics of rhumb lines (except for the trivial case where the positional error is zero). Suppose we have two neighboring points on the surface of the Earth, and we extend a rhumb line from each point at the same azimuth for the same distance. The end points will not, in general, be the same distance from each other as the starting points, nor will their relative azimuths be the same. If we identify one of the starting points with a vessel's true position and the other with its estimated position, we see that the positional error must change as the vessel moves. The change is of order 0.1 nmi for starting points 20 nmi apart and rhumb lines 50 nmi long.

These are small effects, and in applying either of the two basic principles to real navigational situations, we need to be concerned with the resulting errors only if their magnitude approaches or exceeds that of the errors of observation. Clearly, for conventional celestial navigation, where the observational accuracy is of order ±1', neither of the mathematical problems described above rises to this level. Much more important in practice is the fact that we do not know the observer's motion exactly. For the normal case of a ship sailing a rhumb-line track, what we are concerned about is how well the course, *C*, and the speed, *S*, are known over bottom as a function of time. The accuracy of these quantities is usually limited by our inexact knowledge of the local current. In the reduction of a series of celestial observations, the effect of errors in the ship's assumed motion is systematic; the estimated positions, the computed altitudes, and the altitude intercepts all change. How badly the resulting fix is shifted depends on the magnitude of the errors in course and speed and the accuracy, timing, and geometry of the observations. The usual rule of thumb for sights made with a hand-held sextant is that difficulties may arise for observations spread over more than about half an hour. If automated star trackers or similar high-accuracy devices were used for shipboard celestial navigation, observations spread over only a few minutes might be problematic.

In traditional navigational practice, this problem is minimized by taking a small number of observations within a very short period of time–a round of sights. Nevertheless, navigators frequently have to combine observations made hours apart, especially during the day. In such cases the familiar procedures are followed despite the inherent problems because there has been no other choice.

## Another Approach

The observations themselves contain information on the actual track of the vessel, so the possibility exists that the sight-reduction procedure can be made self-correcting. Given enough observations, suitably distributed in time and azimuth, an estimate of the average over-bottom track of the vessel can be obtained as part of the solution for the fix. A development is presented in [6] that includes the observer's motion as an essential part of the mathematics of celestial navigation, rather than as an add-on. This algorithm can recover course and speed information from the observations. The entire problem is thus solved with one mathematical procedure. This algorithm has been incorporated into software developed by the U.S. Naval Observatory for Navy shipboard use.

This approach would be especially useful for high-accuracy automated observing systems. The procedure does not have significant advantages over more conventional methods for the normal round of sights, made with a hand-held sextant, since for low-accuracy observations it can determine course and speed only from an extended series of sights.

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# NAVIGATION BASICS REVIEW

## Celestial Navigation - An Armchair Perspective

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*Editor's note: Beginning with Issue 49, Fall 1995, Director Roger H. Jones is presenting a series of articles on celestial navigation, written in layman's terms and addressed to those members who have nursed ambitions towards the celestial art, but who have been understandably daunted by the common perception of the difficulty of the subject.*

## Article Number 7

*By Roger H. Jones*

Sea berth sailors, you now have the exact coordinates of the GP of the Sun for the exact GMT of your sextant shot, expressed as GHA (longitude) and Declination (latitude). You also have your own distance from that GP, expressed as the degrees, minutes and tenths of arc of the Observed Altitude of the Sun, HO. There is only one more simple thing to do before you enter the sight reduction tables in search of the true direction from the Assumed Position to the GP. *In order to define your AP your AP you must derive an arc value for the difference in longitude between the position of the GP and your own Assumed Position.* Recall that this longitude difference is the angle included between the two sides of the great navigational triangle whose respective sides (meridians) meet at the Pole of the navigator's hemisphere.

This difference in longitude between the AP and the GP of the Sun is expressed in terms of Local Hour Angle (LHA). LHA is the arc distance between the GP and the navigator's AP, whereas GHA is the arc distance between the GP and the Prime Meridian at Greenwich. In both cases it is measured in a westward direction. In the case of LHA, it is measured westward from the navigator's AP. That raises a key question: *how does the navigator determine what Assumed Position to use? He selects one that, in combination with the GHA of the Sun, will render a value for Local Hour Angle that contains whole degrees only - with no minutes and tenths of arc.* This is because the sight reduction tables are arranged such that entry is made with whole degrees of LHA.

How does he do this? If, by virtue of his DR, he is in West Longitude, he subtracts his longitude from GHA, and if he is in East Longitude, he adds it to GHA. In both cases, he seeks a value of LHA that is a *whole* number of degrees.

Consider these cases: The DR is 16-03.2'N, 10-49.3'West, and the GHA of the Sun is 68.16.7'. The navigator is on the eastern side of the Atlantic, and the GP of the Sun is on the western side. The Sun has passed the navigator, and it is afternoon at his DR position. The difference in Longitude is the difference between 68-16.7' and 10-49.3', but for LHA purposes we want a value expressed in whole degrees only. We cannot change the value for the GP of the Sun, but we can *assume a longitude* for our own position that will produce the whole degrees result. The closest one to 10-49.3' that will work is 11-16.7', and when subtracted from 68-16.7' that would render an LHA of 57-00-00. We could also have used an assumed longitude of 10-16.7', but that would have put the AP slightly farther away from the DR, and the LHA would have been 58-00-00.

Another case: The DR longitude is 51-29.6W, and the GHA of the Sun is 20-42.8'. It is morning at the DR,as the Sun has not yet reached the DR's meridian. Again, we subtract the West Longitude of the Assumed Position from the GHA of the Sun. The most convenient way to do this (since the value for the DR is larger than that for GHA) is to first add 360 degrees to the GHA, resulting in a GHA of 380-42.8'. Now, we can subtract an assumed longitude of 51-42.8' and arrive at a Local Hour Angle of 329-00-00. From the assumed longitude in a westerly direction it is 329 whole degrees of arc around to the GP of the Sun, and from the GHA to the assumed longitude it is only another 31 degrees to complete the full circle trip of 360 degrees.

A third case: the DR longitude is 42-41.2'East Longitude, and the GHA of the Sun is 32-14.5'. The difference in Longitude is the *sum* of the navigator's distance to the east of Greenwich and the Sun's distance to the west of Greenwich. To arrive at a proper LHA we'll select an assumed longitude of 42-34.5.E, and that will produce a LHA of 75-00-00. (42.5 plus 32-14.5 equals 75-00-00).

The final example: the DR Longitude is 109-13.8'East, and the GHA of the Sun is 270.05.1'. We'll select an assumed longitude of 108-54.9', and when we do the addition the result is 379-00-00. We'll then subtract 360 degrees and get a LHA of 19-00-00. Does this look right? Yes, because if the Sun has a GHA of 270 degrees it is only 90 degrees to the East of Greenwich, whereas a navigator at 109 East is 19 degrees farther to the east, and the westerly distance from it to the Sun's GP is thus that same 19 degrees.

Our work form, continued on to include the derivation of LHA, would look like this:

| | |
|---|---|
| GHA: | 68-16.7' (Using the first example above) |
| ASS'D Lo.W.: | -11-16.7 |
| LHA: | 57-00-00 |
| | |
| AP: | 16-00-00N (Nearest *whole* latitude to the |
| | 11-16.70W illustrative DR latitude) |

Congratulations are in order! You are now ready to enter the sight reduction tables. From the time you started to enter data on your work form (which is not yet complete) to the point where you have identified your Assumed Position, it has taken you no more than about ten minutes. It's not as fast as GPS or a scientific calculator with a navigation program chip, but it is still not a lengthy process, and it offers advantages. You can recheck your data entries to discover any errors, and you can even use the process in the end to check the accuracy of your GPS or Loran. Most important--celestial navigation does *not depend upon electronics*, which in a salt-laden environment can desert you when you need them the most.

## Article Number 8

*By Roger H. Jones*

Travelers, you are nearing the end of your journey. It started in your arm chair or sea berth with a basic concept--distance and direction. It propelled you out of your comfortable perch below up to the spot on deck where you took your sextant shot. After the shot, you scuttled back below and delved into the *Almanac* for the HE correction and the Main Correction to your HS. To the center of the Earth you ventured to discover HO, and then, without so much as a singed hair on your brow, it was back to your sea cabin. Into the *Almanac* again you went to discover the GHA of the center of the Sun for the GMT of your sextant shot. You had a full head of steam by this time, and you charged right into the simple business of selecting an assumed longitude that would give you an LHA expressed in full degrees only, with no encumbering baggage of minutes and tenths of minutes of arc. With LHA firmly in hand, you are now ready to enter the sight reduction tables in pursuit of the True Bearing of the Sun from your Assumed Position.

"Wait," you command. "I've got my assumed longitude, but a full Assumed Position also requires a latitude." The *assumed latitude* is simply the *whole degree* of latitude that is nearest to the DR latitude. You will enter the sight reduction tables with LHA expressed in full degrees, and with your latitude expressed in full degrees. You'll also enter with Declination of the Sun expressed as a full degree value, by simply omitting (for the time being) the minutes and tenths of arc for the Declination of the Sun at the GMT of the sextant shot. Your profound gratitude will go the designers of the tables, because you don't have to deal with anything more than whole degree numbers on your way into the tables. And when you emerge, it will be with complete numbers all nicely precomputed for you. With any given LHA, Latitude and Declination, the tables will give up, on a single line, just three numbers. These will be labeled respectively as Hc, d and Z. (Z here is *not* the same as Z denoting the observer's zenith). We'll come back to them.

Meanwhile, *what have you really done with your table entry? You have defined the great navigational triangle that existed at the moment of your sextant shot.* With your own assumed latitude you have stated the arc distance of the side of the triangle from you to the Pole of your own hemisphere (North or South). With the Declination of the Sun you have stated the arc distance from the GP to the *same* Pole. With the LHA you have stated the difference in longitude between the GP and your own Assumed Position, and that is the included angle because meridians of longitude meet at the Pole.

Hc (height computed) is the altitude of the Sun that you should have measured if you had actually been at your Assumed Position. The number labeled "d" is a final correction factor used to adjust Hc because you entered the tables with full degrees of Declination, and you need to adjust the shape of your triangle slightly to account for the minutes and tenths of arc of the Declination. Z is the *azimuth angle* from the Assumed Position to the GP of the Sun. Given the length of two sides and the included angle, the tables have presented you with the length of the third side (from you to the GP), and the angle from you to the GP.

Before going to the business of the final "d" correction, let's clear up one other point. The tables are the precomputed solutions for the size and shape of hundreds of thousands of possible triangles based on all the combinations of latitude, LHA and Declination. While one point of the triangle is always the geographic pole of the hemisphere (north or south) of the navigator's DR position, the GP of the Sun or other celestial body could be in the opposite hemisphere. Thus, if the navigator was at, say, 25N and the GP or the Declination was 18S, the *name* of the Declination (south) would be *contrary* to the name of the Latitude. Conversely, if both the latitude and the Declination were in the northern hemisphere, their names would be the *same*. When you enter the sight reduction tables you will see that they contemplate this possible difference, and the pages contain entries for the situation where Latitude and Declination have the same name, and also the pages for the situation where the name is contrary. The size and shape of the triangle is obviously a function of LHA and of how far north or south of the Equator, the AP and the GP happen to be located.

Now as to the final "d" correction. In the sight reduction tables you will find a separate *Interpolation Table*. You enter with the Declination increment of minutes and tenths. This is the increment you omitted when you first entered the tables with only the full degrees of Declination. You will also enter with the "d" value from the main page of the sight reduction tables where you found the Hc, d and Z. For the Declination Increment and the d value you'll find a correction to the computed altitude stated in minutes and tenths of arc. To the HC you will *add or subtract* this number according to whether the "d" value was positive or negative as stated on the main page of the sight reduction tables.

The "Z" value is the *azimuth angle*. It is converted into a True Direction by following the simple instructions on each page of the sight reduction tables. For example, with Latitude and Declination having the *same name*, and with a north latitude, the instruction will be: LHA greater than 180 -- Zn equals Z, LHA less than 180 -- Zn equals 360 minus Z. With an LHA of, say, 348 and with a Z value of, say, 079, the Zn is also 079. *Zn is the True Direction from the AP to the GP*. Why the duality of azimuth angles (Z) and true directions (ZN)? In order to keep the tables to a practical size, the final data is presented for a triangle of a certain size and shape. The mirror image of that triangle would have the same size and shape in terms of the length of the sides and the size of the angles, but the angle from the AP to the GP would result in a different *True Direction* depending on whether the AP was east or west of the GP.

## Article number 9

*By Roger H. Jones*

Well, navigators, you have truly earned that title. Continuing with your work form, the final entry might appear as follows:

| | | |
|---|---|---|
| HC: | ________ | From the sight reduction tables. |
| CORR'N: | ________ | Plus or minus, according to whether "d"in the tables is positive or negative, and taken from the Interpolation Table for the *increment* of Declination stated as minutes and tenths on the Dec. line above. |
| FINAL Hc: | ________ | Hc plus or minus the correction. |
| HO: | ________ | HO taken from above and restated here. |
| ALT. Dif.: | ________ | This is the "Altitude Intercept" or difference between HO and the final Hc. Subtract the smaller from the greater and record its value in minutes and tenths of arc. |
| T or A: | ________ | Pencil in a "T" or "A" according to whether the intercept is towards the Sun from the AP or is away from the Sun. It will be one side or the other of the AP on the True Bearing passing through the AP. |
| Z: | ________ | Taken from the tables. |
| Zn: | ________ | Z converted to True Bearing following the instructions on the same page as the one where Hc, d and Z are found. |

There you have it! What do you do with it? First, let's clear up the matter of Altitude Intercept. Again, it is simply the difference between your own HO and the Final Hc. Your own HO is the altitude of the Sun as measured form your own actual position. The Final Hc is the altitude that you would have measured *if you had been at the Assumed Position*. Since both altitudes represent the *distance, the difference in the two altitude numbers represents a difference in distance*. The AP is one certain computed distance from the GP, and the actual position is normally another certain distance (measured by the sextant) because the AP and the actual position rarely coincide. But remember this: on the surface of the Earth, one minute of arc equals one nautical mile. The altitude difference is thus equivalent to a certain number of nautical miles stated to the nearest tenth. If the altitude difference is, say, 14.3, then that is the number of nautical miles on the True Bearing line from the AP where the LOP will intersect the True Bearing. The question is *which way* from the AP - in an easterly or a westerly direction?

Envision, if you will, a tall flag pole with a halyard from the top hanging down to the ground with some spare length on the ground. At the top the halyard is attached to a swivel so that the halyard can move freely around the pole without wrapping itself around the pole. The top of the pole has a gold ball ornament. This represents the Sun. The bottom of the pole where it meets the ground is directly beneath the Sun on the surface of the Earth, so it is representative of the GP of the Sun.

Now grasp the halyard at any point short of its end and walk straight out from the bottom of the pole until the halyard is stretched to run at an angle from you up to the top of the pole. You are a certain distance from the bottom of the pole, and the angle that the halyard makes relative to the horizontal surface from your feet to the bottom of the pole is a function of how far you are from the pole. At the distance you are from the pole, you could walk around the pole holding the halyard taut, and your feet would inscribe a circle around the bottom of the pole. You are on a Circle of Equal Altitude around the bottom of the pole, and at every point on that circle the angle between the taut halyard and the ground will be the same.

Now, give yourself some more slack and grasp the halyard farther out closer to its end. Again, walk away from the pole until the halyard is again taut. You are further from the base of the pole, and now the halyard forms a *lower* angle with the horizontal of the surface from your feet to the base of the pole. Again, however, you could walk around the pole with your feet inscribing a circle around the base of the pole.

The point is simple. *The closer you are to the base of the pole, the greater will be the angle formed* by the halyard. If you were at the base of the pole, the halyard would go virtually straight up in the vertical plane of a 90 degree angle with the surface of the Earth.

Thus, navigators, if your HO is larger than the Final Hc for the AP, you must have been closer to the GP at your actual position than you would have been at the Assumed Position. If your HO is less than the Final Hc, then you had to have been farther away. Hence the rule: *If HO is larger than Final Hc, the intercept is towards the celestial body; if HO is smaller than Hc, the intercept is away from the celestial body.* The intercept is thus placed on the True Bearing of the celestial body such that is either closer to the body than the AP or farther away than the AP. Place it closer if the HO is larger than the Hc, and farther away if the HO is smaller than Hc.

## Article Number 10

By Roger H. Jones

Navigators, your journey now takes you from the work form to your plot. Grab your chart or perhaps a Universal Mercator Plotting Sheet. Plot your DR on it. Plot your AP on it. The AP will be not too far away from the DR, and the distance doesn't matter because the Altitude Intercept presented in the preceding article will give you a final adjustment to overall distance from the GP for your purposes of plotting your LOP.

Through your plotted AP draw a line of true direction towards and GP. This is the Zn from your work form. Plot it with reference to True North. On the end pointing towards the celestial body, put a small arrow and label it, such as "Sun". Allow the other end of the bearing line to run through the AP in the other direction. Generally, the convention is to plot the line of direction as a *dotted line* to distinguish it from the LOP.

Starting from the AP take your dividers and plot a point that is the nautical mile equivalent of the altitude difference between HO and Final Hc. If that difference is 8.7 minutes of arc, you'll use 8.7 nautical miles on the chart. You'll either march 8.7 nautical miles towards the Sun from the AP along your true bearing line, or 8.7 nautical miles from the AP in the opposite direction. At the appropriate 8.7 mile distance mark a dot, and then construct the LOP perpendicular to the bearing and running through that dot. You are somewhere on that LOP because you have located it the exact distance from the GP that you were when you took the sextant shot. It is only your direction that is yet somewhat imprecise. Unless the bearing from the AP to the GP was identical to that from your actual position to the GP, you cannot be sure where on that LOP you are. Recall the example earlier where you stood on a straight beach looking eastward over the ocean to a point 2,217 nautical miles away. If you could have obtained a bearing on that point, it would not have changed had you then moved to a new spot on the beach ten or even forty miles to the south. The distance is so great that a position change of that magnitude will not result in a bearing change that is great enough to measure and plot.

Now, for the final truth. When you selected your AP, you based it on your DR. In entering the tables you used the nearest whole degree of latitude to your DR latitude, and you used a LHA stated in terms of whole degrees. Since a whole degree of great circle arc is equal to 60 nautical miles, and since you selected values to give you the nearest whole degree of arc, you placed yourself at least within 30 miles of your DR. Normally, it is a lot less than that, and in any case, it won't change the True Bearing unless you happen to be very close to the GP. In that case it would make for a very high altitude shot, which is difficult to get. Stick with bodies no higher than 70 degrees, and the GP will be at least 1,200 nautical miles away.

If your DR happens to be off by many miles from your actual position, this will be revealed in the plot. A perpendicular from your LOP to your DR will be correspondingly long. The closer that your LOP is to your Dead Reckoning Position, the more will be your confidence in both your DR and LOP. Two intersecting Lines of Position from different celestial bodies for the same GMT will render a fix. Two LOPs from the same body for different GMTs, plotted as a running fix, will also be better than a single LOP. However, a single LOP is often very useful also. If you are approaching a shore an LOP roughly parallel with the shore will tell you your distance off, and if you are heading out to sea in the opposite direction, an LOP may tell you your speed made good by virtue of the distance covered. If the bearing of the celestial body happens to be roughly parallel with a distant shore, then the LOP will intersect the shore in a manner enabling you to tell you if it is time to turn toward a specific point on that shore.

A single LOP for the Sun at Local Apparent Noon (LAN) *when the Sun is crossing your meridian and is therefore at its maximum altitude* will, in conjunction with the Declination of the Sun, establish your latitude. You won't, in this case, have to enter the sight reduction tables, and you don't even have to time the shot to the nearest second of time because Declination changes so slowly. For the Greenwich date just use the nearest whole hour of GMT to correspond with your local time, or read the GMT directly on your quartz watch. In any case, use this simple procedure. Observe the Sun, and when it has reached its maximum altitude read your sextant. It will appear to "hang" on the horizon for a moment or two before it starts to dip below the horizon. Apply the normal altitude corrections to HS to arrive at HO and label HO either North or South according to whether you were looking north or south at LAN. From 89-60.0' subtract HO, and label the result ZD (Zenith Distance) with a name *opposite* to the name of HO. If HO is South, label ZD North, etc. From the *Almanac* take the Declination for the nearest whole hour of GMT. It will either be north or south Declination. When Declination and ZD have the same name (North or South), add them together and Latitude takes that same name. When ZD and Declination have opposite names, subtract the smaller from the greater and name Latitude after the greater. It is quick and simple, and it works every time.

We've not covered the procedures for the Moon, the stars or the planets. They are basically the same. We have not covered star and planet identification. We've not covered all the special ways in which the basic celestial theory and procedures can be twisted and turned. What we have done is to cover the celestial art as it applies to the Sun, and with that, mariners, you can sail anywhere in the world! The *Almanac* itself explains the procedural differences for the other celestial bodies.

Just a final word. Get a good *metal* sextant. Learn to adjust its mirrors. Select your own sight reduction tables, but HO 249 is highly recommended. These are the aviation tables, but they are somewhat simpler to use and consist of only three volumes, two of which are good forever. Volume I is for stars and must be replaced every five years, but its star procedure are, by far, the most simple. Always use the current year *Almanac*, and get a reliable (but inexpensive) quartz watch and an ability to check it, such as by radio time tick. Then go out and practice. After ten or so shots, you'll wonder what all the fuss was bout. Good luck and may the trade winds always bless you. As is etched in glass aboard my vessel, *Allidoro*, "May Dolphins Dance Beneath Your Bows!" Roger H. Jones, Ft. Lauderdale, July 3, 1995.

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By Ernest B. Brown*

*(Continued from Issue #50, Winter 1995-96)*

After the near tragedy of the 1925 flight, Roald Amundsen was even more certain that a dirigible was superior to an aircraft for polar exploration. The dirigible had not only longer range and hovering capability but was inherently safer. A minor mechanical problem in an aircraft could compel an extremely hazardous forced landing. In an airship, one could merely stop and make considerable repairs. And the forced landing of an aircraft in fog meant certain death.

Amundsen did not consider the 1925 flight the failure as depicted by the world's press but as a success in studying the conditions over the Arctic waste as far as was possible. The earlier assumption that the atmospheric conditions over the ice-masses were specially suited for an airship passage across the Polar Sea was confirmed.

At a meeting prior to the 1925 flight (See issue #50), Riiser- Larsen drew attention to the Italian airship *N1* as being the craft best suited for the polar sea flight. So after the 1925 flight, Amundsen sought out the builder and constructor of *N1*, then Colonel Umberto Nobile who agreed to a conference in Oslo.

At the subsequent meeting in Amundsen's home in Bundefjord, Amundsen and Riiser-Larsen obtained particulars on the airship from its constructor, further confirming their conviction as to the suitability of the airship for the flight. Colonel Nobile advised them that the Italian State, the owner of the airship, would prove very indulgent in event of any purchase. Soon afterwards, Amundsen and Riiser-Larsen went to Rome to negotiate a contract for the purchase of *N1*. Due to the great interest in the matter by the then head of the Italian government, Benito Mussolini, the contract was easily arranged, much to Amundsen's satisfaction.

*N1*, after a number of alterations, would be ready at the beginning of 1926, at which time the Norwegian crew members would go to Rome and obtain practice in the maneuvering of the airship under Colonel Nobile's instruction.

Soon after his return from Rome, Amundsen set about raising funds for the coming expedition by lecturing in the United States on the 1925 flight. Lincoln Ellsworth, whose wealthy father died during the 1925 flight, then contributed one hundred thousand dollars for the new expedition. Although Ellsworth's contribution was only a third of the whole cost, it was the foundation on which the remainder was obtained.

In the planning for the expedition it was first recognized that a mooring-mast for the airship would be needed at Kings Bay. Then an airship hangar was seen as an alternative. Originally, Riiser-Larsen was to supervise the preparations at Kings Bay. But his lecture tour to raise funds and the press of other matters in the course of the planning and preparation inclined Riiser-Larsen to suggest to the Norwegian Aero Club that First Lieutenant Joh. Höver, Royal Norwegian Navy, could do the Kings Bay job.

Later when the funds for the expedition had increased to such a degree as to impress its directors, the Norwegian Aero Club granted, on September 22, 1995, *both* mooring-mast and hangar for Kings Bay. Höver was requested to go to Kings Bay as soon as possible to make plans for the airship station according to his own judgment, in the most favorable way known as the "technicalities of aviation". First he had to obtain a leave of absence from the Navy.

As a good leader Amundsen picked good men who could in turn pick other good men. (To be continued)

# MARINE INFORMATION NOTES

*Edited by Ernest Brown*

Commencing 1 March 1996, option 54 of the Navigation Information Network (NAVINFONET) will contain the latest threat areas for marine shipping from the Office of Naval Intelligence (ONI). This new file will be a complete replacement of the previous resident data and will be updated each week by ONI. Five weeks of data will be held in option 54, with each new week's data causing the oldest week's data to be deleted. Its new title will be "Worldwide Threat to Shipping".

# BOOK REVIEW

*By Terry Spence*

**Emergency Navigation**
By David Burch,
International Marine Publishing Company,
Division of Tab Books, Inc.
P.O. Box 220
Camden, Me 04843 -248 pages (1986) Cost $14.95

We have taken a voyage, learned the formalities of port clearance, studied the formulae helpful in safely navigating, how to pilot in coastal waters upon our arrival of destination, the use of the stars and a different method of sight reduction; but what would happen if we had an emergency — a navigation emergency. For example, suppose your sextant(s) were unavailable for any reason or a bolt of lightning rendered all vour electronics useless? That is what this book is designed for. A quick review of the chapter headings tells the story of the scope of this book. As a sampling of examples: steering by the stars; steering by other things in the sky; coastal piloting without instruments; and what to do with what you've got— a summary.

Throughout the book are numerous drawings and illustrated examples of problem solving. This is extremely helpful in understanding the principles covered in the text. At this point it behooves me to say that this is not a book to be lightly read and filed away in your mind for future reference. The procedures outlined require practice and more practice and thought, such that should the time come when you are faced with a navigational emergency you can begin instituting the practices.

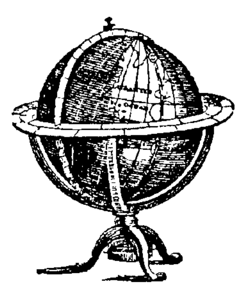
The question of knowing your approximate longitude in an emergency situation is amply covered in the chapter devoted to this subject. How to find longitude from the timing of sunrise and sunset is one method offered. Of course a watch is of critical importance in this explanation - in fact the value of a watch and an understanding of its accuracy is stressed throughout the book. Longitude from LAN is another option offered, as well as an interesting discussion on the equation of time and how to use it.

One of the longest chapters covers latitude at sea - which when coupled with longitude will give you, as we all know, a location on the earth from which direction and distances can be found. Latitude from the length of the day is but one of the methods shown for arriving at latitude especially above 30 degrees of latitude. The stars offer several methods of finding latitude. The use of a kamal is explained in this chapter.

I found the chapter on dead reckoning very interesting as well as the coastal piloting without instruments section. The last chapter is indeed a summary of the contents of the book in the form of "what to do with what you've got". A few of the headings will give you an excellent idea of the thrust of this book. "Everything but GMT": "Everything but a sextant"; "Everything but an Almanac"; and lastly, "Nothing but GMT".

There was an interesting and valuable side benefit from reviewing the book— it helped me understand some of the principles of navigation that I tended to do by rote. I plan to practice some of the procedures whenever I can. A most worthwhile addition to any library on navigation.

*Reviewer's comment: In the near future I am planning on reviewing a computer course on the weather.*



**ANSWER TO DO YOU KNOW . . .?** (From page 1)

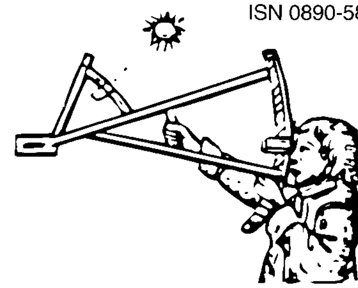
Unlike back-coated sextant mirrors in which the light from the celestial body is attenuated in passing through the thickness of the glass to the back coating, front-coated mirrors do not have this problem.

Particularly at higher altitudes where the length of the light ray path is longer, the attenuation in the back-coated mirrors is considerable. But the front-coated mirrors can easily be scratched or otherwise damaged. Re-silvering a front-coated mirror is *very* expensive compared to re-silvering a back-coated mirror. If a front-coated mirror is damaged, the best answer is to purchase a new mirror. This is much less expensive than re-silvering.

Also, back-coated mirrors produce double images; one distinct image from the back surface and a less distinct image from the front surface. When using filters with the sun, only one image, from the back surface, is transmitted through the filter. When stars are observed, only the more distinct image is seen. For lower limb observations using back-coated mirrors, the back surface reflection is always the lower which is seen in the telescope field of view (assuming the telescope image is erect).

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-TWO, SUMMER 1996

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### E-Mail

A number of members are now using either Compuserve or the Internet to write to The Foundation or place orders. So far it has worked quite well. The only problem I foresee is when I am on travel and away for some period of time. If my messages are not downloaded in a certain period of time, they will be canceled. I will not even be aware that I have missed a message.

To prevent the possibility of having missed a message, expect some form of acknowledgment from me. The message may be short and terse but it will acknowledge that it has been received and I am working on an answer. If you do not receive acknowledgement, you will have to assume that for some reason I did not receive the message. The non-receipt can be caused by a number of factors other than untimely download, like a typo in the address, the server going down, or I am unable to download for some other reason. If you do not receive an acknowledgement in about one week, re-send the message or just a short one saying, "Hi, I am trying to reach you." At least something to that effect.

### Credit Cards

Many members have asked about using credit cards to renew or pay for orders. The Foundation has tried to join the credit card charge system. The banks or the credit card companies themselves would not grant the Foundation credit card authorization. The reason given was basically the same as the Matching Educational Grants contributions. We do not have paid officials to hold accountable, or in the case of the credit card companies, we are too small with too little credit card activity. Sorry, but credit card charges are beyond our control.

### Web Page

Compuserve has included The Navigation Foundation in its web page. The URL is http://www.olyc.com and we are about the third major section from the beginning. We are also cross-referenced in a number of search programs that are standard on most internet computer programs. The web page has generated some little interest in The Foundation and we get about 2 requests a week for additional information about us. So far we are getting about one new member a week from the source, however, it is steady. The only cost to The Foundation is the Compuserve monthly fee for connecting. None for the web page yet. FYI, The Foundation can be reached at 76476.1165@compuserve.com or navigate@ix.netcom.com. Give us an E-mail.

## NEW PRODUCTS

*By Terry Carraway*

A must reference for boaters is *Advanced First Aid Afloat*, 4th ed. by Peter F. Eastman M.D.." List price is $14.95 and members' 20% discounts apply. Published by Cornell Maritime Press and available through The Foundation only, for your discount.

Four new excellent videos for boaters are now available: The Care & Feeding of the Sailing Crew; Cruising with Lin & Larry Pardey; Cruising Coral Seas; and Voy-

DO YOU KNOW . . .?
*By Ernest Brown*

The name of the new agency that will subsume the Defense Mapping Agency?

*(The answer appears at the back of this issue)*

aging with Lin & Larry Pardey. Each video is with Lin & Larry Pardey and from 54 to 59 minutes long. (List price is $29.95 with a $3.50 shipping and handling charge. Members' 20% discount applies to the cost of the video.) The Pardeys have written a number of excellent books: *The Hull, The Capable Cruiser,* and *The Storm Tactics Handbook.*

## Sextant Lighting System

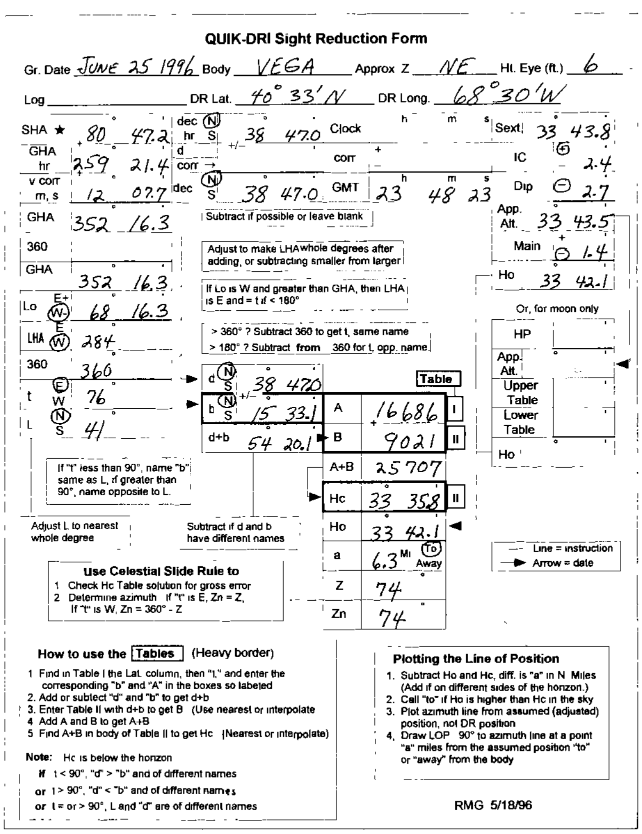
A self-contained lighting unit for installation on sextants not originally provided with a lighting system such as the World War II vintage U.S. Navy Mark II sextant. It employs a 3 volt watch battery, is 1 1/4" long, 3/8" in diameter and weighs less than 2 ounces. Depending on type of installation, the price will vary from $35 to $50.

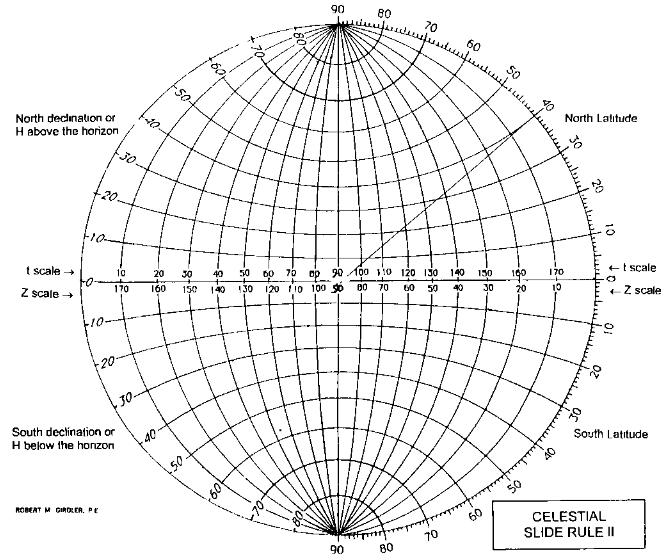
## Duo-Bearing Compass

A small hand bearing magnetic compass manufactured in Switzerland with capability of marking on the compass dial the values of two (2) bearings to obtain a fix. The compass settles in 2 seconds and can be tilted 20° without restricting the movement of the card. It is shock resistant and has phosphorescent illumination. The length is 2 3/8", width is 1 3/4", height is 3/4", and the weight is 2 ounces. It comes with an instruction manual and the price is $93.00.

## Mariner's Check List

A handy 8-page laminated boating check list applicable to power and sail covering, among other things, galley supplies, navigation equipment, and procedures




for mooring alongside a pier. It is of heavy water-proofed map stock construction which works with a wet erase pen. Price $8.95.

## New Version of Quik-Dri

A new version of *Quik-Dri Sight Reduction Tables for Marine Navigation including Celestial Slide Rule* is now available from the author, R. M. Girdler, 4269 Vaucluse Road, Aiken, SC 29801. The price of the 26-page 8 x11 inch booklet is unchanged: $15.00. Front and back covers are mylar-covered and the book cover is the Celestial Slide Rule. A *Sun-Manac* is included which allows sun sights without even hauling out the Almanac and a variety of additional useful applications of the slide rule are described on its reverse. See READERS FORUM for letters from Director Allan Bayless. and from Member William S. Murdock.

# READERS FORUM

*Edited by Ernest Brown*

Director Allan E. Bayless of 116 Gardens Drive #201, Pompano Beach, FL 33069-0946 wrote on July 3, 1996:

"You will shortly receive a copy of a new version of *Quik-Dri Sight Reduction Tables for Marine Navigation including Celestial Slide Rule* from its author, Robert M. Girdler. Director John Luykx wrote a splendid review of Girdler's improved version of Dreisonstok's sight reduction tables. At that time, I was just as impressed as he with the advantages of Girdler's modification, particularly the graphical solution for azimuth. Since then, Bob Girdler and I have devoted a great deal of time to the refinement of his book.

"As a consequence, the present version, in my opinion, deserves further mention in the *Newsletter*. The refinements of the present version include:

(a) Much improved typography and format, especially the recalculated tables. Table I now includes all latitudes from 0°-90°.

(b) The *Celestial Slide Rule* is now based on the stereographic rather than orthographic projection so the values can be accurately located right up to the edge of the diagram.

"In my opinion, this is an outstanding short sight reduction method. Hc is found by two simple arithmetical steps and three table page openings. Z is found directly from the Celestial Slide Rule for meridian angle and assumed latitude.

"Many navigators will sleep more soundly if they have this short, fast and simple celestial method aboard which requires only pencil, paper and brain-power. And many prudent navigators will continue to practice celestial navigation to keep their skills intact as well as to check the honesty of their GPS receiver as these otherwise miraculous instruments actually do go on the fritz, occasionally."

— *Cordially, Allan.*

Member Robert M. Girdler of Omnitronics, Inc., 4269 Vaucluse Rd., Aiken, SC 29801-8852 (803-648-1393) wrote on July 11, 1996:

"Here is a complimentary copy of *Quik-Dri Sight Reduction Tables and* Celestial *Slide Rule* referred to in Allan Bayless' letter to you of July 3, 1996. I don't have much to add to Allan's remarks, except that what you see is the latest of a number of versions, which are nearing, but not yet reaching, the ultimate in perfection. Hence, a few typos still persist, which have been corrected by hand in this copy.

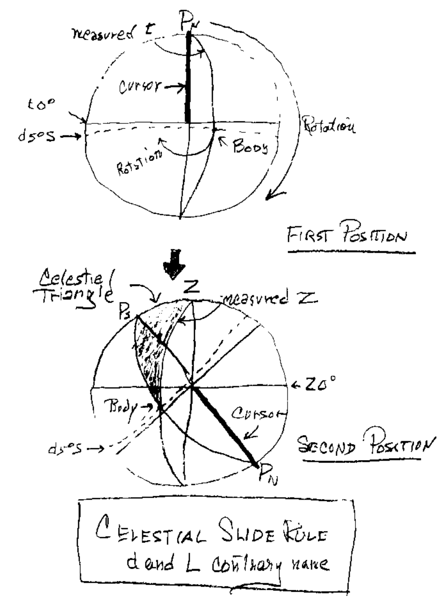
"I agree that the article in *Newsletter #43* should be updated for the reasons stated by Allan, and I would appoint Allan for the job. He is responsible for turning a couple of rough ideas into a practical, salable product."

— *Sincerely, Robert M. Girdler.*

Director Allan E. Bayless, 116 Gardens Drive #201, Pompano Beach, FL 33069-0946 wrote to the editor on July 23, 1996:

"I am delighted you are impressed with Girdler's *Quik-Dri* Tables. I was too. I think the *Slide Rule* is a marvelous innovation to find Zn and the tables a distinct improvement on Dreisonstok's little book. In fact, I think this is the simplest and best short method around and, in my view at least, compares very favorably with inspection tables. It's also cheaper and easily stowed.

"The Slide Rule is a mirror image of the usual meridian diagram, that is t0° is at the left — this is a minor difference in convention of no importance. However, when d and L have contrary names, the cursor is rotated through an arc greater than 90° (in the example you sent 134°). In essence, this involves turning the diagram upside down, this also reverses the scale relative to its usual orientation; Ps has become, to all intents and purposes, the north pole insofar as the conversion of Z to Zn is concerned. If you hold the page you sent from 229 upside down, it will look exactly as the Slide Rule does were all the coordinates drawn (see enclosure — if you want a "pretty" diagram, I'll be glad to provide you one). Which is to say, it is unnecessary to convert the supplement of Z derived by calculation to Zn. In my view, this is a valuable property of the Slide Rule and another worthwhile simplification of sight reduction!




"Insofar as other applications of the Slide Rule are concerned, this only demands careful attention to the wording of the instructions. The instrument will do anything a meridian diagram or the Hyatt Coordinator will do, it just does it differently.

"I think it's a marvelous instrument. As all the curves are segments of circles (bless Hipparchus for the stereographic projection!), and as the located position is transferred by the cursor, it's extremely simple to construct and manufacture. I think Bob Girdler has done celestial navigation a signal service by dreaming it up.

"Actually, Bob and I are involved in no major alterations. If anything is changed, it'll be in the very near future and either I or Bob will let you know whether there are to be any."

— *Cordially, Allan.*

Member John W. Gruol of 14 Andover Court, Red Bank, NJ 07701 wrote on 13 May 1996:

"I have just read the article "Celestial Navigation-An Armchair Perspective" by Roger H. Jones, and while this is a fine dissertation on celestial navigation, there is one statement in the article that I feel obliged to correct.

"In Article 1 the statement is made that 'The fastest time for the Sun to complete one trip around the Earth in its apparent motion is 23 hours, 44 minutes, and the slowest is about 24 hours, 16 minutes.' If this were so we should all soon be experiencing a midnight sun!

"Actually this is a misinterpretation of the meaning of the Equation of Time, which does reach a magnitude of nearly 16 minutes twice each year. But this is the difference in time in the passage of the real sun and the fictitious 'mean' sun over any point. A glance at the Nautical Almanac for November and February will show that the meridian passage of the real sun can be as much as 16 minutes early or 14 minutes late. Actually the sun's trip around the earth never differs from 24 hours by more than about 30 seconds, but the accumulation of these small increments, as in the case of a runner outrunning his opponent by a small amount each lap, soon becomes a sizable lead. If Roger Jones' statement were correct, we would have a new 'daylight savings time' every four days!

"Despite this error, I look forward to more articles by Mr. Jones."

— *Sincerely, John W. Gruol.*

Member David A. Blythe of P.O. Box 125, Oxford, MI 48371-0125 wrote on April 30, 1996:

"I am interested in obtaining copies of several out-of-print navigation publications and I wonder if **The Navigation Foundation** can help me locate any of them.

"I would like to purchase a complete set of **H.O. 214** sight reduction tables in usable condition. I am also looking for a serviceable copy of **H.0. 211 Ageton Table**, complete and preferably published prior to the Bayless Compact Table.

"In another matter, as an exercise in learning by doing, I am programming navigation, writing the program as I learn the relevant mathematics. To date, I have a pretty good HP-48 program based on NAO sight reduction/position fixing with ephemeris data for the sun and stars after Schufelt & Newcomer by way of Richard Plant and Rolf Noer, with some of my own modifications.

"I'm stumped for a line on the math for moon and planet GHA/dec and for moon/Mars & Venus HP.

"Would *The Calculator Afloat* be any help or perhaps Yallop & Hohenkerk, *Compact Data for Navigation and Astronomy?* Do you know where I can find copies of these works for purchase?

"If you can be of any help, I thank you very much."

— *Yours truly, David A. Blythe.*

Director John M. Luykx responded:

"All the books mentioned in your letter are out of print. If you are interested in purchasing the books mentioned in your letter, we would be glad to do a search for them free of charge.

"We do not know whether Schufeldt and Newcomer's *Calculator Afloat* or Yallop & Hohenkerk's *Company Data for Navigation and Astronomy* contain the data you require for moon/planet GHA/Dec and Moon/Mars/Venus H.P.

"We plan to publish your letter in one of the upcoming issues of *The Navigator's Newsletter.* We feel sure that some of our members will be able to provide the information about the books and reduction tables which you require."

Member William S. Murdock of 3424 Lakeshore Drive, Kingsport TN 37663-3370 wrote on April 29, 1996:

"Thank you for the information on The Navigation Foundation. I am interested in receiving your newsletter, so here is a check for $30.

"Let me tell you a little bit about myself. I am a chemical engineer which means that I enjoyed math in school. I have been around boats all of my life even though I live here in the mountains. Ten years ago I took the USPS JN course and was intrigued by the math. I made my own sight reduction tables and programmed a PC and a couple of calculators to reduce sights. I was unable to find a way to calculate astronomical data with 0.1' accuracy, and could not dispense with the Nautical Almanac. That bothered me. In 1990 we moved to England and lived in the north for four and a half years. The village library could get me anything from the British Library, and I found a wealth of information on calculational astronomy.

"During the winters when the weather kept us all indoors, I programmed three calculators to do increasingly complicated celestial problems. In 1993 I was in London and found £15 Texas Instruments TI-67 Galaxy calculators in the shops. I bought one and wrote a sun sight reduction program to fit in its 1500 byte memory. It needed no almanac or tables, had a 200 year 0.1' internal almanac, and even made temperature and pressure corrections. *Practical Boat Owner* (London) published the program and an article about it in March of 1994. They accidentally cut the ends off of three lines of code making the program unusable. I know there was a lot of interest in it. I had perhaps a hundred phone calls and letters before the correction ran two months later.

"Texas Instruments does not sell the TI-67 in North America, so I rewrote the program for the $70 TI-81. I tried to sell the program and article to both *Cruising World* and *Ocean Navigator* in 1994. Neither was interested. *Cruising World* turned me down without comment, and *Ocean Navigator* said it was too technical.

"Last summer I resubmitted the article to *Cruising World*. This time Tim Murphy bought it. It was published in March 1996. Tim had some concerns about running a four-page article with no literary merit, so he removed a table that compares the calculator almanac to the Nautical Almanac and a couple of sentences were accidentally dropped from the examples table. My address was at the end of the article, and I have received 28 phone calls or letters from people who have tried the program. Some have rewritten the program for other calculators or for computers. One used the almanac to write a calculator program that continuously displays the time and the sun's azimuth for correcting compasses.

"The article has references for anyone who wants to follow up on the subject. I wrote the program in an understandable manner so that a reader could figure it all out if he wanted.

"I have enclosed a copy. You are welcome to use it if you wish. If you do I will happily send you a copy of the diskette containing the article.

"After I finished with the sun sight program, I wrote a much longer program for the TI-82 calculator which has 200 year 0.1' almanacs for the sun, moon, four planets, and 93 stars. All of the almanac data is available in either Nautical Almanac or Astronomical Almanac formats. It reduces single sights to altitude and azimuth and multiple sights to latitude-longitude fixes. It will handle running fixes with course and speed constant or with varying course and speed. There are routines for Mercator sailing and great circle sailing on a sphere. For sights of unidentified bodies, it will list the closest bodies in its almanac. There are routines for precomputing altitudes and azimuths for sight planning or for calculating the R.A. and declinations needed for plotting the planets, sun, and moon on a Rude Starfinder. The program basically makes a $90 Wal Mart calculator into a full function celestial calculator.

"The program, its description, and example problems fill a 185 page typewritten book. I have not been able to find a publisher either here or in England, but I have sold 9 Xerox copies text for $25 through word of mouth advertising. Two people have punched the entire program into calculators. Two have copied the program from one of those calculators by connecting the calculators together. I have sent a diskette to one to load into his calculator. The remaining four are (I guess) punching it in by hand which is a 40 hour task.

"This has been (as it should be) fun. I have had a great time doing all of it. I have learned a lot and talked with some great people."

— *Yours faithfully, William S. Murdoch.*

Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona*, wrote to us from Colon, Panama on 10 February 1996:

"Dear Friends, I am going to call my second newsletter 'The Wind is Free — It's the Sails That Cost Money!' This summarizes much of the period since my last newsletter, which has been devoted to repairing the damage incurred off the coast of Brazil. We left Guyana in mid October, bound for Tobago. The romance of having a mainsail with the hand-stitched repairs faded somewhat when we set the main for the first time. The old man's sail loft was the street outside his hovel and the sail was crisscrossed with black oil streaks. Not only that, the stitches gave way in a few hours. Still we got to Tobago OK only to run into a typical bureaucratic problem - Russians need an entry visa and we didn't have one for Evgueni. The immigration official said I could buy him a ticket to Moscow or leave immediately. After a reasoned discussion we compromised - Evgueni was confined to the boat during our stay and a note to this effect was written on our documents. This leads to a catch 22 situation as Evgueni could not now visit the consulates in Trinidad in order to get visas for other islands. When we got to Trinidad we did get him a French visa, which covered the French islands and will be good for French Polynesia. Tobago is one of the last unspoiled Caribbean islands. In the north there is an original rain forest. Anchored off the coast in this area, I was fascinated by the flocks of green parrots that fluttered to the forest each evening to nest, chattering loudly as they flew. From Tobago we sailed to Chaguaramus Bay in Trinidad, a few miles from Port of Spain. In the past few years there has been intensive development of yacht maintenance facilities and many boats now summer over there so as to avoid the hurricane season in the Caribbean - Trinidad is too far south to experience many hurricanes. My friend Red, the ship's wife (old nautical term), sent down many spare parts and we repaired much of the damage and the mainsail was patched again. There were close to a thousand yachts at Chaguaramus, more than half on land, being stored or repaired. There is an active social life, centered around the bars at the three major boat yards. Food and the necessities of life are very cheap in Trinidad. A bus ride to Port of Spain costs 30 cents. Three dollars got you a fish and chip supper with a beer at the yacht club bar/restaurant. Walter found himself a nice girl friend, originally from Venezuela, who ate supper with us many nights. When the devastation caused by hurricane Luis in St Martin became known, the yachties had a collection and organized a rescue mission. They dispatched a trawler loaded with supplies to the island. While we were there some of the participants gave a talk and video show, including footage taken on yachts during the height of the hurricane. The devastation was heart rending; over a thousand yachts sunk or driven ashore, with many deaths. Before we left Trinidad in late November we spent a couple of nights anchored at Chacachacare Island, a deserted island which was formerly a leper colony during British rule. After independence in the 1960's, it was abandoned. Most of the buildings are still in fairly good shape — the church had a curious chute-like structure to the ground. We figured it was to facilitate getting bodies down to ground level as the church was on the second floor of the hospital building.

"We sailed the 90 miles to Grenada overnight. Prices immediately doubled. In the Grenadines I had an interesting experience at Mayreau, a small island about 4 miles from the beautiful Tobago Cays.

"I first visited Mayreau in the late 1960's when Edith and I cruised the Caribbean on *Iona*, with Colin, then aged 3. He used to play on the beach there with a small black kid who was deaf. Edith found out from his old Auntie (no parents lived on the island due to the absence of work) that he had never seen a doctor about his deafness. We gave her some money so she could take the child to Barbados on the next schooner going there. Anyway, Mayreau has developed to some extent and now there are several bars, restaurants and small hotels. A cruise ship even calls there - more on cruise ships later. So we were all sitting at this bar sipping on a beer and I asked the bartender if he had always lived here. "Oh yes," he said. So I told him the story of the little boy on the beach and he immediately said, "That was Phil, the brother of the fellow who owns this bar!" Later on I spoke to Dennis, his brother, and he said Phil did go to Barbados and was fitted with a hearing aid. This enabled him to get an education - he is now an accountant and lives in the States, married to an American. Mayreau is now visited by a cruise ship, which has rented a section of beach and fenced it off. These ships now cause a great deal of resentment in many islands as the vacationers buy virtually nothing ashore and can rapidly destroy the local ecosystem. Mayreau has about 100 residents - the cruise ship lands 1,000! In a Grenada newspaper I read an analysis that said 90% of the island's visitors came on cruise ships and spent 10% of the incoming tourist dollar.

"This part of the Caribbean, as far north as St. Thomas, is infested with charter boats. They are crewed by folks who just want to have a good time for a couple of weeks. If they see a cruising boat they always anchor very close as you must know something. And they don't use much rope when they anchor. In St. Barts we literally had to fend them off. Of course everyone on the other boat had gone ashore to tuck into an expensive meal, the price of which goes up in proportion to the number of charter boats in the harbor.

"Back in St. Martin we completed the repairs and got the bad news from an expert sail maker that the mainsail had had it. So we ordered a new one from England in early December and it was promised to be shipped by air before Christmas. We spent the intervening time visiting Anguilla, St. Barts and Statio.

"We had Christmas dinner with our old friends Kay and Dudley Pope and his daughter, Jane, who used to play with Colin when we all lived on boats. They now live in a condo which was badly damaged by hurricane Luis. The local newspaper reported only 40% of the hotels will be open for the winter season due to storm damage.

"We left St. Martin in early January without a new mainsail and a somewhat depleted cruising account. We also put on board another 30 gallons of Mount Gay rum to replace our depleted stock. We had sailed just under 6000 miles since we left St. Martin in July, or 200 miles/gal. Of course, we had spent a lot of time in port.

"After a brief stop in Martinique we made a direct sail of about 4 days to Bonaire in the Netherlands Antilles. It is famous for its flock of red flamingoes and a few dozen of these birds flew over the boat as we approached the island on the evening of January 16th. The island also has other kinds of birds, and one of them whispered to Walter, who is very tall and handsome, in a seductive Spanish voice what her address was. The next afternoon he dressed up in his cleanest white ducks and ventured into the town of Kralendijk to find her. He returned, chastened, a couple of hours later. The address turned out to be a professional establishment, to put it delicately, complete with price lists and medical certificates. Poor Walter! Nothing seems to have changed for hundred of years in terms of the dangers awaiting the innocent seafaring man when he sets his feet on land. From Bonaire we sailed 700 miles to the San Blas Islands, which lie off the Darien coast of Panama. There must be over a hundred islands covering an area of about 20 by 100 miles. The islands have lovely beaches and clear water. The Kuna indians live here and have a large degree of autonomy, so they have prevented any large-scale development, such as tourist hotels. They still paddle and sail dug-out canoes and the women make a unique embroidered cloth called Mola. Their villages consist of bamboo huts with palm thatch roofs all crowded close together. When we anchored on the lee of the village we could smell the wood fires they use for cooking.

"After ten days we sailed overnight to Colon, the Caribbean entrance point for the Panama Canal. Colon is a very violent town due, I suppose, to the high unemployment rate. All large shops and businesses have guards armed with shotguns at the doors. Visitors are warned to go everywhere by taxi but that didn't prevent me from being attacked a few days ago inside a shop selling electrical parts. Walter and I had gone there to get some bits for the boat. As I stood against the counter I was suddenly seized from behind, an arm went around my neck and I was being choked. Two confederates darted into the store, one to rifle my pockets and one to prevent anyone from aiding me - Walter engaged in fisticuffs with him. I had my hand on my wallet which tore in half in the struggle - but my half had the money in it! And then they were gone - rushing away down the crowded street, it was all over in 20 seconds. On reflection I had to admire the precision of this team, for the attack was impeccably choreographed. I never saw the faces of any of them. Fortunately nobody was seriously hurt - my throat was sore for a couple of days and I sounded a little scratchy. As the old square-rig sailors used to say - there are more sharks on land than there are in the sea. I lost my original wallet when it was picked out of my pocket in Georgetown, Guyana. This trip is proving to be hard on my wallet(s)!

"We have stocked up with fuel, water and food for the long days coming up in the Pacific. We are scheduled to transit the Canal on 13th February - the start of a new phase in the cruise. All being well I'll write again from Tahiti. For the moment, best wishes to everyone - winter up there is almost over."

— *Eric*

Member E. B. Forsyth followed with Newsletter #3 from Papeete, Tahiti on 10 May 1996:

"Dear Friends, During the last couple of months we have made a big dent in the westward progress necessary to get around the world, so the theme of the letter is 'If those are the Marquesas Islands, it must be April.' Indeed, it took us 30 days of continuous sailing from the Galapagos Islands to the Marquesas. To backtrack a little, we made it through the Panama Canal in one day, unusual for a yacht, which usually take two days. After last minute shopping in Balboa we sailed to Taboga Island in the Gulf of Panama for a couple of nights. A charming island with a picturesque village. We then spent three nights at anchorages in the Las Perlas group. At Contradora Island a blond German lady called Claudia came over in her dinghy from a nearby yacht and offered to bake us some German bread, a list of the selection available, with prices, including Weissbrot, Dunkelbrot, Muesilibrot, Zwiebeibrot and Schwarzwalderbrot. She must have been a model and was clad only in the skimpiest of bikinis, so of course we enthusiastically ordered a loaf for delivery in the morning. The Las Perlas seemed idyllic and it was only later that Walter noticed a letter in the SSCA bulletin about a yachting couple whose boat was seized in the Las Perlas area by escaped convicts from the maximum security prison which is located on one of the islands. The couple were forced to take the men to Columbia and the husband was shot for his pains. Good job we read about it after we left, on the way to the Galapagos Islands, a leg which took only six days. It is considerably easier to enter the Galapagos Islands than it was during *Fiona's* first visit in 1990. Then, you had to bribe the port captain. Now, they take about the same amount of money, but it's all official and we easily got permission to stay for five days. We anchored in Academy Bay where there were a considerable number of boats from a British yacht club who were sailing round the world in twenty months. This enterprise is called the Tradewinds Rally, and it comprises over 40 yachts. In the Galapagos there is constant struggle between conservationists and settlers from Ecuador. I think the settlers are winning; sea lions were common in Academy Bay when we anchored there in 1990 but this year I saw only one. We visited the Charles Darwin station where they are breeding the giant Galapagos tortoise and we took a one day tour of the preserve on Plaza Island.

"When we left, most of the Tradewind Rally yachts were scattered in a thousand mile-long swath between the Galapagos and Marquesas Islands. This 3000-mile leg was a three week downwind run for *Fiona* in 1990 but this time we were unlucky with the winds for the first ten days which were mostly light, on the nose or simply zero. After seven days we had made good only 380 miles towards the Marquesas and I began to worry about our food supply if the same conditions persisted. We did use the engine a little to edge south as the meteorologists predicted better winds down there. But I had not refueled in the Galapagos because when I was there in 1990 the fuel was so dirty I had persistent problems with clogged filters for years afterwards. The rally people had a morning roll call on the SSB radio in which each yacht reported its position and weather conditions. We were not becalmed alone - only the yachts five or six hundred ahead had any wind. Being becalmed on the open sea is not pleasant - there is always swell which rolls the boat. The sails, which must be set to catch what wind there is, slat violently from side to side. It is a good job the mainsail was new for the old one would have surely torn in these conditions. As it was, both upper battens were broken and we broke half a dozen nylon sail slides. One morning I was so fed up with the wear and tear I wrote the following poem in the log book:

BECALMED

"The great swells slide across the ocean,
Wind-pecked ripples mottle the sea.
Sullen, the boat rises to the motion
And the sails slat, angrily.

Only when the wind-curved sails fill out
Will she rise and the wheel stiffen.
The captain will scan the rigging and shout,
'Harden sheets — set course again!'

"And would you believe a nice breeze came up for a while. Ultimately it took us thirty days to make the passage, just about all of March. You might think time dragged but it is surprising how quickly it passed. After breakfast comes elevenses - tea and cookies. Then lunch, afternoon tea follows, then happy hour with hors d'oeuvres and rum and juice. Supper follows just before nightfall. After we ran out of bread bought in the Galapagos we baked a loaf every morning.

"At 8 p.m. (ship's time) we go onto 2 hour watches, followed by four hours off. All this routine makes the time pass very quickly. We have lots of tapes, BBC and VOA on the shortwave and a couple of dozen trashy paperbacks, traded with other yachts. An odd thing, which I have noticed before on long voyages, is that I become very bothered by the typical modern shoot-em-up novel. I can only read a page at a time and I absolutely have to peek at the ending, just to avoid nasty surprises. Modern life, with the constant overwhelming TV, radio and other sensory inputs leaves one emotionally desensitized. At sea, one's emotional threshold level sinks, perhaps that's why nothing seems to happen in Victorian novels - the genteel readers would have been shocked if it did. We also had a good supply of the Manchester Guardian Weeklies, sent by my daughter Brenda to Panama. We hoarded these and opened them one a week, to be read over again and again. We also did innumerable crossword puzzles, especially Walter, who had several volumes of collected puzzles. Evgueni seemed to be writing a book. Finally, each day I usually had a number of maintenance tasks as it seems everything on the boat is in the process of corroding, chafing, peeling, cracking, or just plain disintegrating.

"We did have contact with the outside world, however, I was plugged into two radio nets, one operated by other cruising boats and an excellent net run by amateur radio operators. These fellows had directional antennas and powerful transmitters, so communication was much more reliable than the cruising net. Each boat registered with the net was called at a specific time each evening.

After reporting position and weather, a number of services were available such as a doctor and phone patches to the U.S. I called home several times. Towards the end of March we had a glorious view of comet Huakutaki for two evenings, probably better than most other viewers in the world because of the intense darkness at sea once the moon set.

"We made our landfall at Hiva Oa in the Marquesas. The village is about a mile and a half from the dinghy dock - we needed the exercise, one's legs tend to atrophy on a long passage. We walked up a hill to a cemetery overlooking the beautiful bay. In it was the grave of Paul Gauguin, despised by the French during his life for his loose morals but now revered (he is safely dead) as the original portrayer of Polynesian life. We then cruised to Fatu Hiva, where I traded some five minute epoxy for tapa cloth, to Tahuato and to Nuka Hiva, the administrative center of the Marquesas Islands. We were able to get plenty of fresh fruit, especially the delicious pamplemousse, the huge Tahitian grapefruit, which were literally lying on the ground in Nuka Hiva. The bay was full of Tradewind Rally yachts, and we made a number of friends among them. There was general surprise at the Stars and Stripes on the stern of *Fiona* when they heard my strong Lancashire accent. Unfortunately a heavy swell developed due to bad weather to the south and several dinghies were capsized at the dock. Some anchors were lost by several boats, including our stern anchor, on which a shackle worked loose. Despite a search, using scuba gear and probing with a long rod, we were unable to recover it. The last island group we visited before arriving in Tahiti was the Tuamotus. This group comprises about forty low-lying coral atolls. We visited three, at Ahe our anchor got caught on coral but fortunately a Polynesian with scuba gear was nearby and freed us. The natives use scuba to tend the clams hanging in long strings below the surface; they are producing cultivated black pearls. At Apataki we were able to tie up to the dock, the first time we had been alongside since we were in Martinique in early January. We took the opportunity to take all the chain out of the forward locker and lay it out on the dock. We were then able to repaint the marks at 50, 100 and 150 feet and turn it end for end.

"We arrived in Papeete on April 21st, and within a week Evgueni left the boat and returned to Russia. Walter and I are flying back to New York in early May. Walter will return with me in June. We will have to find a new crew member to replace Evgueni. The boat is at a mooring in the lovely Maeva Bay, about five miles from Papeete. Since leaving Patchogue in July *Fiona* has sailed over 14,000 nautical miles.

"There are all kinds of spare parts I will have to bring back, and while I am home there is the annual vintage Bentley rally, so I will have to get my old machine fired up. Until the next time,"

— *Best wishes, Eric*

# HISTORY OF NAVIGATION

## The Plath (SOLD) German Navy Gyro Sextant Type KS-3D of 1945

*By John M. Luykx*

### GENERAL

During the latter stages of World War II (from 1943 onwards) the German Navy, especially the submarine forces, were supplied with a new sextant with a gyro-stabilized artificial horizon and integrator averager. This instrument was a modification of the Plath SOLD Model KM-2 bubble sextant of the single mirror type which was standard and had been used by German forces ever since 1938. It was **designated the KS-3D sextant. (Figure** 1)

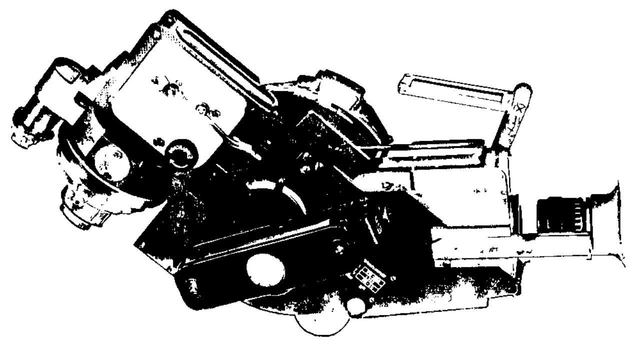


Figure 1.

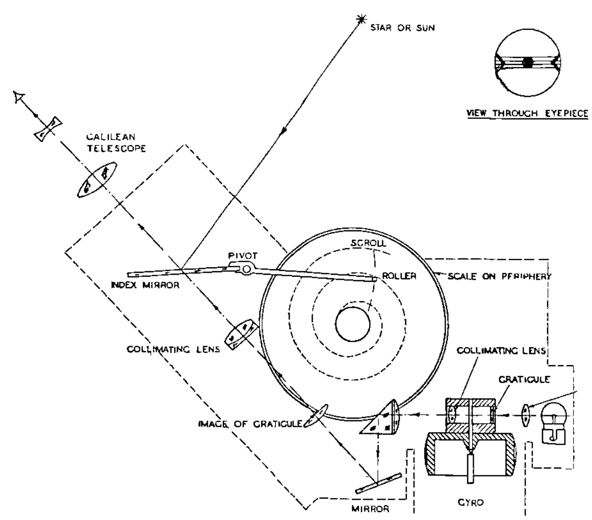



Figure 2.

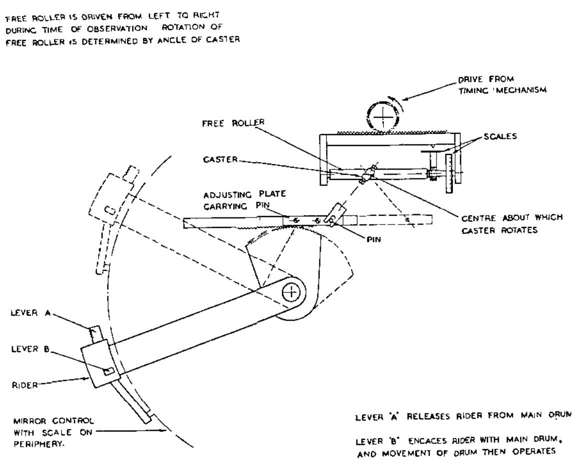



Figure 3.

The gyro artificial horizon principle was that of Captain G. E. Fleuriais of the French Navy which he developed during the latter part of the 19th Century and early 20th Century. (See Issues 27, 31 and 41-42 of The Navigator's Newsletter). The SOLD gyro sextant was the only practical gyro sextant developed by any of the belligerent nations during World War II and the only gyro sextant used with success during the war.

## GYRO OPERATION

The purpose of the sextant gyro is to provide a stable artificial horizon for the sextant. The gyro rotor is air driven and is "run up" to about 3000 rpm either with a hand or foot pump (stirrup pump) or with compressed air. As the rotor only stabilizes a beam of light and has no mechanical output, it is basically a bottom heavy rotor (pendulum gyro) running on a sharply pointed axis (the point of suspension of the gyro rotor is above the center of gravity of the gyro rotor) supported in an almost frictionless jewelled cup. Observations are taken with the sextant as the gyro rotor runs down after erection.

Once the gyro is "blown up" to speed using the hand pump, it will "coast" to a stop in about 17 to 20 minutes. Since it takes approximately 3 minutes for the gyro to erect, the remaining 14 to 17 minutes then become available for taking observations. If additional time is required for observations, the gyro is a) "blown up" to speed a second time, b) 3 minutes is allowed for the gyro to erect and c) the following 12 to 14 minutes are utilized for the additional observations.

When taking observations on submarines:

a) The sextant was "blown up" below in the control room.
b) When the gyro had erected, the sextant was then passed up through the hatch to the observer in the conning tower who shouted down to the control room the time "mark" and the altitude for each observation. Upon completion of observations the sextant was returned down below through the hatch to the control room and secured in its case.

## THE ARTIFICIAL HORIZON

Light from a lamp located forward of the gyro rotor is concentrated on a horizontal lens and graticule situated on top of the gyro rotor. The optical path of light through the rotor lens and graticule is parallel to the plane of rotation of the gyro rotor and is projected on to the index mirror and finally into the sextant telescope. (Figure 2)

The projection of the graticule into the sextant telescope is the artificial horizon. The graticule consists of a group of four horizontal illuminated lines across the field of view of the telescope. When taking sun observations the sun image is placed between the upper and lower lines of the graticule (the distance between them is equal to the sun's diameter) while the inner two horizontal lines (10 arc minutes apart) are used for star and planet observations: the image of the body being placed in between the two inner lines. (Figure 2) During the first 3 minutes following initial "blow up" of the gyro the artificial horizon appears to tilt in various directions; for example: slightly left, then slightly up or down and then slightly right in a continuous decreasing pattern until the gyro rotor is erect. Once the gyro is erect the artificial horizon of four lines appears as four steady horizontal lines across the field of view which only appear to move up and down in the field of view as the sextant is tilted down and up respectively.

## AVERAGING MECHANISM

The SOLD sextant averager is basically a roller type integrator device similar in function to the ball and disc integrators employed in the Bendix A-15 and the Kollsman periscopic sextant averagers. (Figure 3)

The averager consisting of a cylinder in which altitude scales are mounted is driven in an axial direction by the clock work mechanism, set to either 1, 2 or 3 minutes of operation. Bearing on this cylinder is a freely rotating "roller" the axis of which is normally perpendicular to the axis of the cylinder. Rotation of the altitude control knob or drive causes the axis of the roller to be inclined to that of the cylinder thus causing rotation of the cylinder. During the time occupied during observation, the cylinder rotates an angular amount proportional to the angle through which the control knob or drum has been rotated. The integrated rotation of the cylinder, therefore, represents the average angle through which the control knob or drum has been turned and is in effect the actual angle at the mid point of the interval of time run by the averager. At the end of the observation a shutter falls across the optical line of sight and the averager mechanism automatically shuts off. If the exact time is recorded at the end of the observation then the mid time or mean time of the observation is equal to:

$$\text{Mean time} = \text{time at end of observation MINUS } \frac{\text{length of observ.}}{2}$$

The mean observed altitude is recorded on the scale on the averager cylinder.

## OPERATIONS

To use the gyro sextant a supply of compressed air is required or the gyro may be "run up" by using a hand operated stirrup or by bicycle pump. After "running up" the sextant, at least 3 minutes should be allowed for the gyro to settle down and erect. The sun and star is observed in much the same manner as with a normal sextant, the horizontal graticule artificial horizon being used as a reference rather than the visible natural horizon. In smooth seas a 1-minute averaging time is normally selected. For rough weather a 3-minute averaging time is recommended.

## TEST RESULTS

In August 1945 the Admiralty Research Laboratory, Teddington, Middlesex, England conducted comprehensive tests of the German SOLD gyro sextant Model SKS-3D. Although the test reported a)"...There is nothing novel in the sextant construction or in the averaging mechanism...." and b)"...the sextant is heavy and somewhat awkward to use and its accuracy under stable conditions is not as good as that of a bubble sextant...", the report drew the conclusion that: "...Either type of sextant (gyro or bubble) should be capable of giving a fix at sea under calm conditions, within one to three miles and provided a large number of observations are made, similar accuracy may be obtainable in a moderate sea...."

Tests conducted in the U.S. in June 1947 by the Aeronautical Instrument Laboratory Naval Air Experimental Station in Philadelphia came to generally the same conclusion as the British tests.

The U.S. report states:

"...The instrument is clumsy and rather awkward to use...."

"...The gyro itself is small and light and could be incorporated in a much more compact unit...."

"...The instrument appears to be more dependable than experimental American gyro sextants...."

"....It is recommended that different sextant manufacturers be given an opportunity to examine the instrument since the gyro system has several novel features which are worthy of consideration...."

Tests of the German SOLD Gyro stabilized sextant were also conducted in the U.S. by the Operation Development Force of the U.S. Fleet during the summer of 1946. These tests included a large number of observations conducted at sea near the mouth of Chesapeake Bay off Cape Charles.

Tests conducted on 6 August resulted in mean errors of approximately 8'.0, on 7 August the mean errors were 6'.0, on 8 August the mean errors were 4'.8, on 9 August the last day the mean errors were 2'.7.

All the above results were described and tabulated in an unclassified article in the Journal of the Institute of Navigation (U.S.) vol.I, no. 6, pp. 138-141 entitled *The German Gyro Sextant* by Mary E. Hunt.

In 1981 the author conducted a test of a SOLD Gyro Sextant type SKS-3D owned by Mr. G. D. Dunlap of Annapolis. This instrument had a serial number of 5431.

The results of this test were:

A. TIMER ACCURACY

| | |
|---|---|
| 60 seconds set: | 60 seconds run |
| 120 seconds set: | 120 seconds run |
| 180 seconds set: | 179 seconds run |

B. MEAN AVERAGER COMPUTING ERROR

Averager computing errors were less than 1'.0 of arc for twelve computations.

C. GYRO RUNNING TIME USING STIRRUP PUMP

| | | |
|---|---|---|
| 12 strokes | 13 minutes | (Includes time to erect |
| 20 strokes | 15 minutes | and observing time) |
| 25 strokes | 17 minutes | |

D. GYRO ERECTION & PRECESSION RATE

| Time after "Blow Up" M | S | Precession |
|---|---|---|
| 0 | 15 | +40' |
| 1 | 03 | -25' |
| 1 | 45 | +13' |
| 2 | 19 | - 6' |
| 2 | 42 | + 2' |
| 3 | 10 | 0' |

E. IC: Object of Known Height
(six (6) 60 second observations)
Mean Error: -25'.0

F. IC: Celestial Observations on Land
(one) (1) 60 second observation each)

| | SUN | SUN | VENUS |
|---|---|---|---|
| Error: | -31.'0 | -26'.0 | -30.'0 |
| Mean Error: | | -29'.0 | |

## NOTES:

1. The erection and precession rate of the gyro rotor may be varied by adjusting the gyro-rotor position above the pivot point of the rotating shaft.
2. It is felt that from all the data available, the use of the German SOLD Gyro Sextant would be particularly advantageous in a heavy sea. Under these conditions the bubble sextant would be difficult to use and the full capability of the gyro sextant would then be realized.
3. Accuracy tests conducted on land using a Plath

SKS 3-D Gyro sextant from the author's collection were reported in Issue 31 of The Navigator's Newsletter. The results of five averaged observations were:

| Mean Error | Standard Error | 95% Error | Range of Error |
|---|---|---|---|
| 0'.8 | 0'.8 | 1'.5 | 2'.2 |

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By Ernest B. Brown*

(To be continued in Issue #53, Fall 1996)

# BOOK REVIEW

*By Terry Spence*

## Marine Navigation & Marine Navigation Workbook

*By Richard R. Hobbs — Commander, U.S. Naval Reserve*

Naval Institute, 2062 Generals Highway
Annapolis, Maryland 20141
(800-233-8764)

I purchased this text and its companion book — *Marine Workbook* which as its name implies provides questions and answers (every other question) and work forms needed sometime ago. I do not remember the cost but the two items are around $50 I believe. This details the Navy way of navigating — used at the Naval Academy to introduce midshipmen to shipboard navigation.

It is a hefty volume (703 pages) but not heavy reading. The titles of the first two chapters set the "definitely Navy" approach: "The Shipboard Navigation Department Organization" and "The Piloting Team"; however, this should not discourage anyone reading this book.

The three sections to the book are: 1. Piloting; 2. Celestial Navigation; and 3. Electronic Navigation. Included in the appendices is a complete reproduction of Chart #1, most useful if you do not already have this publication. Section 1 includes chapters on the standard dead reckoning, visual aids and other normal discussed piloting needs. The chapters on Tides, Current and Current Sailing which together with the forms suggested make this important subject easy to understand. Chapter 15 covers voyage planning and time. With adaption the principles involved could be used by the small boat navigator. (of course you do not need to report to yourself via "The Captain's Night Orders").

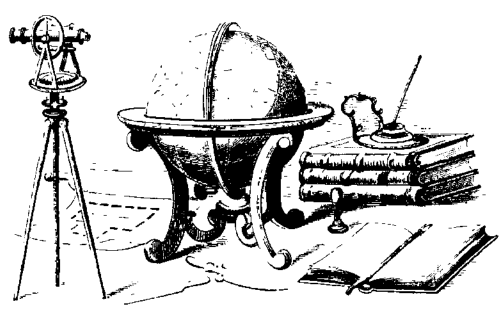
The Celestial Navigation section of the book consists of 12 chapters commencing with earth coordinates, further discussion of time, the sextant and the altitude-intercept method. The complete celestial solutions offered are by nautical almanac and tables no. 229 and secondly by the air almanac and tables no. 249. Required excerpts for all sets of tables are provided for understanding of the text. Chapter 22 discusses alternative sight reduction methods, including calculator and "concise sight reduction tables" which are included in the nautical almanac. The remaining chapters cover the fix and plotting, the Rude Starfinder, determination of latitude, and twilight and rising/setting phenomena. There is a chapter titled "Determining Gyro error at sea" that makes interesting reading.

The third section — Electronic Navigation — is technical in nature. There is a chapter on radionavigation systems with subsections discussing Radiobeacons; Loran-C, Decca; Consol and Omega. The chapter on bathymetric navigation was most interesting and is followed by a chapter on a day's work in navigation at sea.

The Workbook consists of 393 pages covering questions; answers to these questions are provided for in Appendix C but only odd-numbered questions. Other than the usual plotting instruments, to complete the exercises you will need a Nautical Almanac, any year after 1989 and Volume 3 of table 229 (latitudes 30-45 degrees). All necessary work forms are provided.

To a self-taught navigator like myself I found this text and its accompanying workbook most informative and I often go back and complete more of the questions and thus keep myself familiar with disciplines that are not often needed in my back yard.

*Editor's note: Checking the prices at a local nautical store I found the text to be $38.95 and the Workbook $16.95. Both are 3rd editions (1990).*



**ANSWER TO DO YOU KNOW...?**

(From Page 1)

Sometime during 1996 the Defense Mapping Agency will be subsumed into a new National Imagery and Mapping Agency (NIMA). The Central Intelligence Agency's National Photographic Interpretation Center and the Defense Department's Central Imagery Office will also be subsumed into NIMA.

Correction to Answer:

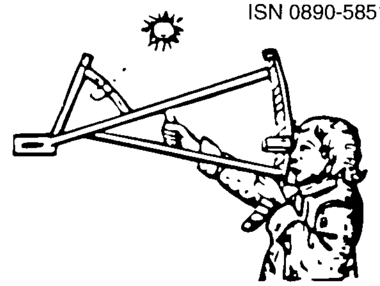
*Back of Issue #51, Spring 1996*

Delete last paragraph and substitute:

Also front-coated mirrors are not subject to prismatic error due to lack of parallelism of the two surfaces of a back-coated mirror.

ISN 0890-5851

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-THREE, FALL 1996

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

### A Reminder

Your annual $30.00 donation to The Navigation Foundation, for membership, is fully deductible from your federal income tax. Please remind your friends and other mariners of this advantage when they join The Navigation Foundation.

## ACTIVITIES

*By Terry Carraway*

### Thanks for Your Help

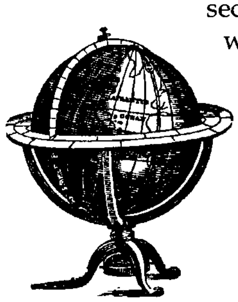
The Foundation thanks all of the members who have passed the word to friends and other mariners about The Navigation Foundation. We have received a number of requests for further information. Some who have received the information have joined. Please keep up the good work.

### E-Mail

Members who are on the Internet or other servers have been using E-mail to contact The Foundation. It has been working quite well. I hope the trend continues. The only difficulty I anticipate is when I travel. The delay in answering orders, queries or requests will normally not exceed two weeks at a time. That is the usual length of time I am away for a given period. Have patience if you do not receive an immediate answer. I will reply as soon as I return.

### The Internet

The Navigation Foundation has two web pages. The first is part of http://www.olyc.com and the second is a stand alone page at http://www.netcom. com/navigate/celestial/nav.html. It is also on the search engine YAHOO. Take a peek. Since the second one is entirely produced by The Foundation let me know what you think we could do to improve it. Keep in mind that I am a novice and have remained within the parameters of the server's templates.



## NEW PRODUCTS

*By Terry Carraway*

### 1997 NOAA Tide and Tidal Current Tables

The new 1997 NOAA Tide and Tidal Current Tables, printed by International Marine, are now available through your Foundation. List prices are $14.95 for the Tide Tables and $13.95 for the Tidal Current Tables.

### Nautical Almanac

Both the government Nautical Almanac and the commercial edition of the Almanac for 1997 are available now. The government edition lists for $25.00. The price of the commercial edition was not available at the time of printing. Call for a current price.

All items ordered through The Navigation Foundation receive the member discount.

### New Version of Quik-Dri

The illustrations of this new product in the last issue are shown enlarged in this issue. See READERS FORUM of last issue (#52) for letters from Director Allan Bayless and Member Robert M. Girdler.

**DO YOU KNOW . . .?**

*By Ernest Brown*

What is wrong with the pole-guy wire analogy which is so useful in explaining the concept of circles of equal altitude?

*(The answer appears at the back of this issue)*

## QUIK-DRI Sight Reduction Form

Gr. Date JUNE 25, 1996 Body VEGA Approx. Z NE Ht. Eye (ft.) 6

Log ______ DR Lat. 40°33'N DR Long. 68°30' W

| | ° ' | | ° ' | | h m s | | ° ' |
|---|---|---|---|---|---|---|---|
| SHA ★ | 80 47.2 | dec (N) hr S | +/− 38 47.0 | Clock | | Sext. | 33 43.8 |
| GHA hr | + 259 21.4 | d corr → | | corr | + − | IC | (+) − 2.4 |
| v corr m, s | + 12 07.7 | dec (N) S | 38 47.0 | GMT | 23 48 23 | Dip | (−) 2.7 |
| GHA | 352 16.3 | | | | | App. Alt. | 33 43.5 |
| 360 | | | | | | Main | + (−) 1.4 |
| GHA | 352 16.3 | | | | | Ho | 33 42.1 |
| Lo E+ (W−) | 68 16.3 | | | | | | |
| LHA E (W) | 284 | | | | | | |
| 360 | 360 | | | | | | |
| t (E) W | 76 | | | | | | |
| L (N) S | 41 | | | | | | |

Subtract if possible or leave blank

Adjust to make LHA whole degrees after adding, or subtracting smaller from larger

If Lo is W and greater than GHA, then LHA is E and = t if < 180°

> 360° ? Subtract 360 to get t, same name
> 180° ? Subtract **from** 360 for t, opp. name

Or, for moon only:

| | ° ' |
|---|---|
| HP | |
| App. Alt. | |
| Upper Table | |
| Lower Table | |
| Ho | |

**Table**

| | | | | |
|---|---|---|---|---|
| d (N) S | 38 47.0 | | | |
| b (N) S | +/− 15 33.1 | A | 16686 | I |
| d+b | 54 20.1 | B | + 9021 | II |
| | | A+B | 25707 | |
| | | Hc | 33 35.8 | II |
| | | Ho | 33 42.1 | |
| | | a | 6.3 Mi (To) Away | |
| | | Z | 74° | |
| | | Zn | 074° | |

If "t" less than 90°, name "b" same as L; if greater than 90°, name opposite to L.

Adjust L to nearest whole degree.

Subtract if d and b have different names

——— Line = instruction
——▶ Arrow = data

### Use Celestial Slide Rule to

1. Check Hc Table solution for gross error
2. Determine azimuth: If "t" is E, Zn = Z; If "t" is W, Zn = 360° - Z.

### How to use the Tables (Heavy border)

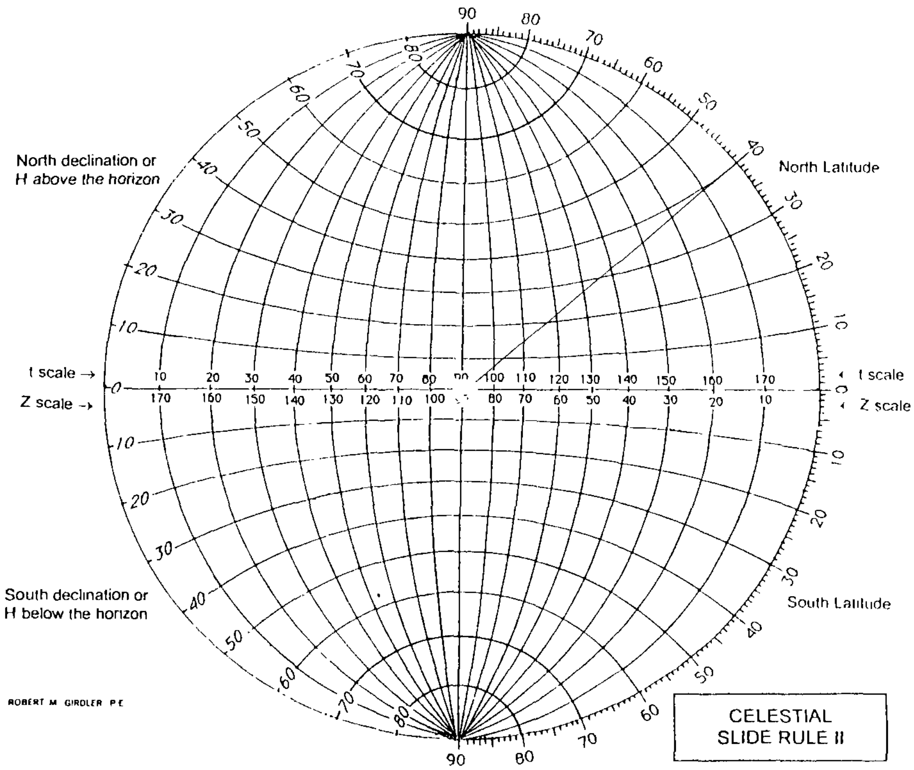
1. Find in Table I the Lat. column, then "t," and enter the corresponding "b" and "A" in the boxes so labeled.
2. Add or subtract "d" and "b" to get d+b.
3. Enter Table II with d+b to get B. (Use nearest or interpolate.
4. Add A and B to get A+B.
5. Find A+B in body of Table II to get Hc. (Nearest or interpolate)

**Note:** Hc is below the horizon
**If** t < 90°, "d" > "b" and of different names
**or** t > 90°, "d" < "b" and of different names
**or** t = or > 90°, L and "d" are of different names

### Plotting the Line of Position

1. Subtract Ho and Hc, diff. is "a" in N. Miles. (Add if on different sides of the horizon.)
2. Call "to" if Ho is higher than Hc in the sky.
3. Plot azimuth line from assumed (adjusted) position, not DR position.
4. Draw LOP 90° to azimuth line at a point "a" miles from the assumed position "to" or "away" from the body.

RMG 5/18/96




# READERS FORUM

*Edited by Ernest Brown*

The daughter of the late James M. Furlong wrote to the Executive Director on August 12, 1996:

"Please accept my apologies for the delay in getting this check to you.

"Your condolences are greatly appreciated by me and my three sisters. It is an especially welcome comfort to me to know that my father found a good listener in you, because although it wouldn't be entirely accurate to call my relationship with him an estrangement, it is true that most of our lives have been spent apart. Only in recent years have I been able to spend time with him on a regular basis, and only since his death have I been able to peruse all the printed material he collected regarding his transatlantic voyage in '50-'52.

"It's quite a story, and it's a real travesty that his own version of it has never made it into the annals of literature and film. Being a writer, I hope to do it the justice it deserves.

"As a result of your letter dated July 18, I now understand how invaluable your services have been to him, and no doubt many others. Fortunately, the estate is ample enough to cover the debt. With a writer's income, I would've been hard-pressed to argue with my landlord over the two hundred dollars. I hope you understand that, as administratrix, I was obligated to inquire about the possibility of returning the materials to you for a refund on the behalf of my sisters and the estate. At the time that I wrote to you his medical bills were looming large, due to his throat and lung cancer, and there was a real possibility that his estate would have to be liquidated by those bills. Since then, the pressure has been mostly relieved by the excellent funding and administration of the M.D. Anderson Cancer Center in Houston.

"Because of that, I am able to send a check in the amount of $225, to include a small contribution ($23.66) toward your Foundation's work. I consider it to be money well spent, and I have no doubts that my father would approve.

"Thank you for your patience."

— *Sincerely, Sandra M. Furlong*

**James M. Furlong**

It is with sorrow that we announce the passing of James M. Furlong on April 16, 1996.

Member Leonard Gray of 7110 Stone Road, Manassas, Virginia 20111-4344 wrote on July 11, 1996:

"In Issue 51 of *The Navigator's Newsletter*, in the "Do You Know?" section, John M. Luykx gives some helpful information about front-coated vs. back-coated sextant mirrors. The last sentence, however, doesn't seem right. Mr. Luykx states that '...the back surface reflection is always the lower...'

"The reason for the two images, I think, is not that a back-coated mirror has two reflecting surfaces (a strongly reflecting back surface and a more faintly reflecting front surface), but that in practice the two surfaces are not perfectly parallel.

"If the back surface were exactly parallel to the front surface, only one image of the celestial body would be seen (because the two would coincide). But if the manufacturing process had made the glass slightly wedge-shaped (a likely possibility), there will be two images seen. Whether the one from the back surface is the lower or the upper one depends on whether the (imperfect) mirror is oriented with its thick edge up or down.

"This can be tested on an optical bench using a flat piece of glass with its two surfaces made parallel to close optical tolerances, in comparison with a sextant mirror that is slightly wedge-shaped."

*— Sincerely, Leonard Gray.*

*Editor's note: The "Do You Know?" section in Issue #51 was corrected in Issue #52 by the deletion of the last paragraph of the answer and substitution of the following: Also front-coated mirrors are not subject to prismatic error due to lack of parallelism of the two surfaces of a back-coated mirror.*

Director John M. Luykx of P.O. Box 47175, Forestville, Maryland 20753 responded to member Leonard Gray on July 31, 1996:

"Your letter to Captain Carraway regarding the Do You Know?" section of Issue 51 of *The Navigator's Newsletter* was referred to me for reply.

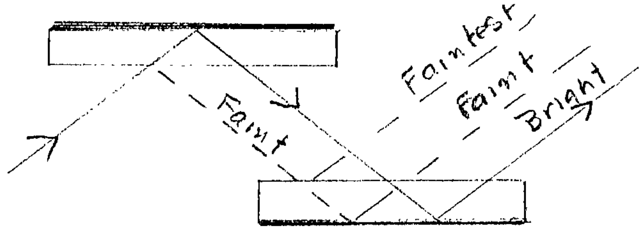
"I am grateful for your comments and am generally in agreement with them. However, based on simple experiments conducted using back surface mirrors, it appears (to me at least) that double reflections do occur from a back surface mirror. I have also found that the angular difference between the two reflections varies *indirectly* with the angle of incidence. This would tend to indicate that the mirror tested had parallel (or nearly so) surfaces.

"Experiments conducted with a front-coated mirror installed on a Russian Navy sextant did not show that a mirror reflects two images.

"Finally, in my experience, when a source of light is reflected to the eye from two back surface mirrors such as from the index mirror and then from the horizon mirror of a sextant, a triple image is seen, i.e., a) the additional reflection from the index mirror, plus b) the additional reflection from the horizon mirror; both in conjunction with the original back surface reflection. When the sextant is held vertically during observation, the brightest reflected image is the <u>lowest</u> of the three and the faintest is the one uppermost.

"Below is a diagram which I feel may help explain the geometry of the double and triple reflections which occur in the marine sextant with back surface mirrors."

*— Sincerely, John M. Luykx*




Member Leonard Gray wrote on August 5, 1996 to John Luykx:

"Thanks for your prompt reply to my July 11 letter to Captain Carraway. Your answer, however, did not deal with the issue I raised.

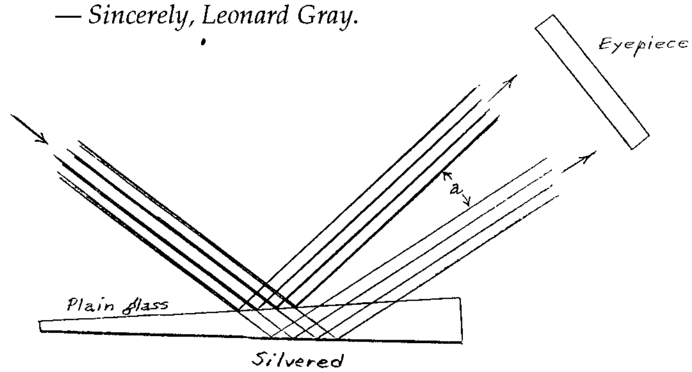
"Your diagram shows only one ray arriving. Actually, from any point source of light at optical infinity (from a star, say), there are many rays arriving, and they are all parallel. (See, for example, *Choosing a Marine Sextant*, by Robert E. Kleid.) Your diagram should show many rays coming in--all parallel, before and after reflection. In the case you depict (two optically perfect mirrors, each with its front surface exactly parallel to its back surface), the multiple images would be coincident, and the observer would experience only one image.

"A sextant will produce separate images only if at least one of its mirrors was manufactured with its surfaces not precisely parallel. The way this happens is shown in the enclosed diagram. (For clarity, I ignored the small refraction at the air-to-glass interface. This does not affect the argument.)

"The separation of the images comes from the difference in viewing angle (a)—not, as your diagram implied, from displacement of a reflected ray away from an incident ray, while staying parallel. (For simplicity, I showed only a few rays, although they would actually be covering the entire glass.)

"If you reject this analysis, I hope you'll check it with an optical engineer or a teacher of physics."

*— Sincerely, Leonard Gray.*




Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona*, wrote to us from Penrhyn Atoll, Cook Islands (9°S,158°W) on June 20, 1996:

"I note in the Fall 1995 issue of the Newsletter that you require the name of my vessel and route for the circumnavigation. My boat is *Fiona*, a Westsail 42. Bought as a bare hull and finished by myself, she was launched in 1983 and has sailed so far about 80,000 miles, including a rounding of Cape Horn. The present trip began July 1995 and originally I intended to sail to Chile, cruise the canals on the west side and then sail to New Zealand and Australia. The boat was damaged by heavy weather in September '95. I returned to the Caribbean for a refit. Transited the Panama Canal in February '96. I am now cruising in the South Pacific and plan to arrive in New Zealand in August. The experience on the Brazilian coast last September is the basis of an upcoming *Ocean Navigator* article. Best wishes for your great Newsletter."

— *Eric Forsyth*

*Editor's note: See issues #51 and 52 for member Eric Forsyth's letters from Georgetown, Guyana; Colon, Panama; and Papeete, Tahiti.*

Member Edward S. Popko of 28 Maverick Road, Woodstock, NY 12498 wrote (by Compuserve 75050, 1357) on August 14, 1996:

"The writeup on Prince Henry arrived fine. Interesting guy. I'm going to check this out.

"On a very different topic, I had an interesting experience this past weekend working on preparing a Sea Explorer's boat for a voyage the scouts have been planning. A local marina loaned the scouts a good compass to mount next to the helm. The job then was to isolate it from magnetic interference from the helm instruments and to swing it.

"The explorer leader was a veteran Coast Guard Auxiliary and knew just how to lay out runs up and across the Hudson River to get it aligned. In the end, he did a good job.

"I decided to check the results by making a sun compass with shadow pin. I calculated the azimuth of the sun every 2 mins. and moved my sun compass rose to keep the pin shadow in line. We checked the sun against the boat's magnetic compass corrected for variation. Minor swing errors remained which mapped to bearing-specific deviations (Plottable on a napier chart).

"Everyone was more than a little surprised at this application of celestial navigation. I did have two big advantages: 1) a sun compass rose with reciprocal readings and 2) my HP 48GX calculator with AP Programming Systems celestial pack. I also know the KP of where I was (only 200' from a major river light house). Had a good time with this sample application."

— *Thanks again, Ed Popko.*

Member Jack R. Tyler of 10635 Islerock Drive, El Paso, TX 79935-1539 wrote on July 27, 1996:

"I have recently returned from a 25-day cruise aboard the M/V *Amazing Grace*, a 1600 ton supply ship. With a registry of Equitorial Guinea, it has a length of 354 feet, a beam of 38 feet and a draft of 17 feet. It is owned by Windjammer Barefoot Cruises, Ltd. in Miami Beach, Florida and carries 40 crew and 96 passengers. The *Grace* sails from Freeport, Grand Bahamas to Port of Spain, Trinidad taking supplies to a fleet of 5 "tall ships" and making various ports of call such as Grand Turk, Puerto Plata, Tortola, Saint Maarten, Saba, St. Kitts, Dominica, St. Lucia, Bequia, Grenada and Tobago. It then makes its way back up through the chain of islands to Freeport.

"I took along with me, my Aries 40 Sextant, a stopwatch, photocopied pages from the Nautical Almanac, a 'pad' of home made sight reduction forms, my HP-42s hand calculator (with a home made program for azimuth and altitude intercept), and a freezer bag of plotting stuff. As I have had very little experience at marine celestial navigation, it took me a few days to learn to anticipate the ship's movement. My intercepts at that time ranged from about 40 to 15 nautical miles! Near the end of the cruise they ranged from 3 down to 1 nm. I used the ship's log for my DR, noting the ship's speed and heading for advancing the LOP. (The Captain gave me 24-hour open bridge access for the entire cruise and encouraged me to make my plots on the ship's charts.)

"I learned a number of things about celestial navigation at sea. The time of day seemed very important. For instance, it seemed that the best time for making a sun shot was during mid-morning and mid-afternoon because the sun's reflection on the surface of the sea was not strong enough to make it hard to see the horizon. Similarly, twilight seemed to be the best time for 'night' shots, as the horizon was usually quite clear. On dip short shots, I discovered that not only was He critical but also the estimated range to shoreline or squall line. I did use, at first, the ship's radar, letting it 'train my eye' so that later I could get better intercepts from this procedure. The cruise provided a wonderful opportunity for this novice navigator to gain a little experience and to improve my skills. Perhaps the last shot I made sums up my feeling for celestial navigation. We were rounding the north end of the island of Eleuthera, pushing as hard as we could (11.8 knots) in our attempt to make landfall at Freeport before Hurricane Bertha (20 knots) caught up with us. The sky was 9/10+ overcast and closing, but the sun showed through momentarily over a very calm sea. I took a quick sighting and as I turned to enter the bridge, the sky closed up to solid overcast. Ten minutes later the 2nd officer moving the dividers along the rhumb line, announced that I had a 0.3 nautical mile intercept!"

— *Sincerely, Jack Tyler.*

# NAVIGATION BASICS REVIEW

## Sextant Altitude Corrections for Observations of the Moon

*By John M. Luykx*

For many navigators the moon correction tables on pages XXXIV and XXXV inside the back cover of the Nautical Almanac are difficult to understand and often confusing in their application, especially for upper limb and bubble sextant observations when the *center* of the moon is aligned with the bubble artificial horizon rather than the *upper* or *lower* limb.

In order to simplify the application of altitude corrections to sextant observations of the moon, the Tables in the Nautical Almanac have been organized into upper and lower sections with arguments of Apparent Altitude (Ha) and Horizontal Parallax (HP) respectively. To better understand the application of these corrections, it is felt that when broken down into familiar components such as semi-diameter, refraction and parallax in altitude, these corrections would be better understood by navigators.

## GENERAL

The correction tables for the moon contained inside the back cover of the current Nautical Almanac include the effect of semi-diameter (SD) parallax (PA), augnentation (A) and refraction (R). In addition to these corrections the observer must also apply corrections for the observer's height of eye (Dip) and the sextant Index Correction (I.C.) as well as non-standard temperature and pressure. The total number of altitude corrections for a moon observation may be summarized as follows:

| CORRECTION | SYMBOL | APPLICATION |
|---|---|---|
| Dip: | -D | Table A2 or D= -0.02931 /Hm |
| Index Correction: | ±I.C. | As observed or determined by observer |
| Semi-Diameter: | ±SD | From Daily Pages |
| Parallax in Altitude | +PA | HP cos Ha |
| Augmentation: | +A | A varies from +0.0 to +0.3 for Ha 00 to 90 (included in PA correction) |
| Refraction: | -R | Table A2 |
| Non-Standard T & P | T/P | Table A4 |

In the Nautical Almanac, moon corrections are combined as upper and lower corrections inside the back cover with arguments of Apparent Altitude (Ha) and Horizontal Parallax (HP). The Table assumes lower limb observations and also contains special rules for upper limb (UL) as well as center (C) (bubble sextant) observations.

In order to demonstrate how moon altitude corrections are applied, three sample problems are given showing for each the mathematical A and the Nautical Almanac tabular solution B.

Example #1 is a lower limb observation of the moon at low altitude.

Example #2 is an upper limb observation at mid-altitude.

Example #3 is a high altitude bubble sextant center observation of the moon. Temperature and pressure are standard.

SAMPLE SOLUTIONS TO MOON SEXTANT ALTITUDE CORRECTION PROBLEMS

| Example #1 | | | A | | B |
|---|---|---|---|---|---|
| Given: | | | | | |
| Hs | 10°00.'0(L) | Hs | 10°00.'0 | Hs: | 10°00.'0 |
| Dip | -5.'8 | D/IC | -5.'3 | D/IC: | -5.'3 |
| IC | +0.'5 | Ha | 09 54.'7 | Ha: | 09 54.'7 |
| HP | +54.'2 | PA/SD/R | +62.'8 | (U): | +62.'1 |
| SD | +14.'8 | Ho | 10 57.'5 | L): | +0.'6 |
| R | - 5.'4 | Ho: | 10 57.'4 | Ho: | 10 57.'4 |
| PA | +53.'4 | | | | |
| *A | 0.'0 | | | | |

| Example #2 | | | A | | B |
|---|---|---|---|---|---|
| Given: | | | | | |
| Hs | 45° 00.'0(U) | Hs | 45°00.'0 | Hs: | 45°00.'0 |
| Dip | -3.'2 | D/IC | -4.'7 | D/IC: | -4.'7 |
| IC | -1.'5 | Ha | 44 55.'3 | Ha: | 44 55.'3 |
| HP | +59.'8 | PA/SD/R | +25.'0 | (U): | +50.'5 |
| SD | -16.'3 | Ho | 45 20.'3 | (L)" | +4.'6 |
| R | -1.'0 | | | | = 45 50.'4 |
| PA | +42.'3 | | | | -30.'0 |
| *A | +0.'2 | | | Ho: | 45 20.'4 |

| Example #3 | | | A | | B |
|---|---|---|---|---|---|
| Given: | | | | | |
| Hs | 85°00.'0(C) | Hs | 85°00.'0 | Hs: | 85°00.'0 |
| IC | +1.'5 | IC | +1.'5 | IC: | +1.'5 |
| HP | +55.'1 | Ha | 85 01.'5 | Ha: | 85 01.'5 |
| R | 0.'1 | PA/R | +4.'7 | (U): | +15.'6 |
| PA | +4.'8 | Ho | 85 06.'2 | (L): | +4.'2 |
| *A | +0.'3 | | | | =85 21.'3 |
| | | | | | -15.'0 |
| | | | | Ho: | 85 06.'3 |

*Note: The correction for Augmentation A is included in the parallax in altitude PA correction. (See bottom of p. 259 of 1996 Nautical Almanac.)

NOTES:

I. The upper part of the moon table at the back of the Nautical Almanac contains corrections to the apparent altitude (Ha) of the moon for parallax in altitude (PA), augmentation (A), semi-diameter (SD), and refraction (R). The tabulated corrections are based on a reference value of horizontal parallax (HP) which is less than the minimum possible actual value of the moon's HP - 54.'0, attained when the moon is at apogee. Since the values of the correction tabulated in the upper part of the moon correction table vary primarily with the value of PA (based on HP), corrections for actual values of HP will always be greater than the tabulated values. The value of HP used as the reference in computing PA in the upper part of the table is approximately 53.'8, i.e., 0.'2 less than the lowest actual value of the moon's HP (to ensure all upper table corrections are +).

II. The lower part of the table contains the second moon correction i.e., the added correction to the moon's apparent altitude (Ha) for the actual value of the moon's HP at the time of observation. This correction is added to the first correction obtained from the upper table. Rules are given in the table for upper limb and bubble sextant (moon center) observations. With arguments of HP and Ha, corrections are tabulated for lower limb (L) and upper limb (U) observations. The difference between L and U corrections derives from the difference in actual moon diameter from a standard value of 30.'0. For example, given a value of 60.'0 for the moon's HP the difference in value between the L and U correction as 2.'7; i.e., the difference between the moon's actual diameter of 32.'7 and the standard value of 30.'0. (D = .5448 HP). Rules given in the lower table state that:

For an upper limb observation the corrections to Ha are:

1. Correction from upper part
2. U correction from lower part
2. Subtract 30.'0

For a bubble sextant observation, the corrections to Ha are:

(celestial body in center of bubble)

1. Correction from upper part
2. From lower part add the mean of the L and & U corrections
3. Subtract 15.'0

For a lower limb observation, the corrections to Ha are:

1. Correction from upper part
2. L correction from lower part

For a bubble sextant observation of the moon where the lower limb is centered in the bubble, the corrections to Ha are:

1. Correction from upper part
2. L correction from the lower part

For a bubble observation of the moon where the upper limb is centered in the bubble, the corrections to Ha are:

1. Correction from upper part
2. U correction from the lower part
3. Subtract 30.'0

III. Although correction instructions for oblateness of the earth sphere are included in the Nautical Almanac, instructions (Page 280 of the 1995 edition) this correction is small and not normally applied to moon altitude observations.

OB = -0.0017 cos Ha

IV. The augnentation correction is included in the correction for parallax in altitude: (PA) [PA = HP cos Ha].

This may be shown by a sample moon observation problem. (Observer's Ht. of Eye: 0.0 feet)

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Simultaneous observations at the same location were taken of the moon by three observers with the following results:

Observer #1 Hs: 87°14.'17 (LL)
Observer #2 Hs: 87°45.'83 (UL)
Observer #3 Hs: 87°30.'00 (C) Bubble Sextant

| | | | | |
|---|---|---|---|---|
| Given: | I.C.: | 0.'0 | Since there are no I.C. & | SD=0°.2724 HP |
| | Dip: | 0.'0 | Dip corrections Hs = Ha | PA=HP Cos Ha |
| | R: | 0.'0 | | |
| | A: | 0.'3 | | |
| | HP: | 57.'0 | | |

| Observer #1 (LL) | | Observer #2 (UL) | | Observer #3 (C) | |
|---|---|---|---|---|---|
| Ha: | 87°14.'17 | Ha: | 87°45.'83 | Ha: | 87°30.'00 |
| PA: | 2.'75 | PA: | 2.'22 | PA: | + 2.'49 |
| SD | 15.'53 | | 48.'06 | Ho: | 87°32.'49 |
| Ho: | 87°32.'45 | SD: | -15.'53 | | |
| | | Ho: | 87°32.'53 | | |

TABULAR CORRECTIONS (PP XXXIV-XXXV)

| | Observation 1 | Observation 2 | Observation 3 |
|---|---|---|---|
| Ha: | 87°14.'17 | 87°45.'83 | 87°30.'00 |
| Upper: | 13.'40 | 12.'90 | 13.'20 |
| Lower | 4.'80 | 3.'80 | 4.'30 |
| | | 88°02.'53 | 87°47.'50 |
| | | - 30.'0 | -15.'00 |
| Ho: | 87°32.'37 | 87°32.'53 | 87°32.'50 |

(Note: In these problems there were no I.C., Dip or Refraction corrections).

In the case of the LL and UL observations, error is caused by a combination of A, SD and PA. For the bubble sextant (center) observation, the only error is that of PA.

Note that the error in observation caused by A in observations 1 and 2 is corrected by the PA corrections +2.'75 and +2.'33 respectively in these two observations. A had no effect on the bubble sextant observations since the moon's center was aligned with the true horizon, thereby eliminating the semi-diameter (SD) correction in Observation 3.

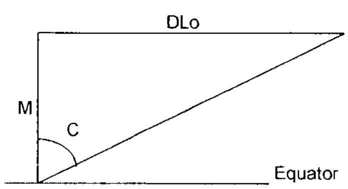
# NAVIGATION NOTES

## A Sailing Problem for Navigators

*By Allan E. Bayless*

Assuming it were possible, how many times would a vessel course 060° spiral around the globe (loxodrome) from the equator to a point one mile from the pole? How many miles would it travel?

**Sailing Problem Solution**




DLo = M tan C

Revolutions = DLo / earth's circumference
= (30375 x 1.73205) / 21600 = 2.44 times

Data

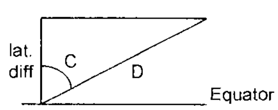
M (sphere) $= R \int \sec L \, dL$
$= R \ln[(1 + \sin L)/\cos L] = 30375.0$

R = Earth's radius = (360° x 60') / 2π

L = 89° 59' = 1.57051 radians

Tan C = tan 60° = 1.73205

Earth's circumference = 2πR = 21,600'




Distance = latitude difference x sec C
= 5399' x 2 = 10,798 nm

Data

Lat diff = 89° 59' = 5399'

Sec C = sec 60° = 2

***Notes:***

(a) The above solution uses meridional parts for a sphere. For an ellipsoid, use either the *Bowditch* table of meridional parts or the equation (equivalent to the expansion shown in *Bowditch).*

$M = M(\text{sphere}) + R\,e/2 \ln[(1 - e \sin L) / (1 + e \sin L)]$

where $e$ = ellipticity = 0.0818191. In this case,

Rev = 30351.6 x 1.73205 /21600 = 2.43 times

(b) Course angle and relative scale in the diagrams are approximate

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By Ernest Brown*

(Continued from Issue #51, Spring 1996)

Following the completion of Joh. Höver's work constructing the mooring mast and dirigible hangar, Roald Amundsen and Lincoln Ellsworth reached Kings Bay by ship on April 12, 1926, to oversee the final preparations for the arrival of *N1* renamed *Norge,* which departed Rome on March 29, 1926, on a flight across Europe.

Some weeks earlier in New York, Amundsen and Ellsworth met Commander Richard E. Byrd, USN, who told them of his plan to fly to the North Pole. They told Commander Byrd about their experience with ice conditions at Kings Bay and expressed their opinion that the ice there would be the best place for him to make his start. Finding the fjord free of ice on their arrival, they were troubled. They wondered whether Commander Byrd would think that they were trying to mislead him. The matter was a topic of daily conversation while hoping that ice would form so that Byrd could use the starting place they had suggested.

Joh. Höver had constructed a huge (110x34x20 meters high) or (350 ft. x 102 ft. x 90 ft. high) roofless hangar to protect the *Norge* from strong winds. Since no timber grew on the island, all of the construction wood had to be shipped from Norway. The long dimension was aligned with the prevailing wind off the fjord.

On April 24, 1926, Commander Byrd and his pilot, Floyd Bennett, arrived by ship at Kings Bay with a Fokker aircraft, the *Josephine Ford.*

Byrd announced that he was flying directly to the North Pole instead of first flying to the coast of Greenland as he said he intended to do when he requested permission to use the facilities at Kings Bay. "That is all right with us," said Amundsen, boring Byrd with his intense blue eyes. Without doubt the criticism he received for racing Robert Falcon Scott to the South Pole affected him at this time. Also Amundsen's interest was flying all the way across the Arctic Ocean; Peary had already discovered the North Pole.

Theodore K. Mason in *Two Against the Ice, Amundsen and Ellsworth,* (Dodd, Mead & Co. 1982) says that Ellsworth found Byrd's arrival to be annoying, giving them "every reason to be disgruntled" for Byrd's flight to the Pole would divert the attention of the public, making them less able to recoup their investment through the book, lectures and motion picture planned. Also, should Byrd be forced down on the ice, they might have to search for

Byrd and postpone their expedition until the next summer at great financial loss.

In helping Byrd to make his flight, Amundsen suggested that a gentle slope near the hangar could be smoothed out for a runway. He told Lieutenant Bernt Balchen, Royal Norwegian Air Force, to provide Byrd whatever assistance he could.

On finding that Byrd was not carrying any survival equipment, Amundsen and Ellsworth provided snowshoes and a sledge. To make the sledge, it was necessary to take a carpenter away from his *Norge* work.

On each of two test flights, one of the Fokker's skis broke and had to be replaced. On one flight the landing gear strut was bent. Norwegians worked all night to repair it.

On May 7, 1926, the *Norge* arrived at the mouth of the fjord.

On hearing of Byrd's preparations after his arrival on the *Norge*, Colonel Umberto Nobile told Amundsen that he could have the *Norge* ready for the polar flight in three days. Nobile was taking into account repairs to one engine damaged on the flight across Europe. Amundsen's response was "Nothing doing. We are not running a race with Byrd to the North Pole. Our job is to cross the Arctic Ocean."

The following afternoon, Byrd attempted the polar flight, but Bennett couldn't get the Fokker airborne. The aircraft ran into ice hummocks at the end of the runway and tipped over in a snowbank. The aircraft was lightened by unloading 300 gallons of reserve fuel and 200 pounds of souvenirs and was taxied back to the starting point. Balchen told the two Americans that if they waited until midnight, when the Arctic sun was low on the horizon, the runway would be frozen solid, offering less resistance.

Byrd accepted Balchen's advice and shortly after midnight the *Josephine Ford* took to the skies over Kings Bay.

(To be continued)

## Navigator's Newsletter Index

**Index 92 (1-35),** published with Issue Thirty-five (Spring 1992), is an index covering Issues One through Thirty-five.

**Index to Navigation Problems (4-33),** published in Issue Thirty-three (Fall 1991), covers navigation problems in Issues Four through Thirty-three.

**Index to Navigation Personalities (12-53),** published in Issue Fifty-three (Fall 1996), covers personalities in Issues Twelve through Fifty-three.

**Index to Book Reviews (36-53),** published in Issue Fifty-three (Fall 1996), covers reviews in Issues Thirty-six through Fifty-three.

**Index to Navigation Personalities (12-53)**

| | | |
|---|---|---|
| Twenty-one<br>Summer 1988 | John Davis | T. D. Davies |
| Twenty-two<br>Fall 1988 | Muhammed Targui<br>(Ulughbek) | T. D. Davies |
| Twenty-three<br>Winter 1988-89 | Radler de Aquino | T. D. Davies |
| Twenty-four<br>Spring 1989 | Nevil Maskelyne | T. D. Davies |
| Twenty-five<br>Summer 1989 | Simon Newcomb | T. D. Davies |
| Twenty-six<br>Fall 1989 | Capt. (later Vice Admiral)<br>William Bligh, R.N. | T. D. Davies |
| Twenty-seven<br>Winter 1989-90 | William Chauvenet | T. D. Davies |
| Twenty-eight<br>Spring 1990 | The Original Star Finder | Capt. Gilbert Rude |
| Twenty-nine<br>Summer 1990 | Henry of Portugal<br>(1394-1460) | T. D. Davies |
| Thirty<br>Fall 1990 | Sebastian Cabot | T. D. Davies |
| Thirty-one<br>Winter 1990-91 | Sir George Biddell Airy | T. D. Davies |
| Thirty-two<br>Summer 1991 | Rear Admiral Thomas D. Davies, USN (Ret.)<br>1914-1991 (Obituary) | |
| Thirty-three<br>Fall 1991 | Sir Francis Beaufort<br>(1774-1857) | Roger H. Jones |
| Thirty-four<br>Winter 1991-92 | George W. Mixter | Roger H. Jones |
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| Forty-five | Robert FitzRoy, Captain | William O. Land |

| | | |
|---|---|---|
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| Forty-six<br>Winter 1994-95 | Roald Amundsen | William O. Land |
| Forty-seven<br>Spring 1995 | Roald Amundsen<br>(Continued) | William O. Land |
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| Thirty-nine<br>Spring 1993 | Celestial Navigation With the<br>S Table<br>by Mike Pepperday | Roger H. Jones |
| | 100 Problems in Celestial<br>Navigation<br>by Leonard Gray | Roger H. Jones |
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| | Formulae for the Mariner<br>by Richard M. Plant | Terry Spence |
| Forty-seven<br>Spring 1995 | Small Craft Piloting and<br>Coastal Navigation<br>by A. E. Saunders | Terry Spence |

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| Forty-eight<br>Summer 1995 | The Star Finder Book<br>by David Burch | Terry Spence |
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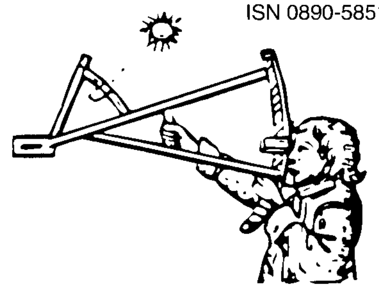
**ANSWER TO DO YOU KNOW...?** (From page 1)

First, the observer is not on or is the pole mounted vertically on the same flat surface. Second, parallel rays of light are received from the star, not a single ray (guy wire) from the top of the pole.

If the surface were flat, the observer would measure the same angles at all places on the flat surface. The parallel rays and spheroid are essential to conventional celestial navigation.

ISN 0890-5851



# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-FOUR, WINTER 1996-97

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Internet Web Pages

The Foundation's Web Pages have generated a small amount of interest in the Navigation Foundation. The Foundation is gaining about two new members a week from this source. The Web Pages are free, which helps immensely in keeping up with the continually rising cost of postage, printing, and other normally occurring expenses. We still need assistance from our members to get our membership numbers up. If we can keep the membership above 500 the Foundation can continue to offer a membership for the annual $30.00 tax deductible contribution. That is true for now. If the cost of printing and postage increases in the next year we will have to re-evaluate our contribution.

Internet Address Correction

One Internet Address published in The Navigator's Newsletter Issue Fifty-Three, Fall 1996 is incorrect. The correct Web Page address is http://www.netcom.com/~navigate/celestial/nav.html. The "olyc" address is correct.

### NIMA Price Increase

NIMA has increased prices on all of its charts and publications. Here are some of the new prices for items normally ordered by members:

| | |
|---|---|
| Harbor and Approach Charts | $15.30 |
| Coastal Charts | $15.30 |
| Bowditch | $23.20 |
| Atlas of Pilot Charts | $28.50 |
| Radio Navigation Aids | $17.70 |
| Sailing Directions | $20.30 |
| Sight Reduction Tables | $11.90 |

All other items have been increased in price from a few cents to a couple of dollars. Members discounts of 20% on all publications and a 25% discount on all chart orders over $50.00 still apply. Postage or shipping as applicable still apply.

### Members' Letters

Letters from members have dropped dramatically over the past year. We do not know if this drop can be attributed to lack of interest, the Newsletter is so non-controversial that no one takes exception, or interest in celestial navigation is waning with the accessibility of inexpensive GPS equipment.

If you find something that interests you and you want more information, or you have a bone to pick with us, or you have something you want others to know about, write us a letter, send us an E-Mail or FAX us your missile. For the FAX only give us a call and leave your telephone number, name and that you want to send a FAX and I will return your call and turn on the FAX machine, which is in my computer.

Our E-Mail addresses are: 76476.1165@compuserve.com or navigate@ix.netcom .com. Our FAX number is the same as our telephone:301-622-6448. Also check out our web pages and give us your comments. The web pages are at: http://www.netcom.com/~navigate/celestial/nav.html or as one of the items at http://www.olyc.com.

### Anyone Interested?

If there is any interest by members, I will write about my son (U.S. Air Force trained in A-10's) and my (U.S. Navy Carrier trained pilot) trip to fly Russian L-39's, SU-25's and MIG-21's in The Crimean section of the Ukraine. We flew with Ukraine Test Pilots and had a great time.

**DO YOU KNOW . . .?**

*By Ernest Brown*

Who were the first two men to reach both poles of the earth together?

*(The answer appears on back page.)*

# NEW PRODUCTS

*By Terry Carraway*

The National Imagery and Mapping Agency (NIMA) has produced a new Tactical Pilotage Chart of Bosnia and Herzegovina. The chart, scale 1:500,00, includes coverage of Bosnia and Herzegovina, most of Croatia and Slovenia, portions of Italy and the Adriatic Sea. In addition to topographic and aeronautical information, the chart includes cease fire and interentity lines and zones of separation. Follow the peace keeping efforts in the region with this chart. Current price is $4.90 plus postage.

*Reed's Nautical Almanacs* are now available through The Navigation Foundation. NOAA/NOS no longer publishes tide and current data. Reed's is one of the publishers of this official navigation data. Reed's Almanacs also include more than 4,000 way points with lat./long. position, over 150 harbor chartlets, VHF, SSB, NOAA weather and weather FAX services and 1997 celestial navigation tables with easy to understand text and examples. Reed's Almanacs come in 3 individual Almanacs and a *Reed's Nautical Companion* (The Handbook to Complement Reed's Almanacs). Individual Almanacs are for North America's East Coast, West Coast and Caribbean. Three Almanacs are $29.95 list. Nautical Companion is $19.95 list, shipping is $4.00. Member discounts apply.

### New Version of Quik-Dri

The Quik-Dri Sight Reduction Form in issue Fifty-three should read Z65°, Zn 065°. See pages 10 and 11 this issue. The current form has a simplified instruction for determining if the body is below the horizon.

# READERS FORUM

Member John G. Hocking of 4205 Meridian Road, Okemos, Michigan 48864 (E-mail address: hocking@pilot.msu.edu) wrote on 12 November 1996:

"Is it appropriate to request of the membership some help in identifying an old sextant I've acquired? Director Allan Bayless has tried to locate people for me and has had the usual sort of problem. This fellow is away on his boat, that one has moved and left no forwarding address, you must know the kind of frustration involved!

"Here is a description: The instrument is brazen, having both mirrors silvered on the rear of the glass. The scale is marked off in twenty minutes steps and the vernier then reads to 0.5'. The markings, on a strip of ivory by the way, are very fine indeed and a swinging magnifying glass is appended to the arm to help the weak-eyed to read the things. There are three sun shades at each mirror, both an open sight and a sighting telescope, and it is all contained in a sextant-shaped wooden box. A pair of eyes much sharper than my own swears that a very badly worn inscription on the arc contains the words "Liverpool" and "Strand". Have I any chance of finding the maker's name, a date, anything at all?

"A dealer in antique nautical equipment to whom I showed the sextant while I was in Wales this past April thought it might stem from the 1820's and valued it well beyond my wildest expectations. In fact, he made me a very handsome offer for it. But a dear friend had just given me the sextant and there was no way that I would sell it. That feeling still holds good, naturally, but I'd not be averse to learning something of its value. My friend did not know anything about the instrument except that it had been in his family forever and I was the only one he knew who might possibly appreciate it. I have made it my own by the simple procedure of manufacturing a brass plaque suitably "antiqued" to fit into the spirit of the thing.

"Thanking all of you in advance, I am"

— *Very sincerely yours, Gib.*

Member Captain R. A. Bowling, U.S. Navy (Ret.) of 4845 San Juan Road, San Diego, California 92103, (619)298-5492 wrote on 27 November 1996:

"I have a WWII Bubble Octant, Type A-8A. It is in relatively good condition except that: (1) there is no longer a bubble, (2) the wire from the battery compartment to the sextant is missing, and (3) it needs adjustments, *e.g.*, the counter is off. I want to restore it to full operational use, but can't seem to find anyone who works on bubble octants, much less one of this vintage. If you or any of your readers know of such a person or firm, I would appreciate the information.

"Currently, I teach celestial navigation to merchant mariners who wish to get that qualification on their limited licenses. In addition, I have had several enquiries from yachtsmen regarding a "quickie" course in celestial as an emergency backup for their GPS. I have developed such a one-dayer that concentrates exclusively on sun shots — morning, LAN, afternoon — using the *Nautical Almanac* and Pub. No. 249. It appears to fill the bill. However, I am still looking for a simpler — less dependence on volumes of tables, *e.g.*, 249 approach, such as Dreisonstok's.

"Based on the positive reports by Allan Bayless and Robert Girdler regarding Bob's *Quik-Dri* slide rule (*Navigator's Newsletter*, Issue Fifty-Two, Summer 1996), it appears that it could be such an approach. Therefore, I have ordered a copy. I'll let you know how it fits my goal.

"Thank you for any assistance you can offer to get my trusty bubble octant back in faithful, full service."

— *Sincerely, R. A. Bowling*

Director John M. Luykx responded to Captain Bowling on December 16, 1996:

"Your A-8A sextant appears to be repairable. The only question I have regards the bubble. Disassembly of a bubble assembly of this type (B&L type) is always a problem since historically the bubble assembly of the A-8A is that part of the instrument which breaks down most frequently. I have repaired the A-8A sextants in the past, so if you would like me to look at your sextant, please send it on via UPS, preferably, and well packed. An examination will be made of the sextant and by return mail a listing of suggested repairs with their cost will be forwarded to you. We won't do any work on the instrument until we receive authorization from you. Upon receipt of your authorization, please allow us three or four weeks to accomplish the work.

"Ship the instrument to: InfoCenter, Inc., 2021 Brooks Drive #319, Forestville, MD 20686."

— *Sincerely, John M. Luykx*

Member Edward S. Popko of 28 Maverick Road, Woodstock, NY 12498 [75050,1357] wrote by E-mail on November 11, 1996:

"The Summer 1996 Newsletter contained several letters from members expressing interest in computational or programming aspects of sight reduction or for ephemeris data. I found "A Navigator's Toolbox — Trigonometry and a little Astronomy for the Serious Navigator" by John G. Hocking very useful. It is published by Triskelion Publishing Company and is available from the author (John Hocking, 4205 Meridian Road, Okemos, MI 48864 (517)349-0958). I believe I paid $25 for it and it is well worth it.

"I'm like David Blythe and also program my HP486GX calculator for piloting and celestial navigation algorithms. Hocking's book contains many useful algorithms and has been a big aid. For the benefit of our readers, let me at least list the main chapter headings for those who might be interested in this work:

"Plane Trigonometry, Spherical Trigonometry, Applications of Spherical Trigonometry (celestial fix, navigational triangle, special methods of sight reduction and great circle sailing), the Ellipse, and Elementary Astrodynamics. This volume is 173 pages of great refresher, introduction to computational algorithms and general explanation of how things work with basic (non calculus) mathematics. If you have a calculator with the trig functions (SIN, COS and TAN), this book is a must."

**Louis J. Spizziri**
It is with sorrow we announce the passing of Louis J. Spizziri on July 25, 1996.

**Donald J. Pegg**
It is with sorrow we announce the passing of Donald J. Pegg.

# NAVIGATION NOTES

## Pocket Sextant for Use on Land

*By John M. Luykx*

In recent months a number of InfoCenter customers have contacted us regarding the availability of a small pocket type sextant which could be used on land and which would be compact and light enough to be carried in the pocket or backpack. Although small box sextants of 18th and 19th century English design are available today as replicas and are basically suitable for navigation purposes, the modifications required (addition of bubble and/or pendulum devices) would be too costly to make them practical for use on land as an artificial horizon sextant. As is, the box sextant can be used on land with a liquid or glass artificial horizon such as that depicted in Issue 49 of The Navigator's Newsletter, but this would defeat the essential purpose of compactness, light weight and portability.

During the past summer, here at InfoCenter, we developed a small compact altitude measuring instrument which shows promise. It is based on a small surveyor's clinometer. With this instrument (see Figure 1) modified to include sun filters and an illumination

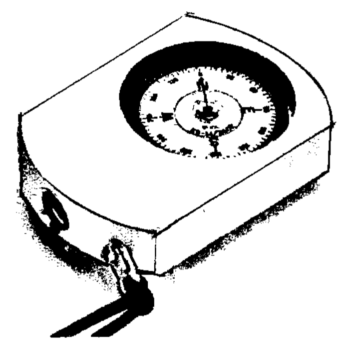


FIGURE 1

system for night use, altitudes can be measured to a precision of one tenth and often to one twentieth of a degree. However, when the mean time and mean altitude of a series of ten or more observations are computed, accuracy to a few minutes of arc are possible for each series of observations.

Tests so far conducted with this instrument have consisted of twenty-one series of ten observations each; sixteen series of sun observations and five series of night observations of the moon, planets and some stars for a total of two hundred ten observations. The mean value of time and altitude for each series of observations was computed and reduced to determine the error of each series in minutes of arc.

The test results shows that:

a) The I.C. of the test instrument was -10.'2.

b) The mean arithmetic error of the twenty-one series of observations was 3.'1.

c) The mean algebraic error was -0.'5.

d) The range of error for the twenty-one series of observations was 13.'1; i.e. from -7.'6 to +5.'5.

Although these tests indicate that a series of observations is required to obtain accuracy, they nevertheless indicate sufficient accuracy for general use in the field as an emergency means of obtaining position on land.

Improved accuracy is possible when the observer leans against a tree or post during low and medium altitude observations or lies down on the ground on his back during high altitude observations.

Instrument dimensions are:

| | |
|---|---|
| Length: | 3″ |
| Height: | 3″ |
| Width: | 3″ |
| Weight: | 8 oz. |

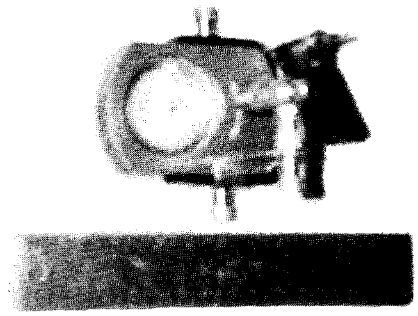


FIGURE 2

The complete instrument can be quickly and easily disassembled into its four component parts: i.e. housing, light system, sun filters and clinometer. (See Figure 2). This disassembly capability will enhance stowage in a small box or case.

For more information, contact InfoCenter, Inc., P.O. Box 47175, Forestville, MD 20747, Phone 301-420-2468.

# NEWSLETTER INDEX

**Index 92 (1-35),** published with Issue Thirty-five (Spring 1992), is an index covering Issues One through Thirty-five.

**Index to Navigation Problems (4-33),** published in Issue Thirty-three (Fall 1991), covers navigation problems in Issues Four through Thirty-three.

**Index to Navigation Personalities (12-53),** published in Issue Fifty-three (Fall 1996), covers personalities in Issues Twelve through Fifty-three.

**Index to Book Reviews (36-53),** published in Issue Fifty-three (Fall 1996), covers reviews in Issues Thirty-six through Fifty-three.

**Index to History of Navigation (3-54),** published in Issue Fifty-four (Winter 1996-97), covers history articles in Issues Three through Fifty-four. This includes articles under the heading Navigation Notes in Issues Three through Seven.

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| Thirty<br>Fall 1990 | The Bygrave Position<br>Slide Rule | John M. Luykx |
| Thirty-one<br>Winter 1990-91 | Le Grant Routtier of<br>Pierre Garcie (1520) | John M. Luykx |
| Thirty-three<br>Fall 1991 | Celestial Navigation by<br>Chronometer Time Sight | John M. Luykx |
| Thirty-four<br>Winter 1991-92 | The Quincentenary of the<br>First Columbus Voyage to<br>the Americas | John M. Luykx |
| Thirty-five<br>Spring 1992 | The Quincentenary of the<br>First Columbus Voyage to<br>the Americas (a continuation) | John M. Luykx |
| Thirty-six<br>Summer 1992 | The Quincentenary of the<br>First Columbus Voyage to<br>the Americas (a continuation) | John M. Luykx |
| Thirty-seven<br>Fall 1992 | The Quincentenary of the<br>First Columbus Voyage to<br>the Americas (conclusion) | John M. Luykx |
| Thirty-nine<br>Spring 1993 | Christopher Columbus: A Man<br>of History | John M. Luykx |
| Forty<br>Summer 1993 | John Harrison: Horologist | John M. Luykx |
| Forty-one and<br>Forty-two<br>Fall/Winter 1993-94 | The Fleuriais Gyroscopic<br>Sextant | John M. Luykx |
| Forty-three<br>Spring 1994 | Determining the Longitude<br>of a Place by Chronometer | John M. Luykx |
| Forty-four<br>Summer 1994 | Origins of Geomagnetic<br>Science | David G. Knapp |
| Forty-five<br>Fall 1994 | Origins of Geomagnetic<br>Science (a continuation) | David G. Knapp |
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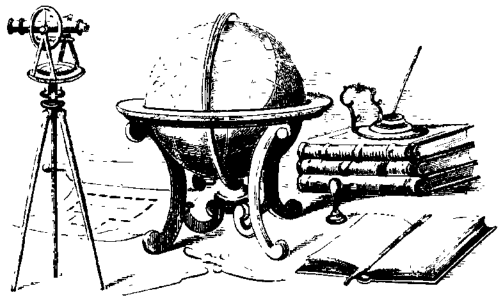
| Forty-eight<br>Summer 1995 | Navigation as it Pertains<br>to Shore Bombardment During<br>Naval Amphibious Operations | John M. Luykx |
| Fifty-two<br>Summer 1996 | The Plath (SOLD) German Navy<br>Gyro Sextant Type KS-3D of 1945 | John M. Luykx |
| Fifty-four<br>Winter 1996-97 | Determining Longitude by<br>Lunar Distance Observation (Part 1) | John M. Luykx |



# HISTORY OF NAVIGATION

## Determining Longitude by Lunar Distance Observation (Part 1)

*By John M. Luykx*

A reading this past summer of the recently published book entitled *Longitude* by Dava Sobel persuaded this writer to pursue some additional research on early navigation with the purpose, eventually, of being able to actually compute the complete solution for the longitude by both the lunar distance and chronometer methods. A description of some of the details of the longitude by chronometer method has already been published in this Newsletter (Issue No. 43, Spring 1994). In this and forthcoming issues of the Newsletter a procedure will be described in some detail for determining the longitude by lunar distance observations.

The historical circumstances which propelled the longitude problem to the forefront of scientific investigation (especially in astronomy) during the 17th and 18th centuries was the need for safer navigation at sea and for the reduction in the number of marine disasters primarily caused by the lack of accurate position determination by ships underway at sea.

The age of exploration from about 1450 to as late as 1800 saw a large and rapid expansion of exploration programs, overseas trade and general ocean travel by the maritime nations of northern Europe. During this period navigational science and technology flourished as evidenced by the introduction of new instruments such as the astrolabe, the cross-staff, the back-staff, the sextant and the chronometer. This period also saw the publication of portolan and plain charts, as well as the publication of rutters and sun, star and planet longitude and declination tables. However, it was not until about 1770 when the chronometer was first perfected for use at sea that the longitude problem could be considered as eventually solved. Prior to the development of the chronometer and the publication of the Nautical Almanac in England in 1767, mariners, during long ocean voyages, were unable to accurately obtain the longitude of the ship's position by observation as well or as accurately as they could the latitude. (Note: the founding of the Paris Observatory in 1667 led in 1679 to the publication of the French Almanac CONOISSANCE DES TEMPS: the oldest of the Astronomical Ephemeris tables for use by astronomers and navigators). Prior to the publication of the first English almanac in 1767, Dead Reckoning was primarily relied upon to establish the longitude; the error of the longitude generally increasing directly with the length of the ocean voyage.

Faulty longitude reckoning often resulted in disaster at the end of a voyage when the longitude error at the conclusion of a voyage (due to the accumulation of a large number of small daily errors) became very large. These disasters, the greatest number of which were groundings and founderings, were attended unfortunately by heavy loss of life and property.

For these reasons a procedure for finding the longitude assumed increasing importance and gained greater recognition among maritime nations, particularly during the first half of the 18th century. Both public and private commissions, agencies, boards and committees were established by the principal maritime nations to study the problem of finding the longitude.

Among these efforts in England, France, Spain, Holland and Venice, those in England provided by far the greatest monetary reward: for the person who was able to find the longitude, the following prize was established:

a. £10,000 for finding the longitude within 50'
b. £15,000 for finding the longitude within 40'
c. £20,000 for finding the longitude within 30'

In 1714 the Longitude Act was passed in Parliament and a Board of Longitude established to study and evaluate methods for determining the longitude at sea. In this regard, the story of John Harrison and his chronometers is well-known and well-documented, so too is the work of the French horologists LeRoy and Berthoud, and the Englishmen, Arnold and Earnshaw, all of whom were instrumental in finalizing the eventual design of the marine chronometer as we know it.

Although by 1770 the chronometer had been sufficiently perfected for use at sea, it was not until almost a century had passed before the majority of ships engaged in long sea voyages were outfitted with them. During the interim, (subsequent to the publication of the Nautical Almanac in England in 1767) the primary means of estimating or computing the longitude was by lunar distance computation. For almost a century, from 1767 to about 1850, when chronometers became more prevalent at sea, it was the lunar distance solution which provided longitude for the mariner and navigator. Due to the importance of this procedure in 18th and 19th century navigation practice, it is felt that it may well be worthwhile to present to our members some details concerning the methods and computations involved in the lunar distance method for finding the longitude at sea.

The principle underlying the lunar distance method is that the moon "moves" across the sky relative to the sun, planets and stars; i.e., the moon circles the earth once every month and in doing so rapidly changes its position among the sun, the stars and the planets in the background. If the position of the moon relative to the sun, a star or a planet could be accurately predicted and this data tabulated (at 3 hour intervals, for example) in a publication such as The Nautical Almanac, then it would become possible to establish longitude by comparing the apparent time of a lunar distance observation to the sun, a star or planet anywhere on earth with the predicted apparent time and lunar distance to the body as predicted and tabulated for the Greenwich Meridian in the Almanac. The difference in time between almanac time — i.e., GREENWICH APPARENT TIME (GAT) — and the apparent time of the observation -- i.e., LOCAL APPARENT TIME (LAT) — converted to an angular value would then be equal to the angular distance of the observer east or west of the meridian established as a reference for the Nautical Almanac. For the English Almanac, the reference meridian is the meridian at Greenwich; for the French Almanac, the reference meridian is the meridian of Paris. Methods for clearing the lunar distance (computing the true, actual lunar distance) and calculating the longitude by lunar observation are legion. Generally, only the details vary among the methods. Some of the more well-known of these mathematical methods are those by Gema Frisius (1530), Tobias Mayer (1752), Jean Borda (1730), Krafft (1791), Delambre (1807), J. R. Young (1856), G. S. Airy (1835), W. Chauvenet (1896).

It was, however, the fundamental theoretical work of Isaac Newton contained in his THEORY OF UNIVERSAL GRAVITATION (1687) which provided a firm basis for the later observational data and calculations of Tobias Mayer (1752) and Leonard Euler (1753) which in turn led to the publication of the first Nautical Almanac in 1767; a project under the direction of Nevil Maskelyne, the fifth Astronomer Royal. Incidentally, the main purpose of The Nautical Almanac was originally to provide data for solving lunar distance problems.

The Nautical Almanac of 1767 is considered a milestone in the history of navigational science. Without the ephemeris data contained in this publication the use of both the lunar distance method or the chronometer method for finding the longitude would have been practically impossible. (To be continued)

# MARINE INFORMATION NOTES

## Defense Mapping Agency Name Change

Effective October 1, 1996, the Defense Mapping Agency (DMA) joins the Department of Defense's newest combat support agency, the National Imagery and Mapping Agency (NIMA), which was created under the authority of the Fiscal Year 1997 Defense Authorization Bill. NIMA consolidates imagery and geospatial resources and management into a single, streamlined DoD agency to provide timely, relevant, and accurate imagery, imagery intelligence, and geospatial information in support of national security objectives.

All products, services and points of contact provided by DMA will remain the same under NIMA.

## Digital Nautical Chart (DNC) Availability

DNCs on CD-ROM in Geographic Areas 9, 14, and 15 are ready for issue to the Department of Defense (DoD), qualified DoD Contractors, and U.S. Government Agencies supporting DoD functions only. These data sets, which only partially cover their respective geographic areas, are issued solely for research, development, training, and evaluation. The DNC is not authorized for use in place of the paper chart for navigation, as the automatic updating service for it is still being developed. Therefore, when evaluating DNC as a navigational aid, the paper chart must be used as the primary means for ship navigation.

For detailed background information on DNC, see pages xx and xxi of the DMA Catalog of Maps, Charts, and Related Products, Part 2-Volume I, Nautical Charts and Publications (7th Edition, February 1996).

## Addresses for Reports

The Navigation Information Network (NAVINFONET) provides a bulletin board service for most of the textual data in the Notice to Mariners. See address and fax numbers below for inquiries.

The following Mailing Instructions can be used to send in corrective information. Please use the Notice to Mariners Marine Information Report and Suggestion Sheet for reporting changes and/or feedback. Please mail the form, together with other available material, to the proper U.S. Government Agency, as follows:

| Agency | Information Affecting |
|---|---|
| MARINE NAVIGATION DEPARTMENT<br>ST D 44<br>NATIONAL IMAGERY AND MAPPING AGENCY<br>4600 SANGAMORE ROAD<br>BETHESDA, MD 20816-5003 | Charts and publications produced by<br>NIMA for foreign coasts and waters;<br>NAVINFONET QUERIES.<br>FAX 301-227-4211/3731 |
| COMMANDANT<br>G NSR 3<br>US COAST GUARD HEADQUARTERS<br>2100 2ND ST SW<br>WASHINGTON DC 20593-0001 | Aids to navigation in U.S. waters.<br>FAX 202-267-4222 |
| COAST SURVEY<br>N CG 26<br>SSMC3<br>1315 EAST WEST HIGHWAY<br>SILVER SPRING, MD 20910-3282 | Charts and publications produced by<br>National Ocean Service for U.S. coasts<br>and waters, including U.S. territories.<br>FAX 301-713-4516 |

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By Ernest Brown*

(Continued from Issue #51, Fall 1996.)

In *First Crossing of the Polar Sea,* Amundsen and Ellsworth simply say that at a meeting in Oslo Colonel Umberto Nobile was appointed commander of the *Norge*. They also go on to say that by this selection of Colonel Nobile who had both built *N1* and flown it for a considerable time, they had secured the man who must know it, surely, better than anyone else; this knowledge could be of utmost importance to the expedition.

In *Two Against the Ice, Amundsen and Ellsworth* author Theodore K. Mason says that Amundsen had earlier opposed Nobile's having any share in the command. But Amundsen and Ellsworth were out of their league in dealing with the Italian dictator, Benito Mussolini, and Colonel Umberto Nobile.

The second in command was First-Lieutenant Hj. Riiser-Larsen, Royal Norwegian Navy. A veteran of the 1925 flight and a qualified airship pilot, Riiser-Larsen was also the navigator of the *Norge.* Emil Horgen, who had taken part in the 1925 flight as a reserve flyer and who was on leave of absence from his employment as chief officer on the Norwegian-American liner *Bergensfjord* was appointed to serve at the two rudders. Horgen, a former First-Lieutenant of the Royal Norwegian Navy was known to have many excellent qualities: a first rate flyer, quiet, self-contained and calm, besides being a skillful navigator. Horgen was assigned the side rudder. The main rudder was assigned to Amundsen's faithful and skillful old comrade of many years' standing, Oscar Wisting, the master of the *Maud* on her last expedition.

Captain Birger Gottwaldt, Royal Norwegian Navy, a radio expert, was aboard for radio direction finding.

Mr. Finn Malmgren, a graduate of Uppsala University, was the meteorologist. Malmgren had taken part in the *Maud* expedition from 1922 to 1925 during which he had obtained enormous experience and practice in dealing with atmospheric conditions.

Mr. Fredrik Ramm was appointed as journalist in order to keep the world informed of the *Norge's* movements through the great unknown.

Genadii Olonkin, engineer and radio telegrapher of the *Maud* expedition who was to serve as radio telegrapher of the *Norge* had to be replaced at the last moment at Svalbard due to an ear infection. His replacement was Frithjof Storm-Johnsen.

The aforementioned were assigned to the main gondola where expedition leaders, Amundsen and Ellsworth, and Commander Nobile were also located.

Flying-Lieutenant Oscar Omdal was assigned to the motor section with the five Italian mechanics who Colonel Nobile chose from the finest motor mechanics in Italy: Chief-Mechanic Cecioni, Rigger Alesandrini, and motor mechanics Arduino, Caratti, and Pomella.

Lincoln Ellsworth made himself available to help wherever he might be needed from time to time during the flight.

As long as all went well, there was no need for Amundsen to do other than to observe the region crossed and to describe it as accurately as possible. Amundsen knew from years of experience that he who has the chief leadership of an expedition ought preferably to be quite free and prepared to come in anywhere if necessary. Should the airship be compelled to land, the only chance for survival would come from Amundsen's preparations for such an event and his experience on the ice. Even if Nobile was commander of the airship, Amundsen was truly the leader of the expedition. (To be continued)

## QUIK-DRI Sight Reduction Form

Gr. Date JUNE 25, 1996 Body VEGA Approx. Z NE Ht. Eye (ft.) 6

Log ______ DR Lat. 40°33'N DR Long. 68°30'W

| | ° | ' | | | ° | ' | | h | m | s | | ° | ' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHA ★ | 80 | 42.7 | dec hr (N) S | | 38 | 47.0 | Clock | | | | Sext. | 33 | 43.8 |
| + GHA hr | 259 | 21.4 | d corr → | +/− | | | corr | + − | | | IC | (+) − | 2.4 |
| + v corr m, s | 12 | 07.7 | dec | (N) S | 38 | 47.0 | GMT | 23 | 48 | 23 | Dip | (−) | 2.7 |
| GHA | 352 | 16.3 | Subtract if possible or leave blank | | | | | | | | App. Alt. | 33 | 43.5 |
| 360° | | | Adjust to make LHA whole degrees after adding, or subtracting smaller from larger. | | | | | | | | Main | + (−) | 1.4 |
| GHA | 352 | 16.3 | | | | | | | | | Ho | 33 | 42.1 |
| Lo E+ (W) − | 68 | 16.3 | If Lo is W and greater than GHA, then LHA is E and = t if < 180° | | | | | | | | | | |
| LHA E (W) | 284 | | > 360°? Subtract 360° to get t same name. > 180°? Subtract from 360° for t opposite name | | | | | | | | | | |
| 360° | 360 | | | | | | | | | | | | |
| t (E) W | 76 | | | | | | | | | | | | |
| L (N) S | 41 | | | | | | | | | | | | |

Or, for moon only:

| | ° | ' |
|---|---|---|
| HP | | |
| App. Alt. | | |
| Upper Table | | |
| Lower Table | | |
| Ho | | |

| | | ° | ' | | | Table |
|---|---|---|---|---|---|---|
| → d | (N) S | 38 | 47.0 | | | |
| → b | (N) S +/− | 15 | 33.1 | A | 16686 | I |
| d+b | | 54 | 20.1 | → B | + 9021 | II |
| | | | | A+B | 25707 | |
| | | | | → Hc | 33° 35.8 | II |
| | | | | Ho | 33° 42.1 ← | |
| | | | | a | 6.3 Mi | (To) Away |
| | | | | Z | 65° | |
| | | | | Zn | 065° | |

If t < 90°, give b same name as L.
If t > 90°, give b opposite name.

Adjust L to nearest whole degree.

Subtract if d and b have different names

Line = instruction
→ Arrow = data

### Use Celestial Slide Rule to

1. Check Hc Table solution for gross error
2. Determine azimuth: If "t" is E, Zn = Z; If "t" is W, Zn = 360° - Z.

### How to use the **Tables** (Heavy border)

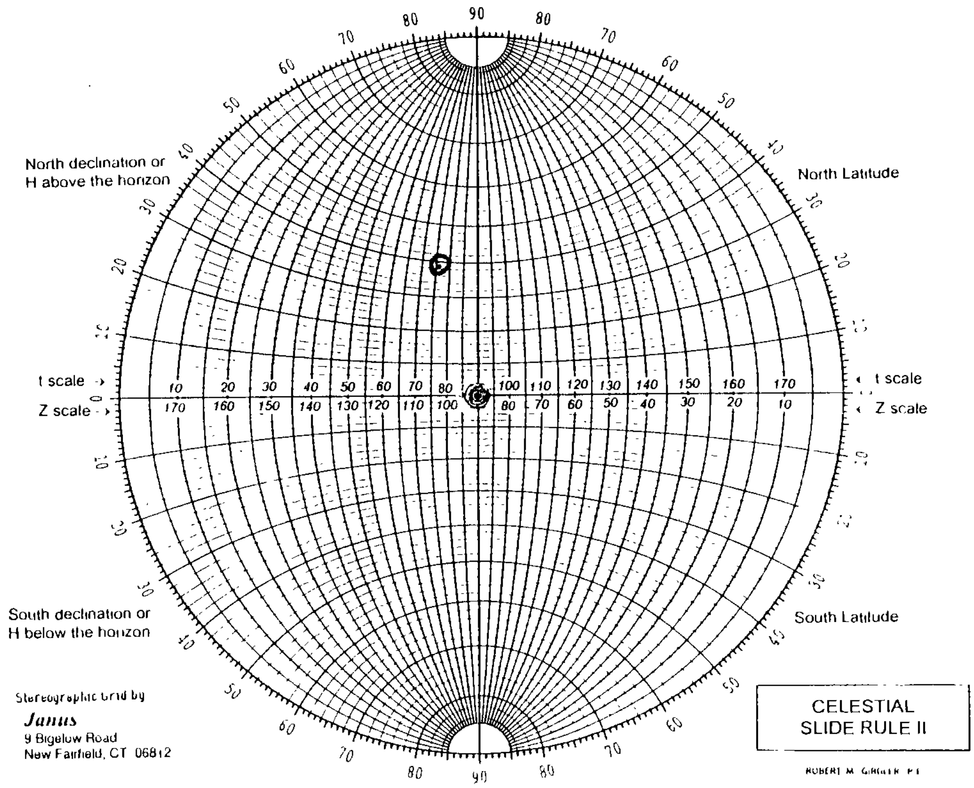
1. In the column for latitude and row for t in Table I, find "b" and "A" and enter in the labeled boxes.
2. Add or subtract "d" and "b" to get "d+b."
3. Enter Table II with "d+b" to get "B" (nearest value or interpolate).
4. Add "A" and "B" to get "A+B."
5. Find "A+B" in the body of Table II to get Hc (nearest or interpolate).

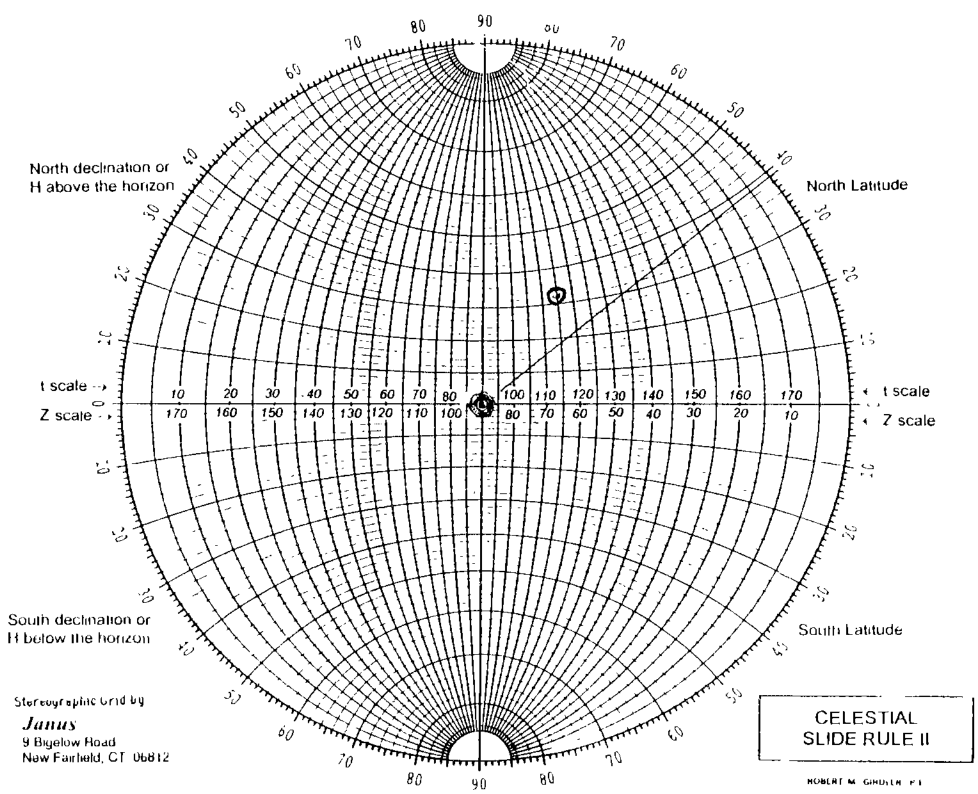
**Note:** Hc is (-), that is, the body is below the celestial horizon, **only** if the larger of b or d is named contrary to latitude.

### Plotting the Line of Position

1. Subtract Ho and Hc, diff. is "a" in N. Miles. (Add if on different sides of the horizon.)
2. Call "to" if Ho is higher than Hc in the sky.
3. Plot azimuth line from assumed (adjusted) position, not DR position.
4. Draw LOP 90° to azimuth line at a point "a" miles from the assumed position "to" or "away" from the body.

RMG 8/4/96




### To find the Azimuth with the Celestial Slide Rule

1. Rotate the transparent plastic cursor-disk so the line points straight up to Latitude 90°.
2. Find the two values that bracket ***t*** on the horizontal scale just above the equator.
3. Find the two values that bracket ***dec*** on the scale for the "parallels" at the edge of the diagram, North or South.
4. Within the 10° x 10° area defined by steps 2 and 3, mark the estimated location of *t* and *dec* with a fine dot (see *Note* below). Circle the dot so it can be found later.
5. Rotate the cursor-disk to bring the line over the assumed ***Lat.*** (North or South)
6. Read and record the new position of the dot. ***Z*** is estimated from the horizontal scale *below* the equator. ***Z*** is always reckoned from the North Pole, either East or West according to the name of *t*.
7. Also, note ***Hc*** can be estimated from the scale for the "parallels" on either side; compare this with the tabular solution for any gross error in calculation.

***Note:*** *Use a plastic wipe-off crayon and remove with dry tissue or a washable porous-tip pen and remove with moist tissue.*

Additional applications of the Celestial Slide Rule are described on its reverse side

**ANSWER TO DO YOU KNOW...?**

Roald Amundsen and Oscar Wisting planted the Norwegian flag at the South Pole on December 14, 1911. At 0125 Greenwich time on May 12, 1926, Amundsen dropped the Norwegian flag at the North Pole from the airship *Norge*, turned around, and grasped Wisting's hand. No word was uttered.

# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-FIVE, SPRING 1997

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Correction

In Issue 53 Fall 1996 under New Products I referred to the 1997 NOAA Tide and Tidal Current Tables. That is in error. Beginning in 1996 NOAA/NOS no longer publishes and prints the tables. The only U.S. Government printed tables are the ones published by the National Imagery and Mapping Agency directly from NOS manuscripts for exclusive use of the Department of Defense and U.S. Coast Guard. ProStar Publications, Reeds and International Marine are printing, publishing and distributing official NOS tide and tidal current data/predictions and all three publishers tables are accepted by the U.S. Coast Guard as satisfying all legal requirements including: 33 CFR Ch.1 (7-1-91 Edition), 164.33 Charts and Publications.

*The titles of the discontinued NOS publications are:*
*Tide Tables:* East Coast of North and South America, Including Greenland.
West Coast of North and South America, Including the Hawaiian Islands.
Central and Western Pacific and Indian Ocean, Europe and West Coast of Africa, Including the Mediterranean Sea.

*Tidal Current Tables:*
Atlantic Coast of North America.
Pacific Coast of North America and Asia.

*Regional Tide and Tidal Current Tables:*
New York Harbor to Chesapeake Bay.

*Supplemental Tidal Predictions:*
Anchorage, Nikiski, Selovia and Valdez, Alaska.

The Navigation Foundation can supply Reed's Almanacs for North America East Coast; North America West Coast and Caribbean; and Reed's Companion, the Handbook to Complement Reed's Almanacs. Reed's Almanacs list for $29.95 each. Reed's Nautical Companion lists for $19.95. Captains packs are available for $39.95 list price. Members discounts apply.

The Foundation also can supply International Marine's Tide and Tidal Current Tales.

### NOAA Telephone Numbers

For availability of any NOAA charts or publications, the toll free number is 800-638-8972. If you want to send a FAX to NOAA the number is 301-436-6829. Remember, you save by ordering your charts through The Navigation Foundation. See Tide and Tidal Current Tables under MARINE INFORMATION NOTES this issue.

### U.S. Coast Guard License Renewal

Renewing your license? From what I hear the new test is really tough. It is a take home test but the people to whom I have talked say that most of the exam is on merchant ship loading and items that merchant seamen would need for safety at sea. The U.S. Coast Guard allows most renewals to qualify by taking an approved course in Rules of the Road, ship safety, fire fighting and lights and shapes. If you need to renew, I would strongly recommend looking into one of the available courses. Also do not forget the drug test. If you are in the business you have to be in an approved random drug testing program. One that I know of is:

The Maritime Consortium, Inc.
P.O. Box 25345
Alexandria, VA 22313-0345
800-775-6985

The annual fee is $60.00 but you have to pay for a first

**DO YOU KNOW . . .?**
*By Allan E. Bayless*
What "dead reckoning" is and the origin of the term?
*(The answer appears at the back of this issue)*

time drug test. This can be done either through the Consortium or through the physician from whom you get your physical. The Consortium will fax you information and an application form by calling their 800 number. Every year we get tougher regulations in every field.

### Rules of the Road

There is a new *Navigation Rules - International and Inland* now in print by the Government Printing Office. For all licensed operators a copy is required on their vessel. It is a good idea for everyone to carry a copy. List price is $8.50.

### Change in Policy

The Navigation Foundation is making a change in the way it reminds members to renew. In the past we have sent a reminder at the beginning of the month of a member's anniversary. This was followed with a "Second" Reminder in about three months. The "Final" notice was mailed about 6 months past the member's anniversary and the member's name was removed from the computer database. If the member renewed, his name was returned to the computer database at the original date and member number of the anniversary.

The new policy is to mail a renewal at the first of month of the member's anniversary as usual. This will be followed in two months with a final notice and the member removed from the computer database. If the member renews after the final notice has been mailed the original member number will be reassigned; however, the anniversary date will be changed to the new date.

The reason for the change is to economize and to reduce some of the workload. We believe that this new procedure will not unduly inconvenience our members, while still providing them with a reminder to renew.

# READERS FORUM

*Edited by Ernest Brown*

Member Robert M. Girdler of 4269 Vaucluse Rd., Aiken, SC 29801-8852 wrote on January 17, 1997:

"Thanks for your letter of the 14th pointing out the error in the azimuth derived in the sample of Quik-Dri shown in Issue 53 of the Newsletter. Sharp-eyed Navigator Steven Tripp is correct. The error arises from reading the Azimuth scale on the Slide Rule in the wrong direction.

"However, this same error on the same example was discovered at least six months ago, brought to my attention by two other alert customers. Recipients of that issue were notified, and subsequent issues had a corrected example. I don't know how the error occurred in the Newsletter example, it's not in my handwriting.

"Anyway, to make amends, here is a copy of the latest issue of Quik-Dri. Perhaps you can make a copy of its example. Also, as you suggest, you can use the attached Slide Rule to photograph the two steps in finding the azimuth. I used a permanent marker so it would last through shipment. The spot can be removed with most any cleaning fluid.

"I'm overwhelmed by, and thankful for all the attention Quik- Dri is getting in the Newsletter. I've received over a dozen orders as a result.

"Note that the enclosed current Form has a simplified instruction for determining if the body is below horizon, due mainly to Allan (the instruction, not the Horizon)."

— *Best wishes, Bob Girdler*

Member Robert M. Girdler of 4269 Vaucluse Rd., Aiken, SC 29801, 803-663-6925 wrote on January 29, 1997:

"I think the membership should be made aware of a superb book, now available, entitled *The Quest for Longitude*, edited by William J. H. Andrews.

"It derives from the Longitude Symposium held at Harvard in November 1993. When I registered at that meeting, I signed up to receive a copy of the Proceedings, when issued. Years went by with no delivery except a few letters of apology. Finally it arrived and it is much more than a drab account of the meeting, and well worth the delay.

"It is a 9"x11"x1.5" beautiful tome, suitable for anyone's coffee table. It contains all of the presentations made at the meeting (plus much more it seems to me because I don't remember half of them). Along with each article are numerous photos, often in color, diagrams of clock mechanisms, and "footnotes" and references (actually placed along side of the text).

"The theme is a record of the long, frantic search for a method of finding longitude at sea, involving not only lunar distance methods and timekeeping (the two only practical ones), but also observations of eclipses of the moons of Jupiter, measurements of the magnetic variation, and such schemes as relaying time signals by gunfire.

"The book is so extensive that I found the best scheme is to have it always available by my reading chair, and pick it up from time to time to read another chapter.

"According to literature I received, it is available for $75 from:

Collection of Historical Scientific Instruments
Harvard University, Science Center B6
Cambridge Mass. 02138"

— *Best regards, Bob Girdler*

Member Phillip H. Sherrod of 4410 Gerald Place, Nashville, TN 37205 wrote by CompuServe on February 22, 1997:

"I have been a member of The Navigation Foundation for about 5 years. It is a wonderful organization and I greatly enjoy each newsletter. I just discovered your Web page via a link from Celestaire. I am pleased to see that you have set up a Web page.

"I do have one question: I own a periscope type aircraft bubble sextant manufactured by Kollsman Instrument Corporation. The one that I have is in very good condition and is fully functional, including the clock-driven averaging unit. However, it is way out of calibration. As best as I can tell, the instrument error is about 1 degree 20 minutes (i.e., 80 minutes)! Fortunately, it seems to be a fairly consistent error, so the sextant is usable. However, I would like to know if you know of anyone who could service and calibrate a sextant like this.

"Thank you and keep up the good work."

— *Phil Sherrod*

Member Neal Peterson [102163,263] wrote by CompuServe on February 22, 1997:

"Hello all friends.

"Departing Charleston, South Carolina, early this month for Bermuda Island to attend the National Speakers Association Eastern Workshop, started out challenging. Half way across the harbor, we were engrossed in heavy fog and could just see the bow of *Sealife* from the cockpit. Without radar and with major outward tide, we were swept towards shallow waters. I made the decision to tie up to a channel mark and wait for better visibility.

"With Gene King, Chairman of Employee Resource Management, and Hose Hernandez as crew making their first trans-ocean crossing, they were dumped in at the deep end. After several hours we navigated our way to sea and began building unique friendships.

"Gene had never sailed out of sight of land, had only been on a sail boat a few times in his life but was quick to adapt to the way of life. He assumed the responsibilities of cooking meals, and to our amazement, irrespective of weather, always produced a great meal without getting seasick once.

"Hose found his bunk and liked it more than the deck. We are not sure which was more wet, the bunk or on deck. He had a lot of sailing experience in several different types of inshore craft, and was given the duties of foredeck and chief bottle washer, when not sleeping or on watch.

"Conditions in the Atlantic in February were as vulgar as could be expected.

"Herb Hilgenberg was our unofficial crew as each day for the last several years, he stands by in Canada to route boats around the offensive weather systems. Herb is the most talented weather router in the Atlantic. He volunteers his time to analyze daily weather trends and to share this information on single side band radio with yachts crossing the Atlantic. He kept us out of the path of several severe storms.

"With Bermuda 780 miles east of Charleston, head winds hampered our progress. Gale after gale battered us, followed by calms. Instead of making a 5-day passage, we took 7 days to get to the island. Hose measured the days by what we had for dinner ... chicken, chicken, steak, fish, clam chowder, clam chowder, pasta. The best I have ever eaten at sea.

"Sadly the delays resulted in us arriving in Bermuda a day after the conference ended. We had missed everyone, but a corporate friendship between Gene and I developed that was most exhilarating. We will be announcing details of our discussions on deck within the next few months, where the seeds of some big challenges were sown.

"Gene flew back to ERM the day after we arrived on the island and Hose and I sailed hours later. Again Herb was on the airwaves and routed us south to avoid a deep storm center. We did encounter winds gusting up to 50 miles per hour. On our eighth day out, we were within sight of Charleston, but could not get there. The winds had completely died and our fuel was contaminated, rendering the engine useless. A friend came offshore to tow us in the last 20 miles.

"Back in the office, Gene and I are following through with our plans, and hope to share them with you soon."

— *Regards, Neal* www.no-barriers.com

Member Louis K. Mantell, N, LT USPS, of 817 Canterbury Hill, San Antonio, TX 78209-6038, wrote on January 17, 1997:

"I deeply appreciate your kind efforts in providing this member with the 1997 N.A. after he again underpaid the cost.

"The most recent issue of The Navigator's Newsletter was news filled and with items of high cognition pertaining to the Art of Navigation that maintains me in anticipation of the next valuable issue.

"Thank you for your uncredited stress on the call to duty and may our New Year associate you with health, happiness and rewards."

— *Very respectfully, Lou*

Member Robert G. Sharrard, Jr., N, P/C Gainesville Power Squadron, of 2803 NW 83rd Street, A-113, Gainesville, FL 32606 wrote on January 17, 1997:

"If there are any collectors of Nautical Artifacts in the FOUNDATION they might be interested in the following items which I have acquired over the past 30 years when I became interested in all things nautical after joining the UNITED STATES POWER SQUADRONS and the U.S. COAST GUARD AUXILIARY:

"STADIMETER, FISK TYPE, #12376-1943, complete with telescope, tools and storage box. See 1984 BOWDITCH, VOL. I, pg 146-147.

STADIMETER, FISK TYPE, W/O telescope, tools & box.

SEXTANT, BUBBLE TYPE AN 5851-1, With Altitude Averaging Device, serial no. AF42-12394, with heavy duty storage box. (see CELESTAIRE CATALOG pg 21).

ASTRO-COMPASS, MARK II, with wood box &

mounting base, (see CELESTAIRE CATALOG pg 39).

PELORUS, U.S. NAVY STANDARD 7 inch dial, Model III, ser. no. 2589, on gimbals in wood box.

AZIMUTH INSTRUMENT, U.S. NAVY, in hardwood box — brand new. (see BOWDITCH pg 168).

*FROM SAILS TO SATELLITES*, The Origin and Development Of Navigational Science by J.E.D. WILLIAMS, Oxford University Press, 1992.

U.S. NAVY PUBLICATIONS including several Sight Reduction vols. as H.O 102, 211, 214, 217, 220, 226, 229, 260, 261, 2665-10 (new DMA 5090) MANEUVERING BOARD pads and DMA Pub 1310 RADAR NAVIGATION MANUAL.

"Those interested may write me at the above address or call me at tel. (352)373-7751 for details and pricing of any of the above items."

— *Sincerely, Gib*

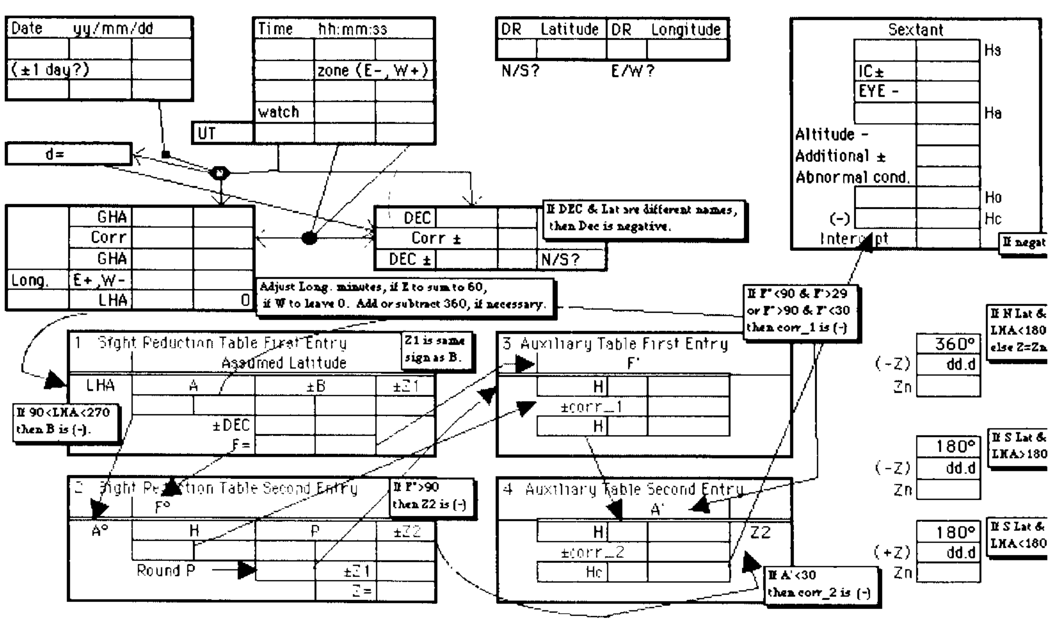
Member Steven Tripp, University of Aizu, Tsuruga Ikki-machi, Aizu-Wakamatsu Cit Fukushima 965 Japan wrote by E-mail on January 9, 1997:

"I have been working on a sight reduction worksheet (yes another) because I don't like any I've seen. I would like comments. You can see it at:

http://www.u-aizu.ac.jp/~tripp/graf/sr2.GIF. I did it in an Excel worksheet. The worksheet doesn't do any calculations; I just used it to lay out the design. It would be very easy to program a worksheet, but I wanted a paper form that would remind me of how to do sight reduction without electronics.

"If you want I can send you an electronic version which you could print out for better quality than my gif image. I did it on a Mac but I assume I could put it in a form that Windows Excel could read."

— *Steve Tripp* (Internet: tripp@u-aizu.ac.jp)




Director Allan Bayless of 116 Gardens Drive #201, Pompano Beach, FL 33069-0946 wrote on January 2, 1997:

"The *Newsletter* arrived today and I saw your *Do You Know...?*

"About 15 years ago, I prevailed on the then Asst/Dir and Ch/JN to abandon the flat earth. Enclosed is what wound up in the JN course as a result, and has been there since.

"At the moment, JN is undergoing 'simplification' and when I reviewed this section, guess what? Yep, back to the flat earth!

"I don't object to the 'pole guy-wire' analogy *provided* the correct explanation appears in the near vicinity. In the case of JN, the new diagram is a lighthouse. I re-argued the point; whether I prevailed, I have no idea.

"I also remember looking up the diagram in *Bowditch* at the time and being semi-horrified to see the diagram it contained — which didn't do my argument any good at all!

"Actually, it's still sort of astonishing to realize the sextant works based on its ability to recognize the curvature of the earth over what I think of as very short distances."

— *Cordially, Allan*

Captain Warren G. Leback, National President, Council of American Master Mariners Inc., of 475 Wall Street, Princeton, NJ 08540, Tel(609)683-4522, Fax(609)683-9633 wrote on January 8, 1997:

"I read with interest John M. Luykx's article 'Navigation Basics Review" in The Navigator's Newsletter, Issue fifty-three Fall 1996. I was particularly interested in when the three (3) observers took simultaneous observations of the Moon.

"It brought to mind my experience with simultaneous star observations. In 1944 after graduating from the United States Merchant Marine Academy, I joined Grace Lines *Santa Ana* as Third Mate. Her Master was Captain Vladimir Zernin, a nationalized citizen of Russian birth and a graduate of Imperial Russian Naval Academy at Kronstadt.

"Captain Zernin believed in simultaneous observations by two or more officers. He believed that this gave confidence to young officers standing their first watches. He required the Third Mate to have worked up star time, bearings and altitudes of at least six stars placing this information on his desk on coming off watch at 1600.

"The *Santa Ana* carried a Master, four Mates and a Cadet. The four mates took turns standing the watch at star time thus allowing three mates to join the Master and Cadet to take simultaneous observations of the same star and the moon when up. Captain Zernin carried the stop watch, calling time when he brought the star down to the horizon. Each observer took down his observed altitude with Captain Zernin reading the time.

"At conclusion of taking stars and the moon if up, we worked out our lines of position. These were placed individually on one plotting sheet for comparison. This gave confidence to the young mates in their ability to determine the ship's position by star and moon observations. This confidence was, in my opinion, an important factor in navigating during World WAR II with a sextant, chronometer, Nautical Almanac and H.O.214.

"Captain Zernin also required each mate to keep a navigation notebook entering our sun, Meridian altitude and star observations. He also required all mates to take noon transit and work out ship's noon position.

"The Navigator's Newsletter is interesting from aspect that is it not a throw back to the "dark ages" of navigation. The watch officers of today still need, in my opinion, to be proficient in celestial navigation. It would be most embarrassing not to be able to navigate the vessel home in the event of failure of the electronic navigation systems.

"I remain"

— *Sincerely, Captain Warren G. Leback*

Member David A. Blythe of 3316 East Drahner Road, P.O. Box 125, Oxford, MI 48371-0125 wrote on 4 December 1996:

"I am most happy to renew my membership in the Navigation Foundation. During my first year of membership, I have found this association to be an excellent network of persons sharing a common interest. Much credit for that is due the leadership of the Foundation.

"Enclosed is a money order for $60.00 to cover the cost of my dues for 1997 and for one (1) copy of the 1997 *Nautical Almanac* (GPO edition), to be sent to me at the above address.

"I hope that I have enclosed enough to cover the cost of all expenses. If not, please send me a bill for the balance. If there is anything in excess of costs, please consider it a donation to the *Foundation*.

"A point of interest: My letter published in the last issue of *Navigator's Newsletter* has generated several interesting responses.

"Thanks for your good work."

— *Yours truly, David A. Blythe*

Member Raphael C. Marshall of 14802 Tabor Avenue, Maple Heights, Ohio 44137 wrote on December 5, 1996:

"Congratulations on the great job you are doing. Best of luck in building up the Foundation's membership.

"I am enclosing a check ($30) plus $25 for a '97 Nautical Almanac. Would you please send to me.

"Do you have access to and can you get me a copy of REED'S ALMANAC '97 edition for the EAST COAST, N. AMERICA and the CARIBBEAN ISLANDS? What will be the price?"

— *Thank you, Raphael C. Marshall*

Member Leslie J. Finch of 261 Madison Street, Mastic Beach, NY 11951 wrote on 9 January 1997:

"Please find a check for #1.74 which is the amount due on my order of a 1997 Nautical Almanac.

"The Almanac arrived in a timely manner. Thank you very much.

"I took your suggestion and sent my A-1ØA aircraft sextant to John M. Luykx at the InfoCenter to be repaired. The work was carried out and I am very pleased. As I said to Mr. Luykx, 'All I need now is a B-29 and a star to steer her by.' It makes inland sights much easier.

"Christmas and New Years have passed. Now to wait out the winter until it moderates into spring and we can go sailing again." — *Yours truly, Leslie J. finch*

John Grissim, Editor and Publisher of *Marine Watch*, wrote on January 14, 1997:

"Please accept my apologies for the unconscionable delay in responding to your kind e-mail letter of June 11th last year. The irony is that I printed out your thoughtful letter and set it aside, intending to give it special attention, and there it languished while I have found myself continuously facing one deadline after another during this first hectic year of publication.

"I'm taking the liberty of enclosing here a copy of your message, together with this declaration of my renewed intention to write Ernest Brown in Houston to offer a reciprocal subscription exchange.

"Thanks again for your interest in *Marine Watch*. I, too, look forward to staying in regular touch with you in the future."

— *Kindest regards, John Grissim*

"P.S. Just received Matt Morehouse's new catalog. It's a pip!"

Executive Director, Captain Terry F. Carraway, U.S. Navy (Retired) sent the following E-mail to *Marine Watch* (marwatch@marinewatch.com) on June 11, 1996:

"Thank you for your very kind letter of June 4, 1996. I find the two copies of *Marine Watch* interesting and informative. We are delighted that Matt Morehouse provided you with a copy of our Newsletter and we are happy that you have suggested a subscription exchange. I will enter you in the computer and you will start receiving a newsletter in the near future.

"Matt was a little misinformed. I am not the editor, just the Foundation's administrator. I handle all of the business, subscriptions, charts, books and publication orders and coordinate the various functions of the organization. Our editor is Mr. Ernest B. Brown, 14207 Duncannon Drive, Houston, TX 77015. Mr. Brown was the editor of Bowditch for many years and to his credit the Newsletter is a publication which our members love. Your reciprocal subscription should be sent directly to Mr. Brown and any requests to reprint any of the Foundation's Newsletter material will have to be approved by him. Mr. Brown is not on the internet but the Foundation is at both 76476.1165@compuserve.com and navigate@ix.netcom.com and will forward any messages that are of interest to us both.

"I will send you an information packet that we usually send to prospective members. It includes a small brochure, a letter from me explaining why we elected to start the Foundation, a list of book and chart prices and a sample copy of The Navigator's Newsletter. I will also enclose the obituary of RADM Thomas D. Davies, USN, who was the founder and president until his death. If you are interested, the January 1990 issue of the National Geographic Magazine has an article concerning our work on the Robert E. Peary controversy. I believe you will find the article interesting and informative. Unfortunately, the Robert E. Peary report is out of print and we have not decided to reprint at this time.

"I look forward to keeping in touch and maybe in the future we can develop a reciprocal link to our web pages. The Foundation is at http://www.olyc.com."

*— Best regards, Terry F. Carraway*

Member Warren L. Hart of 3230 Eagle Point West Avenue, Belton, Texas 76513-4824 (817)939-8468 (answering machine after 4th ring) wrote on February 26, 1997:

"I am one of the volunteer instructors for our adult men's Texas Leadership Training Camp (LTC). LTC is for campcraft leaders and is held each summer in the first week of June. I teach a class called 'Map, Compass, & Stars' which meets two hours a day for five days. I teach the men the basics of using a topographic map, using a compass, and a basic 'naked eye astronomy' identification of the major constellations. If there is any time available (depending upon the skill/learning level of the class members) I also include additional information/techniques that I have picked up over my years of research and experience (Air Force navigator-instructor).

"This additional training includes a basic understanding of celestial navigation and the Global Positioning System. I have a plastic Davis sextant and a GPS hand held receiver that the students use. It is not my intention to make them experts in just one week with either instrument but to understand the basics of why they do what they do and how to apply and transfer that knowledge to their benefit whatever 'navigation' situation they may find themselves in.

"In addition to LTC I have begun working up the plans for a one week course that would include classroom instruction in the mornings followed by afternoon/evening day hikes and evening/nighttime star/constellation identification. This course would allow me to use many more of the 'tricks/techniques' I have researched so far.

"I am interested in hearing from my fellow members who will send their suggestions to me of any map, compass, etc. projects and procedures that are related to navigation. I will take those suggestions and incorporate them in the class. What I am looking for are both fun (novel, trick) and serious ways to use maps and compasses. I am also interested in suggestions for additional resources (books, magazines, etc.) that I may consult. The areas I would be interested in are: maps (preferably topographic), compasses, celestial navigation, emergency navigation, GPS, basic star and constellation identification, simple science, astronomical, and navigational projects, and whatever else might be suggested to make the course fun and practical. I guess you might say that what I am trying to do is to start the men on the road to becoming 'land navigators.'

"I am looking forward to hearing (letters or telephone calls) from my fellow members with a lot of 'tricks of the trade'."

*— In Christian Fellowship, Warren*

Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona* wrote to us from Cairns, Australia:

"Dear Friends, this fourth newsletter starts with a trip home made by Walter and myself from Pepeete. We left in early May and returned in early June, Walter having decided to crew for another year. There is a surreal quality about leaving the mundane problems of cruising in the tropics and a day later finding oneself on Long Island with all the craziness and hurly-burly. Many of my friends seemed to think I was starving to death and I have to thank them for the generous parties and meals they organized on my behalf — I gained 3 lbs during the month! Fred Pallas got busy on internet notice boards and flushed out a new crew member for the next leg. Red Harting had supervised the rebuilding of the engine in the vintage Bentley and it ran like a Swiss watch during the 1,200 mile rally when he and I took it to Vermont. Louise Hanson took care of my cultural deprivation by leading me off to museums, galleries and art films. My daughter Brenda had the domestic scene well under control and my son Colin drove up from Tennessee, so it was a wonderful break. I flew back with my own and Walter's luggage packed with spare parts.

"A few days after our return to Pepeete the new crew member showed up. Jaime is a Spaniard who had been working in S. Korea for an international business consulting firm. He has excellent English and became addicted to crossword puzzles under Walter's tutelage while aboard *Fiona*. After stocking up at the huge supermarket at Meaeva Beach we topped up the fuel and water tanks and headed out. Unfortunately, as we crossed the coral reefs I missed a marker indicating the rather tortuous channel to the pass and the keel bumped heavily on a coral head. At our next anchorage, at Moorea, I swam down with a mask to inspect the damage: a couple of layers of fiberglass at the forward end of the keel had been displaced. As the bottom had not been painted for a year I decided this was justification for a haul-out and I arranged to do this at the Carenage in Raiatea, the same yard at which I left *Fiona* when Edith became sick in 1990. On the way we stopped for the weekend at the beautiful island of Huahine. As we came into the anchorage we passed the most bedraggled boat I have seen in a long time sailing along the fringing reef. The battered hull had once been painted a vivid orange, the tattered jib trailed in the sea and she only showed about 18 inches of freeboard. Ultimately this apparition anchored a hundred yards from us and later we rowed over to speak to the sole crew member — a cheerful young man called Steve. We took him back to *Fiona* and over a glass or two of rum he told us his story. The boat was a Bristol Bay cutter, a traditional inshore fishing boat from Alaska. Steve had sailed her to Mexico and then made a singlehanded passage of 66 days to the Marquesas Islands. He was engineless, as the outboard which hung on a stern bracket had given up the ghost long ago. I sincerely advised him not to go to New Zealand where they now have a rigorous safety inspection of yachts before they are allowed to depart.

"Four days after the haul-out in Riaitea we were back in the water — keel repaired, bottom painted, a new log fitted and numerous repairs taken care of. We than sailed to the scenic island of Bora Bora. We had hoped to touch the most westerly of the Society Islands, a small island called Maupiti, rarely visited, but when we got there we found out why — the single passage through the reef was open to the prevailing trade winds. We sailed as close as we dared but the foaming maelstrom across the entrance looked too dangerous and at the last moment we turned away and headed instead for Penrhyn Island in the northern Cook group, almost 600 miles away. When we arrived we were boarded by a couple of locals in an aluminum runabout. The older man introduced himself as Henry — the customs inspector. The younger fellow was his assistant and also his cousin. After a hint about being thirsty they gratefully downed a couple of stiff rums. It turns out Penrhyn has been a dry island for the last two years. Henry asked if we had any tools on board. Now this surprised me as customs officers usually ask about liquor, tobacco, drugs, guns, etc. When I cautiously said 'yes' he asked me to repair his boat, which desperately needed a few pop rivets! Walter and I did indeed fix up his boat on the shore the next day. I was fascinated to learn there was the wreck of a WWII American bomber on the island and I went looking. Part of the fuselage had been cut up and formed a small hut in the village. Three of the four engines were scattered in a grove of palm trees. It looked like the plane was a Liberator. An old man told me the story of how it got there during the war. An emergency strip had been built on Penrhyn. One night this plane appeared (God knows where it came from — Penrhyn is a long way from anywhere else) but the generator for the runway light was kaput. So they built two fires of coconut husks at each end of the runway. Unfortunately, the fire at the downwind went out and the pilot mistook the fire at the other end for the touchdown point. At the last minute he saw the reef at the upwind end in the glare of the landing light and he managed to pull up, but the undercarriage was damaged. They relit the fires and he crash-landed without loss of life on the strip, and the bits have remained on Penrhyn for more than fifty years. We had a narrow escape ourselves when we came to leave - a brisk wind had sprung up and the waves were breaking on the rocky shore just 100 yards off the stern. Walter was bringing up the anchor with the electric winch and I was easing *Fiona* ahead to lessen the strain on the winch when suddenly the wheel became completely frozen — I couldn't turn the rudder left or right! It seemed like the anchor was about ready to break out, not a good situation with the lee shore so close and no steering. I asked Walter to let go of the chain again and we investigated the problem — the stop on the rudder quadrant had come loose and wedged in the mechanism — easily fixed. When we raised the anchor for the second time we found it was jammed in some coral and it took an effort to free it. Probably it is a good thing the anchor was jammed as that stopped the head from paying off when we first tried to raise it. We left without further incident and headed for American Samoa, 850 miles downwind.

"This proved to be a sleigh ride and we arrived after five and a half days of lovely sailing on the 4th of July. We anchored opposite the Star Kist tuna cannery and waited for customs clearance the next day before going ashore. The main attraction of American Samoa is the ability to stock up with stateside food at a reasonable price. The harbor of Pago Pago is not very pleasant due to the general pollution, the smell downwind of the cannery and the noise from the generating plant. The locals seemed to be raised on a kind of fundamental Christianity. Late one night Walter found himself in a discussion of religious values with a group of young fellows near the dock and when they didn't like his apparently insensitive answer they started to stone him. He had to make a prudent withdrawal but still got a lump on his head before he made it to the dinghy.

"Apia in Western Samoa was our next stop. This is a charming and beautiful island which still retains vestiges of its German colonial past prior to WWI. Every morning about seven-thirty the police brass band marches along the waterfront. The uniform consists of pith helmets and lava-lavas, the cheerful tootling and oom-pohs as we ate breakfast are an unforgettable memory of Apia. We made the mandatory pilgrimage to Robert Louis Stevenson's house — Vailima. A lovely place on a hill about two miles out of town. His mother, who appears to have been somewhat of a harridan, didn't like it because the natives were too noisy! Rugby is taken very seriously in this part of the world and just before we left I was able to watch the match between W. Samoa and Tonga. They play very hard - the first-aid people are kept busy and as a heritage of their Polynesian ancestry the teams engage in a 'haka' at the start of the game. In the old days this was a display of strength and brandishment of weapons. Now the teams face each other with aggressive stances and bulging eyes while giving vent to war chants.

"From W. Samoa we had a fairly short sail to Niuatoputapu at the northern end of the Tonga Islands. When we anchored in the lagoon I dinghied over to a small dock but there was nobody around. A board nailed to a coconut tree had a crudely painted arrow pointing west with the terse message 'customs, 3 km'. So I walked along a sandy path shaded by palm trees until I came to the village. Here I found everybody gathered on the grass between the post office and the police station. A temporary awning had been set up and under it were gathered some local dignitaries and the Prime Minister of Tonga. As it happened we had arrived on the very day of the first ever visit to Tonga by the Prime Minister! Everyone was dressed in their Sunday best. As I sauntered up in my scruffy shorts and t-shirt the Prime Minister was handing out long service medals to local officials. Despite my appearance I was invited to the official luncheon which was already laid out on the grass, covered with lace to keep the flies off. We ate local delicacies such as crawfish, suckling pig and yams, seated cross-legged on the ground. I discovered the real reason for the flying trip of the Prime Minister was local dissatisfaction over the sparse visits by the supply boat from the capital to the south. It was six weeks since the last visit and supplies of staples such as flour, petro and toilet paper were scarce. The difficulty of supplying these small islands lying hundreds of miles from the commercial center reminded me of similar problems facing the 'outports' of Newfoundland, most of which were eventually abandoned. While I was clearing in at the desk of the customs officer (which was in the post office) I found out it was Tuesday even though I knew it was Monday. We had crossed the international date line after leaving Niuatoputapu. There is a jog in the date line even though Tonga lies west of 180°. This is so the Tongans can claim 'time begins in the Tonga Islands'.

"There was one other yacht anchored in the lagoon crewed by a Canadian couple who had been cruising the South Pacific for six years. They told us about a beautiful grotto near the village fed by a fresh water spring, so the next day we all took our soap and towels and had a fresh water bath!

"From Niuatoputapu to Fiji was a five day sail. Fiji, like many former British colonies has a population comprising the original inhabitants (Melanesians) and descendants of east Indian indentured laborers. I found the capital city, Suva, to be a wonderful place, thriving, exotic, inexpensive and friendly. The cultural diversity is amazing. Walter and I attended the first night presentation of HMS Pinafore in which Ralph (the poor sailor) was played by a strapping Melanesian and the captain's daughter by a petite Japanese lady who was a little long in the tooth for that role. The usual expat Brits fleshed out the cast and it was all good fun. While Jaime went on a scuba weekend on Kandavo Island Walter and I flew to the old capital, Levuka, established by whalers before Suva was founded. The museum there depicted in gory detail the continuous and ferocious wars between Fijian tribes which eventually died down as Europeans came to dominate the area. The victors invariably abused, tortured and ate the vanquished. I don't mean to imply the Europeans were particularly altruistic; they just wanted the Fijians to work for them and stop killing each other. But the Fijians didn't like work, hence the east Indians! It does make one ponder the human condition- why did a people unsullied by contact with other races descend to such depths when they were living in a tropical paradise?

"After a week tied up at the Royal Suva Yacht Club it was time to go. I had invited my daughter Brenda to meet us in New Zealand and if we were to get there first we had to leave. Our plans met with raised eyebrows from other yachties on the dock - 'go to New Zealand in winter? Cross the Tasman Sea in winter? You must be crazy,' they said.

"In some ways they were right, although the weather heading south was not so bad. But we did suffer a major equipment failure. About 250 miles from Fiji and 750 north of New Zealand we were running with the jib winged out with a wind of about 30 kts. In the middle of the afternoon the wind began to drop. I was on watch at the time and as the wind dropped we suffered a couple of unintentional gybes. I didn't think them too serious as the main boom was vanged down hard, we had a preventer rigged and two reefs in the mainsail. After the last gybe I reset the steering and engaged the wind vane (Victor the vane, as we call our mechanical helmsman) and I had just vacated the cockpit to watch the vane in operation. Good job I did: as I stood on the stern I felt a sudden wind shift and the mainsail again gybed, but with great violence. The boom snapped like a carrot at the vang and the whole mess fell into the cockpit as the boom was now foreshortened and no longer fully supported by the sail or topping lift. Anyway the wind continued to fall, we rigged the loose-footed storm mainsail and pressed on. The next day we cut the sail off the boom and tidied up — we still got to Opua in Northern New Zealand in a little over a week from leaving Fiji, so the Tasman Sea wasn't too bad — it got its revenge on the way to Australia, as you will learn later.

"We stayed a week in Opua, a charming spot in the Bay of Islands, there we got a second-hand boom and had the sails repaired. Opua is connected to a small town to the south called KawaKawa by a steam locomotive operated by a gang of enthusiasts. On the Sunday of our stay we took a jazz excursion on the train accompanied by a Dixie band to a festival in KawaKawa.

"Jaime left the boat in Opua to go skiing in the south Island, winter still had six weeks to go. When the new boom and sails were ready Walter and I sailed to Auckland and checked into a huge marina in the downtown area. We beat Brenda to Auckland by two days. Auckland is a modern, attractive city. Brenda enjoyed the shopping and we did the round of museums, art galleries and the casino. *Fiona* was tied up only a few yards from the Royal New Zealand Yacht Squadron, where we became guest members for a couple of weeks. The America Cup, which will be defended at Auckland in the year 2000, is prominently displayed. When I took Brenda to see it a hush fell on the room when she said she wanted to see it before it went back to New York!

"We rented a car and for a few days Brenda and I explored the North Island. New Zealand is a charming country with friendly people. In many ways it is more English than present-day England and it strongly reminded me of my youth there. We had recruited a wandering South African fellow called Mike as crew for the leg to Australia. When Brenda returned home Mike moved on board and we worked our way back up the coast waiting for a good weather window for the departure. While we waited we cruised the lovely Bay of Islands. Mike is a keen paraglider and one sunny day at the Island of Urapukapuka he humped his gear up a nice grassy hill and gave us a couple of demonstration flights. Also on this island there were a number of walking trails to diggings at former Maori villages occupied before the arrival of whites. A plaque at the sites showed what the villages must have looked like. I was struck by the extensive defenses — deep ditches still very much in evidence with palisades (now gone) behind them.

"We cruised around and waited for the opportune moment to depart for more than a week. We checked in with marine radio stations and printed numerous weather charts on the fax. The Tasman Sea is notorious for the sudden changes in weather — dominated by high pressure cells moving across the Australian continent and low pressure areas lying to the south. The lows usually lie on fronts stretching north. The best time to leave is after a front has passed and a slow moving high to the north give SW winds for a few days. We waited and waited but the SW winds never came. Finally the forecasts called for the perpetual NW winds to give way to westerly winds so we left. It was a mistake.

"Naturally we had NW winds, as the Queensland Coast lies NW of New Zealand. This gave us a beat. Fred had given me a book during my visit home called *Gentlemen Never Sail to Weather*, the story of a four-year circumnavigation (it is a good read, the author is Denton Moore). I must say after a few days beating in the Tasman Sea, I thoroughly concurred! But we were stuck with it and maybe I'm not a gentleman. The wind was usually in the 25 kt range, so we had reefed sails. One morning a squall fell on us that packed sixty knots. The next day a panel blew out of the jib and it took us seven hours with the sewing machine to put it back together. After six days we staggered into a bay on Norfolk Island, about 500 miles from New Zealand. Fortunately the wind was down and we had a good night's sleep. We called the Australian customs people and they arranged to meet us on a jetty a few miles away. Unfortunately there was a large swell running. Two of us managed to get ashore but the dinghy was slightly damaged so we went back to *Fiona* to gaze at the island from the relative safety of the cockpit. I can report that Norfolk Island is covered with Norfolk pine trees, but that's about all I saw. A couple of charter fishing boats came close, curious to see a boat from New York, and one of them tossed three fresh fish aboard. North of Norfolk we were on the Coral Sea, although the weather didn't get significantly better for another week. For the last two days before arriving at Cairns we had no wind at all and we motored through the Great Barrier Reef under a full moon. With a GPS receiver and radar it is safe to make approaches at night, which I would never have considered prior to getting these instruments. In fact before 1990 *Fiona* often spent a night hove-to or ranging back and forth until an approach to land could be made in daylight.

"Cairns is a lovely up market touristy place (it is about 17 south) and will be the starting point for our exploration of the Queensland Coast and the Great Barrier Reef. Mike has left us to glide off somewhere else and we are expecting Ginny Rynning to join the crew in about a week. Until the next time"

— *Best wishes*, Eric

*Editor's note: See issues 51, 52, and 53 for letters from Georgetown, Guyana, Colon, Panama, Papeete, Tahiti, and Penryhn Atoll, Cook Islands.*

# NAVIGATION NOTES

## Accuracy of Navigation Timepieces

*By John M. Luykx*

The writer has recently incorporated two new additions to his collection of navigation timepieces. One is a 22 jewel 40-hour sweep second-hand 12-hour dial navigation deck watch manufactured by the Poljot watch factory in Moscow. It is 53 mm in diameter and has a highly polished chrome case. It is fitted in a padded three tier mahogany wood case with dimensions of 5"x4"x3". This watch is of interest primarily because it is designated a navigation deck watch by the manufacturers and is made by the well-known Poljot firm which builds chronometers for the Russian Navy. The other timepiece is by the Waltham Watch Co. It is a quartz chronometer which is now supplied to the U.S. Navy as a replacement for the famous Hamilton Model 21 spring-wound mechanical chronometer. It has a twelve hour dial with a sweep second hand and is powered for one year by a 1.5 volt C battery. It is housed in a simple metal cabinet 7"x7"x7".

In order to determine the accuracy as well as the predictability of these two timepieces, they were tested in the same manner as the tests described in Issue 34, winter 1991 (mechanical watches) and Issue 35, Spring 1992 (quartz watches). The timepieces were run for six weeks from 23 September to 4 November 1996. The rate for each timepiece was established during the first two weeks of the test. The predicted error for each timepiece for each of the following four weeks was then computed (based on the rate established during the first two weeks) and compared with the actual error to determine the accuracy with which the timepiece could predict time. During the test two Hamilton Model 22 gimballed, 12 hour dial 35 size two day (56 hour) navigational deck watches were also tested for comparison with the Russian deck watch.

During the test, watches were wound each day at 0930. On Monday of each week during the test the actual error was noted and recorded. The ambient temperature was maintained between 72° and 75° F during the entire period of the test.

## SUMMARY

The results show that the accuracy of the Russian Poljot deck watch is comparable to that of the Hamilton

TEST RESULTS

The results of the test are as follows:
(Time data is tabulated in seconds of time.)

A. HAMILTON DECK WATCH #1

1. Weekly Rate

| | | |
|---|---|---|
| Error 9/23: | +36.0 | |
| Error 9/30: | +41.5 | +5.5 |
| Error 10/07: | +44.0 | +2.5 |
| | | 2/+8.0 |
| Weekly Rate: | | +4.0 |

2. Error:

| Date | Actual Error | Pred. Error | Diff. | Var. |
|---|---|---|---|---|
| 10/14 | +48.0 | +48.0 | | |
| 10/21 | +49.5 | +52.0 | +2.5 | +2.5 |
| 10/28 | +54.0 | +56.0 | +2.0 | -0.5 |
| 11/04 | +56.0 | +60.0 | +4.0 | +2.0 |

Error of prediction over a four week period: +4.0

B. HAMILTON DECK WATCH #2

1. Weekly Rate:

| | | |
|---|---|---|
| Error 9/23: | -15.8 | |
| Error 9/30: | -14.0 | +1.8 |
| Error 10/7: | -12.8 | +1.2 |
| | | 2/+3.0 |
| Weekly Rate: | | +1.5 |

2. Error:

| Date | Actual Error | Pred. Error | Diff. | Var. |
|---|---|---|---|---|
| 10/14 | -11.5 | -11.3 | +0.2 | |
| 10/21 | - 8.5 | - 9.8 | -1.3 | -1.1 |
| 10/28 | - 4.5 | - 8.3 | -3.8 | -2.5 |
| 11/04 | + 0.5 | - 6.8 | -6.3 | -2.5 |

Error of prediction over a four week period: -6.3

C. RUSSIAN POLJOT DECK WATCH

1. Weekly Rate:

| | | |
|---|---|---|
| Error 9/23: | +15.8 | |
| Error 9/30: | +21.8 | +6.0 |
| Error 10/07: | +26.3 | +4.5 |
| | | 2/+10.5 |
| Weekly Rate: | | +5.3 |

2. Error:

| Date | Actual Error | Pred. Error | Diff. | Var. |
|---|---|---|---|---|
| 10/14 | +30.8 | +31.6 | +0.8 | |
| 10/21 | +35.2 | +36.9 | +1.7 | +0.9 |
| 10/28 | +38.0 | +42.2 | +4.2 | +2.5 |
| 11/04 | +41.8 | +47.5 | +5.7 | +2.5 |

Error of prediction over a four week period: +5.7

D. WALTHAM QUARTZ CHRONOMETER

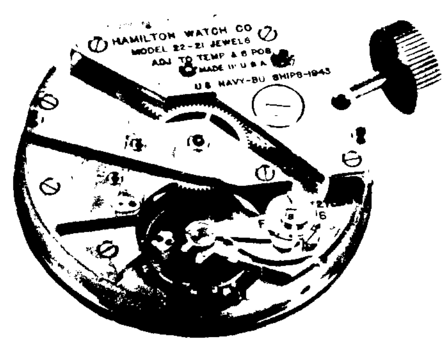
1. Weekly Rate:

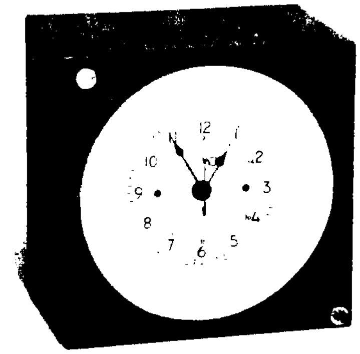
| | | |
|---|---|---|
| Error 9/23: | -3.6 | |
| Error 9/30: | -4.0 | -0.4 |
| Error 10/07: | -4.5 | -0.5 |
| | | 2/-0.9 |
| Weekly Rate: | | -0.5 |

2. Error:

| Date | Actual Error | Pred. Error | Diff. | Var. |
|---|---|---|---|---|
| 10/14 | -4.80 | -4.95 | -0.15 | |
| 10/21 | -5.30 | -5.40 | -0.10 | +0.05 |
| 10/28 | -5.60 | -5.85 | -0.25 | -0.15 |
| 11/04 | -6.00 | -6.30 | -0.30 | -0.05 |

Error of prediction over a four week period: -0.3





*From the left: Poljot Deck Watch, Hamilton Mod. 22 Deck Watch, and the Waltham Quartz Chronometer.*

Model 22 gimballed deck watch which is considered to be one of the finest of its type.

With regard to the Waltham quartz chronometer, the error of prediction after four weeks of testing was found to be -0.3 seconds. This result compares favorably with the error of 0.5 seconds during tests of quartz watches conducted in 1991 and reported in Issue 35 of this Newsletter.

The performance of the Waltham quartz chronometer is equivalent to an annual error of prediction of less than four seconds.

NOTES

1. A 40-hour watch runs for 40 hours; a two-day (56 hour) chronometer or deck watch runs for 56 hours, which is a little over 2 days.

2. A sweep second hand originates or has its axis at the center of the watch face and its length equals the radius of the dial. A second hand which is not a sweep second hand is located toward the 12 o'clock or 6 o'clock position on the watch dial. Its axis is the axis of the 4th wheel rather than the center wheel as in the case of the sweep second hand.

3. A chronometer watch or deck watch is a watch used in navigation to take the time from a chronometer (which cannot be removed from its storage case) and permits chronometer time or Greenwich Mean Time to be carried about the bridge for timing celestial observations.

4. For those who wish to know more about watches and how they operate and are designed, it is recommended that they peruse:

*Military Timepieces,* Marvin E. Whitney, AWI Press, 1992

*The Ship's Chronometer,* Marvin E. Whitney, AWI Press, 1985

These are two tremendous references regarding military timekeeping.

5. Deck watch sizes: A historical development too complicated to get into here. Suffice to say:

A standard R.R. pocket watch is 16 size or 1.700 inches in diameter, while a 35 size deck watch is about 2.330 inches in diameter. The Swiss employ the term *ligne,* where a 16 size watch is equal to 19 1/8 ligne (43.18 mm) and a 35 size watch is reckoned at 25 lignes (58.42 mm).

# NAVIGATION PERSONALITIES

## Roald Amundsen

*By Ernest Brown*

(Continued from Issue 54, Winter 1996-97

*First Crossing of the Polar Sea* by Roald Amundsen and Lincoln Ellsworth includes additional chapters by others aboard the *Norge,* including one by the second in command and navigator, First-Lieutenant Hj. Riiser-Larsen, Royal Norwegian Navy. In his chapter, The Navigation over the Polar Sea, Riiser-Larsen begins by addressing two widely held misconceptions: (1) near the North Pole the magnetic compass does not have enough directivity to be useful, and (2) the needle of the magnetic compass points at the north magnetic pole.

In the course of addressing the first misconception above, Riiser-Larsen brings attention to the fact that the north magnetic pole is at such a distance form the North Pole that even though the horizontal directive force is significantly reduced near the Pole, the remaining directive force is still strong. However, there is a problem with respect to the corrector magnets. In the words of Riiser-Larsen:

"I mentioned that it was also an understood thing that we knew the deviation, and I will briefly explain what is meant by this expression.

"On board a vessel magnetism will as a rule occur, which exercises its influence upon the compasses so much that they do not show the magnetic north, but are attracted a little away to the one or the other side of this point. This disturbing magnetism may be either permanent magnetism in an object in the vicinity of the compass, or it may be a magnetism that is induced by earth-magnetism in the iron and steel parts of the vessel. It is an easy matter to find the amount of deviation for the various compass-directions, but it is troublesome that this disturbing influence of magnetism varies as one changes the parallel of latitude during the navigating. Thus in Italy, where we corrected the compasses, a fairly small permanent magnet will be of less importance when the horizontal component of the earth's magnetism, that which affects the needle of the compass, is very strong. On high latitudes, where our difficult task lay, this component, however, is naturally very small, which causes a fixed magnet to get a proportionately greater influence. As will appear from what follows we also came to notice this trouble. The same varying influence occurs also with induced magnetism. Consequently, in horizontal beams in Italy there will thus be induced a strong magnetism. which will be correspondingly weaker up in the Polar Sea. In the opposite way the magnetism that is induced in upright constructions by the vertical component of the earth's magnetism will be weak in Italy and strong in the Polar Sea.

"By calculation of the so-called co-efficients one can form an idea of how strong influence the various kinds of magnetism exercise, and take these conditions into consideration, but true enough, not to a discriminate degree."

Riiser-Larsen addressed the second misconception as follows:

"There is, however, a peculiarity in magnetic variation that might cause us difficulties in the Polar Sea, where there have not previously been direct magnetic-variations observations taken. The condition is really this: that the compass, apart from a few places, does not point direct to the magnetic pole. It is easy enough to draw up the curves at the places on the earth's surface where one has had occasion to take observations, but up there in the polar basin, we had to sketch in their direction, based exclusively on our judgment. As far as we were concerned there would here come in an uncertainty unless we should get opportunity ourselves to take variation-observations each time, that is, to control the compasses by the position of the sun at the given moment, and, indeed, for that clear weather was required."

If magnetic variation were simply the angle between true north and the direction to the north magnetic pole, there would be no uncertainty as to the variation at a geographic position. The task would be simply mathematical, not geophysical.

Riiser-Larsen goes on to describe the navigational equipment aboard the *Norge*. On departure from Italy there were as many as five magnetic compasses on board. Of these three were discarded one by one as unusable. In Pulham, England, an English aperiodic compass was installed on board as a steering compass. On the polar flight the *Norge* had as standard compasses an English aperiodic compass and a German Ludolph compass, the same arrangement on *N25* during the 1925 flight.

Riiser-Larsen could not say whether one compass type was better than the other. He could say that the two types complement each other for use in polar ares. As a rule, difficulties with each type do not occur at the same time. The difficulty with the aperiodic compass is that it can take a long time to come back to the course. The difficulty with the Ludolph compass is that even though it comes back rapidly, unlike the aperiodic compass, it oscillates a long time on both sides of the course before coming to rest. In the words of Riiser-Larsen:

"Both are equally troublesome when one has little time. The aperiodic compass turned back so slowly that I, in the belief that it had stuck, could have planted my fist on the glass and angrily entreated the compass-card to kindly set itself in motion. Another time I could have clenched my fist at the wildly oscillating Ludolph compass and just as angrily begged it to stop its polkas. In general they behaved well, and should I go the third time I would have the same arrangement. As mentioned above, the two did not indeed have their aberrations at the same time and so we always had one to go by. All airship compasses ought to be provided with jimble suspension with option to lock the rings."

(To be continued)

# HISTORY OF NAVIGATION

## Determining Longitude by Lunar Distance Observation

*By John M. Luykx*

This article is the second in a series of three articles devoted to longitude determination by lunar distance. The first article appeared in Issue #54 of the Newsletter.

### PROCEDURE

Because the plane of the mean value of the moon's orbit around the earth approximates or is nearly parallel to the plane of the earth's orbit around the sun, the moon follows an apparent path through the skies which is approximately defined by the ecliptic and completes its path through the band of the Zodiac in one lunar month, i.e., equivalent to approximately 29 solar days. Keeping this data in mind it can be seen that accurate lunar distance observations for longitude should then only be taken using celestial bodies which have small declinations and which generally lie along the ecliptic and which vary no more than 15° to 25° north or south of it.

Included among these favorably positioned celestial bodies are the sun and the four navigation planets, Mars, Jupiter, Venus and Saturn as well as the following well-known first magnitude stars: Aldebaran, Altair, Arcturus, Procyon, Regulus, Rigel, Sirius and Spica. There are also approximately a dozen additional second magnitude stars which also lie along the ecliptic and which may also be used for observations.

Although small lunar distances are much easier to measure at sea than larger ones (the same is true when measuring altitudes with a sextant), there are disadvantages. If small lunar distances are measured (i.e. 25° or less) and there exists significant difference in the declination of the moon and that of the other body, then it is quite possible that the rate of change of lunar distance will vary appreciably during a short period of time, even one as small as less than one hour. These factors, significant declination difference and small lunar distance, will most probably introduce measurable error in the longitude computations.

To avoid these errors, it is recommended that small lunar distance measurements (from 30° to 40° for example) be attempted only when the two bodies have approximately the same declination. When the declinations of the two bodies differ by over 20° or 30° then a body should be selected which is over 50° to 60° distant from the moon, but less than 90° if possible. To measure lunar distance angles of greater than 90° from the deck of a yawing, rolling and pitching ship is an exercise in great patience which often leads to fatigue and eventually to inaccuracy.

Because the moon's motion across the background of the fixed stars is very rapid, accurate observations are essential. For example, when the moon is at perigee, its motion relative to the stars is 36' per hour and at apogee, 30' per hour for an average of 33' per hour. An error of 1.0 arc minute in measuring the lunar distance will result in a 27 arc minute longitude error. See NOTE.

## THE OBSERVATIONS

In the 18th century, lunar distance observations were taken by a party of four persons all of whom were familiar with the operation of a sextant and a watch set to apparent time. The officer in charge would measure the lunar distance itself while one assistant measured the moon's altitude and the second assistant the altitude of the other body. The third assistant recorded the apparent time (by watch) of each of the observations. Prior to the three series of observations the sextants were checked for proper operation and index correction (I.C.) At least 3 to 5 observations were taken of each body, each on the "standby", "standby", "now" of the chief observer who measured the lunar distance himself.

In the unusual circumstance when only one observer was available to take all the observations, these had to be made in a specific sequence which consisted usually of seven series of observations, as follows:

| | |
|---|---|
| First: | Several horizon or star observations (about 5) would be taken to determine the I.C. of the sextant. |
| Second: | Several (3 to 5) altitude observations of the moon. |
| Third: | Several (3 to 5) altitude observations of the body. |
| Fourth: | Several (3 to 5) altitude observations of the moon. |
| Fifth: | Several (at least 10) lunar distances. |
| Sixth: | Several (3 to 5) altitude observations of the body. |
| Seventh: | Several (3 to 5) altitude observations of the moon. |

The sequential procedure described above provided for the orderly and accurate computation of the altitudes of the moon and the other celestial body by a single observer for the exact mean value of apparent time and the mean distance of the series of lunar distance observations. This was accomplished in the following manner:

1. The mean value of apparent time and altitude for the second, fourth and seventh series of moon altitude observations were plotted on graph paper and a curve "faired" through the three points. (See note below.)
2. The mean value of apparent time and altitude for the third and sixth series of other body altitude observations were also plotted on graph paper and a line drawn through the two points.
3. The mean value of apparent time and mean lunar distance for the fifth series of observations (the lunar distance observations) were computed. The mean time of the lunar distance observations was then entered on the two graphs (a. and b. above) to determine the exact measured altitude Hs of the moon and the other body for the mean time of the lunar distance observations.

NOTE: If one of the bodies is located near the observer's meridian, the rate of change of altitude between the series of observations will vary so that more than 2 sets of observations are necessary. A third set is often required to establish a curve rather than a straight line. For this reason three sets of observations are required for the moon in the sequence list shown above.

## TIME

During the early days of the lunar distance method (last decades of the 18th century) time was normally taken aboard ship using a pocket watch set to apparent time. This watch was usually capable of keeping its rate to within 1 minute per day. A more accurate means of determining the time was by computation from data obtainable at the time of observation. For example, given latitude, declination and altitude (to find the local hour angle), the following formula was often used to determine the time of the lunar distance observations:

$$\cos^2 1/2\, A = \frac{\sin s \sin (s-a)}{\sin b \sin c}$$

where:

s = 1/2 (a+b+c)
A = hour angle
a = co-latitude
b = co-altitude
c = co-declination

The angle A converted to time and applied to either noon or midnight (apparent time) is equal to the local apparent time (L.A.T.).

The standard time sight formula may also be used to find the meridian angle (t) at the time of the lunar distance observation and thus the apparent time of the altitude observation of either the moon or the other body:

$$\cos t = \frac{\sin Ho - \sin L \times \sin d}{\cos L \cos d}$$

In this case the computed meridian angle t when converted to time and applied to noon or midnight is equal to the local apparent time of the lunar distance observation. By applying a time correction from the recorded watch times, the time of observation for altitude of both the moon and the other body can be easily computed.

The time of observation by computation was most probably more accurate and reliable than that obtained using a pocket watch of uncertain accuracy. The use of apparent time rather than mean time in early time reckoning was basically a result of the format of the first nautical almanac of 1767 published by the observatory at Greenwich. The time reference for the early nautical almanacs was Apparent Time rather than Mean Time.

NOTE: In fact, the Nautical Almanacs published in England remained essentially the same until 1834 at which time substantial changes were made, the most fundamental of which was that the time reference for the ephemeris was changed from apparent time to mean time.

According to the original explanation for the use of apparent time as given in the first almanac:

"...Apparent time is that deduced immediately from the Sun whether from the Observation of his passing the Meridian from the Altitude observed at a Distance from the Meridian or from his observed Rising or Setting. This time is different from that shewn by Clocks and Watches well regulated at Land which is called equated or Mean time."

## CLEARING THE DISTANCE

Once the observations were made and recorded, the following calculations would then have been completed:

1. The measured lunar distance was corrected for the semi-diameter (SD) of both bodies as well as sextant I.C. to obtain apparent lunar distance d.
2. the Hs of the moon was corrected for I.C. and Dip to obtain the moon's apparent altitude $Ha_m$.
3. The Hs of the other body was corrected for I.C. and Dip to obtain apparent altitude $Ha_o$.
4. The moon's parallax in altitude was computed: $PA = HP \cos Ha_m$. (Note: HP was obtained from the daily pages of the Nautical Almanac)
5. The moon's semi-diameter was then obtained from the daily pages of the Nautical Almanac or computed: SD = O.2724 HP.
6. The moon's altitude correction for oblateness of the earth was computed: $OB - O°.0017 \cos Ha_m$. (This correction was not included in the early Nautical Almanacs.)
7. The moon's altitude correction for augmentation (A) was included with the PA correction for the moon. It may, however, be found from the formula: $A = 0.3 \sin Ha_m$.
8. Ho of the body is computed by applying the correction for semi-diameter (SD) and Refraction (R):
   $Ho_o = Ha_o \pm SD - R$.
9. Ho of moon is computed by applying the corrections for semi-diameter (SD), Refraction (R), Parallax in Altitude (PA) and oblateness (OB).
   $Ho_m = Ha_m \pm SD + PA - R - OB$

Using data in 1. through 9. above, the following formula may be employed to "clear" the lunar distance, i.e. to compute the true lunar distance (D):

$$\cos D = \frac{(\cos d - \sin Ha_o \sin Ha_m) \cos Ho_o \cos Ho_m}{\cos Ha_o \cos Ha_m} + \sin Ho_o \sin Ho_m$$

where D = True (cleared) lunar distance
d = observed lunar distance (1. above)
$Ha_o$ = apparent altitude of other body
$Ha_m$ = apparent altitude of the moon
$Ho_o$ = observed altitude of the other body
$Ho_m$ = observed altitude of the moon

The formula is the result of the work of the famous astronomer, Jean Baptiste Joseph DeLambre (1749-1822) who served on the French Board of Longitude and succeeded Lalande in 1807 as Professor of Astronomy at the College de France. This method is similar to that of Jean Borda. Any one of a number of mathematical solutions could have been presented to demonstrate the solution in detail. The one by LeLambre is suggested because of its relative simplicity and because it is based on the work of Jean Borda, a French mathematician and astronomer who was considered for many decades around the turn of the 18th century to have published the best method. A detailed discussion of DeLambre's formula is found in C. H. Cotter, *A History of Nautical Astronomy*, pp. 208-214.

## COMPUTING THE LONGITUDE

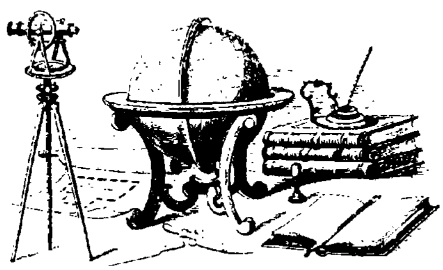
Once the lunar distance was cleared, the longitude could be computed. This was the final part of the problem.

After a lunar distance has been cleared, the observer must then compare the cleared distance with the predicted value of lunar distance in the Nautical Almanac. This is done by noting the times of two predicted lunar distances to the body in question as tabulated in the Nautical Almanac: the one distance greater than and the other less than the cleared distance. The apparent time of the lunar observation by lunar distance is then interpolated between the two times of prediction to obtain the apparent time of observation. From 1770 to 1834 the Nautical Almanac tabulated predicted lunar distance with reference to apparent time. The observer's longitude, therefore, was determined by comparing the local apparent time (L.A.T.) of the lunar distance observation with the predicted value of Greenwich apparent time (G.A.T.) obtained by interpolation in the Nautical Almanac.

In the early days one method of interpolating in the Nautical Almanac for the predicted Greenwich apparent time in the Nautical Almanac for a lunar distance observation was to record, for the nearest hour before and after the observation, the "longitude" and declination of the moon and the other body. Since longitude for our purposes is the same as Greenwich hour angle (GHA), the triangle formed by the Pole, the geographic position (GP) of the moon and the GP of the other body will yield a solution for the angular distance between the moon and the other body. The predicted Greenwich apparent time (G.A.T.) of the lunar distance observation is then found by interpolation from the values of the angular distances between the moon and the other body computed for the nearest tabulated hour in the Nautical Almanac preceding and the nearest tabulated hour following the apparent time of the lunar distance observation.

NOTE: If the stars appear to move across the heavans at the rate of 15º 02.'5 (902.5 arc minutes) per solar hour and the moon's motion relative to the stars is 33 arc minutes per hour, then an error in measuring the lunar distance of as little as 1.0 arc minute will result in loggitude error of 27.35 arc minutes (902'.5 ÷ 33'). The error will vary slightly when lunar distances are measured to a planet or the sun.

In the last of this series of articles on the lunar distance (which will appear in the next issue) an example of the required calculations for the longitude by lunar distance problem will be presented. These will summarize and clarify the thoughts, ideas and procedures discussed in the two previous articles.

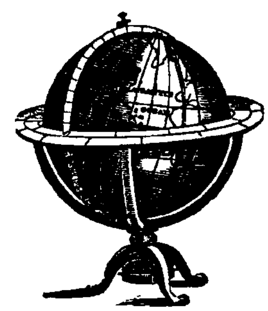


# MARINE INFORMATION NOTES

*Edited by Ernest Brown*

## Tide and Tidal Current Tables

Tide Tables and Tidal Current Tables may be ordered from NIMA by DOD and USCG users. For a brochure, "How to Obtain Tidal Predictions and Data from the National Ocean Service",, civil users should contact NOAA/ National Ocean Service, Products and Services Branch, SSMC4, Rm. 6530, 1305 East-West Hwy., Silver Spring, MD 20910, Tel: (301)713-2815, Fax: (301)713-4436/4500; E-mail: (ipss@ceob.nos.noaa.gov); Internet: (http://www.ceob.nos.noaa.gov). NOAA/NOS can provide civil users with a listing of commercial companies that sell NOS Tables. NOAA/ NOS no longer publishes and sells Tables directly. However, Tables on CD-ROM or IBM compatible 3.5 inch disks are available for sale from NOAA/NOS. Updates to the Tables and related information are also available on the Internet at the address shown above.



# BOOK REVIEW

*By Peter Ifland*

## Elements of Navigation in the Collection of the Mariners' Museum

*By Willem F.J. Mörzer Bruyns*

The Mariners' Museum, 100 Museum Drive, Newport News, VA 23606-3759.
Available from the Museum Shop (757)591-7792 or (800)259-3916.
$12.95

The Mariners' Museum in Newport News holds a world class collection of over 600 navigating instruments and an extensive library of navigating manuals and sea atlases. Willem Mörzer Bruyns, Senior Curator (Navigation) at the Scheepvaartmuseum in Amsterdam, has opened the doors for us on this fascinating and historical material in his latest book, *Elements of Navigation*. This work is based on his three-month fellowship in 1995 during which he surveyed and catalogued the Museum's navigation oriented collections.

The book presents a section on each of the "Elements" of navigation— celestial observation instruments, compasses, chronometers, charts and atlases, and navigation manuals. Specific navigational challenges, early coastal sailing, dead reckoning, latitude, longitude, cartography and meteorology, provide a framework for the presentation. Seldom seen illustrations taken from historical publications in the Museum's library are particularly interesting. The materials from the Museum's collections are presented appropriately in the context of the period in which they were produced and used. Mörzer Bruyns provides a valuable Dutch historical perspective that broadens the American and English views that we usually see.

In 71 richly illustrated pages, *Elements of Navigation* gives us an introduction to the navigation collections in The Mariners' Museum but it also provides a concise and easily readable history of navigation equipment and techniques.

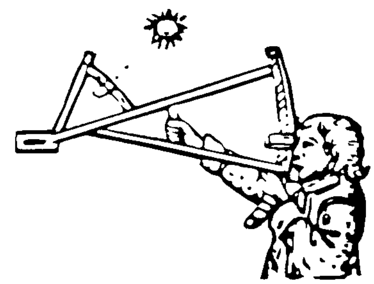
You can also visit The Mariners' Museum at their Web site:

http://www.mariner.org.

**ANSWER TO DO YOU KNOW...?** (From p. 1)

The DR position is found by means of the distance sailed and the direction of the course. No one really knows the origin of the term, although it has been suggested "dead" is derived from "deduced." More likely, it has the same origin as "dead aim," "dead right," "dead on," etc. This goes back a few hundred years to the time when the mariner had little else to go on, so, after his brow-furrowing reckoning of course and speed, *that* was his position.

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-SIX, SUMMER 1997

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

# ACTIVITIES

*By Terry Carraway*

## Reminder

Remember The Navigation Foundation when you are looking for books, charts or navigation publications. We can provide these items from many sources: The Naval Institute Press, Paradise Cay Maritime Publications, International Marine Publishers, Cornell Maritime Publishers, Reed's Almanacs, The U.S. Government Printing Office, McGraw Hill and NOAA. All are with members' discounts.

## History of Navigation

The Institute of Navigation Council has established an ad hoc historical committee to compile the history of the ION and the art and science of navigation. The results of this committee will most probably be prepared for an ION display in the Air Force Museum in Dayton. Foundation Director John Luykx will be assisting Carl Andren, of the ION, to compile the history of navigation for this display.

## Sextants, Chronometers, and Antique Navigation Instruments

If anyone has a question, requires assistance in the use of, or the repair of any traditional navigation instrument they can contact an expert. Director John Luykx is an expert on all traditional instruments of navigation and can be reached at InfoCenter, P.O. Box 47175, Forestville, Maryland 20753 or Telephone 301-420-2468.

## Membership

The Foundation's membership has stabilized somewhat. With the few members we are receiving from our web page and the advertisement in Celestair's new catalog, the new members are offsetting those who have not renewed. We still need more new members to keep the Foundation viable. The cost of everything is increasing and only by keeping a stable membership can we continue without raising the tax deductible membership contribution. Raising the membership contribution is the very last action that we want to take.

## How to contact The Foundation

There are now many easy ways to contact us: The usual telephone answering machine at area code 301-622-6448; a fax at anytime to the same number or an e-mail to either 76476.1165@compuserve.com or navigate@ix.netcom.com; Compuserve mail at 76476,1165; a message on Compuserve's Sailing Forum (Navigation and Communications); or a letter to The Foundation's mail box. Unless I am on travel, all messages are answered each day except U.S. Postal mail. I pick up that mail once a week.

If you fax a letter, order, comment or question to The Foundation, here is what you can expect from the fax machine. The fax is a built-in part of The Foundation's computer but acts like a complete fax machine. If your system is automatic, The Foundation's system will catch the tone and receive our fax. If you have a manual system, press the send button as soon as the answering machine answers. Your tone will trigger the fax. I have had little trouble with this system. However, there are some fax machines that do not work well with the automatic tone.

DO YOU KNOW...?

*By Ernest Brown*

How Eratosthenes used the pointer and bowl of a sundial at Alexandria and the pointer of another sundial at Syene (Aswan) to measure the circumference of the earth?

*(The answer appears at the back of this issue)*

# READERS FORUM

*Edited by Ernest Brown*

Member John G. Hocking, Ph.D., of 4205 Meridian Road, Okemos MI 48864-3125, e-mail: hocking@pilot.msu.edu wrote on July 16, 1997:

"Thank you for forwarding that letter from John Luykx (I think) with the Xerox copies of pages from the Taylor book. With the invaluable aid of those references and the sharper, younger eyes of my grandson and his wife, the maker of my "sextant", which is really an octant, has been found. Well, the probability is very high, to say the least. Led by the Taylor pages, they were able to make out the words 'Gray & Keen, Strand, Liverpool' in the badly worn inscription on the arc. A very careful inspection of the rest of the instrument, however, did not produce a date. So that much is left to be determined. I hope to get that last bit of information when I visit Liverpool this next month.

"I have written a letter of thanks to Luykx, if he is the one who wrote that letter to Captain Carraway, as I expect. Who else could it have been, I asked myself. Incidentally, another source of the same information came in the mail just yesterday. A letter from the Record Office of the city of Liverpool also lists the names of Gray and Keen, giving their address as 25-26 Strand st. (no, I did not omit the capitalization, they did.) This list was compiled in 1843 and adds the name "Jones' to the pair. A note about coincidence: The man who gave me the octant is William Brown of Portaferry, Co. Down, North Ireland. The Record Office is located on William Brown Street. Strange!

"It was Mr. Al Lowring, an antique dealer in Easton MD, who first pointed out that my 'sextant' was actually an octant. I had had the thing over a year without truly looking at it, I guess. I have even dismantled it, very slowly and very, very carefully, used it to take a few sights and shown it off to just about everyone I know. And still I failed to notice the obvious fact that the scale reads to only 114°. I have written to Mr. Lowring to thank him for his contributions to my search. And this letter is another attempt to offer thanks to a most deserving person, You, of course!"

— *Sincerely yours, Gib.*

Member Captain R. A. Bowling of 4045 San Juan Road, San Diego, CA 92103 wrote on June 15, 1997:

"Thank you for referring me to John M. Luykx, Vice President, Infocenter, Inc., for repairs to and calibration of my WWII bubble sextant, Type A-8A. He did an absolutely first-class job at a very reasonable charge. In addition, at no additional cost, he provided me with an adapter that he made—superbly crafted—to better illuminate the bubble for night observations.

"The desirability—even necessity—for this adapter lies in the unique bubble illumination for the Type A-8A compared to that for the earlier A-6, A-6A, and A-8 models. In those models, the bubble is illuminated directly by the reflection and bending (prism) of light from the bubble lamp. But, in the Type A-8A, the bubble is illuminated indirectly by a luminous (radium paint) ring around the bubble. This ring is "charged" (brightened) when the bubble lamp is turned ON. Then, the ring illuminates the bubble. However, in the 50 plus years since manufacture, the luminous property of this ring apparently has declined. As a result, bubble illumination is less than optimum in the normal or designed manner. And there are no spare luminous rings—radium paint.

"Not to be discouraged, John—I take the liberty since I consider him both a professional and personal friend—improvised an adapter that fits snugly over the objective lens tube when the horizon filter is temporarily removed. Inside the adapter is a small red lamp and a small watch-like battery to operate it. A screw type switch turns the bulb ON-OFF. Thus, the light directly illuminates the bubble as in earlier models. In effect he has adapted the Type A-8A indirect bubble illumination to direct.

"As for the sextant itself, after adapting to shooting with my left eye—cataracts on the green side—GPS coordinates were within 2 miles of my fixes from sun, moon, planets and stars. Which confirms the superiority of celestial navigation. If the accuracy of my friend's GPS—it would be apostasy for me to own one personally—doesn't improve I am going to recommend that he send it to John for calibration.

"If any of you have problems with your sextants or any other navigational equipment or have any questions, I heartily recommend that you tell your troubles to John M. Luykx, InfoCenter, Inc., P.O. Box 47175, Forestville, MD 20753, Ph/Fax 301-420-2468. I am not getting a discount for this—just sharing a bit of valuable professional information."

— *Sincerely, R. A. Bowling*

Member Jim Teachey sent by E-mail on May 7, 1997:

"Member Teachey here. I hope you are doing well.

"I wanted to ask you a question about a watch I've received yesterday when my Grandfather passed away. He was 92 and had lived a very full and rewarding life. The watch he gave me was used on a destroyer during WWII. It's a Hamilton model. It's pewter gray and very heavy. On the outside back cover it says 'Bureau of Ships US Navy'. Underneath that it has a capital N with a circle around it with the numbers 4704-1942 following it. I unscrewed the back cover and inside it were the numbers 671932. I pulled the back plate off and found the following: "Hamilton Watch Co., Model 22-21 Jewels, Adj. to Temp & 6 Pos. Made in USA, US Navy-Bu. Ships - 1942. The last number I found was on part of the internal frame. It was 2F12308.

"It's in excellent shape, and I got it to run for a little while. I tried to wind it but it seemed like it wouldn't wind. It would run for a little while and then stop.

"Are there members in the Foundation who might know something about these watches? Can they be repaired? I'd really like to get it in working order.

"If you could help me with this I would sure appreciate it."

*—Sincerely, Jim Teachey*

*Editor's Note: Director John M. Luykx's comment is as follows:*

*"Mr. Teachey's watch is the famous Hamilton Model 22 deck watch which was developed in 1941 and came in gimballed and ungimballed mountings.*

*"His is the ungimballed mounting. These 35 size, 56 hour, 21 jewel deck watches are installed/fitted with INVAR balance wheels and ELINVAR hairsprings which make their running almost impervious to temperature changes.*

*"This is a beautiful watch and the best ever made of its type.*

*"The Time Machine, Inc., 4220 Virginia Beach Boulevard, Virginia Beach, VA 23452 can fix it."*

Member William S. Murdoch of 3424 Lakeshore Drive, Kingsport, TN 37663-3370, wsmurdoch@aol.com wrote on July 2, 1997:

"Enclosed are two copies of an article that I have written describing the calculation of the GHA of Aries and the Sun, the declination of the Sun, and the semidiameter of the Sun. One copy is typewritten and the other is set in two columns to show how it might be fit into *The Navigator's Newsletter*. The two are also on the enclosed diskette as both the original Word 97 files and translated WordPerfect 5.x files.

"The accuracy of the calculated values is about 0.1', which is sufficient for practical celestial navigation.

"This is information that I was not able to find in any navigation textbook or magazine article although it is easy to find in astronomy texts. Two magazine articles that I have written have used the formulas to make calculator programs for Sun sight reduction. The first was printed in *Practical Boat Owner* (February 1994) and the second in *Cruising World* (March 1996). Rather than giving a program for a specific model of calculator, this article gives the formulas and a quick explanation of how they work. A reader can then use them in a program (or spreadsheet) of his own.

"The article has never been published, and you are welcome to use it in *The Navigator's Newsletter*. I will gladly give the Foundation first serial rights for no charge."

*— Yours faithfully, Bill.*

*Editor's Note: We intend to publish Member Murdoch's article, "Calculate Your Own Nautical Almanac Data for Sun Sights" in the next issue."*

Mr. Panagiotis Rovolis of Pindou 122 15669 Athens, Greece, wrote on April 18, 1997:

"I got attention of your Foundation by an old copy (Jan. 1990) of National Geographic, containing the most interesting article, 'New Evidence Places Peary at the Pole' written by Thomas D. Davies, Rear Admiral, USN (Ret.).

"Well I am a 25-year-old biologist and I am very much interested in learning the science & craft of Navigation. I would be most grateful if you could send me any available information about the Foundation, including requirements for membership, instruction publications & newsletters, chances of courses in navigation, etc.

"Thank you very much in anticipation.

*— Yours faithfully, Panagiotis Rovolis*

Member George Rupp (grupp@ix.netcom.com) wrote on April 2, 1997:

"I haven't e-mailed you for some time since I had nothing important to say. I think I do now so I will invade your time.

"Each month I send out many copies of my Celestial Navigation Programs for the PC. They are Freeware so there is a wide distribution. The recipients range from the curious beginner to the serious practitioner.

"I noted, in issue Fifty-Four of *The Navigator's Newsletter* your request for assistance to find new members.

"With your approval, I would like to add a simple note in my accompanying program instructions concerning the Foundation's existence and invite an exploration of the Foundation web page.

"Would you be so kind as to write a sentence or two, making it official and approved, and e-mail it to me so I can include it.

"Yes, I am interested in your Russian flying adventures."

*— Regards, George Rupp*

Member Captain Chris Willems of 30 Springfield Street, Somerville, MA 02143-40180 (e-mail: 2588cwill@umbsky.cc.umb.edu) wrote on April 12, 1997:

"Thank you for sending the introductory package of materials for The Navigation Foundation. My first introduction to celestial navigation came last winter in the form of a month long course at the Boston Sailing Center. I appreciate the services your organization offers and hope to continue to hone my navigation skills.

"I obtained a 50-Ton Masters with towing and sailing endorsements after having worked on marine education and sail training vessels in Long Island Sound. Currently I am finishing up a biology degree and teaching certification. Next year I will be teaching public secondary school and including much maritime material.

"'The Navigation Basics Review', articles 7 and 8 by Roger H. Jones was of particular interest to me. Is it possible for me to obtain back issues #49 and #50 which contain the previous articles?"

*— Sincerely, Chris Willems*

Member A. E. Saunders of 4119 Cherry Blossom Lane, Vineland, Ontario L0R 2C0, Canada phone 905-562-7815, e-mail asaunder@netcom.ca wrote on June 18, 1997:

"Navigators, I receive your valued publication as a member of the Foundation. In almost every issue there is something of value and/or interest. The Spring 1997 issue (fifty-five) was no exception.

"I am extremely interested in the topic of Longitude by Lunar Distance and I am following the series by John M. Luykx with a great deal of interest and will be trying to apply the lessons this summer. I am, however, somewhat confused by an instruction in the second of the series (Spring 1997). 'The third assistant recorded the apparent time (by watch) of each...' and, earlier, '...a watch set to apparent time.' By this, do I assume that the watch was set to Local Apparent Noon at meridian transit? How could a watch (assuming a constant record of the passage of time) be kept on Apparent Time as the Equation of Time is a variable through time? Also is it not true, assuming the vessel is moving and changing longitude through time, that the Local Apparent Time would be a variable?

"Am I somewhat confused about time or some definition or interpretation of what the author means? Please verify that the reference to apparent times is, in fact, Apparent Time and how it is derived. Any advice that I may be given would be appreciated. As I will first be attempting the process from a stationary, known position — please advise me how I can set my watch to apparent time.

"I have another question with regard to 'Do You Know...?' in the same issue. Firstly let me say that I have nothing but the highest regard for the author of the answer — Allan E. Bayless — I first met Allan at a Canadian Power Squadron annual meeting when he was Vice Commander (National Education Officer) of the U.S. Power Squadron.

"My first concern is that Allan's description of how a 'DR position is found' leaves more questions than answers. To wit, '...found by means of the distance sailed and the direction of the course.' Does that mean distance sailed is the distance sailed through the water, a calculation of speed through the water and elapsed time, or the distance sailed over the ground (distance made good) which, until a Fix is obtained must be an estimate. Also, does that mean direction of the course steered or the direction of the course made good (which, again, must be an estimate pending a Fix).

"My understanding is that a DR position is a determination based on distance traveled through the water and True courses steered since departing a known position (Fix). This, of course may be a combination of various courses and speeds since the Fix which is generally applied by plotting (or calculating) intermediate DRS. This, to me, makes sense when you consider the possible derivation of the term — Dead — meaning dead wind and dead water — therefore no consideration of current or leeway. Dead - meaning 'dead' or deduced - therefore a calculation based on known facts — speeds through the water and true course steered, both reasonably precisely measured.

"Again, congratulations on a great publication. I am forwarding under separate cover my renewal of membership.

"I have compiled a series of questions to be posed to the navigator (or astronomer), the answers to which are usually arrived at an understanding of basic navigation astronomy and a few which require pencil and paper (or calculator). In rare exception some ephemeris data is required and is supplied with the question. I attach a few examples for your perusal. If you would like to receive the entire group of questions, please let me know and I will provide them with my compliments. Please note that the material (and any excerpts) are copyrighted by me. You would receive my permission (at no fee) to print them as a series in your Navigator's Newsletter provided that credit for the source is clearly provided to the reader. This permission does not include the printing of the entire series in one publication or issue."

— *Yours very truly, A. E. Saunders*

Director Allan E. Bayless responded by Juno E-mail on July 18, 1997 to Member Saunders:

"Dear Al, I am sorry to be so remiss in 'writing.' I'm doing medical transcription now that I'm a retiree from the medical profession, and have been busier than all getout. Also, I was eliminated from Juno's e-mail list because my modem was too slow. Fortunately, that happened just as I acquired a new computer cum modem, so now all is well again. I am pleased you remember me and I appreciate your high regard. Thanks!

"To 'dead reckoning.' Put yourself in the 16th century, or earlier. You are heading from somewhere to somewhere else across the broad Atlantic, not too long after Columbus and Vasco da Gama started long distance voyaging. You are a navigator but have never heard of variation, let alone deviation. Your cross staff can be in error by several degrees! You know the pole star is north, but you are unable to measure its altitude very accurately even though you have the latest equipment - a nocturnal. Your compass box is divided at intervals of several degrees. You have no way to measure speed except by guesstimate and perhaps that new-fangled chip log. Under these circumstances, your best estimate of where you may be after being away from your point of departure is based on your calculation of position based on approximate speed and approximate time. But it's the only position you have, so that's where you are - for lack of anything better. So, you have to pin your faith on your reckoning and your faith is glued to where your reckoning says you are, hence THE position, the dead-on position, if you will.

"The refinement of the definition of dead reckoning which concerns you came much, much later. In the 16th century, speed over the ground had no significance whatever. Accurate compasses, sextants, fixes, etc. are all modern and used to qualify the calculated position. Still, dead reckoning, though inferior to a fix or a GPS position, is still based on speed, time (from which distance is determined) and direction. Anyway, that's the way it seems to me.

"I wish you the very best. Anything I can do for you, please sing out."

— *Cordially, Allan*

Director Allan E. Bayless also wrote to the editor on July 30, 1997:

"I certainly don't insist anyone agree with me, but consider what the following terms mean:

Dead on  Dead aim  Dead-to-rights  &c.

"I have little doubt you're right, Saunders probably wanted to know what he already knew; I intended to say to him the qualifications we make now concerning positions (estimated, probable, etc.) were irrelevant when the term 'dead reckoning' evolved. Celestial navigation at that time was very nearly useless except for very, very rough approximation. When Wright published his book (1599), he also included Tycho Brahe's values for the declination of the sun, before that, very rough indeed. He also advised considering variation as a correction to compass direction, although, as you know, the value was known for few locations. He also advised using a peep sight for the cross staff to reduce its considerable parallax error (it was customary to rest it on the cheekbone, not a very precise location)..." — *Cordially, Allan*

*Editor's note: John M. Luykx's response to Member Saunders is as follows:*

*"Re apparent time queries,*

*"(1) Apparent time is sun time.*

*"(2) To determine apparent time at any instant and location, compute the meridian angle (t) from values of observer latitude, sun declination and sun altitude (Ho). To do this I prefer the time sight formula.*

*"(3) Convert t to time and (a) in AM subtract from noon or (b) in PM add to noon. Record watch time. The error on the watch on the time thus computed is watch error on apparent time.*

*"(4) Take additional observations throughout the day to obtain watch rate for any convenient interval, i.e., every 3 hours, every 6 hours, every 8 hours, every 12 hours, etc.*

*"(5) If observations are taken of another body (i.e. not the sun), then compute t in the normal manner and apply a correction for difference in GHA or right ascension (R.A.) between the sun and the other body. The corrected t converted to time and added to or subtracted from noon, as the case may be, is equal to apparent time."*

Member Captain Warren G. Leback of 2-B Marten Road, Princeton, New Jersey 08540 wrote on March 12, 1997:

"I am writing to ask for the name and telephone number of the President or Chairman of the foundation.

"As a Trustee of the American Merchant Marine Academy, I would like to nominate the Foundation for the 'Bowditch' Award for the year 1997. The Bowditch Award is given by the Museum each year to a person or foundation who has done much to further Navigation."

"I remain"

— *Sincerely, Captain Warren G. Leback*

James F. Matthews, Executive Director, Air Cybernetics Ltd., Alma House, North Strand, Skerries, Co. Dublin, Ireland wrote on 21 March 1997:

"I called your office recently and ordered a copy of the Report you produced after your Foundation's investigation into Peary's claim. It is a brilliant job, and your final conclusion is one with which I - speaking as a former Boeing 707 Navigator and occasional yacht Navigator - utterly agree. I would like to confirm my order for a copy of your full report, as advertised in National Geographic magazine dated January 1990.

"I am due to speak to my local Yacht Club here in Skerries on Sunday 6th April on Peary's epic feat; this date being the 88th anniversary of his reaching the Pole. I really do not know if your report will reach me in time, but it would be useful if I had read it before giving the talk.

"I wonder if you could clarify a few things for me.

1. Who owned the *Roosevelt*? Was she a USN vessel on loan to Peary?
2. From the picture in National Geographic, I cannot read the arc on Peary's sextant. Is it a quintant or a sextant, and what maker, please? Who made his chronometers?
3. Any information on your foundation would be welcome."

— *Yours faithfully, James F. Matthews*

Our Executive Director responded to Mr. Matthews on April 4, 1997:

"I apologize for the problem we have had trying to contact each other. I wrote you a letter and enclosed information concerning The Navigation Foundation. I also included a letter informing you that the Robert E. Peary Report has been out of print for about 5 years and there are no copies remaining. I am sorry that you will not have it as a reference for your talk to the local yacht club on Sunday, April 6.

"In answer to the questions in your letter:

*"Concerning the Roosevelt—it was built with money from the Peary Arctic Club and constructed as a special ice breaker. (See attachment one.)*

*"Chronometers—Peary's chronometers were special built by Howard of Boston, a maker of railroad time pieces. They were mounted in an aluminum frame and carried in a special pocket built in the top of his underwear. This kept his Chronometers close to his body and at a relative constant temperature. The aluminum frame acted as a heat exchange to keep each*

*chronometer very close to the same temperature.*

*"Sextant— Sextant was manufactured by John Bliss, New York, New York. It has 150 Degrees on the arc and the word English stamped in the metal. That is all of the information that the Archivist at The National Archives could find on Peary's sextant.*

"I hope this information helps in your talk. I also trust that you received it in time to be of use."

— *Best regards, Terry F. Carraway*

Henning Umland of Barwegskoppel 16, 21423 Winsen/Luhe, Germany wrote on June 9, 1997 to Director John M. Luykx:

"Re. Sight Reduction Procedure.

"I am writing you this letter because Mr. Carraway told me you are the residing expert on navigation and the person to contact in this matter.

"I have recently developed a sight reduction procedure deriving a line of position from the horizontal angle between two celestial objects.

"Since I am only an amateur navigator and do not have a comprehensive knowledge of the whole navigational literature, it may be possible that similar methods already exist. In the worst case, I reinvented a procedure long known. At least the most common books like, e.g., *The American Practical Navigator* do not mention such a method.

"Would it be possible for you to look through the attached manuscript and tell me what you think about it? I would really appreciate your comments.

"Thank you in advance."

— *Yours sincerely, Henning Umland*

Member Douglas A. Brutlag wrote on June 13, 1997:

"Thank you for your phone call confirming my order for an Air Almanac. As discussed I am in the process of starting up a nostalgic celestial air navigator course for interested parties. I plan on its being available around late summer or fall. At this time, I would like to hear from members who have practiced celestial air navigation, particularly from the gentleman you mentioned from Ireland. I would welcome all comments, tips, and words of wisdom. I also buy and sell aviation sextants, particularly the A-10 and A-10A. When I am not doing this and family matters, I am a 767 Captain for American Airlines, and fly to Europe and Caribbean. All correspondence can be sent to me at: R.R.3, #2 Aero-Place, Urbana, Illinois 61802. My phone and fax are the same (217)344-2813.

"It was a pleasure talking with you. Thanks for your help."

— *Sincerely, Douglas A. Brutlag*

Member Alfred S. Coslett of 56 Arlington Avenue, Milmont Park, PA 19033-3105 sent by e-mail on 28 April 1997:

"I am a new member, #03920, and I have received the initial newsletter #53 in the initial mailing. I understood the winter issue #54 would be mailed sometime in March but I have not as yet received it. Perhaps the mailing is late or since I am a new member my name etc. did not get on the list. I enjoyed issue #53 very much and don't want to miss the current issue. Should I expect to receive #54 or could I be mailed a copy? I was interested in the Quik-dri and assume it was explained further in the previous issue #52. Would it also be possible to get a copy of that issue if there are any available."

— *Please reply. Alfred S. Coslett*

Member Alfred S. Coslett of 56 Arlington Avenue, Milmont Park, PA 19033-3105 wrote on May 8., 1997:

"I am a new member #03920 and have received the initial mailing including a copy of News Letter #53. I understood that there would be a mailing of the winter edition #54 sometime in March but as yet I have not received that issue. Perhaps the mailing is late or maybe since I am a new member my name etc. was not recorded in the appropriate records in time for that issue. As a navigation instructor in the Coast Guard Auxiliary, I am interested in this organization and most things that pertain to that subject. I sent an E-mail on 28 April 1997 pertaining thereto but did not receive a reply. I realize the Foundation is a volunteer organization with limited time and resources but I would appreciate some type of reply and, if available, a copy of the edition #54."

— *Sincerely, Alfred S. Coslett*

Frank Brennan of 3284 Chrisland Drive, Annapolis, MD 21403 sent by E-mail March 8, 1997:

"I am interested in learning more about your group."

— *Regards, Frank Brennan*

Member Joe Iwanski of 9324 Glenbrook Road, Fairfax, VA (Joeiwanski@aol.com) sent by E-mail to Capt. Carraway on March 26, 1997:

"I'd be interested in your trip to the Crimea to fly Russian war planes."

Member David A. Blythe sent through the Smart Time Network to Captain Carraway on March 27, 1997:

"I for one would be very interested in reading about your Crimean trip to fly several Russian aircraft, particularly the MIG-21. Your son's experience in A-10's would be interesting reading also."

— *David A. Blythe*

Member Dan Hogan of 1622 S. Willow Ave., West Covina, CA 91790-5621 sent by E-mail to Captain Carraway on March 27, 1997:

"Write up your Ukraine visit. It would be interesting."

Member Charles F. Jones sent by E-mail to Captain Carraway on March 19, 1997:

"I would be interested in reading about the trip to fly Russian planes. Hope you do it."

— *Thanks, Charles F. Jones*

Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona* wrote to us from Aden in February, 1997:

"Dear Friends, I am writing this fifth newsletter as we sail to Aden. We are leaving the exotic Far East to enter the Middle East. The trip has been timed to take advantage of the NE monsoon, which should give generally favorable winds as far as the south part of the Red Sea. Walter and I put in a heavy week of maintenance at Cairns before Ginny arrived. The weather in the Tasman Sea had left us with a lot to do, including lifting a few teak deck planks and recaulking underneath. Whilst in Cairns I had hoped to get a permit to cruise Indonesia but I was defeated by the inertia of the Indonesian officials. After wasting $15 on phone cards and mostly being kept on hold I gave up and decided to visit Thailand instead.

"We had strong SE winds for our trip through the Great Barrier Reef. We anchored every night usually making good about 55 miles between anchorages. Lizard Island was the best stop and our last chance to go snorkeling—north of Lizard we were warned to stay out of the water due to the predatory habits of the salt water crocodiles. We spent a couple of days in Cooktown before Lizard — this is the place Captain Cook repaired the *Endeavor* after he crunched on a reef. After repairs he sailed to Lizard Island and climbed the hill in order to plot the best way out through the Great Barrier Reef into open water. Cooktown was established many years later as a trading center for the miners heading for the gold fields on the Palmer River — a fascinating story told in a book we got at the Cooktown Museum. North of Cooktown the Queensland coast is very desolate. Ginny and I had a curious experience when we dinghied up to a small settlement several hundred miles north of Cooktown. We had anchored *Fiona* and gone ashore to trade paperbacks, as we had been told earlier by an Aussie yachtey that this was the place to do it. Instead we ran into a genuine outback character called Barbara who invited us into her ramshackle abode, amused us with stories of the region and finally gave us some 'Holy Heavenly Healing Cloth' which she said would cure any ailment, along with typewritten instructions.

"We sailed past Cape York into the Torres Strait and spent a couple of days at Thursday Island. At one time this was a great pearling center and we were lucky enough to see one of the old pearling luggers, now sailing as a yacht. From Thursday it was a few days sail to Darwin, the modern capital of the Northern Territories. Darwin was very hot — in the nineties every day - goodness knows what it is like in summer. We stayed at a new marina, fortunately there was lots of fresh water available. We had the anchor chain regalvanized and took care of other maintenance chores. We rented a car and most days drove down to the yacht club for a beer and a game of pool each afternoon. We also restocked at the last western style supermarket that we will see for a long time. We then left on the long haul to Thailand, about 3000 miles, paralleling the coast of Java and Sumatra. Our one stop was Christmas Island, an Australian possession developed by the British in the late nineteenth century because of the enormous guano deposits. It was a fascinating place to visit, it has quite a bloody history detailed in a booklet we picked up. The guano was dug up by imported Chinese coolies who sometimes murdered their overseers due to the harsh working conditions. The Japanese invaded in 1942 and the few British soldiers on the island were killed by the Sihk policemen just before the invasion began. Every year on Christmas Island, millions of red land crabs migrate to the sea to reproduce. We were there for the tail end — crabs everywhere. Whatever is in their path they climb over— even three story buildings. We refueled and left — we expected a long, windless passage through the doldrums as we approached the equator. The wind dropped the day after Christmas Island disappeared over the stern horizon and we motored over a calm sea for nearly a week. When we crossed the equator Ginny was truly inducted as a Daughter of Neptune by the old King himself, who climbed over the lifeline to perform the ceremony, using lots of Mount Gay rum. Apart from the odd encounter with Indonesian fishing boats, we saw no one. Above one degree north the fuel got low and we sailed in very light winds, sometimes tacking to within a few miles of the coast of Sumatra, which looked very green, but with no signs of life.

"We arrived in Phuket, Thailand, in early December, thirty-one days after leaving Darwin. Ginny left us here, her son flew down from Nepal and they went off sightseeing before her return to the USA in time for Christmas. I called my daughter Brenda and she posted a notice on the Internet that produced a new crew member for the leg to the Mediterranean within two days. While we waited Walter and I sampled the culinary delights of Thailand, where a dollar or two gets you as much tasty food as you can eat in one meal. We also cruised the spectacular bay to the east of Phuket, where islands of volcanic origin with vertical walls tower up hundreds of feet, crowned with dense vegetation. Parts of a James Bond movie were shot here a few years ago. We wound up at Phi Phi Don, this is a unique island with no airfield, visitors sail here or take the ferry from Phuket. A few pleasant hotels and guest houses provide accommodation. The village has several streets, each no more than ten feet wide, absolutely packed with small shops and eating establishments. The place never seems to close, even in the small hours. We even found a pool hall, a game the Thai play very enthusiastically and noisily. Robert flew in from Seattle the day after Christmas, after another brief visit to Phi Phi Don we sailed to Sri Lanka.

"This turned out to be a glorious sail, a wonderful introduction to ocean cruising for Robert, whose experience had been confined to coastal cruising. We covered the 1,200 miles in just over eight days and fortunately arrived in the late afternoon at Galle in time to beat the harbor curfew. The curfew is imposed by the Sri Lanka Navy, who close the harbor at dusk and then proceed to discourage Tamil rebels by dropping grenades and sticks of dynamite into the sea near the entrance for the rest of the night. The civil war has clearly had a profound impact on the country, including a severe economic penalty. It is probably the poorest country we have visited since Guyana. The political situation reminded me of Northern Ireland. The Tamils, who originated from India, just across a narrow sea to the north, are Hindu, the majority of Sri Lankans, called Sinhalese, are Buddhist. They are concentrated in the south. In contract to Ireland, the Tamils are fighting for a separate state of their own, will the fighting in Ireland continue if it is united, with rebels fighting for a state of their own?

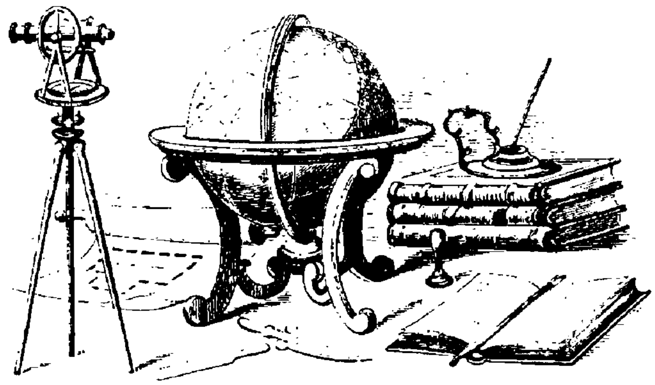
"We made a two day van ride to Kandy, the old capital with beautiful Buddhist shrines, the one we visited was said to hold a tooth of Buddha. The central part of Sir Lanka is lovely, with intensively cultivated hillsides and, of course, lots of tea plantations. Several times we passed through police road blocks. Their job is no sinecure, on the day we left twenty-two policemen were killed by Tamils. Prices are very cheap, our hotel in Kandy cost $6 per room, with private bath. Expertly made carvings, mostly in teak and ebony, are available for a song. On our arrival in Galle the naval officer had noticed from the passports that Walter's Birthday was the next day. 'Come to the party,' we gaily said. 'I will,' he replied, 'I'll bring my boss.' Sure enough a bevy of navy people showed up at sundown the next day and we had quite a party, as several yachties had already been invited aboard, and a couple of bottles of our Caribbean rum were sacrificed to cement Sri Lanka-American relations.

"From Sri Lanka we sailed a few hundred miles southwest to the Maldive Islands. These comprise over a thousand islands grouped in about 18 atolls spread from several degrees north to the equator. The capital, Male, lies halfway along the chain at about four degrees north. I had expected them to be poor, rather like other atolls we had visited such as the Tuamotus and the Cook group in the South Pacific. This view was reinforced by an article written by Ginny's son Ian describing a trip he made in the traditional dhow to atolls lying to the south of Male but I was wrong. The Republic of the Maldives is the first Islamic country we have visited and unfortunately we arrived in the middle of Ramadan. Many business and government agencies open only for a few hours in the morning. Moslems fast during daylight hours and restaurants open only after nightfall. It is considered bad form for Westerners to be seen eating or drinking in public. Besides these minor problems Male is one of the worst anchorages we have encountered. The water is deep, typically 150 ft, currents are strong, there are no facilities to handle dinghies and we anchored cheek by jowl with over twenty freighters sharing the harbor. The freighters, however, are the clue to the Maldives amazing prosperity, for they export virtually nothing, the freighters brought only imports. The prosperity has been achieved in the thirty years since independence from Britain by a very hard look at what they did have and how to cash in on it. What they did have was over a thousand charming tropical islands. Up till now seventy-nine have been developed exclusively as luxurious beach hotels. A huge airfield, nearly two miles long, funnels dozens of jets in each day, packed with tourists. An infrastructure of ferries, helicopters and planes deals with the transportation of the pale, mostly European, tourists to their designated luxury islands. No natives, except staff, live on the resort island, native villages are to be found on the other one hundred and sixty-nine islands - they have no tourists. After customs and immigration formalities in Male we sailed to one resort island and anchored off a lovely beach. We were welcome to use the facilities on shore. The hotel here was beautifully designed and landscaped, prices were out of sight for poor yachties — $30 lunches, but we splurged (once) on $10 cheeseburgers and a beer by the pool.

"We returned to Male for outward clearance. The first time we had anchored with all our chain plus 200 ft. of rope. It had taken us two hours to raise it, the weight of 150 ft. of chain hanging straight down was simply beyond the capacity of the anchor winch. On our return we used all rope with just 30 ft. of chain. One of the very few times (perhaps the only time) when I have used rope instead of chain for the anchor. We ate out in Male after sunset for only a few dollars and I was amazed how the streets filled with laughing happy people once the fasting was over for the day. The two week sail to Yemen from Male was very pleasant; lots of marine life. At night the phosphorescence was almost enough to read by — as dolphins swam around the boat they left greenish-white "contrails" in the water. Ever so often there was a slurpy gasp as they sharply inhaled. Walter caught several fish on the trolling line, most got off the hook but we did land and eat two. Aden is very battered due to the recent civil war, the town is located between harsh, barren mountains. Most women wear long black robes and head veil, the hijab, brown eyes peer at you through a little slit in the head-dress. Everyone is very friendly, we will refuel, reprovision and leave for the Red Sea, the Suez Canal and the Mediterranean."

*— Until the next time, best wishes from, Eric*

# NAVIGATION NOTES



## A Navigation Problem: Equation of Time by Nautical Almanac

*By Ernest Brown*

"Find the equation of time (Eq.T) at GMT $9^h14^m48^s$ on September 17, 1997, using the *Nautical Almanac* but without reference to the Eq.T table therein.

### Solution:

(1) The equation of time is the difference at any instant between apparent and mean solar time. This may be taken as (a) the difference in the right ascensions (customarily expressed in time units), (b) the difference in the local mean time (LMT) and local apparent time (LAT), (c) the difference in Greenwich mean time (GMT), and Greenwich apparent time (GAT), and (d) as the difference in the Greenwich hour angles of the mean and apparent suns expressed in time units.

(2) Either (c) or (d) suits the purpose here.

(3) Adding (or subtracting) $12^h$ to GMT gives GHA mean sun in time units. The difference of this value and the GHA apparent sun as extracted from the daily pages of the *Nautical Almanac* is the equation of time (Eq.T).

| | | |
|---|---|---|
| | | Sept. 17, 1997 |
| GMT | | $9^h14^m48^s$ |
| | | $+12^h$ |
| GHA | | $21^h14^m48^s$ (mean sun) |
| From daily pages | | |
| GHA $9^h$ | 316°22.'7 | |
| $14^m48^s$ | 3°42.0 | |
| GHA apparent sun | 320°04'.7 | $21^h20^m18.8^s$ (apparent sun) |
| | Eq.T | $5^m31^s$ |

(4) To find Eq.T by GMT~GAT, find the GHA from the daily pages, add or subtract 180°, convert to time units and compare the GAT so found with GMT.

| | | | |
|---|---|---|---|
| | | | Sept. 17, 1997 |
| GMT | | | $9^h14^m48^s$ |
| From daily pages | | | |
| GHA | $9^h$ | 316°22.'7 | |
| | $14^m48^s$ | 3°42.'0 | |
| | | 320°04.'7 | |
| | (-) | 180° | |
| | | 140°04.'7 | |
| GAT | | $9^h20^m18.8^s$ | |

| GMT ~ | GAT | = Eq.T |
|---|---|---|
| $9^h14^m48^s$ | $9^h20^m18.8^s$ | = $5^m31^s$ |

NOTES:

1. In each case the time diagram makes the solution obvious.
2. By noting the LMT of meridian transit (LAT $00^h$ or LAT $12^h$), one can easily see how Eq.T is to be applied (+or_) to apparent or mean time.

# NAVIGATION PERSONALITIES

## Roald Amundsen

By Ernest Brown

*(Continued from Issue #55, Spring 1997)*

In his chapter, The Navigation Over the Polar Sea, in *First Crossing of the Polar Sea* by Roald Amundsen and Lincoln Ellsworth, First-Lieutenant Hj. Riiser-Larsen brings attention to the fact that dead reckoning is much more difficult in the air than on the sea. With the airship moving forward in the body of air itself moving in the direction of the wind of the locality, drift of much higher magnitude than what is experienced by the mariner is the usual case. And it changes with much greater frequency because the airship with its greater speed moves more rapidly into new areas of differing winds. Should the airship change its altitude, the drift may change as the winds direction and force usually change with change in height above sea level.

For the *Norge* flight, Riiser-Larsen had the same Goerz combined drift and speed meter used in the 1925 flight. He said that it was useless in the dark but the best he knew for use during daylight. This telescope-like instrument was mounted in the bottom of the pilot's compartment of the gondola. It rested in a bearing on a graduated disc. With the disc set to the zero graduation, an observer looking through the optics down to the ground would see in a rotatable glass within a diametral line pointing forward, the drift line. The observer might also see recognizable objects on the ground being passed over follow along the drift line. If this is the case, there is no drifting from the course. There is either no wind, or wind from ahead or astern. A speed determination is then necessary to resolve the matter.

If the objects do not follow along the drift line, the wind is at an angle with the heading of the airship, causing drift. The aforementioned glass is turned clockwise or counterclockwise until the objects follow along the drift line. The angle between the longitudinal axis of the airship and the direction of the drift line is the angle of drift.

If the angle of drift is small and the wind slight, it may be sufficient to steer a corresponding number of degrees into the wind. But with a wind of any strength and much athwart the heading, the direction of the wind in relation to the heading is changed as one turns into the wind. The result is the angle of drift on the new heading is not the same as before turning into the wind. One must then find the new drift angle by turning again into the wind. Once that is done, it is necessary to measure the ground speed.

In the lower part of the Goerz instrument projecting below the bottom of the gondola, there is a prism which oscillates around a transverse axis of rotation. The interconnections of this prism with the top of the instrument are such that the orientation of the prism can be controlled. On the aforementioned rotatable glass with the drift line, there is also a transverse speed line.

To measure the ground speed, the instrument is set to the drift angle and the prism is placed on +45°. The sight line through the instrument is then leading forward and 45° down. At the instant a recognizable object passes the speed line, a stop watch is started. The prism is then placed so that the sight line is vertically downward. When the object again crosses the speed line, the watch is stopped. At this point one has the time it takes the airship to travel a distance over the ground equal to height above ground (the base and altitude of a 45°-right triangle). Entering a suitable table with time and height, the ground speed is determined.

If the airship is not in level flight (bow upwards or downwards), the angle must be taken into account. Riiser-Larsen said that any giving of orders to the steersmen to keep a steady heading and horizontal flight will result in error in the speed determination. The extra effort to maintain a steady heading and height by the two steersmen over a short period of time results in a speed higher than the actual speed over the ground for a longer interval. With the long turns at the rudders by steersmen of the highest quality, maximum performance can be maintained over only short periods.

Since the speed measurement takes up to a half minute or more, the airship's height may change, in which case the average height is used for entering the table.

The limitations of the barometric altimeter was the largest cause of error in the speed measurement aboard the *Norge*. With altitude set at 0 or the height of the starting place when the airship is on the ground, error is introduced as the airship in flight moves into areas of atmospheric pressure different from the starting place. A change of pressure of 9 mm causes an error in altitude of 100 meters, which in turn causes an error up to 10% in the speed measurement. Riiser-Larsen's problem was that the *Norge* was moving into areas where there were no prior meteorological observations and, of course, no radio broadcasts of pressures which could be used to correct his altitude readings.

Working closely with Finn Malmgren, the meteorologist on board the *Norge*, Riiser-Larsen could from measurements of temperature and study of weather charts drawn up on board obtain some guidance as to pressure changes. He could also from time to time go down to such a low altitude as to be able to estimate the height of the airship above the surface. He had on board a military range finder of 70 cm base, which he had used with some success in the flight across Europe where there were enough straight lines, railways for example, for accurate measurements. But this coincidence type range finder was to prove useless flying over polar ice with rarely any straight line cracks. Also because of the low altitude of the sun in the polar region, Riiser-Larsen was unable to use the shadow of the airship method which requires that the sun be high and in such position that there is a sharp full-length shadow of the airship on the ground. Under such conditions, the angle between the bow and stern of the shadow and the angle from the vertical to the shadow are measured. The altitude can than be calculated. Riiser-Larsen found the shadow too far away and not sufficiently distinct in its contours. For the same reason the shadow could not be used for direct speed measurement. However, the method was employed to compare with results by other means. In this method the time required for the airship to travel its own length over the ground is measured by timing the interval from the instant the bow shadow reaches a point on the ground until the stern shadow passes the same point. (to be continued)

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**Index to Navigation Notes (1-56)**, published in Issue Fifty-six (Summer 1997), does not include the navigation problems and history articles previously published in the Navigation Notes section.

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| | | |
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# HISTORY OF NAVIGATION

## Determining Longitude by Lunar Distance Observation: A Sample Solution

*By John M. Luykx*

This article is the third and last in a series of articles devoted to longitude determination by lunar distance. Previous articles appeared in issues 54 and 55 of the Newsletter.

### OBSERVED DATA

In order to test out the Jean Borda and Jean Delambre solutions for finding the longitude by lunar distance, the author, during the evening of 26 August 1996, took a series of altitude observations of both the moon and Jupiter plus a series of lunar distance observations between them. The following data was recorded:

| | | |
|---|---|---|
| 1. Date: | 26 August 1996 | |
| 2. Observer Position: | N 38°51.'8<br>W 76°55.'1 | |
| 3. Bodies Observed: | Moon altitude<br>Jupiter altitude<br>Lunar distance Moon/Jupiter | |
| 4. Watch Error: | 0.0 seconds (GMT was used for all observations) | |
| 5. Weather: | Warm - clear | |
| 6. Sextant: | ARIES 40 with 6x30 prismatic telescope. For the altitudes of the moon and Jupiter an artificial (bubble) horizon, manufactured by InfoCenter, Inc. was attached to the sextant and used in making the observations. | |
| 7. Jupiter (SD) | Semi-diameter:18".0 (0.'3) | |
| 8. Moon (HP) | Horizontal Parallax: | 61.'1 |
| 9. Moon (SD) | Semi-diameter:16.'6 | |
| 10.Sextant I.C. | | -0.'5 |
| 11.Bubble artificial horizon I.C.: | | +0.'2 |

12.Observations:

| | |
|---|---|
| a. Moon altitude: | GMT: 02-46-55 (27 Aug)<br>Hs: 35°54.'8 (Mean of 3 observations) |
| b. Jupiter altitude: | GMT: 02-50-55 (27 Aug)<br>Hs: 24°14.'4 (Mean of 3 observations) |
| c. Moon altitude: | GMT: 02-53-33 (27 Aug)<br>Hs: 36°16.'0 (Mean of 3 observations) |
| d. Lunar distance: | GMT: 02-59-24 (27 Aug)<br>d: 33°04.'4 (Mean of 10 observations) |
| e. Jupiter altitude: | GMT: 03-05-37 (27 Aug)<br>Hs: 23°02.'8 (Mean of 3 observations) |
| f. Moon altitude: | GMT: 03-09-10 (27 Aug)<br>Hs: 36°46.'8 (Mean of 3 observations |

Note: a,c and f above were plotted on graph paper and a curve "faired" through the three points. b and e were also plotted on graph paper and a line drawn through them. The mean values of lunar distance and time (d above) were then plotted on the two graph plots above to obtain the mean values of the Moon and Jupiter observations.

13. Mean values of the observations:

| | GMT | Angle |
|---|---|---|
| a. Lunar distance: | 02-59-24 | ds: 33°04.'5 |
| b. Moon Hs: | 02-59-24 | Hs: 36°29.'0 |
| c. Jupiter Hs: | 02-59-24 | Hs: 23°33.'2 |

14. d Lunar Distance (observed)

| | |
|---|---|
| ds | 33°04.'5 |
| IC | - 0.'5 |
| SDj | + 0.'3 |
| SDm | +16.'6 |
| d | 33°20.'9 |

15. Ha Jupiter (apparent altitude)

| | |
|---|---|
| Hs: | 23°33.'2 |
| IC:(sext) | -0.'5 |
| IC:(bubble) | +0.'2 |
| Ha: | 23°32.'9 |

16. Ha Moon (apparent altitude)

| | |
|---|---|
| Hs: | 36°29.'0 |
| IC:(sext) | -0.'5 |
| IC:(bubble) | +0.'2 |
| Ha: | 36°28.'7 |

17. Ho Jupiter (observed altitude)

| | |
|---|---|
| Ha: | 23°32.'9 |
| R: | -2.'2 |
| Ho: | 23°30.'7 |

18. PA Moon-Parallax in altitude

PA HP cos Ha
+61.'1 x .80499
PA +49.'2

19. SD Moon - Semi-Diameter

SD .2724 x HP (61.'1)
SD 16.'6

20. A Moon Augmentation

A +0.'3 sin Ham
+0.'3 x .59324
A +0.'2

21. OB Moon Oblateness

OB -0.0017 x cos Ham
-0.'1 x .80499
-0.'08
OB -0.'1

22. Ho - Moon observed altitude

| | | |
|---|---|---|
| Ha: | 36°28.'7 | |
| R: | -1.'3 | |
| Pa: | +49.'2 | |
| SD: | 0.'0 | (artificial horizon was used) |
| OB: | -0.'1 | |
| Ho: | 37°16'.5 | |

## CLEARING LUNAR DISTANCE

### DeLambre Method

The Delambre method of clearing the lunar distance is described in the following paragraphs. It was selected as one of the solutions for the sample problem because of its relative simplicity and because it is very similar to the method of Jean Borda which is considered one of the best of the 18th Century methods.

In this method the altitudes of both the moon and Jupiter are required (in addition to the lunar distance itself) in order that the exact values of refraction and parallax for the moon and refraction for Jupiter can be ascertained.

The formula for clearing the lunar distance is:

$$\cos D = \frac{(\cos d \sin j - \sin m) \cos J \cos M}{\cos j \cos m} + \sin J \sin M$$

where:

D = True lunar distance (cleared distance)

d = Observed lunar distance corrected for IC, SD, and SDm = (33°20.'9)

j = Ha of Jupiter = 23°32'.9

m = Ha of Moon = 36°28.'7

J = Ho of Jupiter = 23°30.'7

M = Ho of Moon = 37°16.'5

$$\cos D = \frac{(.83535 - .23752)\ .72969}{.73714} + .24161$$

cosD = .83342

D = 33°33.'1

Because of its simplicity, the Delambre method is well-suited to solution by calculator or computer.

### The Jean Borda Method

The Jean Borda method of clearing the lunar distance is also simple and direct. It provides a cleared lunar distance from values of:

| | |
|---|---|
| Observed (corrected lunar distance): | d |
| Moon's apparent altitude: | Ham |
| Jupiter apparent altitude: | Haj |
| Moon observed altitude: | Hoj |

Tables of log trig functions are required if the 18th century procedure is to be followed. The advantage of this method is that it is more practical when a calculator or computer is not available. Thus, this method is best employed when demonstrating early 18th and early 19th century lunar distance solutions employed prior to the advent of electronic computing devices.

The Jean Borda formula for clearing the lunar distance is:

$\log\sin D/2 = 1/2\ [\log \sin (M+J/2+\Theta)+\log\sin M+J/2-\Theta]$

where:

D = cleared lunar distance

M = Ho of Moon (37°16.'5)

J = Ho of Jupiter (23°30.'7)

d = measured lunar distance corrected for I.C.,SDj, and SDm (33°20'.9)

m = Ha of Moon (36°28.'7)

j = Ha of Jupiter (23°32.'9)

$\Theta$ = Value derived from m, j, L, (L-d), M and J as in (e) below

Auxiliary Values

L = 1/2 sum of d, m and j

$\varnothing = \frac{M+J}{2}$

**Procedure**

a. Compute M, J, m and j

b. Compute d

c. Add d, m and j. One half their sum is L.

d. Subtract d from L.

e. From the tables obtain log secant m, log secant j and log cosines of L, (L-d), M and J. Add these six quantities and divide the sum by 2. The result is log cosine $\Theta$.

f. Add M and J and divide by 2. This is $\varnothing$.

g. Compute the sum of and difference between $\Theta$ and $\varnothing$. Add the sines of the sum and difference and divide by 2.

h. The result is the log sine of one half the true (cleared) lunar distance; i.e, D/2

**Solution**

| | | |
|---|---|---|
| d: | 33°20.'9 | |
| m: | 36°28.'7 | log sec. 0.09470 |
| j: | 23°32.'9 | log sec. 0.03776 |
| | 2 \ 93°22.'5 | |
| L: | 46°41.'3 | log cos 9.83631 |
| L~d: | 13°20.'4 | log cos 9.98811 |
| M: | 37°16.'5 | log cos 9.90077 |
| J: + | 23°30.'7 | log cos 9.96236 |
| | 2 \ 60°47.'2 | 2 \ 19.82001 |
| $\varnothing$: | 30°23.'6 | |
| $\Theta$: | 35°37.'6 | log cos 9.91000 |
| $\Theta + \varnothing$: | 66°01.'2 | log sin 9.96080 |
| $\Theta - \varnothing$: | 05°14.'0 | log sin 8.96005 |
| | | 2 \ 18.92085 |
| D/2: | 16°46.'7 | log sin 9.46043 |
| D: | 33°33.'4 | |

## COMPUTING THE LONGITUDE

Once the lunar distance has been cleared, the cleared distance must be applied and/or compared to tabulated data in the Nautical Almanac for the time of observation. This is best accomplished by solving the oblique triangle formed by a) the moon's geographical position (GP), b) Jupiter's geographical position (GP), and c) the nearest pole. Two solutions are required; one for the nearest hour tabulated in the Nautical Almanac preceding the time of observation and the other for the nearest hour tabulated in the Nautical Almanac following the time of observation. In each case the angular value of the side of the triangle between the moon's GP and Jupiter's GP is computed. This side is equal to the true lunar distance. An interpolation is then made for the exact Greenwich mean time (GMT) of the lunar distance observation which is then compared to the local mean time (apparent time corrected for equation of time (Eqt) of the observation). The difference between the two converted to an angular value is the longitude of the observer.

**Step One**: Solution for the true lunar distance at 0200 27 August 1996 (GMT); the tabulated hour preceding the time of the lunar distance observation.

The GMT of the lunar distance observation on 27 August 1996 is 02-59-24

NAUTICAL ALMANAC DATA

| BODY: | Jupiter | Moon |
|---|---|---|
| DATE: | 27 August 1996 | 27 August 1996 |
| GMT: | 02 00 00 | 02 00 00 |
| GHA: | 86°58.'1 | 53°47.'4 |
| DEC: | S23°22.'6 | S13°20.'8 |

NAVIGATION TRIANGLE

Angle A: Difference between GHAs
86°58.'1
-53°47.'4
A = 33°10.'7

Side b: Co-Dec Moon
90°00.'0
- 13°20.'8
b = 76°39.'2

Side C: Co-Dec Jupiter
90°00.'0
- 23°22.'6
c = 66°37.'4

Calculator solution when the two sides and the included angle of the navigation triangle are known: (Law of cosines)

cos a = cos b x cos c + sinb x sinc x cos A
cos a = .23084 x .39667 + .97299 x .91791 x .83696
= .09157 + .74749
cos a = .83907
a = 32°57.'5

Logarithmic solution when the two sides and the included angle of the navigation triangle are known: (Law of cosines)

cos a = cos b x cos c + sinb x sinc x cos A
where:
a = True Lunar Distance
b = Moon Co-Dec (76°39.'2)
c = Jupiter Co-Dec (66°37.'4)
A = GHAj - GHAm (33°10.'7)

| | | |
|---|---|---|
| log cos b: | 9.36350 | |
| +log cos c: | 9.59854 | |
| | = 8.96204 | .09163 |
| log sin b: | 9.98811 | |
| +log sin c: | 9.96281 | |
| +log cos A: | 9.92277 | |
| | = 9.87369 | +.74760 |
| cos a: | | = .83923 |
| a: | | 32°56.'5 |

**Step Two**: Solution for the true lunar distance at 03-00 27 August 1996 (GMT); the tabulated hour *following* the time of the lunar distance observation.

a. The GMT of the lunar distance observation on 27 August 1996: 02-59-24

b. NAUTICAL ALMANAC DATA

| BODY: | Jupiter | Moon |
|---|---|---|
| DATE: | 27 August 1996 | 27 August 1996 |
| GMT: | 03-00-00 | 03-00-00 |
| GHA: | 102°00.'6 | 68°12.'0 |
| DEC: | S 23°22.'6 | S 13°12.'5 |

c. Navigation Triangle

Angle A: Difference between GHAs
102°00.'6
- 68°12.'0
A = 33°48.'6

Side b: Co-Dec Moon
90°00.'0
- 13°12.'5
b = 76°47.'5

Side c: Co-Dec Jupiter
90°00.'0
- 23°22.'6
c = 66°37.'4

d. Calculator Solution

(Two sides and included angle are known.) (Law of cosines)

cos a = cos b x cos c + sinb x sinc x cosA
= .22849 x 39677 + .97355 x .91791 x .83088
= .09066 + .74250
cos a = .83316
a = 33°34.'6

e. Logarithmic Solution

(Two sides and included angle are known.) (Law of cosines)

cos a = cos b x cos c + sinb x sinc x cos A
where:
a = True Lunar Distance
b = Moon Co-Dec (76°47.'5)
c = Jupiter Co-Dec (66°37.'4)
A = GHAj - GHAm (33°48.'6)

| | | |
|---|---|---|
| log cos b: | 9.35887 | |
| + log cos c: | 9.59849 | |
| | 8.95736 | .09065 |
| log sinb : | 9.98836 | |
| +log sinc : | 9.96281 | |
| +log cos A: | 9.91955 | |
| | 9.87072 | +.74250 |
| cos a: | | = .83315 |
| a: | | 33°34.'6 |

## COMPUTATION OF LONGITUDE

a. True lunar distance at GMT 02 00 00: 32°56.'5
b. True lunar distance at GMT 03 00 00: 33°34.'6
Difference: 38.'1
c. True lunar distance at GMT 03 00 00 : 33°34.'6
d. Observed (cleared) lunar distance: 33°33.'4
Difference: 1.'2

e. GMT of cleared lunar distance observation

GMT = (03 00 00) - 1.'2 hours
38.'1

38.'1 x = 4320s

x = 113.4s

x = 1m 53.4s

GMT = 03-00-00
- 1-53

GMT = 02-58-07

f. Local mean time of lunar distance observation

1) cos t = sin Hoj - sinL sin d / cos L cos d (Time Sight Formula)

where: Hoj = 23°30.'7
L = 38°52.'0
dJ:= S23°22.'6

cos t = sin 23°30.'7 - sin 38°52.'0 x sin 23°22.'6 / cos 38°52.'0 x cos 23°22.'6

= .39897 + .24898 / .71471

= .90617

t = 25°01.'1

2) GMT: 02 58 07
GHA(Sun): 224°09.'4
GHA(Jup): 101°32.'3
\Diff: 122°37.'1
tw(Jup): +25°01.'1
Tw(Sun):= 147°38.'2

147° converted to time: 09 48 00
37.'9 converted to time: +2 33
Time: 09 50 33
12 hour correction: 12
Local apparent time: 21 50 33
Eqt: +1 31
Local mean time: 21 52 04

3) Observer longitude:
Date: 27 August 1996
GMT cleared lunar observation: 02 58 07
LMT of lunar observation: 21 52 04
difference: 05-06-03
time to arc: 76°30.'8
Longitude by lunar distance: 76°30.'8W
Actual longitude: 76°55.'1W
Longitude error: -24.'3

During the late 18th and early 19th century the time reference in the English Nautical Almanac was apparent time. Events were tabulated in the almanac with reference to Greenwich Apparent Time (GAT). Thus, the observer who used lunar distance observations to establish the longitude of his position compared the local apparent time (LAT) of his lunar distance observation with the Greenwich apparent time (GAT) of the "cleared" lunar distance found by interpolation in the

Nautical Almanac. In 1834 when the time reference was changed to mean time, the procedure remained the same; the only difference being that the observer was required to convert the local apparent time of the lunar distance observation to local mean time by applying the equation of time (Eqt) to the local apparent time.

Apparent time was easily and accurately determined at sea by taking an altitude of the sun and solving for meridian angle t from values of latitude (L) declination (dec) and observed sun altitude (Ho). In the forenoon t was subtracted from noon (12 00 00) to obtain local apparent time; in the afternoon t was added to noon to obtain the local apparent time. Watches keeping apparent time were set regularly during the day using this procedure. If a body other than the sun was used for a lunar distance observation, the meridian angle t determined from using that body was corrected for the difference in GHA between the sun and the observed body to obtain the local apparent time of the observation.

# NEW PRODUCT

*By Ernest Brown*

## Are You a Navigator? I Mean Really!

*By A. E. Saunders*

*Alzarc Enterprises*
*Vineland, Ontario*
*LOR 2 CO Canada*

This book, consisting of some 118 questions, is printed on one side only to provide some space for the user's calculations and/or sketches.

Mr. Saunders' position, as stated in the book, is: "A really knowledgeable navigator should have a sufficient grasp of the mechanics of the relative motion of celestial navigation bodies to answer the questions without reference to the use of almanacs, tables, astronomical or navigational programs or calculators. The navigator should have a reasonable knowledge of navigational astronomy and basic approximate data for some of the bodies used for celestial sights."

Mr. Saunders also states: "The answers to these questions (five of which are reproduced here with the author's permission) will be approximate due to the non-availability of precise data. The altitudes, latitudes, longitudes, declinations and hour angles should be correct within a very few degrees and the locations requested should be exact as given - country, ocean, sea or continent as the case may be."

## Are You A Navigator - Really?

©1997 A. E. Saunders

Answer the following questions without benefit of: almanac, atlas, chart, CPS or navigation calculator.

1. You notice the star Alnilam is directly overhead on March 21st at Longitude 15° West. On May 14th you know it will be overhead somewhere in:

a) northern Brazil
b) central Africa

c) Saudi Arabia
d) central Mongolia
e) northern Australia

2. Capella is overhead while rowing across the Atlantic Ocean, in a small boat, every night at the same time during the month of June. Capella SHA 281° dec 45° N on June 21.

(a) What is your approximate vessel speed in knots?
(b) What is your True Course?

3. In question 2 above, at which of the following countries will you make landfall:

a) Argentina
b) France
c) Canada
d) New Zealand

4. If the star in questions 2 and 3 were Deneb and during the month of December, at which of the following countries would you make landfall:

a) Argentina
b) France
c) Canada
d) New Zealand

5. If the star in questions 2 and 3 were Canopus and during the month of September, at which of the following countries would you make landfall:

a) Argentina
b) France
c) Canada
d) New Zealand



**ANSWER TO DO YOU KNOW**...(From page 1)

How Eratosthenes (c. 276-194 B.C.) measured the circumference of the earth is not included in the fragments which remain of his works. However, the second century Greek astronomer Cleomedes in his work *On the Circular Motion of the Heavenly Bodies* describes Eratosthenes' method. A 1941 translation of this work by Ivor Thomas in *The Portable Greek Reader* edited by W. H. Auden and published by the Viking Press, New York, 1948, is used as the basis for the comment here.

Cleomedes' presentation of the method of Eratosthenese does not differ in principle from the usual description found in encyclopedias. In place of the well at Syene at the time of summer solstice there is a vertical pointer of a sundial. The fraction of the earth's meridian between Alexandria and Syene (Aswan) is found not by measuring how many degrees (7°.2) the parallel rays from the sun differ from the vertical at Alexandria. The fraction (1/50) is found by the use of a second sundial at Alexandria, specifically the vertical pointer and bowl of this sundial.

In the usual encyclopedia presentation, only one circle is used, the earth's meridian assumed to pass through both Alexandria and Syene. Cleomedes presents a second circle, also a great circle, which is the proper circle of an arc in the bowl of the sundial formed by the shadow of the vertical pointer.

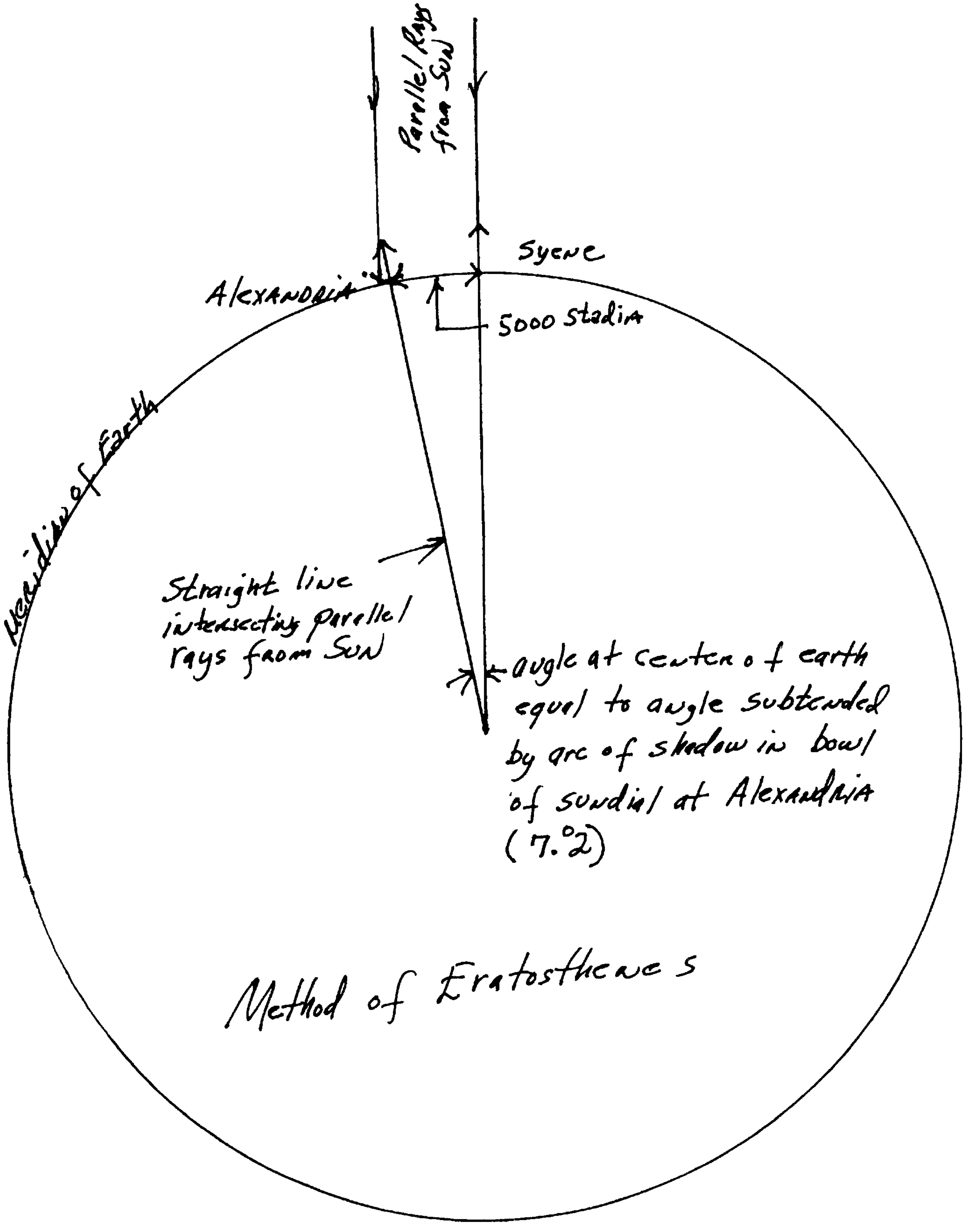
One extremity of the shadow is the base of the vertical pointer. At the other extremity, a straight line conceived as drawn from this extremity to the top of the pointer and on to the sun is one of the parallel rays from the sun, one of which can be conceived as passing through the vertical pointer at Syene and on to the center of the earth.

At Alexandria a straight line can be conceived as passing through the vertical pointer and on to the center of the earth.

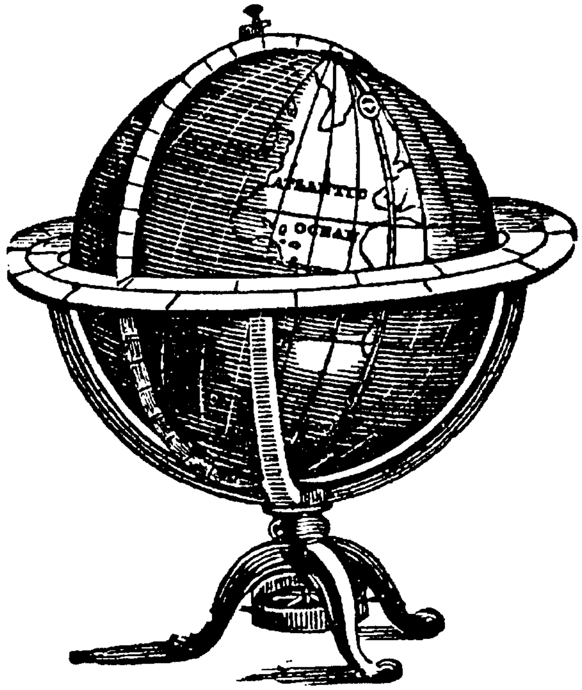
The result of these constructions is that there is an angle at the center of the earth subtended by the arc of the meridian between Alexandria and Syene. At the top of the pointer at Syene, there is a second angle subtended by the arc in the bowl of the sundial. These two angles are equal because they are alternate angles formed by the crossing of parallel lines by a straight line.

According to Cleomedes, Eratosthenes measured the arc in the bowl of the sundial as one fiftieth of its proper circle. Since arcs subtended by equal angles are similar, i.e. have the same ratio to their proper circle, Eratosthenes found the meridian of the earth through Alexandria and Syene to be 50 times the Alexandria to Syene arc (5000 stadia) or 250,000 stadia.

Eratosthenes had been told that a camel caravan needed 50 days to travel from Alexandria to Syene. He assumed that the rather constant speed of the camel was 100 stadia per day, thus the 5000 stadia between Alexandria and Syene.



Parallel Rays from Sun
Syene
Alexandria
5000 Stadia
Meridian of Earth
Straight line intersecting parallel rays from Sun
angle at center of earth equal to angle subtended by arc of shadow in bowl of sundial at Alexandria (7.°2)
Method of Eratosthenes


ATLANTIC
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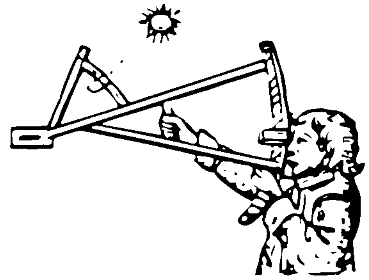
# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-SEVEN, FALL 1997

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Donation

George Lear, who taught Celestial Navigation as a volunteer in the Naval Academy Sailing Squadron and also as an independent teacher, notified the Foundation that he has a large quantity of instruction materials for donation to a non-profit ("charitable") organization or training activity. The materials include copies of HO229, HO249, the Nautical Almanac, the Air Almanac, Rude Starfinders, Bowditch Vols. 1 & 2, Coast Guard pubs, charts, and navigation texts. These materials were used by students during courses which George has taught. If you are interested and qualify, contact George Lear at telephone/Fax 301-986-0314.

### Reminder

As a member you can order charts, books and publications for your friends at a discount. We would, of course, be delighted to have them as members but as a courtesy to your members, we can help you with a chart, book or publication for a friend or relative. Consider a nautical or navigation gift for Christmas.

All past issues of The Navigator's Newsletter are available. They are $2.00 each, postage paid. Let us know which issues you want and they will be sent to your address of record, unless otherwise specified.

### 1998 Government and Commercial Nautical Almanac

Both almanacs are available from the Navigation Foundation. The Commercial version lists for $17.95 and the Government issue lists for $28.00. both receive a members 20% discount. Book rate postage is about $2.00 per copy. Order at any time via the U.S. Postal Service, E-mail, Fax or just a telephone call. If you call, please speak your name and telephone number slowly and distinctly. As I age, my aviator's ears are losing the ability to discern a lot of sounds on mechanical speakers.

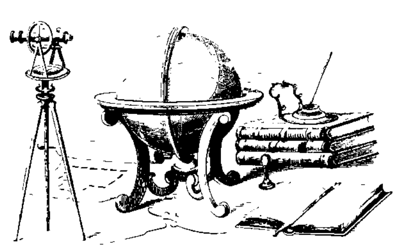
### Patience

Starting in October, my wife and I take a trip once a month for either one or two weeks. We continue traveling until the end of May. In recent years we have been traveling in Eastern Europe and have covered many countries. If anyone has plans to travel to Eastern Europe and would like to discuss the area with me, please call and leave your name and telephone number and I will return the call.

If you call the Foundation, the answering machine will give you one of two messages. One, if I am available, will say I will return your call within 24 hours. The other will give a date on which I will return and be able to give you a call. Please have patience. With my 38 years of traveling the globe without having my wife see the wonderful sights, I now want to provide her with an opportunity to see the things I enjoyed while she was raising our family.

### Celestial Navigation Courses

We get a few queries concerning celestial navigation courses, from the Internet. They are from many different areas of the world. If you teach celestial or know of a course in your area, please let us know and we can pass the word along. This will help us keep a file of courses for our members but we will also be able to provide the information to prospective members who ask us for information. Give us a note, e-mail, fax or any other means of communicating that you have available. We will keep an updated file.



# READERS FORUM

*Edited by Ernest Brown*

Member Bruce Stark of 3770 Onyx St., Eugene, OR 97405 wrote to the Executive Director on July 19, 1997:

"You were there, and would know, but it seems to me Admiral Davies was convinced lunar distances would be quite helpful in promoting the art of celestial navigation. The year before he died he was working on a new method that would make the calculation more acceptable, and he took time from his busy schedule to review my method (*Newsletter* issue twenty-eight, page three, and issue thirty-one, page thirteen).

"I put together the full set of tables for that method several years ago. Using the tables, taking it easy and checking as I go along, it takes me about seven minutes to clear a lunar distance. It takes another twelve minutes to get two comparing distances from the *Nautical Almanac* and find Greenwich time.

Since last fall I've been trying to get the tables arranged, explained, and cleaned up enough to present to the public. You can judge for yourself how far I've succeeded. A few glitches remain in the explanation and formatting, but I can't find enough to justify an immediate reprint. I'm sending two copies, one for you a ıd one for Lt. Comdr. Luykx.

"Luykx's first two articles on the lunar are well worth reading, and I'm looking forward to the third. I'm especially glad he pointed out that for the better part of a century after Harrison 'solved the longitude,' chronometers didn't really solve the problem.

"Perhaps my copyright warning overshoots the mark. You have permission to print the preface to the tables in the *Newsletter*—I'd be delighted if you did, especially the last part of the preface.

"You may have forgotten, but we had a good telephone conversation back in 1991. I hope we can talk again."

— *Sincerely, Bruce Stark.*

*Editor's Note: See NEW PRODUCT at back of this issue.*

Member Charles W. Taylor of 10910 SE 201 St., Inglis, FL 34449 wrote on 7 October 1997:

"Enclosed is my check for $30.00 for one year of *The Navigator's Newsletter*. I have recently pored over the past 5 years issues of the Newsletters, thanks to member Tom Dalby. I have found them to be informative and interesting.

"I am one of the few who have installed member Bill Murdock's TI-82 program (Summer 1996 Newsletter) and have now adapted it to the New TI-86. It is certainly a comprehensive and accurate set of programs.

"While I hope some day to actually navigate using a sextant, I presently teach celestial in the Crystal River, Florida Power Squadron."

— *Sincerely, Charles W. Taylor*

Mary Chibnall, Assistant Librarian, Royal Astronomical Society, Burlington House, Piccadilly, London W1V ONL, wrote on June 18, 1997:

"We have in the past received *Navigator's Newsletter* from you, which we have found extremely useful in our library.

"Thank you very much for sending us the following issue of it:

*Navigator's Newsletter* No. 55 (Spring 1997)

"Could we possibly have the following back number of it, which we appear not to have received: *Navigator's Newsletter* No. 54 (1996-1997)."

— *Mary Chibnall, Assistant Librarian*

Member Robert Eno of Box 1213, Iqaluit, NWT XøA øHø Canada wrote by E-mail on Nov. 10, 1997:

"... On another topic, I recently received the latest issue of *The Navigator's Newsletter* and as always, I thoroughly enjoyed it. There never seems to be a shortage of fascinating (sometimes esoteric) topics to cover, nor does there seem to be a shortage of interested navigators to write about them. All of which brings to mind a query that I posed to you some time ago, but never did receive a response. With all of this expertise and interest within the Foundation's membership, why don't we organize a conference where we can all gather and discuss our common interests? The conference would consist of the delivery of seminars/papers on various topics (John Luykx certainly comes to mind as a speaker); follow-up discussion groups; workshops, etc. etc. I suggest that it be held in Washington, DC or Baltimore; somewhere in your vicinity. I really do believe that many of the Foundation's members would be interested in such a conference. Certainly I would be willing to make the long trip from Iqaluit to attend.

"Why not put it to the members in the next newsletter? If enough people are interested and enough of our in-house experts are willing to deliver papers or seminars, then I do not see why this cannot be put together. A good friend of mine is a member of some obscure cartridge-collecting group and even they have regular gatherings where they exchange information (and cartridges). The Institute of Navigation holds regular meetings. Why not us? It would not only be a good opportunity for the members to meet and discuss our common interests but might serve to strengthen the Foundation, thus ensuring its continued existence and relevance as a serious navigation organization. (I'm not saying that it is irrelevant now; I just think that conferences tend to increase the profile and prestige of an organization). The Foundation for the Promotion of the Art of Navigation is the only organization that I know of that is dedicated to the preservation of the 'old' methods. Is it not time we expanded our scope a bit?

"Obviously, I am too far away to be in a position to do the actual ground work of organizing such a conference, but if there is anything that I could do from up here, I am certainly willing to help out. Just to show you that I am not just pulling this idea out of thin air, here are a few suggested topics of discussion that I would like to throw out:

"1. GPS: Will it mean the ultimate demise of celestial?

Or will it mean a renaissance of celestial as a backup? My understanding is that GPS will eventually supersede (if it hasn't already) and render obsolete, most other forms of electronic navigation systems such as LORAN and Omega; apparently governments can no longer afford to keep all of the systems up and running so pretty soon, GPS might be the only system left. Perhaps celestial will re-emerge as the only backup system available. Consider this: the US Army recently demonstrated that a satellite can be knocked out of the sky using ground-based lasers. As one US politician said: (paraphrased) 'We've shot ourselves in the foot.' So what kind of position does that put the allied defense system (including navigational) many of which are so heavily dependent on satellite technology? Will the day ever come when the powers-that-be start beating the bushes looking for old geezers who still know how to use a sextant?

"2. Sextant Technology

Before GPS, a number of firms had been developing some pretty high tech sextants (refer to Bruce Bauer's 'Sextant Handbook'). What happened to them? Has celestial come to a standstill in terms of development? Anything out there? Any budding inventor/geniuses have some ideas?

3. The Peary Controversy

I think that I can safely say that this topic alone would generate some interesting, if not heated discussions. I've read a lot of dogma from both sides. Maybe it is time to have a sober, intelligent discussion on the subject, without resorting to slander, name-calling, and bad feelings all around. Then again, perhaps it is just too hot a topic to discuss....

"4. Specialized Navigation

Polar, tropical, desert, underwater, outer space (I read about a 'space sextant' in an old Dutton's; it would be interesting if someone could bring one in and explain how it works).

"In addition to seminars/papers, workshops and discussion groups could also be organized. John Luykx, for example, could present a workshop on bubble sextants: history, repairs, calibration.

"So Terry, I leave the ball in your court. I think that this would be a great conference and I think that it would work. Like I said before, I am willing to help out from up here in whatever way I ca¨œ We have the expertise, the interest and if I am interpreting the newsletter correctly, an enthusiastic membership. I look forward to hearing a response from yourself, the directors and the members.

"I will be in touch."

*— Keep up the good work. Robert Eno.*

*Editor's note: The Executive Director replied in part: Most of our members would rather stay at home and do all of their conferencing by letter and telephone. Admiral Davies tried to hold a conference in Annapolis at the Yacht Club, just a few people were interested. We will see what interest is generated by your letter.*

Member Peter H. Dunphy of 12 Mitchell St., Apt. 10, Saint John, N.B., Canada E2K 4Z5 wrote on Nov. 10, 1997:

"I recently received Issue 56 (Summer 1997) of *The Navigator's Newsletter.* My copy was missing pages 9, 10, 11 and 12, and pages 7, 8, 13 and 14 were duplicated. Please send me a complete issue or replace the indicated missing pages.

"I would like to enlist the help of any knowledgeable members of the Foundation for a project I have undertaken for the Canadian Power and Sail Squadrons—a sister organization to the US Power Squadrons and the US Coast Guard Auxiliary—on the development and revival of techniques, tools, wrinkles and rules of thumb for pilotage in waters whose customary aids-to-navigation are few and far between, lighted aids are reduced in intensity and range, and where hydrographic charts no longer give any topographic information.

"Recent budget cuts have led the Canadian Coast Guard to eliminate many visual aids to navigation such as buoys and light stations. The shift to electronic navigation systems in commercial and naval vessels has markedly reduced reliance on visual aids, and new development in hydrographic surveying have all but eliminated land to a 'no water zone'. This does not bode well for the pleasure boater or the 'Neo-Luddite' boater who eschews GPS, electronic navigation, etc.

"Such changes will render much of the content of CPS coastal navigation courses—and no doubt those of USPS and USCGA also—obsolete and 'useless' to today's boater.

"I would appreciate it if any Foundation member could supply me with any references, articles, or personal techniques useful in overcoming this pilotage problem. My limited research to this point suggest that such techniques might include 'seamen's eye', 'visual navigation' and 'small-angle (horizontal and vertical) navigation.'.

"Thank you for your anticipated cooperation in this venture."

*— Yours, Aye, Peter H. Dunphy*

*Editor's note:* The Practical Pilot: Coastal Navigation by Eye, Intuition and Common Sense, *by Leonard Eyges (a Foundation member) was reviewed in Issue Twenty-six (Fall 1989).*

Director Roger H. Jones of P.O.Box 2430-867, Pensacola, FL 32513 and of Yacht *Allidoro* wrote from Provincetown, RI on August 26, 1997:

"Avast, ye Irish Hurricane Admirals, heave to under the lee of the long boat, and I'll bring ye up to date on the Northerly Wanderings of *Allidoro* and her crew of yours truly and Long Tom Drews.

"We departed the Port Everglades Sea Buoy at 12:00

on June 5, 1997, bound for St. Augustine via the outside ocean route. All sails were set in a light N.E. breeze, and the speed was 5.8 knots. The push from the inshore Gulfstream was a factor, and it was estimated to be in our favor by at least two knots. After a calm night at sea ten to twenty miles off the Florida coast, a calm and clear June 6th arrived. A phone call came in also alerting me that a very dear friend of more than 40 years, Dr. Peter Mamunes of Parkland, Florida, had died very suddenly in Ithaca, New York, while attending our Class of 1957 Reunion at Cornell University (an event which I regretfully missed due to our late departure from south Florida in *Allidoro*). We changed course for Cape Canaveral, and put in there and then proceeded directly to the Intracoastal Waterway (ICW) and further north via that route to St. Augustine. In St. Augustine, I rented a car, drove all night to Richmond, Virginia, and attended Peter's funeral. After making the return trip by car, we departed the Bridge of Lions in St. Augustine at 0715 on June 12th, and headed for Cumberland Island, Georgia, via the continuing ICW.

"As expected, the channel and buoy markings in the Nassau Sound on the ICW north of St. Augustine were totally confusing. Many vessels avoid this area like the proverbial plague because of the danger of grounding, and with our seven-foot draft I was a bit worried. We got through this area OK, but we had to deliberately ignore one key buoy and proceed well along the supposedly wrong side of it in order to avoid a four-foot shoal on the 'correct' side, the presence of which was noted by the alarming readings on the depth sounder. Joy to the World and the Army Corps of Engineers whose jurisdiction this was indeed!

"Arrival at Cumberland Island was at 1750 on June 12th, and we anchored in good holding territory just off the Park Service dock. Cumberland Island is a pristine nature preserve with secluded paths beneath live oaks hung with Spanish moss, and it is truly a nature lover's paradise. The burned remains of a Carnegie mansion are also there along with a very old burying ground that at one time was the resting place of Light Horse Harry Lee of Revolutionary War fame. He was the father of General Robert E. Lee, and was later reburied in Virginia.

"It was off the hook at 0705 on the 14th, and we proceeded further north on the ICW to Jeckyll Island, Georgia, after passing the King's Bay nuclear submarine base in the St. Mary's River. It is not uncommon here to meet a surfaced submarine in the ICW, and when in radio contact with one in order to coordinate traffic in the narrow channel, the good ole boys of the U.S. Navy refer to themselves aboard a submarine as "Navy Unit in the channel."I guess they don't want the listening public aboard the numerous small vessels to know that they are, in fact, a unit of over 450 feet in length, powered by a nuclear reactor. More about Navy security precautions later in this tale when we get to New London, Connecticut. (*Allidoro's* nine-foot rubber dinghy posed a threat to the *Nautilus*, the first nuclear submarine.)

"Jeckyll Island is a must stop because of its beauty and the old historic area of 'cottages' of the super wealthy set—the Vanderbilts, Firestones, and many others of similar industrial and bank account might. This village of twenty to forty-room cottages reminds one of Newport, Rhode Island, but the setting is Old South as opposed to Upper Crust New England.

"After Jeckyll, we went up to the St. Simon's sound and re-entered the Atlantic Ocean for a passage to Charleston, South Carolina. Our departure was on June 15th, and our first night at sea was a rough one. In fact, it was rough enough to really shake up the two fuel tanks and their respective diesel oil, and we experienced a problem with gunk in the fuel filters that had apparently broken loose from its perch on the sides of the tanks (inside, of course). Meanwhile, we were proceeding under sail, and we eventually arrived in Charleston. Lots of fun there. Great walking tours through the old market area and the old homes dating back to a very different time before the Civil War. We also got acquainted with the lore of Charleston's celebrated ghosts, one of whom was a lusty lass who kept a tavern where she had an arrangement in one of the guest rooms to tip the bed into a cellar via a hidden trap door, and in the cellar the guests were murdered. She was caught and hung in downtown Charleston, and her ghost reportedly visits the place of her imprisonment.

"The real fun in Charleston, however, was cleaning out the starboard fuel tank, after hand pumping its contents of more than fifty gallons of dirty diesel fuel into jerry jugs. We also replaced a clogged bilge pump line there with a 'temporary' splice that is till working fine. On a complex vessel, don't mess with what appears to work, and there is a Law that bespeaks a solemn truth: at any given time, one or more systems will be on the blink! At present, that includes: the anchor windlass, a masthead light, the battery charger, an emergency engine-driven bilge pump and deck wash system, and one or two other little goodies. None has prevented us from continuing along the Northerly Wanderings, and thank all the female gods for my new solar panel system which, even at a dock, produces the electricity for charging that the shore power to a charger would otherwise provide.

"On June 19th we took on new, clean fuel and departed Charleston for the ocean route to Beaufort, North Carolina. We were deliberately going 'outside' from the ICW in order to make good time, although this meant bypassing lots of beautiful and interesting spots along the Waterway. And at 0100 on June 20th, I performed a simple thing as requested by my cousin, Dr. Brenda Kiessling. From the log:

"June 20th, 0100. Position 33-02.9N; 78-39.2W - in the Gulf Stream off the coast of South Carolina. I quietly spread the ashes of Oscar Kiessling and Alice Heyl Kiessling upon a calm sea. The moon was full and bright, Jupiter was rising in the Southeast. There was a surreal day-like quality to the night, with a gentle SW wind, a vessel speed of only two knots, and celestial light almost bright enough to read by. Rest ye well, Uncle Oscar and Aunt Alice. May you travel gently forever upon the Great Gulf Stream of Earth, and upon the Greater Stream of Elsewhere!

"We arrived and entered the Beaufort inlet at 1722 on June 20th and proceeded to anchor well along in the deep creek that fronts this beautiful little town. The next day we saw my old friends, Karen and Dwight Rettie, and Karen made us some memorable crab cakes for lunch. She and Dwight are no longer living aboard their sailing vessel, but they have new adventures in a large motor home.

"June 22nd saw us up and underway from Beaufort on the inside, ICW route, at 0840. That night we anchored in the Pungo River at mile number 139 on the Waterway south of Norfolk, Virginia. On the 23rd we again put the hook down in the flank of the Waterway channel at mile number 60. On the 24th, I adjusted the prop shaft gland to allow a greater drip of sea water where it passes into the tube leading to its exit on the aft edge of the keel. These glands provide for sea water cooling and lubrication, and they mean that there is a constant drip into the bilge, but the automatic pumps keep it nice and dry. Following the packing gland drill, we were again underway at 0725 on the 24th of June, and after passing through the Waterway lock at Great Bridge, Virginia, we entered Norfolk via the Elizabeth River.

"Here there is a fairyland of naval vessels of all vintages, including the WWII battleship *Wisconsin*, numerous carriers, even more numerous lesser vessels, and even some modern submarines. The hook was down off of Hospital Point across the river from the restored Norfolk downtown waterfront at 1930 on June 24th. During the evening we watched the huge ocean vessels, mostly tankers, passing by our anchorage. We were only 100 yards from them, but at their reduced harbor speeds they passed silently like great brightly lighted clouds in a twilight sky.

"Norfolk has lots of interesting places to visit. My favorite is the General Douglas MacArthur museum. This is a must for any history-minded person. There is also an air and space museum, a wonderful sea aquarium, and much, much more.

"We remained anchored in Norfolk on June 25th, and, indeed, had not used a mooring or marina slip during the 900 (plus) nautical mile passage from South Florida except for one night in Jeckyll Island. We also had touched the bottom only twice during the run of days since June 5th. Practice makes for some improvement, but my seven-foot draft on *Allidoro* requires some very careful and precise navigation in many places along the waterway and in the ocean inlets.

"June 26th dawned bright and promising, and then went to hell! We were on a passage up the Chesapeake Bay to Annapolis, and at 2100 (9:00 p.m.) a storm came up quite suddenly out of the Northwest. Winds increased rapidly to over 55 mph, and we had a Chinese Fire Drill getting all the sails down—in a hurry. The waves were short and steep, and it was pitch black. We were more than twenty miles from the nearest shelter—in the wide lower Bay. So we slogged into it at 1.5 knots under power. A miserable night, but not unmanageable. Radar was a big help here because the visibility was nil, and there was still big ship traffic on the Bay to contend with. We heard one Coast Guard Cutter on the radio reporting that it was making a run for shelter. They were a lot closer to the shore, and it was a sensible thing for them to do. After four hours, the wind began to die down, the direction of it shifted (a clear indication that the center of the low had passed), and the barometer began to inch up a bit.

"June 27th was one of those crystal clear days, with visibility from 'here to forever' and we were by late morning approaching Annapolis, which lies 120 miles north of Norfolk. The anchor went down in Back Creek, Annapolis at 1235. This was my old stomping ground, as I kept a smaller sailing vessel there in the late 1960's and early 1970's.

"We were in Annapolis until July 13th. Repairs to a starboard rubbing strake, new batteries, a visit to my son, Roger, and his wife, Janet, and my three grandchildren, visits to old friends in Annapolis and the Washington, D.C. area, and numerous other things transpired. Tom found Annapolis to be 'his kind of town.' On July 4th we watched the spectacular fireworks sitting in the dinghy and tethered to the Naval Academy sea wall.

"Enough of Annapolis! On July 13th we motor-sailed to St. Michaels on the Eastern Shore of the Bay, and anchored in Long Haul Creek just off the dock of my old friend, Les Callaway. We were there for several days, and it was good to see Les, as he had spent the winter of 1995-96 aboard with me and Peter Wolf in the Bahamas.

"The 16th dawned calm and without a breath of wind. Up the Bay we went under diesel power to Baltimore, and we anchored there in a pocket off of Fells Point. The next day we re-anchored in the inner harbor adjacent to the WWII submarine USS *Torsk*, which is part of a maritime museum. She sank the last two enemy vessels of WWII. Also there is the Chesapeake Light Ship and the Coast Guard Cutter *Taney*. *Taney*, named for the great Chief Justice, is the sole survivor of the attack on Pearl Harbor that is still afloat. In a sense we became part of the maritime museum too, as we were anchored bout 50 yards from the paddle boat docks, and we had a constant stream of paddle boat visitors interested in *Allidoro* with her Los Angeles hail port. (I sailed her to the East Coast from Los Angeles in 1994.)

"While in Baltimore we walked to the nearby Camden Yards Stadium of the Baltimore Orioles, and took in a night baseball game. Also visited the home of Edgar Allen Poe, and we watched a marvelous actor portray him with readings of his poems and short stories. Baltimore is a fun town, and we were there until July 28th.

"Comes the 28th, and again no wind. It was up the Bay to the Sassafras River and the quiet little town of Betterton two miles into the River. You have to see Betterton to believe it. It is truly a throwback to another, more innocent era. We went for a walk at night and came upon a couple out walking their dog. In conversation with them I noted that there seemed to be only one pay phone in town. The woman told me that no one locks a door, and that I should feel, Íee even at 2:00 a.m. to come into her home unannounced to use the phone. She was sincere, but I didn't have to take her up on her offer.

"We were anchored over the night off Betterton, and the next day brought one of those incidents that can only be counted as 'paying the piper for the cruising lifestyle.' The nearly one-half-mile-wide mouth of the Sassafras River was a virtual forest of crab and fish traps. While winding our way through the buoy markers, some only 25 feet apart, we snagged a buoy line on the prop. Helmsman got the engine into neutral fast, and an anchor overboard even faster! Then, yours truly had to drag out the full SCUBA gear and go under the boat to cut loose the line wound tightly around the prop blades and shaft. This was a 45 minute task in water visibility of about 18 inches. It was done with a sharp bread knife, and mostly by feel. The bread knife is the best tool for the job because it has saw-like teeth, and it takes some teeth to saw through a tightly wounc nylon line. The jellyfish made life under the boat all the more interesting. (They were nothing compared to the ten-foot alligator that visited me once in South Georgia when I was also then cutting away a fouled line. Gator fellow was not aggressive, but he got my attention by watching me from four feet away, and I was persuaded to get back aboard post haste!)

"Well, we did get loose, and some waterman lost a fish trap, but we were underway again after a while, and we proceeded to Schaeffer's Canal House dock on the Chesapeake and Delaware Canal. The currents in the canal can reach 5 knots, so it was prudent to take a firm hookup to a dock for the night, and await the fair current that would pop us through all 12 miles of the canal the next day.

"The current running eastward in our direction the next morning put us into the Delaware River some 50 miles above Cape May, New Jersey, and the Atlantic Ocean well before noon on July 30th. We plugged into the GPS computer various waypoints and routes down the Delaware, around past Cape May, and up the Jersey coast to Sandy Hook at the mouth of the New York harbor. We had intermittent sailing winds and spent a long night passing Atlantic City and other Jersey shore places, and came up to Sandy Hook on July 31. Via a true forest of confusing markers and sea lanes we rounded Sandy Hook and put down the anchor off of Atlantic Highlands at 1610 on the 31st (ten minutes after 4:00 pm.). Again we explored ashore, saw a couple of movies, and just 'regrouped' for a few days. Also did considerable research on the problem of navigating the Hell Gate in New York City. And on August 1st I changed the engine oil and transmission fluid. This is a messy and intricate job on *Allidoro*. Also cleaned the turbo charger air screen and the oil breather air screen. This is big time Gunksville!

"On August 3d we departed under engine up Sandy Hook Bay and into the lower Hudson River. We passed close aboard the Statue of Liberty and then entered the East River at the Battery at the lower tip of Manhattan Island. This was carefully timed to arrive at the Hell Gate at the changing of the current direction there, as the Gate is narrow with very swift currents and lots of nasty whirlpools. We hit it right, and passed into Long Island Sound with no problems. The Hell Gate is notorious, and I have to admit I was somewhat concerned in advance.

"That night we anchored just east of the Throggs Neck Bridge in Western Long Island Sound. The next day we visited City Island, and then proceeded to Hempstead Bay and the Hempstead Harbor Club on the north shore of Long Island. We took a mooring there, and explored the quaint town of Sea Cliff.

"The weather on the 4th had been rainy and overcast, but on the 5th of August it cleared, and we were off to Norwalk, Connecticut, still in the western end of the Sound. The entrance channel into Norwalk is a long and winding avenue flanked on each side by very shallow waters and fronted in the Sound by a group of islands. We found our way in and anchored in 15 feet where the chart indicated it was only five feet deep. Went ashore by dinghy and called my old friend and Justice Department colleague, Vince Promuto. Vince is also a former All Pro guard for the Washington Redskins. He spends his summers at his waterfront home in Norwalk and his winters in Ft. Lauderdale aboard his large motor vessel at the Coal Ridge Yacht Club. It was good to see Vince and call other old buddies from his terrace phone.

"On August 6th *Allidoro* cleared Norwalk and headed east, bound for New London, Connecticut. Had we gone all the way it would have meant entering the harbor at night, which I don't do unless I have prior local knowledge. Thus we anchored on the Connecticut shore of the Sound at Hammonasset Beach at 1630 on the 6th. It was a lee shore in a westerly wind, but we were firmly hooked and did not drag a bit. The radar variable range feature permits establishing a range ring at any distance from the vessel, and when the ring just touches the shore as viewed on the radar screen, any relative movement can be instantly seen, even a movement of as little as a few feet.

"August 7th saw us into New London and an anchorage in Greene's Cove on the western shore of the Thames River by a few minutes before 2:00 in the afternoon. The weather turned to overcast gray skies on the 8th, so we went by dinghy several miles up the Thames to the Submarine Museum. The *Nautilus* is the feature exhibit, moored permanently in the river next to the large museum building. As we approached her in the rubber boat, no less than three naval ratings warned us away, sternly telling we were entering restricted waters. Meanwhile a steady stream of visitors was to be seen entering into the *Nautilus*. Our red rubber boat posed such a threat to the world's first nuclear submarine that she lost her serene composure and rocked in the wake of a passing large ship, despite heavy steel mooring beams. The U.S. Navy wanted to blame that on us with our 3.3 hp outboard engine, but the three naval ratings were embarrassed to suggest it. We therefore moved to a spot 500 yards down the river and tied up to a heavy plank and walked up the railroad tracks to the museum. These tracks run through the museum grounds and the people visiting the *Nautilus* cross the tracks to get to her berth. Upon reaching the museum the three ratings were horrified to learn we had come up the tracks, even though they were open with no gate or enclosure. Approaching from the south via the tracks posed a shoreside threat, it seems. The Navy needed a modern Paul Revere to warn 'one if by land, two if by sea!' So it was back down the tracks, then up the embankment to the road, and back to the museum by road, whereupon we were received with open arms and three naval ratings who could not then do enough to make us feel at home. It was all worth it, and the museum is free. It is a must stop for cruising sailors, but go by road.

"I had become acquainted with Admiral Hyman Rickover, the father of the nuclear Navy, when I worked for the Atomic Energy Commission in the early 1960's. The *Nautilus* was then still a very new boat, and she was the first to travel under the arctic ice cap to the North Pole. Her mapping of the bottom features in the Arctic Ocean more than 40 years ago played a then-unforeseen role in my own life in 1990. I was in 1990 (and still am) a member of the Board of Directors of The Navigation Foundation, and it had been commissioned by the National Geographic Society to do the definitive study of Peary's evidence that he reached the Pole by dog sled in 1909. Peary took soundings with a long length of piano wire (6000 feet) through holes cut into the ice cap. His data on bottom depth changes near the Pole conforms exactly to the actual Lomonosov Ridge now known to exist near the Pole and the presence of that underwater feature was noted by the *Nautilus*, confirming bathymetric data published by the Russians in 1954. (A Russian nuclear sub did not equal the record of the *Nautilus* under the ice cap until some years after the run of he *Nautilus*.) Thus, for me, a visit to the *Nautilus* was doubly meaningful.

"While in New London I made a road trip to Northwestern Connecticut to visit my mother in a nursing home. Tom did serious research on New London watering holes and night spots during my four day absence. He is a dedicated researcher whose findings are generally not to be questioned.

"August 14th saw us off to Block Island, Rhode Island, in the Atlantic beyond the eastern tip of Long Island. We entered the narrow cut into the large Great Salt Pond in the middle of Block Island and anchored at a spot well distant from the docks because of the many permanent moorings. In fact we were a mile by dinghy from the dinghy dock, but the dinghy ride was worth it. Block Island is a picture perfect New England destination, and there were several hundred private vessels in the harbor. It is also served by large ferry boats from Pt. Judith and Montauk Point. President and Mrs. Clinton were due in while we were there, but we departed prior to their arrival. Block Island is highly recommended as a destination for cruising sailors. This is now fog country, so be prepared with radar, etc. On one dinghy trip across the Great Salt Pond I had to use a compass to reach the docks, as the fog reduced the visibility to about 100 yards.

"Dawned the 17th of the month of August, and we were off to New Bedford, Massachusetts. In the 19th Century, New Bedford was probably the principal U.S. whaling port, and *Moby Dick*'s opening pages are centered on New Bedford. The sister town of Fairhaven across the Acushnet River from New Bedford is the place where Joshua Slocum rebuilt his *Spray* and launched her on his epic solo circumnavigation (the first ever) in the year 1895 (if memory serves me correctly). Both towns are delights to visit on foot and the whaling museum in New Bedford is a must. It sports the world's largest ship model, a one half scale of a 118-foot whaling brig that is itself 59 feet long with complete detail including sails and rigging.

"New Bedford has an impressive, closeable hurricane barrier at the mouth of the harbor. We entered and anchored just off of Crow Island well inside, and a short dinghy ride to a hospitable marina. It is still a working seaport with a large fleet of serious fishing trawlers.

"(Historical note: When Melville wrote *Moby Dick* he based it upon the true event of the sinking of the whale ship *Essex* by a very large whale. *Essex* was in the Pacific equatorial whaling grounds when she was repeatedly rammed by a bull whale estimated to be over 85 feet in length. She was sunk in 1819, the year of Melville's birth, and the epic voyage of survival in open boats by the crew of *Essex* almost rivals that of Captain Bligh and his mates after the mutiny on the *Bounty*. Those same Pacific equatorial whaling grounds have been the general locale of the sinking by whale attack of several modern yachts. Mariners, it might pay to do research on the Pacific whaling grounds when planning a voyage from Panama to the South Pacific.)

"On August 19th *Allidoro* departed New Bedford and motor-sailed to an anchorage at the western end of the Cape Cod Canal. We spent a quiet night on the hook, awaiting low tide the following morning, as the flooding tidal current runs through the Canal towards the eastern end. Again, it was a matter of not trying to buck a 5-knot current. Up at 0530 on the 20th, we rode the current through the Canal into Cape Cod Bay, and proceeded to Plymouth, Massachusetts, twenty or so miles up the coast from the eastern end of the canal.

"A serious gale was brewing, so we took a dock space in Plymouth, and indeed late in the night of the 20th it turned a bit nasty. Winds of over 40 mph with waves in the shallow Cape Cod Bay that were 12 to 15 feet high. We went ashore to explore Plymouth where the Pilgrims landed off of the *Mayflower* in 1620. In fact, the enshrined Plymouth Rock was just a short distance from our berth. Midst all the rain I went to the Mayflower Society to do some research on my Mayflower ancestor, Edward Doty. He was the indentured servant of Stephen Hopkins, but he apparently had served his contract by 1627 because he shared in the division of cattle in that year. He was a bit of a rogue and was sentenced to be 'tied neck to heel' for fighting a sword duel in the early years of the Plymouth Colony. Hopkins intervened and got him off lightly, but the records show he was involved in many disputes and law suits before his death in 1655. By his second wife, Faith, he sired nine children after 1634, and they produced *seventy-five* grandchildren! I am descended from one of Edward's sons, and also from a Fuller who was another Mayflower passenger. I've never made much fuss over this, but it was fun to spend a rainy, windy day poring through historical records. Doty, I noted, was something of a rogue in another sense as well. He married Faith when she was barely 16, and this was in 1634. He must have been over 35 years of age, as he was born in England before 1600. Poor Faith. He gave her no rest during the twenty-one years before his death. Can you imagine her trying to keep track of 75 grandchildren?

"We lingered at the marina in Plymouth while repairs were performed by the yard. A protruding bolt head on the dock face had deeply scratched *Allidoro's* hull. This gave us a chance to visit my old friend Saul Arvedon, whose home overlooking Cape Cod Bay in South Plymouth is a true museum in its own right. It is a large A-Frame, filled with paintings, carpets, nautical curiosities, books, and hundreds of items that can be described as flights of fancy. It is Saul to a T, and is a charming place. He even has a genuine Rembrandt etching, signed by the man himself, hanging in a place of honor, but you would have to have it pointed out to you, because its art-work neighbors are numerous and arranged in no discernible order. Saul also spends his winters in South Florida.

"It was off to Boston on August 22. Here we moored just off of Rowe's Wharf in the center of the downtown Boston district. Long walking tours of Fanueil Hall, the Quincy Market, the Old North Church where Paul Revere hung his warning lanterns, the home of Paul Revere, the Boston Commons, and the Tea Party ship. We also went to see the USS *Constitution* by dinghy.

"Then on the 25th, we motored on a dead calm sea southeast across Cape Cod Bay to Provincetown at the tip of Cape Cod. We tucked inside the huge harbor surrounded by the curling tip of Cape Cod, and anchored in 20 feet. Again it is a long dinghy ride to the dock. We are about to go ashore to rent bikes. Provincetown was also first settled by the Pilgrims, and like Plymouth it is steeped in history.

"From here our route will be back to Boston, then further north, and then south to Martha's Vineyard and Nantucket. After that, we'll begin the 1,700 mile passage back to South Florida.

"We've had almost perfect weather the whole time, with the exception of the days and nights noted. We've also had very light winds, or almost no wind at all. We've sailed when we could but have not been too much the purists to use the engine.

"I hope you will find at least some small interest in the above account. I've gone on at length, for which I offer my apologies. I'll end now with my fond wish: *MAY DOLPHINS DANCE BENEATH YOUR BOWS!"*

— *Roger*

Member Leslie J. Finch of 261 Madison St., Mastic Beach, NY 11951 wrote on 8 Nov. 1997:

"It is November again so it's time to order a 'Nautical Almanac for the year 1998.' Please find a check for $25.00 which I hope will cover all costs.

"As you might remember, I am a sergeant in the New York Army National Guard. The annual training for 1998 is to be held in Honduras for our Engineer company. We are to build or start to build a school building in an under-developed area of the country. This will be in January-February. It will be my last A.T. before retirement. I am going to try to make an adventure of it, to be an explorer, find our position with sextant and artificial horizon, find our altitudes by the temperature of boiling water, and so on.

"This brings me to the point. I need information about how to find altitudes by the boiling point of water. What temperature indicates what altitude? Can you help me?

— *Yours truly, Leslie J. Finch*

Member E. B. Forsyth of 2 Bond Lane, Brookhaven, NY 11719 and of Yacht *Fiona* wrote to us from Almeria, Spain on May 17, 1997:

"Dear Friends, in this sixth newsletter, May has rolled around again and it's time to leave the boat for a month. This time last year we were in Tahiti, since then we have sailed about 18,500 nautical miles. We sailed 5,000 miles of that since I wrote the last newsletter in Aden, the weather could not have been different - we swapped the Pacific and Indian Ocean Trade Winds for the head winds of the Red Sea and the Mediterranean. But mostly this letter is concerned with what we did on shore in the Old World, not our time at sea. After we left Aden we sailed directly to Port Suez, at the south end of the Canal. This took sixteen days. The Trades stayed with us for the first few hundred miles but after that we had persistent NW'ly winds — dead on the nose — with a typical velocity of 25 kts. After a couple of days of beating to windward the old Genoa jib blew to smithereens. I was attached to that sail; we rounded Cape Horn with it set in 1992 and it had sailed many tens of thousands of miles. It took a couple of days before the weather moderated and we could safely lower it and set the Yankee jib. When we got to Port Suez the log showed we had sailed 2,200 miles to make good a direct passage of 1,300 miles. In Port Suez I got in touch with Jim Meehan of Shore Sails, who built the old jib, and asked him to air freight a new one to Israel, which he did in about a week. Our agent in Egypt was the Prince of the Red Sea, a charming old man and his son. He arranged our Canal transit and tour of the Cairo Museum and Pyramids at Giza. The museum with its priceless collection of antiquities was fabulous. The Pyramids were simply impressive - all that labor for the glorification of one man (per pyramid). The touts selling guided tours, camel rides, trinkets, etc. were an unremitting nuisance. Robert, who had joined us in Thailand, decided to tour the Med by bus after we arrived in Port Suez (the Red Sea does that to you). Fortunately, we met a Dutch yacht which we had first encountered in Sri Lanka, the captain was planning to refit in Cyprus and so one of his crew took Robert's place. Our new crew member is a young English woman called Celia who has been bumming round the world for the last three years. Celia joined us in Port Said after we made the two-day trip through the Suez Canal. We had to pay baksheesh to the pilots and tender operators — we had laid in a stock of Marlboro cigarettes just for this purpose.

"We were greeted off the Israeli coast by a small gunboat as the sun rose. After some questions on the radio they waved us on to Ashkelon. The marina is home to more than a dozen liveaboards, we arrived just in time for the weekly barbecue. After a couple of days we got the message that the new jib had arrived at Ben Gurion Airport. I rented a car and Celia and I drove off to get it. We arrived at the airport in a torrential rain storm, dealing with the bureaucracy took all day, but we finally left with the sail. I had to pay 25% of its value as a deposit on custom duties, which I was told would be refunded when it was inspected on the boat. It was duly inspected but getting the money back was difficult. I finally wound up with a check, written in Hebrew, which was cashable only at a certain bank in Tel Aviv. To make a long story short, my name was incorrectly written in Hebrew and when the teller looked at my passport the bank would not cash the check. Finally, with the help of a local businessman, I signed the check with the name on it (Eric Patrick in English!) And I wound up with 3000 shekels in cash. The next day we all drove to Jerusalem where the money changers outside the Temple gave me greenbacks for the shekels. We had a wonderful day in Jerusalem because the tourists had been scared off by the threats of violence associated with the Jewish plan to build new houses in east Jerusalem. The sites and restaurants were relatively empty and we had a great day. We even visited the two tombs of Jesus, one inside the walls and one outside — there is a great deal of uncertainty about where things actually happened 2000 years ago. The next day we drove to the Dead Sea and Masada. The latter is very interesting, particularly as we made our ascent by the ramp erected by the Romans to storm the place, not by the cable car used by most tourists. The region is stark, to say the least, and it is staggering to think of the effort needed to erect the ramp in about three months, it rises several hundred feet from the desert floor and is still usable after 2000 years. On the way back to the marina I got caught speeding by the cops, but when they discovered I was a visitor I was let off with a warning. The next day we left in fairly grungy weather for the short hop to Cyprus. We tied up in Larnaka, on the Greek side, Cyprus being an island divided between peoples of Turkish and Greek ethnic origin. It was a public holiday when we arrived, it celebrated Greek Independence Day. This may help explain the enmity on the island; how many countries have a holiday celebrating an event in another country (when the Greeks overcame the Turks)? We stayed three days, I got lots of Xerox copies of charts for the trip west, in Cyprus 'Copyright' means it's all right to copy! From Cyprus we sailed to Antalya, on the Anatolian coast of Turkey. Another hop of three days but with its share of heavy weather — we sheltered for the night in Limassol Harbor before we could weather the western end of Cyprus. The marina at Antalya is about five miles from the old town. A cosmopolitan collection of cruising boats wintered there and we arrived in time for the wind-up party of the social club. When a couple from New England discovered Walter and I lived on Long Island the wife confessed to having attended Patchogue High School — small world! A few days later we went to a dinner party at the jazzy restaurant on the marina site and I wore a tie and blazer for the first time since the circumnavigation began. The archeological sites in the vicinity of Antalya are fantastic, most of the ruins are of Roman origin. We rented a car for a day and visited three sites. Perges covers an extensive area, much of the public baths with its complicated heating system remain. Fragments of statues, columns and mosaics literally lie under your feet as you walk among the ruins. At Aspendos the amphitheatre looks much as it did in Roman times — they could put on a play tomorrow with seating for about ten thousand people. Side is a seaside resort full of restaurants and souvenir shops but the remains of an old temple are next to the shore on a beautiful cape. The place was swarming with tourists, mostly German, and I imagine it is pandemonium at the height of the season.

"From Turkey we faced a thousand-mile leg to the island of Malta. This took eight days. Much of the wind was on the nose with gusts as high as 40 kts, we were reefed most of the time. Occasionally the wind dropped to nothing and we had to power. As someone remarked in one of our cruising guides "In the Med you power from gale to gale." On moonless nights the fiery comet Hale-Bopp hung over our starboard bow. When we got to Malta we noticed several strands had broken on the bobstay (7/16" diameter wire rope) and we had to have a rigger make us a new one. Malta has been a fortress for centuries. As you approach the harbor vast sand-colored stone walls loom up on every shore. Behind the ramparts one can see the dome of the cathedral and the towers of numerous churches. We went for lunch at the yacht club which is housed in one of the old forts on Manoel Is. The walls penetrated by the narrow windows that overlook the water are five feet thick. It was a short bus ride or a 45 minute walk from our berth on Msida creek to Valletta, the Capital. The old, narrow streets are crowded with shops and restaurants punctuated here and there with graceful plazas. We visited museums, the fine arts gallery and the underground labyrinth which comprised the military control center in WWII. The rooms have been restored and filled with period equipment complete with mannequins dressed in uniforms of the day. The island and its defenders were awarded the George Cross, Britain's highest civilian award for valor, after the intense German and Italian bombing during the war. The story of the blockade and the ships that ran supplies to Malta is a central theme of several exhibitions. The day before we left was another of my 39th birthdays. Celia and Walter planned a surprise party by inviting several couples we had got to know on adjacent boats. Unfortunately, I spotted the cake they had bought when our agent came to get paid and they watched with trepidation as I cut it up into large slices and suggested we should all eat (along with the usual rum). The guests showed up a little later but there was enough left to get the party going. After we cleared Malta we ran into a NE gale which whisked us to Bizerte in Tunis in a couple of days; downwind sailing for a change. Bizerte is a small, pleasant town with an old walled section containing the Casbah. The highlight was a visit to Tunis by means of a one hour bus ride. The Bardo museum has the most amazing collection of mosaic from the Carthaginian and Roman periods which I have ever seen. Many of them are huge, forty feet square, they were often mounted vertically so they could be viewed easily and were virtually complete. The subjects were mostly gods and their associated legends of local scenes showing people at work or fishing. Many used such small fine stones to form the picture I was reminded of the pointillism style of French impressionistic painting. I was also struck by the thought that the scenes were so pastoral for an era one thinks of as fairly brutal. In contrast, the Fine Art Museum in Valletta had a good collection of Italian classical paintings, many of them depicted in gory detail martyrs dying in every imaginable manner and, of course, numerous versions of Jesus Christ hanging on the cross. The Bardo also had some rooms from old Islamic mosques containing the most elaborate stone carvings. After the Bardo and lunch in Tunis it was a short taxi ride to Carthage; the center of the empire that was ultimately conquered by Rome about 200 BC. The place is sprinkled with ruins, including the old circus where, according to the guide, the still visible tunnels are the ones used to let lions loose in the ring where they ate Christian captives. There is a plaque celebrating two Christian lady saints that the lions refused to eat in 203 AD, thus convincing the frustrated spectators that maybe their religion had something after all.

"Our six-day trip to Almeria in Spain was plagued by long calm spells under engine and occasional head winds. Ironically we had waited an extra day in port for a forecast gale to clear the area. After clearing with the authorities in Almeria we moved down the coast to a charming marina in Aguadulce, where the boat will stay for four weeks under the care of Celia while Walter and I fly to New York."

— *Until the next time, best wishes from Eric*

Member E. B. Forsyth above also wrote from Block Island in September 1997:

"Dear Friends, in this seventh newsletter, Walter and I left *Fiona* in Aguadulce on Spain's Costa del Sol and flew to New York in May. Fortunately, Walter was able to get a good job for three weeks to replenish his cruising kitty. I had a large number of repairs to electronic equipment to take care of and also squeezed in the annual vintage Bentley rally. When we returned, the willowy Celia, who had been watching over *Fiona*, announced she had got a job modeling swimsuits, leaving Walter and I to sail the boat to Gibraltar. We jogged down the coast in easy stages, but each afternoon we had strong winds, on the nose, of course. Most nights we tied up in marinas, where we usually enjoyed a sunset rum and exchanged yarns with other cruisers. The numerous restaurants in this part of the world are mostly quite inexpensive and we were able to take a break from the spam and beans suppers on board. We also ran into old friends of the British Tradewinds rally whom we had seen periodically since we were in the Caribbean. Unfortunately, the marinas are littered with flotsam and jetsam and at Fuengirola I had to don scuba gear to clear a rope which had wrapped itself around the propshaft. So high were the forces generated that the cotter pin had sheared and the nuts holding the propeller had worked loose; we were lucky not to shed the propeller.

"We sailed to Gibraltar to sock up for the Transatlantic leg and to pick up our new crew member, Derek.

Derek and I had both served as pilots in the RAF and had briefly been stationed at Gibraltar more than forty years ago; this was my first return visit since then. It is massively changed; the military presence is gone and huge buildings now dominate what flat land there is. One afternoon I climbed to the top of the Rock. I had the adrenalin pumping by negotiating a narrow path up the cliffs on the east side. At the top I ran into the famous Barbary apes and later explored one of the tunnels driven into the rock by military engineers. By the time the British Army left they had drilled over 33 miles of tunnels— the famous 'solid as the Rock' is really Swiss cheese! Walter and I took the ferry to Tangiers one day but this turned out to be rather a bust — we were the targets of relentless touts everywhere we went. When Derek showed up we beat out of the Med through the legendary Pillars of Hercules against a stiff wind and current. Once into the Atlantic conditions eased and we had some lovely sailing to Tenerife in the Canary Islands. As usually happens it was the middle of the night when we arrived at Santa Cruz. This is a very pleasant town with many sidewalk cafes and we stayed three days before leaving for Bermuda, 2,500 miles away. Although by this time it was well into the hurricane season, cyclonic activity was low, although I carefully monitored weather forecasts on short wave and printed weather faxes as soon as we got within range of the US stations. We had a very easy passage with winds rarely over 20 kts and for four days we used the engine to push us over a windless sea. When the wind dropped we often took the opportunity for a swim, it's always fun to swim in blue, warm water going down two and a half miles under the boat. On one occasion we found the propeller had become fouled by a piece of fishing net and it took Walter and I in turns some time to cut it free. Derek had a birthday during the trip. We baked a cake and gave him a card on which we inscribed:

"ON REACHING 65

Congrats on reaching sixty-five.
Tho' your eyes may be dim
And you're not quite so slim
It certainly beats the alternative!

"In reply Derek wrote in the log book:

"THANKS FOR THE PARTY

Though birthdays are by custom only
annually repeating
With increasing age the time between
them seems more fleeting
But should I make another ten
And reflect on all this, then
My 65th on board this ship will
certainly take some beating!

"The muse, of course, was inspired by liberal swigging of our Mount Gay rum. About half way across the Atlantic I succeeded in rising Mike McKeown and Fred Pallas on the ham radio with the help of an amateur operator in Barbados. From that point on our friends and relatives at home had some knowledge of our progress. With winds that were usually in 10 to 12 knot range we had a leisurely sail and sighted Bermuda just over twenty days after leaving Tenerife. We finally tied up at St. George in the middle of the night (of course). Bermuda marked the completion of the circumnavigation as we left from there in July, 1995, for the Caribbean. I was apparently in such a rush to touch land I dented the pulpit on a post at the customs dock.

"There is lovely cruising in Bermuda and we sailed *Fiona* to a few of my favorite anchorages so Derek could see some of it before he flew out to rejoin his family who were vacationing in Florida. Isn't modern technology wonderful? — in a few hours Derek was transported from the idyllic, tranquil life aboard *Fiona* to the frenetic madness of Disneyland! Just before Derek left we were joined by Walter's older sister Del who flew down for a few days and a couple of days later his sister Debbie dropped in. When they left Walter and I took the boat over to Castle Harbor, the only anchorage in Bermuda which, over the years, I have not explored. There are interesting ruins on Castle Island, which was fortified in 1612 by the first English settlers. We also did the last in a series of noon sights which we stared in mid-Atlantic to see how accurately we could measure longitude by knowing the time of the sight, all this inspired by Dava Sobel's interesting book on the development of the marine chronometer.

"For the third crew member of the leg from Bermuda to Newport RI, I recruited Ginny, who had already sailed with us from Australia to Thailand. The day after Ginny flew in we refueled and left. We had an easy sail. The sea was quite placid when we crossed the spot where *Fiona* lost the mast in 1988, also it was within a day of the same date, so I was pleased when we got north of the Gulf Stream with its potential for violent weather. We arrived in the middle of the night (as usual) and anchored in Mackerel Cove on Jamestown Is. until it was late enough to enter Newport Harbor and clear customs. Ginny took a bus back to Maine where she is supervising extensive alterations to her house on Peaks Island. A day later Walter left to attend a wedding on Long Island, I was left alone for a short while. I sailed *Fiona* to Block Is. so we were positioned for the final leg to Patchogue, the idea being to arrive 800 days after we left. We actually left earlier than planned because the wind was forecast to be SE, changing to SW, SE being very desirable. We left as soon as Walter's friend Tim arrived on the ferry from Montauk; he was the last in a long line of third crew members. The trip along the Long Is. coast turned out to be a great sail but then we had to anchor for over twelve hours before traversing the shoals of Gt. South Bay.

Walter has been combing through the log books and here are a few statistics he came up with:

| | |
|---|---|
| Total Distance: | : 34,360 nautical miles |
| No. of days at sea | : 298 |
| Average sailing day | : 115 n.m. |
| Total diesel consumption | : 1900 galls |
| Total rum consumption | : 70 galls |
| No. of novels read | : about 250 (and about 113 Weekly Manchester Guardians) |
| No. of countries visited | : 34 |

"In summary, it's been quite an experience. I greatly enjoyed visiting the many countries but usually after a week or two I was ready to move on because I also like the challenge of ocean sailing. I have fond memories of lying in my bunk reading a Patrick O'Brian novel with the sounds of the wind and creak of the main sheet blocks — this greatly added verisimilitude to his stories. The social side of cruising is great fun — there are a lot of interesting folks out there and there is a strong camaraderie among cruisers. We had about 180 guests on board at various times for happy hour (so *that's* where the rum went) representing 18 countries in addition to those we visited.

*"I have to thank Walter for sticking with me for the whole trip; he has developed into an excellent seaman. Now* Fiona *needs a lot of work to repair the ravages of all those sea miles, after that, who knows?"*

— Best wishes, Eric

*Editor's note: See issues 51, 52, 53, 55 and 56 for letters from Georgetown, Guyana; Colon, Panama; Papeete, Tahiti; Penryhn Atoll, Cook Islands; Cairn, Australia; and Aden.*

# NAVIGATION NOTES

## Accurate Time

*By Wilson Van Dusen*

Some years ago I asked myself if I needed to buy an expensive timepiece for celestial navigation. That began a long and pleasurable research into time keeping instruments. The celestial navigator needs time to the nearest second. Greater accuracy is not needed. Less accuracy leads to position error.

First I tried to determine what accuracy older ships formerly used to cruise the world. They had two or three expensive, gimbaled, wind-up, mechanical chronometers. I found a tabulation of the best mechanical chronometers over 74 years of tests. My worst cheap quartz watch at 136 second error per year was better than the best mechanical chronometer ever found in 74 years of tests! Realize that total error is not as important as predictability of rate. But if your timepiece has little error in a year it also probably has little variability in rate. So I immediately eliminated these expensive but lovely old mechanical chronometers.

I proceeded to set up a Chronometer Rate Book and tested everything I had that could read out in seconds. Over time, even with an attempt to adjust the rate, I discarded several timepieces. Not all watches permit rate adjustment. Some with an adjustment screw simply don't stabilize. The chronometers I ended up with were all quartz, digital read out watches. Quartz watches with hands seem less useful. They are difficult to read out to a tenth of a second, and the gearing lessens accuracy. I could easily get quartz watches to have less error than 60 seconds per year so this became my standard for a chronometer. The average jeweler or watch maker can't set a quartz watch to this level, but a few individuals and the factory may have the means. The average navigator can do it with a little patience. I used a Radio Shack Time Cube for the time signal, but a short wave radio can also be used.

To record results I used an ordinary ruled notebook that I ruled off in five columns. For each check of a watch I recorded date, GMT, CE (total chronometer error), number of days since last check, rate per day, and rate per year. A business calculator gave me days between dates. The change in CE divided by number of days equals rate per day. This times 365 equals rate per year. I used separate pages for each instrument. I could later go back and examine results. I recorded chronometer error to a tenth of a second as did the chronometer experts. It takes practice to do this. Form an impression of the one-tenth figure while waiting for the mark of a minute. The one-tenth level helps guard the accuracy of the nearest second. The best overall figure for quality of the chronometer is the total error per year.

A major finding that emerged was that I could turn some pretty inexpensive watches, all costing less than $50.00 into chronometers. A friend of mine threw away three watches which currently have rates of 12, 16, and 21 seconds per year. One doesn't even have a case! I bought a Radio Shack Micronta Stop Watch that also keeps clock time. It is currently at 27 seconds per year. I recommend InfoCenter's Master Navigation Watch. It is a fine timepiece that comes already adjusted for $50.00. Mine currently is at 15 seconds per year. In other words, I currently have 6 chronometers, half of which someone threw away. All are digital read out and quartz movements.

To adjust rate expose the inner workings and turn the rate screw clockwise to speed up and counter clockwise to slow down. You will soon be down to the level where, even under a magnifying glass, you can't be sure if the screw turned! The man who did the finest rate adjustment I have seen says he ends up simply applying a little pressure to one side of the screw. Over time you will find a small drift in rate, but my chronometers easily stay within 60 seconds per year and often within 30 seconds per year. Position doesn't affect a quartz watch as it does a mechanical watch. But temperature does. I found they did better in a padded box. Cold slows the quartz crystal, heat increases its rate. At this level of accuracy my watches are considerably better than the best gimbaled mechanical timepiece ever made. I tested a brass Boston "chronometer." Because it had hands it was more difficult to read precisely. Though it was in a handsome case, its innards were a surprisingly unadjustable cheap quartz movement. It was so much poorer than my watches that I sent it back. I know of few timepieces that can beat my chronometers and they often cost over $1000.00 Considering that time ticks are available all over the world, and that my watches are far superior to what past mariners used, I don't see the need of greater accuracy.

There is one other remarkable chronometer I should mention. for $50.00 Radio Shack sells a digital clock that adjusts to WWV six times a day. It gives time, date, month, year, and day of the week. Mine has never deviated from WWV. So in effect, you not only have a fabulously accurate chronometer, but it can substitute for WWV as a standard. From the navigator's viewpoint its only limitation is it can only be set to one of our US time zones, not GMT. But this is a little problem, though I certainly would have other chronometers for a round the world voyage.

All my chronometers are on Greenwich Mean Time. It is preferable to have watches on 24 hour time or to give an indication of AM or PM. To also have day and date is possible with these watches. These watches are so accurate a weekly check when adjusting rate is enough. For doing long term study of a watch I check them monthly. When using them for position finding one should have two or three for comparison. With only two, when one goes awry you may be unsure which one it is. With three watches, the one in error is clear. Knowing the rate of change per day makes calculating the correct time simple.

For taking sights I use a battery operated quartz stop watch in the LAP function. This enables me to precisely time a whole series of sights by stopping the watch for each without losing the internal time keeping. Few mechanical stop watches can do this.

So my original question, do I need a very fine timepiece, was answered in a resounding, no! Plus I had the pleasure and challenge of developing my own chronometers. I recommend the navigator develop their own rate book and chronometers.

## Regulation of Master Navigation Watch

*By John M. Luykx*

The Master Navigation Watch has been regulated to a monthly rate not more than approximately 1 second per month. The regulation was accomplished over a period of several weeks during which the ambient temperature remained between 73° and 75° F. The rate of the Master Navigation Watch, however, may change slightly as a result of motion, oscillation and shock during shipment and will definitely change (as is the case with all quartz watches) when used in an area where the ambient temperature differs from that of the test location. Tests have shown that, within the limits of 40° to 100° F, the rate of the watch will change approximately 0.3 seconds per day for every plus or minus 10° F change of ambient temperature. When the temperature increases, the rate is plus; and when the temperature decreases, the rate is minus. It is recommended, therefore, that ambient temperature be taken into consideration when computing and evaluating the daily, weekly and monthly rates of the Master Navigation Watch.

*Editor's note: Director John M. Luykx is Vice-President of InfoCenter, Inc. which produces the Master Navigation Watch referred to in the foregoing article "Accurate time" by member Wilson Van Dusen, Ph.D.*

## Some Comments on Establishing Longitude by Means of a Noon Sight

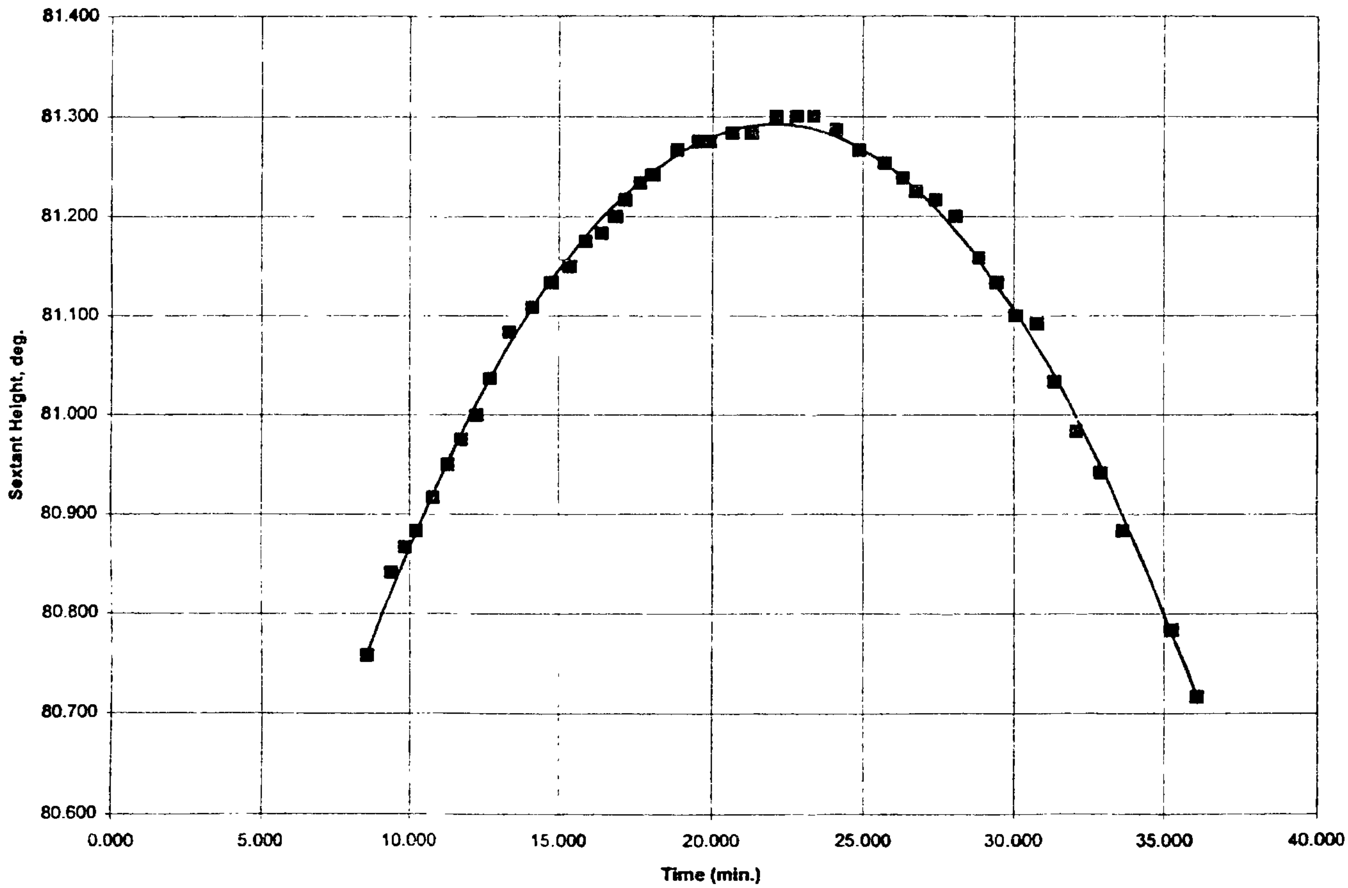
*By Eric B. Forsyth*

Inspired by Dava Sobel's recent book, I decided to take a series of noon sights during a transatlantic trip in the Summer of 1997 to determine just how accurately one could measure longitude by knowing the precise time of the sun's meridian passage. The Longitude Act of 1714 created the top prize for the determination of longitude with an error less than ± 30'. Sir Isaac Newton expressed the problem succinctly:

"One is, by a watch to keep time exactly: but, by reason of the motion of a ship, the variation of heat and cold, wet and dry, and the difference of gravity in different latitudes, such a watch hath not been made."

John Harrison did indeed make such a watch and in 1762, after a trip to Jamaica, the error was determined to be only 5 seconds, corresponding to a longitude error of 1.25'; well within the specified error. But how did the observers know the time of local noon? To an observer at a fixed point the sun's trajectory through the sky is a sine function, the time of meridian passage is the instant that the sine wave reaches its peak. To determine this instant with any accuracy from a series of sights grouped about the meridian passage is by no means easy and the observer's conclusion that the chronometer had a random error of 5 seconds implies they measured the passage to an even higher degree of accuracy; say 1 second. This is indeed astonishing. Nowadays it is quite easy to check a quartz crystal timepiece to accuracy of better than 1 second using WWV or similar radio time pips. Longitude can be read continuously from a GPS receiver to an accuracy of better than 0.1". Thus it is possible to repeat the trial of Harrison's chronometer, but without any possibility of significant random error. I give below

Fig 1, Data Set 1, Fit to Minimize the Sum of the Squared Deviations 7/25/97




the results of three sightings, two taken on successive days when the boat was traversing the Azores - Bermuda high and conditions were calm. The boat was traveling west at about 5 kts during the 20 minutes or so required to complete a set of sights. This motion produces a slight distortion of the sine wave but should not affect the accuracy of the measurement of meridian passage. The third set was taken from a cliff on Castle Island, Bermuda. A data set, taken on 25 July 1997, is plotted in Fig. 1. The apparent height of the sun, shown in decimal degrees, is plotted against the time in minutes, hours are not shown. Also plotted is a sine function derived by a computer program to fit the data by minimizing the sum of the squared deviation for each data point. Once the fitted curve is derived the computer finds the peak value and the corresponding time. This computer program was not available on the boat and of course such aids were not available to Harrison's assessors. At sea I tried various methods to estimate the maximum height ($H_{smax}$) and the time of meridian passage (MP). the method that gave the best results was to plot the data on a large piece of thin graph paper and then determine MP by creasing the paper parallel to the ordinate so that the ascending and descending points lay on top of each other, as closely as possible. The location of the crease then gave MP. The results of the two methods are shown in Table I. These data can then be reduced to lat and long, as shown in Table II. Corrections for height of eye, semidiameter, watch error, etc. are applied and latitude found by adding zenith distance to the sun's declination at the time of the sight. Longitude was determined by deducting the equation of time from MP and then calculating distance from the center of the time zone based on the rate of the sun's GP (4 minutes per degree).

The latitude calculation is in good agreement with the GPS readout using either method to calculate $H_s$. The errors of the sights taken at sea are a few tenths of a minute, the larger error seen in the land-based sight (about 1.4") are almost certainly due to an incorrect estimation of the dip; I could only guess at the height of the cliff I stood on: a change of 15 ft in the height would reduce the latitude error to nearly zero.

The errors in the calculation of longitude are less using the computer generated data in the case of the sights taken at sea, averaging +1.2" but worse for the sight taken in Bermuda: -2.9'. M.P. derived graphically resulted in errors averaging +2.9' for the sea sights but was only -0.5' for the series of sights taken in Bermuda. None of the results appear to be as reliable as those achieved by the assessors of Harrison's chronometer,

Table I. Comparison of M.P. and H max Measurements

| | Computer Curve Fit | | Graphical Method | |
|---|---|---|---|---|
| Date | M.P. | $H_{s-max}$ | M.P. | $H_{s-max}$ |
| 7/25/97 | 22m 02.7s | 81°17.5' | 22m 08s | 81°18.0' |
| 7/26/97 | 30m 34.3s | 81°46.8' | 30m 42s | 81°46.7' |
| 8/25/97 | 20m 37.0s | 68°07.6' | 20m 48s | 68°07.8' |

Table II. Comparison of Lat and Long With GPS Position

| Date | GPS | | Comp'r Data | | Graphical Data | |
|---|---|---|---|---|---|---|
| | Lat | Long | Lat/Error | Long/Error | Lat/Error | Long/Error |
| 7/25/97 | 28°03.0'N | 33°52.6'W | 28°03.7'N +0.7' | 33°53.7'W +1.1' | 28°03.2N +0.2' | 33°55.0'W +2.5' |
| 7/26/97 | 27°21.3'N | 35°59.8'W | 27°21.1'N -0.2' | 36°01.1'W +1.3' | 27°21.2'N -0.1' | 36°03.0'W +3.2' |
| 8/25/97 | 32°20.4'N | 64°40.3'W | 32°19.2'N -1.2' | 64°37.4'W -2.9 | 32°19.0N -1.4' | 64°39.8W -0.5' |

which is curious as there was no source of randomness except errors in the sights themselves. One would expect curve fitting to minimize this source of randomness. It would be interesting to learn:

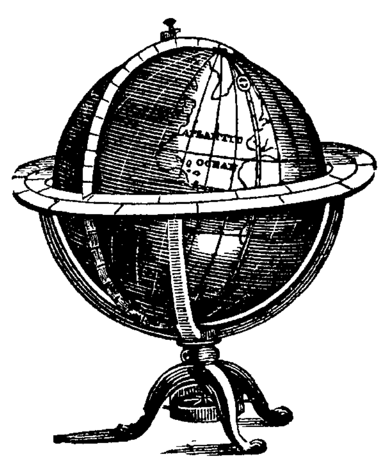
1) Precisely how the trial was conducted in 1762, or perhaps I should say "How was the trial conducted so precisely?"
2) How was the equation of time derived for each day, as this must be known with better accuracy than the precision being strived for in the trial of the chronometer? Was the motion of the earth known so accurately in 1762 that itcould be calculated beforehand?

I am indebted to Walter Van Vleek, Jr. for assistance in taking the series of sights and Richard A. Thomas for help with the computer analysis.

*Editor's note: Eric Forsyth was a Senior Scientist and formerly Chairman of the Accelerator Development Department at Brookhaven National Laboratory on Long Island. Since his retirement in 1995 he has completed a 2 year circumnavigation aboard his 42-ft. Westsail Cutter Fiona.*

*Director John M. Luykx advises that the reported error of 5 seconds in Harrison's watch, H4, during the test at Jamaica in 1762 is actually the difference between the actual error and the predicted error.*

*The effects of vessel velocity and rate of change of declination on the time difference between meridian transit and when a body is at maximum altitude are greater when the vessel's velocity has a large northernly or southerly component and the rate of change of declination is high. In the case above, Fiona was sailing west at about 5 knots when the rate of change of the declination of the sun was low.*



## Calculate Your Own Nautical Almanac Data for Sun Sights

*By Bill Murdoch*

It is not hard to calculate the almanac data needed to reduce a sun sight. The calculations are too long to do by hand, but they can be easily done with a programmable calculator or computer program. The *Nautical Almanac* gives instructions for calculating the corrections, so all that is left is to find the GHA, declination, and semidiameter of the sun. (As part of the process, the GHA of Aries must also be calculated, and it could be used in the reduction of star sights.)

The first step is to change the common units of time into a single unit. The chosen unit is the number of centuries after noon 1 January 2000. Time has a value of -.5 at 1200 on 1 January 1950, 0 at 1200 on 1 January 2000, and +.5 at 1200 on 1 January 2050.

Van Flandern and Pulkkinen give a short formula for converting common UTC (or GMT) time to UTC centuries that is valid from March 1900 to February 2100.

Tu = (367*yr-trunc(7*(yr+trunc((mo+9)/12))/4)
+trunc(275*mo/9)+day+(hr+(min+sec/60)/60)/24
-730531.5)/36525

The formula fails outside those dates because 1900 and 2100 are both years divisible by 4 which are not leap years. The function *trunc* is the integer part of the number within the brackets; any fractional part is dropped. To have an accuracy of one second, the value of time must have 11 significant digits because there are about 6 billion seconds in two centuries.

The way the formula works is a little vague and is best explained working backwards. At the end of the formula dividing by 36525 converts the units from days to centuries. Subtracting 730531.5 gives the formula a value of 0 at noon on 1 January 2000. The term day+(hr+(min+sec/60)/60)/24" converts the date of the month and time into the number of days since the beginning of the last day of the previous month. The remaining part of the formula handles the changing number of days in the months and accounts for leap years. You can get an idea of how it works by solving it for the first day of each month for four consecutive years writing down the numbers from within each set of parentheses.

We must keep up with two kinds of time. One is UTC and is related to the rotation of the earth. The other is ephemeris time and is related to the speed that the earth revolves around the sun. These two kinds of time are slowly drifting apart because the earth's rotational speed has been slowing for the last several decades. Every time a leap second is inserted into UTC the two get farther apart.

An equation for converting centuries of UTC time to ephemeris time is

Te =Tu+((63+60*Tu)/3,200,000,000)

This says that the difference between the two kinds of time is 63 seconds in January 2000 and is increasing by 60 seconds per century. The formula is accurate for the last few decades and will probably be accurate for several more.

With time out of the way, the second step is to calculate the apparent ecliptic longitude of the sun. Because the moon and nearby planets perturb the orbit of the earth, we must first make rough estimates of the positions of the planets, moon, and earth.

The position of the venus, earth, mars, and jupiter are calculated as their mean anomaly which is the angle between their perihelion and position. The results are in degrees with values oftentimes greater than 360° or less than 0°. That does not matter to most calculators, but you may find it necessary to subtract the extra revolutions before taking the sines of the angles in later calculations.

V = 50+(58517*Te)
E = 357.52558+(35999.04974*Te)
M = 20+(19140*Te)
J = 19.9+(3034.6*Te)

Two formulas give the longitude of the moon's ascending node and twice the sun's longitude both measured in degrees.

N = 125.0-(1934.1*Te)
L = 200.9+(72001.7*Te)

With these intermediate values in hand; it is possible to calculate the apparent ecliptic longitude of the sun. The formula is long and somewhat repetitious.

EL =
E+(1018585.1+(6191.2*Te)+(1.1*Te$^2$)
+6892.8*sin(E-0.0018)
+72.0*sin(2*E)
-17.4*Te*sin(E)
+7.2*sin(E-J-90.5)
+6.5*sin((445267.1*Te)-62.1)
-6.4*sin((20.2*Te)+71.4)
+5.5*sin((2*E)-(2*V)-58)
-4.8*sin(E-V-29)
-2.7*sin((2*E)-(2*J)-3)
-2.6*sin(J+7)
-2.5*sin((3*E)-(2*V)-46)
+2.0*sin((2*E)-(2*M)+74)
-1.9*sin((150*Te)+28)
+1.8*sin(E-(2*M)-70)
-1.6*sin(E-(2*J)+20)
-1.6*sin((4*E)-(3*V)-75)
+1.0*sin(3*E)
-1.0*sin((5*E)-(3*V)-48)
-20.5
-17.2*sin(N)
-1.3*sin(L))÷3600

The result is in degrees, but the units of each of the

A Comparison of the Calculator Almanac with the Nautical Almanac

| | | Sun | | | | | | | | | Aries | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | G.H.A. | | | Declination | | | Semidiameter | | | G.H.A. | | |
| | | N.A. | Calc. | Error | N.A. | Calc. | Error | N.A. | Calc. | Error | N.A. | Calc. | Error |
| Date | Time | ° ′ | ° ′ | ′ | ° ′ | ° ′ | ′ | ′ | ′ | ′ | ° ′ | ° ′ | ′ |
| 1 Jan 95 | 0000 | 179 12.0 | 179 12.2 | +.2 | S23 03.2 | S23 03.3 | +.1 | 16.3 | 16.3 | 0 | 100 10.7 | 100 10.7 | 0 |
| 2 Jun 94 | 0100 | 195 32.5 | 195 32.6 | +.1 | N22 07.9 | N22 07.9 | 0 | 15.8 | 15.8 | 0 | 265 16.6 | 265 16.6 | 0 |
| 7 Feb 90 | 200 | 206 48.0 | 206 48.0 | 0 | S 8 23.2 | S8 23.2 | 0 | 16.2 | 16.2 | 0 | 186 55.3 | 186 55.3 | 0 |
| 3 Sep 93 | 0300 | 225 08.4 | 225 08.4 | 0 | N 7 34.8 | N7 34.8 | 0 | 15.9 | 15.9 | 0 | 27 15.8 | 27 15.9 | +.1 |
| 20 Mar 92 | 0400 | 238 07.5 | 238 07.4 | -.1 | S 0 04.7 | S0 04.7 | 0 | 16.1 | 16.1 | 0 | 237 56.5 | 237 56.5 | 0 |
| 10 Oct 92 | 0500 | 258 15.1 | 258 15.0 | -.1 | S 6 44.1 | S6 44.1 | 0 | 16.0 | 16.0 | 0 | 94 03.2 | 94 03.2 | 0 |
| 23 Apl 91 | 0600 | 270 23.5 | 270 23.4 | -.1 | N12 22.5 | N12 22.5 | 0 | 15.9 | 15.9 | 0 | 300 47.3 | 300 47.3 | 0 |
| 16 Nov 91 | 0700 | 288 49.7 | 288 49.7 | 0 | S18 37.7 | S18 37.7 | 0 | 16.2 | 16.2 | 0 | 159 51.5 | 159 51.5 | 0 |
| 8 May 90 | 0800 | 300 52.9 | 300 52.9 | 0 | N17 03.0 | N17 02.9 | -.1 | 15.9 | 15.9 | 0 | 345 53.6 | 345 53.5 | -.1 |
| 13 Dec 90 | 0900 | 316 29.5 | 316 29.5 | 0 | S23 08.5 | S23 08.5 | 0 | 16.3 | 16.3 | 0 | 216 47.5 | 216 47.4 | -.1 |
| 26 May 89 | 1000 | 330 45.6 | 330 45.7 | +.1 | N21 09.5 | N2 1 09.5 | 0 | 15.8 | 15.8 | 0 | 33 57.2 | 33 57.2 | 0 |
| 6 Jun 84 | 1100 | 345 20.2 | 345 20.2 | 0 | N22 41.8 | N22 41.8 | 0 | 15.8 | 15.8 | 0 | 60 02.3 | 60 02.3 | 0 |

summed elements are seconds of arc. The first line calculates the mean ecliptic longitude of the sun. The next eighteen lines move the sun on an ecliptical orbit and correct for the tugs and pulls of the moon and planets. Because we see the sun where it was about 8 seconds ago, 20.5 seconds of arc must be subtracted. The last two lines correct for the nutation of the earth's axis.

The next task is to change from ecliptic to equatorial coordinates. If we assume that the sun's celestial latitude is zero, the formulas for right ascension and declination are short, and we need only know the obliquity of the ecliptic.

$$\text{Ob} = 23.43929-(0.013*\text{Te})+(0.00256*\cos(\text{N})) +(0.00016*\cos(\text{L}))$$
$$\text{RA} = \tan^{-1}(\tan(\text{EL})*\cos(\text{Ob}))$$
if $90° < \text{EL} < 270°$, then $\text{RA} = 180+\text{RA}$
$$\text{Dec} = \sin^{-1}(\sin(\text{EL})*\sin(\text{Ob}))$$

The GHA of Aries can be calculated from the universal time in centuries with a relatively short formula. The answer is in degrees and may need to be reduced to an angle between 0 and 360°. This formula needs about 12 significant digits to keep an accuracy of 0.1' between 1900 and 2100. The GHA of the sun is the difference between the GHA of Aries and the right ascension of the sun.

$$\text{ARIES} = 360*(0.7790573+(36625.0021390*\text{Tu}) +(0.0000011*\text{Tu}^2)-(0.0000122*\sin(\text{N})) ( -0.0000009*\sin(\text{L})))$$
$$\text{GHA} = \text{ARIES}-\text{RA}$$

The semidiameter of the sun varies with its distance from the earth and that depends on the position of the sun. The semidiameter of the sun in degrees can be calculated from its mean anomaly.

$$\text{SD} = \sin^{-1} (0.004659/(1-0.0167*\cos(\text{E})))$$

It is easy to incorporate the formulas in a calculator program, a spreadsheet, or a PC program. To help in debugging such a program two examples are given in the table below. They were calculated in an Excel spreadsheet. The results might be slightly different with other programs or calculators.

The astro formulas give results that closely match the *Nautical Almanac*. The accuracy seems to be 0.1' or better. In December and January the results may appear worse, but remember that the *Nautical Almanac* GHA entries are slightly in error then to avoid a 'v' correction for the sun.

The formulas used in this article from Van Flandern and Pulkkinen, "Low Precision Formulae for Planetary Positions", *The Astrophysical Supplement Series*, vol 41, p 391, (1979), and from Montenbruck and Phleger, *Astronomy on the Personal Computer*, Springer-Verlag, Berlin, 1991. They were put into the form used by B. Emerson in *N.A.O. Technical Note Number 47— Approximate Solar Coordinates*, Her Majesty's Nautical Almanac Office, November 1978.

A 1500 byte program for the TI-67 Galaxy calculator and a 2259 byte program for the TI-81 calculator using the method outlined here were published in the February 1994 issue of *Practical Boat Owner* and in the March 1996 issue of *Cruising World*. Copies of those articles or a similar program for a TI-82 calculator are available from the author.

Comments and criticisms are welcome. Please address them to:

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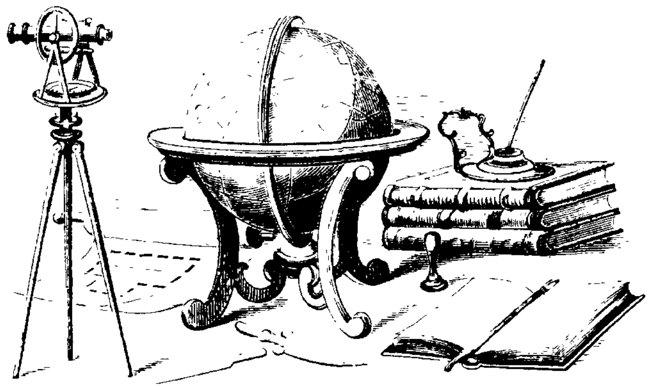
### Test Problems

| | | |
|---|---|---|
| yr | 1972 | 1994 |
| mo | 06 | 04 |
| day | 23 | 08 |
| hr | 00 | 21 |
| min | 17 | 54 |
| sec | 52 | 09 |
| Tu | -0.275249489 | -0.057319299 |
| Te | -0.275249475 | -0.057319280 |
| V | -16056.77351 | -3304.152330 |
| E | -9551.193949 | -1705.914046 |
| M | -5248.274945 | -1077.091027 |
| J | -815.3720558 | -154.0410883 |
| N | 657.3600089 | 235.8612202 |
| L | -19617.53010 | -3926.185630 |
| EL | -9268.363115 | -1421.172693 |
| Ob | 23.44388492 | 23.43873142 |
| RA | 91.78407641 | 17.37102545 |
| Dec | 23.4337 | 7.3752 |
| ARIES | 275.7377 | 165.4627 |
| GHA | 183.9536 | 148.0917 |
| SD | 0.2626 | 0.2666 |



# NEW PRODUCT

*By Ernest Brown*

## Tables for Clearing the Lunar Distance

## Second, revised edition

*©1995, 1997 by Bruce D. Stark (E-mail: Stark@aol.com)*
*Lant-horn Press*
*3770 Onyx Street*
*Eugene, Oregon 97405*

### Preface

*(Used with permission)*

These tables are the outcome of nearly two decades of experience with, and research into, the problem of getting Greenwich time from the moon. They reduce the calculation that clears a distance of refraction and parallax to a simple routine. The method fills a special niche. Unlike other easy-to-use procedures for clearing, it remains accurate when the distance is short. Short distances are the only ones the navigator of a quick-motioned small boat can hope to measure with confidence.

Lunars were more important in navigation—and for a longer period—than is commonly recognized. It is true they became really practical only in 1767, the first year of the *Nautical Almanac,* and that by then John Harrison had already perfected his best timekeeper. But special "watches" such as Harrison's were extremely difficult and expensive to build, and generations passed before they were standard equipment for ocean-going ships. On a long voyage a ship that did have a chronometer used it in conjunction with lunars.

Bowditch had more faith in lunars than in chronometers. Of longitude-by-chronometer he wrote:

"This method is useful in a short run; but in a long voyage, implicit confidence cannot be placed in an instrument of such a delicate construction, and liable to so many accidents."

And of longitude-by-lunar distance:

"Other methods of finding the longitude at sea have been proposed, but among them all there is not one of such practical utility, as that by measuring the angular distance of the moon from the sun, or from certain fixed stars situated near the ecliptic, usually called a *lunar observation*, or, more frequently, *'a lunar.'"*

(These quotes from the 1851 edition of *The New American Practical Navigator*, page 225. Wording is different in the 1821 edition, page 148, but the message is the same.)

Although each 0.'1 of error in the distance causes about twelve seconds of error in Greenwich time—3' of longitude—Bowditch had no trouble taking his ship from one place to another quickly and safely. He had a good idea what his maximum error in longitude could be at a given time, and allowed for it when shaping a course or making the land.

But by the middle of the nineteenth century chronometers were so reasonably priced that ships often carried three, and geography had improved to the point that almost any land raised served to check longitude. More and more steamships were being built—ships that couldn't be held up for weeks by a headwind or calm. Lunars were less and less needed. By the eighteen-nineties they were, as Captain Lecky put it in his *Wrinkles in Practical Navigation,* "... as dead as Julius Caesar."

Actually they weren't quite *that* dead. Joshua Slocum and a few others were still using them.

Now GPS is about to do for the rest of celestial navigation what chronometers and radio time signals did for the lunar. This might seem an awkward time for it, but if you enjoy using a sextant you will welcome the resurrection of the lunar distance. For one thing, lunars could help keep celestial navigation alive.

The present justification for celestial is that it provides a backup when electronics fail. The argument will have more force if lunars are part of the navigator's kit, since the electromagnetic shock wave from a nearby lightning strike can derange the timekeepers, even spring driven ones, in the same instant it takes out the electronics.

A more compelling point is this: Nothing else comes close to the lunar for developing skill with a sextant—and the observation is demanding enough to hold one's interest for a lifetime. On land a navigator who already knows his position can observe a distance on a moment's notice, day or night, without a horizon of any kind. When he compares his result with known GMT he will get the clean, reliable feedback he needs to continually improve his technique.

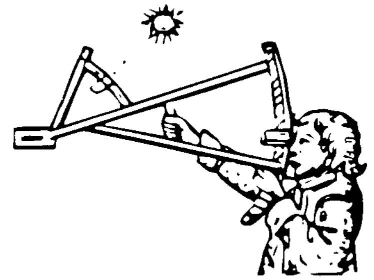
A third reason for resurrecting the lunar is to encourage more people to use sextants. At present it doesn't make sense to have a sextant unless you take it to sea. There's no way to get enough satisfaction out of it to justify the price. Lunars will make land-based celestial navigation interesting enough to take up for its own sake, and amateur astronomers will find a sextant is worth owning.

The sextant doesn't belong exclusively to the sea. Explorers, geographers, and surveyors depended on sextants as they mapped the continental interiors. Not all these men are forgotten. Read a bit of history on the western two-thirds of the continent and you'll find references to Canada's intrepid David Thompson. And there are others. But of all the men who observed lunar distances on the river banks and in the mountain passes of the North American continent, the two best known—in the United States at least—are Lewis and Clark. The details of lunars are recorded in their journals. They weren't seamen, but they were navigators.

*Editor's note: In issue thirty-one (Winter 1990-91) the late Rear Admiral Thomas D. Davies commented on the lunar distance tables as follows:*

"Member Bruce Stark of Eugene Oregon has sent me a long paper entitled *Resurrecting the Lunar Distance* in which he argues for publishing a set of tables for lunar distances by the Foundation. He has studied the problem for some time and proposes a new set of tables which could be contained in a book the size of the present *Nautical Almanac.* His tables are not yet fully generated but he establishes their details, which include the use of Gaussian logarithms. The major use of tables is in determining the several corrections necessary to 'clear' the lunar distance observation for use in the calculation. He uses the calculated distance between the moon and star from *Almanac* (GHA). Data for the nearest time to the assumed time is used, and the time correction calculated by simple proportion between these. He proposes to calculate this distance without modern tables (such as the *Concise Tales* in the *Almanac).* His paper is too long to publish in the *Newsletter* but he will probably respond to interest by other members, addressed to him through the Foundation."

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE FIFTY-EIGHT, WINTER 1998

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

# ACTIVITIES

*By Terry Carraway*

## APOLOGY

This has been a busy winter. My wife and I have been to Croatia, The Netherlands, Hungary, Italy and Hawaii. I was also required to file Foundation income tax returns for past years. As a non-profit, tax exempt, tax deductible Foundation, we are only required to file if our gross income exceeds a certain gross amount. Since we had not filed in a few years, the Internal Revenue Service wanted to see our income. Trying to fit our members contributions and our expenditures into a form where all of the examples concerned a non-profit HMO was really a challenge. It took an inordinate amount of time.

My delay in providing an Activities Column has helped delay this issue of The Navigator's Newsletter.I apologize for being a contributing factor in this delay and will endeavor to be more punctual in the future.

# READERS FORUM

Member William S. Murdoch of 3424 Lakeshore Drive, Kingsport, TN 37663-3370 wrote on February 18, 1998:

"The continuous checking and rechecking of calculations is the bane of the navigator. Occasionally, in spite of the best of efforts, a mistake gets through. In my article published in Issue 57 of the *Navigator's Newsletter* there is an error. On page 17, the first column, in formula for the GHA of Aries, the last term of the equation should be

-(0.0000009*sin(L)))

rather than (-0.0000009*sin(L))).

*"The mistake is entirely my own. I left the opening parentheses out of the original copy of the article, discovered my mistake in the proof, and inserted the parentheses in the wrong place in the correction. I apologize for any problems that it might have caused."*
— Yours faithfully, Bill

Member Lee Ruetz of P.O. Box 58956, Houston, TX 77258 wrote on February 3, 1998:

"Enclosed is my check for another year of membership in the Foundation. I always look forward to receiving the Newsletter.

"Do you know of a source I may contact for possible sale of my sextant?

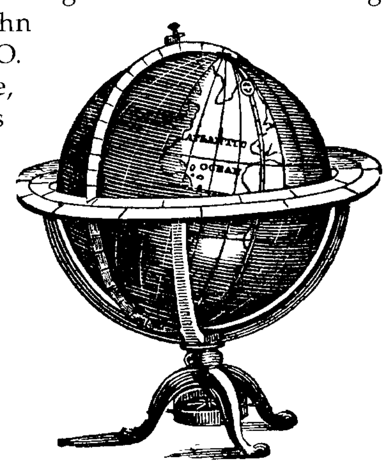
"The sextant, a prized World War II survivor, is a PLATH in excellent condition. It had been issued to a German submarine commander; acquired by an American tanker skipper; and then passed on to me.

"I would be interested in obtaining a quote or two on the approximate dollar value of this instrument.

"I am making an effort to return to the INTERNET and should have another E-Mail address soon."
— *With best wishes, Lee*

The Executive Director, Capt. Terry F. Carraway, U.S. Navy (Ret.) responded to Member Ruetz on February 17, 1998:

"I have tried several times to reach you by telephone concerning the sale of your sextant. Early on I left a message on your answering machine recommending that you contact John Luykx at InfoCenter, P.O. Box 47175, Forestville, MD 20753. His telephone number is 1-800-852-0649 or 301-420-2468.



"John Luykx will be able to inform you on the possible sale and an appraisal of the instrument. Give him a call.

"We are looking

forward to your returning to the Internet and having an e-mail address. It makes communicating easier."

— *Best regards, Terry F. Carraway*

Member Vanildo Maldi sent by FAX to the Executive Director on January 24, 1998:

"I acknowledge receipt of your very kind letter and thank you for your words which indeed I do not deserve.

"Men like you, Cmdr. Luykx and others whose wisdom enrich the articles of the Foundation magazine deserve our utmost respect. I think that to fully taste the flavor and bouquet of a good wine, one must know about the vintage and history of such a wine. Modern navigators are so dependent on electronics navaids that if something goes wrong they will be really in a mess. I take in pride my Foundation membership condition and think that it is unique as an association dedicated to celestial navigation.

"If I may remind you, I did not receive my membership card as yet. I thank you again and hope some day to meet you personally, which would be a great pleasure to me."

— *Respectfully, Vanildo Maldi*

Member Bruce D. Stark wrote by e-mail (Stark4677@aol.com) on February 24, 1998:

"Judging from letters I've gotten, the Newsletter was sent out ten days or so ago—and I still don't have a copy. But instead of bitching about mail service I'll do the sensible thing and send you our full zip code. You asked members for that some time ago, as I recall. It is 97405-4332.

"Has anyone offered criticisms or suggestions about the tables? Since I don't know anything about optics I'm especially anxious to have John Luykx either back up or correct what is said in the middle of page viii, where I advise sliding the 'scope all the way in toward the frame of the sextant.'"

— *Sincerely, Bruce*

"P.S. I'm still holding back, waiting for input, but a new batch of tables will have to be printed shortly."

*Editor's note: The Executive Director, Captain Terry F. Carraway, U.S. Navy (Ret.) responded in part:*

"It is too early to get a response from our members. It usually takes from a month to six weeks for a response to an item in the Newsletter. I have had one person ask about getting the tables.

I referred him to your e-mail address."

Member Bruce D. Stark wrote on February 25, 1998:

"Your offer of space in *Navigation Notes* was much appreciated, and sparked a celebration at our supper table. I've been waiting for the *Newsletter* to come before acting on your offer, but the *Newsletter* still isn't here, and you may want something in hand if you're going to keep the space open.

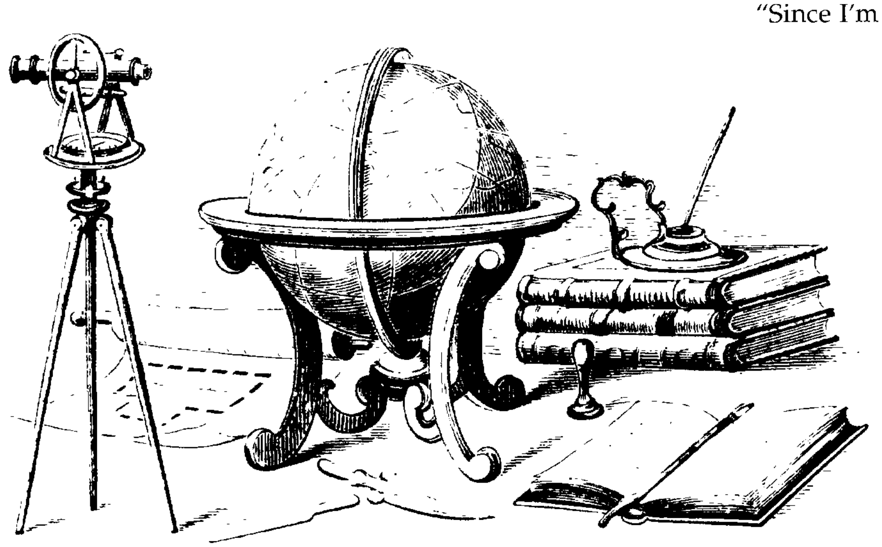
"If it makes sense to you, what I'd most like the *Newsletter* to publish next is more—and more fully detailed—advice on observing the distance. It can be a frustrating business for a beginner. If they go into it cold some navigators will give up on lunars before they get started. The two pages I'm sending for consideration are slightly revised versions of what you've already seen.

"I'd like to add a few things to the remarks Admiral Davies made about this method. Corrections are conveniently grouped and there is never a question as to where they go or how to apply them. In the calculation that clears the distance there are only three simple additions (one number added to another), three subtractions, and the division of a number by two. There is no interpolation or other mental arithmetic. And there is no puzzling over what to do next or how to do it. The set of tables has fewer pages than the *Nautical Almanac*, but is an inch taller and one and a half inches wider. Print is correspondingly larger than that in the *Almanac*, and is easier to read.

"The *Foundation* has been invaluable in getting this method out into the light of day. I deeply appreciate that.

"Since I'm sending this directly to your address I'll also mail a copy to Captain Carraway."

— *Sincerely, Bruce Stark*



Member Bruce D. Stark wrote to Director John M. Luykx on March 4, 1998:

"Thank you for the quick response. I'll junk that advice about using the 'shadowy zone' to keep the line of sight parallel to sextant frame.

"You also point out that WHEN THERE IS A CHOICE the bright object should be reflected and the dim one looked at directly. I didn't say anything about that because it so often happens there is no choice - unless you put yourself in an uncomfortable position. When there's haze the moon may not be visible during the day except when she's higher than the sun. At night the most inviting stars and planets are, as often as not, higher than the moon. Once in a while I do hold the sextant upside down, left handed. But if this is a strain, I just reflect the dim object.

"I can't conduct experiments with various sextants and telescopes. I don't have the resources - or the eyesight. I'm hoping you will continue to write about these matters.

"Thank you again for your help. Advice in the tables will be improved."

— *Sincerely, Bruce*

Member Bruce D. Stark wrote on March 7, 1998:

"[Your] 'Advice on Observing . . .' suits me fine as a title. But I'm revising the first page (page iii in my tables) and will fax you a copy from somewhere in town, probably tomorrow. I realize it may be too late.

"I like your idea of showing how John Luykx's lunar can be worked with my tables, and believe I can get the material to you in time.

"I'm thinking I'll just clear the lunar. That's where the puzzle is for most navigators. They already have ways to get comparing distances from the Almanac and proportion for GMT. If the form and the explanation could be on facing pages, that would be ideal. I intend to start out easy, just showing what you do. But if it turns out there's room I'll get into what the elements are, and maybe even show how the formula was derived. It won't matter if you cut this stuff off.

"These are only preliminary thoughts. We'll see how it works out.

"Thank you for your comments — I'll bear them in mind."

—*Sincerely, Bruce*

Member Bruce D. Stark wrote on March 13, 1998:

"Some way or other the 4677 got left out of my e-mail address on page 18 of the last *Newsletter*. The address should be: Stark4677@aol.com

"It seems curious none of the queries about the tables came by e-mail, but I only just now took a hard look at the address given in the *Newsletter*. No harm done — as long as those who are interested will try again. I hope it isn't too late to get the correct address in the next issue. I'm going to fax this to you just in case Capt. Carraway is off in Eastern Europe this week."

— *Sincerely, Bruce*

Member Jack R. Tyler of 10635 Islerock Drive, El Paso, TX 79935-1539 wrote on January 13, 1998:

"Thanks for reminding me to renew my membership with the Foundation.

"This year's activities took me into the Western Caribbean (Yucatan Coast, Belizian Reef, Honduran North Coast), plus the Bahamas, Turks & Caicos, and the Eastern Caribbean Chain from Tortola to Trinidad. All of this was as a passenger on either 3 or 4 masted windjammers or a small passenger freighter of about 1500 tons. I was able to improve my skills with the sextant to the point of consistently obtaining daily fixes within 3 nautical miles of the DR (as determined by the ship's log and GPS plot). A few times I was able to plot a fix on top of the DR. A calm sea and a clear horizon is a many splendored thing for a celestial navigator!

"I also improved on a navigation 'toy' that I've been developing over the last few years. It is a small metal pocket size box that used to hold throat lozenges. I pasted a small strip of paper that was marked with a millimeter scale into the bottom of this box and added small carpenter's line level next to it. Placing the box on a reasonably flat surface, I used a handkerchief to level it and point it directly at the sun. The arctangent of the height of the box divided by the length of the shadow on the scale gave me the sun's altitude. This along with the time of sight allowed me to compute azimuth and intercept. Depending upon the sharpness of the shadow's edge and prudent timing of the sights I was able to obtain fixes from 4 to 6 nautical miles from a GPS DR. At this time, I'm working on a small almanac for the 'sunbox'.

"Hoping that our membership is still enthusiastic about celestial navigation, I am"

— *Sincerely yours, Jack R. Tyler*

Member Andrew W. Williams sent by e-mail (andywilliams@pcola.gulf.net) on March 27, 1998:

"I have been interested in the lunar distance method for determining longitude for some time. Due to illness and death in the family my reading for enjoyment and knowledge literally stopped for most of last year. Imagine my delight when I started reading John Luykx's articles on Determining Longitude by Lunar Distance Observation. Unfortunately, I cannot find issue Fifty-four, Winter 1996-97, which contains the first article in the series of three. Is it possible to obtain John's article from that issue, if not the complete issue?

"I have been communicating with two USPS members who have expressed an interest in the lunar distance method. I would like to share some of John's articles with these two as an enticement to joining the Foundation and feel obligated to ask John's permission. Could you please put me in touch with him? I am also directing the two to the Foundation's web page."

— *Thank you. Andrew W. Williams, Jr.*

The Executive Director responded to Member Williams by e-mail on March 29, 1998:

"Thank you for your e-mail. We are always delighted to receive comments, requests or any other communication from members.

"Concerning sharing John Luykx's articles with your friends, I am certain he would not object. However, if you would like to call him I know he would appreciate hearing from you. His telephone number is 301-420-2468. That is the number of InfoCenter, John's company.

"I will send you a copy of Issue #54. We always have extra copies for those who have not received them due to a 'glitch' in the postal system. We also have back copies at $2.00 for new members who would like to obtain all issues."

— *Best regards. Terry F. Carraway*

Chief Quartermaster Daniel W. Holzemer, USCG, wrote on February 1, 1998:

"After reading your home page statement on the Internet at http://www.olyc.com/navigation/navfound.htm, I am interested in joining the Foundation. Presently I am a navigation and shiphandling instructor at the U.S. Coast Guard Academy in New London, CT.

"Please send me a copy of your Newsletter to review. I thank you in advance for your reply."

— *Sincerely yours, Daniel W. Holzemer*

Member Alvis Williams of 32 Outer Drive, Santa Paula, CA 93060 wrote on November 17, 1997:

"...You mailed the Almanac book rate on 13 Nov. I received it on 15 Nov. I was truly amazed how quickly it came. I can't mail a letter first class across town in that amount of time. Ha ha."

— *Yours truly, Alvis Williams*

Member Eric B. Forsyth of 2 Bond Lane, Brookhaven, N.Y. wrote on April 5, 1998:

"I want to thank you for your letter of 8 December, 1997, and the enclosed papers. I apologise for my tardiness in replying. The paper by J. N. Wilson was most interesting as he also discusses means of determining the time of MP. He mentions errors of typically 5' in position measurement from a single body. This is certainly comparable with my longitude errors of - 2.9' to + 3.2' shown in my letter.

"There is an interesting article by Alan Littell in the March/April '98 *Ocean Navigator.* He discusses the test of *H4* and concludes the assessors reached an unjustified level of accuracy in their results. I am sure Harrison's supporters had to use every weapon they could to fight his detractors and a little fudging of the results does not detract from Harrison's genius. Thank you for publishing my letter

— *Yours sincerely, Eric Forsyth.*

*Editor's note: The paper "Position from Observation of a Single Body" by James N. Wilson is in Issue Fifteen (Winter 1986-87).*

# NAVIGATION NOTES

## Advice for Observing the Lunar Distance

By Bruce D. Stark *©1995, 1997 by Bruce D. Stark, Used with permission.*

### PREPARATION

If you don't already have a better way of recording your sights, try this: Find an open cylinder (such as a smooth-sided tin can with both ends out) of a size to fit on your forearm. Fold a sheet of notebook paper lengthwise, wrap it around the cylinder and snap a rubber band over it to hold it in place. Slide this on your arm until the inboard end is snug. Roll your sleeve back and stuff it under the outboard end, to make that secure. This also gets your sleeve out of the way of the watch, which can be worn on the palm side of the wrist and, during daylight at least, read at a glance.

For night observations a mechanic's penlight with flexible stem is convenient. It can be clipped in the shirt pocket and the stem bent to suit. To keep it from flopping around, cut a stiff piece of plastic to fit in the pocket, and clip the light over both pocket and plastic. For the sake of night vision you may want to paint the bulb or lens red.

### CHOOSING THE OTHER BODY

Naturally the body from which the moon's distance is measured should be more or less in line with her orbit. The sun is ideal in this respect. At night you can discover the moon's orbit by imagining a line drawn through her narrow dimension. Or, put another way, her orbit is perpendicular to a supposed line joining her horns. When she's too near full for this to work it is worth knowing where the ecliptic is among the stars. Pages 266 and 267 of the *Almanac* show it as a curving line. The moon will be within about five degrees of the line, and her orbital motion nearly parallel to it.

### GETTING A ROUGH CONTACT

Take the telescope off the sextant and put it in a safe, handy place, such as a clean left front pants pocket. This gives you a wide view, and lets both eyes work. Turn up the shades you think you'll need and set the index to zero. If confusing reflections are coming from the shades or mirrors, try using a sight tube. The usual way of bringing the objects together is to hold the sextant so its frame is in line with both, and looking through the horizon glass at one, move the index forward until the other appears. This is easy if the distance is short.

Alternatively, start with the higher object. Hold it in the silvered side of the glass and bring it across the sky to the other. This is like bringing a star down to the horizon for an altitude, but more difficult, since the destination is easier to miss and the motion seldom vertical. It is usually necessary to bring the first object even with but well to the side of the other, until shades are readjusted.

A less sporting approach is to calculate the two comparing distances from the *Almanac* beforehand and set the index somewhere in between. This will be close enough to put both objects in the horizon glass.

Adjust the images to a comfortable, and equal, brightness. Usually this will take fewer shades if you look through the horizon glass at the dimmer of the two objects and reflect the other.

## MEASURING THE DISTANCE

Put the telescope back on and make the contact on the moon's fully rounded limb at the point the sun, or star, can just touch when the sextant is rocked on the axis of the telescope. But split a planet's image on the limb. That way you can ignore its semidiameter. The images may be easier to control if you use your right hand simply to keep one body—the one you are looking at directly—centered in the telescope. The reflected image will follow your left hand as it rocks the sextant.

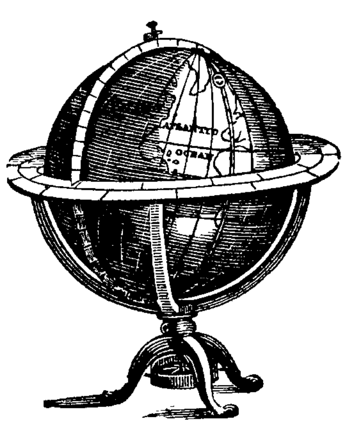
Don't try for perfection—just take an interest in the way the contact looks as the images brush. It shouldn't take much over a minute to get and record each contact and watch time.

While it's customary to use the average of from three to six measurements (and watch times), it may work as well to put a mark beside the best one and use it only. This might be a good idea for those who have trouble averaging sexagesimals.

## ALTITUDES

Fortunately, altitudes are not critical. They are only wanted for their refraction and parallax corrections, and to determine the shape of the triangle formed by the two bodies and the observer's zenith. Still, try to get the altitudes within 1' or 2' of the truth—especially if the distance is short.

**At sea, a lone observer** measures the altitudes twice, once before getting a set of three or more distances, and then again afterward. Watch times are noted with the altitudes, just as they are with the distances. The operation is best completed in ten minutes or so since altitudes don't change at a steady rate. Get the rough contact for distance before you begin and write it down. Also make a mental note of the shades you'll want. That way you can set the sextant for the distance as soon as you have the first altitudes.



An example at the bottom of page 290, facing Table 7, shows how to proportion the altitudes to agree with the time of the distance.

**If there are three observers,** the one measuring the distance calls "Mark" each time he has a contact. The other two, who have been following the altitudes, note what they have at the moment. Altitudes are recorded along with each measurement of the distance. The mean of the altitudes will agree with that of the distances. If the altitudes make a reasonable cut you won't need a watch, as you can use the mean altitudes for a position fix after you've found Greenwich time.

**At home**—or any place on land where you know latitude, longitude and time—save yourself trouble by leaving the artificial horizon in its box. That way you can step out the door and be back with a set of distances in five minutes. When you're ready to work the observation, compute altitudes using your true position and the true GMT of the average distance. A hand-held calculator, if programmed for this job, makes short work of it.

## INDEX CORRECTION

I get wildly variable notions of index error from the horizon or a star. I wear trifocals, and my eyes were never particularly sharp anyway. But the sun's diameter, measured on and off the arc, still gets a reliable correction. The method isn't much used nowadays, so is given here.

If there is a dark glass in the sextant box fit it on the eye end of the telescope. Otherwise you'll have to use a lot of shades. Set the index to zero and then turn the micrometer drum forward to about 30'. Perfect the contact between limbs of the sun's two images and record it. Unclamp the index, set it on the other side of zero—off the arc—and perfect the contact again. Bear in mind that measurements off the arc must be read in the opposite direction to the numbers. This applies to both micrometer drum and vernier. Perhaps it would make more sense to read the normal way and then subtract from sixty.

Get two or three measurements each side of zero. The difference between the sum of "on" measurements and the sum of "off" measurements, divided by the total number of measurements will be index error. Name it "on" or "off" after the biggest sum.

| ON | OFF |
|---|---|
| 32.8 | 32.6 |
| 32.6 | 32.2 |
| 32.8 | 32.3 |
| 98.2 | 97.1 |
| 97.1 | |
| 1.1 | |

0.'2 on
6 | 1.1

## CLEARING A LUNAR DISTANCE WITH THE NEW TABLES

*By Bruce Stark*

*Editor's note: The tables are TABLES FOR CLEARING THE LUNAR DISTANCE, second edition, ©1995, 1997 by Bruce D. Stark, Lant-horn Press, 3770 Onyx Street, Eugene, Oregon 97405*

For clearing a lunar distance observation a set of tables can be handier than an electronic calculator. Director John Luykx shows, in issue fifty-six, how to clear a lunar with a calculator. The accompanying work sheet shows how to clear the same lunar with a book of tables.

From John Luykx's data we take the Greenwich date (Aug. 27, '96) and approximate time (between 02 and 03, but closer to the latter hour). For 03 hours the *Almanac* gives the moon's H.P. as 61.1'. That goes in the box in the upper right corner of the form.

We also need the apparent altitudes of the centers of the two bodies—symbolized as Sa and Ma. The unorthodox notation is used because "apparent altitude" or "Ha" commonly refers to the sun's or moon's limb, not the center. John used a bubble horizon, so his altitudes *are* of the centers, and can be entered on the form as Sa and Ma.

Follow the big arrow to the right of Ma and (supposing you have the tables in hand) go to table 2. Across from the nearest value of Ma and in the column for H.P.61' the numbers 47.76 and 440.2 are side-by-side, ready to be copied onto the form. A small table in the margin gives 0.08 and 0.8 for the additional 0.1' of H.P. Copy these onto the second line.

In table 3, in the column "SATURN, JUPITER, or STAR" and across from the nearest value of Sa, are the numbers 2.20 and 0.0, ready for the third line. Added together, the three numbers on the left give the total correction for refraction and parallax. The three on the right give a function I've dubbed "Q."

Move on to table 4 and with H.P. 61.1 and the nearest value of Ma take out the moon's augmented semidiameter (16.'84). The sun had no part in this, so table 5 isn't needed. And, since the moon wasn't low, table 6 isn't needed either. A planet's semidiameter is most conveniently dealt with when measuring the distance, by splitting its disk on the moon's limb. But if you prefer to measure from a planet's edge, as was done in this case, enter its semidiameter on the line provided for the sun's.

Had the moon's enlightened limb faced away from Jupiter it would have been a "far limb" observation—that is, contact would have been made on the side of the moon farthest from the planet. But, since the moon's enlightened limb faced toward Jupiter, this is a "near limb" observation. Bring the total semidiameter correction to the left and place it accordingly. (Any time your outcome is about half an hour off, this is the first place to look for the blunder. The second place is the line for table 5—did you or did you not actually use the sun?)

John's sextant distance, Ds, was 33_ 4.'5. His index correction was -0.'5 (on the arc) and there was no instrument error. The form shows what to do with these and the semidiameter correction to get Da, the apparent distance between centers.

We have already used two-thirds of the work sheet just organizing the elements of the problem. Ahead, in the remaining third of the sheet, is the actual calculation for clearing the lunar distance.

Begin by bringing down Ma-Sa and subtracting it from Da. Now add it to Da. Find the numbers corresponding to the two resulting angles in the "K" table and add the numbers together. Divide the resulting sum by two. Bring down Q and add.

On the left, bring down H~H. Look up its K and copy that onto the form. Compare this with the number to the right of it. Copy the smaller number into the space beneath the larger and subtract. With the resulting 0.68156 look in the Gaussian table. Copy the value you find there into the remaining space on the second line from the bottom and subtract again. The number you now have (1.07926) is the K of the cleared lunar distance, which the K table shows to be 33"33.'2. (The first time I worked this I got a cleared distance of 33_33.'1. The cause, it turned out, was a blunder in copying a number out of table 4.)

It's a good idea to strike through the number used to look up the Gaussian as soon as you no longer need it.

### REMARKS

Altitudes are not critical. An error 1' in an altitude will have, at most, only a slight effect on the outcome of a lunar. Usually it has none. But the elements shown in the middle of the work form, from the line for table 4 on down to the one for Da, *are* critical.

The elements taken from tables 2 and 3 may or may not be critical. The sole purpose of the calculation for clearing the distance is to determine how much effect they have. At one extreme they can show up 100% in the outcome. At the other extreme they don't show up at all.

The second work sheet—which calculates two comparing distances from Almanac data and finds GMT—would probably take as much room to explain as this one has. If allowed that much space in the *Newsletter* I would rather use it, in a later issue, to explain the equations underlying this method and perhaps show a drawing of the lunar problem.

## Calculate Your Own Nautical Almanac Data for Sun Sights

*By Bill Murdoch*

### CORRECTION

On Page 17 of Issue Fifty-seven (Fall 1997), in the left hand column, and in the formula for GHA of Aries, the last term of the equation **should be**

-(0.000000*sin(L)))

**rather than**

(-0.000000*sin(L))).

♃ ☉ near side ☽ Aug 27 '96 GMT, about 3h John Luykx's Observation

| | Sun/Star ° ' | | Moon ° ' |
|---|---|---|---|
| Table 1 | . | Table 1 | . |
| Sa | 23° 32.9 | Ma | 36° 28.7 |
| (subtract lesser) | ° . | or | 23° 32.9 |
| Ma~Sa | ° . | | 12° 55.8 |
| | − . | | + 50.0 (round) |
| H~H | ° . | | 13° 45.8 |

from Almanac, the moon's H.P. = 61.1

| | | |
|---|---|---|
| Table 2 | 47.76 | 440.2 |
| | .08 | .8 |
| Table 3 | 2.20 | .0 |
| | 50.04 | 441.0 Q |

♃

| | | |
|---|---|---|
| Table 4 | 16.84 | add |
| ~~SUN?~~ 5 | .30 | |
| | 17.14 | |
| Low sun or moon? 6 | − . | |
| (round) | . | |

| | off + | on − |
|---|---|---|
| Index error | . | .5 |
| Instrument | . | . |
| Moon's Limb Near? | 17.1 | . or Far? |

| | | |
|---|---|---|
| Ds (Sextant Distance) | 33° 04.5 | . |
| | 33° 21.6 | |
| | − .5 | |
| Da | 33° 21.1 | |
| Ma~Sa | 12° 55.8 | |
| Da - (Ma~Sa) | 20° 25.3 | K 1.50 273 |
| Da + (Ma~Sa) | 46° 16.9 | K .81 123 |

| | | |
|---|---|---|
| K | 1.50 | 273 } add |
| K | .81 | 123 |
| | 2.31 | 396 |
| half | 1.15 | 698.0 } add |
| Q | | 441.0 |
| | 1.16 | 139 (round) |
| | .08 | 213 (subtract lesser) |
| | 1.07 | 926 |

| | | |
|---|---|---|
| H~H 13° 45.8 | K | 1.84 295 |
| | or | 1.16 139 |
| D 33° 33'.2 | | ~~0.68 156~~ |

# NAVIGATION BASICS REVIEW

## The Sign of the Equation of Time

*By Ernest B. Brown*

Prior to the 1997 *Nautical Almanac*, the sign of the equation of time was addressed as follows in the explanation (para. 18) of the Almanac:

> The equation of time is given, without sign, for $00^h$ and $12^h$ UT on each day. To obtain apparent time, apply the equation of time with a *positive* sign when GHA Sun at $00^h$ UT *exceeds* 180°, or at $12^h$ *exceeds* 0°, corresponding to a meridian passage of the Sun before $12^h$ UT; otherwise apply with a *negative* sign.

In the current Almanac, one now finds:

> The equation of time is given daily at $00^h$ and $12^h$ UT. The sign is *positive* for unshaded values and *negative* for shaded values. To obtain apparent time add the equation of time to mean time when the sign is *positive*. Subtract the equation of time from mean time when the sign is *negative*. At $12^h$ UT, when the sign is *positive*, meridian passage of the sun occurs *before* $12^h$ UT, otherwise it occurs *after* $12^h$ UT.

Since the meridian passage of the sun is *always* $12^h$ LAT, a quick glance at the time (LMT) of meridian passage— just to the right of the equation of time— is certainly the easiest and most foolproof way of determining both the sign of the equation of time and how to apply it to obtain LAT from LMT or LMT from LAT.

NEWSLETTER INDEX

**Index 92(1-35)** published with Issue Thirty-five (Spring 1992), is an index covering Issues One through Thirty-five.

**Index to Navigation Problems (4-33),** published in Issue Thirty-three (Fall 1991), covers navigation problems in Issues Four through Thirty-three.

**Index to Navigation Personalities (12-53),** published in Issue Fifty-three (Fall 1996), covers personalities in Issues Twelve through Fifty-three.

**Index to Book Reviews (36-53)**, published in Issue Fifty-three (Fall 1996), covers reviews in Issues Thirty-six through Fifty-three.

**Index to History of Navigation (3-54),** published in Issue Fifty-three (Fall 1996-97), covers history articles in Issues Three through Fifty-four. This includes articles under the heading Navigation Notes in Issues Three through Seven.

**Index to Navigation Notes (1-56),** published in Issue Fifty-six (Summer 1997), does not include the navigation problems and history articles previously published in the Navigation Notes section.

**Index to Navigation Basics Review (13-58),** published in Issue Fifty-eight (Winter 1997-98), covers those articles written as reviews of the basics of navigation in Issues Thirteen through Fifty-eight.

| | | |
|---|---|---|
| Nineteen<br>Winter 1987-88 | The Sailings | John M.Luykx |
| Twenty<br>Spring 1988 | The Sailings | John M. Luykx |
| Twenty-one<br>Summer 1988 | Mercator Sailing/Middle Latitude Sailing | John M. Luykx |
| Twenty-two<br>Fall 1988 | Great Circle Sailing | John M. Luykx |
| Twenty-three<br>Winter 1988-89 | The Sextant Altitude Corrections | John M. Luykx |
| Twenty-four<br>Spring 1989 | The Personal Equation, Variation in the Dip Correction, Random Error in Sextant Observations | John M. Luykx |
| Twenty-five<br>Summer 1989 | Averaging Sextant Observations | John M. Luykx |
| Twenty-six<br>Fall 1989 | The Most Probable Position from Celestial Observations | John M. Luykx |
| Twenty-seven<br>Winter 1989-90 | Checking Steering Compass Accuracy Using Celestial Observations | John M. Luykx |
| Twenty-eight<br>Spring 1990 | Checking the Accuracy of Navigation Equipment and Procedures | John M. Luykx |
| Twenty-nine<br>Summer 1990 | Arithmetic Calculations | John M. Luykx |
| Thirty<br>Fall 1990 | Time and Longitude by Celestial Observations | John M. Luykx |
| Thirty-one<br>Winter 1990-91 | Determining Positive Ashore from Celestial Observations | John M. Luykx |
| Thirty-three<br>Fall 1991 | Celestial Navigation in the Arctic | Robert Eno |
| Thirty-four<br>Winter 1991-92 | The Accuracy of Mechanical Spring-Wound Navigation Chronometers and Deck Watches | John M. Luykx |
| Thirty-five<br>Spring 1992 | The Accuracy of Quarts Timepieces | John M. Luykx |
| Thirty-six<br>Summer 1992 | Great Circle Sailing and Triple Interpolation | William O. Land |
| Thirty-seven<br>Fall 1992 | An Ancient Interception Device: A pre World War I Torpedo Director | William O. Land |
| | The Use of the Calculator in Navigation | John M. Luykx |
| | A DR Independent Two Celestial Body Solution | R. B. Derickson |
| Thirty-eight<br>Winter 1992-93 | Addendum to a DR Independent Two Celestial Body Solution | R. B. Derickson |

| | | |
|---|---|---|
| Thirty-nine<br>Spring 1993 | The Use of the Calculator in Navigation | John M. Luykx |
| | Calculator Tricks and Two-Body Mathematics | Mike Pepperday |
| Forty<br>Summer 1993 | The Use of the American Rail-road Watch as a Back-up Time Reference at Sea | John M. Luykx |
| Forty-one and<br>Forty-two<br>Fall/Winter 1993-94 | Running Fix by Calculator from an Unknown Position | Edward T. Matthews |
| | The Astro-Compass | John M. Luykx |
| | The 57 Navigational Stars | William O. Land |
| Forty-three<br>Spring 1994 | The Accuracy of the Hand-Bearing Compass at Minimizing the Effects of Deviation | John M. Luykx |
| | Celestial Slide Rule-Assisted Sight Reduction Method | Robert M. Girdler |
| | A Navigation Problem | Douglas Davies |
| Forty-four<br>Summer 1994 | Checking the Deviation of Your Compass | John M. Luykx |
| Forty-six<br>Winter 1994-95 | A Navigation Instruction Hint | Ernest Brown |
| Forty-seven<br>Spring 1995 | Use of H.O. 229 for Check Solution | Ernest Brown |
| Forty-nine<br>Fall 1995 | Celestial Navigation - An Armchair Perspective | Roger H. Jones |
| Fifty<br>Winter 1995-96 | Celestial Navigation - An Armchair Perspective (a continuation) | Roger H. Jones |
| Fifty-one<br>Spring 1996 | Celestial Navigation - An Armchair Perspective (a continuation) | Roger H. Jones |
| Fifty-three<br>Fall 1996 | Sextant Altitude Corrections for Observations of the Moon | John M. Luykx |
| Fifty-eight<br>Winter 1997-98 | The Sign of the Equation of Time | Ernest B. Brown |

**Index to Navigation Foundation Peary Project (23-42),** published in Issues Twenty-three through Forty-one/Forty-two, covers articles and comments on the analysis of the data of Robert E. Peary's expedition to the North Pole in 1909.

| Issue | Article | Author |
|---|---|---|
| Twenty-three<br>Winter 1988-89 | Foundation Investigates Peary Data | T. D. Davies |
| Twenty-four<br>Spring 1989 | Peary Investigation Continues | T. D. Davies |
| Twenty-five<br>Summer 1989 | Peary Project | T. D. Davies |
| Twenty-six<br>Fall 1989 | The Peary Project | T. D. Davies |
| Twenty-seven<br>Winter 1989-90 | Peary Report Completed | T. D. Davies |

| | | |
|---|---|---|
| Twenty-eight<br>Spring 1990 | The Peary Report Continued | T. D. Davies |
| Thirty<br>Fall 1990 | The Supplementary Peary Report | T. D. Davies |
| Thirty-one<br>Winter 1990-91 | Comment on the lecture on *Robert E. Peary at the North Pole,* delivered by T. D. Davies in London Oct.1, 1990, at an annual meeting of the *Permanent International Association of Navigation Congresses* | T. D. Davies |
| | Remarks on Aspects of Polar Navigation | T. D. Davies |
| Thirty-three<br>Fall 1991 | New Foundation President (Co-designer of the methodology and techniques of the photogrammetry used to analyze the Peary photographs) | Roger H. Jones |
| Thirty-eight<br>Winter 1992-93 | Peary Project Update | Doug Davies |
| Forty-one & Forty-two<br>Fall/Winter 1993-94 | Peary Update: Local Apparent Noon at High Latitudes | Doug Davies |

# MARINE INFORMATION NOTES

*Edited by Ernest Brown*

## NIMA'S MARINE NAVIGATION DEPARTMENT HOME PAGE

NIMA'S Marine Navigation Department has developed a new web site. This site is provided as a demonstration of concept and is not a replacement for NIMA's paper products. The navigation information located at this web site is for prototype testing purposes only. It has not been updated with the most current navigation safety information available at NIMA and in addition some graphics may be incomplete or missing. In the near future it is the intent of the Marine Navigation Department to place accurate, complete and up-to-date navigation publications and information on this web site. This data will be the equivalent of, and a viable replacement for, the respective hard copy product that is published by NIMA. Notification of the availability of this data will be widely promulgated via the U.S. Notice to Mariners and other means. Until that time, use any navigation information located at this web site for training purposes only, NOT for navigation. In order for NIMA to improve this site your input and comments are necessary, so please use the e-mail on the site or the Marine Information Report and Suggestion Sheet at the back of each Notice to Mariners.

The site can be accessed through the "What's Hot" button via NIMA's Homepage at the world wide web (www) address: www.nima.mil.

The navigation publications on this site are in portable document format (pdf) and require Adobe Acrobat Reader to access. Adobe Acrobat Reader is free and may be downloaded from: http://www.adobe.com/

## DIGITAL NAUTICAL CHART (DNC) PROGRAM STATUS

The National Imagery and Mapping Agency (NIMS) continues to make progress compiling a worldwide DNC database. DNC compilation consists of converting and digitizing the NIMA chart portfolio in Vector Product Format (VPF). Twenty-five percent of the portfolio has already been digitized and advance sets of data are now available on CD-ROM. Approximately fifty-five percent of NIMA's charts will be completed by September 1998. Completion of the DNC database is projected for September 1999.

The DNC is *currently* available to the Department of Defense (DoD), qualified DoD contractors, and U.S. Government Agencies supporting DoD functions only.

# THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION ISSUE FIFTY-NINE, SPRING 1998


This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Awards

The Foundation is pleased to have presented awards for navigation excellence and a check for $100.00 to two of the four educational institutions which receive our awards. The plaque is wood with a raised metallic foundation emblem, a brass plate with the name of the award and the recipient's name with the caption "For Excellence in Navigation". Each school has a perpetual plaque with the name of each year's recipient on a brass plate for the year in which they won the award.

The two recipients are:

At the United States Naval academy: The Benjamin Dutton Award to Midshipman Third Class Theodore R. Dyckman, 001710. The Foundation's Naval Academy Officer contact is LT Luc M. Pages, French Navy Exchange Officer.

At Tabor Academy of Marion, Massachusetts: The RADM Thomas D. Davies, USN Award to Student Alex Erving. The Foundation's Tabor Academy contact is Captain James E. Geil.

The RAD Thomas D. Davies, USN award presented at the U.S. Coast Guard Academy is presented in the fall. The Coast Guard midshipmen are judged during the summer while operating and navigating the Coast Guard ship *Eagle*. The recipient is selected when they return to their academic studies.

The Foundation has not received an award recipient from Gould Academy.

### Nostalgia

While wandering around the Baltimore, Maryland Harbor I saw a WWII Liberty Ship moored to a pier that had been vacant. When I wandered over, I found it was a restored fully functional ship that was crewed by volunteers. Having been a seaman in WWII it was a bit of my history. Many of my friends were part of the "Armed Guard" on these ships. Many were wounded and many more lost their lives. My father, a U.S. Coast Guard Commissioned Warrant, convoyed these ships to North Africa and Sicily. The Liberty Ship SS. *John W. Brown* was one of the "armed" ships and had as many guns as a destroyer escort. When the "Project Liberty Ship, a non-profit tax exempt volunteer organization" found the *Brown* it was being used as a floating classroom and had been stripped of guns and many other items. The ship now has the guns replaced, most of the standard equipment of the Liberty Ships and the troop bunks and some examples of cargo such as field artillery, jeeps and other army equipment. It has visited, under its own power, New York City; Greenport, Long Island; Boston and Halifax, Nova Scotia It regularly schedules day cruises on the Chesapeake Bay and annual trips to ports along the east and gulf coasts.

When I went aboard, my guide was one of the sailors who had sailed to Europe as part of the "Armed Guard" during the war. He had many tales to regale and was able to give a first hand, interesting, account of life aboard a merchant ship for uniformed sailors.

If anyone is interested in more information, please write:

Project Liberty Ship
Box 25846
Highland Station
Baltimore, Maryland 21224-0846
Or telephone: 410-661-1550

### DO YOU KNOW...?

***By Ernest Brown***

The range at which a small, portable 4-watt jammer can take out GPS civil signals?

*(The answer appears at the back of this issue)*



Sat, Jul 11, 1998 6:13 PM

# READERS FORUM

*Edited by Ernest B. Brown*

Member Bruce D. Stark of 3770 Onyx St., Eugene, OR 97405-4332, wrote on May 10, 1998:

"In your March 16 letter you suggested you'd have a place in issue 59 for an explanation of how the new tables get comparing distances and proportion for GMT. Although I haven't seen #58 yet I'm sending you the material for #59. Janice and I will be gone from the 14th through the 26th and will be pretty busy from now until sometime after we get back. I'll e-mail that information to Capt. Carraway.

"Your remark about the ease of following the clearing procedure was reassuring. Also as you can see, I squeezed in something this time about how long it takes. It should make a difference in the number of navigators willing to give lunars a try.

"The written part was formatted somewhat like the *Newsletter*, to see how it would look. The copy of the work sheet is scaled down to 90% so it will fit between the margins of the *Newsletter*.

"I hope you'll keep me informed as to what you'd like—and what you'd like changed. And if there's any way of formatting the material or sending it that would be more convenient, let me know. Just bear in mind that all I know about computers is what was necessary to produce the tables. I'm a slow learner—and quick forgetter—of such stuff. But I'll try."

— *Sincerely, Bruce Stark.*

Member James O. Muirhead of 1158 W. 11th St., Unit A, San Pedro, CA 90731, wrote on April 28, 1998:

"The article by Bill Murdoch on calculating your own nautical almanac data for the sun was interesting. However, the time for light to travel from the Sun to the Earth was misstated as 8 seconds. The mean distance of the Earth from the Sun is approximately 93 million miles. At 186 thousand miles per second, Sun light requires 8.3 minutes to reach the Earth. The value -20.5 seconds is the 'constant of aberration' which is a shift in apparent position of a star as the result of the compounding of the motion of Earth with the finite velocity of light. It is used in the calculation of the apparent position of all celestial objects except for the moon. The value of the aberration varies somewhat because of the eccentricity of the orbit of the Earth. The actual value for the Sun is about -20.5"/R, where R is the radius vector of the earth orbit in astronomical units (AU). As the orbit of the Earth is not very eccentric, and R is always very nearly one, it can be used as a constant without division by R. The aberration correction for the planets uses the same constant, but is more complex and there is a separate 'light time' correction required because the distance from Earth to a planet varies by a large amount.

"For those wishing to know more about celestial calculations, there are a number of books available at reasonable prices from Willmann-Bell Inc., P.O. Box 35025, Richmond VA 23235. (Tel. 804-302-7076). They will send you a catalogue if you ask.

"Since retiring in 1994, I also have pursued the calculation of a nautical almanac and have experimented with methods of celestial sight reduction. The two books I have found to be of the most value are *Astronomical Formulae for Calculators* and *Astronomical Algorithms*, both by Jean Meeus, a Belgian astronomer. Both books are published by Willmann-Bell. With the latter book, there is a diskette available, at additional cost, with the algorithms in source code in a number of programming languages, including Basic and C. The language must be specified at the time of order. The prices are reasonable. I purchased my copies some time ago for about $25 for the book and the same for the diskette.

"I have used Jean Meeus' *Astronomical Algorithms* to compose a sight reduction workbook in Microsoft Excel. I have included a copy of the workbook in the attachment to this e-mail and on a 3" diskette with a copy of this letter in the U.S. Mail.

"The Excel workbook contains an almanac which calculates the GHA and Declination of each of the observed objects. The use of the workbook is very simple. Enter the sextant IC and atmospheric data into the appropriate cells. Pull down menus are then used to select each object. Then the date and time of the observation is entered in the appropriate cells. Next, the sextant altitudes are entered without correction. The upper and lower limb of the Sun and Moon must be selected. (This has no effect on the planets or stars because their SD is zero). The workbook calculates the dip, refraction, the horizontal parallax of the Moon, and the semi-diameter of the Sun and the Moon.

"Because the positions are calculated to the second of time, no *v* or *d* corrections are required.

"The entry of an Estimated Position is optional. If entered, lines of position (LOP) are calculated for each altitude entered. This is good when only two objects are observed. Once all the data for a given sight is entered, use the mouse to click on the "Enter" button. This causes a macroinstruction to copy the entered data and paste it into the proper cells in the Almanac and the Sight reduction sheet. The Screen will blink between the copy and past operations. The time taken for this varies with the speed of the computer, but it is pretty fast with the Pentiums.

"I am a retired radar system engineer with no experience in celestial navigation. I was unfamiliar with the standard sight reduction methods and was looking for a closed form solution. The iterative method provided in the nautical almanac looked intimidating and I didn't understand it. Therefore the workbook uses what I believe is an original algorithm to calculate the observer's longitude and latitude directly from three observations. The method is as follows:

"The direction cosines of the GHA and latitude are derived. The direction cosines are the cosines of smallest angles between the ground position of the object (or the observer) and the Cartesian axes of the Earth. The Cartesian axes are arbitrary (but mutually orthogonal). For convenience O° Lat. (Dec.) and 0° Long (GHA) is used as the X-axis, 0° Lat. (Dec.) and 270° Long (GHA), for the Y-axis and the poles for the Z-axis. (They can be arbitrarily chosen because they are used only temporarily.)

"The direction cosines are used because they allow a closed form solution of the observers Latitude and Longitude from three sights. This is because of the relationship between the direction cosines of two GPs:

$$\mathrm{Cos}A_1\mathrm{Cos}A_0+\mathrm{Cos}B_1\mathrm{Cos}B_0+\mathrm{Cos}C_1\mathrm{Cos}C_0=\mathrm{Sin}H_{01}$$

Where $A_1$,$B_1$,& $C_1$ are the angles between GP of a celestial object and the X, Y and Z axes respectively, $A_0$,$B_0$ and $C_0$ are the same (unknown) angles for the observer's position and $H_0$ is the observed altitude.

When three bodies are observed, three such equations are obtained providing the required three equations in three unknowns.

$$\mathrm{Cos}A_1\mathrm{Cos}A_0+\mathrm{Cos}B_1\mathrm{Cos}B_0+\mathrm{Cos}C_1\mathrm{Cos}C_0=\mathrm{Sin}H_{01}$$
$$\mathrm{Cos}A_2\mathrm{Cos}A_0+\mathrm{Cos}B_2\mathrm{Cos}B_0+\mathrm{Cos}C_2\mathrm{Cos}C_0=\mathrm{Sin}H_{02}$$
$$\mathrm{Cos}A_3\mathrm{Cos}A_0+\mathrm{Cos}B_3\mathrm{Cos}B_0+\mathrm{Cos}C_3\mathrm{Cos}C_0=\mathrm{Sin}H_{03}$$

The worksheet uses matrix algebra to solve for the observer's direction cosines. These are then converted into the observer's latitude and longitude.

The relationship between the direction cosines and the GHA (long.) and Dec. (Lat.) are:

CosA=Cos(Dec.)Cos(GHA),
CosB=Cos(Dec.)Sin(GHA), CosC=Sin(Dec.)

There is no need in sight reduction to convert from Lat. and Long. When converting from the direction cosines back to Lat. and Long., CosC is converted first.

"This method may seem a bit strange and unfamiliar at first, but with a bit of use it is more intuitive than solutions using spherical trigonometry and lines of position. Please use the attached Excel file as you see fit and evaluate the results. You will need Excel 5.0 or higher. If it is deemed to be usable, you are free to copy it and share it with all the members with no obligation on anyone's part. I haven't used it for navigation yet, although I have tested it on a number of navigation problems in text books and on a problem from Bowditch. The results so far have been very good. The spreadsheet is protected, so don't worry about accidentally messing it up. If anyone would like a copy of the spreadsheet via e-mail I will send one along. It is about 1 megabyte in a self extracting zip file. E-mail your request to **jomuirhead@aol.com** and I will send you a copy by return e-mail. My son is going to set up a web site for me. If there is interest in this, I will post it on the site so that anyone can download it.

"If anyone would like a copy on a disk, send me a $10 bill to cover the cost of the disk, the mailer, the postage and a six-pack."

— *Jim Muirhead*

Member James O. Muirhead wrote by E-mail to the Executive Director on May 12, 1998:

"Hope you and your wife enjoy Finland. My wife and I are making our annual journey to Germany in June. We will spend a week there and then go to Portugal for a week. We plan to hang out in Lisbon for a couple of days and then to just drive around Portugal and see the sights. I would like to visit the museum of Henry the Navigator while there.

"If anyone reads the sight reduction papers and would like to comment have them write, FAX or call.

"By the way, I found a German Celestial Navigation site on the web. It is owned by a fellow named Henning Umland. He has some interesting stuff there. He is publishing a paper on navigation. Herr Umland also has an Excel workbook for sight reduction. He and I have traded workbooks. His does the traditional method of sight reduction. He expressed amazement at the idea of using linear algebra rather than spherical trigonometry. You should visit his site at 'h.umland@gmx.de (Henning Umland)'

"Have a good trip. See you later."

— *Jim Muirhead*

Member James O. Muirhead [jomuirhead@aol.com] wrote by E-mail on May 19, 1998:

"As you may know, Ernest Brown put me in touch with Dr. Kaplan of the US Naval Observatory. Dr. Kaplan was very cooperative and sent me a copy of an article by Paul Janiczek published in the Journal of the Navigation Institute titled 'Sight Reduction with Matrices." Janiczek's paper, published in winter of 1978/79, presents essentially the same algorithm that I have. His paper is more mathematical however. I plan to rewrite my paper, giving Janiczek credit for his work and presenting the method in an easy to follow manner (more user friendly). It is very useful, especially in an age where everyone takes laptops to sea with them. I would still like to make the Excel spreadsheet available to any member who wants it.

"I'll try to stay in touch."

— *Best regards, Jim Muirhead*

*Editor;s note: Dr. Paul M. Janiczek is a former director, Nautical Almanac Office, U.S. Naval Observatory.*

*Sight Reduction With Matrices by Ens. Roger Watkins, USN and P. M. Janiczek, U.S. Naval Observatory, is in the Institute's Professional Forum section of Vol. 25, No. 4, Winter 1978-79, NAVIGATION: Journal of the Institute of Navigation.*

Member James O. Muirhead wrote by E-mail to the Executive Director, Captain Terry F. Carraway, USN (Retired) on May 21, 1998:

"Thanks for all your help. I felt all along that it was too much to expect that I was the first to use vectors for this application. There are too many smart people out there. I would like to hear from Dr. Janiczek and discover what led to his discovery of this method.

"Have a wonderful trip to Northern Europe. I think I mentioned that my wife and I are going to Germany (Bayern) around the middle of June for a week and then on to Portugal. I would like to visit Sagres where Prince Henry had his school for navigators. I understand that Columbus visited there before his epic voyage to the New World.

"We are also planning to visit Lisbon. However, the World's Fair is being held there this year. Now we are planning to stay well outside the city and take public transportation into the city.

"Because you and your wife are traveling so much you should take the opportunity to share your experiences with the membership. After all, navigation is about travel. Otherwise we wouldn't need it. I use my GPS when I go hiking in Germany to find my way back to the Gasthaus."

— *Gute Reiser Terry und Frau, Jim und Sandy*

Member William D. Murdoch responded to member James O. Muirhead's comment on June 18, 1998:

"Jim Muirhead is correct: the time required for light to reach the Sun from the Earth is 8 minutes, not 8 seconds. I got the units wrong and failed to catch my mistake.

"There are two ways to explain the 20.5" annual aberration correction to the position of the Sun. The first is the one that Jim refers to in his letter. It assumes that the Earth is in motion around the Sun. In order for a photon of light from the sun to pass through a tube on the Earth, the tube must be aimed toward a point just ahead of where the Sun actually is located. Otherwise the photon will strike the inside of the tube before it passes completely through (Imagine a film of a hunter shooting a duck played backwards. The shot leaves the duck, flies through the air, and back down the barrel. The annual aberration is the angle that the hunter must lead the duck.)

"In this explanation the annual aberration is the arctangent of the ratio of the speed of the Earth in its orbit to the speed of light.

k = arctant (18.5 mi per sec/186,000 mi per sec)
k = 20.5"

"The second way to explain the annual aberration assumes that the Sun is moving through the heavens around a fixed Earth. Each year the Sun makes one revolution with respect to the stars. Because it takes a few minutes of time for light to pass from the sun to the Earth, an observer on the Earth sees the Sun where it was a few minutes ago. The Sun is really a bit ahead of the Sun we see. The annual aberration is the angle.

93,000,000 mi/186,000 mi per sec = 500 sec (or 8.3 min)
500 sec/31,557,600 sec/yr = 0.00001584 yr
0.00001584 revolutions of the Sun around the Earth
20.5" = k

"There is really no difference between the two explanations. Knowing that the arc tangent of a small angle is equal to its value in radians, the two formulas can be shown to be identical. I used the second explanation because I was working with the ecliptic longitude of the Sun which describes the position of the Sun among the stars.

"Willmann-Bell is a great source for astronomical information. I can spend a nice hour or more with their catalogue. When I am through, I am ready to take up astronomy as a hobby.

"I own both the books Jim refers to, and they are both excellent. Jean Meeus has done a great service in writing them as they have in one place information that is quite difficult to find elsewhere.

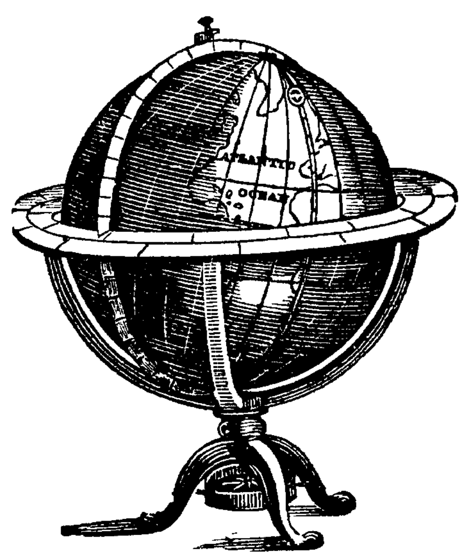
"I find the letters to be the best part of the *Navigator's Newsletter*. They help us all learn more about navigation and bring into the discussion the information and sources each of us has discovered."

—*Yours faithfully, Bill*

Member Capt. J. Regan (retired M.N.) of 104 Emma Street, Wooloowin, 4030, Brisbane, AUSTRALIA, wrote on 30 April 1998:

"Please find enclosed copy of 'Regan's Simplified Star Sights' for your perusal and comments.

"Encouraged by the favorable feedback from both the veteran and novice yachtsman in Australia, and being



informed of the Foundation's interest in navigation, I have enclosed the 'Simplified Star Chart' along with the proposed method in simplifying star observation that may interest the U.S. Yachtsman.

"The enclosed letter of reply from the U.S. Defense Mapping Agency, Washington, D.C., is in response to my request in seeking their confirmation in regard to the proposed method in the early stages of compiling the star chart.

"The Star Chart is specifically compiled to allow the mariner to choose the most suitable stars for the observation, and to plot and predict the result of the proposed star observation during the day, and confirm the result at the time of sights. It also provides the L.H.A., Dec., and altitude for all the navigational stars listed in the *Nautical Almanac* for any geographical position, for any given date and G.M.T. throughout the world, between Lat. 75°N, and 75°S.

"With the aid of the Star Chart, and the use of an inexpensive scientific calculator, that can digest the odd minutes in the calculations, the required altitude of the chosen stars can be found with a minimum amount of calculations, and with the chosen star's altitude clamped on the arc of the sextant at the time of sights, the chosen star will be found closest to the rim of the horizon when viewed through the sextant mirrors in the direction of the star's azimuth. A slight adjustment to the micrometer is all that's required to capture the sextant altitude of the chosen star at some precise G.M.T. of the observation.

"The other advantage in the use of the proposed method, is that it is no longer necessary to calculate the L.H.A. to enter the sight reduction tables, or create a convenient assumed position to make the L.H.A. a whole number, you can use the actual D.R. position and the calculator-reduced celestial sight will tell you how far off you are.

"The use of the star chart can best be described by the following extract from my soft covered Textbook entitled – 'The Navigator's Concise Notebook for Celestial Observations' that accompanies the purchase of each Star chart. . .

*Editor's note: The extract deleted above is more appropriate for another section of this Newsletter or a subsequent issue.*

"The other unique feature of the star chart is that the novice can set their own examples for practice for any chosen star that's listed in the *Nautical Almanac* for any given G.P. and for any given date and G.M.T. throughout the world, and justify the result of their calculations by placing a five cent coin appropriate to the G.P. of the celestial body onto the star chart, and with the centre of a protractor placed on the observer's estimated G.P. their calculations can then be verified according to the result of the celestial bodies calculated azimuth. This will also assist the novice in fully understanding the reason for each calculation that's required for every celestial observation. . .

"The Star Chart, complete with the soft covered notebook, entitled 'The Navigators' Concise Notebook, for Celestial Observations' is available from the above address, priced at $35 + $5 Aust. for postage and handling. WHOLESALE PRICES ON REQUEST.

"In closing, I wish to thank the Foundation for any advice they can offer in regard to the commercial aspects in introducing the Star Chart and the above method to the U.S. Yachtsman, and also for providing the opportunity to donate the enclosed subscription to a worthy cause."

— *Yours sincerely, James Regan*

Member George R. Rupp <grupp@ix.netcom> wrote by E-mail to the Executive Director <navigate@ix.netcom.com> on May 27, 1998:

"Even though the Academy has abandoned celestial, interest continues. In nine (9) months, my page has been accessed over 4,000 times and my celestial programs have been downloaded 15% of the hits. Maybe it is Freeware; maybe it is also some interest in the art. Whatever, it is interesting. I get about 3 E-mails/week on the subject. I answer them all with whatever knowledge I have. Most interesting, was a query from a British scientific team at the South Pole who are tracking albatross birds. They needed sunrise/sunset times in the regions below 50 degrees, where the almanac stops. My program gives the data but who knows whether it is accurate? I don't and can't get a confirmation. Further, I don't want to go down there to verify anything.

"Hope you have your antique Jaguar up and running."

— *Regards, George*

The Executive Director received the following E-mail <Alum USNA@USNA.Com> on June 8, 1998:

"Celestial navigation and the use of the sextant will continue to be taught at the Naval Academy. The laborious drill of punching through tables and using a sight reduction form will be introduced, but the actual derivation of the fixes will be done with the assistance of a computer and existing software. Media accounts which report that celestial navigation will no longer be taught at the Academy are inaccurate. The Naval Academy is continuing to teach celestial navigation, but is modifying the way it is taught. The sextant has not 'been thrown overboard'."

— *Beat Army*

*Editor's note: A recent column by Jennifer Harper, The Washington Times, quoted Frederick Davis, associate dean for academic affairs at the U.S. Naval Academy, as saying that a curriculum committee has "recommended dropping a celestial navigation course that has been a fixture at the Academy for 153 years."*

Member Captain Warren G. Leback of 202 Marten Road, Princeton, New Jersey 08540 wrote on June 3, 1998:

"It was reported recently that beginning with the 1998 incoming class at Annapolis that those entering midshipmen will not be taught the use of the sextant. This decision was based on the fact that celestial navigation is accurate within one to two miles while the Satellite Navigation system is accurate to within fifty feet or less.

"Naval Officers graduating four years from now and forward will rely solely on electronics without the basic grounding in time and spherical trigonometry. What happens when the electronic systems either fail, malfunction or provide erroneous positions? The failure of the satellite handling 'beepers' created problems within the business, medical and service areas. This could happen with the navigation satellites.

"Midshipmen and cadets at the Naval Academy, Coast Guard Academy, U.S. Merchant Marine Academy and the State Maritime Academies should continue to be taught celestial navigation, maneuvering board, plotting board, dead reckoning and the sailings. I would not want to be in command of a vessel, lose all the electronics either through combat or satellite failure, resulting in the loss of the vessel. I am more than sure that those who made the decision to eliminate sextant looked only in their minds that it becomes obsolete due to electronics. One must look at being prepared for all eventualities. Remember for lack of a nail a horse was lost, lack of horse a kingdom was lost.

"Fortunately I will not live to see that day when not one of the officers can navigate using celestial navigation as the ship is lost. Proper training, a sextant and a chronometer are cheap insurance to insure the investment in people and ships is secure."

*—I remain, Sincerely, Warren G. Leback*

# NAVIGATION NOTES

## More on the Lunar Distance

*By Bruce Stark*

It may be worth mentioning that some distances—even short ones—can be so difficult to measure that they are best left alone. When the dim object is higher than the other one, and so dim it can't be seen clearly by reflection, you have to hold the sextant upside-down in your left hand and reflect the bright object. Sometimes this is easy. But if it puts you in an awkward, shaky position let the observation go. You may be able to get it later, after the altitudes have changed.

In the last *Newsletter* I showed how to clear a lunar using the new tables. Although speed is not a consideration, it says something for the convenience of the method that I normally complete the whole procedure in seven minutes.

But, unfortunately, the *Nautical Almanac* does not at present give comparing distances, and I have to compute *them* too. This job takes longer and, unlike clearing, would be easier to do with a calculator. The only advantage of the tables for this part of the work is that they make you independent of electronics.

One morning recently I measured a sextant distance of 115°48.'8 between the moon and sun. According to the watch the observation was made between 15:00 and 16:00 April 17 GMT. I cleared the observation and got a true observed distance, D, of 115°50.'2.

The next job was to calculate from *Almanac* data what the distance was at 15:00 (D#1) and at 16:00 (D#2). You can follow the work on the accompanying form.

Begin by entering the Greenwich date and first hour at the top of the work sheet. Then open the *Almanac* and note the GHA's of the two bodies for that hour. Copy these onto the form. Since you'll be subtracting to get their difference, put the lesser one below the other.

Had a star been observed you could have used the lines in the corner for the extra steps getting GHA.

Note the declinations. When one is north and the other south—as they are here—it won't matter which you place above the other. You'll get their difference by adding. But when they are both the same you'll be subtracting, so put the lesser one underneath.

Drop down to the second part of the form and fill in GHA's and declinations for the next hour. That's all you take from the *Almanac*. There is no need of v's and d's or increments and corrections.

On the form, find the difference of GHA's and the difference of declinations for each hour. Then, supposing you have a copy of my tables in hand, look up the "K" functions of the differences and copy these onto the form. You can cut table openings in half by working both hours at once. Their functions won't be far apart.

Look up a "log Dec." for each declination. Add the log Dec.'s to the K of the difference of GHA's. Compare the sum with the number on its left. Since 0.18186 is less than 1.19677, place it underneath. Subtract.

With the remainder, 1.01491, look in the Gaussian table and take out .04006. Put that in the other column and subtract again. This gives you the K of the distance at 15:00. Open the table to the nearest whole degree of the observed distance and this K and its corresponding angle (116°17,'3) will be nearby.

Now you have comparing distances, and can proportion to find a GMT that fits the one that was observed. Tables 7 and 8 make it easy to do.

Copy D#1 either above or below D#2 and take the difference. Then write in the observed distance, D, above or below D#1 and take that difference too.

Put the remainders—27.'1 and 29.'1—into the places provided at the bottom of the sheet. Look for logarithms on the first page of table 7. Subtract one log from the other. Enter table 8 with the remainder—0.0309—and take off 55 minutes, 53 seconds.

So, according to my lunar, GMT was 15:55:53.

But this observation was for practice, and I know

STAR: S.H.A. ° '
G.H.A. Aries ° ' } add
° '
-360?
° '

date: April 17 '98 GMT
Previous Hour: 15

G.H.A. 159° 28'.5
G.H.A. 45° 6.4
difference 114° 22.1 ---> K 0.15 | 101
Dec. (N or S.?) 10° 32.8 -----> log Dec. ----> . | 740
Dec. (N. or S.?) 18° 39.6 -----> log Dec. ----> . 2 | 345
difference 29° 12.4 K 1.19 | 677 or 0.18 | 186 (subtract lesser)
0.18 | 186 .04 | 006
D#1 116° 17.3 ~~1.01 | 491~~ 0.14 | 180
D = 115 50.2
27.1

STAR: S.H.A. ° '
G.H.A. Aries ° ' } add
° '
-360?
° '

date: GMT
Following Hour:

G.H.A. 173° 57'.7
G.H.A. 60° 6.6
difference 113° 51.1 ---> K 0.15 | 355
Dec. (N. or S.?) 10° 33.6 -----> log Dec. ----> . | 742
Dec. (N. or S.?) 18° 40.4 -----> log Dec. ----> . 2 | 348
difference 29° 14.0 K 1.19 | 599 or 0.18 | 445 (subtract lesser)
0.18 | 445 . 4 | 036
D#2 115° 48.2 (77.3) ~~1.01 | 154~~ 0.14 | 409
29.1

Table
D ~ D#1 27'.1 7 0.9472
D#2 ~ D#1 29.1 7 — .9163
8 0.0309 55 min. 53 sec.

from the watch it was 52 seconds later than that. Two table openings and one addition (usually done in the margin but not shown here) give precise feedback:

The table 8 log for 52 seconds is 1.8403. Add that to the log you subtracted in the previous operation (0.9163) and look for the sum in the top rows of table 7. This shows the error in my measurement of the distance was 0.'4.

A small diagram on the page that faces table 7 shows that the distance was measured too long, and that if the fault was in the contact it was that I overlapped the images.

## Celestial Sight Reduction Using Direction Cosines

*By Jim Muirhead*

This is a closed form solution to an observer's position from three sextant observations. It is a very simple and elegant algorithm. It does not involve spherical trigonometry, but uses linear algebra and a method of determining locations by means of a set of numbers known as the direction cosines. The accompanying drawing illustrates the relationships.

As seen from the illustration, for every location on the globe, there will exist a unique set of angles defining that location. These angles, here called $\alpha$, $\beta$ and $\gamma$ are the direction angles from a location to the X, Y and Z axes as defined by the illustration. The relationship between the direction angles and the normal navigational coordinates are shown on the illustration. The cosines of these angles are called the direction cosines. The useful property of the direction cosines here is that the angle between two locations on a globe is defined by sum of the product of their direction cosines. That is for locations A and B, the cosine of the angle $\Theta$ separating them is given by:

$$\text{Cos}\alpha_A\text{Cos}\alpha_B+\text{Cos}\beta_A\text{Cos}\beta_B+\text{Cos}\gamma_A\text{Cos}\gamma_B=\text{Cos}\Theta$$

This is a linear equation. It is interesting to note that $\text{Cos}\Theta$ would be equal to SinHo of a sextant observation from one location to the other if one is the ground position of a celestial object.

Therefore, if an observer made, with his sextant, three altitude observations (corrected to Ho) of three celestial bodies (1,2 and 3) and converted their GHA and Dec. to the direction cosines, he would have three equations in three unknowns.

$$Cos\,\alpha_1 Cos\alpha_0+Cos\beta_1 Cos\beta_0+Cos\gamma_1 Cos\gamma_0 = SinHo_1$$
$$Cos\,\alpha_2 Cos\alpha_0+Cos\beta_2 Cos\beta_0+Cos\gamma_2 Cos\gamma_0 = SinHo_2$$
$$Cos\,\alpha_3 Cos\alpha_0+Cos\beta_3 Cos\beta_0+Cos\gamma_3 Cos\gamma_0 = SinHo_3$$

Or, in vector notation:

$$\begin{vmatrix} Cos\alpha_1 & Cos\beta_1 & Cos\gamma_1 \\ Cos\alpha_2 & Cos\beta_2 & Cos\gamma_2 \\ Cos\alpha_3 & Cos\beta_3 & Cos\gamma_3 \end{vmatrix} \begin{Bmatrix} Cos\alpha_0 \\ Cos\beta_0 \\ Cos\gamma_0 \end{Bmatrix} = \begin{Bmatrix} SinHo_1 \\ SinHo_2 \\ SinHo_3 \end{Bmatrix}$$

Where the o subscripts are the observers direction cosines and the 1,2,3 subscripts are those of the celestial objects at the time of observation.

This can be compactly expressed as:

$$A\{\mathbf{x}\} = \{\mathbf{b}\}$$

Where A is a 3 x 3 matrix of the direction cosines of the celestial objects, {**x**} is a 1 by 3 column vector of the observer's direction cosines (unknown) and {**b**} is a 1 x 3 column vector of the sines of the three corrected sextant altitudes.

The solutions to the observer's direction cosines are determined by Cramer's Rule: The determinant, D, of A is found. Dr is the determinant of the matrix A found after replacing the *r*th column of matrix A with the column vector {b}. Then:

$$x_r = \frac{\overline{D_r}}{D} \qquad r = 1,2,3$$

In this case, $x_1$ is $\text{Cos}\alpha_0$, $x_2$ is $\text{Cos}\beta_0$ and $x_3$ is $\text{Cos}\gamma_0$. These three numbers define the observer's position on the globe. Using the relationships shown in the illustration, they are easily converted to latitude and longitude. The observer's latitude is then $90°-\gamma_o$, and his longitude is arctangent $(\alpha_o\beta_o)$. In this example the chosen coordinate system puts positive longitude in the Western Hemisphere. Putting a minus in front of the arctangent reverses that.

For those unfamiliar with matrix algebra, help may be found in most any encyclopedia or handbook of mathematical tables and formulas.

It looks like a lot of work, even with a pocket calculator; and it is unless the calculator does matrix algebra. The better TI and HP calculators have matrix capability and make the calculations easier. Both Lotus© 1,2,3 ad Microsoft Excel© have powerful matrix capability.

For instance, in Excel if a 3 by 3 matrix occupies the range A1:C3, then entering =MDETERM(A1:C3) will return the numerical value of the matrix to that cell.

## CORRECTIONS:

### Clearing a Lunar Distance With the New Tables

*By Bruce Stark*

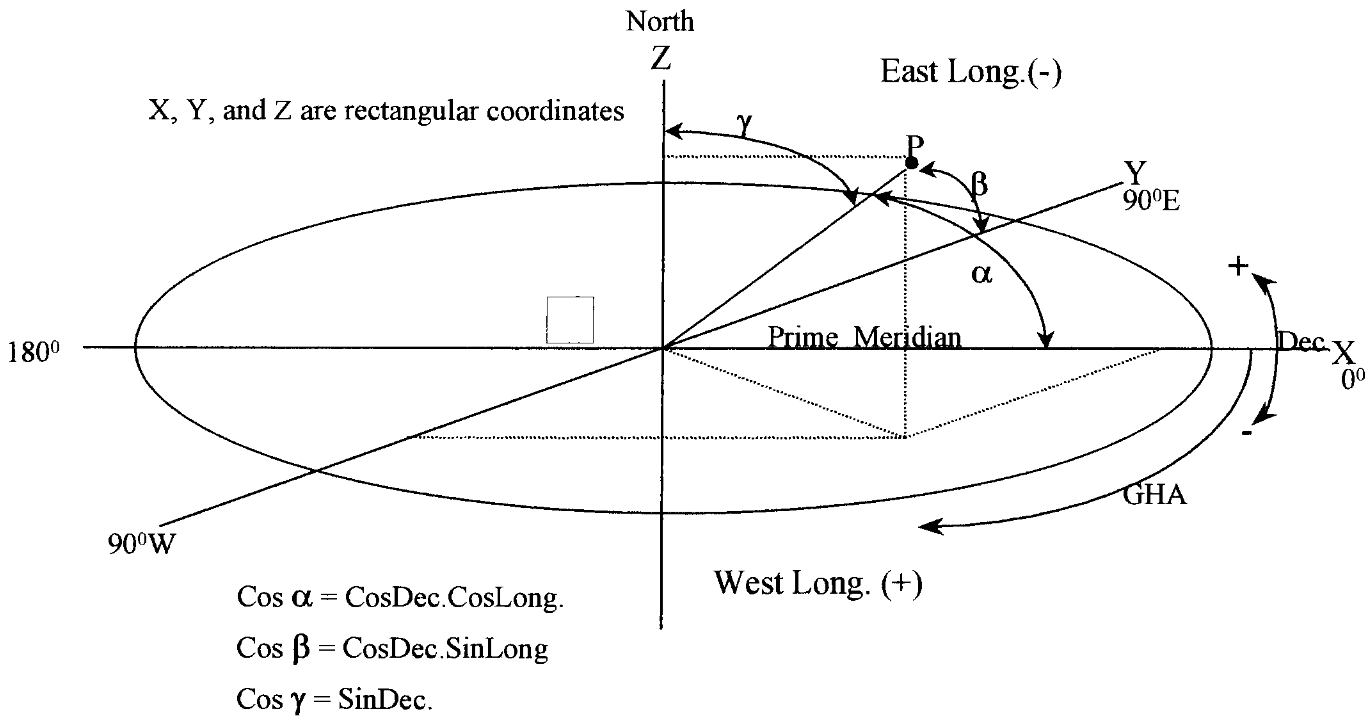
On page 6 of Issue fifty-eight (Winter 1997-98), change the fourth and third lines from the bottom of the left-hand column to read:

"outcome is about an hour off, or about two hours for a sun lunar, this is the place to look for a blunder. If it is about half an hour off, look at the line for table."

### Calculate Your Own Nautical Almanac Data for Sun Sights

*By Bill Murdoch*

On page 17 of Issue Fifty-seven (Fall 1997), change the fifth line from the top of the left-hand column to read: "because we see the sun where it was about 8 minutes ago."




**Relationship between Direction Cosines and GHA, Long. and Declination**

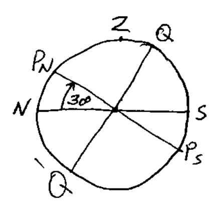
# NAVIGATION BASICS REVIEW

## The Observer's Zenith on Star Charts

*By Ernest B. Brown*

Star Charts often display the stars on a Mercator projection or simple rectangular grid with declination as the vertical coordinate and sidereal hour angle (SHA) or right ascension (RA) as the horizontal coordinate. The zenith of the observer is at the intersection of the parallel of declination equal to his latitude, and the hour circle coinciding with his celestial meridian. This hour circle has an SHA equal to 360°-LHA° (or RA=LHA°). The horizon is everywhere 90° from the zenith.

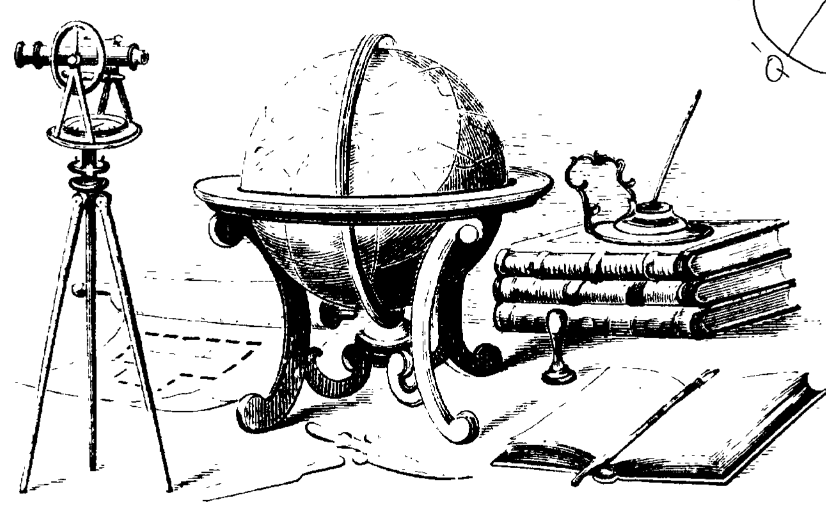
As can be seen in the diagram on the plane of the celestial meridian, the elevated pole is 30°N; the declination of the observer's zenith is QZ.




$NP_N+P_NZ=90°$

$\underline{QZ+P_NZ=90°}$

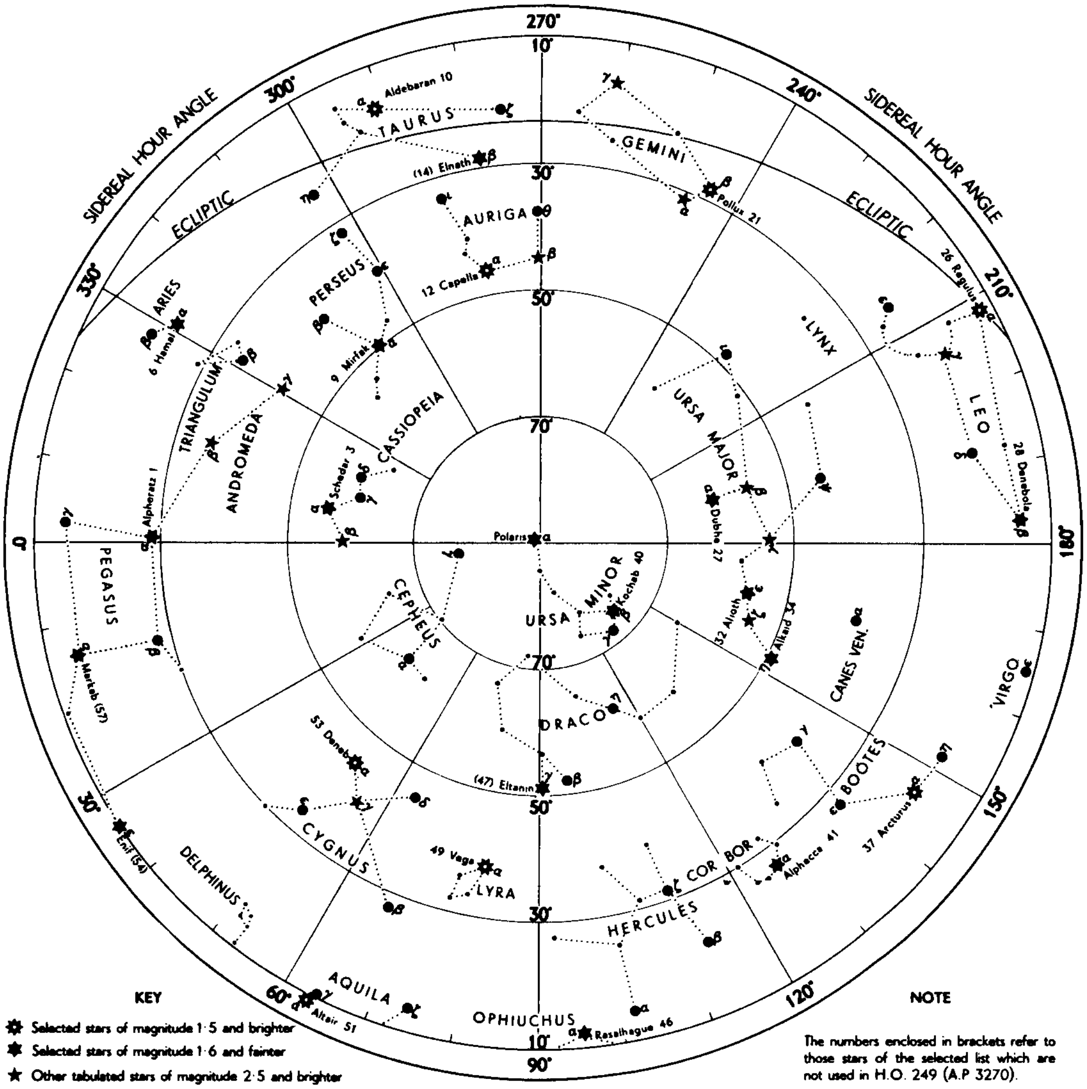
$\therefore QZ=NP_N=\text{Lat.}=30°$



The *Nautical Almanac* has four star charts. The two principal ones are on the polar azimuthal equidistant projection, one centered on each celestial pole. Each chart extends from its pole to declination 10° (same name as pole). Below each polar chart is an auxiliary chart on the Mercator projection, from 30° N to 30° S. On any of these charts, the zenith can be located as indicated above, to determine which stars are overhead. The horizon is 90° from the zenith.

# STAR CHARTS

## NORTHERN STARS



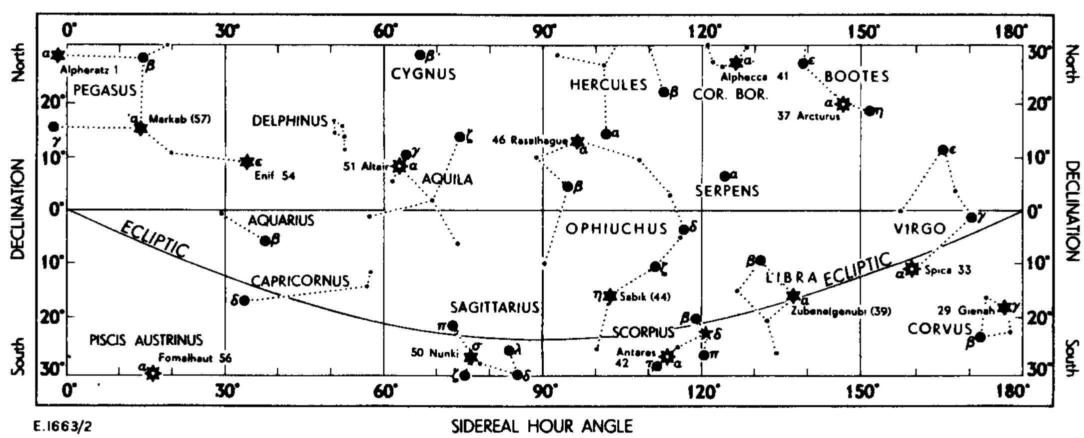

**KEY**

- ✡ Selected stars of magnitude 1·5 and brighter
- ✸ Selected stars of magnitude 1·6 and fainter
- ★ Other tabulated stars of magnitude 2·5 and brighter
- ● Other tabulated stars of magnitude 2·6 and fainter
- • Untabulated stars

**NOTE**

The numbers enclosed in brackets refer to those stars of the selected list which are not used in H.O. 249 (A.P 3270).

## EQUATORIAL STARS (S.H.A. 0° to 180°)

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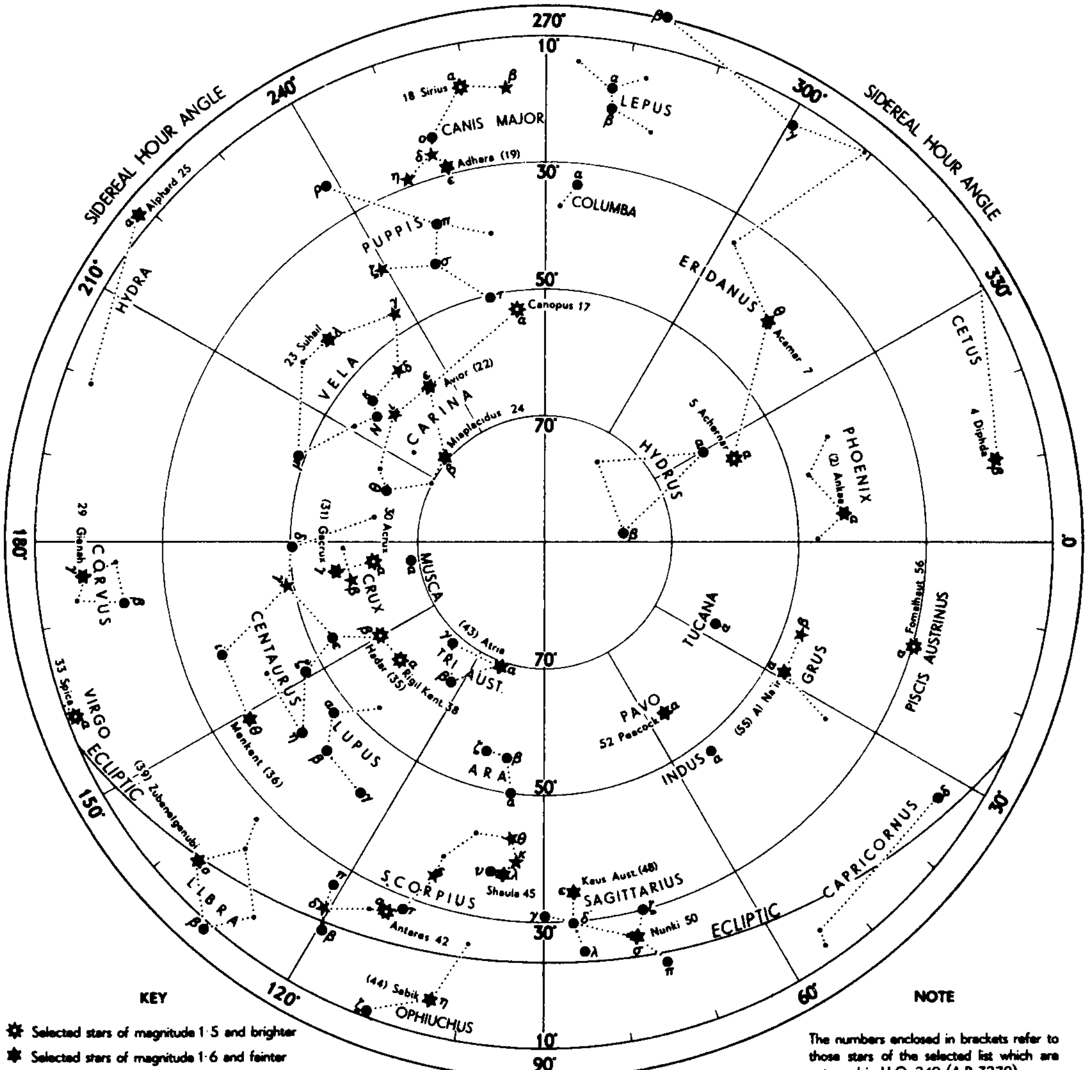
# STAR CHARTS

## SOUTHERN STARS



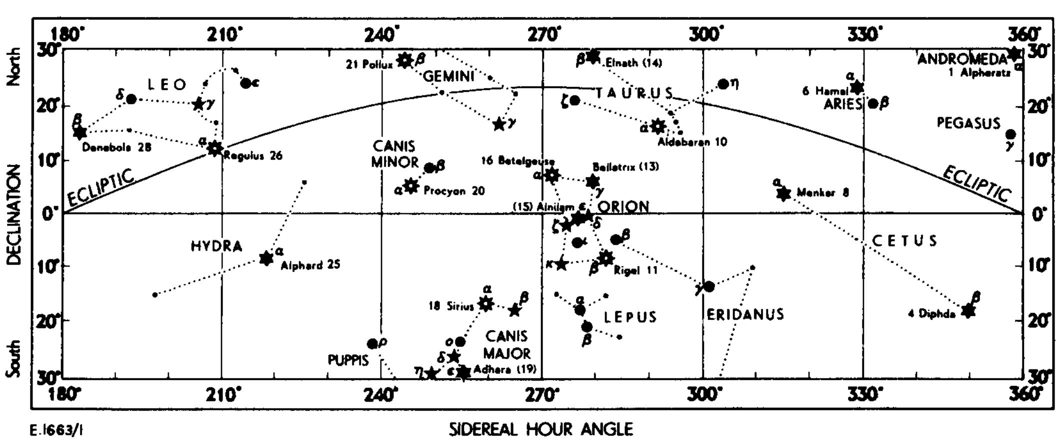

**KEY**

- Selected stars of magnitude 1·5 and brighter
- Selected stars of magnitude 1·6 and fainter
- Other tabulated stars of magnitude 2·5 and brighter
- Other tabulated stars of magnitude 2·6 and fainter
- Untabulated stars

**NOTE**

The numbers enclosed in brackets refer to those stars of the selected list which are not used in H.O. 249 (A.P. 3270).

## EQUATORIAL STARS (S.H.A. 180° to 360°)

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# MARINE INFORMATION NOTES

*Edited by Ernest B. Brown*

## PRINT-ON-DEMAND

Print-on-demand (POD) is the use of large formatted inkjets or electrostatic plotters that produce NOAA nautical charts. NOS has been experimenting with this technology as one possible way to provide mariners with more up-to-date charts. To use print-on-demand, NOS would update digital files of all charts each week for all Notice to Mariner items. Charts would then be printed when ordered using these updated files.

Print-on-demand offers the potential benefits of:

- Providing mariners with nautical charts that are up-to-date when they are printed instead of charts that are one or more years old;
- Eliminating wasteful condemnations of obsolete charts as it is done now by only printing charts when they are ordered.
- Avoiding inventory expenses;
- Allowing charts to be customized with special information such as a user's standard routes or an excerpt of the Tide Tables.

NOS has explored operating a prototype POD site in Silver Spring, Maryland. The Maritime Exchange for the Delaware Bay and River operates a prototype site also. Additionally NOS has inquired about the experience of NIMA and U.S. Geological Survey who have operated or experimented with this technology. The analysis shows the following:

- The technology is adequate to produce a usable, up-to-date chart but the image and paper quality are below what is presently provided.
- Professional mariners thought the product was acceptable and that the up-to-date information would be valuable if priced right.
- The technology is slow and more difficult to operate than an office copier, and so it is probably not suitable for point-of-sale printing.
- NOS has brought the chart suite up-to-date for all Notice to Mariner items and is able to keep that suite (almost) up-do-date weekly as would be needed.

NOS has several opportunities for packaging and positioning the POD charts. Packaging and positioning can potentially result in widespread usage of this superior product thus improving maritime safety which is NOS' primary concern.

Information is still needed from chart sales agents about the potential effects of POD on their businesses and on their customers. Such information will be helpful as NOS continues its evaluation of POD to determine if it should be deployed and, if so, in what manner so as to best serve mariners.

### BACKGROUND

The idea of printing NOAA nautical charts on demand has been around for several years. The original concept envisioned chart agents buying or leasing inkjet printers and actually printing charts at the time a customer wanted them. Informal feedback from agents to NOAA was that this would not work with current technology because each chart takes about 20 minutes to print.

The Coast Survey has recently proposed a new "print on demand" (POD) concept which would totally replace the current system of lithographic printing. Until several agents learned of this in early February, it seems clear that the Coast Survey (CS) hoped to push this through senior officials of the National Ocean Service (NOS) with no consultation with the chart agent network.

Under this concept, NOS would sign a Cooperative Research and Development Agreement (CRADA) with 3M (or another company) to handle print on demand using "large format inkjet and electrostatic plotters to print charts when ordered from up-do-date raster files." Agents would send their orders for NOAA charts directly to the contractor (rather than to NOAA), and the contractor would fulfill the orders the same day. NOAA agents would carry no inventory of NOAA charts; instead, they would order charts as needed for customers from the contractor for delivery by Federal Express the next business day. The POD charts would be sold by agents for $10.00, with agents making a 20% margin or $2.00 per chart.

A prototype version of POD was tried in Philadelphia for approximately six months, but it resembled the current POD concept only in the respect that up-to-date charts were printed and made available to users at a remote site. The Philadelphia test was by no means a full test of POD.

### STATUS

On Feb. 4, 1998, representatives of the Coast Survey briefed Capt. Evelyn Fields, acting deputy assistant administrator for NOS, on their proposal for print on demand. After the briefing, Capt. Fields put POD on hold temporarily until to obtain more information.

### ADVANTAGES

As a concept, print on demand has some significant advantages. They include:

- The ability to get up-to-date charts in the hands of mariners.
- This can improve maritime safety, a prime concern of both NOS nautical chart agents and NOS.

- Reducing wasteful condemnations of obsolete charts by printing charts as required.
- Allowing charts to be customized with special information such as a user's standard routes or an excerpt from tide tables.

## PROBLEMS

There are also some disadvantages to the concept as proposed. Among them:

- Both the technology and concept are unproved for printing and distributing nautical charts, except for an extremely limited local test which does not validate the concept or technology.
- Image and paper quality for POD are below what is currently provided.
- The idea of agents carrying no NOAA chart inventory is unworkable, does not serve mariners with an immediate need for charts, and would detract from maritime safety.
- There is no credible evidence that 3M or any other contractor has the capacity and experience to fulfill chart orders by printing, packing and shipping charts on the same day orders are received for next-day delivery to chart agents as envisioned by the Coast Survey.
- The proposed pricing and discount structure make no financial sense for chart agents.

## DISCUSSION

Good management dictates moving very slowly on any proposal that would dismantle a printing and distribution system for NOAA charts that has worked effectively for decades and replace it with a system that is essentially untested and unproved. A limited test in a single location such as Philadelphia may provide preliminary indications, but it cannot replace a full-fledged national test which would involve one or more contractors, all nautical chart agents, and a wide sample of chart users from both the professional maritime and yachting worlds.

## POSITION

By a wide margin, large and small NOAA chart agents who have been informally polled agree that print on demand has a number of advantages and that the concept should be further tested. It should be tested as *an addition to* the current chart distribution system, however, not as a replacement for the current system.

*Agents recommend that NOS conduct an all-agent national test of the print on demand concept outlined above on a side-by-side basis with the current lithographic printing and distribution system for a minimum of 12 months, with a full evaluation thereafter and a final NOS decision made after full consideration of the evaluation. Specifics are as follows:*

- Agents will stock printed NOAA charts and print on demand charts in inventory.
- Print on demand charts will be offered as a "value added" product at an "upscale" price.
- Print on demand charts will be called "Flagship Edition" charts, will contain a prominent "Flagship Edition" NOS logo, will be printed on premium stock, and will retail for $20.00, which is comparable to or lower than charts from other agencies and companies.
- Standard charts will be called "Standard Edition" charts and will sell for $14.00.
- In the event of price increases, the relative price differences will be maintained.
- Standard NOAA agent discounts of 40% will apply to all NOAA charts, both Flagship Edition and Standard Edition throughout the test period.
- No Flagship Edition more than 30 days old may be sold by a NOAA agent.
- Both Flagship and Standard Edition charts will be returnable for full credit.
- Once the test if completed, the results will be evaluated by an independent group with equal representation from (1) the Coast Survey, (2) end users from both the yachting and shipping industries who have used both products, and (3) chart agents; and this group will make its formal written recommendations to NOS on the future of print on demand. The chairman of the group will be a USCG licensed master with time in command at sea during the evaluation period.
- The evaluation group will include representation from the distribution branch (or its successor agency) as ex-officio (non-voting) members.
- NOS will make no decision on implementation of print on demand until the final report of the independent group is duly considered.

## Marine Differential GPS Beacon Information

As differential GPS information becomes available worldwide, the National Imagery and Mapping Agency's Marine Navigation Department intends to publish details of DGPS beacon's name, location, transfer rate, range, frequency, identification number and any remarks (such as transmitted message types) in its List of Lights publications.

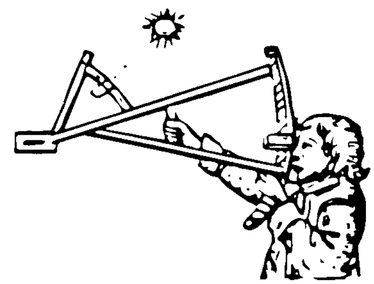
DGPS reference stations determine range errors and generate corrections for all GPS satellites in view. The DGPS signals are broadcast usually using existing radiobeacons on frequencies in the 285-325 kHz band and add a greater degree of accuracy for positioning.

**ANSWER TO DO YOU KNOW...**
*(from page 1)*

In August 1997 a small, portable 4-watt jammer that can take out civil signals over a 200-km range was displayed at the Russian Air Show.

At Griffis Air Force Base, about 100 miles west of Albany, New York, Air Force contractors who had been range testing a new GPS antenna, inadvertently left a 5-watt trans- mitter on the L1 band turned on from December 30, 1997 to January 12, 1998. Government offices received reports of serious interference to GPS signals in the Albany, NY area in late December and early January.

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE SIXTY, SUMMER 1998


This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

### Membership

It is with great trepidation that I must inform you of the decision that we have found it necessary to increase the annual, tax deductible, contribution to $35.00. This is the second increase in the history of The Foundation. Since our last increase in 1990 the price of office supplies has increased. The cost of printing has increased by 1/3. The cost of laying-out the Newsletter has doubled and postage, postal fees, business reply and stamps have all increased. We have reached the point where we must increase the contribution to survive. Even with no paid employees, Directors or other personnel costs, we have been dipping into our very small cushion of reserve. We know this is going to be a burden on many of you who are on fixed incomes, but I hope that you will all take advantage of the tax deductible contribution which will alleviate some of the increase. We will continue to keep all of our costs to a bare minimum and still keep up our service to all who order charts, books and publications through The Foundation.

I am sorry to have to inform you of the increase in the contribution, but we must to survive. With the increase of cost of everything over the last 8 years, there was only one other choice, to cease to exist because of the lack of resources. I sincerely hope that this will not deter you in remaining a member of this unique group of navigators.

This increase is now effective for all new members. Our Web Pages, advertisements which are contributed by publishers and information packets reflect this increase. For our current members, the increase will not take effect until December 1998. Renewal notices sent after December 1 will indicate the increase.

## READERS FORUM

*Edited by Ernest Brown*

Member Steven C. Carleton of 234 Compton Ridge Drive, Cincinnati, OH 45215 wrote to the Executive Director, Capt. Terry F. Carraway, USN (Ret.) on 27 July 1998:

"Many thanks for the timely attention to my request for back issues of the newsletter. I received them in the mail today, and now have bedtime reading for the next few months. Please find the enclosed check for $106.00. While the invoice was for $100.00, I am enclosing additional funds in the hopes of also getting issues 52, 53 and 54. This will complete my collection through issue 58. If they are still available, I will look forward to a future mailing. If not, consider the additional money as a donation.

"Please excuse the condition of the check. My wife only gives me one at a time, and this particular one has been riding in my back pocket since 1997.

"Many thanks also for putting me into contact with Bruce Stark. He has tables for clearing lunar distances available, and I intend to order a set in the near future. I am also grateful for your mailing of the Nautical Almanac pages on lunar distances.

"A question: Is Issue #59 out yet? I have not received it, and was uncertain as to whether I had missed it. I understand that you have been busy of late. Please do not interpret this as impatience...rather just pleasant anticipation of future reading.

### DO YOU KNOW . . .?

*By Ernest Brown*

How much shorter is the route from Europe to Japan via the Northern Seaway than via the Suez Canal?

*(The answer appears at the back of this issue.)*

"I discovered an interesting sextant while fiddling around on the Internet. It may be of interest to members. It is a reproduction of a mid-19th century instrument that Celestaire used to carry in a high-end, highly accurate form which was very expensive—$65.00 or so. This particular rendition was $79.00 from a firm in Stockton, CA. The instrument is somewhat rough, but can be adjusted to eliminate index error and unparallel mirrors. It is all brass, weighs about a pound, is 3" in diameter and 1.7" thick. I have confirmed, as I have done many times before with other instruments, that I am still just north of Cincinnati with an accuracy of about 10 miles—not great, but not really bad for something you can carry in your shirt pocket. I modified the shade with Mylar foil to allow sun sights without cooking the eyes. The sextant has the additional virtue of being pretty. If anyone wishes for more information on sources, I will gladly provide it through e-mail, conventional mail or phone.

"Again, keep up the good work. I enjoy my membership and the newsletter and hope that the preservation and promotion of celestial navigation will be long-lived and successful."

— *Sincerely, Steve Carleton*

Member David A. Blythe (twowaydave@aol.com) or david.a.blythe@ecumet.org) wrote on 25 July 1998:

"I recently downloaded astronomy software from Index Librorom Liberorum that contained a list in the category navigation stars consisting of sixty stars. Only twenty-two stars in that list matched any of the fifty-seven stars included in the navigational stars used by The Nautical Almanac.

"I'm sure there are lists of navigational stars that differ in scope and content from The Nautical Almanac, but in this case no source was given. I'm interested in knowing the criteria that identified these sixty stars as being useful for navigation and what kind of navigation was contemplated.

"Are you aware of any lists of navigational stars containing sixty stars? Sounds like a dumb question. The name of the software mentioned above is HOME PLANET. It's a planetarium (in English) but Index Librorom Liberorum is a web site

< www.fourmilab.ch/ > in Switzerland.

"Any help you can provide in tracking down the source of HOME PLANET'S list of navigation stars will be appreciated."

—*Thanks. Best regards, David A. Blythe*

Member Dr. George H. Kaplan, Astronomical Applications Dept., U.S. Naval Observatory, 3450 Massachusetts Avenue NW, Washington, D.C. 20392-5420 (e-mail: gkaplan@usno.navy.mil) wrote on 4 August 1998:

"I received Mr. Brown's letter of 28 July regarding Mr. Blythe's inquiry about a list of navigational stars in Home Planet, a piece of software which he obtained from a web site in Switzerland. Apparently the list of 60 stars had only 22 that overlapped the list of 57 navigational stars published in The Nautical Almanac.

"I'm afraid I can't be of much help regarding Home Planet. There is a plethora of astronomy and navigational software available, of a wide range of quality, and we at USNO simply do not have the time available to evaluate it. I suggest that questions regarding the star list in Home Planet be directed to the software's authors.

"However, the origin of The Nautical Almanac's star list is a different matter. I would be willing to look into the history of the NA list if you believe there is any interest among the Newsletter's readers."

—*Sincerely yours, George Kaplan*

Member David A. Blythe wrote on 4 August 1998:

"Thanks for your effort in my behalf to help in finding the source of the HOME PLANET navigation star list. For several reasons, my guess is that the list was taken from a French source. For me, that's a blind alley. Unfortunately, the author of HOME PLANET (John Walker < kelvin@fourmilab.ch >) has been unresponsive.

"Curiosity is a great motivator and I'll keep trying to pin this one down. If I ever do, I'll let you know the result.

"For your information, I'm attaching a file listing the names of the sixty stars in question.

"Again, thanks."

—*Regards, David A. Blythe*

Member Paul Dedieu of Haywood, Manitoba, RöG öWö, Canada, wrote on May 25, 1998:

"... My copy (of issue 58, Winter 1997-98) consisted of pages 1,2,3,4,9,10,11 and 12. I am short of the center section (pages 5,6,7,8).

"If you could send me my missing pages, I would be most grateful. I thoroughly enjoy all the articles of the Newsletter."

—*Paul Dedieu*

*Editor's note: An un-authorized person sends a message from one of your web pages: "I am a math student and very much interested in navigation. I shall be thankful if kindly tell me how to calculate the distance b/w two points on earth which are given in long. & lat."*

*We gave him the formulas for the great circle solution.*

Member Bruce Stark of 3770 Onyx St., Eugene OR 97505-4332 (541-344-5896) wrote on July 30, 1998:

"Here is the piece on the ideas and equations underlying my Tables. What with this and that, it has taken a lot longer to write than I expected. Just finished it this afternoon. I'll try to get it to Kinko's copy shop to fax to you before dinner is on the table. I hope it will work for you. If not, let me know."

—*Sincerely, Bruce Stark*

# NAVIGATION NOTES

## Ideas and Equations Behind My Tables for Clearing the Lunar Distance

*By Bruce Stark*

Short distances are easier to measure than long ones. The reflected image is less skittish—easier to keep in the mirror and easier to find again if it does get lost. Also, parallelism is less a problem. Hardly any error is caused if your line of sight isn't parallel to the sextant frame at the moment of contact. For the navigator of a quick-motioned small boat using a sextant without a collimating telescope, anything other than a short distance is out of the question.

But there are problems connected to short distances. One is that they generally have a big "second difference" in rate of change. To the extent the other body is not directly in line with the moon's motion the rate of change is itself changing rapidly. The GMT that fits the observed distance can't be found by simple interpolation.

Fortunately for modern lunarians, the maximum error a second difference can cause is proportional to the *square* of the interval between comparing distances. In the old *Nautical Almanac* the interval was three hours. While the present *Almanac* doesn't give distances, it does give data for calculating them. And it gives the data for *every* hour, so that linear interpolation is often acceptable with distances as short as three degrees.

Another problem with short distances was the lack of an easy way to clear them.

Methods of clearing can be divided into two groups: those that calculate the true distance itself, and those that calculate corrections that turn the apparent distance into the true. Methods of the first group use spherical trigonometry all the way. They should be worked with six or seven decimal place tables, and take more time and effort than most people care to expend at one sitting. Methods of the second group mix plane trigonometry with spherical, and need only four or five place tables. They are less demanding, and were more popular.

While methods of the second group can be excellent within their range, they become unreliable when the distance gets shorter than about twenty degrees. They work by making an untrue assumption, then adjusting out the resulting error. The adjustment depends on two approximations, and these get more and more out of line with reality as the distance becomes short.

Most methods of the first group handle short distances well, but they take so much effort they discourage you from making observations.

Almost any equation will do if you're using an electronic calculator that figures to eleven decimal places at the push of a button. But it's hard to come up with an equation for do-it-yourself navigation that's both reliably accurate *and* easy to use.

I searched through every old navigation manual and book on practical astronomy I could lay hands on without finding anything better than methods I was already using. My own efforts with oblique spherical trigonometry created nothing worth saving.

Then one evening, just noodling around, I folded a time-sight formula with the cosine-haversine formula. Here is the line of thought:

In the triangle formed by the two bodies and your zenith, one element is unaffected by refraction and parallax. This is the zenith angle. You could use the apparent altitudes and apparent distance to calculate the zenith angle. Then you could use the *true* altitudes and zenith angle to calculate the true distance.

Put in terms of a more familiar triangle—the one formed by the pole, zenith, and a heavenly body—the first calculation is like a time-sight. In a time-sight you use the altitude, latitude, and the declination to calculate the hour angle—the angle at the pole. The second calculation is like getting $H_c$ for a line of position. There you use the hour angle, latitude, and the declination to calculate the altitude.

The best time-sight formulas were based on a standard spherical equation. It is, in generic terms:

$$\sin^2 {}^1/_2 A = \frac{\sin(s\sim b)\sin(s\sim c)}{\sin b \sin c}$$

Here, "a", "b", and "c" are the sides (of the spherical triangle), "s" is half the sum of the sides, and "A" is the angle opposite side "a".

Plug the elements of the apparent lunar triangle into this, using "Da," Ma," and Sa" to represent apparent distance an altitudes. Clean it up and arrange it as:

$$\sin^2 {}^1/_2 A = \frac{\sin {}^1/_2 [Da-(Ma\sim Sa)] \sin {}^1/_2 [Da+(Ma\sim Sa)]}{\cos Ma \cos Sa}$$

Here "A" is the zenith angle of the lunar triangle.

Moving on to the next step, the best equations for calculating altitudes were versions of what eventually became known as the cosine-haversine formula. This, in terms of the true lunar triangle is:

$$\text{hav}D = \text{hav}A \cos H_m \cos H_s + \text{hav}(H_m \sim H_s)$$

"A" being the zenith angle the previous equation would calculate. But the haversine of an angle is identical with the square of half the angle. That is:

$$\text{hav}A = \sin^2 {}^1/_2 A$$

So you can replace "havA" with the right side of the previous equation. That folds the time-sight formula into the cosine-haversine formula. Then, if you use the haversine identity again you get:

$$\text{hav}D = \text{hav}(H_m \sim H_s) +$$

$$\left(\frac{\cos H_m \cos H_s}{\cos Ma \cos Sa}\right)\sqrt{\text{hav}[Da\sim(Ma\sim Sa)]\text{hav}[Da+(Ma\sim Sa)]}$$

That's it. Not pretty at first glance, but if you look closely you'll see some nice features.

The parcel of cosines has such a narrow range that you don't have to calculate it. In fact you don't even have to make a table opening for it. You get it at the same time you take the refraction and parallax corrections from Table 2 and Table 3. I call its logarithm "Q" and leave it negative. The decimal point and leading zeros are dropped and the sixth decimal place (which is there only to prevent rounding error) set off by a comma. It won't exceed 766,0.

Only one other function is called for, and it is ideal. Log haversine never leaves you to decide for yourself which quadrant and angle near 90° falls in. It changes at a reasonable rate in the areas of our concern—neither too fast or too slow for the job at hand. And it doesn't shift from negative to positive. I leave it negative and call it "K."

Both K and Q remain negative throughout their range. That saves a lot of figures. It also saves you having to know anything about logarithmic calculation. You don't even have to know you're using logs.

K needs only five decimal places because of the way it behaves, and because there are no tall stacks to add. The radical over the last part of the equation further reduces the problem of rounding error buildup by halving the error for two of the values.

Unfortunately there is one bad feature in the equation—that plus sign in the middle of it. Although a Gaussian addition log does a precise job of bridging over the plus sign, it takes an extra table opening and subtraction.

I've tried to show, in a reasonable amount of space, what the *Tables* are built on. While some of the individual tables are unlike anything that's been seen before, they will probably speak for themselves.

Still, I'd would like to say just a few things for them. First, some readers will know that Q is essentially the same as the "Logarithmic Difference." From the late eighteenth century on into the early twentieth, those sets of navigation tables that had six-place trig-log tables often had a Logarithmic Difference table too. It was used with Dunthorne's, Borda's, and similar methods of clearing.

The Log Difference and Q are arithmetical complements—added together they equal ten. If the Log Difference of a pair of altitudes is 9.995555, then Q is 444,5. Remember that with Q the decimal and leading zeros are dropped and a comma put between fifth and sixth decimal place.

But Q isn't always the exact arithmetical complement of the Log Difference you find in old navigation tables. That's because the values of refraction used in calculating them are not always the same.

I built the base for tables 2 and 3 by working out a refraction table that goes from 4° to 90° at 2' intervals. It is founded on, and agrees with, the table carried in Bowditch from the latter part of the nineteenth century on through World War II. At intervals ranging form 5' to 1°, that table gives refraction to one tenth of one *second* of arc and, I assume, is based on a thorough investigation by astronomers in the middle of the nineteenth century.

To my knowledge no one formula can generate that table precisely. To get a perfect match I had to change formulas seven times going from 4° to 90°. I did it in a computer spreadsheet, and checked the result by examining second and third differences.

The discrepancies between various refraction tables are too small to trouble a navigator. My point is that the lack of agreement is not a reflection on the quality of the Tables.

## Box Sextant With Artificial Bubble Horizon For Use on Land, Sea and In the Air

*By John M. Luykx*

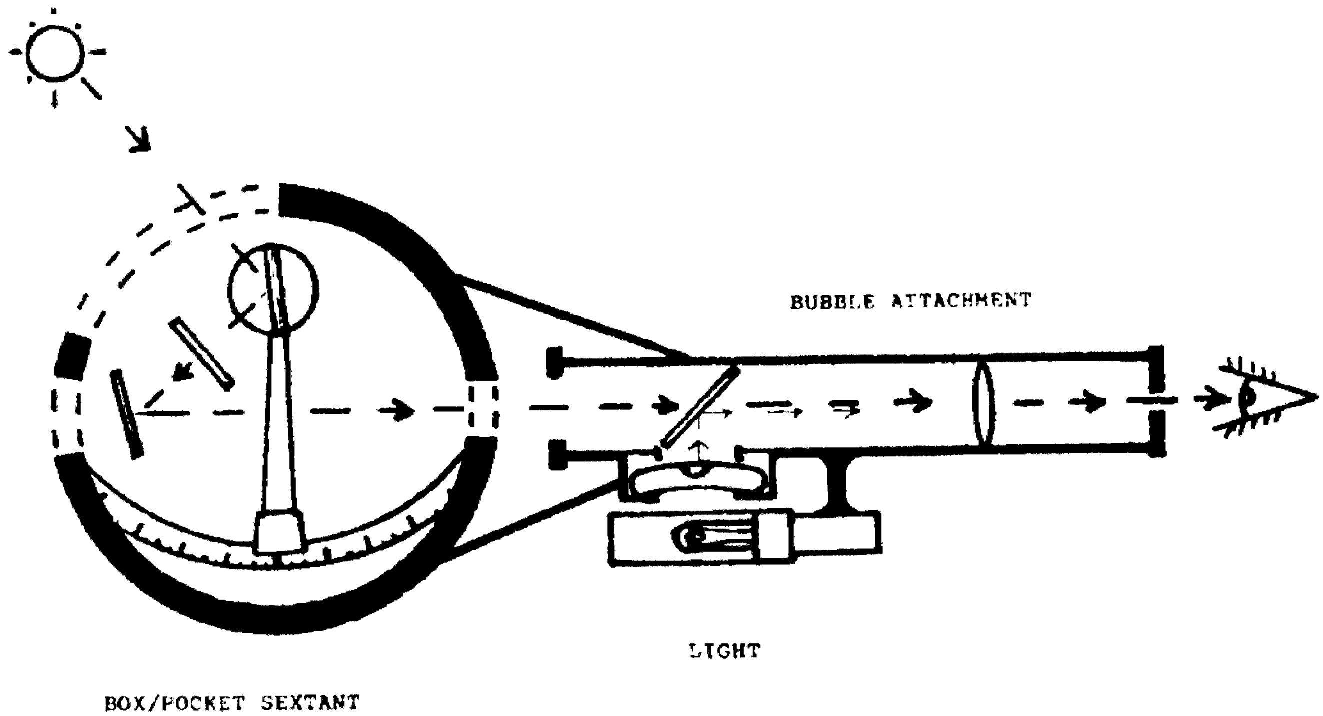
As a follow up to the article "Pocket Sextant for Use on Land" in Issue 54 of *The Navigator's Newsletter* (Winter 1996-97), INFOCENTER has recently completed a prototype instrument which incorporates a longitudinal bubble attachment fitted to a traditional all brass vernier "snuff box" or box sextant. This instrument is primarily designed for use in land navigation, although it can also be used at sea and in the air.

The box sextant is a current reproduction instrument and the artificial horizon is a modified surveyor's hand level. A schematic of the instrument is shown in Figure 1.

During observation the artificial horizon in the form of a bubble is seen in the mirror of the artificial horizon on the right side of the field of view. The celestial body is reflected into the field of view by the sextant horizon mirror which is seen in the left side of the field of view.

When properly collimated during observation, the image of the celestial body is adjusted to the exact same level as that of the bubble image which is kept centered midway between the top and the bottom of the bubble attachment reflecting mirror. This alignment is shown in figure 2.

For day observations of the sun a neutral density filter is inserted between the sextant's index and horizon mirrors. For night observations an eyepiece with a large orifice of 5 mm to 6 mm is substituted for the day eyepiece which has a narrow 1 mm orifice. In addition the self-contained light is positioned as shown in figure 1 to illuminate the bubble at night. During




SCHEMATIC PRESENTATION OF BOX/POCKET SEXTANT WITH BUBBLE ATTACHMENT

the day the light is swung down out of the way to permit ambient light to illuminate the bubble.

Daylight tests of this instrument using the sun were conducted on 25 and 26 June 1998 in the vicinity of the author's home in Maryland outside of Washington, DC. Forty observations of the sun were taken arranged in eight groups of five observations each. These observations were not corrected for I.C. However, they were corrected for refraction.

The results of the these tests are:

| SERIES | MEAN ERROR |
|---|---|
| 1 | +1.'4 |
| 2 | 0.'0 |
| 3 | +1.'8 |
| 4 | +1.'8 |
| 5 | +0.'4 |
| 6 | +2.'4 |
| 7 | +1.'8 |
| 8 | +3.'7 |
| | 8/+13'.3 |
| Mean Error: | +1.'7 |

Night observations of the moon (Age: 7 days) were conducted during the evening of 1 July 1998. Twenty shots were taken grouped in 4 series of 5 observations each. These observations were not corrected for I.C. but the standard corrections were applied. The results of these tests are shown below:

| SERIES | MEAN ERROR |
|---|---|
| 1 | -4.'0 |
| 2 | -4.'0 |
| 3 | -0.'1 |
| 4 | -1.'8 |
| | 4/-9.'7 |
| Mean Error: | -2.'4 |

During the day, on 1 July, thirty-five observations (seven groups of five observations each) were made from the North Beach/Chesapeake Beach area, south of Annapolis on the Western shore of Chesapeake Bay. The observations were conducted in the morning using the visible horizon. The box sextant was removed from the artificial horizon bubble attachment housing and used as a normal marine sextant. These observations were corrected for I.C., height of eye, refraction and semi-diameter.

The results of these observations are:

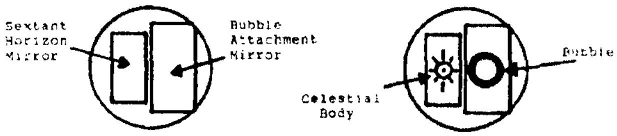


Figure 2

| SERIES | MEAN ERROR |
|---|---|
| 1 | -0.'1 |
| 2 | +1.'3 |
| 3 | -0.'9 |
| 4 | +0.'2 |
| 5 | -0.'3 |
| 6 | +0.'5 |
| 7 | +2.'4 |
| | 7/+3.'1 |
| Mean Error: | + .'4 |

For greater accuracy, when using the box sextant with artificial bubble horizon, it is recommended that each series of observations consists of ten or more observations where only the mean values of time and sextant altitude for the series are used in reducing the observations for a line of position (LOP).

The dimensions of the box sextant with artificial bubble attachment are:

| | |
|---|---|
| Weight: | 1.8 lbs. |
| Length: | 9.5 inches |
| Width: | 3.5 inches |
| Height: | 2.5 inches |

The instrument is provided with instructions, a night eyepiece and spare batteries for the lighting system. When used with the natural sea horizon for marine navigation, the box sextant itself is removed from the housing and then used in the normal manner. The dimensions of the box sextant itself are:

| | |
|---|---|
| Weight: | 1.25 lbs. |
| Height: | 1.75 inches |
| Diameter: | 3.0 inches |

For reading the sextant vernier scale at night, a small pocket flashlight with red bulb should be carried by the observer.

It is felt that because of its light weight and compact size the box sextant with bubble attachment would be useful to land navigators as a backup navigation system to the GPS. It would also be useful as a substitute system for use at sea and in the air.

# MARINE INFORMATION NOTES

*Edited by Ernest Brown*

## Potential Problems for Users of GPS Receivers

*(The following is from Notice to Mariners (31/98)*

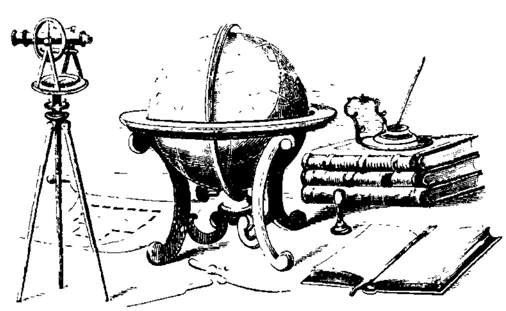
Users of GPS receivers are advised of potential problems due to "GPS roll over". This problem is related to the first "roll over" of the 1,024 week GPS clock cycle which will occur at midnight on August 21, 1999.

All GPS receivers keep GPS time which began on January 6, 1980. GPS time is included as a data field in the navigational message transmitted by each satellite. Some GPS receivers have limited storage space for this time information and can only hold a maximum of 1,023 weeks. These systems will interpret week number 1,024 as 0.

Many GPS receivers are known to be unable to make the transition from week 1,023 to 1,024. During this time the internal clocks of these GPS receivers will experience a lack of absolute reference and may give the wrong **time** and **position** or may lock up permanently.

Some of these GPS receivers are repairable with upgrades and others will become unusable. Users are advised to check with their GPS manufacturer regarding the status of their receiver. Currently GPS receivers are in the 900's week.

For further information see Section 2.3.5 (pages 18-19) of the GPS SPS Signal Specification, 2nd Edition, issued June 2, 1995 which repeats the words and warnings of ICD-GPS-200. In addition GPS SPS Signal Specification may be obtained from the web as an Adobe Acrobat (.pdf) document at the U.S. Coast Guard's site at www.navcen.uscg.mil/gps/reports/sigspec/sigspec.htm. Remember, failure to correct the problem could lead to serious navigational problems by placing lives and property at risk.



# NEWSLETTER INDEX

**Index 92(1-35)** published with Issue Thirty-five (Spring 1991), is an index covering Issues One through Thirty-five.

**Index to Navigation Problems (4-33)**, published in Issue Thirty-three (Fall 1991), covers navigation problems in Issues Four through thirty-three.

**Index to Navigation Personalities (12-53)**, published in Issue Fifty-three (Fall 1996), covers personalities in Issues Twelve through Fifty-three.

**Index to Book Reviews (36-53)**, published in Issue Fifty-three (Fall 1996), covers reviews in Issues Thirty-six through Fifty-three.

**Index to History of Navigation (3-54)**, published in Issue Fifty-three (Winter 1996-97), covers history articles in Issues Three through Fifty-four. This includes articles under the heading Navigation Notes in Issues Three through Seven.

**Index to Navigation Notes (1-56)**, published in Issue Fifty-six (Summer 1997), does not include the navigation problems and history articles previously published in the Navigation Notes section.

**Index to Navigation Basics Review (13-58)**, published in Issue Fifty-eight (Winter 1997-98), covers those articles written as reviews of the basics of navigation in Issues Thirteen through Fifty-eight.

**Index to Navigation Foundation Peary Project (23-42)**, published in Issue Fifty-eight (Winter 1997-98), covers articles and comments on the analysis of the data of Robert E. Peary's expedition to the North Pole in 1909 in Issues Twenty-three through Forty-two.

**Index to Marine Information Notes (3-60)**, published in Issue Sixty (Summer 1998), covers only those notes of more lasting interest in Issues Three through Sixty.

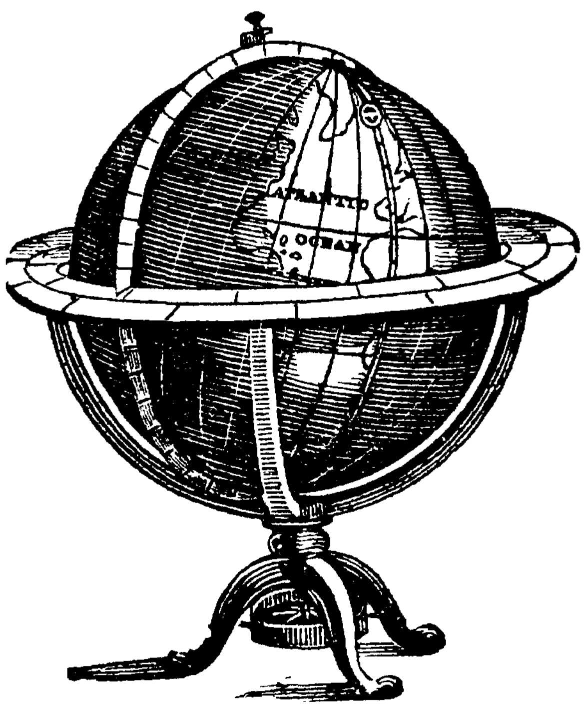
| | |
|---|---|
| Twenty-six<br>Fall 1989 | Navy Commendation Medal Presented to Member Richard E. Kabrick |
| Thirty-three<br>Fall 1991 | Satellite Position Indicating Radio Beacon |
| Forty-three<br>Spring 1994 | Vessel Squat in Shallow Water |
| Forty-eight<br>Summer 1995 | Unannounced Hydrographic Products |
| Fifty-five<br>Spring 1997 | Tide and Tidal Current Tables |
| Fifty-eight<br>Winter 1997-98 | NIMA'S Marine Navigation Department Home Page |
| Sixty<br>Summer 1998 | Potential Problems for Users of GPS Receivers |

**Index to Navigation Problems (34-60),** published in Issue Sixty, covers navigation problems in Issues thirty-four through Sixty.

| ISSUE | PROBLEM | AUTHOR |
|---|---|---|
| Thirty-four<br>Winter 1991-92 | Problem 34. What is the basic principle underlying all forms of navigation, and in celestial navigation what is the great navigational triangle? | Roger H. Jones |
| Thirty-five<br>Spring 1992 | Answer to Problem 34.<br>Problem 35. What is the great principle by means of which the navigator can use the navigational spherical triangle to determine the position of the vessel, and what are the basic tools of the navigator that enable him to so use the great triangle? | Roger H. Jones |
| Thirty-six<br>Summer 1992 | Answer to Problem 35.<br>Problem 36. How does the navigator use these tools in determining his position; what is the practical meaning of the information obtained from the sextant shot, the Almanac, and the sight reduction tables? | Roger H. Jones |
| Thirty-seven<br>Fall 1992 | Answer to Problem 36. | |
| | Problem 37. Tying answers 34, 35 and 36 together, what is a succinct statement of the theory of celestial navigation? | Roger H. Jones |

| | | |
|---|---|---|
| Thirty-eight<br>Winter 1992-93 | Answer to Problem 37.<br>Problem 38 How does one know whether to plot the LOP on the direction line, using the offset, closer to the GP than the assumed position or farther away from the GP than the assumed position? | Roger H. Jones |
| Thirty-nine<br>Spring 1993 | Answer to Problem 38.<br>Problem 39. Conceptually, why or how does a measurement of the altitude of a body above the visible sea horizon constitute the distance that the observer is from the GP or the celestial body? | Roger H. Jones |
| Forty<br>Summer 1993 | Problem 40. A navigator should be able to picture in his mind the reasons why the various altitude corrections are either a plus or minus value, and he should always remember that true zenith distance is only arrived at after all applicable altitude corrections are made. What picture should be formed in the mind in order to determine instantly whether an altitude correction is a plus or a minus value? | Roger H. Jones |
| Forty-one/<br>Forty-two<br>Fall/Winter<br>1993-94 | Answer to Problem 40.<br>Problem 41. Can you form your own mental image that will easily resolve for you the question, when crossing the International Data Line, of whether you lose a day or gain a day? | Roger H. Jones |
| Forty-three<br>Spring 1994 | One of the questions surrounding the Peary controversy that we have been studying is why Peary did not make a longitude observation when camped at 87°45′N (shown by his latitude sight taken at the time of local apparent noon on the 70W meridian). Part of the answer could be that, being unfamiliar with modern position line methods, he did not know how easy such a line would be at that latitude. Using only arithmetic and normal plotting instruments, determine Peary's position if a second sight taken at 22:12:40 GMT had an observed altitude (after applying all corrections) of 5°15′30". Assume that from the almanac, the sun's declination at midnight GMT is 4°50′48" and the hourly change in declination was plus 56". The GMT of meridian passage was given in the almanac as 12:04:32. | Douglas Davies |

| | | |
|---|---|---|
| Forty-four<br>Summer 1994 | Three-Star Fix by H.O. 229 | William O Land |
| | Answer to Last Issues's Problem | Douglas Davies |
| Forty-five<br>Fall 1994 | Initial Great Circle Course and Distance by H.O. 211 | William O. Land |
| | Answer to Last Issue's Problem | |
| Forty-six<br>Winter 1994-95 | Three-Star Fix by H.O. 229 | William O. Land |
| Forty-seven<br>Spring 1995 | Great Circle Vertex | William O. Land |
| | Answer to Last Issue's Problem | |
| Forty-eight<br>Summer 1995 | Three-Star Fix by H.O. 229 | William O. Land |
| | Answer to Last Issue's Problem | |
| Forty-nine<br>Fall 1995 | Answer to Last Issue's Problem | William O. Land |
| Fifty<br>Winter 1995-96 | Horizon Sight Without a Sextant | Allan E. Bayless |
| Fifty-three<br>Fall 1996 | A Sailing Problem for Navigators | Allan E. Bayless |



# NEW PRODUCT

*Edited by Ernest Brown*

**GPS Instant Navigation,** A Practical Guide from Basics to Advanced Techniques by Kevin Monahan and Don Douglass

Fine Edge Productions
Route 2, Box 303
Bishop, CA 93512
FAX: 619-387-2286
TEL: 619-387-2412
ISBN O-938665-48-0

This book lives up to its title. The illustrations as a whole are outstanding.

**Captain Kevin Monahan**, a licensed Home Trade Master (unlimited tonnage), has worked as a fisherman and professional mariner in British Columbia for over twenty years. He presently serves as captain of a Canadian Coast Guard cutter.

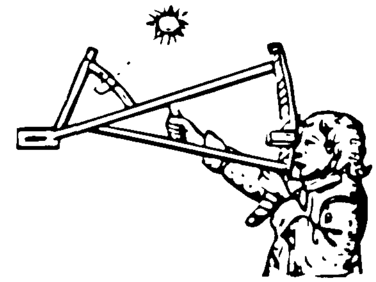
Born in London in 1951, Monahan, a resident of Vancouver Island, emigrated to Vancouver and attended the University of British Columbia where he majored in creative writing. His articles and short stories have appeared in various magazines, including *Monday Magazine* and *Fine Homebuilding*, as well as in *Western Fisherman* which published a series of his articles on electronic navigation. Captain Monahan has testified in court as an expert witness in the use of GPS in navigation.

**Don Douglass** has over 150,000 miles of cruising experience, from 60'N to 56'S. His intensive practice with GPS has been gained in the Inside Passage to Alaska, around Cape Horn, and in the Strait of Magellan. He is an honorary member of the Cape Horner Society, and his wife's book, *Cape Horn; One Man's Dream, One Woman's Nightmare*, has become a cruising classic. Douglass holds a Bachelor of Science Degree in Electronic Engineering from California Polytechnic University and a Master in Business Economics from Claremont Graduate University. He has authored and co-authored ten outdoor guidebooks, including four nautical cruising guidebooks.

**ANSWER TO DO YOU KNOW**...(from page 1)

Although the Northern Seaway, which was opened to international shipping in October 1987, shortens the route from Europe to Japan by about 40 percent, traffic has been light because the route is seen as dangerous. Also that part of the Seaway from the mouth of the Yenisey River to the Bering Strait is open only from July to October.

# THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

ISSUE SIXTY-ONE, FALL 1998

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a readers forum for the expression of our members' opinions and their questions.

## ACTIVITIES

*By Terry Carraway*

We have been informed that another of our interesting members has passed away. Swiss Ambassador Claude Huguenin had navigated both the Saudi and the Sahara deserts by celestial navigation. He used engine oil in a pie tin for his artificial horizon. Three years ago he did his first marine navigation when he was the Swiss Ambassador to an East African country. Having access to the ocean, he bought a boat and did his first navigation on the water. A few years ago while Ambassador to a Central African country he wrote the Foundation a letter admitting to having gotten lost while navigating the plains by celestial. He had forgotten that he was south of the equator and did not take this into account in his calculations, thus getting completely confused and lost.

Member Dr. Pete W. Ifland has written a book that should be of great interest to celestial history buffs. The title is *"TAKING THE STARS: Celestial Navigation from Argonauts to Astronauts"*. It is available from the Mariners' Museum in Virginia, e-mail publications@mariner.org. The list price is $59.00 for the hardback edition. It is not currently available through the Foundation, unless 6 or more are ordered at one time. If you are interested in trying to purchase the book through the Foundation, send us a query by e-mail or letter. There will be a delay in receiving your book because we have to wait to get 6 orders. E-mail to us at navigate@ix.netcom.com or 76476,1165@compuserve.com

Member Dr. David Burch, Director of The Starpath School of Navigation, has just completed a great new training CD. It is The Starpath Nav Gator electronic version of Chart No. 1. This is the name used by most nations for their official paper booklet compilation of nautical chart symbols and abbreviations. This CD is an electronic version of this important information, applicable worldwide for all nautical charts, plus many more features to aid in nautical chart reading. CD ROM for Windows $49.00. For more information contact Starpath Corporation, 311 Fulton St., Seattle, WA 98109-1740; Sales 800-955-8328; Telephone 206-284-8328; Fax 206-283-5074 or e-mail at info@starpath.com. CD cover shots, screen captures, reviews and more details are available at www.starpath.com.

From time to time members have expressed a concern about the Foundation releasing member lists. The policy of The Navigation Foundation is to not sell or give the names of any member to any person or organization other than members of The Navigation Foundation. If a member should wish to contact another member based on a letter or item appearing in *The Navigator's Newsletter*, that person's address will be released unless he has specifically requested that his name not be released. If a member does not want his address released, he should so advise the Foundation by letter. This will allow members to contact each other concerning items of interest or for questions. Again, if any member does not want his/her address released, please let us know.

The 1999 Nautical Almanacs are available through the Foundation. Commercial edition is list priced at $17.95 and the government edition is list priced at $27.00. Members receive their 20% discount, plus postage.

### DO YOU KNOW . . .?

*By Ernest Brown*

Why the building of a junk with more than two masts was a capital offense in China in A.D. 1500?

*(The answer appears at the back of this issue)*

# READERS FORUM

Member Dr. Peter Ifland wrote from Cincinnati, Ohio on October 22, 1998:

"My new book, *Taking the Stars: Celestial Navigation from Argonauts to Astronauts* has just been published by The Mariners' Museum, Newport News, Virginia. It's about the development of hand-held celestial navigation instruments and, as the subtitle implies, covers the subject from the beginning up through the Gemini space flights. A special chapter deals with aircraft navigation instruments. A major theme is the ideas and designs that were tried but that did not succeed in the mainstream of instrument development. I think the members of the Navigation Foundation will be interested.

"Concurrently, I am donating my collection of about 165 instruments to The Mariners' Museum.

"John Luykx is familiar with the book project and my collection. The attached flyer describes the book in more detail and tells how to obtain copies.

"I personally continue to enjoy my membership in the Foundation and read the bulletin with great interest. Good work!"

*—Best regards, Peter Ifland.*

Ms. Jessica Johnston of The Mariners' Museum wrote from Newport News, VA on October 20, 1998:

"Thank you for considering for the Navigation Foundation's newsletter a book review of The Mariners' Museum newest publication, *Taking the Stars: Celestial Navigation from Argonauts to Aeronauts* by Peter Ifland. Enclosed is a copy of this engaging study chronicling 1,000 years of improvements and advances in the evolution of celestial navigation instruments and information about ordering the book.

"Ifland has written *Taking the Stars* for both the scholar and the layperson, including in the publication a glossary of specialized information for the serious navigator and special 'how to' boxes describing the proper use of the instruments. The book contains carefully researched information compiled by one of the foremost experts in marine navigation.

"We hope your readers will enjoy learning more about the interesting world of celestial navigation through a review of this publication. If I may provide you with any additional information, please contact me at 757-591-7737 or by e-mail at jjohnston@mariner.org."

*—Sincerely, Jessica Johnston*

Member Dr. John G. Hocking wrote from Okemos, MI on August 27, 1998:

"D'Arcy Emery of St. Thomas, Ontario recently asked for my help on the following problem: Given a value M for the meridional parts of a latitude L, find L. Because Mr. Emery is working on the ellipsoidal model of the earth, the problem amounts to solving the equation

$$M = a\ln\left\{\frac{1+\sin L}{\cos L}\right\} + \frac{ae}{2}\ln\left\{\frac{1-e\sin L}{1+e\sin L}\right\}$$

for L in terms of M. (In the equation, a is the equatorial radius of the earth and e is the eccentricity of a meridian.)

"Knowing that some sort of iterative numerical procedure would have to be used, I first solved the simpler equation.

$$M = a\ln\left\{\frac{1+\sin L_o}{\cos L_o}\right\}$$

for $L_o$, it is easy to show that

$$\sin L_o = 1-2/(1+e^{2M/a})$$

This gave me a first approximation to use in an iterative process.

"No method I considered avoided very tedious calculations at each interaction. Mr. Emery had used a binary splitting method which took fifteen to thirty iterations to get sufficient accuracy. And after setting up the equation for Newton's method, perhaps the simplest of the methods to be applied, I gave up. There had to be a better way! Geometry came to my rescue.

"Given M, the value $L_o$ I computed with the formula above is exactly correct for the spherical earth. Now, I think of the ellipsoidal earth as sitting inside the spherical one, sharing the same equator and the same polar axis. With this picture in mind, think on the point $P_o$ on a meridian of the sphere and having latitude $L_o$. Then $L_o$ is also the geocentric latitude of the point P on the ellipsoid nearest of $P_o$.

"The second term on the right of my first equation above is always negative (for positive latitudes), the value of $L_o$ is always less than that of L. (You may have to think about that one.) I also knew that the geodesic latitude $L_1$ of any point is greater than its geocentric latitude. So, I thought, $L_1$ would be a better approximation to the desired value L. the two latitudes are related by the equation

$$(1-e^2)\tan L_1 = \tan L_o$$

where e is again the eccentricity of the earth.

"How good is this approximation, I asked myself. The obvious test is to assign values to M, compute the value of $L_1$ by my method and then use $L_1$ to re-compute M. Using the WGS84 values of a = 3443.9185 and c = 0.081819191, I got these results:

| M | Re-computed M |
|---|---|
| 1000 | 1000.02067 |
| 2000 | 2000.00373 |
| 3000 | 3000.00898 |

| | |
|---|---|
| 4500 | 4500.01660 |
| 7000 | 7000.02335 |

"As another test I worked in the opposite direction, assigning value of L, computing the corresponding values of M and then getting the values of $L_1$ my way. The results were even better.

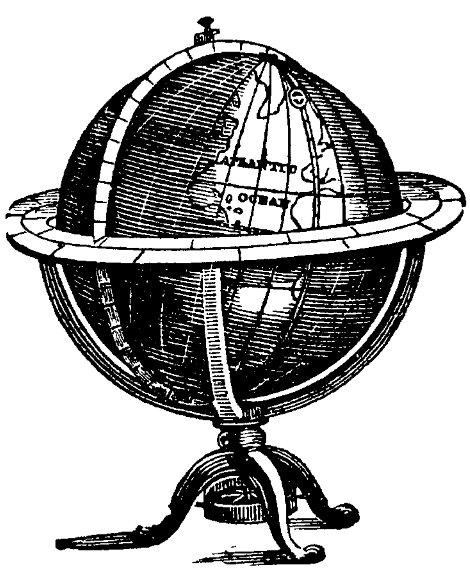
| L | $L_1$ |
|---|---|
| 15 | 15.00000713 |
| 30 | 30.00004637 |
| 45 | 45.00010723 |
| 60 | 60.00139550 |
| 75 | 75.00010033 |

"Mr. Emery was quite pleased with these numbers and is testing the method for himself as I write this. In closing I remark that the geocentric-geodesic latitude interchange has useful applications in several other navigational calculations. I hope to present some of these in later reports to the Newsletter."

—John G. Hocking

Member Alex Erving wrote from Plympton, MA on September 3, 1998:

"This past year I was honored to receive the RADM Thomas D. Davies, USN award for "Excellence in Navigation." It was presented to me after studying Celestial in a class taught by Capt. James Geil, at Tabor Academy. This past summer I practiced my new skills while sailing aboard the schooner SSV *Tabor Boy* in the Penobscot Bay area of Maine. This upcoming fall the schooner will be sailing to Bermuda, and later on to St. Thomas. The student crew and I, along with Capt. Geil, are looking forward to navigating the voyage with the GPS turned off. Now I can just hope for fair weather!



"I'd like to thank all the members of the Foundation for this award, it means a lot to me. I am honored to be a member of the Foundation. I look forward to continuing my education of Celestial, and eventually passing on the knowledge to others. I am a big supporter of your cause, keep up the good work."

*—Most sincerely, Alex D. Erving*

Member Jeremy Allen, by e-mail on Nov. 11, 1998:

"I have been faithfully reading your newsletter and have found some of the more unusual navigation techniques fascinating. I do have a question though. Are you able to supply me with Bruce Stark's Tables for Clearing the Lunar Distance? I would like to try the techniques out when I next go to sea. If you are unable to provide them, perhaps you can direct me to where I might obtain them." ...

*—Jeremy C. Allen, 3rd Mate*

The Executive Director responded to member Allen:

"I am sorry but The Foundation is not a book dealer for any publisher that supplies Bruce Stark's Tables. However, it may be ordered from CelestAire at e-mail-info@celestaire.com

"Your commercial version of the Nautical Almanac will be ordered today and you should receive it in about one week.

"Thank you for your interest in The Navigation Foundation."

*—Best wishes, Terry F. Carraway*

Member David A. Blythe wrote to the Executive Director, Capt. Terry F. Carraway USN (Ret.) on November 7, 1998:

"I read with interest your apologetic notice of a dues increase for Foundation membership in the current issue of Navigator's Newsletter. I would like to add for the record my opinion that in addition to the benefits of membership you listed in your notice, the Navigation Foundation is a most excellent network for purposes of idea and information gathering. Unlike many other 'networks', the Navigation Foundation network works! That alone justifies the modest dues increase now in place. I too am on a fixed income but when the time comes for me to cut back because of increasing costs, I can dispense with many other items before terminating my membership in the Foundation.

"It's mostly to your credit, Capt. Carraway, that the Navigation Foundation functions as well as it does and even though there are many others who contribute to the operation of the Foundation, you are to be commended for your diligence." ...

*—Thanks, David A. Blythe*

Dear member Blythe:

"Thank you for your kind words. They are very much appreciated."

*—Best regards, Terry F. Carraway*

*Editor's note: From the executive Director:*

*"It is because of our members loyalty that we are happy to keep working to make The Navigation Foundation an interesting and useful organization. Some members have been with us for the entire period of our existence. We thank you, our loyal members, for your support, for without it we would cease to exist as a Foundation."*

Director William O. Land wrote to the Executive Director from Norristown, PA on November 5, 1998:

"Please accept my thanks for the 1999 N.A. The service was tops. In my library I have a complete set of N.A.s as far back as the 1960's when I first got interested in celestial navigation. It's really a very fabulous book. I often asked my classes 'Where else for so little money can you get a book that gives the geographical position of the Sun, Moon, four planets and 57 stars, for every one second of time for an entire year to an accuracy of 1/10 of a mile?'

"If you wonder why I keep my old N.A.'s, I find them useful when I run across an old celestial navigation problem in a back issue of a magazine. I can check the solution to see if they did it correctly.

"Also thank you for the phone call. It's always a pleasure to talk with you."

*—Best wishes, Bill*

Member James N. Bodurtha wrote from Ridgefield, CT on May 20, 1998:

"Thank you for the recent 1998 membership notice and now yesterday's arrival of the current *Newsletter*. In and out of hospitals the past few months with hip and spine problems, I have had too little time for navigation interest and attention.

"Please now have the enclosed check as dues or as a donation to the Foundation. Whether I should continue as a member or let it go and try later to contribute with a small endowment is to me presently unclear. My interest in navigation and regard for the Foundation remain great.

"But meanwhile I probably must dispose of many navigation books, probably all of NF *Newsletters*, most copies of ION's *Navigation* since 1960, maybe my older GPS, plus aircraft periscopic and dome sextants. The texts include a 1938 Bowditch, a Dutton, Coffin-Collins, *The World of Mathematics*, Weems, etc. The sextants have been renovated by John Luykx of InfoCenter whose knowledge and skills we so highly regard. Know you of any organization or even individual that might like these as a gift? There's the still great 1968 Encyclopaedia Britannica, too. Perhaps something could be cooperatively arranged on delivery. Please let me know of any ideas you might have.

"Your and Mrs. Carraway's travels sound great as well as now your back-to-work regimen.

"Thank you and best wishes."

*—Sincerely, James Bodurtha*

LTJG Robert Stover wrote from San Diego, CA on June 24, 1998:

"I just completed reading my roommate's copy of your Winter 1997-98 newsletter. I was very impressed.

"I am the navigator on USS Benfold (DDG-65) homeported here in San Diego and have just completed the Navigation & Senior Quartermaster Course at Naval Station 32nd Street.

"I have been in the Navy for ten years. When I was commissioned in 1995, after 7 years in the submarine force, I chose a surface warfare designator for a chance to navigate from a surface perspective. I have thoroughly enjoyed doing that these past 3 years.

"Please send me information concerning membership and fees required to obtain back issues of your newsletter to the above address."

*—Sincerely, Robert Stover, LTJG, U.S. Navy*

Member James O. Muirhead by e-mail to the Executive Director on September 14, 1998:

"I hope you had a pleasant summer and had fun on your trip to Finland.

"I have continued messing with the direction cosines and have developed a method for directly calculating one's lat. and long. from only two celestial sights. The method provides two solutions, so one must know one's location within a few thousand miles or so in order to know which to believe. It does take a lot of multiplying and division and a square root or two of course, but it works surprisingly well. The paper includes a spreadsheet example using sight data taken from the 1977 Bowditch. The spreadsheet implements the solution exactly as the paper describes. In the example East takes a negative sign. Each of the intermediate coefficients is shown in order that one may follow along using a pocket calculator.

"Would you please share this with Ernest Brown. Also, would you and Ernest Brown please take a look at it and provide any comments you wish for improvements. If you feel that it is worth publishing, I could provide a figure to illustrate the concepts."

*—Best regards, Jim Muirhead* jom@aol.com

Mr. Rick Klepfer wrote from St. Vincent, West Indies, on September 6, 1998:

"I have received the information package on the Foundation; thank you for sending it to me. I do have a few questions whose answers would help me to determine if membership for me would be worthwhile.

"I am extremely amateur in the practice of celestial navigation, but would like to become much more proficient. In reading through the sample copy of the newsletter and the descriptions of back issue articles, I find that the content seems to be largely that of history or articles on the refinement of modern day practice; I do not see too much that would be helpful in aiding someone who is barely able to work through a simple sight but wishes to improve himself.

"My problem is that there are no courses available to me here on the tiny island of Mustique. I have attempted to teach myself celestial by the use of books, and to this end I have been working with Hubbard's *'Boater's Bowditch'*, Blewitt's *'Celestial Navigation for Yachtsmen'*, and even Brown's *'One Day Navigation."* The problem with these texts is that one has no way of evaluating one's own work, and if there is a problem, it is extremely difficult to find where you went wrong in your calculations. There are also difficulties that books do not address, but that could be answered quite easily if an instructor were standing nearby, such as how does one know which way to face when taking a round of noon sights when the sun has almost no declination with regard to the observer's position? Another problem is deciding which method of sight reduction to use; I decided upon H.O. 229 at the recommendation of Mr. Hubbard, but most other texts that I read to try and resolve a problem are using H.O. 249; this might not be a problem, but with my limited understanding of the subject, I don't know. One of the basic problems with trying to self-educate out of navigation primers is that all of them seem to assume that you know more than the rank beginner would, and none can elaborate on a particular point that you find inadequately explained in the text.

"Your literature indicates that you can direct individuals at my level to various schools or courses where they can learn the basics in a rational manner; in my case this does not work. Are there alternatives to this that I could avail myself of? I don't even see much in the way of correspondence courses listed in boating magazines, nor do I have any way to know if the people producing the few courses available are competent.

"It does appear that celestial navigation by sextant is a dying art, but surely there are people like myself that want to learn, but are thwarted by the lack of a means to go about it - I had hoped that the Foundation might be the answer to this. One thing that I have found in my quest is that, despite the claims that celestial is nothing more than addition and subtraction, there is a huge amount of things to learn before one can navigate by this method with any degree of comfort.

"Another question that I have concerns the charts that are available through the Foundation; I prefer to use Chart Kit type charts since they are far easier to deal with in the cockpit of a small boat - do you offer these type charts?

"I would be happy to join the Foundation if it would be of value to me and result in my developing my level of competence to higher standards. I look forward to your response to my concerns. Thank you."

*—Best regards, Rick Klepfer*

The Executive Director responded on September 23, 1998 as follows:

"Thank you for your letter of 6 September 1998. We are always delighted to receive correspondence from prospective members.

"Being an amateur in celestial navigation is one thing all of us have to go through in the beginning. With time you will advance and the art will become much more familiar.

"I agree that trying to learn from books is difficult. One cannot always find the answer to a pressing problem nor evaluate, with the books, how one is doing. I also agree with your assessment that there is much more to celestial navigation than addition and subtraction. When members have the difficulty that you state you are having and there are no celestial navigation courses available, I recommend taking a home study course. With a study course you can get answers to your questions and help on difficult areas of celestial. The Starpath School of Navigation in Seattle, Washington has an excellent home study course. They also have an internet web site and also will answer questions on their e-mail. They will provide help on their e-mail site for those taking the home study course. I strongly recommend that you contact Dr. David Burch at Starpath about his course.

"In regards to your question concerning charts, we provide only U.S. Government charts to our members. We do not have a dealership with anyone making Chart Kits.

"In regards to using Pub229 or Pub249 (formerly H.O. 229 and H.O. 249), that is a personal choice. Many people tell me it is easier to use Pub249. However, in the U.S. if one is attempting to get a merchant marine master's license, the test in celestial uses Pub229.

"I hope I have answered some of your more pressing questions. If you have some short questions, please e-mail us at navigate@ix.netcom.com or 76476,1165@compuserve.com."

*—Best wishes, Terry F. Carraway*

A message from Barry B. Bourdon from one of our web pages:

"I am a 28-year old sailor who would like to teach myself how to navigate by the stars but don't know the first thing about it. Can you recommend a good book so I can do so? I would love to take a course but I can't afford it right now."

*—Thank you! Barry B. Bourdon*

The Executive Director responded as follows:

"Almost any book that you can check out, on celestial navigation, from the library will give you a start. The 'Bible' for celestial navigators is a pre-1995 edition of the government publication, *The American Practical Navigator*. It is referred to as 'Bowditch' or DMA Pub9.

"Some books that you may find in the library system are *Celestial Navigation* by Jonah Slocum, Basic Science Press, ISBN 0-917410-08-4; *Primer of Navigation* 7ed by George W. Mixter, W. W. Noreton & Co., New York ISBN 0-393-03508-5.

"Do not let the mathematics discourage you. Learn how to use a sextant from the books, learn how to use the Nautical Almanac, sight reduction form and sight reduction tables. Borrow a sextant and go out to any beach and try some sights. You can cover almost 180 degrees with the ocean as a horizon. That will give you three stars that are far enough apart in degrees to give you a right fix. The fix should show your position on a chart.

"Later you can get into the fine fundamentals of how to calibrate a sextant, practice 'dip' and all of the other ancient mariner terms of celestial."

*—Best wishes, Terry F. Carraway*

*Editor's note: Barry B. Bourdon sent his thanks.*

Member Doug Brutlag wrote from Urbana, IL on November 4, 1998:

"Enclosed is a copy of a brochure announcing The *Aviation Celestial Navigation* Course. It is a short course of instruction about cel nav and how to do it in aircraft. Since launching this venture, I have received inquiries from interested parties who not only want to learn this skill, but also wish to obtain the FAA flight navigator certificate, In response to this, we plan to begin offering celestial navigation instruction starting in late April of 1999. This instruction will be offered aboard our 1944 vintage SNB-5 navigation trainer (and genuine warbird).

"We will be offering celestial navigation flight instruction/ experience/practice to classes of 6 persons at a time, first come first served. This will be actual training flights and the time can be logged towards qualification for the FAA flight navigator certificate. Eligibility requirements are:

- Be at least 21 years old.
- Be able to read, speak, write, and understand the English language.
- Hold at least a 2nd class FAA medical certificate or higher.
- Must be a current licensed pilot & having logged at least 500 hours of cross-country flight time, 100 hours of which must be at night.

"Additionally, for those who desire to go through the flight navigator certification course, they must have passed (before starting flight course) the FAA flight navigator written exam. My company, Brutlag Aviation, Ltd. is offering *The Flight Navigator Written Test Book And Study Guide*. It is a comprehensive book containing test questions, answers, and reference material for those who need to prepare for the exam. Price is $20 + $3 shipping. It is currently the only exam guide available pertaining to the FAA flight navigator written exam.

"Additionally, Brutlag Aviation, Ltd. will soon offer for interested pilots and air navigators, the ASTROCOMP Flight Navigation computer. It is a pocket computer based on the Sharp PC-1270, programmed to perform great circle nav computations, flight planning, celestial navigation sight reduction, grid navigation, star identification, and much more — all in a 5-inch by 2 3/4 inch by 3/8 inch computer device. Completely replaces the H.O. 249 sight reduction tables and will make celestial navigation practical for air navigation. For these products and any other information contact Doug Brutlag at:

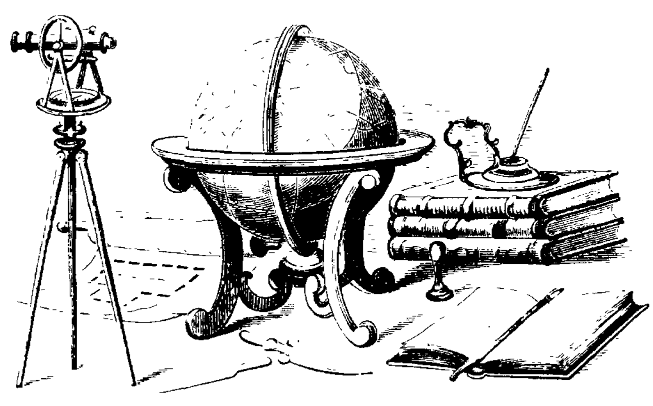
Brutlag Aviation, Ltd.
1793 Aero-Place
Urbana, IL 61802
(217)344-2813
(217)344-1884 FAX

"I appreciate your getting this information in the newsletter. Thanks a lot!"

*—Sincerely, Doug Brutlag*

Bob and Diane Woodruff sent Skipper's Log #2 from 30°35'N, 71°04'W at 21302 on 29 September 1998:

"After last night's dinner of Gwen's homemade, I had to climb the mast to fix the spreader. Down haul of the spinnaker sock wrapped around the radar dome when taking it down. No fun scaling twenty feet free handed in the dark, but no option. Tacked to the NE for several hours. Then gybed over this morning in sight of *Rapscallion*. The two boats sailed in sight of each other for about six hours till George did a horizon job on me. Water length is everything. I put up a hard fight, helming till I dropped. Auto pilot will not steer with big asymmetric spinnaker. I did not sleep much last night and got very little today. Four hours collectively. Lot of self discipline not to sleep longer. I helmed of course. I should of stayed about forty miles more north. Ran the engine for two hours to get battery charged. I called my mom and then sister. It's great having a phone. I am seeing many small flying fish and plastic debris floating. I am getting ready to eat freeze dried chicken and broccoli. Will indulge in a slice of ham later. Will start to read letters from children. Look forward to having the schools call soon. Spoke with Palladin on single side band radio and had e-mail from him. He is biting at my heels."



# NAVIGATION NOTES

## The Peter Ifland Collection of Navigation Instruments

*By John M. Luykr*

On Saturday evening, the 31st of October 1998, at Newport News, Virginia, Dr. Peter Ifland, a member of The Navigation Foundation officially donated his unique and extensive collection of historically important navigation instruments to the Mariner's Museum.

Over 160 instruments were included in the gift to the museum which included a cross-staff, a back-staff, various Hadley octants, many marine sextants, reflecting circles, distance measuring instruments, surveying instruments, artificial horizon sextants, and air sextants as well as other instruments dating from as early as the mid 17th century to modern times. Many well-known makers such as Edmund Gunter, George Adams, Jesse Ramsden, George Dollond, Edward Troughton, Lenoir de Paris, Ponthus et Therode, Heath & Co., Henry Hughes, and Carl Plath are represented by their instruments in the collection publication of Dr. Ifland's heavily illustrated book: *Taking the Stars: Celestial Navigation From Argonauts to Astronauts.*

The official presentation of the collection to the museum and the announcement took place at a reception and dinner in the grand foyer of the museum.

The addition of Dr. Ifland's collection of instruments to the existing collection at the Mariner's Museum now makes the navigation instrument holdings of the museum one of the largest and most significant in this country. Museum officials, scholars and enthusiasts are looking forward to the eventual display of these instruments, preparations for which have already gotten underway.

A review of Dr. Ifland's book by Ernest Brown is included inthis newsletter.

## A Wayward Problem

*By John G. Hocking*

Dr. Allan E. Bayless programmed a spreadsheet to compute waypoints along a great circle track to be used as turning points for a series of rhumb line legs approximating the great circle. He used two different methods of doing so, the first specifying the longitudes of the waypoints, the second giving the distances between the waypoints along the great circle. Wasn't there yet another method, he asked me. Could he select the approximating rhumb line direction at each waypoint? This seemingly innocent question can be formulated as follows: Suppose a great circle track emanates from a point P on the sphere and so does a loxodrome. Where do the two curves next cross?

I began by assuming a point of departure $(\varnothing_1,\lambda_1)$ and a destination $(\varnothing_2,\lambda_2)$. The usual equations for the distance $d_1$ and the angle $\alpha$, the bearing of the destination from the point of departure are

$$\text{Cos } d_1 = \text{Sin } \varnothing_1 \text{Sin} \varnothing_2 + \text{Cos} \varnothing_1 \text{Cos } \varnothing_2 \text{Cos}(\lambda_2-\lambda_1) \quad (1)$$

$$\text{Sin } \alpha = \text{Cos } \varnothing_2 \text{Csc } d_1 \text{Sin}(\lambda_1-\lambda_1) \quad (2)$$

Trying to get an expression for longitude $\lambda_2$ in terms of latitude $\varnothing_2$ from these equations I found to be very cumbersome. Matters can be simplified a good deal by referring the great circle to the point $(O,\lambda_o)$ at which it crosses the equator. To do this I first need the angle $\gamma$ to be seen in Diagram 1 below. This angle is between the meridian through $(O,\lambda_o)$ and

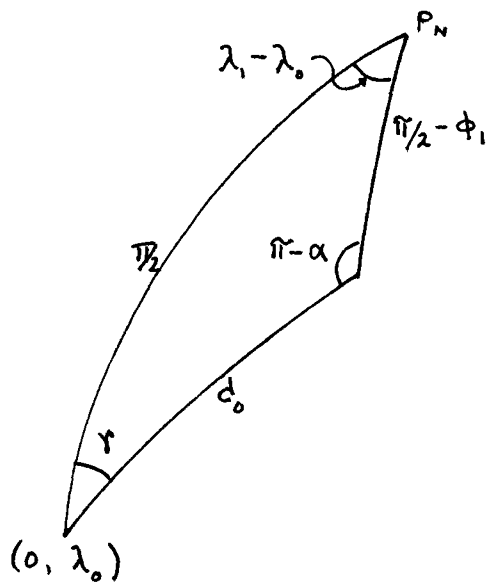



*Diagram 1*

the great circle. It is also the complement of the angle between the plane of the equator and the plane of the great circle. Note that the triangle in Diagram 1 is quadrantal and therefore the usual Napier formulas can be used. For instance, the sine law yields

$$\text{Sin } \gamma = \text{Sin } \alpha \text{ Cos } \varnothing_1 \quad (3)$$

The cosine law gives me the distance $d_o$ by means of the formula

$$\text{Tan } d_o = \text{Sec } \alpha \text{ Tan } \varnothing_1 \quad (4)$$

Using the sine law again I have

$$\text{Sin}(\lambda_1-\lambda_o) = \text{Sin } d_o \text{ Sin } \alpha \quad (5)$$

Next I use the quadrantal triangle in diagram 2 to derive an easier relationship between the latitude and longitude of points on the great circle. The cosine law yields the

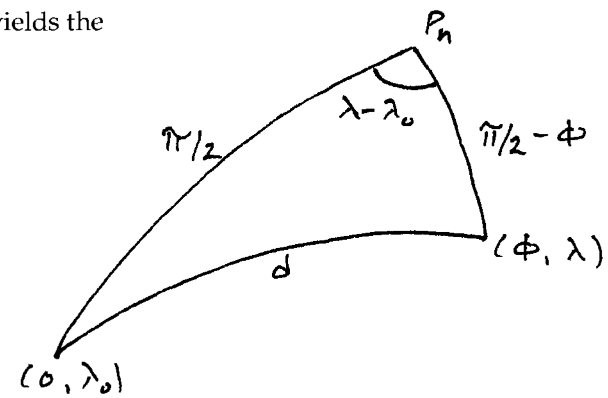



*Diagram 2*

formula

$$\text{Sin } \varnothing = \text{Sin d Cos } \gamma \qquad (6)$$

while the sine law gives me

$$\text{Sin } (\lambda-\lambda_o) = \text{Sec } \varnothing \text{ Sin d Sin } \gamma \qquad (7)$$

Substituting the value of Sin d from (6) into (7) I come up with

$$\text{Sin } (\lambda-\lambda_o) = \text{Tan } \gamma \text{ Tan} \varnothing \qquad (8)$$

Thus, the equation I shall use to relate the longitude and latitude of a point on the great circle is

$$\lambda = \lambda_o + \text{Arcsin}(\text{Tan } \gamma \ \text{ Tan} \varnothing) \qquad (9)$$

The curve followed by a rhumb line track is called a loxodrome and its equation, which I shall not derive, is

$$\lambda = \lambda_1 + \text{Tan } \beta[\text{Ln}(\text{Sec} \varnothing + \text{Tan} \varnothing) - \text{Ln}(\text{Sec} \varnothing_1 + \text{Tan} \varnothing_1)] \qquad (10)$$

The resemblance to the formula for meridional parts on the sphere is not accidental!

With all of that prelude, the mathematical problem Dr. Bayless wanted me to solve amounts to solving the equation

$$\lambda_o + \text{Arcsin}(\text{Tan } \gamma \text{ Tan } \varnothing)$$

$$= \lambda_1 + \text{Tan } \beta[\text{Ln}(\text{Sec} \varnothing + \text{Tan} \varnothing) - \text{Ln}(\text{Sec} \varnothing 1_1 + \text{Tan} \varnothing_1)] \qquad (11)$$

A closed solution of this monster is beyond my powers but the program "Mathematica" on my computer can at least solve numerical examples of it and do so quite readily.

My usual test track departs (30,-75) with destination (45,-5), roughly a course from St. Petersburg, Florida to Ushant, France. The formulas above provide me with the following values, all in radians because that is the only unit that Mathematica recognizes.

| | | |
|---|---|---|
| $d_1$ | = | 0.964573 |
| $\alpha$ | = | 0.871222 |
| $\gamma$ | = | 0.724299 |
| $d_o$ | = | 0.730965 |
| $\lambda$ | = | 1.845092 |

As a first verification of my formula(11), I used it to compute the vertex of the great circle. Denoting the vertex as ($\varnothing_3$,$\lambda_3$) and knowing that $\lambda_3 - \lambda_o = \pi/2$, equation(9) becomes merely

$$1 = \text{Tan } \varnothing_3 \text{ Tan } \gamma$$

From this I get the value

$$\varnothing_1 = 0.846498$$

Using one of Napier's Rules gives us the latitude of the vertex via the formula

$$\text{Cos } \varnothing_3 = \text{Sin } \alpha \text{ Cos } \varnothing_1$$

This gave me the identical value, to nine decimals. Very gratifying.

For the second test of my equation I set $\beta = \alpha + 2°$ which, in radians, is 0.906129. Equation(11) now becomes

$$-1.845090 + \text{Arcsin}(0.884702 \text{ Tan } \varnothing)$$
$$= -2.009990 + 1.27694 \text{ Ln}(\text{Sec} \varnothing + \text{Tan } \varnothing)$$

Given an initial value of $\varnothing$=0.6, Mathematica very quickly came up with

$$\varnothing = 0.644997$$

from which I got

$$\lambda = -1.175115$$

(In degrees, this is the point (35.0648, -0.57.3291). Using this point, I next re-computed the values of $\alpha$, $\gamma$ and $\lambda$. Once again there was agreement to nine decimals with the earlier results.

I tried one more time by setting $B = 60° = \pi/3$ radians and running through all of the calculations again. This time Mathematica arrived at the point (0.800905), -0.695556). All computations were again in exact agreement. I am satisfied that my re-formulation is correct and that Mathematica can solve the equation arising. There is yet a difficult problem ahead of me, however. Can I develop a method which Dr. Bayless can program into a spreadsheet? As yet, no but perhaps a later communique will be forthcoming.

# Closed Form Solution of Lat. and Long. With Two Sights

*James O. Muirhead*

## Introduction:

This paper describes how to use the direction cosines to directly obtain latitude and longitude from two sextant altitudes when one knows one's position within a few thousand miles. If you don't have a clue, you'll need three sights. The method provides two solutions; one is your actual position and the other will be very far from your position. There is a lot of calculation required, but the method can easily be programmed into a calculator or spreadsheet.

The direction cosines are described in "Celestial Sight Reduction Using Direction Cosines", *The Navigators Newsletter*, issue 59, Spring 1998, pp. 8-9.

The direction cosines, in addition to giving the direction of something from the origin, may also define a plane in space. For instance, if the direction cosines of a celestial object (found from dec. and GHA) are a, b and c and the corrected sextant altitude from the observer's position is Ho, the equation,

$ax+by+cz = \sin Ho$

defines a plane in three dimensions which cuts through the Earth. The direction cosines define the orientation of the plane, which is orthogonal to a line from the center of the earth to the ground position (GP) of the celestial object. The closest distance of the plane to the center of the Earth is sin(Ho) times the radius of the Earth.

The direction cosines of a celestial body may be calculated as follows.

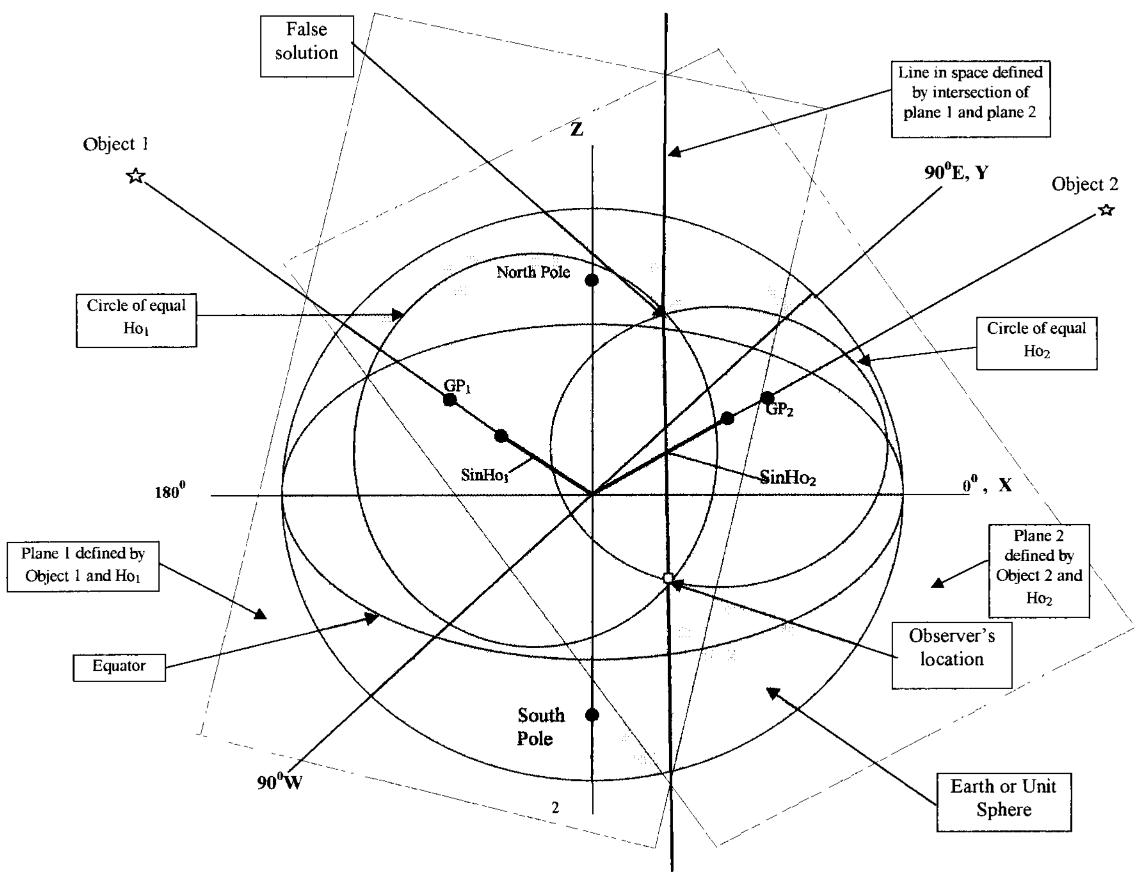
a = cos(dec.)cos(GHA), b = cos(dec.)sin(GHA), c = sin(dec.)

The intersection of the plane with the Earth defines the circle of equal altitude that includes the location of the observer. Unfortunately, one cannot write the equation of a circle or any other line in space unless it lies in one of the three principle planes. It takes at least two equations to define a line in three dimensions.

## Lines in space:

Elementary geometry tells us that the intersection of two planes in space defines a straight line. When the altitudes of two celestial objects are measured, from the same location, and their GHA and dec. are known, two planes in space are defined. Figure 1 illustrates this. The fact that the intersections of these planes with the Earth's sphere defines circles of equal altitude is well known. However, the intersection of the two planes also defines a straight line in space. That line passes through the Earth and therefore must intersect the Earth's surface in two places. One of these places is the observer's location, and the other will generally be a very large distance away. That distance is of course defined by the geometry of the two sights. One may also think of this method as the solution for the crossing points of the two circles of

**Figure 1. Geometry of the Underdetermined Fix**



equal altitude.

The same rules for correct celestial geometry as used by the graphical Sumner/Saint-Hilaire methods apply. This method is simply a direct calculation of the results.

## Derivation of the "under-determined" fix:

This derivation is of the simultaneous solution of the equation of a sphere of unit radius and of the equations of two planes defined by the direction cosines and the sines of the altitudes of two celestial objects. Because only the angles (lat. and long.) are desired, the size of the sphere need not be known except for correcting the sextant.

## Equations:

Unit Sphere: $x^2 + y^2 + z^2 = 1$ (1)

Plane1: $ax + by + cz = \sin H_{01} = r_1$ (2)

Plane2: $dx + ey + fz = \sin H_{02} = r_2$ (3)

Solving (1 and 3) for x,

$$x = \sqrt{1 - y^2 - z^2} \quad (4)$$

$$x = \frac{r_2 - ey - fz}{d} \quad (5)$$

Combining (4) and (5),

$$\frac{r_2 - ey - fz}{d} = \sqrt{1 - y^2 - z^2} \quad (6)$$

Solving (2) for x,

$$x = \frac{r_1 - by - cz}{a} \quad (7)$$

Combining (5) and (7),

$$\frac{r_1 - by - cz}{a} = \frac{r_2 - ey - fz}{d}$$

Multiplying both sides by a and d and solving for y,

$$y = \frac{(dc - af)\, z + ar_2 - dr_1}{ae - db}$$

Letting A = (dc-af)/(ae-db) and B = $(ar_2 - dr_1)/(ae-db)$, then

$$y = Az + B \quad (8)$$

Substituting (8) into (6),

$$\frac{r_2 - eAz - eB - fz}{d} = \sqrt{1 - A^2z^2 - 2ABz - B^2 - z^2} \quad (9)$$

Gathering terms,

$$\frac{-(eA + f)z + (r_2 - eB)}{d} = \sqrt{1 - A^2z^2 - 2ABz - B^2 - z^2} \quad (10)$$

Substituting C = -(eA+f)/d, and D = $(r_2 - eB)/d$,

$$Cz + D = \sqrt{1 - A^2z^2 - 2ABz - B^2 - z^2} \quad (11)$$

Squaring both sides,

$$C^2z^2 + 2CDz + D^2 = 1 - A^2z^2 - 2ABz - B^2 - z^2 \quad (12)$$

Gathering terms again,

$$(C^2 + A^2 + 1)z^2 + 2(CD + AB)z + (D^2 + B^2 - 1) = 0 \quad (13)$$

Substituting once more, let
$E = C^2+A^2+1$, $F = 2(CD+AB)$, $G = D^2+(B^2-1)$,

$$Ez^2 + Fz + G = 0 \quad (14)$$

This quadratic equation has two roots, both real in this case because the planes resulting from sextant altitudes must intersect within the Earth. Using the quadratic formula we find,

$$z_1 = \frac{-F - \sqrt{F^2 - 4EG}}{2E} \quad (15)$$

and

$$z_2 = \frac{-F - \sqrt{F^2 - 4EG}}{2E} \quad (16)$$

These two roots ($z_n$) are to be numerically evaluated and substituted into (8) to find the numerical value of the $y_n$.

$$y_1 = Az_1 + B, \; y_2 = Az_2 + B \quad (17)$$

Then both $y_n$ and $z_n$ are substituted into (7) to find the numerical value of the $x_n$,

$$x_1 = \frac{r_1 - by_1 - cz_1}{a}, \; x_2 = \frac{r_1 - by_2 - cz_2}{a} \quad (18)$$

When $x_n$, $y_n$ and $z_n$ are known, the latitude is $\mathrm{ASIN}_n(z_n)$ and the longitude is $\mathrm{ATAN2}_n(x_n, y_n)$ (using BASIC terminology). The $z_n$ here is, of course the North/South Cartesian Earth axis, not the North relative bearing of a celestial object. Two sets of coordinates are thus obtained. One is the geographic location of the observer, and the other is invalid. If the two bodies observed have good geometry, the two coordinates will be thousands of miles apart and the ambiguity easily resolved.

The solution is then very algorithmic. One simply solves for A through G and plugs E, F and G into the quadratic formula.

**Example:** The following example is a spreadsheet solution of the celestial data given in Bowditch, 1977 edition, pp. 528-529. No attempt was made to advance the sights for ship motion. All data has been converted from degrees and minutes to degrees and tenths for convenience. In this case, East takes the negative sign.

Date: June 2, 1975
DR position: 1742hrs, lat. 41° 10'S, 128° 00'E

| | Sight 1 | | Sight 2 | | Sight3 | | Sight 4 |
|---|---|---|---|---|---|---|---|
| | **Spica** | | **Regulus** | | **Procyon** | | **Canopus** |
| Dec. | -11.037 | | 12.086 | | 5.287 | | -52.686 |
| GHA | 175.218 | | 225.916 | | 264.687 | | 284.838 |
| Dec. rad. | -0.193 | | 0.211 | | 0.092 | | -0.920 |
| GHA rad. | 3.058 | | 3.943 | | 4.620 | | 4.971 |
| Ho | 32.375 | | 36.824 | | 34.955 | | 52.676 |
| Ho. rad | 0.565 | | 0.643 | | 0.610 | | 0.919 |
| **Calculate:** | | | | | | | |
| a | -0.97808835 | d | -0.680290608 | g | -0.092202598 | j | 0.155236898 |
| b | 0.08182294 | e | -0.70239783 | h | -0.991467943 | k | -0.585974203 |
| c | -0.19143714 | f | 0.209384759 | I | 0.092141186 | l | -0.795321154 |
| $r_1$ | 0.535458336 | $r_2$ | 0.599356161 | $r_3$ | 0.572932899 | $r_4$ | 0.795219575 |

**Combining pairs of sights**

| | | | 1&2 | | 2&3 | | 3&4 |
|---|---|---|---|---|---|---|---|
| | | A | 0.451114831 | A | 0.071142035 | A | -0.283864341 |
| | | B | -0.298862012 | B | -0.548607223 | B | -0.780326296 |
| | | C | -0.157987363 | C | 0.234333308 | C | 4.051768496 |
| | | D | -0.572455548 | D | -0.314594434 | D | 2.177114459 |
| | | E | 1.228464597 | E | 1.059973288 | E | 17.497406906 |
| | | F | -0.088760687 | F | -0.225497977 | F | 18.085341176 |
| | | G | -0.582976143 | G | -0.600060457 | G | 4.348736498 |
| | | $Z_1$ | 0.725954095 | $Z_1$ | 0.866253549 | $Z_1$ | -0.380613915 |
| | | $Z_2$ | -0.653700742 | $Z_2$ | -0.653514248 | $Z_2$ | -0.652987308 |
| | | $Y_1$ | 0.028626647 | $Y_1$ | -0.486980183 | $Y_1$ | -0.672283578 |
| | | $X_1$ | -0.687147121 | $X_1$ | -0.111602374 | $X_1$ | 0.634954989 |
| | | $Y_2$ | -0.593756111 | $Y_2$ | -0.595099556 | $Y_2$ | -0.594966484 |
| | | $X_2$ | -0.469179092 | $X_2$ | -0.467734589 | $X_2$ | -0.468638943 |
| **Degrees** | Latitude 1 | | 46.548 | | 60.026 | | -22.372 |
| | Longitude 1 | | 177.614 | | -102.908 | | -46.636 |
| | Latitude 2 | | -40.821 | | -40.807 | | -40.767 |
| | Longitude 2 | | -128.315 | | -128.167 | | -128.227 |

Each of these solutions may be considered "fixes" at the time of the second sight of the pair. Advancing the Ho of the first sight to accommodate ship movement will, of course, yield better positions.

# HISTORY OF NAVIGATION

*Origins of Geomagnetic Science*, reprinted in issues forty-three through forty-seven, was taken from chapter VI of the Coast and Geodetic Survey Serial 663, *Magnetism of the Earth*, published in 1945.

As to the possible Chinese origin of the magnetic compass, the position in *Origins of Geomagnetic Science* is summarized as follows:

## EUROPEAN ORIGIN NOW ACCEPTED

In the words of Crichton Mitchell, the present position with respect to the invention of the compass may be stated as follows:

"(I) That while it is possible that the Chinese were acquainted with the directive property of a magnet by 1093 A.D., they made no further use of that property for at least two hundred years thereafter.

"(II) That there is no evidence of the origin of any such knowledge among the Arabs, and it is improbable that they transmitted any information on the matter to Europe, their earliest mention of the compass being nearly half a century after its first mention in Europe.

"(III) That the compass was in use in western Europe by 1187 A.D., and taking into consideration the fact that the directive property must have been discovered much earlier, it is most probable that a knowledge of that property and its application in western Europe were of independent origin and as early as, if not earlier than, [the same developments] in China."

As to Chinese application of the magnetic compass, *Origins of Geomagnetic Science* addresses the matter, in part, as follows:

"It must be recognized that a knowledge of the directive property of magnetized needles may have preceded by a long interval the embodiment of the principle in the form of a useful instrument, particularly if the secret was known only to a select class and carefully guarded. A remarkable passage in a work entitled 'Mêng-ch'i-pi-t'an,' which appeared toward the end of the eleventh century A.D., seems to establish that the directive property was known in China at that period. This passage is as follows:

"A geomancer rubs the point of a needle with the lodestone to make it point to the south, but it will always deviate a little to the east, and not show the south: that to use the needle, it may be put on water, but it would not be steady; and also it may be put on the nail of a finger or on the lip of a bowl, but it is too apt to drop, because its motion is very brisk; that the best method is to hang it by a thread, and to prepare the contrivance, one has to single out a fine thread from a new skein of floss silk and fix it with a piece of beeswax on the middle of the needle, the latter to be hung up where there is no wind; that the needle would then always point to the south, that, on rubbing a needle with a lodestone, it may happen by chance to point to the north, and he (the author) owned needles of both sorts, and that no one could as yet find the principle of it.

"This passage was repeated in several later Chinese works without essential revision, but we have no trustworthy evidence of any application of this knowledge for many centuries to come."

On page 96 of her 1956 book *The Haven - Finding Art*, A History of Navigation from Odysseus to Captain Cook, the late Professor E.G.R. Taylor says, "As to the common story that it (the magnetic compass) had been brought in from China by Arab sailors, there is no evidence whatever to support it."

Since 1956 much work has been done on early Chinese navigation. Now there is the translation of Ma Huan's *The Overall Survey of the Ocean's Shores* by J.V.G. Mills for the Hakluyt Society. Ma Huan was the Muslim interpreter for Admiral Chêng-Ho, who made a series of expeditions across the Indian Ocean to East Africa between A.D. 1400 and 1433. There is the monumental work *Science and Civilization in China* by Joseph Needham, F.R.S. Volume IV, part 3 (section 29) of this work, some 316 pages, deals with nautical technology. Volume IV, part 1, deals with the history of the magnetic compass.

The second edition (1971) of *The Haven - Finding Art*, published after Professor Taylor's death, includes a 5000-word appendix on early Chinese navigation which is a distillation of Dr. Needham's work on the subject.

Dr. Needham's finding of the Chinese use of a compass on shipboard is solidly attested by A.D. 1090 or about a century before its appearance in western Europe. However, the type of mariner's compass used by the Chinese up to the time of the arrival of the Dutch in the 16th century appears to have been "a thin leaf of magnetized iron with upturned edges" floating on water.

# MARINE INFORMATION NOTES

*Edited by Ernest Brown*

## National Data Buoy Center Meteorological Buoys

The National Data Buoy Center (NDBC) deploys moored meteorological buoys which provide weather data directly to the mariner as well as to marine forecasters. Recently (reported January 1998), a disproportionate number of these buoys have had mooring failures due to abrasion of the nylon mooring line by trawls, tow lines, etc.

These buoys have a watch circle radius (WRC) of 2,000 to 4,000 yards from assigned position (AP). In addition, any mooring in waters deeper than 1,000 feet will have a floating "loop" or catenary that may be as little as 500 feet below the surface. This catenary could be anywhere within the buoy's WCR. Any underwater activity within this radius may contact the mooring causing a failure.

To estimate a buoy's WCR in yards, divide the charted depth (in feet) by three. For example, the WCR of a buoy moored at a charted depth of 12,000 feet can be estimated at 4,000 yards.

To avoid cutting or damaging a moor, mariners are urged to exercise extreme caution when navigating in the vicinity of meteorological buoys and to remain well clear of the watch circle. If a mooring is accidentally contacted or cut, please notify NDBC at (228-688-2835 or (228)688-2436.

For further information relating to these buoys consult the NDBC home page **(http://seaboard.ndbc.noaa.gov).**

### New Editions of Hydrographic Products Catalog

Catalog production was assumed by the Defense Logistics Information Service (DLIS) of the Defense Logistics Agency (DLA). The ninth edition of the National Imagery and Mapping Agency Catalog, Part 2-Volume I, Hydrographic Products, Nautical Charts and Publications, April 1998, is now available. The NIMA Catalog volume is corrected through NM 9/98 A list of "Cumulative Catalog Corrections for Volume I (9th Ed.) from Notice to Mariners 10/98 through 32/98" is located in section II.

Customers can expect formal changes in this new catalog to include at least the following:

- The numerical list of charts found at the end of each region now refers to **figure numbers** as opposed to **page numbers** for graphic referral. Exceptions where **page numbers** are referenced vice **figure numbers** will be indicated with an asterisk.
- The textual descriptive pages aligned with the figure graphic pages now include National Stock Numbers followed by the NIMA Stock Number.
- **Notice to Mariners**, Section II containing the "NIMA HYDROGRAPHIC PRODUCTS CATALOG CORRECTIONS" will continue as in the past to reference **page numbers** only when referring to all corrections.

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# BOOK ANNOUNCEMENT

### TAKING THE STARS: Celestial Navigation from Argonauts to Astronauts

*By Peter W. Ifland*

The Mariners' Museum, Newport News, Virginia and Krieger Publishing Company, Florida Available through The Mariners' Museum Shop (757)591-7792 or (800)259-3916. Hardbound, $59.00 ISBN #1-57524-095-5 240 pages, 198 illustrations

For wholesale order information (six or more copies), contact the Publications Department at (800)581-7245; (757)591-7738; fax (757) 591-7320; e-mail—publications@mariner.org. or visit the Museum's Web site at www.mariner.org.

The following is from the new book announcement of the Mariners' Museum:

"The Mariners' Museum and Krieger Publishing Company are pleased to announce the publication of *TAKING THE STARS: Celestial Navigation from Argonauts to Astronauts* by Peter Ifland. This richly illustrated book documents the evolution of celestial navigation instruments over the past 1,000 years, from astrolabes and sextants to the modern-day global positioning systems. *TAKING THE STARS* also highlights the accomplishments of the craftsmen and inventors responsible for these precise and beautiful instruments.

"*TAKING THE STARS* is written for a diverse audience, and is appropriate for the backyard navigator as well as the collector of scientific instruments. The hardcover book includes 120 color photographs and over 40 line drawings. Also featured are special 'how to' sidebars explaining the proper use of the instruments described in the book, a glossary of technical terms, and an appendix with information for the serious navigator or scholar.

"This historical look at these magnificent instruments, which have been used by the earliest seafarers to modern day sailors, will delight scholars and novices who wish to understand the mysteries of 'taking the stars,' said Claudia L. Pennington, director of The Mariners' Museum.

"Peter Ifland has produced a wonderfully readable and remarkably thorough account of the history of sextants and other instruments designed for celestial navigation," praises Deborah Jean Warner, Curator, Physical Sciences at the National Museum of American History.

"Peter Ifland, a retired Commander in the United States Navy with extensive navigational experience, brings outstanding qualifications to the study of celestial navigation instruments. Ifland holds a Ph.D. in biochemistry and has been a student and renowned collector of navigation instruments for over 20 years. Mr. Ifland is donating 169 navigation instruments from his unparalleled collection to The Mariners' Museum, where they will round out one of the most extensive collections of its kind in the world.

"The Mariners' Museum, one of the largest and most comprehensive maritime museums in the world, houses more than 35,000 artifacts inspired by humanity's relationship with the sea. For 68 years, The Mariners' Museum has celebrated the spirit of seafaring adventure, assembling a renowned and strikingly diverse collection of maritime artifacts, including figureheads, scrimshaw, hand-crafted ship models, decorative arts, prints, paintings, and small craft from around the world."

*Editor's note: This book will certainly delight just about anyone who is fortunate enough to have a copy. The book is fascinating.*

*Apparently in addressing advances in celestial sight reduction in the small space of only part of page 188 the author has omitted too much to make the results other than misleading. Also there are minor errors on this page.*

**ANSWER TO DO YOU KNOW**...(from page 1)

The winning side in a power struggle, the agrarian society oriented Chinese bureaucracy, protected its victory, withdrawal from expensive maritime expansion, by making the building of a junk with more than two masts a capital offense in A.D. 1500.