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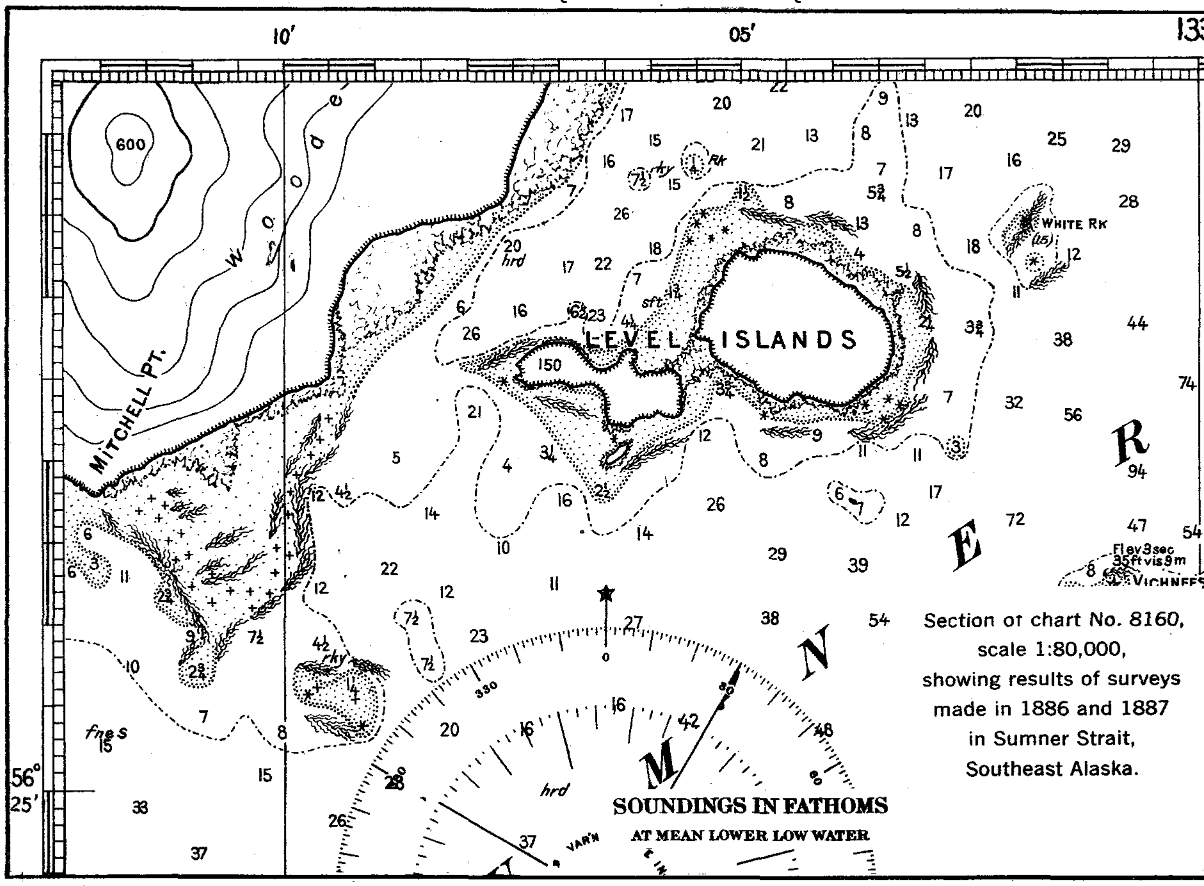
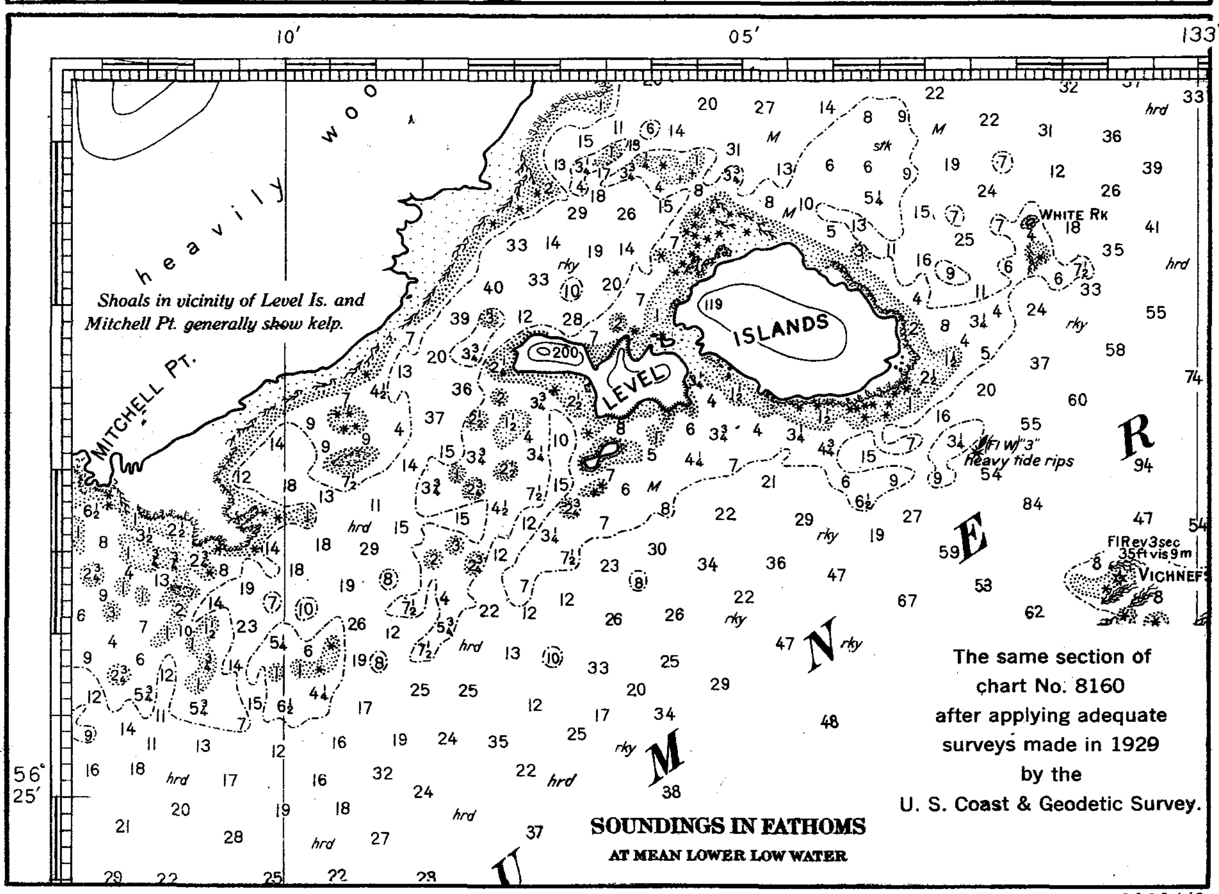
CONTRAST BETWEEN ADEQUATE AND INADEQUATE SURVEYS



Section of chart No. 8160, scale 1:80,000, showing results of surveys made in 1886 and 1887 in Sumner Strait, Southeast Alaska.



The same section of chart No. 8160 after applying adequate surveys made in 1929 by the U. S. Coast & Geodetic Survey.

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GEM

THIS BULLETIN CONTAINS

MAP PROJECTIONS*

Charles H. Deetz
Cartographic Engineer, U.S.C. & G. Survey.

Under the subject, "Thoughts on Map Construction" by Francis Bacon, we find the following pertinent passage: "All depends on keeping the eye steadily fixed upon the facts of nature, and so receiving their images simply as they are; for God forbid that we should give out a dream of our own imagination for a pattern of the world."

In view of the growing interest in maps and charts as brought about by the interrelation of countries and communities through more rapid transportation and various agencies, I shall try to present in outline some of the underlying principles of constructive cartography as supplied by the map projection. The term "map projection" is applied to that orderly arrangement of reference lines of latitude and longitude which constitute the framework of a map. It is imperative that this framework should structurally embody everything that can in any way assist in bringing the vessel or airplane safely to port, in facilitating the problems of the engineer, and in depicting accurate information as nearly true to nature as it is possible to make it.

As a spheroidal surface can not be spread out upon a plane without distortion, any representation of an extensive part of the earth's surface must necessarily involve a certain amount of approximation or compensation systematically accomplished, or it must be restricted to the desired special property that will meet a problem under consideration.

The errors which arise are those of distortion, which implies deviation from right shape in the meridians and parallels, involving curvature in these reference lines; deformation of angles; changes of scale, and errors of distances, errors of bearings, and errors of area.

PROPERTIES OF PROJECTIONS

The principal properties that govern an orderly arrangement of meridians and parallels, and which we aim to obtain within reasonable limits at the expense of other properties are:

1. The correct angles between meridians and parallels and true shape for restricted areas as found in the conformal projections.

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*A paper read before the Board of Surveys and Maps, March 8, 1932.

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2. Equivalence of area as represented in the equal-area projections. (If we take a coin, a paper weight, or, if you like, a small irregular piece of cardboard and place it upon an equal-area projection, the same piece of paper in any orientation whatever on any part of the map will always cover the same amount of area of the country represented).

Other potential properties of projections are:

1. The representation of the rhumb line as a straight line, as in the Mercator projection.

2. The representation of the great circle as a straight line, as in the Gnomonic projection.

3. The representation of true azimuths and distances from a given point, as in the azimuthal equidistant projection.

On an accompanying plate is shown an ideal head plotted into a globular projection. By plotting the outline of this head into the corresponding graticules of an orthographic, stereographic, Mercator, and a rectangular system, the properties of the globular projection are shown in a distorted picture in these other four systems. This does not imply that the globular projection has any intrinsic value (in fact it has not), being nothing more than a geometrical design easily constructed. The normal head for the Mercator might as well have been used as a base at the expense of the others. The diagram merely illustrates how it is impossible to hold more than one or two desirable properties in a given projection.

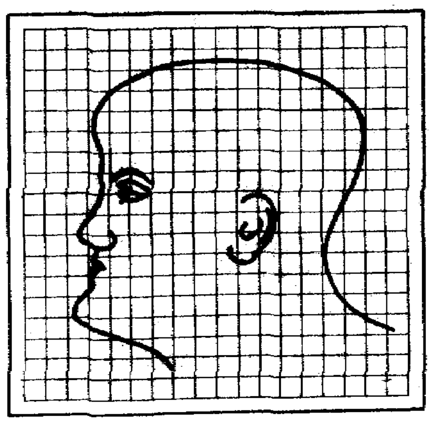
The selection of a projection is, therefore, the first important step in the compilation of any map or chart, as the value of the product to the particular purpose it is designed to serve depends largely on the projection upon which the chart is constructed.

HISTORICAL

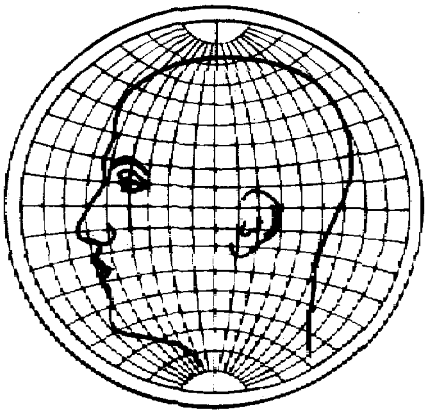
As several projections date back to antiquity, we should at least mention Hipparchus (*ca*. B.C. 160-125). Mathematical cartography is indebted largely to him. He was the founder of scientific astronomy, and he applied astronomic methods to mark the position of places upon the earth's surface. He is recorded as having invented trigonometry and as having devised the stereographic and othographic projections for maps. In mathematical cartography he has, therefore, a direct appeal as being one of the landmarks of the science and the one person who gave us the first solution for the development of the earth's surface upon a plane.

THE MERCATOR PROJECTION

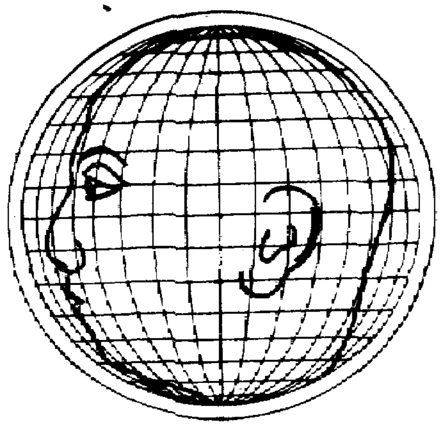
Gerhard Kremer, better known by his Latin surname Mercator, was



Rectangular coordinates



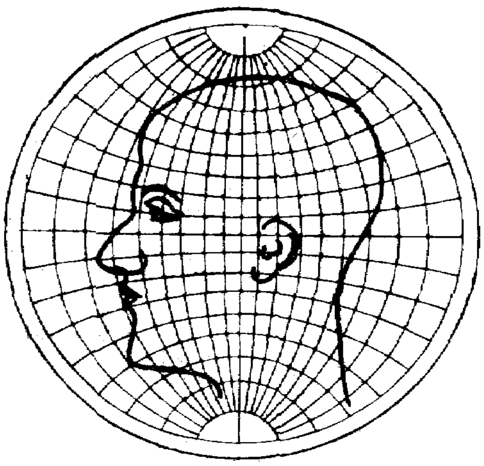
Globular



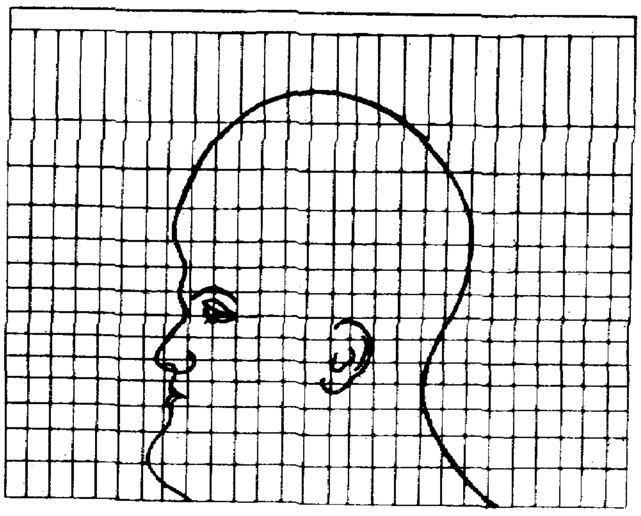
Orthographic

Illustration of relative distortions

Globular, Orthographic, Stereographic and Mercator Projections.



Stereographic



Mercator

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born in Flanders in 1512 and was a graduate of the University of Louvain. With an exceptional talent he devoted his life to the betterment of maps, improving and formulating new devices in their mathematical framework. The first known map bearing his name is a map of the world in 1538 on an equal-area projection.

Another world map in 1569, on the projection which is named for him, appeared as an original creation and made him famous, transmitting his name to all time. It was the first projection with straight, equidistant and parallel meridians on which the latitude increased proportionally with the longitude. For nautical purposes this system of projection is now universally employed and will probably be so as long as ships fellow the loxodrome, i.e., base their courses on rhumb lines. It may be stated that Mercator's nautical chart stands alone in map history, isolated from his many other works as a violent departure and improvement over methods existing before his time. In contemporary judgment he was styled as, "In cosmographia longe primus", which translated means: <u>In cosmography by far the first</u>. He was the chief of his generation in putting in order the accumulating stores of geographic knowledge.

It is frequently stated or implied in treatises on geography and elsewhere that the Mercator projection is a perspective projection from the center of the spheroid upon a tangent cylinder. It is not. The Mercator projection demands greater mathematical respect, and it is better to discard all mention of its relation to a cylinder and view it entirely as a conformal projection upon a plane.

It is derived by mathematical analysis. The distances of the various parallels depend upon an integral, and the required values are not obtained by any simple formula.

MERITS AND OTHER OBSERVATIONS ON THE MERCATOR PROJECTION.

The loxodrome or rhumb is a line that crosses the successive meridians at a constant angle. A ship "sailing a rhumb" is, therefore, on one course continually following the rhumb line and will, theoretically at least, pass all points along that line exactly as they are charted. The only projection on which such a line is represented as a straight line is the Mercator. On other projections a navigator, assuming a straight line as his course, will not track the line because he is consciously or unconsciously sailing a rhumb.

The simplicity of the projection commends itself -- north and south are up and down, and a course can be laid off from starting point or from any meridian along the line, or even from the right or left border except in oblique charts.

Positions are mere readily plotted because the grids are rectangular, and a straightedge can be placed across the chart between corresponding border divisions. This can not be done with any other projection in common use. The border scales of the Mercator chart can be subdivided as minutely as desirable, leaving the chart free from further subdivisions which are frequently necessary where one or both systems of reference lines are curved.

One of the main differences between the Mercator system and that of the polyconic or other conic projections consists in laying off courses. In the former system it is customary to base the course upon the meridian of origin; in the other systems, a true course angle is measured with the meridian nearest half way along the course. The two methods are equally good, but they don't begin the same way.

The Mercator projection is not intended for geographic studies but as a convenient working base for the navigator to determine his courses. For navigational purposes, particularly ocean navigation as contrasted with coastwise navigation, it has stood the test and enjoyed the momentum of success.

In addition to its value for nautical charts, it is useful for showing continuous commercial routes around the world, for communication charts, and for pilot charts supplying information as to winds and currents. For the latter purpose it is important that the cardinal directions, north and south, east and west, always point the same way respectively, and remain parallel to their corresponding borders of the chart. Charts with cardinal directions running every way are undesirable, and it can at least be said, even for geographic purposes, that the Mercator projection is free from discontinuities, butterflies, and bloomers, as seen in the framework of some world maps.

There is one important feature in particular, however, in which the projection does not respond directly, and that is in the plotting of radio bearings to or from a distant point. As the path of radio signals is a great circle, it becomes necessary to convert true bearings to mercatorial bearings. This must be accomplished by the use of conversion tables such as are given in our Coast Pilots. In this connection, I wish to call attention to a noteworthy publication which has appeared recently, "Radiobeacons and Radiobeacon Navigation," by George R. Putnam, Commissioner of Lighthouses.

The Mercator projection with scale continually increasing, when extended beyond 60° latitude shows distances and areas seriously exaggerated and critics invariably cite Greenland and Alaska. The remark has been made that it places Alaska too far north. This observation after all is not so far-fetched when we consider that at latitude 60°, the scale of the projection is increased 100%, and not only are corresponding areas larger but distances seemingly increased.

For ordinary geographic purposes, the Mercator nautical projection has no value and was not intended to be used as such by the inventor. In the mapping of political divisions and continents, he held to equal-area representation of his own or his contemporaries.

Let none dare to attribute the shame
Of misuse of projections to Mercator's name;
But smother quite, and let infamy light
Upon those who do misuse,
Publish or recite.

It is interesting to note that the word "atlas" as used to-day was borrowed from the Greek mythology and introduced by Mercator as a geographic term.

The most recent and best tables for the construction of a Mercator projection are issued by the International Hydrographic Bureau at Monaco, 1928.

GNOMONIC PROJECTION.

In this projection the eye of the spectator is supposed to be situated at the center of the terrestrial sphere, whence, being in the plane of every great circle, it will see these circles projected as straight lines upon a plane tangent at a selected central point. It follows then that a straight line between any two points on a gnomonic chart represents the track line or shortest direct route on the earth's surface between them.

The projection is used chiefly as an adjunct to the Mercator system to which the finally selected route can be transferred by corresponding graticules of latitude and longitude. The great circle thus transferred becomes a curved line on the Mercator projection where it may be resolved into convenient sailing chords so that the port bound for may be reached by the shortest practicable route.

Between a great circle and a rhumb line, the actual difference is frequently immaterial, being but 1/4 mile in 500 statute miles along parallel 40° and diminishing to zero along the meridian. For greater lengths the difference increases very rapidly.

The gnomonic projection requires a considerable amount of computation, is difficult to construct, and the scale of distances is complicated. Its chief fault is that localities near the boundary of the map become greatly distorted in distances, areas and shapes. This is because at 90° from the center of the map, the projecting line approaches parallelism to the plane of projection and its intersection recedes to infinity. The area which can be mapped on this projection is less than a hemisphere.

A gnomonic chart of the United States in a size approximating our Lambert conformal base map, 26" x 40", would serve as a general control map for many purposes and for office use especially. It would be useful in the study of air routes and in the ready solution of problems involving the definite location of the minimum line between two distant points on the earth's surface. In other projections, the localities through which a great circle passes are a matter of approximation or conjecture.

With future possibilities such as a more general use of the gyroscopic compass, with radio signals coming from great distances with clearness and precision so that ships or aircraft may be guided entirely in their voyages by signals emanating from their destination, with the prospects of a deviometer and other new instruments, the gnomonic projection may come into more general use. At the present time, however, excepting for a small number of harbor charts by the British Admiralty, it has hardly been more than an auxiliary to the Mercator chart.

POLYCONIC PROJECTION.

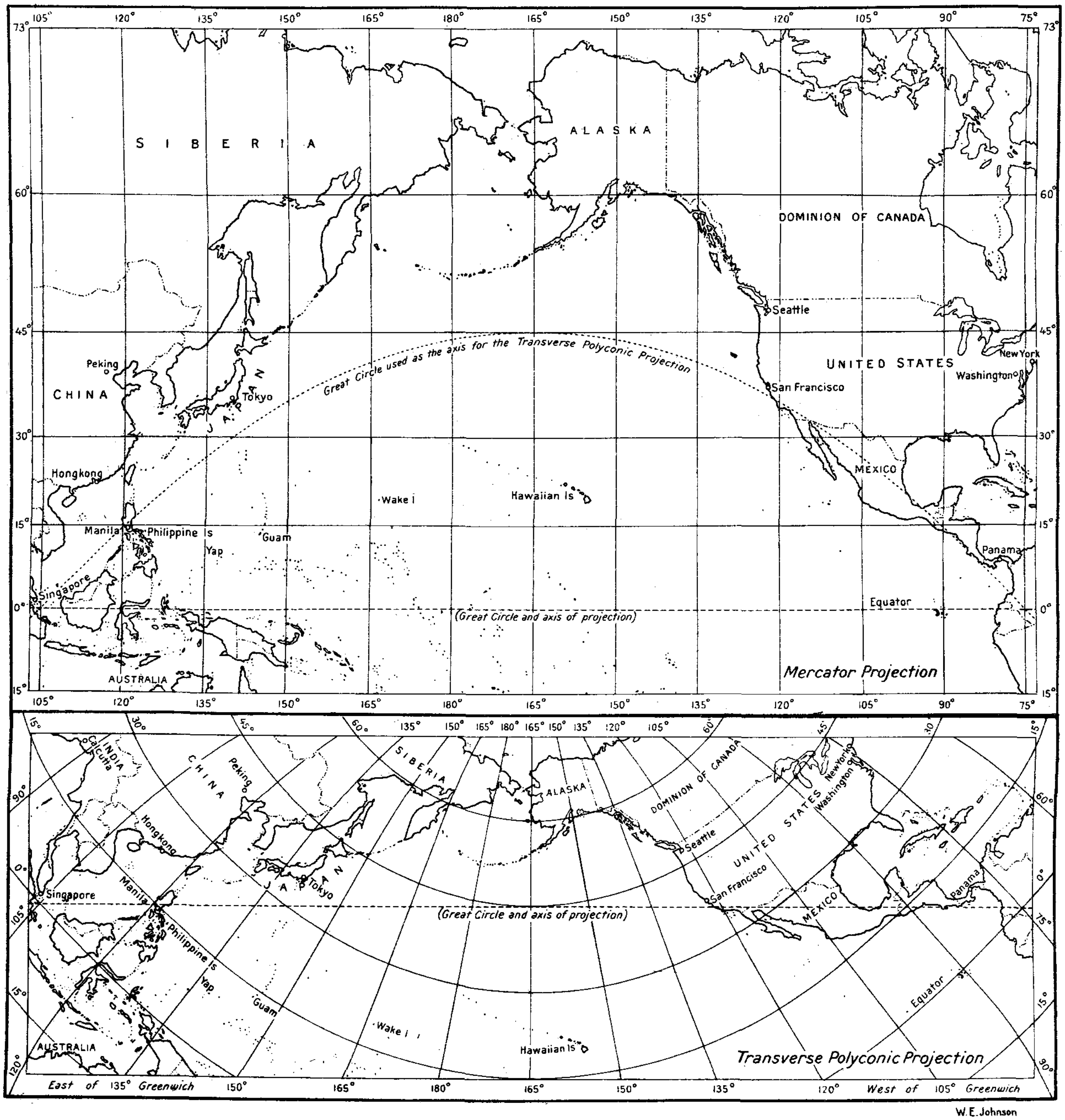
The Polyconic projection was devised by Prof. Hassler, the first Superintendent of the Coast and Geodetic Survey, and possesses great popularity on account of mechanical ease of construction and the fact that a general table for its use has been calculated.

In this system the reference lines, excepting the equator and central meridian, are curved, the parallels being non-concentric circles. The central meridian is truly spaced and the even divisions of the parallels are true to scale. The lengths of the arcs of latitude increase as we recede from the central meridian, but in the United States, for a longitudinal extent within 560 statute miles on either side of a central meridian, the error in scale and areas does not exceed 1%. In latitude, the projection can be carried as far as may be desired. The use of the projection for extensive areas should thus be restricted to maps of wide latitudes and narrow longitudes.

Within the limits described the projection attains an accuracy that meets all general purposes, by reason of compromising various conditions impossible to be represented on any one map or chart, and is sufficiently close to other types possessing special properties to determine its choice.

Due to the curvature of its outer meridians, adjoining maps constructed on their own central meridians, will present curvature in opposite directions, east and west, thus interfering with a neat junction when the projection is carried too far.

For a map of the United States with its wide longitudinal extent, the Albers and Lambert conformal projections are better suited, either of them offering certain additional or special properties of their own which are only approximated in the polyconic projection.



THE NORTH PACIFIC REGIONS ON THE MERCATOR AND THE TRANSVERSE POLYCONIC PROJECTIONS

The rapidly increasing scale of the Mercator projection, reaching 100 per cent increase in latitude 60° apparentty "puts Alaska too far north". In contrast the transverse polyconic projection shows qeoqraphical features more nearly in their true relative positions, sizes and shapes.

The errors of the polyconic projection within the limits described are reasonably small but increase approximately as the square of the distance from the central meridian. We observe in proceeding farther out from the central meridian that this increase amounts to as much as 500 per cent in the outer meridian of a map of the world. We further observe that the outer meridian in approaching the north pole seemingly takes a turn to the southward in reaching it. This reminds one of the statement once made by an ex-President of the United States that a certain locality was west of the north pole.

TRANSVERSE POLYCONIC PROJECTION.

The polyconic projection can be transversed in a way to meet a configuration of predominating east-and-west dimension. A great circle at right angles to a central meridian at the middle part of the map can be made to play the part of the central meridian in the ordinary polyconic projection, the poles being transferred (in construction only) to the equator.

Our map No. 3080 features an area adapted to this transverse arrangement. On other maps and charts, this important section of the North Pacific Ocean can not readily be visualized on account of excessive scale variations.

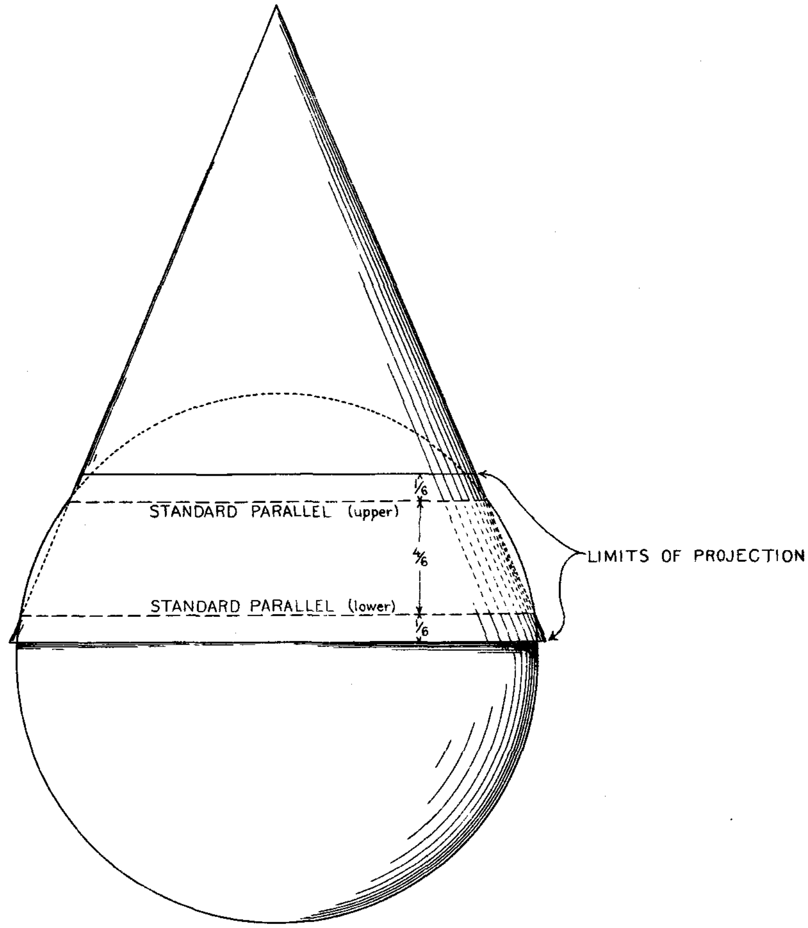
The map is not intended for navigational purposes but is of great interest from a geographic viewpoint as exhibiting in their true relations, important localities covering a wide expanse. An accompanying plate showing the North Pacific region on both the Mercator and transverse polyconic projections explains the reason for the remark "The Mercator projection puts Alaska too far north."

THE LAMBERT CONFORMAL CONIC PROJECTION AND TEE ALBERS EQUAL AREA PROJECTION

These two projections are somewhat similar in appearance but different in their properties. Points in common are: Both are conic projections and both have two standard parallels of true scale; the projections being conic, their meridians are straight lines converging in the direction of the pole, and the parallels are concentric circles intersecting the meridians at right angles. On the selected parallels, arcs of longitude are represented in their true lengths, or to exact scale.

Their differences are: In the former projection the intervals of the parallels depend upon the condition of conformality; in the latter they depend upon the condition of equal-area.

Definition of conformality: If at any point the scale along the meridian and the parallel is the same (not necessarily correct, but the same in both directions) and the meridians and parallels are at right angles to one another, then the shapes of all elementary figures



LAMBERT'S CONFORMAL CONIC PROJECTION

Diagram illustrating the intersection of a cone and sphere along the two standard parallels.

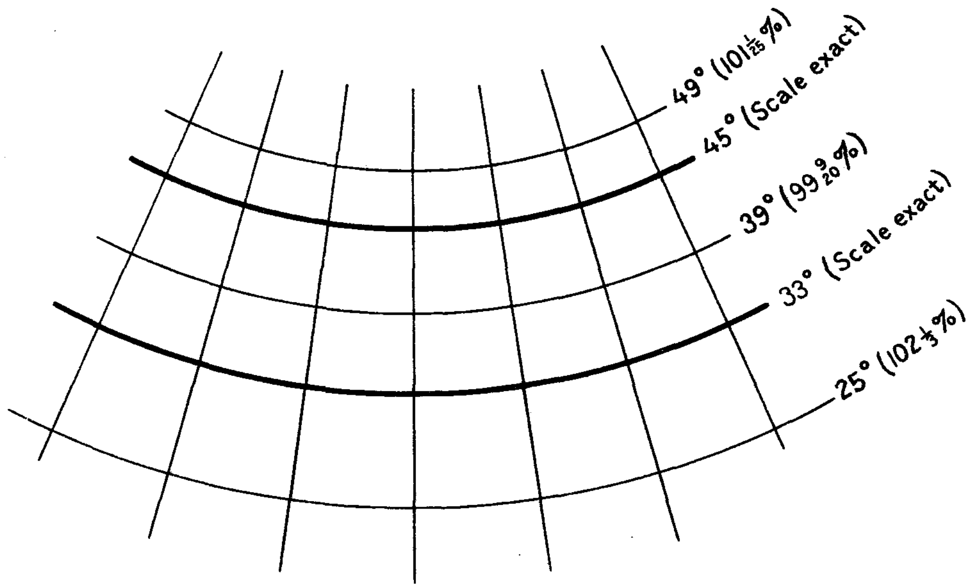


Diagram showing the standard parallels at 33 and 45 and scale variations for a map of the United States. It will be noted that between the standard parallels the scale is slightly too small while outside of these limits the scale is slightly too large.

on the map are the same as their corresponding areas upon the earth.

In the Lambert projection the scale is too small between the standard parallels and too large beyond them; in the Albers projection the meridional scale between the standard parallels is too large and the scale along the parallels correspondingly too small, the reverse condition existing beyond the standard parallels.

The Lambert projection was used in France for military maps during the World War. Our map No. 3070, North Atlantic Ocean with Eastern North America, is constructed on this projection, having been prepared for the Army War College and also used by the Shipping Board during the World War.

Former maps and charts of this area showed excessive variations in scale. On a polyconic projection for the same limits, the scale error would be about 100%; on a Mercator projection the scale variations would be about 180%. On our Lambert map, the scale shows a maximum increase of only 11 per cent, and that occurs in latitude 70° , an unimportant part of the map. The great central portion of the map, from latitude 30° to latitude 60° shows scale variations varying from zero to 2 per cent.

MERITS OF TIE LAMBERT PROJECTION.

In a map of the United States with standard parallels at 33° and 45° the greatest change of scale is but $2\frac{1}{2}$ per cent. As employed by the U. S. Geological Survey for state maps, 1-500,000, the projection is ideal and should meet engineering, military and geographic requirements. It is also employed in the construction of airway maps by the Coast and Geodetic Survey for the Aeronautics Branch of the Department of Commerce.

The graphic scale of any state map should be based upon the local or middle latitude scale as given in the tables for different latitudes. This operation will assist in bringing the excess or reduced scale of any state still closer to true scale.

For the measurement of distances in all directions within the United States, the Lambert projection is superior to any other excepting only the Albers projection.

However, by use of a scale factor (ordinarily not necessary), the Lambert projection provides for exact scale; and if exact scale is not obtained, the reasons for it are due to errors of compilation, method of printing, shrinkage or expansion of paper in opposite directions.

In errors of azimuth as compared with the Polyconic, Lambert Zenithal, and Albers, it is superior to the others here mentioned. To obtain any azimuth on a Mercator projection requires a special computation or the use of tables.

We find in projections like the Polyconic, the Bonne, and the Mercator that, after proceeding about 25 degrees from one of the axes, the scale errors or scale variations become so increasingly greater that these projections totter and can no longer be utilized for geographic purposes. The Mercator projection is at its best from, say, 35 north latitude to 25° south latitude, and for the rhumb line property alone, it may be carried to higher latitudes. The United States is, then, beyond the zone of usefulness of the Mercator projection except for the property of the rhumb line, but the rhumb is retained at the expense of the great circle, directions, and scale variations.

For a line from New York to San Francisco, we find the great circle passing through its extremities has departed from the rhumb 181 miles. Higher-up, before reaching the 49th parallel, the difference in a 2700-mile line is 240 miles. It is evident, in these higher latitudes especially, that the Mercator chart may require an auxiliary chart or special computations for meridional crossings of the great circle. In many instances it may necessitate the conversion of true bearings to mercatorial bearings.

If radio signals following the great circle can be utilized on the Lambert projection, it might seem that the Lambert projection and the Gnomonic projection are identical. They are not identical, but numerous tests show that on the Lambert, by reason of conditions imposed by its standard parallels of true scale, a straight line may follow the great circle closely, it may cross it and recross it, never receding from it excessively. It is sufficiently close to the great circle to become directly available for radio beacon signals.

Distance comparisons, New York to San Francisco:

New York, (Lat. 40° 45', Long. 73° 59'); San Francisco, (Lat. 37° 47', Long. 122° 25').

*True distance New York to San Francisco, by long distance formula . . . . 2572.3 statute miles.

Approximate distance obtained from C. & G. S. Chart No. 3060 (Lambert projection), applying scale factors . . 2574 statute mi.

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*The final test of measured distances from any map or chart depends upon the system of projection, the accuracy of compilation, method of printing, etc. It may be advisable in many instances where long distances are involved not to use the map or chart, nor even the solution from a spherical triangle. For example, the distance from New York to San Francisco by solving the spherical triangle, using sphere equivalent in area to spheroid, is 2566 statute miles - or 6 miles less than the actual distance. For the computation of long distances, see Special Publication No. 138, pp. 207-8.

Rhumb line (or straight line on Mercator chart),
computed . . . . 2609.3 statute miles.
(The rhumb line is longer than the true distance 37.0 " ")

Distance of straight line (New York to San Francisco) below the great circle on the Lambert projection at a central meridian is only . . . . 9.5 statute miles.

Distance of rhumb line below the great circle on the Mercator projection, at a central meridian, is 181 statute miles.
This is also the actual distance between them on the earth.

If a straight line be drawn on a Mercator chart and a plane sets a course to follow that line, it will pass over the features through whose charted positions the line passes. However, the following data, taken from a Lambert projection covering latitudes 47° to 49°, show the small amount that a plane would depart from charted features. This particular chart was chosen as showing the most unfavorable conditions in both the Lambert and Mercator projections:

In 100 statute miles (Lambert projection) the departure is only 1/3 mi.
In 200 " " " " " " " " 1-1/4 "

As the rhumb line would pass directly over the charted features, the above comparison favors the Mercator projection by the small amounts indicated.

On the other hand, in a radio range, assuming a line 200 miles long, the Lambert projection straight line departs from the great circle 1/3 statute mile - an error quite negligible. In contrast, on the Mercator projection, unless the conversion from true to mercatorial bearing is applied, the error is 5.6 miles. At 300 miles this becomes 12.6 miles and at much greater distances, unless conversions are applied, these errors of the Mercator become excessive.

All indications point to an increase in use of radio ranges to guide planes. While in general, up to this time, the distances used have been short, there have been cases, as in that of the <u>Norge</u> in its flight across the north pole, where radio bearings have been taken to stations hundreds of miles distant. It is apparent therefore that the utility of the Mercater projection of former years is being lessened by modern safety devices.

The question of bearings in northern latitudes, unfavorable to the Mercator chart, will not be discussed in this paper.

In connection with nautical charts, Admiral Tonta, of the International Hydrographic Bureau, Monaco, says: "We are convinced that in very many circumstances, the Lambert projection can, with appreciable advantage, replace Mercator's projection as a basis for nautical charts."

LAMBERT OR MERCATOR FOR AIRWAY MAPS.

The question arises in aerial maps whether we prefer a projection like the Mercator which has a certain special property and conveniences and which will permit, if necessary, the incorporation of navigational fundamentals from an auxiliary chart, the Gnomonic; and, furthermore, which will follow the style set by nautical charts; or whether we prefer a projection like the Lambert which, besides its own properties, is not too remote in other requirements, but is sufficiently accurate to be used directly for the receipt of radio signals emanating from long distances; a projection which structurally provides for the best pattern of the United States that can possibly be attained, and therefore well adapted for pilotage; a projection which will facilitate the accurate and immediate solution of problems of distance and direction, and in this respect far superior to the Mercator; a projection with minimum scale variations (the Mercator having an increment of 40% in the United States at its northern border, necessitating adjustments to these increments when making compilations); a projection which will serve for engineering, tactical or other wider uses.

The better facilities at this day for determining location and direction, as furnished by radio beacons, lights, prominent objects, terrain, etc., bring aerial navigation methods in the United States more and more into the plane of pilotage than they are over the open oceans where landmarks are seldom available and the problem is largely one of celestial navigation.

The Lambert's chief point of superiority lies in its peculiar suitability to all radio navigational methods - a consideration of primary importance since it is evident that radio navigation is destined to assume an important place, and that other methods will become largely supplementary thereto.

Airway maps within the United States present a problem distinctly of their own. For these maps, the sufficiently close approximation to the great circle as supplied by the Lambert projection, together with pilotage, outweigh the rhumb line. It may be well to remember that the Lambert projection is based upon two standard parallels of true scale within our own domain. It is not based upon a distant equatorial line causing increased scale variations, etc., as previously stated.

In this summation I have endeavored to present the salient features of the Mercator and Lambert projections, and may even have emphasized too strongly Mercator's masterpiece. This has been done that you may feel that I have acted without discrimination. In this final analysis, however, the object has been to show in a few sentences the changed conditions from the days of the Portolan charts to the day of the Lambert projection, conditions as new as the airplane itself.

MERITS OF THE ALBERS EQUAL AREA PROJECTION.

In the new wall map of the United States constructed by the U. S. Geological Survey on the Alters projection, scale 1:2,500,000 with standard parallels at 29° 30' and 45° 30', the greatest scale error is but $1\frac{1}{4}$ per cent. It may be noted that the former wall map of the United States on the polyeonic projection had a maximum scale error of 7 per cent.

It is in keeping with the practice followed by the best European atlases that political divisions, continents and hemispheres should be based upon equal-area representation, a property which best meets the problems of geography. Where the scale is the same, direct comparisons for area and distribution become available.

If the Lambert projection as used for states were extended to a general map of the United States, the scale variation would indicate an excess in areas of as much as 5 per cent along the southern border. If the Albers projection were used for the separate states, a better area representation would have been obtained at the expense of conformality which is a desirable property in engineering projects. We must remember that in conformal maps, conditions at any point on the map are better than in equal-area maps, where the scale, when one per cent too large in one direction, is one per cent too small in the direction approximately at right angles to it, so that at any point or from any point, conformality better meets engineering requirements. In units of the size of states these requirements have certain rights and the Lambert projection serves them better. In the larger general map of the United States, 1:2,500,000, the requirements are mostly those of geography, in which minimum scale error and equal-area representation govern.

The Albers projection with its two standard parallels of true scale has, in addition, at every point on the map two intersecting lines or curves of true length scale, equally inclined to the meridian and approximately at right angles to each other. These curves of true scale are termed isoperimetric curves running at oblique directions through the map. It is believed that these curves are sufficiently flat to indicate directions of true scale in such a way that straight lines which lie approximately northeasterly or northwesterly, or their opposites, along the path of these curves are practically true to scale. As far as we know, no diagrammatic study has been made of this interesting feature. Besides its special equal-area property, there is in the Albers projection a liberality of true scale not to be found in other systems.

THE AZIMUTHAL EQUIDISTANT PROJECTION.

This projection takes its name from the fact that straight lines radiating from the center of the map represent great circles in their true azimuths from it, and the distances along these lines are true to scale. The projection is neither equal-area nor conformal.

In recent times several of these projections have appeared, one by the General Electric Company with center at Schenectady, N. Y., and two by the Hydrographic Office, one of these with the center at Washington and another with its center at San Francisco. Any important city can well afford to have a map constructed on this projection for general use.

It is doubtful, however, whether for geographic purposes this projection should be used for continents, as its center in most instances would ordinarily be a point of no cartographic interest, and the true scaling properties from such a point would be obtained at the expense of greater scale errors in other parts of the map. Much is lost and nothing gained. The Lambert azimuthal equal-area is, for geographic purposes, more desirable in having besides its special property a lesser maximum scale error, than the equidistant projection.

WORLD MAPS

In regard to world maps, it might be stated that none have appeared that are entirely free from criticism. However, we can avoid cartographic crimes in unbalanced forms or lack of symmetry suggesting reflections from a comic mirror. Projection lines should appear at reasonable intervals. They are the control and key which tell us that the mathematical structure is sound. They should be lightly drawn so as not to detract from the general picture, and the name of the projection should appear on the map as an index to the purpose it may serve.

A few solutions of the most difficult problem of delineating the world in one continuous sheet can be observed by reference to the following maps:

1. The world in a tripartite arrangement on a Sinusoidal or Mercator Equal-Area projection, prepared by W. E. Johnson, formerly of the U. S. Coast and Geodetic Survey. A series of eight sheets on this projection is published by the Rand McNally Company. They are distribution maps showing: Density of population, races, physical relief, etc.

2. Diagram for a map on the Lambert meridional equal-area projection of the tangent hemispheres, prepared by the U. S. Coast and Geodetic Survey.

3. The Parabolic Equal-Area projection with the Americas in the center, prepared by the U. S. Coast and Geodetic Survey.

4. The Parabolic Equal-Area projection for Pan-America, prepared at the U. S. Coast and Geodetic Survey for the Carnegie Institution, Department of Genetics.

5. A map of the world within a cylinder on a Mollweide homalographic projection as used by the New York Times.

JEFFERSON DAVIS: AN EARLY FRIEND OF THE COAST SURVEY

H. S. Shaw, General Radio Corporation, Cambridge, Mass.

(Mr. Shaw is also a good friend of the Coast and Geodetic Survey and is much interested in our work. For eighteen months he maintained, at his own expense, an automatic tide gauge at Prospect Harbor, Maine, and presented the records to the Bureau.)

Few of the present personnel of the Bureau probably realize that Jefferson Davis, best known as President of the Confederate States of America, took a special interest in the Coast Survey, and for many years followed its work. This interest on the part of a man of such wide attainments is worth bringing to your attention. And it was while serving as Senator from Mississippi that he had occasion to prevent a reduction in the appropriation for carrying on the work of the Survey.

This friendship on Mr. Davis' part for the Survey and his concern in keeping the Bureau up to its high state of efficiency came to my attention while I was engaged, as a matter of personal interest, in recovering some of the old triangulation stations in Eastern Maine.

In ascending Lead Mountain (also called Humpback) I used a trail leading to the fire lookout tower. This trail I learned was locally known as the "Jeff Davis Road," and an old man who formerly lived in the vicinity told me, when I inquired as to the reason for the name, that Jefferson Davis had been there surveying for military purposes before the Civil War.

As this seemed highly improbable, to say the least, I looked into the matter further and found that Mr. Davis had actually visited the mountain, but as the guest of Professor Alexander Dallas Bache, Superintendent of the Coast Survey from 1843 to 1867, when the latter was occupying triangulation station Humpback in 1858.

In a biography of Jefferson Davis, written by his wife and published in 1890, a chapter is devoted to a summer outing for his health, containing also a detailed account of a trip to Maine. It was on this trip that Senator Davis convalesced in Professor Bache's camp on the top of Humpback mountain. The following is quoted from the biography:

> "As the summer advanced we were invited by Professor Bache to go into tents with him and his party of triangulation on Mount Humpback. We travelled by rail to Bangor, and then took stages to Mount Humpback, spending a night in an old-fashioned inn on the road, much visited by trout fishers. Here was the first man milliner we had met. He was six feet in height, strong in proportion, and an exquisite seamster, as he proved by making a delicate 'shirred' satin bonnet, At supper we had immense dishes of speckled trout caught by the gentlemen anglers who were spending a few weeks there.

"At day dawn we heard a voice disclaiming, in a most impressive tone, apparently to a crowded meeting. Mr. Davis arose and was seized with such spasmodic attacks of laughter that I joined him and looked into the barnyard. On a small cart, which was standing in the yard, arrayed in a long, figured calico dressing-gown, stood the deft seamster of the night before, with a pan of shelled com, surrounded by a Block of chickens, turkeys, geese, and ducks, each applauding vociferously while he addressed them with a certain kind of eloquence upon all the topics of the day. As he threw one handful of corn after another out of them, he pleaded, 'Consider, weigh, and accept these arguments, be just to one another, your liberties, your lives depend upon it.' When ho saw Mr. Davis' laughing face at the window he made a deep bow, and said: 'Fellow-citizens, allow me to present one more able and more eloquent than myself. Hear ye him.' After breakfast we proceeded on our journey, and the oratory of the merry mountebank has ever since remained a cheerful reminiscence often recalled.

"We drove nine miles over a most wonderful natural road called by the country people 'horseback,' elevated over sixty feet and sloping steeply down on each side to the valley which it intersected, like a levee built by Titans. Interspersed throughout the rich valley on either side, in the lush green grass, were the most enormous bowlders of granite, many of which looked like Egyptian tombs. As there was no stone of the kind underlying the soil, Professor Bache thought they had been left there by some great flood. The apex on which we drove was only about twenty-five feet wide and nearly uniform throughout its whole length,which stretched to the foot of Mount Humpback. There we found an ox team in waiting hitched to a sled, and we were driven up the side of the mountain, which was so steep that the oxen seemed sometimes to be about to fall back upon us. These were the first oxen I ever saw goaded, and Mr. Davis remonstrated many times against it with the driver.

"On a plateau near the top were white tents pitched, one for each of us, an excellent cook, tenderloin steaks from Bangor, vegetables from the neighboring farms, and to all this comfort was added the newest books, and an exquisite and very large musical box which played 'Ah, che la morte,' and many other gems of the then new operas of Verdi. Professor Bache, who could not sing a tune, kept up a pleased murmur of unmusical accompaniment as an expression of his delight. He read aloud at night, and a part of the day we watched him taking observations and enjoyed his clear explanations of his methods. As the sun went down and shown upon the heliotropes, one fixed star after another gleamed out on the distant hill-tops, and our heliotrope answered back again to the dumb messages sent by scientists on every hill. The most noticeable thing to us, who were used to the insect clamor or our summer nights, was the silence on the mountain, and we saw no evidences of insect life. The fall of a leaf could be plainly heard, and it seemed to afford relief to Mr. Davis' exacerbated nerves, after the noise and bustle of Washington, to stay in this secluded place where he could be a lotus eater for a while.

"When not engaged in watching the survey work, we looked for the numerous signs of the glacial period, reasoned and wondered over them, picked up 'ghost flowers' and found exquisite mosses, sometimes a foot deep, of velvety green. Mr. Davis took our little girl with us on his shoulder, and did all the things so joyful to towns-people on an outing in the country. So health came back to his wasted form, and his sight improved daily. After three happy weeks we returned to Portland, bade our good friends there farewell, and went down to Boston."

The "Jeff Davis Road" is therefore the trail some two and one-half miles long which was built by the Coast survey to give access to Station Humpback. This road was built by Thomas McDonnell, "Artificer in the Coast Survey," as he is called in the original description of the station, who apparently played an important part in the establishment of some of the early stations. It is not surprising it was that worthwhile to build fairly good roads to these stations, some of which were occupied for weeks at a time. The primary triangulation of Maine, one of the many areas of control survey laid down during that period, took about thirteen years to complete. Usually only one or two primary stations were occupied in a season. This is certainly in marked contrast to the achievements of recent years. It must have been a real problem to transport the cumbersome instruments which were used in those days, sometimes including, as in this case, a 30-inch theodolite. A knowledge of some of the difficulties which men like Professor Bache and his associates had to overcome makes one appreciate all the more the precise results which they were able to secure. According to the annual report for 1858, 6 primary points, 8 secondary points and an azimuth mark were observed upon with the 30-inch theodolite, at "Humpback," 1,200 observations of horizontal angles having been made and recorded. There were 150 measures of vertical angles with a micrometer on the theodolite and 350 with an 8-inch vertical circle. There were also many astronomical observations for azimuth, latitude and time, as well as magnetic and meteorological observations.

The depth of Mr. Davis' friendship for the Survey and Superintendent Bache is attested by the following incident taken from Mrs. Davis' biography:

"Mr. Seward came daily until the day Mr. Davis was taken in a close carriage up to address the Senate on an appropriation for the coast survey. Mr. Seward and I both objected earnestly, but Mr. Davis said, 'It is for the good of the country, and for my boyhood's friend, Dallas Bache, and I must go if it kills me.' He left me at the door of the waiting-room with beef-tea and wine in a little basket and went in - carried his point, then came almost fainting home. From that time he began to slide back into his accustomed place for an hour or two each day, and convalescence had its gentle and perfect work."

Mr. Davis was a graduate of West Point and during his nine years of Army life, probably learned of the need for accurate surveys; and while Secretary of War-under President Pierce, he directed valuable surveys for a railroad to the Pacific Coast.

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I wish to acknowledge my indebtedness to Captain Paul C. Whitney for his kindness in partially rewriting this article and putting it into proper form for publication in this bulletin.

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From the Superintendent of Lighthouses
Sixteenth District

Ketchikan, Alaska,
January 28, 1932.

Captain R. S. Patton,
Director, Coast and Geodetic Survey,
Washington, D. C.

Dear Captain Patton:

I have just finished reading from cover to cover the December Bulletin issued by the Association of Field Engineers, U. S. Coast and Geodetic Survey. This number like those which have preceded it is exceedingly interesting, especially to one who for some years during the impressionable period of his life has participated in the fascinating work of the Coast and Geodetic Survey and in the varied experiences which are inseparably associated therewith.

The Bulletin is a credit to all who are concerned in its design and preparation. It is, without doubt, of great value as well as interest to the personnel of the Coast and Geodetic Survey, but besides serving well this worthy purpose the various issues contribute material of considerable value to engineering literature.

I appreciate very much the receipt of this and previous numbers.

Yours very truly,

(Sgd.). W. C. Dibrell

OPERATION OF TWO SHIPS USING THE SAME PAIR OF HYDROPHONE STATIONS

W. E. Parker, H. & G. Engineer, U.S.C. & G. Survey

The 1950 work on the survey of Georges Bank, when only one vessel was available for use as a hydrophone station ship, showed conclusively that it is desirable to have two R.A.R. station ships for the rigid control of sounding lines where there are strong and variable currents over an area requiring close development, rather than to depend upon one R.A.R. distance and otherwise control the lines by dead reckoning. Radio bearings were tried in conjunction with R.A.R. distances but proved unsatisfactory where good control is necessary.

For the 1931 work in continuation of that of 1930, two R.A.R. station ships were used for the control of all soundings. This, of course, increased the unit cost of soundings, and to offset this increased cost, two sounding ships were assigned to the project so as to double the amount of sounding work that could be accomplished from the pair of station ships. Heretofore a sounding ship has had the exclusive use of a pair of hydrophone stations, except that in a few instances ships working in adjacent areas may have received bomb returns from a hydrophone station belonging to the other ship. It was therefore not known whether two ships could work off the same pair of hydrophones without seriously interfering with each other.

The experiment was begun in an area of considerable depth with fairly uniform bottom configuration so that sounding lines need not be very close - the minimum line spacing required was one mile and the maximum four miles. It was agreed between the two sounding ships that each should have the exclusive use of the hydrophone stations for alternate periods of fifteen minutes, one ship taking the first and third quarters of every hour and the other the second and fourth quarters.

This arrangement worked out fairly well in this area so long as the station ships could be depended upon to receive and transmit a bomb record whenever required and the current was not so perplexing as to require a fix more often than about every fifteen minutes. It would not, of course, work when more frequent fixes were required. Nor was it satisfactory if a sounding ship was unable to get bomb returns during any of its fifteen-minute intervals, for in that case the ship was required to wait fifteen minutes before trying again. The currents were sufficiently variable throughout most this area to require fixes at intervals of not longer than 30 and usually nearer to 15 minutes to maintain the necessary control over the sounding lines. One station ship occasionally failed to receive or to report several bombs in succession and at times both ships failed on one or more bombs. At such times one or both of the sounding ships were urgently in need of a bomb return and it was difficult to maintain schedule and not interfere with each other.

Various plans mere tried to get around these difficulties. The time intervals were reduced to ten minutes and even to five minutes and once it was agreed that the ships should bomb alternately without regard to time schedule. By the latter plan one ship would detonate a bomb and then as soon as the "air was free" the other ship would have a turn regardless of whether or not the first ship had succeeded in getting returns from its bomb. The plan worked fairly well, but was likely to lead to confusion if the radio operators were not very careful to determine if the "air was free," that is, if the ship which had last bombed had finished with the receiving ships, had got bomb returns or word there would be no returns.

In general, two sounding ships can work conveniently off the same pair of hydrophone stations, provided the sounding lines are not difficult to control and bomb returns do not fail often. Where there are strong and variable currents and where a close development is necessary (lines spaced closer than one mile) two ships will experience considerable difficulty in using the same set of hydrophones, and especially so if bomb failures are frequent.

As there were large areas in the 1931 survey of Georges Bank which required a development such as results from a line spacing of one half mile and even of one quarter mile, and since in these areas the currents were strong and extremely variable, requiring much splitting of lines to get the prescribed development, it was necessary to devise some other method for operating two sounding ships simultaneously. The following double sounding unit method was tried and proved so successful that it was used thereafter whenever sounding lines were spaced closer than one mile.

One ship only controlled its course by R.A.R. fixes and, consequently, was at liberty to detonate a bomb and communicate with the station ships whenever desired. This ship operated exactly as if there were no other ship present, except when turning onto a new sounding line, and except for certain instructions, described later, which it must give to the other from time to time. With this freedom of action, the ship could drop bombs as often as desired, limited only by the time required for the compression waves to reach the hydrophones and for the necessary radio instructions to the station ships, and so could detect any deviation of the sounding lines in time to correct it, at least as readily as in any kind of R.A.R. work.

The other ship followed the bombing ship, keeping a little abaft her beam and at the desired distance, i.e., the line interval or such distance as might be necessary to effectively fill a gap between earlier sounding lines. Distance was maintained by means of a range finder.

For plotting her soundings, a fix was obtained whenever the bombing ship obtained a fix by taking a compass bearing and a range finder distance on the bombing ship at the instant the bomb was dropped. That instant was known by watching the bomber when the ships were very close or by listening in on the bombing ship's radio signal to the station ships. Of course, the following ship could not plot her line of soundings at the time, but at convenient intervals her bearings and distances were radioed to the bombing ship on whose boat sheet the track of the following ship was plotted. Also any unusually shallow sounding was reported by radio to the bombing ship with its estimated distance from the last fix. In this way it was possible to determine if sufficient development was being obtained.

To assist the following ship in keeping station, all changes in course were communicated by means of flags or radio, usually the former unless the information was too complicated for rapid transmission by flags. Communication between the sounding ships was the least satisfactory part in this system; the radio was often too busy with messages to and from the station ships to be able to take on much additional work and flag signalling is too slow. However, it is hoped that radio telephones, on which the operators are working this winter, will provide a convenient means of communication between these ships.

On completion of a pair of sounding lines the ships maneuver as follows: To take up return lines parallel to the old and to the left, the right hand ship turns sharply 90 degrees to the left and passes astern of the other ship, which continues on course a distance equal to the line spacing. The latter ship then turns 90 degrees to the left and runs the amount of the line spacing and then turns again 90 degrees to left and steadies on the new course. The first ship continues on course a distance equal to three times the line spacing and then turns to the left onto the new course. When this maneuver is executed correctly the ships will be exactly abeam when all turns are made, and by noting this fact and by maintaining distance by range finder and watching carefully the log it is possible to start the return lines very close to the desired positions.

To take up return parallel lines to the right, the maneuvers of the two ships are exactly reversed. These are the maneuvers most frequently made and have been designated "standard turns." They may be varied slightly so as to increase or decrease the line spacing by increasing or decreasing the runs made by both ships during the maneuver. Just before reaching the ends of the old lines, the following ship will be notified by radio that a "standard turn" will be made to the left or right, as the case may be, on the next bomb or on a whistle signal. The maneuvers will then be executed without further communication between the ships. They have been executed at sounding speed and with the ships as close as a quarter mile without any indication of danger of collision.

It is sometimes necessary to turn onto new lines which can not be reached by the maneuvers described above, but that happens so infrequently that it has not seemed advisable to develop a method for such cases. If the changes are too complicated or uncertain for easy explanation in advance by radio, the following ship is advised that a change will be made on a designated signal and requested to drop back to the quarter or astern of the bombing ship and hold that position until the "bombing ship has worked into position to start the new lines. She then waits until the following ship can take her position.

Some of the advantages of this method are:

1. Full use of the hydrophones when it is necessary to get fixes quite frequently.
2. Pairs of lines at least which are correctly spaced throughout.
3. Some check on sounding apparatus since alternate pairs of lines are surveyed by different apparatus.
4. Greater facility for filling gaps between sounding lines and for placing a line of soundings as desired, for it is possible to so regulate the track of the following ship by causing her to open or close the distance to the bombing ship that she can be placed where it would be very difficult, if not impossible, to place the bombing ship without many attempts.

The disadvantages of the method are:

1. It will not work when fog is so dense that the guiding ship can not be seen.
2. The officer in charge of the following ship can not plot up his boat sheet at the time the soundings are taken, nor does he know if the required development is being achieved; his job is to follow instructions.
5. More than ordinary care and judgment are required in making the turns when the ships travel close together.

It is my belief that three sounding ships could operate together in this way with little or no more difficulty than two. This would increase the output fifty per cent with no additional expenses other than the operating cost of the third surveying ship. This is an important matter since the cost of R.A.R. with two station ships is considerable. At the cost of operation of five ships, fifty per cent more work can be done than at the cost of four ships.

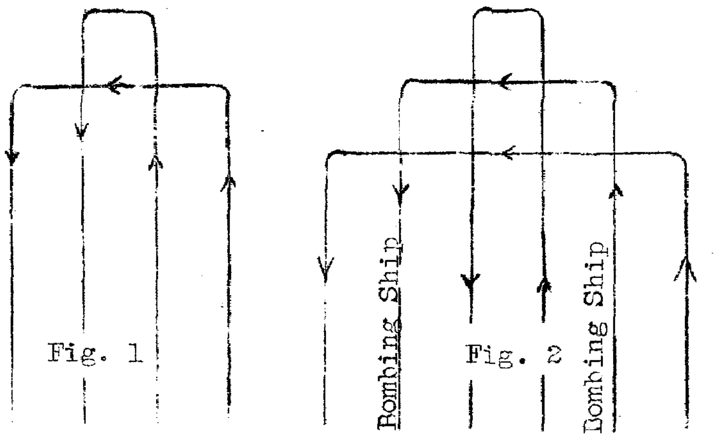


Diagram showing (Fig. 1) how two sounding ships maneuver onto return lines and (Fig. 2) how this could be accomplished by three ships.

LOCAL MAGNETIC DISTURBANCES

E. W. Eickelberg, H. & G. Engineer, U.S.C. & G. Survey.

"While the instructions for declination observations issued to field parties require observations only at intervals of several miles, it is nevertheless important to develop any indications of abnormal declination shown by the compass declinometer. Similarly with the declinatoire, where the instructions call for only one magnetic meridian on each topographic sheet, it is important to make frequent observations with that instrument in order to discover the presence of local magnetic disturbances. These disturbances often exist where there are no particular surface materials to account for them. Any disturbance of importance found with the declinatoire should be verified by the compass declinometer.

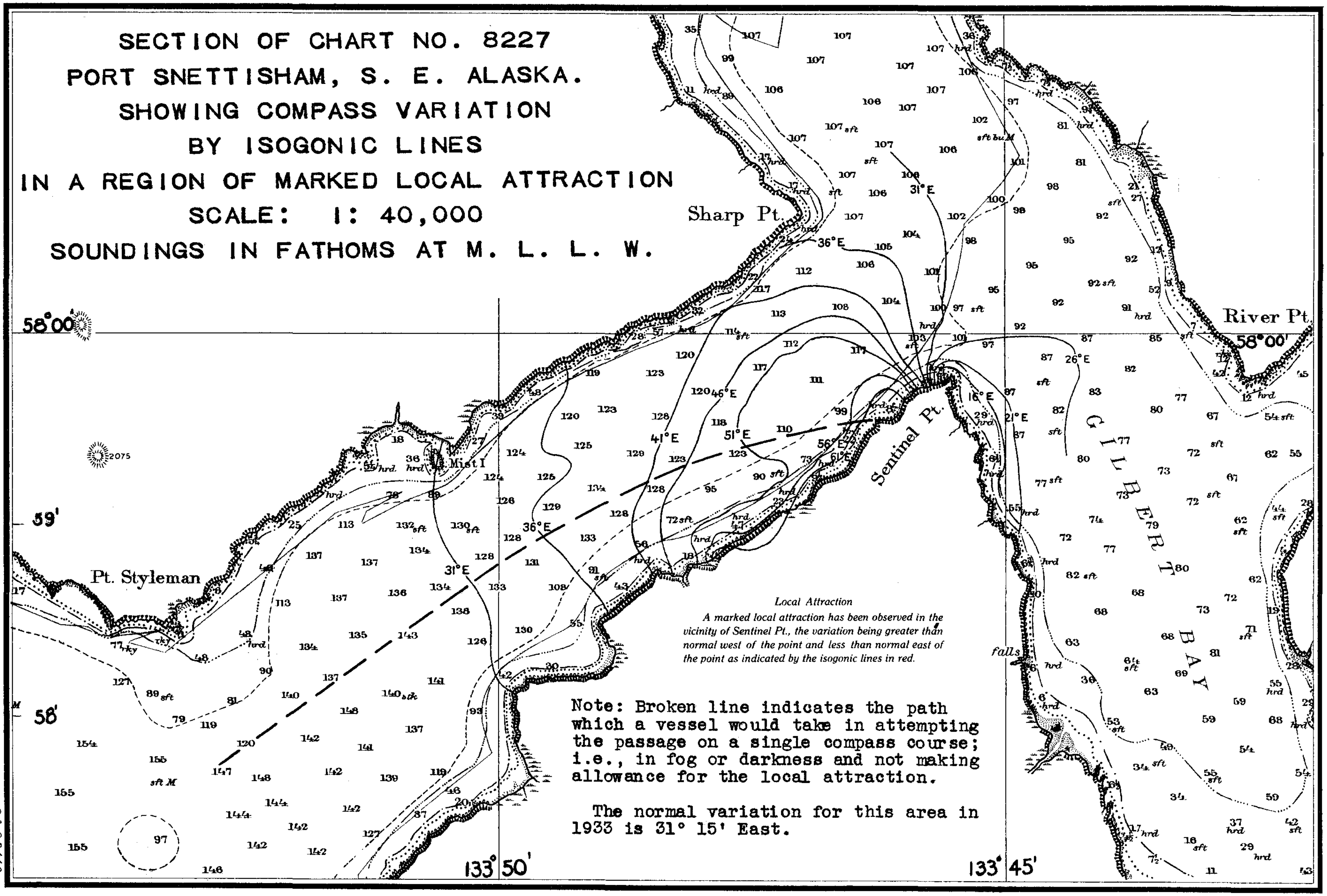
Differences of one degree are common, and yet may be important when consideration is given to the fact that a ship might determine compass deviations in that locality. In Behm Canal, S.E. Alaska, at Walkers Cove, the passage is two miles wide, and the declination on opposite shores differs by 1° 17'. Chesapeake Bay on the Atlantic Coast is known to have local attraction of that order, one such place being in the main channel near Cape Henry.

Localities of large disturbance have been found in the inside passages of Alaska. A local magnetic pole with a dip of 90° was found on Douglas Island, near Gastineau Channel. Lynn Canal was found to have variations of 3° to 20° from the normal values. The southern end of Keku Straits showed differences of 2° in a distance of one-half mile.

In Port Snettisham off Sentinel Point a 20° difference was found in midchannel in a depth of 112 fathoms. This disturbance is felt over an area of 20 square miles. In this case a very complete survey was made and reported on by Captain N. H. Heck, Ship EXPLORER, in 1931. A similar investigation will be made this year by the party on the Ship EXPLORER, of an area in Dixon Entrance off Duke Island. This will supplement a previous survey made by Commander Siems in 1924. The disturbance is somewhat smaller, but extends well out into the shipping lanes.

The Chart Division is now printing isogenic lines in red over the limits of the disturbed area, and for this purpose needs well developed magnetic surveys. In addition to frequent compass declinometer observations on land, there should be a system of lines and cross lines, similar to sounding lines (except that compass can not be used to steer by), to determine the extent of the disturbance over the nater. The deviation is then observed at intervals along these lines and from the known deviation determined in an undisturbed area the local declinations can be found. A section of the Port Snettisham chart with isogonic lines in the disturbed area is shown on an accompanying plate.

An interesting point brought out in the report of Port Snettisham is shown on this chart. The broken line is the path which a vessel would take in attempting the passage on a single compass course, i.e., in fog or darkness and not making allowance for the local attraction.


SECTION OF CHART NO. 8227
PORT SNETTISHAM, S. E. ALASKA.
SHOWING COMPASS VARIATION
BY ISOGONIC LINES
IN A REGION OF MARKED LOCAL ATTRACTION
SCALE: 1: 40,000
SOUNDINGS IN FATHOMS AT M. L. L. W.
Sharp Pt.
River Pt.
Sentinel Pt.
Mist I
Pt. Styleman
GILBERT BAY
falls
58°00'
59'
58'
133°50'
133°45'
36°E
31°E
46°E
41°E
51°E
56°E
61°E
26°E
16°E
21°E
Local Attraction
A marked local attraction has been observed in the vicinity of Sentinel Pt., the variation being greater than normal west of the point and less than normal east of the point as indicated by the isogonic lines in red.
Note: Broken line indicates the path which a vessel would take in attempting the passage on a single compass course; i.e., in fog or darkness and not making allowance for the local attraction.
The normal variation for this area in 1933 is 31° 15' East.
C.&.G.S 442

GEODETIC CONTROL FOR NORTH CAROLINA HIGHWAYS, ITS ADVANTAGES AND ITS PROBABLE EFFECT ON ENGINEERING PRACTICE IN THE STATE

George F. Syme, M. Am. Soc. C. E.
Senior Highway Engineer, State Highway Commission, Raleigh, N. C.

(The following paper by Mr. George F. Syme was delivered on the afternoon of Jan. 31, 1932, at the meeting in New York City of the Surveying and Mapping Division, Am. Soc. C.E. The paper deals at some length with the proposed triangulation and leveling which will be executed by the Coast and Geodetic Survey in North Carolina within the next two years. Mr. Syme was instrumental in having his state government set aside funds to assist in carrying on the field work in North Carolina. Already part of the funds in question have been turned over to the Coast and Geodetic Survey and the remainder will be forwarded to this Bureau on or about July 1, 1932. Mr. Syme was elected a member of the Executive Committee, Surveying and Mapping Division, Am. Soc. C.E., for the five-year term beginning Jan. 1, 1932. An abstract of this paper appeared in the March, 1932, number of Civil Engineering.)

At the January, 1930, convention of the North Carolina Society of Engineers in Raleigh, a paper was presented by the president of the society calling attention to the urgent need of geodetic control for all future surveys made within the state.

Without going into detail here, the paper caused an enthusiastic discussion on the floor, and the society unanimously voted to present a bill to the General Assembly, meeting in January, 1931, asking for an appropriation sufficient to secure the immediate completion of the triangulation of the state by the U. S. Coast and Geodetic Survey.

A committee was appointed to pilot the measure along, and after a year's study and preparation, it presented the bill to the 1931 Assembly.

The measure passed the House, but was killed in the Senate because of the financial depression.

One of the ablest members of the legislature, the Honorable E. B. Jeffress, was an enthusiastic proponent of the bill, and fortunately for the state, he was appointed Chairman of the State Highway Commission after the legislative adjournment.

Having assumed his new duties, he was quick to visualize the possibilities of geodetic control for state highway surveys, and on September 3, 1931, he brought the matter before the Commission which unanimously authorized the appropriation of funds sufficient to secure a complete triangulation of the state.

Shortly thereafter a contract between the Commission and the U. S. Coast and Geodetic Survey was entered into, therein the latter agreed to perform all of the work and to rush it with all possible speed to a conclusion, and at the same time to bear the major portion of the expense. The time required to perform the work was estimated at two years. The survey is now under way.

The state will be cut into areas by first order triangulation arcs at intervals of about 100 miles and these will be cut by second order arcs so that there will be no point in the state more than about 25 miles from one of the triangulation stations. All arcs will be rigidly tied together and adjusted so as to furnish final geographic positions of great accuracy. Lines of first and second order levels will be run. Like the triangulation, these will be distributed over the state in such a way that no point will be more than 35 miles from a bench mark.

Each triangulation station will be monumented with the Survey's standard monument and an azimuth mark will be placed within 1200 to 1500 feet from each station, ready for use by the local surveyor. In addition, supplementary triangulation stations will be established close to each main highway and each county line crossed by the triangulation arcs.

The Survey's standard bench marks will be set at intervals of about two miles along the lines of levels, and, in addition, at least two bench marks will be established in each incorporated city or town. A bench mark will also be placed at each important railway and highway crossed along the routes.

After the work is completed and adjusted, the results will be published by the Survey in pamphlet form for public use.

It is the intention of the Highway Commission to build up a supplementary system of monumentation which will be tied to the triangulation net. As many of its surveys as possible will start from or be tied to a geodetic station. Such surveys will be more accurately made than heretofore and they will be carefully checked and monumented so that other surveys may be tied to and based upon these monuments, and, in turn, become a part of the state system.

The specifications for these surveys have not yet been written, but it is certain that work of less accuracy than 1 in 5,000 will not be incorporated in the system.

Thus, in a few years, monuments available for all surveying purposes will be conveniently located everywhere in the state.

At first thought it might seem that it would require many years to complete this supplementary monumentation, but the additional stations which the Coast and Geodetic Survey will place near each county line and main highway crossed by its triangulation arcs will greatly facilitate the rapid consummation of this work.

In addition, the Highway Commission may confidently expect substantial assistance from many sources. Other state departments, counties, municipalities, corporations, and individuals will make use of the geodetic and supplementary stations, and many of their surveys will be monumented with standard supplementary monuments, thus extending the system. Furthermore, nearly all engineers in the state are intensely interested in the work and their enthusiastic cooperation will be a great asset.

It is highly probable that the North Carolina Society of Engineers will next sponsor and work for a complete topographical survey of the state by the U. S. Geological Survey, and if its efforts are successful, the monuments of that Survey will of course become a valuable part of the general monumentation scheme.

Why does the Highway Commission desire geodetic control for its surveys? What advantages will it derive from such control? What prompted it to take this unprecedented action?

The answers to these questions may be inferred from the following description of our past methods of surveying and mapping highways, which methods I fear are practiced in many other states to-day.

In building our state highway system it was necessary to carry on the work in short, disconnected sections, or projects, of about 5 to 12 miles in length and to scatter them as uniformly as possible throughout the state so that all communities could profit alike from the road program. The state system at present consists of nearly 10,000 miles of roads, which required 11 or 12 years to construct.

If the average length of the projects was 8 miles, about 1,250 separate final location surveys were made, not to mention numerous preliminaries, revisions, abandoned locations, hundreds of surveys for bridge sites, and some 1,250 sets of detailed plans, each set consisting of from 10 to 100 standard sized sheets.

Generally, the procedure was to take the magnetic bearing of the first course as a base from which all other bearings of that particular survey were computed, while the levels were started from a bench mark whose elevation was assumed. The bench marks were generally chopped in the root of a tree, or consisted of a spike driven in a telegraph pole or in some other perishable object.

It is evident, therefore, when two such project surveys meet from opposite directions that we obtain the absurdities of two different computed bearings for the same tangent approaching the point of junction and two different elevations at that point. Neither of these elevations has any meaning with reference to elevations on our other highways because each is based upon an assumed datum. Furthermore, unless the alignment is carefully referenced to permanent monuments and the bench marks are on permanent objects, it soon becomes impossible to accurately reproduce these otherwise wholly unsatisfactory surveys. This condition alone has often caused much embarrassment and expense.

Blue-prints and field notes of such surveys serve only for construction purposes and in a few years become almost entirely worthless. Imagine the frightful economic loss of 10,000 miles of location costing a million or more dollars, which, after construction, are utterly valueless for future accurate usage! It is like casting priceless by-products of a great factory into the sea.

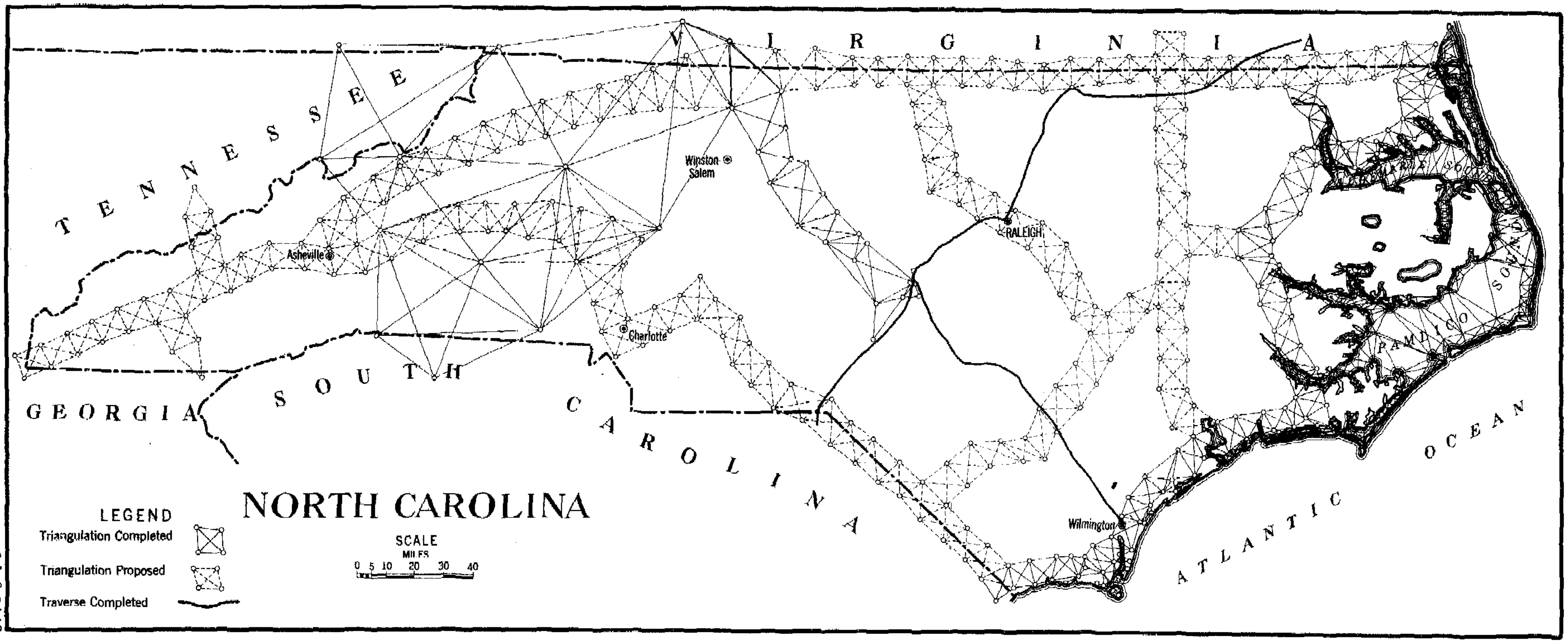
Maps of the highway system, based upon such surveys can not be expected to represent anything other than a crude picture. Likewise county lines, towns, streams, railways, etc., are only roughly sketched, and their true positions are unknown. Such maps are devoid of meaning when the position of any point in the state with reference to any other point is desired. The bearing and length of a line between such points can only be determined by an expensive, time-consuming survey.

When our future surveys have been subjected to horizontal and vertical control and monumentation, each will become a part of the state system. It can be easily and correctly reproduced at any future date and from it other surveys may spring and become a part of the common system. Thus in a short while these surveys will form a composite structure, each in its true position with reference to the others, and maps of our highway system will have a new and valuable meaning. By a very simple computation the exact distance and azimuth of a line between any two points in the state can then be determined in a few minutes, thus giving information which might require weeks to secure by our present methods. Bridges may be identified or located on the map by coordinates.

In the matter of bridge site surveys, vertical control or mean sea level datum will greatly facilitate securing stream plan data and stream profiles. In stream studies where this control is lacking much costly field and office work is necessary to obtain data which otherwise would have been available. Backwater conditions and high water elevations along a stream are easily and accurately determined where all projects are vertically controlled, but require much time and present many opportunities for mistakes where each project is based upon a different assumed datum.

In making the appropriation for this survey, the Commission considered <u>only</u> its justification from a strictly highway standpoint, although it was, of course, cognizant of the tremendous profit that would accrue to other state departments, counties, municipalities, corporations, and property owners.

The Commission will make use of the triangulation stations and bench marks as soon as possible after each has been established, and will carefully check and monument its own surveys, but as yet plans



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COMPLETED AND PROPOSED TRIANGULATION AND TRAVERSE IN NORTH CAROLINA have not been perfected for the general utilization of the system by other parties. Such plans will, however, be developed and put into operation before the triangulation is completed.

Possibly some sort of general mapping agency, armed with the necessary authority but not connected with the Highway Commission, will be set up at Raleigh which will serve as a clearing house to write specifications, to collect and preserve all worthwhile survey data from all parties who use the system, to check all computations of such surveys - discarding those which do not meet the specifications, to map the correct location of county lines, corners, streams, railways, etc., as they may from time to time be determined, to erect monuments on satisfactory surveys made by parties who fail to monument their work, to control all monumentation, to furnish the public with any information desired, to keep an accurate, up-to-date state map and other records showing the positions of all monuments, and to perform the many other duties which will develop as the monumentation is expanded.

Since the geographic position of each control station will be known, plane coordinates will be used in our future surveying and mapping operations, for their use is both logical and very simple. However, the length of the state of North Carolina in an east and west direction is so great that it probably will be advisable to have more than one plane system, each being centered upon a control station.

These plane systems are not limited as to their north and south extent, but they must be restricted as to their width, east and west, according to the degree of accuracy required.

The following tabulation derived from Special Publication No. 71 of the U. S. Coast and Geodetic Survey gives the limiting widths of belts for plane systems which may be used under several requirements of accuracy - it being understood that the origin of coordinates is to be at a control station at the mid point of an east and west line across the belt.

Width of belt in miles	Error due to use of plane coordinates
37.2	1 part in 100,000
49.8	1 part in 50,000
80.0	1 part in 20,000
111.8	1 part in 10,000
159.0	1 part in 5,000

We thus see that it would be possible to extend the plane coordinate system over the entire state of North Carolina with the use of four different origins and still maintain an accuracy of 1 part in 5,000. In each of the large cities of the state, where greater accuracy is desired, it would be necessary to have a local origin. In some cases this local origin may coincide with one of the origins for the state as a whole.

In using the plane system, whether one or more belts are employed, records should be made showing the relation between plane and geographical coordinates of certain control stations so that in the future there may never be any doubt of the exact location of any point or corner.

The completion of our fundamental and supplementary control systems and their use by the State Highway Commission presages the dawn of a new day for surveying work in North Carolina, and we confidently predict a far reaching and beneficial effect upon our engineering thought and education as well.

These predictions are based upon the fact that the engineers in the state, possibly without exception, as well as the Highway Commission, have demonstrated their recognition of needed improvements by their whole-hearted endorsement of our plans for a horizontal and vertical control system. This clearly shows that the time is at hand for a general house cleaning in our surveying practice and it now seems certain that practically all important future surveys in the state will be controlled.

There seems to be little doubt but that the subject of surveying, despite the fact that it is one of the largest foundation stones upon which rests the whole profession of civil engineering, has been relegated to a neglected corner in the curriculum of some (I fear many) of our engineering colleges, and this may, at least in part, account for some of the chaotic conditions which we encounter daily in the practice of surveying.

Such terms as geodetic control, geographic positions, first and second order arcs, triangulation nets, precise levels, horizontal and vertical control, spherical coordinates, U. S. Coast and Geodetic stations, parallels, longitudes and all the rest seem to stun the average engineer who has been accustomed to work only along the beaten path.

This is merely because he has not had occasion to think in these terms, or to work with these tools. Given one day's experience and he will find them as simple as the terms he has been accustomed to, and that the methods to be used in connection with them are simpler and much more logical than he ever dreamed of. In fact, about the only major differences between the two methods are that in one case elevations are based upon an assumed datum, computed bearings are based upon a magnetic course, and a protractor is generally used in plotting the work. In the case of controlled surveys, elevations are based upon mean sea level datum, true azimuths or true bearings are obtained at a control station, and in plotting, plane coordinates referred to the control station are used.

However, in the first case, his survey generally serves only the one purpose for which it was made and in a few years it is often lost beyond hope of recovery. In the second case the survey is indestructible. If the corners are destroyed they can be easily replaced and the survey can be utilized for many purposes, like the by-products of a factory.

The local surveyor need no more concern himself with the intricate calculations and delicate instrument work performed by the U. S. Coast and Geodetic Survey in preparing the system for his use than a man driving over a bridge need be concerned with the detailed computations of the engineer who designed the bridge.

The advantages of the state of controlled surveys are too many and too obvious to further enumerate here. Suffice it to say that by means of the appropriation of an inconsequential sum by an intellectual Highway Commission, the state expects to mass within a few years data of unlimited value.

The writer cannot close this paper without acknowledging the splendid cooperation and assistance so cheerfully given by the U. S. Coast and Geodetic Survey to the engineers in North Carolina in their effort to secure geodetic control for the state.

Encouraged by the friendly advice of Captain Patton and Dr. Bowie, by constant correspondence with the Bureau, and aided by its various pamphlets and other publications, they finally suceeded after a series of failures.

They found that this remarkable organization, recognized around the world as the highest authority in its many lines of scientific endeavor, is here to serve and to help and that engineers who form contacts with it may be assured of courteous, friendly and most valuable assistance in the solution of handling of their problems.

While the North Carolina Society of Engineers conceived the idea and sponsored the movement for controlled surveys, credit for the final accomplishment belongs to the brilliant Chairman of the Highway Commission, the Hon. E. B. Jeffress.

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Work thus far accomplished on the North Carolina project includes observing of the first order Atlantic Coast arc, reconnaissance for the arc closely, following the 78th meridian and the one along the North Carolina-Virginia boundary. Reconnaissance work will be continued to completion of the program. First order leveling has been completed along a line paralleling the coast from the Virginia boundary to Wilmington, N. C. Second order levels, 50 miles further inland, extend across the state. To control the survey of the Chovan River, the party on the NATOMA extended second order triangulation between the Atlantic Coast arc and the Virginia-North Carolina boundary arc. It was found practicable on this work to place stations on main highways and at several county seats. A double first order triangulation party will start work in the state about November.

ALUMINUM MOUNTED TOPOGRAPHIC SHEETS

I. Roger C. Rowse, Ship EXPLORER

On July 3, 1931, an aluminum mounted sheet, 24" x 30", with plane-table board designed especially for use in connection with it, was received from the Washington office, accompanied by a request for a report on the fitness of the sheet for use in the field.

The area including the upper part of Rudyerd Bay, Behm Canal, S. E. Alaska, was chosen for making the test of the sheet in the field. The projection was made on July 7, 1931, and verified on July 30, 1931, no distortion of any sort being discovered after this period of 23 days. The sheet was used in the field by the topographic party from August 4 to September 26, 1931, under varying weather conditions, and no evidence of any distortion was discovered during this period. This was evidenced by the fact that all three of the schemes of planetable triangulation checked exactly in direction and distance between stations at the extreme heads of the Punchbowl, the South Arm and the North Arm.

In order to test the sheet thoroughly, it was tried out during a light rain with fair visibility. Although every precaution was taken to keep it dry, a few raindrops inevitably found their way to the surface of the sheet, where they made slight blisters which remained in a pulpy condition until dry. When the metal base of the alidade was placed over such spots after wiping with a dry cloth, stains were produced which could be removed only by the laborious use of a hard ink eraser. Distortion due to the absorption of moisture was not in any way evident.

As regards convenience to the topographer, the use of this sheet eliminated the use of a chart tube for carrying the field sheet, since it could be attached to the planetable board during the entire period of the survey. The glazed surface of the sheet made it necessary to use a very hard pencil and more than the ordinary amount of pressure in order to preserve the pencil lines and prevent them from being rubbed off by ordinary use of the sheet in the field. This in turn made it necessary to use a rubber pencil eraser when cleaning the sheet after inking, instead of the usual art gum eraser.

When the sheet was inked it was found that the surface glaze had been intensified by the use to which the sheet had been put in the field, making it difficult for the paper to "take" the ink. An appreciable amount of pressure on the pen was necessary in order to accomplish this end, and consequently a crowquill pen was used on this sheet where a number 170 or 303 is ordinarily used on the standard type of topographic paper. In drawing the projection lines it was necessary, in several places on the sheet, to go over them two or three times before the paper "took" the ink properly.

In summary, the writer is of the opinion that for accuracy and convenience in the field the aluminum mounted sheet is ideal, while for inking and cleaning it presents slight difficulties not found in the Whatman type of paper.

II. George A. Nelson, Ship DISCOVERER.

The area selected for the field trial comprised the eastern portion of the Barren Island group. A survey of the "western islands of that group was already under way on the standard type, cloth mounted Whatman's paper.

For comparative purposes, definite and equal distances were laid off on the two sheets, two distances on each sheet normal to each other. Measurements of the distances were taken from time to time. The following is a tabulation of the results:

Conditions	Whatman's Cloth Mounted Sheet				Aluminum Mounted Sheet	
under which used	East-West	% of change	North-South	% of change	East-West	North-South
Several days in field sheet dry	14,000 m.		10,000 m.		14,000	10,000
Foggy sheet damp	14,042 m.	.30	10,050 . m.	.50	No change	No change
Clear sheet dry	13,947 m.	-.38	9,988 m.	.12	" "	" "
Clear sheet dry	13,885 m.	-.82	10,003 m.	.03	" "	" "
Cloudy, sheet slightly damp	14,010 m.	.07	10,025 m.	.25	" "	" "
Clear sheet dry	13,979 m.	-.15	10,006 m.	.06	" "	" "
Cloudy slightly moist	14,008 m.	.06	10,026 m.	.26	" "	" "

A glance at the results shows that under conditions that made the unmounted sheet distort nearly 1%, the aluminum mounted sheet distorted not at all. While the weather conditions to which the aluminum sheet was subjected were not as severe as would have been desirable, yet it may be safely assumed that distortion on the new type of sheet is zero. One day's field work was done in which the wind attained a velocity of 35 to 40 miles an hour in the gusts. The umbrella man was used to hold the tripod legs to keep the table from blowing away, but the sheet itself gave no trouble. Of course, work on a Whatman's sheet would have been practically impossible under like conditions. Transporting the sheet safely presented some difficulties, but a section of fir three-ply veneer, faced with cloth and backed by light canvas, solved the problem satisfactorily. The veneer was cut the exact size of the planetable, the cloth face placed against the sheet, and snap fasteners on the canvas flaps secured it firmly to the planetable. The cloth can easily be renewed if it becomes soiled and the veneer protects the surface of the sheet from accidental injury.

The sheet was exposed to a drizzle for the better part of an hour, purposely to test its resistance to water. The water apparently had no deleterious effect, although while damp or wet it was difficult to slide the alidade the slight amount necessary for an exact pointing on a signal.

This disadvantage is not considered serious.

The field trial brought out the following advantages over the Whatman's paper:

(1) No distortion
(2) Not subject to wind disturbance.
(3) The harder surface permits greater nicety of detail.
(4) Takes ink more easily.

Disadvantages:

(1) Smaller sheet area.

Recommended Improvements:

The effective working area of the sheet may be sensibly enlarged by adopting a different type fastener. Instead of the screw type fastener with its attendant countersunk areas, a flange or channel clip type of fastening, continuous around the entire sheet, could be devised. In addition, the present countersunk margin could be reduced to, say, 1/4 or 3/8 of an inch, the clip fastening fitting fairly snug against the shoulder. This increase of sheet area, slight as it is, would tend to eliminate the greatest disadvantage of the sheet.

Also, the fact that the sheet can be used in a wind too strong to permit the use of a sunshade would suggest the advisability of a cream or light buff tint to reduce eye strain, unless there are photographic objections to a tinted sheet.

No opportunity was presented for testing the resistance of the sheet to a prolonged exposure to dampness, such as it would be exposed to by a camp party. This, of course, applies particularly to Alaska, where the moisture content is always high. If water-proof glue is used in the construction of the sheet, the danger of the bond failing between the several layers is probably not great.

III. Leroy P. Raynor.

Undoubtedly the metal sheets which, I understand, are being tried out for use with the planetable will prove more accurate than the Whatman's paper which has been used in the past. However, I believe that there are many advantages in the use of the paper and that with the proper precautions, it can be made to give better results than is usually obtained. There are two things which will help to produce better results, first, the proper pre-treatment of the paper, and, second, the proper procedure after the paper has been treated.

In the treatment of the paper, each sheet should be carefully seasoned in the climate of the locality where it is to be used, and for as long a time as possible before the projection is laid on the paper. The practice of keeping the paper in a large pile will not, to my mind, season any but the top sheet. To effectually season the paper, each sheet should be hung up or laid out separately so that it will be completely exposed to the air. In order to hasten the seasoning, the method that was used on the PATTERSON, under the late J. B. Miller, appears quite satisfactory. The sheets were hung up in one of the tents used by the shore party, and for several days they were given a light sponge bath on the face of the sheet. The sheet was allowed to dry and then given another bath. Usually the sheet was hung from opposite ends after alternate baths. If my memory serves me right, these sheets distorted very little in the field.

The procedure after the sheets were seasoned was also a help in producing accurate results. Before the projection was laid on the sheet, a reconnaissance was made of the area to be covered by the sheet and pole or rock cairn signals erected at points where it was thought subsidiary control was needed. Then as soon as the projection was made, and before there was any liklihood of a change in the sheet, one or more triangulation stations were occupied and orientation lines were drawn to the subsidiary stations. These subsidiary stations were then located by intersection from other triangulation stations or by resection, i.e., by planetable triangulation. The orders from the commanding officer, which I think were the crux of the matter, were that all shoreline should be located from set-ups that were on closed traverses between triangulation stations or subsidiary stations. No three point fixes were to be used except for the location of points used only for the sketching of contours. While I realize that one of the advantages of the planetable is the fact that a three point fix can be graphically obtained in the field, I do not believe that with the present paper, such a fix gives an accurate enough determination, while a closed traverse run between triangulation stations is rigid test of the accuracy of the traverse. If the closing error is small, the traverse and shoreline can be accurately adjusted, while if the error is too large, a blunder is indicated and the line will have to be re-run. The instructions in 1914 did not provide for triangulation stations to be spaced as closely as at present, so that the planetable triangulation was then necessary. When the triangulation stations are spaced in accordance with the present instructions, very few stations located by planetable triangulation will be necessary, and it is believed that a traverse as indicated will materially reduce the errors now introduced by the unequal shrinkage or expansion of the paper sheets.

IV. E. W. Eickelberg

"The proof of the pudding is in the eating." So with the small size aluminum mounted topographic sheet. To one who has tried to read a rod while the wind was puffing up the old sheet or tried to draw a line and found a long clamp under the alidade, the new sheet is a real treat. Also I might say that in making the projection on the new sheet, viz., the construction lines, I found no difficulty in making a straight line pass through three points. That is more than one can always say about the old sheet, which is in the process of distortion or contortion every time someone opens the chart room door.

The utility of the small sheet can readily be seen when given an area to survey where the hydrography progresses with greater speed than the topography due to deep water with little necessary development. Working from a single base a second topographer can be added to the work, instead of waiting for one man to finish a very lengthy sheet, or proceeding with hydrography in advance of topography, which is not always satisfactory. By having two topographers the topographic work is not forced and results are bound to be better, besides enabling the hydrographic party to work more efficiently.

Most of the objection in the old sheet is that it is too long and has to be rolled and unrolled too much besides becoming creased over the edge of the table, and, if this is done in rainy or even damp weather as in Alaska, these creases almost take a permanent set.

I believe the new sheet, with its depressed edges and smooth clear surface, with no obstructions for the alidade to strike, presents a marked improvement and convenience over the old type of sheet and will result in work of high order of accuracy.

(V) - F. S. Borden

Three point fixes which, theoretically speaking, might be entirely satisfactory are often weakened by the distortion in cloth mounted sheets. The metal mounted sheet will strengthen all three point fixes, particularly those inclined to be weak.

When three or more cuts taken to a hydrographic signal or to some definite object fail to intersect in a point on the metal mounted sheet there can be no "passing the buck" to distortion. Triangles of error will practically cease to exist. If they occur the topographer, by taking an additional cut, can readily locate the trouble; this can not be said of cloth mounted sheets where so often additional cuts only add to the confusion.

Also there can be no alibis for a poor projection. Oftentimes errors of discouraging magnitude are found in projections when checked in the office. Presumably these result from distortion. Metal mounted sheets will furnish the incentive for taking more care in laying down projections.

The position of topographic and hydrographic signals can be scaled from a metal mounted sheet at any time in the future with exactly the same accuracy with which they were plotted. The survey can always be reproduced with the accuracy with which it was made; this is far from being true when it is made on a non-rigid sheet.

THE TRANSFER OF ALASKA TO THE UNITED STATES

(Copy of a letter dated March 23, 1916, written to Dr. William Bowie, Chief, Division of Geodesy, by the late Stehman Forney, Assistant in the Survey. The letter gives some of the details of the transfer of Alaska from the Russian Government's Commissioner to Gen. Rousseau, U. S. Army, in 1867. Capt. Forney was then a member of the party of the late Assistant George Davidson, who accompanied Gen. Rosseau.)

After a lapse of 49 years, I am reminded of some interesting events that transpired on the cruise of the Revenue Cutter "Lincoln" that I made as an aid in the Coast and Geodetic Survey, when attached to the party of Professor George Davidson, on the coast of Alaska in 1867.

The party was composed of Assistant George Davidson, Chief of Party; Assistant A. T. Mosman, Astronomer; Aid Stehman Forney, aid to Assistant Mosman; Dr. Kellogg, Botanist; Dr. Harford, Conchologist; Captain William Howard, senior officer, U. S. Revenue Cutter Service; Captain White, U. S. Revenue Cutter Service, commanding the "Lincoln"; a geologist, and a full complement of deck officers and steam engineers.

We sailed from San Francisco early in June, 1867, and proceeded to Sitka, Alaska, by the inside passages, remaining at Sitka until after the official transfer of the territory was completed.

The transfer was made by Alexa Pestchourof, Russian Commissioner, to General L. H. Rousseau, U.S.A., who received the new possessions on the part of the United States. The ceremonies accompanying the transfer took place in the throne room of the palace or Governor's mansion and were historical and interesting. From the throne room we adjourned to the porch of the palace, where the ceremony of hauling down the Russian flag and replacing it with Old Glory occurred. Then General Rousseau placed Brigadier General Jefferson Davis, U.S.A., in command of the Department of Alaska.

Sitka at that time was surrounded by a heavy wooden stockade twenty feet high, with a strong heavy gate, locked and barred from the inside. Outside the stockade were encamped about 1500 Chilcat Indians and other tribes who had congregated there from different parts of the territory to see and find out what was going on at the Prince's mansion.

After the transfer of the national flags, General Davis happened to look down in the direction of the Indian village, and saw that the Russian flag was still flying at their flag pole. He turned to his chief of staff and said, "Major, send a commissioned officer with a guard and the American flag to that camp, haul down the Russian flag and hoist the American ensign." Our official interpreter, a Russian Jew, interrupted and said, "General Davis, excuse me, but I wish to say that such a move will be unwise and dangerous and may cause the loss of many lives in the future. May I suggest that you send several commissioned officers with a guard, have them take fifty blankets and about five pounds of tobacco, go down there and have an Indian 'potlatch' present the chiefs with the "blankets and smoke the pipe of peace. Then, with your approval, I will go to the camp and give them a talk and explain the situation to them."

This method, after some discussion, was approved by the Departmental commander and the military party started for the encampment. In the mean time, the Indian chiefs had sent word to General Rousseau that if the Boston man (the Indian name for American) would treat them the same way he had treated the Russian Prince, they would treat with him.

From our position on the porch of the Government house we could look over the stockade into the Indian camp. Watching the proceedings we saw the Indians gather abound the American soldiers and the interpreter, saw the latter gesticulating to them as he spoke. Then we saw the Russian flag come down and the American flag go up in its place, amid cheers from our party on the hill and the Indians in the camp below us. We also saw the distribution of army blankets and the smoking of the pipe of peace by the American officers and the Indian chiefs.

This wise treatment of the Indians no doubt prevented an outbreak among them which would have caused the loss of many American lives.

From Sitka we cruised along the coast of Alaska as far north as Bering Strait, but we could not reach Point Barrow on account of the ice pack. From there we cruised along the Siberian coast, and then around the Aleutian Islands and back to San Francisco where we arrived in October, 1867. On our cruise we established geographic positions of headlands and prominent objects on the coast, as well as making a reconnaissance and examination of the approaches to the coast.

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The following is a copy of a letter addressed to:

"U. S. Coast and Goedetic Survey,
21st and Constitution Ave.
Washington, D. C.

"Kindly send copy of talk, 'The Gulf Stream' by H. A. Marmer over the air at 3.45 P.M. to-day. Was very much interested but did not get entire speech. I try to absorb some knowledge from the radio each day and then pass on to my husband at night. He's so smart, I have to work hard and concentrate to keep up with him."

Needless to say, copy was promptly forwarded.

THEORETICAL VELOCITY OF SOUND IN SEA WATER AND ITS PRACTICAL USE IN R.A.R. HYDROGRAPHY

T. B. Reed, H. & G. Engineer, U.S.C. & G. Survey.

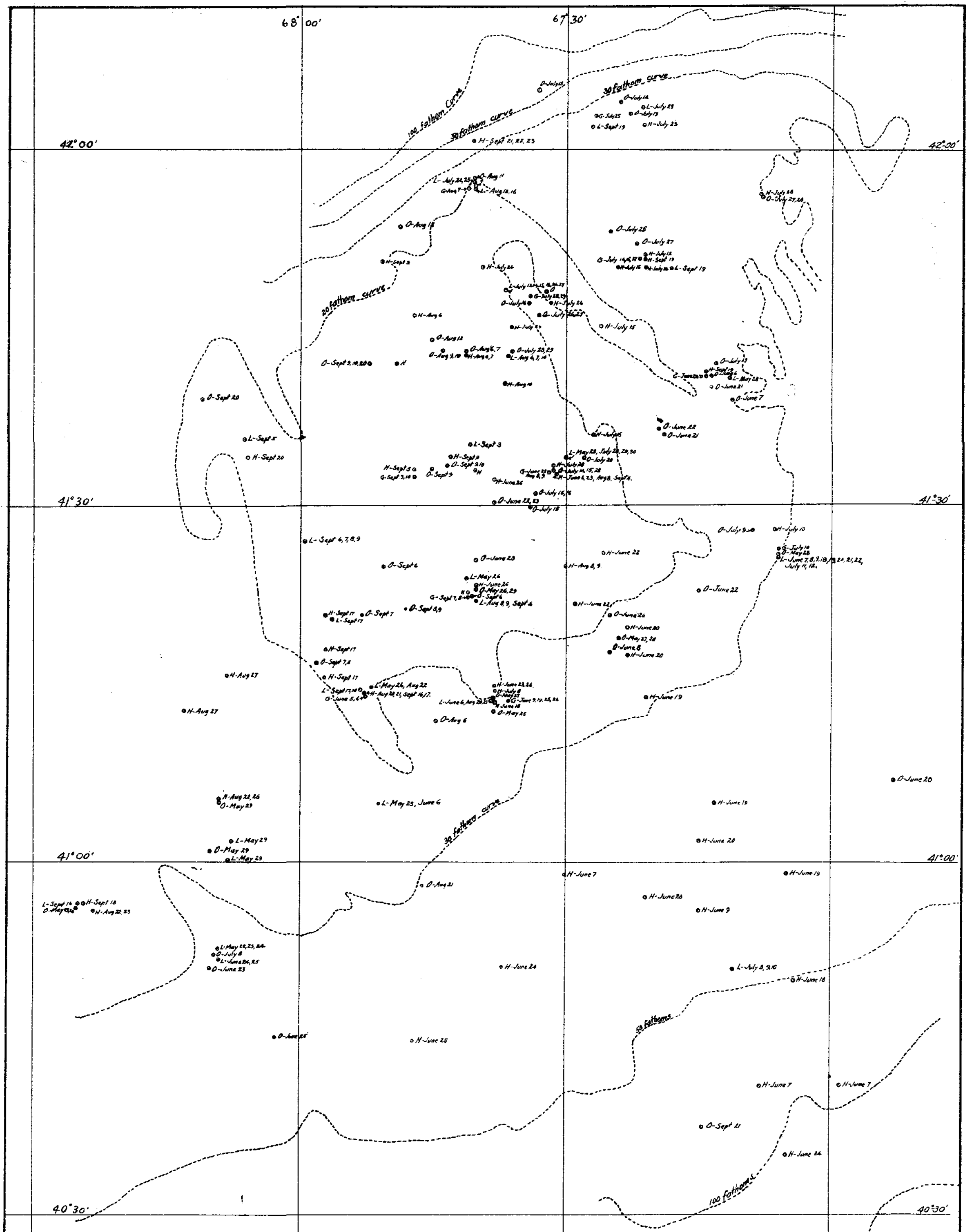
The development of radio acoustic ranging for control of hydrographic surveys on the Atlantic Coast brought new problems in determining the velocity of sound to be used in computing radio acoustic distances. In R.A.R. work on the Pacific Coast accomplished during the past several years, experimental velocity determinations were possible in the immediate vicinity of the areas surveyed so that resort to theoretical velocity was unnecessary; hence the small amount of study that had been done on this subject until it was desired to use R.A.R. control in areas such as Georges Bank where similar experimental velocity determinations are not possible.

The following article is a resume of conditions encountered and methods employed for computing the velocity of sound by the party on the U.S.C. & G.S.S. OCEANOGRAPHER on the survey of Georges Bank, season of 1931:

Tests made during this season and by previous parties, and data gathered into a comprehensive report by Mr. A. L. Shalowitz of the Washington office, were considered to show that the THEORETICAL BOTTOM VELOCITY based on temperature, salinity and pressure would furnish the best value of the velocity of sound through the water area surveyed. The accompanying graphs were compiled from the observations made for such data during the season of 1931. From these were obtained values of velocities used in computing distances between stations in the R.A.R. triangulation scheme as well as the distance between hydrophone stations and bombing positions when plotting the soundings on the hydrographic sheets of the HYDROGRAPHER and OCEANOGRAPHER.

TEMPERATURE AND SALINITY OBSERVATIONS: For the purpose of establishing the theoretical bottom velocity for the various R.A.R. lines during the season, all temperature and salinity observations made by all four ships working on this project were combined for study. These consisted of 300 sets of observations of temperature and salinity taken during the period from May 32 to September 21, 1931. The positions of these temperature and salinity stations were then plotted on a sketch of the area, showing the date of each observation alongside the station. The stations were found to be well distributed and of sufficient number over the Bank proper to give a comprehensive knowledge of conditions but were too few in the deeper water both to the southward and northward of the Bank. The study of the above data was made with particular reference to the seasonal change of temperature in this area.

In order to determine whether temperature conditions varied in different sections of the Bank and whether mean curves drawn through



GEORGES BANK PROJECT - 1931

SKETCH SHOWING TEMPERATURE AND SALINITY STATIONS OCCUPIED BY THE SHIPS:

H-HYDROGRAPHER
O-OCEANOGRAPHER
L-LYDONIA
G-GILBERT

SCALE OF CHART 1107

C & G.S. 442

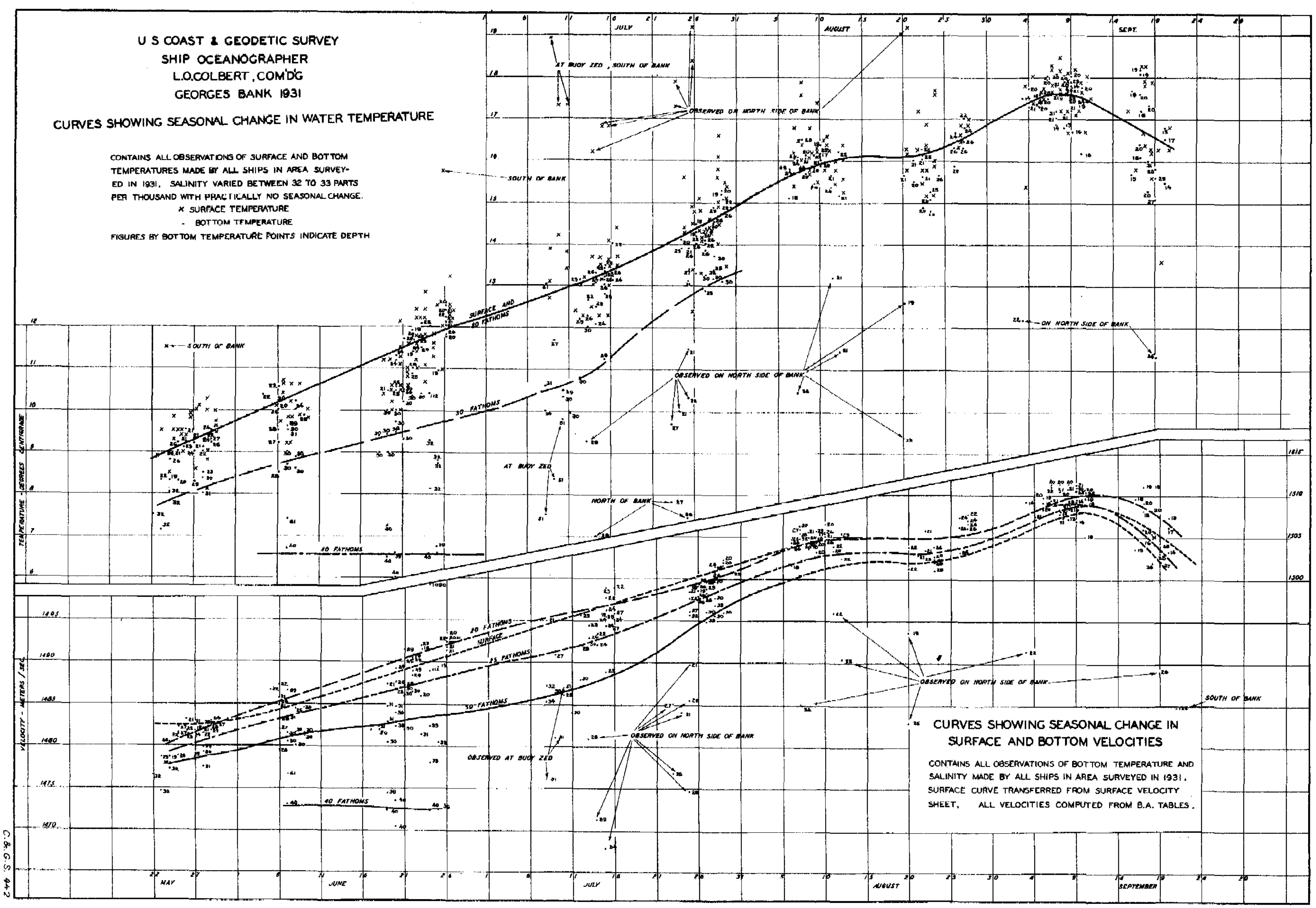
all observations of the same depth would be correct for all areas, four small areas located in various sections of the Bank were selected for study. Comparison between temperatures obtained in these areas and the mean temperature of the entire Bank was made by graphs and from these comparisons it was determined that the entire area, shoaler than 30 fathoms, with the exception of the area on the extreme north side of the Bank, could be considered as a whole and mean curves drawn for both temperature and velocity. The water in the area on the north side of the bank, in close proximity to the deep water of the Gulf of Maine, was found to be considerably colder in depths of 20 fathoms or deeper than over the remainder of the Bank.

The seasonal change in water temperature during the period from May 22, 1931, to September 21, 1931, is shown on an accompanying plate. The graph includes all observations taken and the curves are the mean of all observations except the low temperatures previously mentioned on the north side of the Bank. In drawing the curves it was assumed that the temperature change was constant over the remainder of the Bank. It is believed that the mixing of surface and bottom water caused by the strong currents keeps the temperature fairly constant between surface and 20 fathoms in this area. All observations upon which the 30 and 40 fathom temperature curves are based were obtained on the south side of the Bank, as there were insufficient observations in these depths on the north, or Gulf of Maine, side. It is believed that the effect of the direction of the current upon subsurface temperature variation is much greater on the north slope than in other sections in which hydrography was done.

It was found that an unusual condition existed in the deep water area extending to the southward - the water in a depth of 40 fathoms just south of the Bank being considerably colder than that in depths of 50 to 200 fathoms further south. This warmer water undoubtedly defines the northern edge of the Gulf Stream.

<u>SEASONAL CHANGE IN VELOCITY OF SOUND</u>: Bottom velocity in meters per second was computed for each temperature and salinity observation during the season and is shown by curves on an accompanying graph. British Admiralty Tables, H.D. 282, were used for obtaining all theoretical velocities. This graph also shows the seasonal change in surface velocity. This value does not enter into the computations but was computed as a matter of comparison. In general, the 20-fathom curve is fairly well defined throughout the season. There is some question, however, at some places on the 25 and 30-fathom curves due to scarcity of, or scattered, observations. The section of 40-fathom curve in June is quite well defined. These values are checked by a bottom velocity of 1472.5 obtained in 40 fathoms off buoy LOVE on June 25, while making a velocity test by wire.

The 25, 30 and 40-fathom temperature curves shown on this graph are considered as a good average for their respective depths for all


U S COAST & GEODETIC SURVEY
SHIP OCEANOGRAPHER
L.O.COLBERT, COM'D'G
GEORGES BANK 1931
CURVES SHOWING SEASONAL CHANGE IN WATER TEMPERATURE
CONTAINS ALL OBSERVATIONS OF SURFACE AND BOTTOM TEMPERATURES MADE BY ALL SHIPS IN AREA SURVEYED IN 1931. SALINITY VARIED BETWEEN 32 TO 33 PARTS PER THOUSAND WITH PRACTICALLY NO SEASONAL CHANGE.
x SURFACE TEMPERATURE
· BOTTOM TEMPERATURE
FIGURES BY BOTTOM TEMPERATURE POINTS INDICATE DEPTH
CURVES SHOWING SEASONAL CHANGE IN SURFACE AND BOTTOM VELOCITIES
CONTAINS ALL OBSERVATIONS OF BOTTOM TEMPERATURE AND SALINITY MADE BY ALL SHIPS IN AREA SURVEYED IN 1931. SURFACE CURVE TRANSFERRED FROM SURFACE VELOCITY SHEET. ALL VELOCITIES COMPUTED FROM B.A. TABLES.
TEMPERATURE - DEGREES CENTIGRADE
VELOCITY - METERS / SEC.
MAY
JUNE
JULY
AUGUST
SEPT.
SEPTEMBER
SURFACE AND 20 FATHOMS
30 FATHOMS
40 FATHOMS
20 FATHOMS
SURFACE
25 FATHOMS
SOUTH OF BANK
AT BUOY ZED, SOUTH OF BANK
OBSERVED ON NORTH SIDE OF BANK
ON NORTH SIDE OF BANK
AT BUOY ZED
NORTH OF BANK
OBSERVED AT BUOY ZED
C.&.G.S. 442

sections of the Bank except on the north side where, as previously stated, deep water from the Gulf of Maine approaches close to the Bank. The water below 30 fathoms on the north side is considerably colder, as is shown by the scattered low values on this graph, which were all observed in this area.

Possible effect of the direction of the strong current upon temperatures was studied with the idea that it might be the cause of high or low temperatures. This was done, after noting comparatively large variations in observations taken the same day, to determine if the direction of the current might have some effect on the temperature at various times of the day. It was thought that colder water might be brought down from the northward with a northerly current. However, since there appeared to be no consistency between direction of the current and high or low temperature, this effect was considered to be negligible or of too complicated a nature to permit of computation from the data at hand.

*METHOD OF OBTAINING VELOCITY FOR R.A.R. TRIANGULATION LINES: Before assigning a velocity to R.A.R. triangulation lines, the date, average depth, time of bombing and place of temperature observations in the same area were carefully studied to obtain the most probable value for each line. When observations were made at both ends of the line near the time of bombing, the mean of these values was used. Most velocity rates for computing the lines were taken directly from the "Seasonal Change in Bottom Velocity" curves, using the date and average depth along the line. Average depths were considered as the mean of the depth taken every mile along the lines as shown on the boat sheet.

THE DETERMINATION OF AVERAGE DEPTH BETWEEN STATION SHIP AND SOUNDING VESSEL ON HYDROGRAPHIC LINES: The method of computing a bomb velocity for the average depth traversed by the sound wave was used on all hydrographic positions in the same manner as it was used in computing velocities for R.A.R. triangulation. The average depth, in fathoms, from the station ship to each bomb position was written in the bomb records in the velocity of sound column above the theoretical bottom velocity. These average depths are the straight mean of depths taken every mile along the line from the bomb position to station ship.

The following simplified method was used in obtaining average depths to all bomb positions: A sheet of tracing paper was laid over each boat sheet and on it in different colors corresponding to the various station buoys were drawn in "Curves of average depth"

*Tabulation showing dates, depths, velocities, lengths of lines, etc., for all R.A.R. triangulation on Georges Bank is given in Association of Field Engineers Bulletin, December, 1931.

from each buoy used as a station, covering all the area in which the buoy was used as R.A.R. control. These "curves of average depth" can be quickly drawn by using a combination of slide rule and an adding machine with a subtotal key. A scale of miles to the scale of the boat sheet was laid off on the edge of a long strip of adding machine paper and this laid on the tracing paper with the zero on the station buoy from which it was desired to draw average depth curves. One officer then read off soundings each mile to another operating the adding machine, obtaining frequent subtotals and dividing with a slide rule by the number of soundings to obtain "average depths." From these depths, points on "average depth" curves at intervals of 10 fathoms or less were interpolated and marked on the tracing paper. The mile scale was then rotated about the station buoy and, in a similar manner, other points were determined throughout the area so that curves of average depth could be drawn in for the entire area in which the station buoy was used. It was then a simple matter to go over the boat sheet and, by interpolating between the curves of average depth on the tracing paper, to note in the bomb record the average depth of each R.A.R. line.

THE DETERMINATION OF VELOCITY TO BE USED ON HYDROGRAPHIC POSITIONS: Velocities for R.A.R. positions, having an average depth of less than thirty or, in some cases, 35 fathoms, were taken directly from the Seasonal Change in Bottom Velocity Curves. This includes all hydrographic positions on the Bank out to about the 35-fathom curve.

Due to the unusual temperature condition existing to the southward of the Bank, a different method was employed in determining velocity for the deeper lines to the southward than that for the deeper lines to the northward.

The method of determining velocity for the deeper area to the southward is shown by the graph and tables on an accompanying plate. Velocities in the tables on this graph were used for reducing all bomb positions for hydrography in the deeper water to the southward.

Due to the small number of temperature observations taken below 40 fathoms and the rather wide variation in those taken, considerable approximation was necessary in constructing the graphs beyond 40 fathoms. It is certain, however, from the observations that both surface and bottom water are considerably warmer to the southward of the 40-fathom curve. This is probably due to warmer water along the northern edge of the Gulf Stream.

The depth curve on the graph is a general profile of the depth from the line of the station buoys at DOG 2, HAVE and LOVE to the 1200-fathom curve at the south edge of the sheet. Points on the temperature curve and velocity curve are plotted relative to distances and depths on the depth profile. The velocity curve from 29 to 40 fathoms was transferred from the Seasonal Change Curve and a mean value between June 6 and June 25 (the time of sounding in this area) taken to avoid making the computations too complicated. The

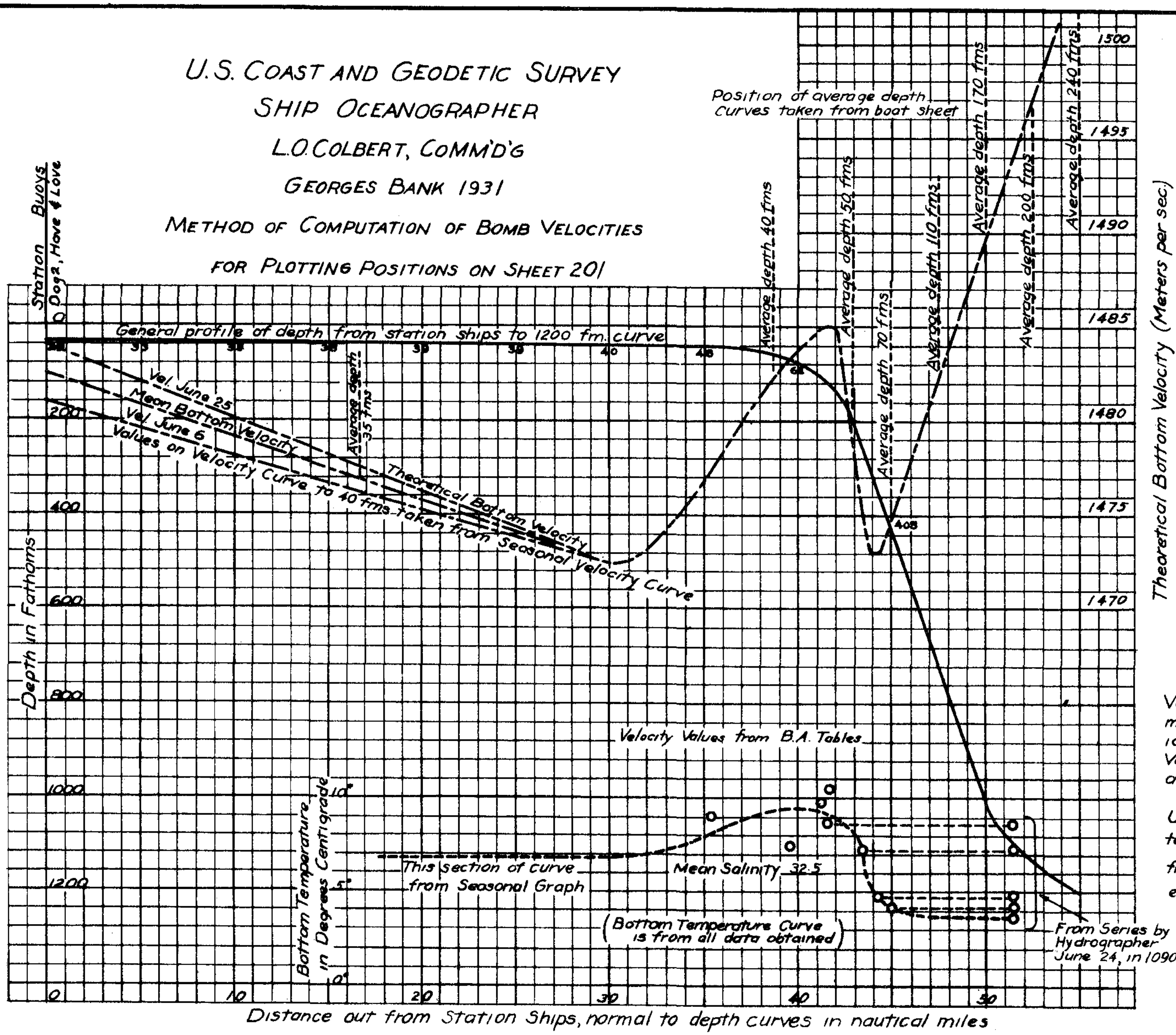
U.S. Coast and Geodetic Survey

Ship Oceanographer

L.O. Colbert, Comm'd'g

Georges Bank 1931

Method of Computation of Bomb Velocities for Plotting Positions on Sheet 201



Mean Bottom Velocity
Bombs To Buoys
Dog 2, Have, & Love

Average Depth Fms	Velocity Meters per sec.
35	1479.7
36	1478.9
37	1478.3
38	1477.6
39	1477.0
40	1477.4
45	1477.7
50	1478.0
55	1477.9
60	1477.9
70	1477.8
90	1477.8
110	1477.9
140	1478.1
170	1478.4
200	1479.2
240	1480.2

Values in above table are means taken from the Theoretical Bottom Velocity Curve. Values of each nautical mile along the curve were used.

Unusal rise in bottom temperature south of 40 fm. curve due to Northern edge of Gulf Stream.

velocity curve shows actual and not mean velocity values at all points.

The velocity curve below 40 fathoms is derived from the temperature curve at the bottom of the page, using a mean salinity of 53.5. This bottom temperature curve is somewhat approximate, due to considerable variation in the small amount of data available and to the fact that most of the curve below 100 fathoms depends upon one serial temperature taken by the HYDROGRAPHER in 1090 fathoms and the serial temperatures carried back to their respective depths for constructing the bottom temperature curve. The sharp upturn of the velocity curve at about 300 fathoms is due to the increasing plus correction for pressure overcoming the minus correction for temperature.

Points of average depth shown on the bottom velocity curve were obtained from the "average depth curves" drawn on the tracing paper over the boat sheet. These points were obtained from a general profile extending offshore normal to the line of station buoys. While not at the same distance from the stations in all directions, it is believed that the error caused by some variation of these distances will be small. This is evidenced by the table of velocities to Buoys ICG 2, HAVE and LOVE, in which there is a maximum variation of only 5 meters per second.

Mean bottom velocity tables on this graph are a mean of bottom velocity values taken every mile along the bottom velocity curve from the station ships to the corresponding average depth point. For instance, the value of 1477.8 m.p.s. from the table for an average depth of 70 fathoms is the mean of 46 values scaled each mile along the curve from 0 to 45 miles. The maximum average depth computed was 240 fathoms. It is realized that a straight average of a variable quantity such as a velocity, in this manner, is not mathematically correct. However, the error introduced by a straight average in this case is negligible.

It was at first intended to select some arbitrary point such as the 500-fathom curve to discontinue using bottom velocity. However, in the absence of much data on this subject and in view of the fact that the difference in actual distance would be very small, regardless of which method was used, it was decided for consistency to carry the bottom velocity to the end of the lines.

A similar velocity graph was made from data observed in the deep water area surveyed on the north side of Georges Bank. This graph was drawn up to be used in the same manner as the graph for the area south of the Banks.

CONCLUSION: The wide range of velocity of sound experienced on Georges Bank during the past season shows very definitely the importance of comprehensive observations of temperature and salinity during the entire season and covering the entire area in which hydrography is accomplished. Upon such observations depend practically the entire accuracy of work such as was done by this vessel during the past season.

The theoretical bottom velocity change in 108 days on Georges Bank was 30 meters per second, or about eight meters per second per month. This was due to the rising temperature during the summer months reaching a maximum the first week in September.

Since the length of the buoy scheme during the past season depending for control on the velocity of sound was about 70 miles, it can easily be seen how a large error might accumulate if insufficient data to establish the correct velocity were not known. In this connection, I might mention the following, which shows conclusively the need for sufficient temperature and salinity data:

Referring to the main buoy scheme between buoys ABLE and CAST (about 70 miles apart) located by R.A.R. triangulation during the past season. This chain of R.A.R. triangulation was accomplished during the latter week in May and the first week in June. The average velocity of sound used in its computation was about 1480 meters per second, from temperature and salinity values taken at that time. The distance from ABLE to CAST was rebombed in two sections on September 16 and 18, and recomputed using the theoretical velocity of 1507 meters per second from temperature and salinity observations at that time. This distance from ABLE to CAST checked the former determination by about 50 meters, whereas if the same velocity had been used for these different periods, there would have been a discrepancy of over 3000 meters in this distance.

The following suggestions are made with regard to the improvement in accuracy of future work of this kind:

1. Temperature and salinity observations (bottom at least) at both ends of each R.A.R. triangulation line should be measured at, or near the time of bombing. Take the mean of these observations, with consideration of course to the average depth over the line, as the velocity of computing the R.A.R. triangulation line. The comparatively wide range of temperatures in the same depth and on the same day during the past season has shown this to be necessary.

2. Sufficient observations of temperature and salinity in deep water areas surveyed should be obtained to allow a comprehensive knowledge of actual conditions without resort to approximation in computing velocity for bomb positions. The results of these observations should be worked up while the field work is in progress to determine if sufficient data are at hand both for reducing R.A.R. positions and for reduction of soundings. It is felt that improvement can be made during the next field season in the method of recording and working up these data.

3. More experimental data to determine the path of the sound wave; while some factors during the past season checked very close to the "theorectical bottom velocity theory", others seemed to indicate a higher velocity. If possible to establish recoverable stations, velocity tests between them should be made at least at the beginning and end of the season. It is thought that the "piano wire base test" is capable of greater possibilities for offshore areas, especially if executed under varying temperature and depth conditions. The piano wire base test could probably be successfully made in deep water by buoying the wire up at short intervals by small floats. It is felt that current conditions on Georges Bank present difficulties which may prevent collection of correct data.

It is my opinion that a more definite knowledge of the velocity of sound is the most important problem remaining to be solved for R.A.R. work on the Atlantic Coast.

THEORETICAL VELOCITY OF SOUND DIAGRAMS

On the two following plates are shown diagrams convenient for determining theoretical velocity of sound in sea water. The first diagram covers temperatures from 0 to 15° Centigrade; the second from 15° to 30°. The first diagram includes instructions for their use.

The diagrams were constructed from theoretical velocity values computed by the use of British Admirality Tables, H.D. 282, using a depth unit of fathoms instead of meters. A velocity in fathoms table was also added for use in reducing soundings.

Due to the small scale of the diagram, small differences may be found between values from the diagram and tables. This should be negligible, however, if care is used in interpolating between the curves.

It is thought that these diagrams will prove more advantageous for use in obtaining velocities than the tables in use heretofore.

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Comments on this article by Mr. A. L. Shalowitz, Senior Cartographic Engineer, appear elsewhere in this issue of the bulletin.

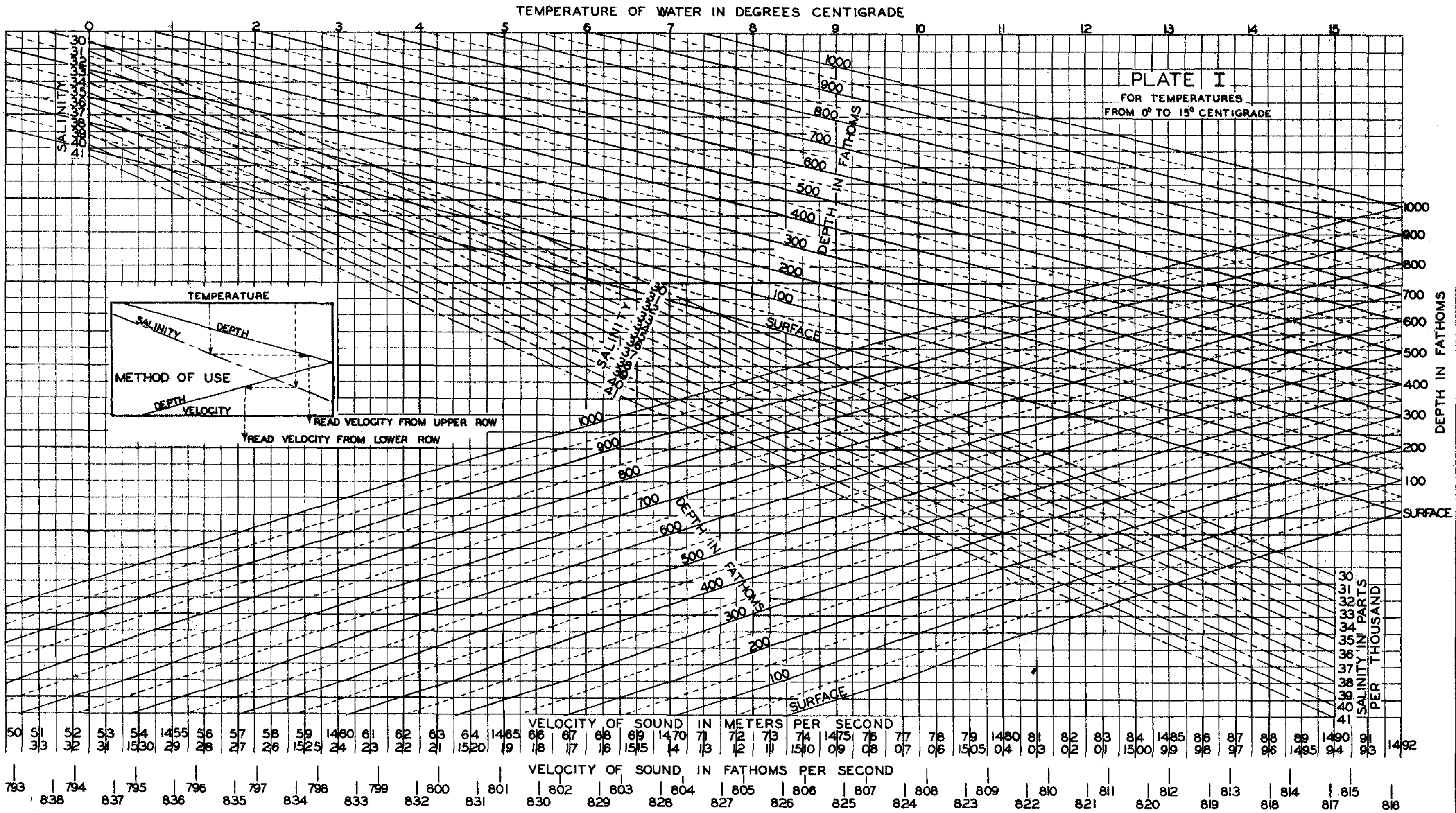

DIAGRAM FOR OBTAINING
VELOCITY OF SOUND IN SEA WATER

BASED ON THEORETICAL VELOCITY VALUES IN B. A. H.D. 282

DIRECTIONS

FOLLOW VERTICALLY FROM TEMPERATURE AT TOP OF PAGE TO SALINITY CURVE, THEN HORIZONTALLY TO DEPTH CURVE THEN VERTICALLY TO VELOCITY AT BOTTOM OF PAGE. FOR UPPER AND LOWER DEPTH CURVES USE UPPER AND LOWER VELOCITY VALUES RESPECTIVELY.

DEVISED BY THOS. B. REED H. & G. E. U. S. C. & G. S.

C. & G. S. 442

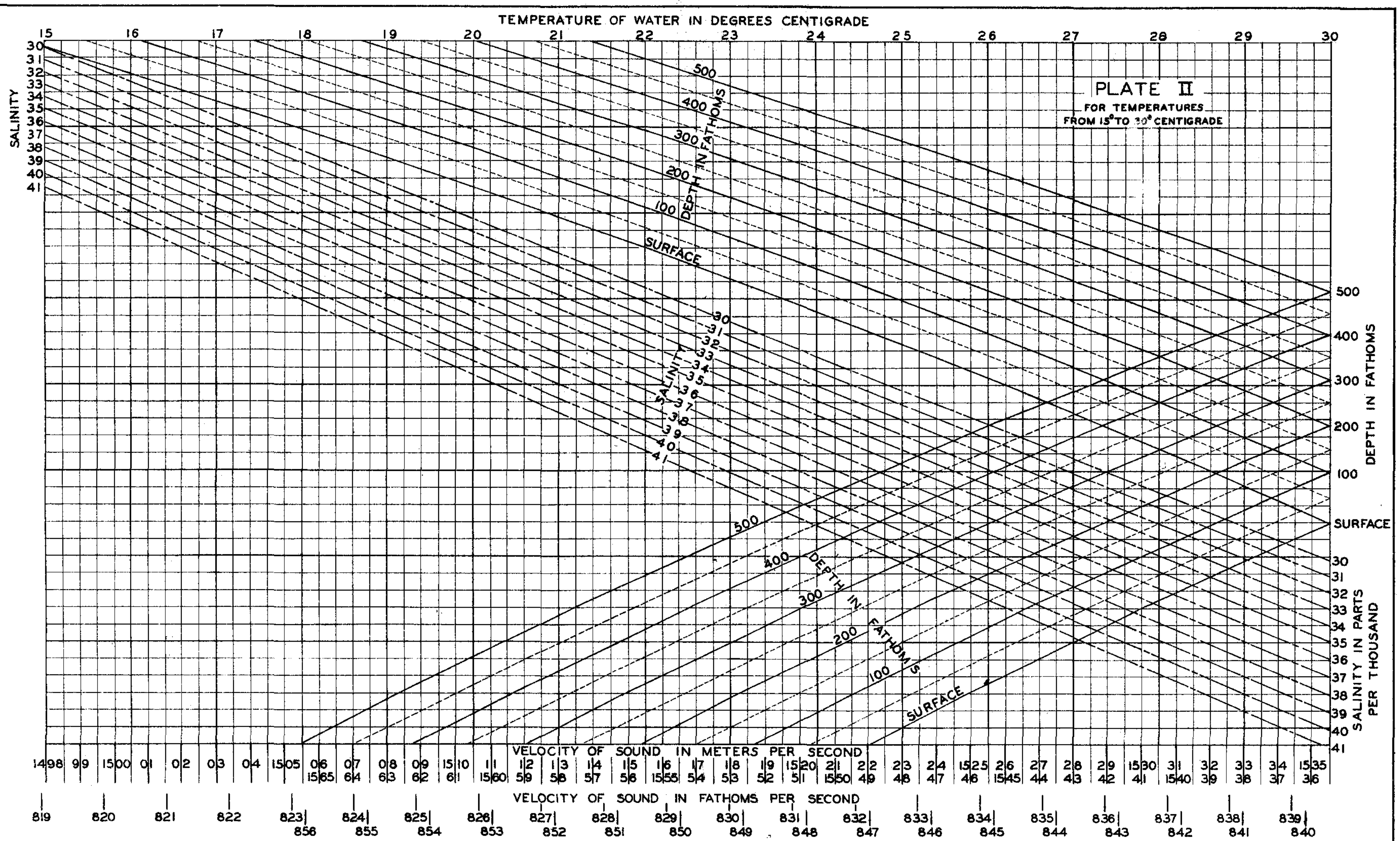

DIAGRAM FOR OBTAINING
VELOCITY OF SOUND IN SEA WATER

FOR DIRECTIONS AND METHOD OF USE SEE PLATE I.

BASED ON THEORETICAL VELOCITY VALUES IN B. A. H. D. 282

DEVISED BY THOS. B. REED H. & G. E. U. S. C. & G. S.

C. & G. S. 442

A POSSIBLE CAUSE OF SUBSURFACE EARTHQUAKES

William Bowie, Chief, Division of Geodesy
U. S. Coast and Geodetic Survey

(This article appeared, under the title "Sur une cause possible des tremblements de terre ne se manifestant pas a la surface du globe", in the February, 1932, issue of the Comptes Rendus of the Academy of Sciences of France)

Since earthquakes are due to the sudden breaking and shifting of rock, it seems probable that the shrinkage of crustal matter under an area base leveled by erosion may cause earthquakes which leave no evidence at the surface of their occurrence. There are many earthquakes which cause no surface movements that are visible to the eye. No fractures of the surface are noticeable. Such earthquakes, no doubt, occur at various depths, but whether they occur below the lower limit of the crust is still an undecided question. The isostasist is inclined to the view that earthquakes do not occur below the crust for the subcrustal matter must have a low degree of viscosity. If it were otherwise we could not have the almost perfect isostatic equilibrium which exists.

In any event, the balance is maintained during erosion and therefore the segment of the crust below moves upward as a result of the influx of subcrustal matter to crustal space. Eventually an area becomes base leveled. Perhaps as much as five miles of erosion may have occurred and the crust will have moved upward about four miles. Sometime after the base leveling the erosion area may sink as a result of the contraction from loss of heat. The crust having been raised four miles, the temperature will be about 200° C. higher than the normal. With loss of heat and shrinking the uplifted matter should tend to pull away from the unaffected sides. The contraction tends to be cubical, and, therefore, there should be subsurface fissures running parallel and also at angles to the axis of the affected zone.

It is probable that the temperature of the surface would be close to normal because of its exposure to the atmosphere, but any part of the lower matter will surely have a higher temperature than what is normal for the depth. The shrinking will be mostly cubical with the formation of fissures, and with the fissuring there will be earthquakes.

If this process is actually in operation the location of the activities involved must be within the crust, or at depths not greater than about 60 miles.

The subsurface fissures may be filled by slumping of surrounding material, the intrusion of matter lower down which becomes plastic with the relief of pressure., or by these processes associated with the formation of ore bodies and fissure veins.

Such contraction or tension earthquakes may occur in the late stages of the erosion of an area or during its sedimentation after the surface had begun to sink.

THE START OF THE ACOUSTIC WORK OF THE COAST AND GEODETIC SURVEY

N. H. Heck, H. & G. Engineer, U.S.C. & G. Survey.

Recent numbers of the Bulletin of the Association of Field Engineers have made it clear that acoustic determination of depth and position have become an essential part of the Bureau's work. The development work is now well organized and a considerable part of the personnel has knowledge of the details. The success of this work warrants the placing on record of the history of its inauguration, when none of these favorable conditions existed.

In the early part of 1933 successful use of acoustic methods in obtaining deep soundings through the use of the sonic depth finder by the Navy Department, as well as similar work by the French and British, indicated that these methods might be adapted to our special problems. The British had also been successful in locating a vessel by radio acoustic methods though without the automatic return to the vessel of the radio signal which has made our work so effective. Colonel E. Lester Jones, then Director, with the advice of the officers concerned decided that the Coast and Geodetic Survey should take up this work. It was felt that the difficulties of location of position off the Pacific Coast on account of fog made it desirable that both depth and position determination should be developed at the same time.

My personal association and my relation to the work which occasions the writing of this article should be explained, especially since at that time I was Chief of the Division of Terrestrial Magnetism, and continued that duty during my association with the acoustic work. There were no personnel familiar with the details of this work, but I was brought into close contact with several phases of it at New London, Connecticut, and London, England, while in the Navy during the World War. I was also personally acquainted with those who had done the development work and their method of attacking the problems. I was therefore sufficiently familiar with the general problem, both from the viewpoint of the fundamental research and development and from the viewpoint of hydrographic work, to be qualified to serve as a kind of liaison officer between those doing the development work and the as yet untrained Coast Survey personnel.

It was obvious to me that the radio acoustic work could not be carried on along previous lines, that is, by recording at several stations and then sending the distance by radio from each station. Tests made at the Washington office under my direction indicated that recording aboard ship with the necessary accuracy was possible and the problem was outlined with this feature and the automatic sending of radio signals by the arriving sound wave. The Bureau of Standards was then consulted, funds were transferred, and the development work was assigned to Dr. E. A. Eckhardt who had previously developed radio longitude apparatus for the Bureau. His principal assistant on the work was M. Keiser.

The Ship GUIDE, which had recently been put into commission, based at New London during the preliminary experimental work. During the development period R. F. Luce was in command, K. T. Adams, executive officer, and J. H. Service, whose previous advanced work in physics proved invaluable, was also assigned to the vessel. In the radio acoustic experiments off New London, Colonel R. S. Abernethy and Major H. C. Allen, U. S. Coast Artillery Corps, gave valuable advice and assistance.

The preliminary tests made steady progress, though beset with many difficulties, and were completed in late November. During this period there were several cruises to obtain practice in the use of the sonic depth finder. On one occasion a test was made to find out how far the bomb signals would carry. It was demonstrated that a signal could be transmitted and received accurately a distance of 55 miles, with an average depth of 20 fathoms. This success proved somewhat misleading, since later attempts to use radio acoustic methods on the Atlantic Coast proved that such results are possible only under exceptionally favorable conditions. Just before the GUIDE started for the Pacific Coast, a demonstration cruise was made to prove to Colonel Jones and a party of Coast Survey officers and guests, among whom was Captain Bob Bartlett, that the apparatus had passed the preliminary tests and was ready for test in actual surveying.

There were a number of difficulties and annoyances having chiefly to do with mutual interference in radio transmission in a region where there were many sources of interference. On one occasion a test was started during the broadcasting of a world series game and we were promptly invited to postpone operations. It should be understood that control of wave lengths was not then as rigid as now, and the short waves were not available so that we were not far from the broadcast and marine bands. On one occasion Mr. Keiser informed the listening nautical world that the ship would "park" in a certain harbor at 5:00 P.M.

The GUIDE sailed in late November for her field of duty near San Diego, California, and proceeded via Porto Rico to the Panama Canal in order to secure a wide range of depths for testing the sonic depth finder. In the Pacific she followed a prescribed course with relation to previous soundings by vessels of the Bureau passing between the east and west coasts. This particular course followed a series of deep troughs off the Central American and Mexican-coasts, a part of which was previously known as the Acapulco Deep, though depths much greater than any previously charted were found. The trough was found to have a maximum depth at least twice as great as the depths on either side. This was later found to be an active earthquake region.

The program of the GUIDE included the taking of acoustic soundings at the same time as the wire soundings. Temperatures were observed and water samples obtained so that shortly after the end of the cruise salinity determinations had been made by the Scripps Institution at La Jolla, California. The skill of Commander Luce and his complement was evidenced by the fact that all wire soundings, except those in regions of very strong currents such as the Gulf Stream and in a few places in the Pacific, were vertical and that while soundings were taken in depths up to 4,600 fathoms (Nares Deep) in the Atlantic and up to 3,500 fathoms in the Pacific, no sounding wire or attached apparatus was lost. Such a record with piano wire is probably without precedent. On one occasion in the Pacific, with specially favorable weather conditions, and a depth of about two thousand fathoms, three separate sets of thermometers and water specimen cups were attached at different depths and all were recovered.

As a result of the route selected, the range of depths was exceptionally great and the problem immediately developed as to what velocity of sound to use. It was evident that any attempt to use the same value for all soundings, as in previous practice, gave results considerably at variance with the simultaneous wire soundings. This constituted a problem better suited to an office force than to a ship personnel actively engaged in surveying operations, but since it had to be solved, Mr. Service and I gave particular attention to its solution. It could be accepted that the velocity varied with temperature, salinity and pressure, but we had available none of the fundamental data. The first attempt was made possible through Mr. Sercice's discovery of the volumes of the results of the CHALLENGER expedition, at the University of Porto Rico at Rio Piedras, near San Juan. He copied enough data to show that we were on the right track. However, the method was very cumbersome and not practical.

On arrival at San Diego consultation with Dr. Geo. F. McEwen of the Scripps Institution resulted in our securing tables of constants of sea water prepared by V. Bjerknes under the auspices of the Carnegie Institution of Washington. We were able to develop comparatively simple formulas for obtaining the velocity and, by temporarily ignoring the adiabatic correction, were able to compute satisfactory values of the velocity. Later these results were expanded into Special Publication No. 108, "Velocity of Sound in Sea Water." We adopted the plan of considering the water in layers and working out the mean velocity for each, not rigidly correct but with no important error except in the upper layer. In all the deeper sounding the effect of error in the upper layer was not serious. The values in Special Publication No. 108 do not differ materially from those given in British Admiralty Tables H D 282, although the latter are better suited for shoal water work and for computing horizontal velocities. With regard to the cruise of the GUIDE, the comparison of the wire and acoustic soundings with velocity of sound values computed as has been described showed an average agreement within one per cent, all that could be expected.

On a special survey off the California coast, a special effort was made to obtain the highest accuracy in the acoustic determinations and in the soundings at depths of 600to 800 fathoms, and it was demonstrated that the acoustic method had the possibilities required in shoal water work. However, it was found that the sonic depth finder as designed at that time was not suited to shoal water. It should be recognized that it was work of this type which laid the foundation for the later successful use of the fathometer.

On arrival at San Diego work started on the radio acoustic ranging apparatus and installations were made at Oceanside and at La Jolla, the latter stations being peculiarly suited to development of the work through the courtesies afforded by Dr. T. Wayland Vaughan, Director of the Scripps Institution, on whose pier the station was placed. Valuable experience was obtained, numerous difficulties were solved and the technique was gradually worked out. The surveying work was continuous, but only a portion of the position location was by radio acoustic ranging. Great difficulty was found in securing proper detonation of the bombs, and for this reason some studies of sound transmission which were intended had to be deferred to a later date. An interesting use was made of one of the shore stations. The inshore work of the ship had caught up with the triangulation so that on one afternoon, the results of the day's work of the shore triangulation party was sent off by radio telephone, computed, and used the next day by the ship.

By April, after a visit of inspection by Captain W. E. Parker, Chief of the Division of Hydrography and Topography, it was agreed that the preliminary stages were over and that there were no fundamental difficulties in the way of successful use and that the foundation had been laid. I therefore returned to my duties in Washington, thereby completing an experience of unusual interest.

The complement of the GUIDE demonstrated that the transition to the new form of hydrographic work could be made without fundamental changes in the personnel, though the need for development work by specialists had become evident. I find it difficult to single out the work of individuals since so many contributed. The work of chief radio operator Vincent of the GUIDE was specially noteworthy because of his ability to solve radio problems as they arose, often with limited facilities for the work. On one occasion off the coast of Mexico part of the apparatus on the control panel burned out and the oscillator (Fessenden) could be operated only at full power, making soundings difficult and painful to the operator. He made temporary repairs which lasted until arrival at San Diego. H. E. McComb, magnetic observer, in addition to making a magnetic survey between the Mexican border and Los Angeles, gave advice, based on his experience with precise physical instruments, to those in charge of shore stations, which helped in establishing a proper technique.

There was one great surprise in the results. All of those who discussed the project in its early stages questioned whether radio acoustic work would be successful on the northwest Pacific Coast of the United States on account of heavy surf noise interfering with the signals and the difficulties of installing shore stations and cables, while it was taken for granted that no difficulty would be encountered on the Atlantic Coast. The exact opposite proved the case and it is only recently in the course of the Georges Bank work that use under Atlantic Coast conditions has proven practicable.

In view of the fact that radio acoustic ranging is now used so extensively, it may not be improper to point out that the original conception of the problem was correct, and that while scarcely a trace of the original apparatus remains in the present equipment, there have been no fundamental changes in principle and method.

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NOTES ON FATHOMETER OPERATION

F. B. T. Siems, H. & G. Engineer, U.S.C. & G. Survey

On pages 102 and 103 of the December, 1931, Field Engineers' Bulletin, Dr. Dorsey points out that the time elapsing between the instant of closing circuit of alternating current and the response of oscillator as registered on the Fathometer depends in part upon the point of the alternating voltage wave at which the circuit happens to be closed. It is stated that this period of time in successive closing of the circuit may vary from this cause alone, the time equivalent of one cycle of alternating current; and, accordingly, that this may cause wandering of nearly one fathom in the registered soundings when the usual frequency of about 500 cycles is used.

Sounding extensively in regular depths of 10 to 16 fathoms, the SURVEYOR has consistently experienced a fluctuation of the neon flash of l/2 fathom as a maximum. As stated in the writer's notes on Fathometer operation, a low frequency of 440 cycles, a high negative grid potential in amplifying tubes and a constant hydrophone current were used to obtain this small fluctuation. The 1/2 fathom variation is then probably entirely due to the circuit being closed at various points of the alternating voltage wave. Since there are two complete impulses to each cycle, it would appear that the difference in registering due to any two closings of the circuit would not exceed the time equivalent of a half cycle, or about l/2 fathom on the Fathometer dial.

The Fathometer sounding was not read as depending on a single flash but rather the mean of the quick succession of about four to six of them constituted the reading. With the hand lead going simultaneously, it was possible to consistently anticipate the hand lead soundings to the nearest 1/4 fathom. A fathometer sounding was read an interval of time before the lead line assumed its vertical position, to have both soundings taken approximately at the same spot. In this respect, the speed of the vessel and distance between sounding chair and oscillator, both on the same side of the vessel, were taken into consideration.

THE 432 TYPE FATHOMETER

Fred A. Riddell and James C. Tison, Jr.
Jr. H. & G. Engineers, U.S.C. & G. Survey.

This report on the 432 type fathometer installed on the U.S.C. & G.S.S. HYDROGRAPHER is made for the purpose of giving a brief outline of various phases of the fathometer's operation during the 1931 Georges Bank field season. Problems met with and corrective measures taken are set forth, but no attempt is made to discuss technically the operation of this fathometer or to theorize concerning imperfections which were noted.

From May 25 to June 29, 1931, Dr. Herbert Grove Dorsey, Senior Electrical Engineer, was assigned to the HYDROGRAPHER. He made all preliminary fathometer adjustments, and actual sounding was begun on June 7 with the apparatus functioning properly. During the first day of sounding, the fathometer dial was set to read depths from the ship's keel, thus necessitating a correction to soundings in amount of the draft of the ship. This correction was of course a part of the total correction obtained by a comparison of fathometer with wire soundings, and made it a rather large figure - as much as seven fathoms at the end of the day. To avoid this large correction, the dial was reset by Dr. Dorsey before beginning work on June 8 so as to read approximate surface depths.

Shortly after hydrography was begun, Dr. Dorsey installed an apparatus for obtaining deep soundings, or those over one hundred fathoms, by which the echo of the slow white light method was converted into a red flashing light on the dial. This new method, hereafter referred to as the slow red light method, was used for deep soundings throughout the remainder of the season, and was found much more satisfactory in degree of accuracy and in ease of reading than the slow white light method which it replaced. Soundings could now be read to the nearest two fathoms, whereas by the slow white light they were readable only to the nearest five fathoms with a possibly large equation of personal error. In water deeper than five hundred fathoms, ship and water noises very often caused a confusing number of flashes on the dial, but by listening to the echo in the head phones it was comparatively easy to pick out the corresponding flash and so obtain accurate soundings.

On June 21 at the end of the sounding day, the spring of the impact oscillator broke and was replaced by a new one. The next morning, when comparisons were made between fathometer and wire soundings, the fathometer was found to have a plus five fathom correction instead of the minus half fathom correction which existed before the spring broke. The outer ring of the rotating disc (red light method) was reset to make the correction approximately zero.

During the sounding day of July 10, the first day of sounding after Dr. Dorsey had been detached, a sudden fluctuation in the position of the initial flash was noted while using the impact oscillator red light method. The ship was stopped shortly afterwards, and good vertical cast comparisons made in fifty fathoms of water showed that the fathometer correction had changed more than three fathoms in a little more than three hours. This change in correction was assumed to have occurred at the time the initial flash fluctuated and was attributed to a slipping of the fathometer dial. The initial flash ordinarily only came in after increasing the fathometer's sensitivity for soundings of more than forty fathoms; therefore this fluctuation would not have been noted had the ship been sounding in shoal waters. Shortly after hydrography was resumed on this date, the slow red light method was employed for the remainder of the day for sounding in the vicinity of Corsair Gorge. Before shifting, however, the impact oscilator apparently operated perfectly.

No hydrography was done again Until July 13, when work was started on Sheet #3 in shoal waters. Comparisons were made at the beginning and end of the day, which was very short, and while the correction had changed three fathoms in three hours, the fathometer had apparently functioned properly. From time to time the initial flash was made to come in for short periods, but no fluctuation or jumping was noticed. It may be well to mention here that the fathometer was always started well before sounding was begun and vertical cast comparisons made. This was done to reduce to a minimum any sudden change in the correction to soundings which might have been caused by changes of temperature as the various parts of the fathometer became heated.

Unfortunately, no comparisons were made on July 14 until the end of the day, when the fathometer was found to be reading four and a half fathoms low. The correction at the start of the day was assumed to be the same as had existed when work was completed on July 13, namely, plus one and one-half fathoms. Upon two occasions shortly before the end of the day, very shoal soundings by the fathometer caused some alarm at the possibility of running aground, but each time the engines were stopped and an attempt made to get hand lead soundings while the ship was still underway. "No bottom" soundings resulted both times with at least five fathoms of leadline in the water, indicating that the fathometer correction had changed considerably. On this date the HYDROGRAPHER was running as "follow ship" to the OCEANOGRAPHER in "tandem" hydrography and it was not convenient to stop for vertical casts. This was especially true at the time the discrepancy in fathometer correction was noted, in view of the fact that the day's work was soon to end. The fathometer had seemingly operated perfectly during the day, and the initial flash was always steady when as an occasional check it was made to come in for short periods. The large change in fathometer correction was at the time attributed to a sudden slipping of the rotating disc, and this disc was again reset to read approximate surface depths. An examination of the smooth sheet, however, shows no place at which a sudden jump can definitely be said to have occurred, The soundings on this day do not check well with other work, and seem to indicate either that a series of such jumps occurred or that the initial flash fluctuation noted on the following day existed at this time also.

On the following morning, July 15, while anchored in fifteen fathoms of water, it was found that successive fathometer soundings differed by as much as 3-1/2 fathoms. The bottom was perfectly regular, but the initial flash of the fathometer wandered back and forth over a short section of the reading scale, with its position having a definite relationship to the error of corresponding soundings. Thus if each sounding was corrected by an amount dependent upon the position of the initial flash, it was made to check with the true depth obtained by vertical casts. A table of corrections was made on this basis and a series of twenty fathometer soundings corrected. These corrected soundings differed at most by three-tenths of a fathom. A small scale was prepared on paper and pasted over that section of the fathometer scale where the initial flash came in, so that by glancing at the position of the flash with respect to this scale it was immediately apparent what correction to apply in order to obtain surface depths. Later during the day a second series of thirty fathometer soundings was corrected in like manner while anchored in 25 fathoms of water. Good results were obtained, and this second series showed that the table of corrections was not dependent upon the depth, but only upon the position of the initial flash of the fathometer. Of course this table of corrections took care only of error due to the fluctuating initial flash, and any error caused by a future slipping of the dial or other mechanical means had to be applied in addition. This fact was apparent on the following day when a plus half fathom correction had to be applied in addition to that discussed above.

Upon arrival in Boston on July 17, the Submarine Signal Company was advised in detail of the trouble which had been encountered with the fathometer. On the 18th they sent two representatives to inspect the apparatus, but the trouble was not determined. A repair engineer made a more thorough inspection on the 20th, and after making timing adjustments and checking all connections, pronounced the fathometer in perfect working order. However, on account of the shallow water alongside the dock, no actual test could be made to determine whether the fluctuation in soundings had been eliminated.

Sounding was resumed on Georges Bank July 23, and while not so pronounced, the initial flash fluctuation still existed. Frequent changes in fathometer correction, irrespective of that due to initial flash fluctuation, also continued and were attributed to a slipping of the outer dial ring. On the 24th this ring was carefully reset to read surface depths and one set screw tapped through into the inner ring to hold the two in the same relative position permanently. No decided improvement in operation resulted, and the same corrections already discussed had to be applied to all soundings.

The ship returned to Boston on July 30th, and on the 31st two representatives of the Submarine Signal Company removed the entire fathometer timing apparatus and took it to the company's laboratories for inspection. It was reinstalled on August 4th, and on the 5th Mr. Turner, of the Submarine Signal Company, sailed with the ship as far as Provincetown to make actual sounding observations while crossing

Cape God Bay. The same initial flash fluctuation continued, and Mr. Turner found that the rotating discs of the fathometer had never been keyed to the shaft of the drive motor. He was undecided as to whether this condition was an oversight in construction or existed because a friction fit was thought sufficient, but nevertheless, upon his advice and under his supervision, the rotating discs were keyed to the drive shaft. This action successfully eliminated the frequent changes in fathometer corrections which had been attributed to dial slipping, but had no effect upon the initial flash fluctuation. Mr. Turner seemed to think the method used in correcting for this fluctuation quite sound, so its use was continued during another trip to Georges Bank.

While in Boston on August 18 the Submarine Signal Company installed an entirely new fathometer striker, with the hope that it would correct the initial flash fluctuations and hence stop the variation in successive soundings taken at a known depth. Its installation apparently had no effect on the fathometer's operation, for upon returning to Georges Bank on August 19 the same trouble still existed.

On August 20 the neon tube suddenly stopped flashing, and when the installation of a new tube and a thorough test of all batteries and radio tubes in the hookup failed to correct the trouble, Mr. Burmister was asked to come over from the OCEANOGRAPHER and ascertain the trouble. After a long search he found that the neon tubes had become charged with a negative charge of electricity, and that by grounding them to remove this charge, the usual flash occurred.

Aside from the fluctuation of the initial flash already described, no further trouble was experienced with the fathometer during the remainder of the season. This fluctuation was never corrected, and after July 14 it was necessary to correct all fathometer soundings by an amount dependent upon the position on the scale at which the initial flash came in. Of course this method necessarily involved a small personal equation of error in that the operator could not read both the initial and echo flashes simultaneously. An examination of smooth sheets, however, shows that sounding done by the HYDROGRAPHER checks itself very nicely, and it is felt that this fact proves accuracy of soundings was not noticeably impaired by imperfections in fathometer operation.

COMMENTS ON THE ABOVE REPORT
Dr. H. G. Dorsey, U.S.C. & G. Survey.

It seems to me that this excellent report proves conclusively that the variations in depth indications are due to changes in the striker rather than in the indicator itself. Of course, the hub should have been pinned or keyed to the shaft by the makers and the omission is inexcusable.

In June, while at the Submarine Signal Company's laboratory, the engineers told me they thought the variations were caused by the indicator and not by the striker, and that they never had any variations when testing the strikers in a tank of water.

In this striker about 0.05 second elapses between the time the circuit is opened and when the plunger hits the diaphragm. This is a long time interval to maintain constant and any uncertainty makes large discrepancies in the indication. Beside going to the bottom to produce an echo, sound from the diaphragm travels along the bottom of the ship to the hydrophone producing what is called the initial in this report, but which I prefer to call the direct signal, as has already been practiced in connection with the 312 type fathometer, the initial flash there meaning a red light flash showing at the instant the oscillator circuit is opened.

Any variations in the surfaces of the plunger and holding magnet, caused by particles of dirt or chips broken from the spring will change the instant of release and produce a variation in the time of striking, and any variation in friction between the plunger and its guides will also cause a change in the time of travel. This latter change may be due to rolling of the ship, and as this is about the only condition not present in the laboratory it may be the principal cause of variation.

Since the direct signal will always appear at a definite interval after the blow is struck, the fluctuations of its occurrence give an indication of the variation in time of producing the sound and, hence, an index of the correction as has been done. It would be interesting to note the effect of rolling to see if it does have any effect and, if so, the amount of correction might be sufficiently anticipated to make easier the reading of the direct signal.

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U. S. Experimental Model Basin
Navy Yard, Washington, D. C.

13 April 1932.

Captain Paul C. Whitney,
U. S. Coast and Geodetic Survey,
Washington, D. C.

My dear Captain Whitney:

I am informed by Lieutenant Roop that you have recently issued a most excellent bulletin under the heading of the Association of Field Engineers, and that we could get some valuable pointers by studying it.

I would greatly appreciate having you arrange to send one or two copies to us so that we may study it first hand.

Very sincerely,

(Sgd.) H. E. Saunders,
Commander, (CC), U.S.N.

REINFORCING CONCRETE BENCH MARKS

(Circular letter sent to Chiefs of Parties attached to Division of Geodesy)

There are quoted below a letter, dated February 27, 1932, from Mr. Lewis A. McArthur, Secretary of the Oregon Geographic Board, Portland, Oregon, dealing with the question of reenforcing concrete bench marks, and a letter dated March 20, 1932, written by Mr. Jasper S. Bilby, Chief Signalman of the U. S. Coast and Geodetic Survey, to whom the letter was referred for comment and suggestions.

I feel confident that the information and advice given by Mr. Bilby will be of great value to every chief of party and to those members of the several parties who are engaged in setting bench marks and triangulation stations.

Mr. McArthur's letter reads as follows:

"It is apparent that, in a number of places in this state during the past year, your concrete bench mark posts have been broken off at the top by impact of vehicles.

"I would recommend that serious consideration be given to the matter of reenforcing the tope of these posts. The work would be very simple and certainly not costly. Almost any piece of scrap iron or heavy wire between 18 inches and 2 feet long could be stuck into the forms and would provide suitable reenforcing. There is no doubt that the field crews could for a very small sum pick up junk material around blacksmith shops and garages which could be used for this purpose. Almost any electric power and light utility would be glad to give you surplus transformer hooks, which would be highly suitable and which can be had for the asking in most cases."

Mr. Bilby's letter reads as follows:

"I have your letter of March 14, enclosing a copy of a letter from Lewis A. McArthur, of Portland, Oregon, regarding the reenforcing of concrete bench marks.

"If I understand Mr. McArthur correctly, the top of the marks were not chipped off on the edges and corners, as marks often are, but all the top was broken off. If that is the case, there is no question in my mind but that the cause was due to faulty material and poor workmanship on the part of the man who set the marks.

"When setting the marks the hole is dug and concrete is filled in up to near the surface of the ground, then the form for the top is set on and the form is filled with concrete, level with the top of the form. When the form is set on, loose dirt often falls in on the concrete, or if the hole has not been made large enough to take the form, the edges are trimmed and the dirt falls in on the concrete. If the men are not very careful in removing the loose dirt which has fallen on the cement, the dirt will be absorbed by the water and cement. The result will be that, when the concrete is placed in the form, it will not be thoroughly mixed with the concrete that had been placed in the hole. A dirt seam may thus be formed, completely across the post, so that any heavy jolt on the mark will break it off at the dirt seam. Also the dirt would let in moisture which would freeze, if the station should be in high latitude, and the top would be lifted off or loosened, so that the slightest jar would break it off.

"Reenforced rods in such cases would hold the top on for a time, but not permanently. Moisture and air have no respect for Government regulations of hours of labor for a day of work. They work twenty-four hours per day including Sundays, then comes the freeze during the winters and the combined work of the three elements would, in a few years, destroy the block of concrete.

"I have often found old concrete blocks with the corners and top edges chipped off. Reenforced rods would not prevent the corners from being broken off and it is quite probable that if rods were placed near the corners and they became exposed, the small boys and some of the old boys would take pleasure in bending the rods and further destroying the mark.

"I have a very good test applied to all concrete marks set for the triangulation stations. When the tower is taken down, the forms are taken off of the concrete blocks and sent forward. In removing the forms, the man takes an axe, pick or some heavy bar and gives the form a few heavy jolts to break it loose from the concrete. He then takes a bar and pries the form off. Should there be a dirt seam, the heavy jolts would break the top loose and the top of the concrete block would come off with the form. I have had this happen a few times.

"The reenforced concrete blocks may add a little to their life, but the all important thing is good material, good workmanship and a man that can be trusted to do first class work at all times. Marks should be tested quite often by giving them a heavy jolt on the sides near the top. This will jar the top loose in case of a dirt seam.

"Necessarily, the chief of party must train new bench mark setters and tell them of the importance of not letting any dirt fall into the concrete. If the man in charge of setting the bench marks cannot grasp the significance of this or if, through carelessness, he does not improve his methods, he should be placed on other work and a more careful man be given the task of setting the marks. This applies also to setting marks for triangulation stations.

"Should you decide to use the rods for reenforcing the concrete, they should be placed far enough from the corners or edges so they will not become exposed if the edges are chipped off the top of the block."

The letters quoted above bring up a most important subject and I should like to have the opinions of various chiefs of parties and of other members of the Division of Geodesy which may lead to securing the most perfect marks for leveling bench marks and triangulation stations that it is possible to obtain. Of course, we cannot go to excessive expense in making our marks because it is a great deal better to have much leveling and triangulation done, with very good marks, than to cut down the amount of actual surveying by the use of large amounts of money to secure what might be called absolutely permanent marks. There is a desirable balance that should be maintained in the division of our funds among the different parts of the work, but a reasonable degree of permanency in the marks set is of prime importance.

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COMMENT ON THE ABOVE

N. H. Heck, Chief, Division of
Terrestrial Magnetism and Seismology

In view of the plan for using triangulation stations for magnetic stations, consideration should be given to the possibility that the introduction of reenforcing material in the concrete might produce artificial magnetic disturbance sufficient in amount to affect magnetic observations made over the mark. While no quantitative results are available on which to base an estimate of the possible amount of induced magnetism in the rods or wire used for reenforcement, and although the effect would probably be negligible as far as declination and horizontal intensity observations are concerned, it might be sufficient to give different values of dip for different heights of the instrument above the mark, and thus introduce a possibility of error in the determination of secular change of dip at a station at which observations are repeated from time to time.

Wm. Bowie, Chief, Division of Geodesy.

Responses to the circular letter regarding reinforcement of bench marks would indicate that the best method of preventing destruction of a mark, from collision or shock, is to have good materials for the concrete and to have them properly mixed. I concur in this view.

Necessarily, the triangulation mark should not be reinforced with iron or steel for it is certain that these marks will be used very extensively in the future by magnetic observers of this Bureau and by local engineers and surveyors in getting the variation of the compass.

Bench marks, and other monuments perpetuating surveying stations, should, as far as possible, be placed in positions that will be least subject to disturbance.

REFRACTION ON GEORGES BANK, 1931

L. S. Hubbard, H. & G. Engineer, U.S.C. & G. Survey

REFRACTION: When an observer at sea uses a sextant he measures an angle between two rays of light. In the case of star sights, one ray comes from the star, the other from the horizon below the star. He does not measure the true angle because the paths of both rays are bent by refraction.

Light In passing through a gas will be refracted as the density, temperature, and composition of the gas changes. Light from the stars will pass from a vacuum and absolute zero temperature through increasing pressures and temperatures of air to the final pressure and temperature of air at the earth's surface. The total amount of refraction will depend upon the angle of incidence through these successive layers of air. Tables in Bowditch give the refraction for all angles of incidence and for a standard pressure and temperature at the observer. Additional tables give the corrections for variations from the standard pressure and temperature. Changes in refraction due to humidity are slight and may be neglected. The pressure, temperature, and humidity at the observer are the only data that the observer can obtain of the medium through which the light rays pass from the star to the observer.

Light rays from the horizon to an observer on shipboard also pass through a medium of varying properties. These variations are unknown, except that the temperature at the horizon may be assumed to be known because the temperature of the water is usually uniform over a large area and will usually be the same at the horizon as measured at the ship.

Observations were taken in 1931 on Georges Bank to determine what effect the difference in temperature between the surface water and the air temperature at the observer had on refraction. The dip to the horizon was measured and compared with the computed dip under normal conditions of the atmosphere. The difference between the observed and the computed dip was assumed to be due to refraction resulting from the difference between air and water temperatures.

INSTRUMENT USED: A Pulfrich "horizon meter" was used to measure the dip of the horizon. In this instrument the horizons to the left and right of the observer are reflected through mirrors to an eyepiece in such a way that when the horizons are in coincidence the dip of the horizon may be read on a micrometer screw. This instrument is described in detail in an article by Captain E. Moll in the May, 1931, issue of "The Hydrographic Review".

This instrument takes practice to use effectively because the horizons appear as vertical lines, and the rocking motion of the wrist required to keep the horizons in coincidence while the ship is rolling and pitching differs from that used with a sextant and feels awkward at first.

Discrepancies in successive readings indicated that the dip of the horizon can be measured within an accuracy of two-tenths of a minute in arc. The greatest fault found with this instrument was that the index error changed from day to day. To eliminate this error, the instrument was read in a direct and in a reversed position, and the initial reading subtracted from the average reading. Even this may not have eliminated error due to shifting occurring between direct and reverse readings. The readings on a single day, however, indicate that such errors were slight.

<u>METHOD OF OBSERVING</u>: Observations were taken at three heights of eye, at 14-1/2 feet on the forecastle deck, at 24-1/2 feet on the navigation bridge, and at 32 feet on the flying bridge. At each height of eye two sets of observations were made at right angles to each other, and a third set in whatever direction the horizon appeared best. It was hoped to determine by this manner of observing whether the refraction varied in different parts of the horizon. The errors of observation, however, were greater than any differences found between sets taken at right angles.

At the same time the dip was observed, the temperature of the surface water and of the air at the height of the observer was taken, and the barometric pressure and the humidity on the bridge were noted. The temperatures of air and water were taken with a centigrade thermometer standardized by the Bureau of Standards.

<u>LIMITED QUANTITY OF OBSERVATIONS</u>: Sights were taken only on days when the horizon was clear and definite. This limited the number of sights taken since fog or haze prevails much of the time on Georges Bank.

<u>RESULTS</u>: The results of these observations are somewhat incomplete and unsatisfactory. The results plotted on graph paper give a scattered pattern through which no definite curve can be drawn. To compare the results obtained on Georges Bank with those given by Koss' formula, $\text{Dip} = 1.82\sqrt{h} - .003h - 0.41\Delta$ ("h" equals the height of eye and Δ equals the temperature of the air minus the temperature of the water), a dotted curve based on the third term of Koss' formula was drawn on graph paper, and a full line paralleling Koss' curve was drawn averaging the results obtained on Georges Bank. This curve is 0.40 of a minute below Koss' curve, indicating that the formula from $1^\circ\Delta$ to minus $1^\circ\Delta$, centigrade, when applied to Georges Bank would have an added constant term, -0.40. The formula would be as follows:
+ $\text{Dip} =.1.82\sqrt{h} - 0.003h - 0.41\Delta - 0.40$.

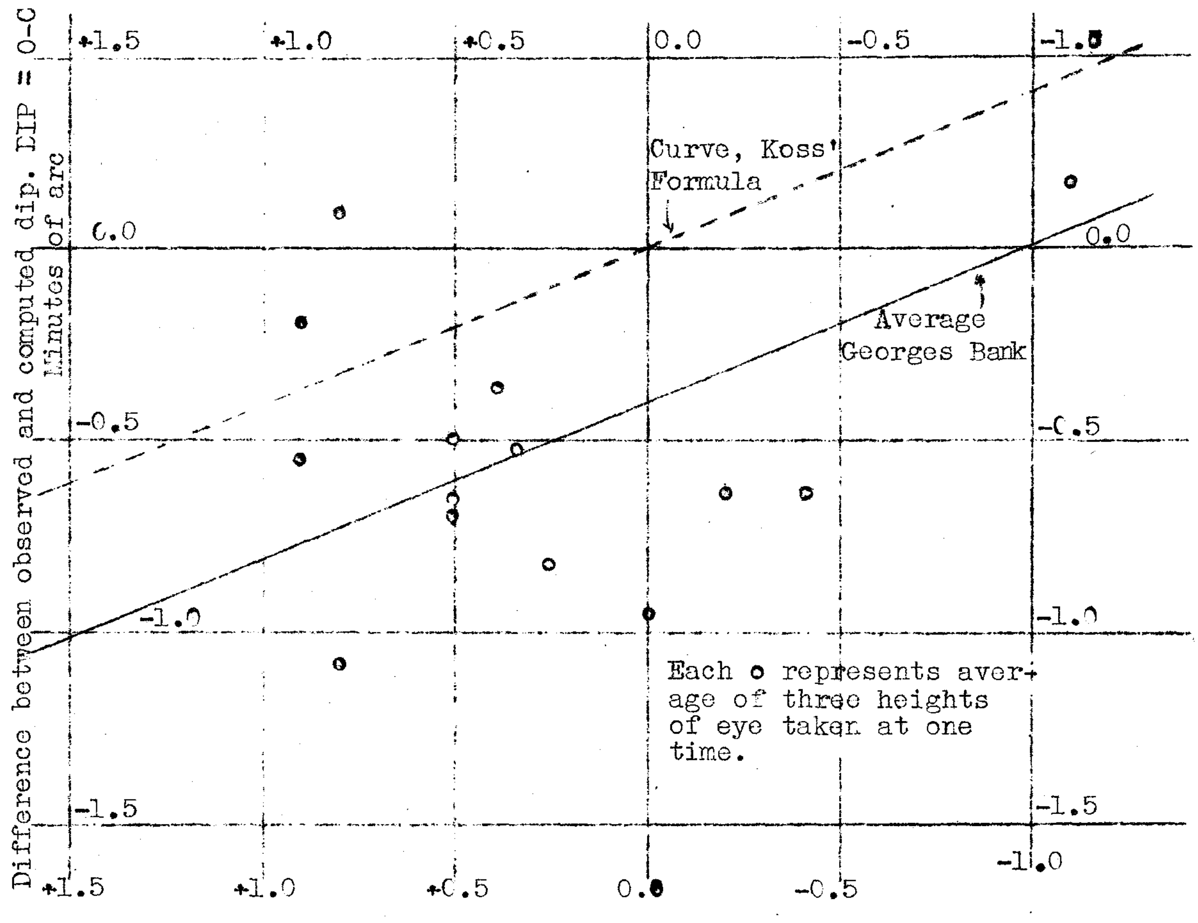
Incidentally, the curve based on the previous season's star sights has the same constant, -0.40, The formula for dip based on the curve of the previous season's star sights from plus $1^\circ\Delta$ to plus 6°, Fahrenheit, was $\text{Dip} = 1.82\sqrt{h} - .003h - 0.17\Delta - 0.40$
or expressing in degrees Centigrade, $\text{Dip} = 1.82\sqrt{h} - .003h - 0.30\Delta - 0.40$

It will be noted that the differences between air and water temperatures in 1931 were small compared with those of the season previous, usually being less than one degree centigrade. This was because the Ship LYBONIA worked in waters about 40 miles west of where she did the season previous and that much further from the Gulf Stream.

<u>CONCLUSION</u>: The unsatisfactory results are considered due to two facts. First, the dip measuring instrument is not precise enough in measuring the dip. Second, the temperature of the water and air at the horizon and of the air along the line of sight are not actually known. It is assumed that the water temperature at the point in the horizon observed is the same as that observed at the ship and this may be true much of the time, but certainly not all the time in a shoal area of strong and changing currents such as Georges Bank.

An abstract of the dip observations is shown on an accompanying plate.

COMPARISON BETWEEN RESULTS OBTAINED ON
GEORGES BANK AND THOSE GIVEN BY KOSS' FORMULA



Difference in Air and Water Temperatures, Δ = (A-W) Degrees Centigrade

ABSTRACT OF DIP OBSERVATIONS, GEORGES BANK, 1931.

Date & Time	Place	Horizon & Weather	Therm. Dry } Wet } Humidity	Barom. inches Therm. Att.	Hgt. of eye feet	Obs. Dip	Comp. Dip	Diff. Dip O - C '	Temp. Air "C"	Temp. Water "C"	Diff. Temp. A - W
Aug.22 1-20 PM	"BOY" Lat. 41-14 Long.67-52	Excell- ent. Breeze		30:08 65.5°F	15½ 24½ 32	3.10 4.33 4.32	3.85 4.85 5.55	-.75 -.52 -1.23 Av.-0.83	17.75 17.80 17.70	17.50	+0.25 +0.30 +0.25 Av.+0.25
Aug.22 3-30 PM	"BOY" Lat. 41-14 Long.67-52	Clear cut	67.0°F 66.5°F 97½%	30:11 70.0°	15½ 24½ 32	2.78 4.55 5.10	3.85 4.85 5.55	-1.07 -0.30 -0.45 Av.-0.61	16.7 16.8 16.6	16.9	-0.2 -0.1 -0.3 Av.-0.2
Aug.23 9-30 AM	"KING" Lat.41-04 Long.67-38	Clear ship rolling & pitch- ing.	64.4 63.1 97%	31.04 79.0	15½ 24½ 32	2.80 4.92 4.90	3.85 4.85 5.55	-1.05 +0.07 -0.65 Av.-0.54	16.8 17.0 16.5	15.9	+0.9 +1.1 +0.6 Av.+0.9
Sep. 4 9-25 AM	"GEORGE" Lat. 41-23 Long.67-40	Fair - raining Light swell	67.0 69.9 99½%	29.93 75.5	15½ 24½ 32	4.30 5.10	3.85 4.85 5.55	+0.45 -0.25 Av.+0.10	18.8 18.9	18.0	+0.8 +0.9 Av.+0.8
Sep. 7 9-20 AM	"TARE" Lat. 41-27 Long.68-00	Excell- ent.Mod. swell & breeze	66 64 90%	29.77 69.2	15½ 24½ 32	3.48 4.62 5.05	3.85 4.85 5.55	-0.37 -0.23 -0.50 Av.-0.37	17.2 17.7 17.5	17.2	0 +0.5 +0.3 Av.+0.4
Sep. 7 3-00 PM	"TARE" Lat. 41-27 Long.68-00	Excell- ent.Mod. swell fr.NNW breeze	65 64 95%	29.75 79	15½ 24½ 32	2.65 4.00 4.68	3.85 4.85 5.55	-1.20 -0.85 -0.87 Av.-0.97	17.7 17.6 17.8	17.7	0 -0.10 +0.10 Av. 0
Sep. 8 9-00 AM	"TARE" Lat. 41-27 Long.68-00	Excell- ent Mod. sea & Bz.	66.0 65.1 93%	29.75 68.5	15½ 24½ 32	2.93 4.27 5.13	3.85 4.85 5.55	-0.92 -0.58 -0.42 Av.-0.64	17.3 18.0 17.7	17.2	+0.1 +0.8 +0.5 Av.+0.5
Sep. 8 4-45 PM	"TARE" Lat. 41-27 Long.68-00	Excell- ent Mod. Sea & Bz.	67.5 67.0 97½%	29.77 78.5	15½ 24½ 32	3.27 4.20 4.88	3.85 4.85 5.55	-0.58 -0.65 -0.67 Av.-0.63	17.1 18.0 17.5	17.9	-0.8 +0.1 -0.4 Av.-0.4
Sep. 9 9-15 AM	"TARE" Lat. 41-27 Long.68-00	Exc. smooth sea Lt. NW'ly Bz.	66 66 100%	29.80 72.0	15½ 24½ 32	3.22 4.50 4.98	3.85 4.85 5.55	-0.63 -0.35 -0.57 Av.-0.52	17.4 18.0 17.3	17.25	+0.15 +0.75 +0.05 Av.+0.32
Sep. 9 6-50 PM	"SAIL" Lat. 41-41 Long.67-52	Exc. smooth sea Lt. airs.	64.0 63.5 97½%	29.84 77.0	15½ 24½ 32	3.40 4.26 5.10	3.85 4.85 5.55	-0.45 -0.59 -0.45 Av.-0.50	18.6 17.1 16.5	17.1	+1.5 0 -0.6 Av.+0.5
Sep.10 9-10 AM	"SAIL" Lat. 41-41 Long 67-52	Exc. smooth sea Lt. airs.	67.6 66.8 96%	29.97 73.0	15½ 24½ 32	2.50 3.80 4.70	3.85 4.85 5.55	-1.35 -1.05 -0.85 Av.-1.08	18.1 18.5 18.4	17.5	+0.6 +1.0 +0.9 Av.+0.8
Sep.16 7-00 PM	"CAST" Lat. 40-55 Long 68-25	Fair Mod.sea & breeze	61.5 60.5 94%	30.17 71.0	15½ 24½ 32	3.40 4.00	3.85 4.85	-0.45 -0.85 Av.-0.19	15.4 16.0	15.2	+0.2 +0.8 Av.+0.5
Sept.17 1-40 PM	 Lat. 41-21 Long.67-56	Good Lt.sea Lt.airs	67.4 66.1 94%	29.99 71.5	15½ 24½ 32	2.46 * 2.33 2.37	3.85 4.85 5.55	-1.39 * -2.52 -3.18 Av.-2.36	18.1 19.2 18.7	18.3	-0.2 +0.9 +0.4 Av.+0.4
Sep. 18 11-20 AM	"BOY" Lat. 41-14 Long.67-52	Good	67.0 66.0 95%	29.83 73.5	15½ 24½ 32	3.40 4.80 5.47	3.85 4.85 5.55	-0.45 -0.05 -0.07 Av.-0.19	18.4 19.4 18.5	17.9	+0.5 +1.5 +0.6 Av.+0.9
Sept.19 1-40 PM	"OBOE" Lat. 42-03 Long.67-25	Exc. sl.roll fr.NW'ly breeze.	58.5 54.4 78%	31.9 72.0	15½ 24½ 32	4.03 5.03 5.77	3.85 4.85 5.55	+0.18 +0.18 +0.22 Av.+0.19	11.6 14.0 12.0	13.6	-2.0 +0.4 -1.6 Av.-1.1

* Observations questionable.

C.&G.S. 442

CREATING A HORIZON

BY LIEUTENANT COMMANDER J. Y. DREISONSTOK, U. S. NAVY

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THE modern navigator is so indoctrinated with the use of the sea horizon, that it becomes difficult to persuade him that there are other methods of bringing down a heavenly body so as to obtain a true altitude. In the good old days it was not an infrequent occurrence to see a ship's captain make use of a soup plate of molasses in taking his time sight. And this is still a good practice, especially when one takes full advantage of the use of gimbals by placing the plate of molasses atop his pelorus.

The vagaries of our friend "sea horizon" are so many that at times one wonders where he is. Especially is this true in localities where there is a marked difference in temperature between the air and sea water. This is especially so around the Gulf Stream where the water is so much warmer than the air that the sea horizon is often displaced as much as 14' of arc. One of the most striking examples of displaced horizons occurs in the Red Sea. The hot winds and sands blowing from the deserts create a marked difference between the air and sea water temperatures, and the visible horizon is raised out of all proportion to its true position. As a result the dip is decreased and the resultant true altitude is often as much as 18' greater than that obtained by using the ordinary dip table.

During the past three or four concentrations of the fleet at Panama, the navigation of our ships has been sharply criticized. Let us consider the reasons that caused poor navigation (or rather, poor results) during these maneuvers. There is a general drift current that sets to the north out of the antarctic regions. This current upon striking the shores of the South American continent is divided into two branches. One of these branches, known as the Peruvian, Chilean, or Humboldt current, flows northeast in the direction of Valparaiso conforming somewhat to the coast lines of Chile and Peru. Near Cape Blanco the current leaves the coast of America and bears toward the Galapagos Islands. This current is exceedingly cold. As an illustration, on one side of Albermarle Island of this group the temperature of the sea was once found to be 80° while on the other side of the same island it was 60°—a difference of 20°. Small wonder that our old friend, the sea horizon, has the "jumps" especially when we consider that these islands are practically on the equator.

It is the writer's belief that this remarkable current has considerable effect on our navigation outside of the Panama Bay area. From the writer's own experience, there have been many days when a heavy mist hung over the horizon in spite of a beautiful sky overhead.

To overcome these difficulties of navigation in regions where this condition exists, whether the horizon can be seen or not, it is recommended that the method to be described be used when possible.

The use of another ship as a horizon is by no means new. It has been described and used on many occasions. However, the writer has compiled a set of convenient tables with which to correct the resultant altitude, thus making such a procedure easy.

The method is simple. The observing ship directs the "target" ship to steam on a course at right angles to the bearing of the heavenly body. The observing ship then steams on a parallel course on the line of bearing of the "target" ship and the heavenly body and at a known distance from the "target" ship. The heavenly body is then brought down to the water line of the "target" ship and corrections from table A and B are applied similar to the method employed in the front of *H. O. Publication No. 208.* Table A contains the correction to be applied for semidiameter, parallax, and refraction in the case of the sun and for the mean refraction in the case of stars. Table B contains the dip to be applied for various heights of eye and for various distances in yards between the two ships. It was computed from the formula :-

$$\text{dip} = \frac{565h}{d} + .423d$$

where h = height of eye in feet,
and d = distance between the ships in nautical miles.

From an inspection of them it will be seen that the lower the height of eye and the further away the "target" or horizon, the less the correction becomes.

CORRECTIONS TO BE APPLIED TO THE OBSERVED ALTITUDE OF THE SUN'S LOWER LIMB OR OF A STAR TO FIND THE TRUE ALTITUDE WHEN ANOTHER SHIP OR THE SHORE IS USED AS A HORIZON.

TABLE A

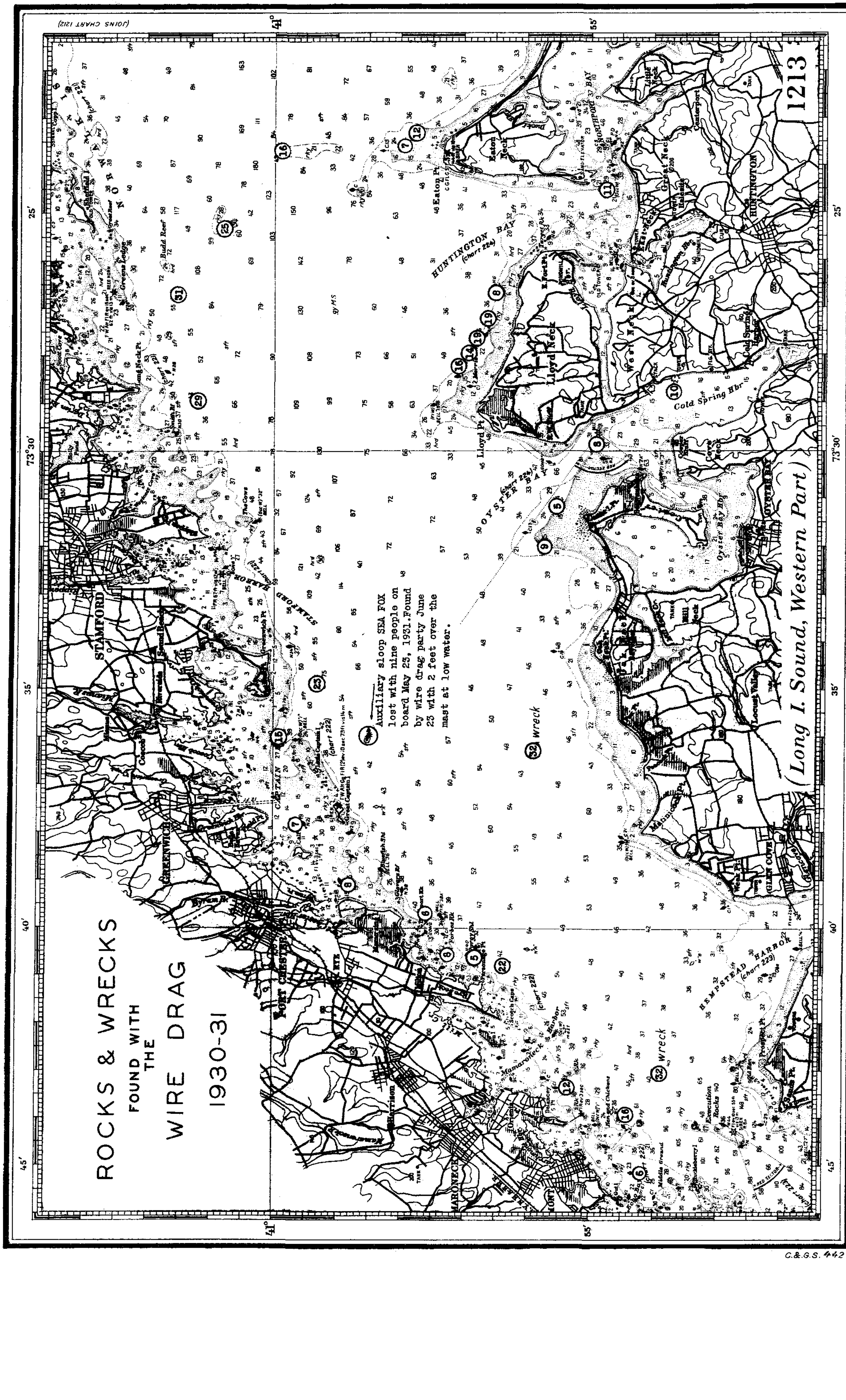
OBS. ALT.	SUN'S CORR.	STAR'S CORR.
° ′	′	′
6 30	+ 8.3	-7.9
7 00	+ 8.8	-7.4
7 30	+ 9.2	-7.0
8 00	+ 9.6	-6.6
8 30	+10.0	-6.2
40	+10.1	-6.1
50	+10.2	-6.0
9 00	+10.3	-5.9
20	+10.5	-5.7
40	+10.7	-5.5
10 00	+10.8	-5.3
20	+11.0	-5.2
40	+11.2	-5.0
11 00	+11.3	-4.9
30	+11.5	-4.6
12 00	+11.7	-4.5
30	+11.9	-4.3
13 00	+12.0	-4.1
30	+12.2	-4.0
14 00	+12.3	-3.8
15 00	+12.6	-3.6
16 00	+12.8	-3.3
17 00	+13.0	-3.1
18 00	+13.2	-3.0
19 00	+13.4	-2.8
20 00	+13.5	-2.6
22 00	+13.8	-2.4
24 00	+14.0	-2.2
26 00	+14.2	-2.0
28 00	+14.3	-1.8
30 00	+14.5	-1.7
32 00	+14.6	-1.6
34 00	+14.7	-1.4
36 00	+14.8	-1.3
38 00	+14.9	-1.2
40 00	+15.0	-1.2
45 00	+15.2	-1.0
50 00	+15.3	-0.8
55 00	+15.4	-0.7
60 00	+15.5	-0.6
65 00	+15.6	-0.5
70 00	+15.7	-0.4
75 00	+15.8	-0.3
80 00	+15.9	-0.2
85 00	+15.9	-0.1
90 00	+16.0	-0.0

TABLE B

Height of eye	DISTANCE OF SHIP USED AS HORIZON IN YARDS												
	500	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000
Feet	′	′	′	′	′	′	′	′	′	′	′	′	′
10	-22.7	-11.5	-6.1	-4.4	-3.7	- 3.3	-3.2	-3.1					
11	-25.0	-12.6	-6.6	-4.8	-4.0	-3.5	-3.3	-3.3					
12	-27.3	-13.8	-7.2	-5.2	-4.2	-3.8	-3.6	-3.4	-3.4				
13	-29.5	-14.9	-7.8	-5.5	-4.5	-4.0	-3.7	-3.6	-3.5				
14	-31.8	-16.0	-8.3	-5.9	-4.8	-4.2	-3.9	-3.7	-3.7				
15	-34.0	-17.2	-8.9	-6.3	-5.1	-4.4	-4.1	-3.9	-3.8				
16	-36.3	-18.3	-9.5	-6.7	-5.4	-4.7	-4.3	-4.1	-4.0	-4.0			
17	-38.5	-19.4	-10.0	-7.0	-5.6	-4.9	-4.5	-4.2	-4.1	-4.0			
18	-40.8	-20.6	-10.6	-7.4	-5.9	-5.1	-4.7	-4.4	-4.2	-4.2			
19	-43.0	-21.7	-11.2	-7.8	-6.2	-5.4	-4.8	-4.6	-4.4	-4.3	-4.3		
20	-45.3	-22.8	-11.7	-8.2	-6.5	-5.6	-5.1	-4.7	-4.5	-4.5	-4.4		
21	-47.6	-23.9	-12.3	-8.6	-6.8	-5.8	-5.2	-4.9	-4.7	-4.6	-4.5		
22	-49.8	-25.1	-12.9	-8.9	-7.1	-6.0	-5.4	-5.8	-4.8	-4.7	-4.6		
23	-52.1	-26.2	-13.4	-9.3	-7.3	-6.3	-5.6	-5.2	-4.9	-4.8	-4.7	-4.7	
24	-54.4	-27.4	-14.0	-9.7	-7.6	-6.5	-5.8	-5.4	-5.1	-5.0	-4.9	-4.8	
25	-56.6	-28.5	-14.5	-10.1	-7.9	-6.7	-6.0	-5.5	-5.2	-5.0	-4.9	-4.9	
26	-58.9	-29.6	-15.1	-10.4	-8.2	-6.9	-6.2	-5.7	-5.4	-5.2	-5.1	-5.0	
27	-61.1	-30.7	-15.7	-10.8	-8.5	-7.2	-6.3	-5.8	-5.5	-5.3	-5.2	-5.1	-5.1
28	-63.4	-31.9	-16.3	-11.2	-8.8	-7.4	-6.6	-6.0	-5.7	-5.5	-5.3	-5.2	-5.2
29	-65.6	-33.0	-16.8	-11.6	-9.1	-7.6	-6.7	-6.2	-5.8	-5.5	-5.4	-5.3	-5.3
30	-67.9	-34.1	-17.4	-11.9	-9.3	-7.8	-6.9	-6.3	-5.9	-5.7	-5.5	-5.4	-5.4
31	-70.2	-35.2	-17.9	-12.3	-9.6	-8.1	-7.1	-6.5	-6.1	-5.8	-5.6	-5.5	-5.5
32	-72.5	-36.4	-18.5	-12.7	-10.0	-8.3	-7.3	-6.7	-6.2	-6.0	-5.8	-5.7	-5.6
33	-74.7	-37.5	-19.1	-13.1	-10.2	-8.5	-7.5	-6.8	-6.3	-6.1	-5.8	-5.7	-5.6
34	-76.9	-38.6	-19.6	-13.5	-10.5	-8.7	-7.7	-7.0	-6.5	-6.2	-6.0	-5.8	-5.7
35	-79.2	-39.8	-20.2	-13.8	-10.8	-9.0	-7.8	-7.1	-6.6	-6.3	-6.1	-5.9	-5.8
36	-81.5	-40.9	-20.8	-14.2	-11.0	-9.2	-8.1	-7.3	-6.8	-6.4	-6.2	-6.1	-6:0
37	-83.7	-42.0	-21.3	-14.6	-11.3	-9.4	-8.2	-7.4	-6.9	-6.6	-6.3	-6.1	-6.0
38	-86.0	-43.2	-21.9	-15.0	-11.6	-9.6	-8.4	-7.6	-7.1	-6.7	-6.4	-6.2	-6.1
39	-88.2	-44.3	-22.5	-15.3	-11.9	-9.9	-8.6	-7.8	-7.2	-6.8	-6.5	-6.3	-6.2
40	-90.6	-45.5	-23.0	-15.7	-12.2	-10.1	-8.8	-8.0	-7.4	-7.0	-6.7	-6.5	-6.3
41	-92.8	-46.5	-23.6	-16.1	-12.4	-10.3	-9.0	-8.1	-7.5	-7.1	-6.8	-6.5	-6.4
42	-95.0	-47.7	-24.2	-16.5	-12.7	-10.6	-9.2	-8.2	-7.6	-7.2	-6.9	-6.6	-6.5
43	-97.3	-48.8	-24.7	-16.8	-13.0	-10.8	-9.4	-8.4	-7.8	-7.3	-7.0	-6.7	-6.6
44	-99.6	-50.0	-25.3	-17.2	-13.3	-11.0	-9.6	-8.6	-7.9	-7.5	-7.2	-6.9	-6.7
45	-101.8	-51.1	-25.8	-17.6	-13.6	-11.2	-9.7	-8.7	-8.0	-7.6	-7.2	-7.0	-6.8
46	-104.1	-52.2	-26.4	-18.0	-13.9	-11.5	-9.9	-8.9	-8.2	-7.7	-7.3	-7.1	-6.9
47	-106.3	-53.3	-27.0	-18.4	-14.1	-11.7	-10.1	-9.0	-8.3	-7.8	-7.4	-7.2	-7.0
48	-108.7	-54.5	-27.6	-18.7	-14.4	-11.9	-10.3	-9.3	-8.5	-8.0	-7.6	-7.3	-7.1
49	-110.8	-55.6	-28.1	-19.1	-14.7	-12.1	-10.5	-9.4	-8.6	-8.1	-7.7	-7.4	-7.2
50	-113.1	-56.7	-28.7	-19.5	-15.0	-12.4	-10.7	-9.5	-8.7	-8.2	-7.8	-7.5	-7.2
51	-115.4	-57.8	-29.2	-19.9	-15.3	-12.6	-10.9	-9.7	-8.9	-8.3	-7.9	-7.6	-7.3
52	-117.6	-59.0	-29.8	-20.2	-15.6	-12.8	-11.0	-9.9	-9.0	-8.4	-8.0	-7.7	-7.4
53	-119.9	-60.1	-30.4	-20.6	-15.8	-13.0	-11.2	-10.0	-9.2	-8.6	-8.1	-7.8	-7.5
54	-122.1	-61.2	-30.9	-21.0	-16.1	-13.3	-11.4	-10.2	-9.3	-8.7	-8.2	-7.9	-7.6
55	-124.4	-62.4	-31.5	-21.4	-16.4	-13.5	-11.6	-10.3	-9.5	-8.8	-8.3	-6.0	-7.7
60	-135.7	-68.0	-34.3	23.2	-17.8	-14.6	-12.6	-11.2	-10.2	-9.4	-8.9	-8.5	-6.2
65	-147.0	-73.7	-37.1	-25.1	-19.2	-15.7	-13.5	-11.9	-10.9	-10.1	-9.5	-9.0	-8.7
70	-158.3	-79.3	-40.0	-27.0	-20.7	-16.9	-14.4	-12.8	-11.2	-10.7	-10.0	-9.5	-9.1
75	-169.6	-85.0	-42.8	-28.9	-22.1	-18.0	-15.4	-13.6	-11.9	-11.3	-10.6	-10.0	-9.6
80	-180.9	-90.6	-45.6	-30.8	-23.5	-19.1	-16.3	-14.4	-13.0	-12.0	-11.2	-10.6	-10.1
85	-192.2	-96.3	-48.4	-32.7	-24.9	-20.3	-17.3	-15.1	-13.7	-12.6	-11.7	-11.1	-10.5
90	-203.5	-101.9	-51.3	-34.6	-26.3	-21.4	-18.2	-16.0	-14.4	-13.2	-12.3	-11.6	-11.0
95	-214.8	-107.6	-54.1	-36.4	-27.7	-22.5	-19.2	-16.8	-15.1	-13.8	-12.9	-12.1	-11.5
100	-226.1	-113.2	-56.9	-38.3	-29.1	-23.7	-20.1	-17.6	-15.8	-14.5	-13.4	-12.6	-12.0

ADDITIONAL CORRECTION FOR SUN'S ALTITUDE

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
+'.3	+'.2	+'.2	-'.0	-'.2	-'.2	-'.2	-'.2	-'.1	+'.1	+'.2	+.'3


ROCKS & WRECKS
FOUND WITH
THE
WIRE DRAG
1930-31
1213
(Long I. Sound, Western Part)
Auxiliary sloop SEA FOX
lost with nine people on
board May 23, 1931. Found
by wire drag party June
23 with 2 feet over the
mast at low water.
STAMFORD
GREENWICH
PORT CHESTER
MAMARONECK
HUNTINGTON
HUNTINGTON BAY
OYSTER BAY
Cold Spring Hbr
Lloyd Neck
Eaton Neck
HEMPSTEAD HARBOR
wreck
(JOINS CHART 1212)

C.&G.S. 442

GYRO EQUIPMENT OF THE HYDROGRAPHER

Elliott B. Roberts, H. & G. Engineer, U.S.C. & G. Survey

Condensed from Report "Compass Equipment of Ship HYDROGRAPHER" (Report No. 175 - 1931)

The gyro compass on the HYDROGRAPHER is a Sperry Mark VIII standard design, with a 60-pound rotor which operates normally at 6,000 r.p.m. It is so suspended that the only constraint upon complete freedom of the rotor is that applied by the weight of a mercury ballistic. The rotor tends to hold a direction fixed in space. Unless its axis is parallel with that of the earth, it tilts from the horizontal as the earth rotates. The resulting flow in the ballistic produces unbalanced weight which acts upon the rotor, precessing it toward parallelism with the earth's axis. The precession is oscillatory, of about 85 minutes period, and two-thirds of the amplitude is damped out with each swing. If the gyroscope is started with its axis approximately oriented, it will lie virtually on the meridian within 15 to 30 minutes, but from a random start several hours may be required.

A motor controlled from the rotor through a virtually frictionless trolley contactor does the work of turning the compass card and the repeater transmitter. This azimuth motor actually oscillates its driven parts rapidly over an angle of about a degree as the trolley rides from one segment of the contactor to the other. This oscillation, or "hunt", is eliminated from the repeater indications by a "lost motion" linkage connecting the compass card and the transmitter. It should be noted that the "hunt" must be controlled at a proper value to correspond exactly with the lost motion of this linkage, else a lag (or a "hunt") will prevail in the repeater indications.

A converter supplies the three-phase rotor current; all other parts of the equipment operate under direct current supplied at the proper voltages from the control panel.

The maintenance has not been found arduous. An hour or two a week suffices for the necessary cleaning and lubrication. Frequent azimuth sights are taken as a check, though this is a perfunctory routine when the compass is functioning under proper adjustment.

Our experience has shown the apparatus to be sturdy, the only mechanical troubles having been traceable to burned resistances, the result of surges of high voltage from the ship's auxiliary generators.

It has been found that it is easy to prevent deviations once a reasonable familiarity with the mechanism is obtained. Deviations are of two kinds - semi-permanent and variable. The semi-permanent deviations are the result of so many complicated phases of the balancing of the gyroscope that they can not here be described. If of large magnitude they demand readjustment of the whole apparatus. If small they can easily be compensated by a simple adjustment of the torsion of the suspension, a flexible cable upon which is hung the entire weight of the rotor and its case. The adjustments affecting semi-permanent deviation, including that of the suspension, are lasting and positive.

Variable deviations have been found to result from a number of things, principal of which has been fluctuating line voltage, which, of course, causes accelerations in rotor speed and changes the dynamics of the whole mechanism. Other possible causes are undue friction in bearings, dirty mercury in the ballistic, dirty or burned contactors and trolleys. After a sufficient degree of experience was obtained so that all these causes could be understood and avoided, a remarkable constancy in the indications of the compass prevailed, no appreciable deviation being observed at any time.

REPEATERS, by means of which the compass indications are made available where needed, are mounted at the regular and emergency steering stations, under the radiocompass pointer, and on the bridge wings. They consist of illuminated compass cards in weatherproof cases, turned by step-by-step motors actuated through the gyrocompass transmitter. The repeaters turn by l/6th degree steps, and, once synchronized with the master compass, give faultless service. During periods of continuous operation for two weeks, involving the running of hundreds of miles of sounding lines and almost constant maneuvering, they were never known to lose a single step in their following of the master compass .

There seems little need for calling attention to the remarkable benefit of having, in place of a pelorus, a live compass card known to be ever true in its indications. Bearings to the quarter-degree may readily be observed with a telescopic alidade fitting those repeaters. On a moment's notice, with no call for steadying the ship on her course, without reading the ship's head, without considering variations or deviations, or without swinging of the card, true bearings are instantly available.

The GYRO PILOT consists of two major parts. In the steering wheel stand is a control unit, containing a step-by-step repeater motor which actuates contactors controlling the flow of current to the power unit, aft alongside the steering engine. This power unit contains a motor strong enough to operate the steering engine controls. The effect of the whole assembly is to permit of setting the ship upon any heading, any subsequent deviation from which is inmediately and automatically corrected by easy rudder action controlled by the gyro-pilot mechanism. The resulting action of the ship is a slow easy yaw of small magnitude.

Upon first installation the gyro-pilot failed to steer the ship except at very slow ship speed. The reasons for this are deeply involved with the characteristics of the ship's design. The remedy, eventually found to be successful, lay in the substitution of a double speed gyro-pilot repeater motor.

From the time of this change, the results have been truly excellent. Depending upon the state of the sea and the trim of the ship, the yaw varies from one to about three degrees each way from the course, consisting of a gentle swing back and forth. This is far better than the best possible hand steering of the HYDROGRAPHER. In operation the action is as follows: A yaw of perhaps a third of a degree results in action of the gyro-pilot contactors, and the immediate application of about five degrees of corrective rudder. This may or may not stop the yaw; if not, additional rudder is applied as the yaw increases until, at a point between one and three degrees off course, depending on conditions, the rudder stops the swing and starts the ship swinging back to the course. Immediately the contactors reverse the rudder action, and, as the ship swings back toward the course, contrary rudder is applied to meet her. In practice the return swing is seldom exactly met and an opposite yaw results.

Almost no trouble of any kind has been experienced with the gyro-pilot. On one occasion a slight loss of adjustment resulted in a lag in the repeater motor action, but this was readily corrected.

The operation of the steering devices is remarkably quick and easy. Control can be shifted from manual to automatic within a second or two. When steering automatic, a shift of any desired small change of course can instantaneously be effected by a turn of a small hand wheel. Changing through a large number of degrees is more quickly effected by shifting to manual control during the turn.

The COURSE RECORDER is mounted in the pilot house. While it is thoroughly dependable in operation, it is not of precise design, having an inherent mechanical lag of about a degree. It moves in setting, moreover, by one degree steps, thereby making difficult exact synchronization with the steering repeater. It appears, therefore, that its indication can not be assumed at any moment to be within, perhaps, 1/2 degree of correct. It is probably, nevertheless, that its error of synchronization is a constant and that its lag error is washed out because of the ship's normal yaw. From these considerations the statement is made that the course recorder is capable of supplying a very accurate record of <u>relative</u> courses steered. This is far more important in the plotting and adjustment of sounding lines than any consideration of absolute courses. The course recorder, therefore, may be accepted as a wholly satisfactory instrument of its kind for the use made of it; namely, the recording of courses while on precise dead reckoning, or other, hydrographic lines. No failures or troubles of any kind have been experienced with it.

Very briefly, the conclusion of the writer is that the gyro-compass equipment as installed on the HYDROGRAPHER has proven itself very reliable, and with further experience in its operation, even this degree of reliability should be heightened. This modern apparatus adds materially to the facility and accuracy of performance of hydrographic surveys. It is unqualifiedly recommended with the suggestion that it

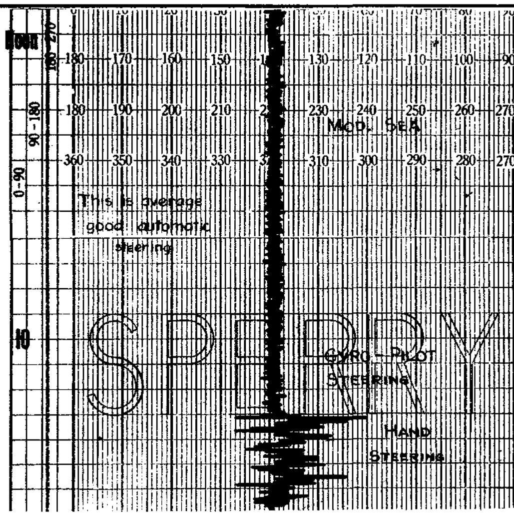


Fig. A

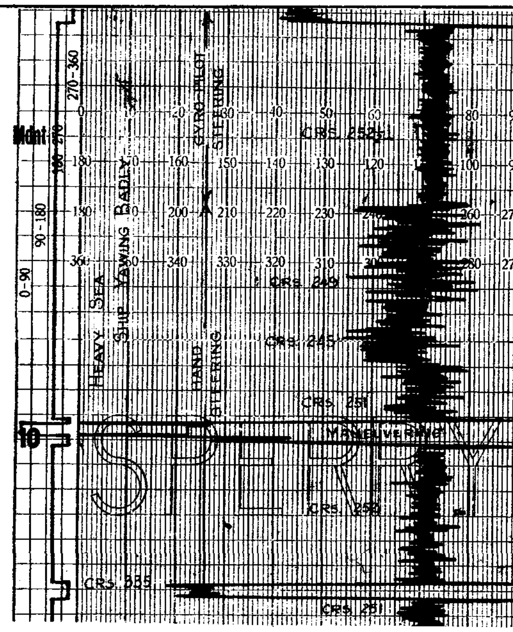


Fig. B

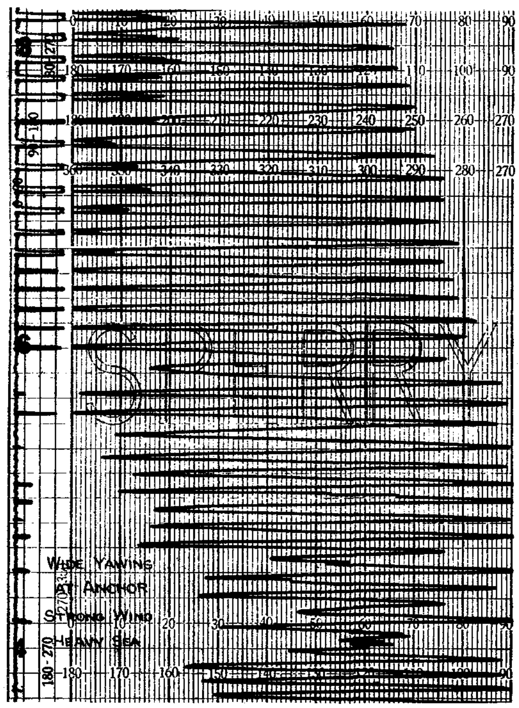


Fig. C

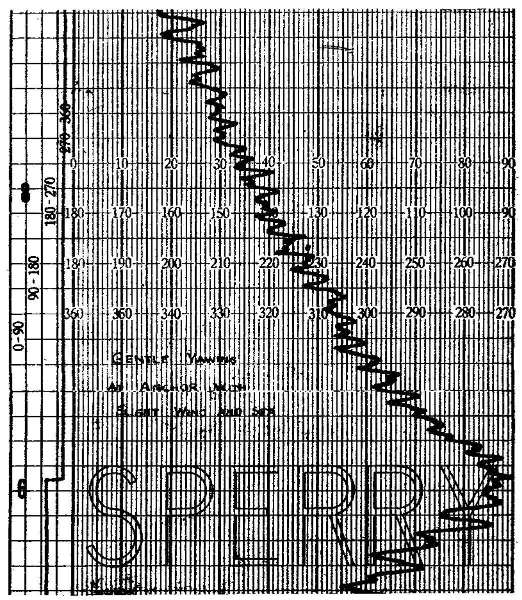


Fig. D

The specimen records of course recorder above show clearly the difference between hand and automatic steering on the HYDROGRAPHER. In Fig. A it will be seen that with automatic steering in a moderate sea the ship is usually held to within one degree of the course and that deviations to the right and left balance almost perfectly. The course made good is clearly 221° (the line to the left shows the quadrant — in this case the third). Contrast with this the hand steering record at the bottom, where it is shown that the ship's head fluctuated between 213° and 240° and the course made good is uncertain to about 2°,

Fig. 6 shows the results of hand and automatic steering in a heavy sea. Here with automatic steering the deviations from the set course average about 2-1/2° on each side, but they balance within 1/2 degree of the course. Deviations from hand steering exceed 10° and do not balance within several degrees. It should be explained that in every case hand steering was guided by the gyro repeater, not the magnetic steering compass, and that the deviations would have been much greater had the helmsman endeavored to hold a course by means of a magnetic compass.

Fig. C and Fig, D show the behavior of the ship while at anchor, the former in a strong wind and heavy sea and the latter in a light wind and sea. With such yawing as indicated by Fig. C, it is impossible to get current observations of any value.

SPECIMEN RECORDS SPERRY GYRO COURSE RECORDER SHIP HYDROGRAPHER 1931

GEM

should be on every ship of sufficient size to carry the apparatus. In particular, owing to the almost complete uselessness of magnetic compasses on a ship so much disturbed electrically and magnetically as the HYDROGRAPHER, it has been actually indispensable to this particular vessel.

The telescopic alidade mentioned by Lieutenant Roberts as used with the gyro-repeaters for taking bearings is described elsewhere in this issue of the bulletin. Ed.

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ECHO-SOUNDING ON THE SUBMARINE "NAUTILUS"

Floyd M. Soule, Carnegie Institution of Washington

(Extract from a report on echo soundings taken on the Wilkins-Ellsworth Trans-Arctic Submarine Expedition of 1931. In transmitting the report and soundings to the Director, Coast and Geodetic Survey, Mr. J. A. Fleming, Acting Director, Department of Research in Terrestrial Magnetism of the Carnegie Institution, stated: "We take this opportunity of expressing our thanks to you and your officers, especially Captain W. E. Parker, for advice given Mr. Soule on February 16, 1931, preliminary to his departure on the expedition".)

The NAUTILUS was provided with a Submarine Signal Company Fathometer equipped for taking shallow soundings up to 125 fathoms by the red-light method and deeper soundings by the white-light method. An impact oscillator was used as a sound source for the red-light method and a small Fessenden type oscillator operating on a 540-cycle alternating current supply was used for the white-light method. The microphones were located at a distance of 16.8 meters forward of the oscillator in sealed water tanks having the steel skin of the submarine as one side.

Operating conditions were unfavorable and, as was expected, the NAUTILUS proved to be a "noisy" ship. The contributing conditions were as follows: (1) The steel construction of the vessel; (2) the extensive electrical power system having old wiring and consequently poor insulation; (3) the dripping wet interior conditions caused by condensation of moisture on the cold walls of the submarine; (4) the frequent occurrence of grounds and shorts in spite of the creditable vigilance and diligence of the electrical force; (5) the scraping of ice against the hull; (6) insecure stowage of small stores near the microphone tanks; and (7) occasional noises from the comparatively loose towing pennant.

Noise limited the sounding range to a depth of about 3500 meters. This range might have been greater in quiet water; certainly it was less in the heavy weather encountered away from the ice. Noise and the resulting inability of the observer to distinguish the echo constituted the most important single item interrupting the sounding program. Only one other major interruption occurred. Through some oversight, the port microphone tank had been filled with fresh water when it was installed. As the submarine cooled off, the freezing point was reached and passed, and the microphones were imprisoned in solid ice. Several hours were required to free them without the use of injurious force and to refill the tank with salt water.

Complete calibration of the fathometer before our departure from Bergen was not deemed advisable because of the press of other duties. However, it was desirable to determine which reed of the frequency meter corresponded most nearly to a velocity of 1450 meters per second and to synchronize on this reed during all soundings. Accordingly, a short series was taken in Bergen on August 3,1931, in which the time of 190 revolutions of the white light (500 fathoms depth per revolution) was measured with a pocket chronometer.

With the middle reed vibrating at maximum amplitude the mean of three observations of the time of 190 revolutions gave 236.5 seconds, corresponding to a velocity of about 1469 meters per second. With the reed next to the middle on the left vibrating at maximum amplitude the mean of three observations of the time of 190 revolutions gave 239.2 seconds, corresponding to a velocity of about 1453 meters per second.

These measurements were rough but of sufficient accuracy to indicate that the reed next to the middle on the left should be used in all soundings in order to make the work of correction a minimum.

Subsequently, in the field (September 5, 1931) a more thorough calibration was made. A Longines stop-watch reading to one-fiftieth second was compared against a Nardin chronometer having a negligible rate, for five periods of 4 minutes each. The stop-watch readings were 0.50, 0.64, 0.55, 0.56, and 0.66 second, respectively, in excess of four minutes; thus the mean stop-watch interval corresponding to four minutes on the accurate Nardin chronometer was 240.58 seconds, whence to obtain true time intervals the results obtained by the Longines stop-watch must be multiplied by the factor 0.9976.

A series of seven observations of the time of 190 revolutions of the white light was then taken with the Longines watch and resulted as follows: 240.54, 240.04, 240.24, 239.81, 239.57, 239.47, and 240.17 seconds. The mean of these is 239.98 seconds on the stopwatch or true time interval is 239.98 x 0.9976 = 239.40 seconds, corresponding to a velocity of 1451.4 meters per second. Tables of correction factors made out on the basis of an assumed velocity of 1450 meters per second needed, therefore, to be multiplied by a factor of 0.9990 before they could be applied to these soundings. However, as the correction factors do not depart much from unity, it was sufficiently accurate to subtract 0.0010 from them. Criticism may be made that this represents an unnecessary and insignificant refinement. Nevertheless, all determinable corrections have been carried through to the finally reduced depths which have then been qualified with the uncertainty of the value.

Tables of correction factors representing the ratio between the true sounding velocity at any depth and the assumed velocity of 1450 meters per second were prepared from observed temperatures and salinities in accordance with the procedure described in a paper by Soule and Ennis[1)] and based on the British Admiralty Hydrographic Department Publication No. 282 entitled "Tables of the Velocity of Sound in Pure Water and Sea Water for Use in Echo-Sounding and Sound-Banging." Six such tables of correction factors were prepared from observations of temperature and salinity made on the NAUTILUS, and a seventh table from unpublished observations made on the FRAM in 1923 and supplied through the courtesy of Professor Björn Helland-Hansen, of Det Geofysiske Institutt of Bergen, Norway.

Because of the location of oscillator and microphones, a constant correction of 5 meters has been added to all soundings for draft. The horizontal separation of the oscillator and microphones being 16.8 meters, it can be shown that the error in assuming the transmitted and reflected sound paths to be identically vertical amounts to less than one meter for all soundings greater than 35 meters plus draft or 40 meters. As the shallowest sounding listed is 51 meters, no correction has been applied. The uncertainty of observation was ± 2 meters in red-light method and ± 10 meters in the white-light method. On several occasions more than one observer participated in a single sounding without revealing discrepancies greater than these limits. It is therefore considered probable that among our four observers, errors in coordinating sound and sight were within the above limits.

As the accuracy of speed control of the rotating light was about l/2 per cent, the uncertainty in the depths is considered to be as follows:. White-light method ± l/2 per cent or ± 10 meters whichever is greater; red-light method ± 2 meters.

[1)] F. M. Soule and C. C. Ennis, Sonic depth-finding on the CARNEGIE, Cruise VII, Trans. Amer. Geophys. Union, 11th annual meeting, 264-274 (1930).

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NEW WIRELESS SOUNDING APPARATUS

From "Nautical Gazette", May 28, 1932

The Deutsche Betriebsgesellschaft fuer drahtlose Telegraphie (German Wireless Telegraph Company) recently installed a new wireless sounding apparatus in the steam trawler FLADENGRUND. This apparatus functions through the quality of a stone crystal, particularly a quartz crystal, by transforming electrical impulses into mechanical vibrations and vice versa. It is claimed that the apparatus is completely silent and automatic when set in operation. * * * * * * *

WIRELESS LONGITUDE OBSERVATIONS IN MID-PACIFIC

E. O. Heaton, H. & G. Engineer, U.S.C. & G. Survey

During the month of August, 1931, observations for second order longitude were made on Lisianski Island, Territory of Hawaii, located in latitude 26° 04' 03.88", and longitude 173° 58' 09,48". From these observations it was determined that the charted position of the island was about three miles south and one mile west of the true position.

The observations were made with a Troughton-Simms direction theodolite having a 10-inch horizontal circle and a vertical circle which could be read to 10 seconds. The telescope was fitted with an eleven line glass diaphragm for observations by the key method. A special key was furnished by the office to be used in connection with the chronograph for recording the meridian star passages. Time signals were recorded on the chronograph by the audio-visual method and a correction for personal equation was applied to the results.

An R.C.A. short wave receiver No. AR-1145 was used with an aerial consisting of 100 feet of wire attached to the radio tent at one end and to a pole about 25 feet high at the other.

Lisianski Island is approximately 5,500 miles west from Arlington, "Virginia, but no difficulty whatever was experienced in receiving the time signal from the Arlington station. This signal was used for longitude four successive nights, but was also received twice daily for six additional days when weather conditions were too poor for making astronomic observations. The day the equipment was installed the earphones were placed on the chronograph table and the signal was loud enough so that it could be heard distinctly at any place in the 8' x 10' tent which housed it.

The observations were taken on four consecutive nights and consisted of meridian passages of 20 stars each night. On each night two half sets with clamp east and west were observed before the time signal was received and the same number afterward. The summation of A factors was kept below unity.

The results for the four nights are listed below:

August 23	llh	35m	52.72s	or	173°	58'	10.83
24			52.50				07.50
25			52.74				11.14
26			52.56				08.43
	Mean		52.63				09.48

From the above it will be seen that the maximum variation from the mean was 0.13s in time. These results do not include the lag of the radio signal at Arlington, because they have not yet been received in the field.

NEW METHOD OF MEASURING FIRST ORDER BASES

C. L. Garner, H. & G. Engineer, U.S.C. & G. Survey

The use of railroad tangents for the measurement of first-order bases has been in practice for a considerable time. Owing, however, to the more recent extension of triangulation into more level and, frequently, highly developed country, the location of bases along railroads and highways has become almost the rule rather than the exception. Obviously the reason for using railroad rights of way is in order to secure a straight alignment where there will be no obstructions throughout the length of the base and also where the difficulties of entering into numerous areas of private property and of resulting controversies with the owners of the property may be avoided.

The main problem in this connection has been to determine the means whereby measurements along railroads may be made most accurately and economically. It will be recalled that, previous to the development of the Bilby steel triangulation tower, it was considered that horizontal control could be extended over flat wooded areas only by traverse along highways or railroads, and in the extension of this traverse it was customary to make measurements with invar tapes supported throughout on a rail of the railroad track when the measurements were made along a straight line. There is a serious objection, however, to regular measurements of first-order bases over the rail with the tape supported throughout, as the adhesion of the tape to the rail under changing condition of temperature and moisture is uncertain. Furthermore, the uncertainty of temperatures is considerably more under such conditions than where the tape is entirely free of the rail.

Most railroad tangents are particularly adapted to base measurements as the alignment is sufficiently accurate or the necessary corrections for lack of alignment either horizontally or vertically can be determined with a reasonably small amount of work. Due, however, to slippage of the rail, caused by changing temperature and passing trains, and to the causes mentioned in the preceding paragraph, most of such bases in recent years have been measured over stakes set at the side of the track. Setting stakes usually consumes from 25 to 40 per cent of the parties' time while engaged on any one base, and it was therefore desired to devise a means whereby measurements could be made with the tape supported above the rail, thus saving the time of setting stakes.

More than a year ago the Chief, Division of Geodesy, suggested that measurements might be made over the rail of a railroad by supporting the tape at four points, namely, the 0, 12-1/2, 37-1/2 and 50 meter points, in such manner that no point of the tape, except the two ends, would come in contact with the rail. This method was first tested on a section one kilometer long of the Shreveport, La., Base in April, 1921, with a single tape as follows:

(l) Three measurements were made over stakes.

(2) Four measurements were made over the rail using the so-called four-support method with the 0 and 50 meter points of the tape in contact with the rail, but with the 12-1/2 and 37-1/2 meter points elevated 0.5 ft. above the rail (this amount was found by experience to be sufficiently high for all invar tapes to clear the rail by at least one-quarter of an inch even over vertical curves).

(3) Two measurements with the tape supported throughout on the rail.

The points on the rail between which measurements were made (corresponding to the kilometer points on the stakes), were determined by accurately centering the 7-inch repeating theodolite over the mark on the stakes and turning off angles of 90° from the opposite ends of the section. The points on the rail thus located were marked and a number of repetitions of the 90° angles were made, using different parts of the theodolite circle. None of these differed in position more than 0.3 millimeter.

The inclination correction for the measurement over stakes was applied in the usual manner from the differences in elevation of the stakes, as determined with a wye level. The inclination correction for measurements over and on the rail were determined from levels taken at each of the tape ends, it being assumed that the rail formed a straight line vertically between the tape ends.

It is well to remark here that in making these measurements every possible precaution was taken against errors due to slippage of the rail, caused by temperature or by passing trains. This was accomplished at the section ends by setting two stakes on each side of the bottom flange of the rail at a height convenient for nailing on copper strips used in making contact marks on the strip and rail. These stakes were set in between the ties, and by using the mean value of the four it is believed that a very accurate value was obtained. In this system of measuring it is impossible, of course, to take care of a slip of the rail caused by temperature changes during the actual measurement from one section point to another. It is realized that for any individual tape length, or small number of tape lengths, some error might result. When considered, however, for the measurement of an entire base, which on the average is about ten kilometers long, such errors undoubtedly tend to cancel each other and the total accumulation should be very small.

The length of the section as determined by the four point method of support over the rail was 0.57 mm., or 1 part in 1,750,000 shorter than that determined by the three point support over stakes, using standardization values for each method of support as determined at the Bureau of Standards. This is well within the limit specified in Special Publication No. 120 for first-order bases, but is not as close an agreement as had been expected in the field. This difference probably is explained to some extent by the fact that the tape broke at the Bureau of Standards just before standardization, which made it necessary to use the value of the previous standardization about one year old.

Under these conditions and with the results obtained it seemed that the measurement of a base line over the railroad rail by using the four-point method of support was entirely reliable for the measurement of first-order bases, and recommendation was made to the Director that this method be tried, at least for a time, on the measurement of bases along standard railroad tracks where the rail is in good condition and alignment. This recommendation was approved and railroad bases have since been measured in this manner.

Incident to this method of measuring over a railroad rail, attention should be called to the fact that the catenary of most of the invar tapes is such that, were the rail straight between the ends of the tape, 5-1/2" would be a height sufficient to bring the center of the tape tangent to and just slightly above the rail. To take care of vertical curves on the railroad and also the difference in mass of the various tapes, however, it was necessary to raise the supports at the 12-1/2 and 37-1/2 meter points 6" above the rail. Under these conditions, no case was found where the center of the tape was nearer the rail than 1/4". It should also be explained that since the balances have a drawbar with a vertical dimension of about 1", and because of the 12-1/2 and 37-1/2 meter points being raised higher than necessary under average conditions to bring the center of the tape tangent to the rail, the 0 and 50 meter points, when under proper tension, were an average of about 3/4 of an inch above the rail. It was therefore necessary to press the tape down to the rail in order to make contact. Recently a ballbearing roller with a small handle for use by the forward contact man has been made in this office for the purpose of pressing the tape down to the rail and avoiding any errors in the tension throughout the tape.

It will be recalled that during the years of 1917-1920, when a large amount of traverse along railroads was being executed, contact marks were made directly on the rail by means of a glass cutter. Considerable question as to the accuracy obtained by this method has arisen. Due to the fact that the cutting edge of this instrument is a wheel and cannot be brought flush with the tape contact mark, it is possible for parallax to be introduced. Also the horizontal play in the wheel introduces more inaccuracy in the marking. There is also some injury to the tape when using glass cutters as the cutting wheel frequently comes in contact with the edge of the tape.

During this work contact was obtained by the use of adhesive tape and strips of fairly heavy paper. The tape, which had adhesive matter on both sides, was pressed down on the rail and the strip of paper pasted on top of it. The thickness of the two about equalled the thickness of the invar tape and the contact marks were made with a pair of dividers, a needle, or a hard pencil, the suitability depending on the sharpness of the point and the hardness of the paper.

Objections to this system are that it requires slightly more time and the passing of a train obliterates the marks.

On the measurement of the Ashdown Base, the first full base measured by the new method, there were only two section marks at which the slippage of the rail between measurements could not be determined with entire satisfaction. One of these was much worse than the other and, while on a straight track, appeared to be caused by a sidewise motion of the rail due to passing trains. At this one place the movements as recorded on the four different stakes were not consistent, but the differences were of the order of 2.5 millimeters, which is certainly inconsiderable for the base as a whole. Incidentally it should be mentioned that such a difference does not enter into the actual length of the base itself, but merely in the agreements of the measures of the two sections on either side of the mark. For this reason it is considered unimportant. A condition of this nature could not occur at the ends of a base as extra heavy stakes are set by the rail at end offset stations to obviate this question.

In the matter of leveling at the tape ends on the rail, it was found that an efficient leveling party, consisting of an observer and one or two men, can level along the track as rapidly as the taping party can make one measurement. When there is sufficient personnel, therefore, the leveling and angle measurements can be made while the taping is done and a base can be measured at an average progress of from 2 to 3 miles per day of completed line. With a limited personnel, all of whom are required on the tape measurements, the best procedure is for the taping party to measure the base and then divide up into units for doing the leveling and angle measuresmemts.

Standard base measuring apparatus was used, except that the 12-1/2 and 37-1/2 meter supports were 2" ballbearing brass rollers suspended from a universal joint 8" above the bearing in order that the entire roller would swing as a pendulum and thus avoid any errors of tension.

SPECIAL FISHING CHARTS OF GEORGES BANK

E. H. Kirsch, Jr.H. & G. Engineer, U.S.C. & G. Survey

To the shipping industry, Georges Bank is widely known because it lies in the principal steamship track between New York and Europe. To the fishing industry, it is just as widely known because it happens to be one of the world's most important fishing banks. Therefore, the Coast and Geodetic Survey, in making detailed surveys of this region for the purpose of constructing modern charts, has "killed two birds with one stone."

However, while the basic data obtained on these surveys serve a double purpose, the nautical charts constructed therefrom are lacking in some details desired by the fishermen. To meet their needs the Bureau has undertaken the construction of two special fishing charts of the Bank and adjacent waters. The writer was assigned the duty of constructing one of these, and it is the purpose of this article to present some of the special features to be shown, as well as some of the problems involved in showing them. For, in reality, what the fishermen actually want is something that combines all the advantages peculiar to both large and small scale charts, and it has been found that complying with their desires is not such a simple matter.

Some of the specifications and desirable special features suggested by the Massachusetts Fisheries Association in the interest of the fishermen were:

(a) All of Georges Bank to be shown on two charts on a scale between 1:200,000 and 1:300,000.
(b) Show more soundings than are ordinarily shown on a navigational chart.
(c) Show the 10, 20, 30, 50, 100 and 130 fathom depth curves.
(d) Show magnetic courses from Peaked Hill Bar Gas and Whistling Buoy (three miles north of Cape Cod) to various sections of the Bank.
(e) Show magnetic bearings, in points, from the radio compass stations available for use in this region.
(f) Increase the number of bottom characteristics.

The scale of 1:220,000 was selected for the two companion charts. This is the maximum scale that will permit inclusion of the entire area as defined by the 100 fathom curve, while at the same time allow sufficient overlap of the two charts to show the dangerous Georges Shoal on each of them. The more easterly of the two embraces, in general, the area surveyed during the 1930 and 1931 seasons. The surveys of the present season will fall, for the most part, in the area embraced by the westerly chart,

Inside the thirty fathom curve, where the bottom is very irregular, soundings were selected as close together as possible, consistent with clearness and legibility. Fisherman are particularly desirous of a knowledge of existing lumps and holes when setting their trawls which are often badly damaged, and sometimes completely destroyed, on this extremely broken bottom. Outside the thirty fathom curve, where the bottom is more regular, the soundings were opened up somewhat, but are plotted with sufficient intensity to permit the delineation of all depth curves. A considerable number of the trawlers are now equipped with Fathometers and in the future will undoubtedly use them to advantage in fixing their position on the Bank. All bottom characteristics available were shown and it is not unlikely that fishermen will supplement these from their own findings.

As the two charts embrace areas well offshore and far removed from Peaked Hill Bar Buoy, the desired magnetic courses from this buoy were plotted, by transfer, from courses plotted on chart 1107. These are shown in red for every half point from East to South, the variation used being the mean between that at the buoy and that along the central meridian of the new chart.

A distance arc, 155 miles from the buoy, is also shown. As a distance arc is not a circle on a Mercator Projection, the curve representing this arc was drawn on a Lambert Projection constructed on a scale small enough (1:500,000) to permit showing both the buoy and the area in question. The curve was then plotted on the new chart after transferring numerous points along it from the arc on the Lambert Projection.

The representation of radio bearings presented the most difficult problem. Very few of the fishing vessels are equipped with radio compasses, but they make considerable use of the true radio bearings furnished them from shore stations. The request had been made that radio bearings be shown by lines drawn across the chart, at one point intervals, from each of five stations. This representation was tried on a preliminary layout but it was very soon apparent that the multiplicity of lines would be very confusing. Several other methods were tried and rejected largely because in each case they detracted from the clearness of other important features.

The following method which is shown on the accompanying plate was finally adopted: Five narrow borders, each representing a separate shore radio direction finder station, are shown around the outside limits of the chart and on these are indicated by dashes, and in units of one degree, the true directions from the respective stations.

To determine the directions, as indicated by the dashes, the various radio shore stations were plotted on the Lambert Projection, previously referred to, and from each of these true bearings were plotted with a protractor across the area embraced by the new chart. The points at which these intersected the various border lines - also plotted on the Lambert Projection - were then transferred to the corresponding borders on the new chart.

Bearings obtained from shore stations are to be plotted as received. While the chart is on the Mercator Projection no Mercatorial corrections will have to be applied, since these have been taken care of by transfer of bearings from the Lambert Projection. There is a small error due to the fact that a line of bearing is a great circle, but in the width of the chart this error is negligible in comparison to the probable error of the bearing received. In plotting a bearing, dashes on two opposite or adjacent borders must be used rather than one dash and the compass rose, since the radio bearing of 90°, for example, will not correspond to the same bearing by the compass rose.

Five different shades of blue will be used to indicate the various areas between depth curves, ranging from dark blue for depths under 10 fathoms to light blue for depths greater than 100 fathoms. Current diagrams similar to those on chart 1107 will be shown.

In addition to its usefulness to New England fishermen, it is believed that, on account of its comparatively large scale, the chart will be found useful to mariners, particularly to those on the New York - Halifax run.

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FISHING HARDSHIPS ON GEORGES BANK

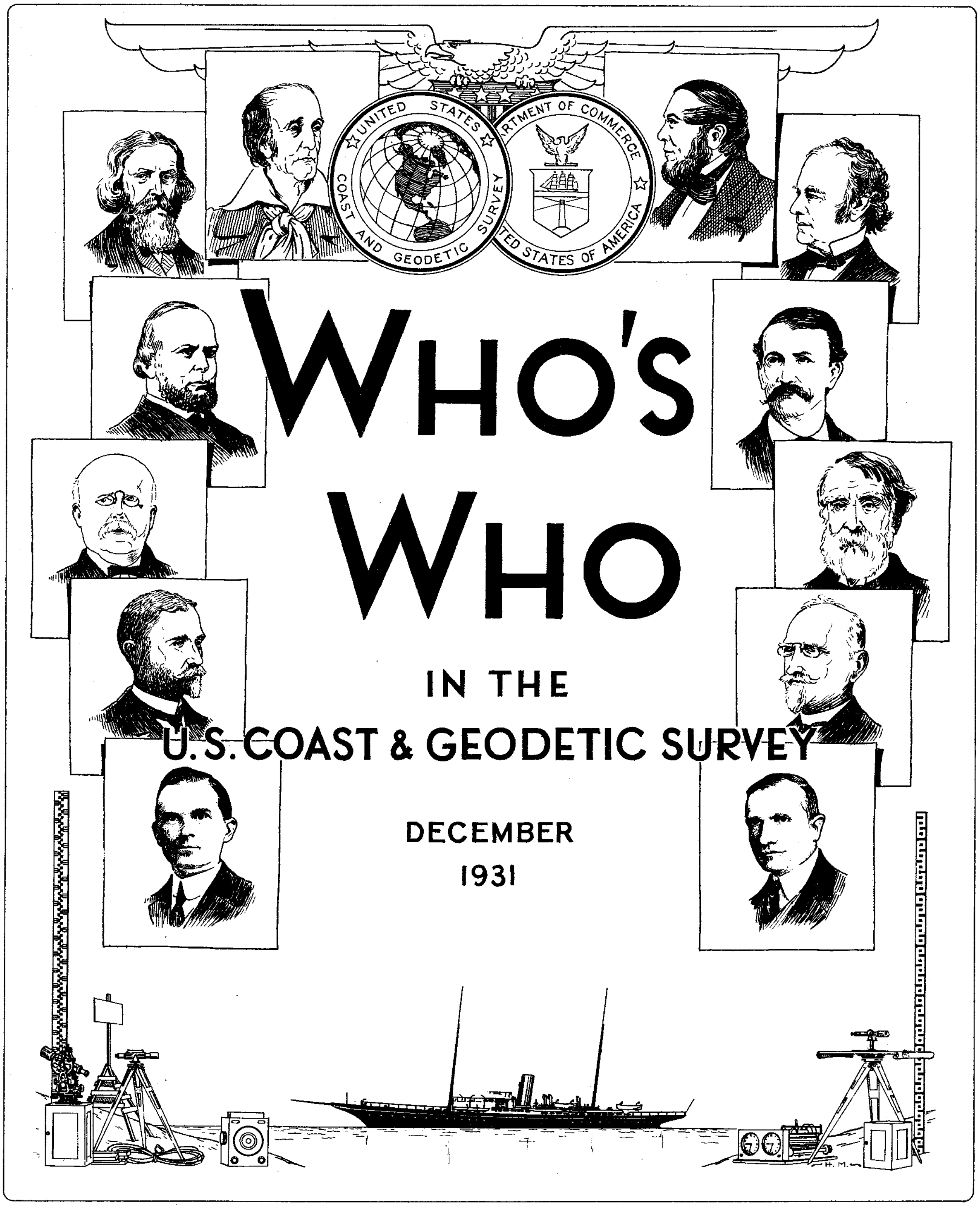
Extracts from "What's East of Nantucket?"
by. W. A. Ellison, Jr., "Fishing Gazette", Feb., 1932.

We don't know how long Georges Bank to the eastward of the Channel has lent itself to commercial fisheries, but it is quite probable that the adventurous Portuguese, who established in 1530 their fishing village on Sable Island, came on to the south and west and knew a little of Georges Bank. * * * * * * *

Hundreds of lives have been lost out there, unimaginable suffering and hardships have been endured that the industry might grow to its present proportions, that men might have food and wealth. Kipling and Connelly have made famous the sail carriers and the men who have toiled on them. The trawler lends itself not so easily to romantic colors, but some day one who can write will tell the story of these trawler men and their trials and hardships.

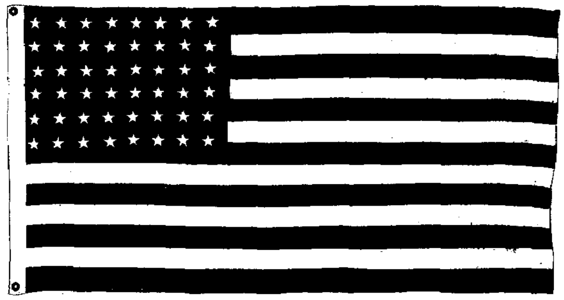
* * * * * * * * * * * *

There's the limestone bottom north of 41 and the limestone bottom west of 66. They are spots on the banks that will be recognized just as certainly by fishing skippers as New York, Cleveland or Boston would be recognized by a traffic manager. There are spots out there which are peculiar. There is a place known as the Spiders and another known as the Green bottom. There's the Big Moss on the Northern rim of Georges, the Little Moss east of 66° longitude and John Hall's moss south of 41° latitude. There's that awful macaroni, the white and the black kinds. They usually steer clear of that stuff for it fills the net with dead weight and has to be shoveled over the side. It consists of the tubes of sea worms and it looks, for all the world, like macaroni.

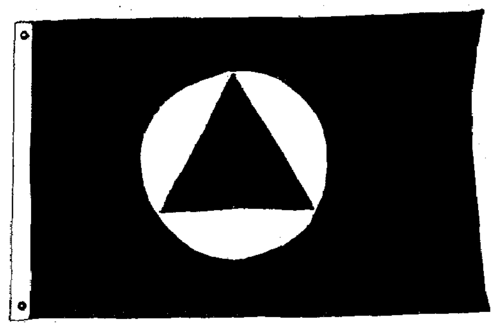

UNITED STATES
COAST AND GEODETIC SURVEY
RTMENT OF COMMERCE
TED STATES OF AMERICA
WHO'S WHO
IN THE
U.S. COAST & GEODETIC SURVEY
DECEMBER
1931

C.&G.S.442

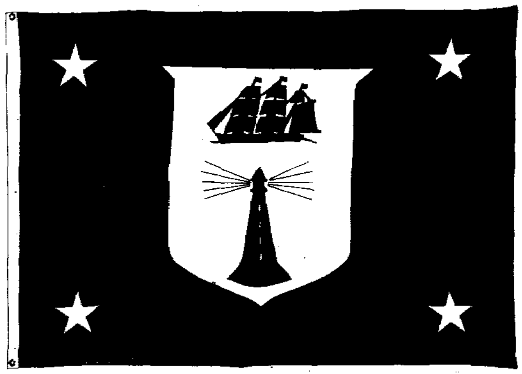
FLAGS USED BY U. S. COAST AND GEODETIC SURVEY



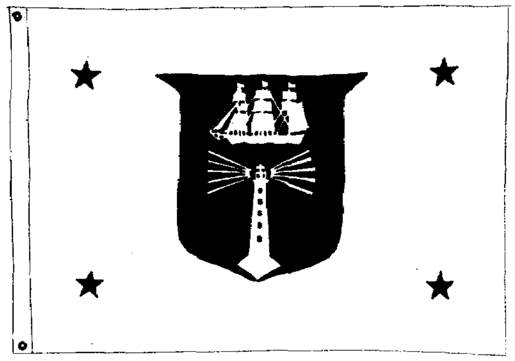
U. S. Ensigns:
No. 6, 8.94' hoist
" 8, 5.00' "
" 9, 3.52' "
" 10, 2.90' "
" 11, 2.37' "



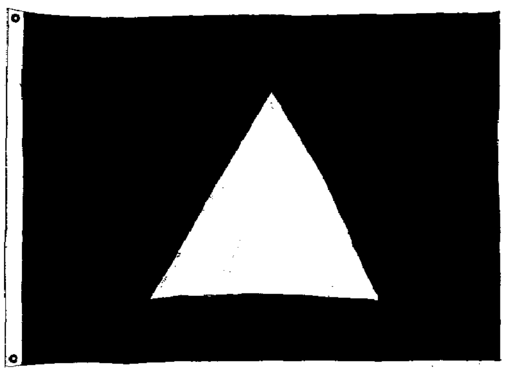
Coast and Geodetic Survey:
2½ x 4 ft
5 x 8 ft.



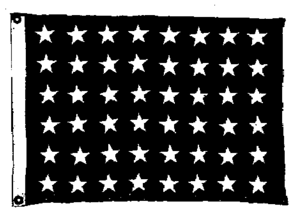
Secy. of Commerce:
3 ft. x 4 ft. 3 in.
7½ ft.x 10 ft.8 in.



Asst. Secy. Commerce:
3 ft x 4 ft. 3 in.
7½ " x 10 ft.8 in.



Director, C & G Survey:
3 ft. x 4 ft. 3 in.
7½ ft x 10 ft. 6 in.



Union Jacks:
No. 6, for 8.94' US flag
" 8 " 5.00 " "
" 9, " 3.52 " "
" 10, " 2.90 " "

Pennants, C & G Survey:
3 in. x 6 ft.
4 in. x 9 ft.
4½ in.x 15 ft.

R-267

USE OF RANGE-FINDERS FOR HYDROGRAPHIC SURVEYING

(I) W. E. Parker, E. & G. Engineer, U.S.C. & G. Survey

Last summer there were issued to the Georges Bank surveying fleet three Barr and Stroud one meter navigational range-finders. One was issued early in the season to test its value in fixing the position of an R.A.R. receiving ship and its trailing hydrophone with reference to the station buoy near which the ship was anchored. The range-finder was borrowed by one of the sounding ships and was found to be so useful for other purposes that two additional instruments were issued to the fleet.

DESCRIPTION: This range-finder consists of a tube about 2 inches in diameter (3 inches at the ends) and about 43 inches long. Windows in the tube, one near each end, admit views of any object in the plane cutting the two windows and normal to their surfaces, which views are reflected to the center of the tube and can be brought into contact by turning a milled head screw on the under side of the tube. On the top of the tube, at its middle length, are two eye pieces, the right hand one for viewing the reflected images and the left for reading a scale of distances. This scale moves with the sliding of the wedge which brings the two images into contact and indicates the distance to the object when the two images of it are in contact. The scale is calibrated in yards from 250 yards to 20,000 yards and is illuminated by means of a window in the tube.

The range-finder can be supported on a braced metal tripod stand, the feet of which clamp into foot plates screwed into the ship's deck. The range-finder fits into sleeves on the top of the stand, which clamp around the tube but permit it to be rotated in a vertical plane as desired. This movement is controlled by a handle attached to the tube to the left of the eyepieces. The handle, a short stick of wood, travels over a curved guard on the stand, which assists the hand in making, a small movement of the tube. Rotation in a horizontal plane is provided by a free movement of the top of the stand which is secured to the tripod head by a vertical pin, free to move in the latter unless clamped. To the rotating part of the head is secured a curved body rest which permits the observer to steady himself against the roll and pitch of the ship and keep the range-finder on the desired object.

The range-finder may also be supported by a harness which fits onto the observer and transfers the weight of the instrument to his shoulders. This is useful when it is necessary to move the instrument from place to place to got a clear view, but it is rather more difficult to use the instrument in this way and measurements are not likely to be so accurate as when the instrument is secured to the tripod stand.

For observations at night on a light, there is an arrangement within the range-finder tube by which the rays of the light can be converted into a vertical band of light. By this means better and more definite contact can be made between the two reflections of a light, such as produced by a lantern, than is possible with daylight objects unless the object has a sharply defined, nearly vertical, straight side or line.

The base line of this instrument is one meter in length. The magnification is 13.3 diameters. The angular field is 3 degrees and 4 minutes.

The calibration is as follows:

Intervals	of	10	yards	from	250	yards	to	1,000 yards
"	"	25	"	"	1,000	"	"	1,500 "
"	"	50	"	"	1,500	"	"	2,000 "
"	"	100	"	"	2,000	"	"	5,000 "
"	"	500	"	"	5,000	"	"	10,000 "
"	"	5000	"	"	10,000	"	"	20,000 "

The scale can be read easily by interpolation as follows:

To	the	nearest		yard	up	to	500 yards
"	"	"	2	"	"	"	1,000 "
"	"	"	5	"	"	"	1,500 "
"	"	"	10	"	"	"	2,000 "
"	"	"	25	"	"	"	3,000 "
"	"	"	50	"	"	"	5,000 "

ACCURACY: Recently we have readjusted the range-finder and have tested it on distances across water that were furnished by the LYDONIA triangulation party in the vicinity of Norfolk. These distances range from about 300 to 5,400 yards and are defined by suitable objects for observation by range-finders. As all distances were almost entirely over water, the images were sharp and contacts could be made with much more certainty than during the earlier tests.

These tests show that the instrument is more precise up to 2,000 yards than I had claimed in the earlier report and that it is probably free from systematic errors of any appreciable magnitude. Beyond that distance the errors increase in magnitude and are all of the same sign, which seems to be due to errors of graduation.

The accuracy of this instrument when in perfect adjustment and when used from a reasonably steady stand, over water, with good visibility, on well defined objects appears to be as follows:

Distance	Error of a single observation	Error of the mean of 5 or 6 observations
1,000 yards	1% of distance	less than 1%
2,000 "	2% " "	1%
4,400 "	3% to 4% "	2%
5,400 "	7% to 8% "	5%

The table below shows the results of the last test.

Range Finder #2

From Sta.	To Sta.	True Dist. Yds.	Observed Distance E.B.E.	Observed Distance J.C.T.	Mean Yds.	R.F. Corrected
LEJ	LEH	313	312	312	312	+ 1
			311	311		
			312	312½		
LEC	LED	451	447	447	448	+ 3
			450	448		
			447	447		
LAF	LAD	704	703	707	704	0
			703	701		
			704	703		
LAC	LAD	1063	1055	1060	1062	- 1
			1060	1065		
			1070	1062		
LAB	SAND	1167	1162	1150	1153	+ 14
			1150	1140		
			1165	1150		
LAB	LAF	1485	1450	1500	1470	+ 15
			1450	1485		
			1455	1475		
			1475			
LAB	LAD	1916	1880	1900	1893	+ 23
			1910	1890		
			1870	1910		
BAC	L.H.	2107	2150	2120	2133	- 25
			2140	2130		
			2140	2120		
BAB	L.H.	2556	2495	2510	2494	+ 62
			2520	2500		
			2460	2500		
			2480	2490		
			2490			
GRAIN	Tank	4417	4300	4390	4344	+ 73
			4350	4300		
			4380	4350		
			4280	4400		
GRAIN	L.H.	5411	5150	5100	5131	+280
			5200	5000		
			5250	5250		
			4900	5200		

USES

(1) For Location of Hydrophone* - The position of an R.A.R. station ship and of its trailing hydrophone are determined by observing from the ship the distance and direction to the station buoy and then the distance and direction to the buoy which supports the hydrophone. The position of the station buoy anchor is known and the position of the buoy is determined by the direction of the current and scope of the buoy anchor cable.

Before range-finders were received, the distances were determined in one of two ways as follows: (1) by depression angle or (2) by sextant triangulation on the buoy from two ends of a base line measured on deck. The first method gave good enough results for short distances when the horizon could be seen, but was useless during fog or after darkness and gave uncertain results during low visibility. The second method was not so good when the direction to the buoy made a small angle with the keel line.

The range-finder gave a means for getting the distance at any time when fog was not so dense as to shut out the buoy continuously, a condition extremely dangerous for hydrography where there is any shipping. When working at night a lantern was hung on the buoy. It would have served our needs better had the range-finder been constructed to measure distances down to 100 yards as it is desirable that the receiving ship anchor as close as possible to the station buoy. The limiting range of 250 yards of this instrument makes it necessary to anchor at an excessive distance from the buoy in order that under no condition of swinging the ship and buoy will approach closer than that distance. It is believed that the greater the distance is between ship and buoy the more likelihood there is for large errors in measuring the distance between station buoys and the distances to sounding positions. Finally, it would have been better had the range-finder been calibrated in meters, thus avoiding a new unit of measure in our records or the necessity of converting observations to the metric system.

(2) For Surveying - Subaqueous sound ranging is not satisfactory when the distance is less than about 1500 meters, for the recording device has only a second or less to recover from the explosion before the radio report from the hydrophone station arrives, and during that time the recording apparatus must be shifted from the ship's hydrophone circuit to the radio receiving system. Consequently, it is necessary to have some other means for getting the position of soundings while the surveying ship is in the proximity of the hydrophone station. The range-finder, in conjunction with the ship's compass, furnishes this means admirably. As stated above, the error of a range-finder measured distance of 2,000 yards or less is not likely to exceed 3% of the distance, especially when measured

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* See "Relating Magnetophone to Buoy Anchor on R.A.R. Buoy Control Hydrography", G. D. Cowie and F. A. Riddell, Field Engineers Bulletin, December, 1931, page 15.

over the water, and distances of this degree of precision when plotted along good compass bearings should give fixes sufficiently accurate for most work for which R.A.R. is acceptable.

In R.A.R. work, such as was done on Georges Bank, it frequently happens that one receiving ship fails to report a bomb, due to a temporary disarrangement of its receiving or sending gear or to the fact that an intervening shoal interferes with the free passage of the compression wave; sometimes both ships fail. At such times the range-finder and compass save the situation, if one of the receiving ships is in sight and not too distant, and enable the surveyor to continue the line with sufficient control until the sound ranging can be resumed.

When developing the shallow (except the very shallowest) and broken bottom area of Georges Bank, it was found most convenient to operate the two sounding ships as one unit. One ship only used R.A.R. for control and the other ship followed beside the first at a distance equal to the required line spacing. This distance was maintained by means of a range-finder. The following ship heard, by means of its radio, the bomb signal, given at the instant the bomb was dropped, and at that instant got a fix by means of a bearing and distance to the bombing ship. Its line of position was then plotted from the line of position of the bombing ship.

<u>CONCLUSION</u>: I believe a range-finder is a most useful instrument on a surveying ship and that many uses will be found for it other than those described herein. My experience with it has been limited to distances not in excess of 2,000 yards and, accordingly, I think of it as a surveying instrument only to that distance. It may be that its range can be extended for some classes of work; it should be a valuable aid to navigation at much greater distances. It would be very useful for running surveys or reconnaissances.

(II) G. D. Cowie, H. & G. Engineer, U.S.C. & G. Survey.

Early in the season a Barr and Strand one-meter range-finder was received by the party on the LYDONIA for use in relating the magnetophone to the reference buoy, Georges Bank survey.

The range-finder was tested on a 300-yard base and it was found that an observer could check this distance within two yards. Tests at greater distances were not made, as it was not intended to use it on long distances.

The finder is mounted either on a light tripod or carried on a standard resting in a socket of a harness slung from the observer's shoulders. In either case, the finder can be swung horizontally or rotated vertically. A small finder is mounted near the eyepieces to aid in picking up the observed object. One eyepiece is used for sighting the object and for making coincidence. The other is for reading the range simultaneously.

A cylindrical lense can be thrown into the line of sight by moving a small lever and converts the image of a point of light into a bright vertical line. This allows a coincidence to be made at night with practically the same ease as in daytime observing and with about the same accuracy.

One objective lens is rigid in its end of the tube of the finder, the other can be moved (1) in order to make the finder read the correct range, (2) in order to correct the coincidence feature, i.e., so that the optical images appear as in sextant mirrors properly adjusted for parallelism. These adjustments are easily made by means of gear wheels moved by the observer's thumb.

The finder increases the accuracy of measuring the distance from the bridge to the buoy over the depression angle method and can be used when the latter could not be, i.e., when horizon is not visible. It is as accurate as the method of determining the distance by two sextant angles measured at the ends of a base line on the ship and has the further advantage that it requires but one observer instead of the two needed for the base line method.

It is particularly valuable on a small vessel where height of eye is small (making poor distance by depression angles) and where only a short base line could be used.

This instrument might find various uses in connection with hydrographic surveys, such as obtaining the distance off a buoy in a dead reckoning run, in obtaining a fix by a single angle between two buoys and a distance to one of them, for use in running/traverse of a small stream, etc. It has been used in determining the distance between the HYDROGRAPHER and OCEANORAPHER when both ships were running parallel sounding lines and only one of them was getting positions by RAR methods.

III. Major R. Ll. Brown, R. E.

(Extract from a paper read at the Empire Surveyors' Conference, July 15, 1931, on "Optical Distance Measurements", as published in the Empire Survey Review, London, April, 1932.)

(3)* Base at Observer.

This group contains the constant—base coincidence range-finders. These have been produced in considerable varieties for naval and military purposes, but their application to survey has not so far been very extensive. The types which chiefly concern the surveyor are the smaller portable models. Of these, the Barr & Stroud 80 cm. and 1 metre base instruments are good examples. These instruments can be

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* Parts (1) and (2) not reproduced here are: (1) Base at Object and Double Observations, such as the Hunter, Short Base Apparatus; (2) Base at the Object and Single Observations, such as the Beaman Arc.

made up for surveying purposes to read in any units and with any minimum scale reading (which will be referred to later).

The great speed with which they can be operated is really very remarkable. It is not too much to say that ranges can be read with them as quickly as they can be estimated with the unaided eye. By the time you have summed up the situation, considered adjacent objects and so on, the observation on the instrument has been taken. Designed with the object of speed largely in view, for circumstances which make the need of speed more urgent even than they appear in survey, these instruments have achieved a notable success in this direction, which should make them appeal to surveyors.

In stadimetry the subtended angle is fixed and the base increases with the distance. The magnitude of the theoretical error therefore varies with the distances. With these instrument's the base is fixed and the subtended angle alters. The magnitude of the theoretical error varies in this case with the square of the distance. The accuracy with which coincidence can be made and the fact that the base is horizontal and therefore eliminates, if not all, at least the most considerable portion of differential refraction, goes a long way to make up for the theoretical disparity. This consideration, however, makes it necessary to fix an upward limit to the ranges to be read, according to the accuracy required. In stadimetry this limit is automatically supplied by the maximum length of the ranging-pole in use. It can be achieved automatically in the range-finder by not graduating the scale beyond a certain limit.

The length of the actual scale upon which the graduations are engraved is limited for the various sizes of instrument. In this case it is about 6-1/2 inches, that is, between the minimum scale reading and the infinity mark. The minimum scale reading can be fixed at any definite amount to suit the purposes for which the instrument is required. The distance between unit divisions, however, is very large towards the lower end of the scale and diminishes In progression rapidly as the scale reading increases. This means that any addition to the scale at the lower end, i.e. a reduced minimum reading, takes up a very large portion of the allotted 6-1/2 inches and greatly reduces the space available for the higher graduations and consequently reduces the accuracy with which they can be used.

The following table gives the scale reading in yards, at fixed points along the scale, of instruments with different "minimum readings":

Minimum reading	Distance along the scale					
	$1\frac{1}{2}$"	$2\frac{1}{2}$"	$3\frac{1}{2}$"	$4\frac{1}{2}$"	$5\frac{1}{2}$"	6"
250 yds.	325.00	406.25	541.6	812.5	1625	3250
150 "	195.00	243.75	325.6	487.5	975.0	1950
110 "	143.00	178.75	238.3	357.5	715.0	1430

This table shows how the accuracy of the higher readings must be sacrificed to obtain a lower minimum reading. Immediately above 325 yds., 1 in. of scale represents 80, 160, and 350 yds. respectively as the "minimum reading" is reduced.

Coincidence methods of observing, even with the inverted-upper-image system which is usually employed with those instruments and which is to my mind the best for surveying, presuppose a fairly well-defined object with clear shadows or edges. Though these should be as nearly vertical as possible, the base can be swung out of the horizontal to make use of inclined marks. The astigmatizer, which was, I think, first introduced for sighting upon lights at night, makes almost any object a suitable sighting mark. It introduces a cylindrical lens into the optical system which elongates the images vertically. In nearly all types of country suitable sighting objects are surprisingly numerous; even in desert country they are by no means lacking. The astigmatizer is operated vary simply and can be brought in or out of the system, whilst the observation is being made, by a simple pressure of the thumb.

The following table gives the approximate uncertainty of observation under favourable conditions. The probable error would be about half these values under these conditions, but it increases rapidly with poor visibility and badly defined objects:

Distance	Uncertainty of observations	
	80 cm. base	1 m. base
Yds.	Yds.	Yds.
500	1.2 = 1/416	1.0 = 1/500
1000	4.7 = 1/213	3.8 = 1/263
2000	19 = 1/105	15 = 1/133
3000	43 = 1/67	34 = 1/88
4000	76 = 1/53	61 = 1/66
5000	119 = 1/42	95 = 1/53
6000	171 = 1/35	137 = 1/44
7000		187 = 1/37
8000		244 = 1/33

It is essential to check the coincidence adjustment at frequent intervals, as it is liable to be upset. This is a very simple operation and can easily be carried out daily. Several devices, amounting to artificial infinities, can be provided for this purpose.

One of the great advantages of those range-finders for the surveyor is that the object ranged-on need not be visited either by the surveyor or by a staff man. This results in a saving of labour and a further saving of time. The corresponding saving of money depends upon the price of those commodities. As an auxiliary to plane-table work they are certainly valuable, though their size and weight, as compared with other plane-table accessories, do not, I think, warrant their being carried except where a large number of points have, owing to the nature of the country, to be inserted by the measurement of distances, or where labour is cheap and plentiful. For exploration surveys they are undoubtedly of great value, and it is surprising how accurately quite large distances can be masured with them. They might be a useful adjunct for triangulation reconnaissance for rough ranging and identification, particularly when this has to be undertaken quickly, though the remarks about transport also apply here. An instrument with a low minimum range is not suitable.

For certain types of traverse, where ordinary taping methods cannot be employed, they sometimes afford a means of executing the work rapidly which cannot be provided in any other way with the same degree of accuracy and speed. This is particularly noticeable in rapid river traverses. These have often had to be undertaken in the past by such means of measurement as floating ropes and even by timing the passage of a canoe over the leg of the traverse. The inevitable inaccuracies with such methods need no comment. A traverse of this nature can be carried out with a range-finder at an average speed of 6 miles a day, and with a little care gives very consistent results, which are comparable with those obtainable on land with a small stand-compass and a steel tape. For this use of the range-finders a ranging mark is necessary. A white cord suspended with a weight at the end has given good results. An upper limit of range has to be imposed according to the accuracy required, but there is no difficulty about this on small rivers. The rub comes when the course of the river necessitates a leg shorter than the minimum range of the instrument. A buoyed rope, of this length and standardized wet, is useful for this emergency, if a special short-distance range-finder cannot be carried.

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From A. S. Cutler, Professor of Railway Engineering
University of Minnesota.

I have received the bulletin of June 1931 of the Association of Field Engineers, U.S.C.G.S., for which I thank you.

I would like to be placed on your permanent mailing list, if you have one, and would be glad to pay for the publication. The articles are all very valuable and of great interest to anyone concerned with the various types of surveys.

I am especially pleased to find in your personal items and roster the names of several of our graduates; and to know of the progress they are making in the organization. Among these names, I find Pagenhart, Mattison, Nelson, Bolstad, Aslakson, Lushene and Morris.

USE OF TELESCOPIC ALIDADE FOR OBTAINING BEARINGS

W. S. Parker, Commanding Ship HYDROGRAPHER

Last summer there was issued to this ship a U. S. Navy type telescopic alidade which carries the following markings:

U. S. NAVY BUR OF NAV
TELESCOPIC ALIDADE
INSP'R. R.B.T. MK. 1 MOD. 1 NO. 152
U. S. NAVAL GUN FACTORY
WASHINGTON, D. C. 1931

This instrument consists of a plain, flanged, circular ring, similar to the usual type of azimuth circle ring, on which is supported an erecting telescope of about 3 power. The telescope is rigidly secured to the ring by four substantial bowed legs which are well braced and securely screwed and pinned to the ring. There is a window in the under side of the telescope through which an image of about one inch of that part of the pelorus repeater scale which is vertically below the telescope can be reflected, by means of prisms, into the field of view of the telescope and just below the object sighted upon. A vertical line in the field of the telescope serves for directing the telescope on the object for which the bearing is desired and the image of the scale is reflected across this line. A short level tube is slung under the telescope, at right angles with its axis and so that it is reflected through the window to a position just under the image of the scale and across the vertical line.

Two shade glasses of different degree of density are provided for use when sighting into the path of the sun. A prism attachment is included for use in taking bearings on celestial bodies other than the sun. The prism can be rotated so as to reflect a body at any altitude suitable for bearings. This attachment screws to the objective end of the telescope. A soft rubber eye shield fits over the eyepiece and is very convenient when sighting into the path of the sun. Apparently there are no adjustments possible in this instrument other than to the level tube.

This ship has also a Ritchie, Mark 111, prismatic and open sight azimuth circle, designed especially for Sperry gyro pelorus repeaters and Ritchie azimuth circle of the usual type issued to ships having Navy Standard 7-1/2 inch magnetic compasses. Both will fit our gyro pelorus repeaters and either, depending upon the preference of the officer on watch, was used until the telescopic alidade arrived.

With either of those azimuth circles it is rather difficult to read a bearing on a gyro repeater when sighting toward the sun or in that general direction. And it was frequently necessary to move the head enough to introduce parallax. It is doubtful if bearings were often obtained that were accurate to one degree.

With the telescopic alidade the scale and level are in view at all times when sighting through the telescope. Consequently, it is easy to read the bearing even if the ship yaws, rolls and pitches so much that the vertical wire can be held on the object only for an instant. The low power telescope is a great help in finding and pointing on an indistinct object. A bearing can be taken to the nearest half degree when conditions are not too unfavorable, that is, with a moderate sea and fair visibility. Under favorable conditions bearings are probably accurate to one-half degree and possibly closer. Clear reflection of a substantial strip of the scale (about one inch) reduces greatly the chance of a mistake in reading a bearing.

With this instrument it was frequently possible to get a good fix by means of a bearing and distance, either R.A.R. or range-finder, when one or both bombs failed to register because of nearly simultaneous arrival of the wave at both hydrophones, failure of one hydrophone to detect the wave, failure of radio to report it, or distance too short for chronograph to recover from the explosion.

Of course, the accuracy claimed for this alidade applies only to its use with a gyro compass repeater. On a magnetic compass it would indicate as precisely the compass bearing at the instant of observation, but the compass might have swung off its steadying point at that instant.

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American Society of Civil Engineers
New York

January 8, 1932.

Captain R. S. Patton
Washington, D. C.

Dear Captain Patton:

The copy of the "Bulletin" for December, 1931, No. 4, which you kindly sent to Society headquarters has come to my desk. You are doing a splendid piece of publication and in a unique way.

In looking over this copy, it appears that many members of the Society would appreciate obtaining copies as they are published, for the many interesting items contained in it. If copies are available even in limited numbers we would be glad to give some publicity to this effect in the February issue of CIVIL ENGINEERING.

There is an article on page 40 by R. R. Lukens, M. Am. Soc. C.E., concerning the early attempt to get the mapping of the Pacific Coast under way which we would like to reprint in the February issue in the department "Items of Interest" - if this is agreeable to you and to Mr. Lukens. * * * * * *

With best wishes for the continued success of the work of the Association of Field Engineers, I am

Very sincerely yours,
(Sgd.) Sydney Wilmot

BY-PRODUCTS OF THE CHOWAN RIVER SURVEY

C. A. Egner, H. & G. Engineer, U.S.C. & G. Survey.

"If you will pardon me, please, what is that tall tower for?"

"Part of the survey of the Chowan River."

"But listen, brother, tell me just how you do that;
we are a long way from the river."

* *

The above typical conversation, whether at Newsome Corners, at Gatesville, or at Cannon Ferry, could be recorded almost daily during that period when parties of the NATOMA were hoisting pieces of short-leaf pine skyward in building the triangulation scaffolds to control the Chowan River, N. C., survey.

It may seem like a far cry from a triangulation station established in the center of a county seat to a hand lead sounding in a river miles distant, so these questions are never considered absurd. They spring from a wholesome curiosity engendered by the sight of building parties flying by truck here and there at places seemingly illogical for the survey of a river. The reasons behind the question "Why is a tall wooden tower" go deeper into the general subject of survey control than would appear on the surface. So it is a wise man, or a true diplomat, who can answer, or parry, such a question by a sentence or two of explanation and leave the interrogator satisfied.

THE BACKGROUND: When the state of Worth Carolina recently embarked upon the ambitious program outlined so well in Mr. Syme's paper* before the Surveying and Mapping Section of the A.S.C.E., it was based upon a conception of control which has only lately become recognized as logical and economical. This paper discusses the reason behind this change in policy which, briefly stated, is that the previous system of having a multitude of separate datums scattered over his state, all assumed and uncorrelated, is now considered wasteful and that economy in the future will be gained by the establishment of a rigid common basis for all surveying datums throughout that commonwealth.

To provide this basis there was needed a network of horizontal and vertical control of the highest order of accuracy; this was to be broken later "by a system of secondary "bridge" schemes so that eventually the most remote parts of the state would be within a reasonable distance of some rigid control stations, either of first or second order. This phase of the North Carolina program touches heavily upon the Coast and Geodetic Survey, which is the organization established for the purpose of providing that needed basis framework upon which this state, or any other state, could erect such a structure.

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* Page 23, this issue of the Bulletin.

Already much has been accomplished; the Atlantic Coastal First Order Arc crosses the eastern part of the state and soon the Virginia-North Carolina Boundary Arc is to be completed. Many miles of precise levels are being added each week.

Parallel to this highest grade of control there are being inserted as occasion arises some of the secondary schemes. When, as part of its state-wide program for the development of natural waterways, North Carolina recently requested a survey of the Chowan River, the first consideration was for the accumulation of such data as would provide a basis for a chart of this river, that is, for navigational purposes.

The Chowan River is one of the principal tributaries of Albemarle Sound. In some of its sections a beautiful stream where bluffs reach the very banks, it is in others a desolate monotony of cypress swamp. In these latter aspects it certainly is no joy for a surveyor to contemplate. Surprisingly deep even to the very edge of the trees, there is accordingly very little beach line. Above Holiday's Island, where previous surveys had reached, the river narrows to a width such that any sort of an extended scheme for control would become rapidly weak. A weak chain of this sort would serve for the navigator for such a depth has for years permitted freight boats to ply their trade as far as Murfreesboro both by day and by night, though the upper portions are entirely unlighted. But such a survey, inexpensive now, would leave nothing for the future. The control would, like a long, cantilever beam, bend of its own weight; and when the established points far up the river were later used by some surveyor accustomed to the control of which Mr. Syme speaks — well, he would have a lot of embarrassing questions to ask!

With comparatively little added expense and with an actual ultimate saving, if long range considerations were given weight, there could be instituted here something fitting into the general North Carolina framework and at the same time give the Coast Survey something it could bank on in future work in this locality.

In 1931, to carry out the survey of the Port Royal Sound area in South Carolina, the work was done in a manner termed "Coastal Triangulation." This had several distinctive features, which were described in the June Bulletin of that year.

Among these were:

(1) Easy junction with an arc of a higher order.
(2) Coordination of existing work in the locality.
(3) Control for future aerial surveys.
(4) Provision for future expansion.
(5) Usefulness in hydrography and topography.

The Chowan River area presented a very similar opportunity. It so happens that this river lies between two of the basic control arcs.

These are the Atlantic Coastal Arc and the Virginia-North Carolina Border Arc. It seemed logical, therefore, that this project should look beyond the point of view of the navigator and fit the survey into the state system by joining it north and south to these two prominent arcs. With this idea in mind, the work was undertaken early in the present year by the Coast Survey Ship NATOMA.

In many ways, a coastal control survey is similar to what the state of Worth Carolina desires, for the basic idea behind each tends toward: (1) coordination of control, (2) permanence of established points, (3) usefulness, (4) provision for expansion. These are nearly a repetition of the principles adopted on the coast of South Carolina the year before.

So we come back to the opening conversation and its leading question: "Why is a tall wooden triangulation scaffold?"

The obvious answer is to enable one station to be seen from another over the tops of the trees, permitting observations which will tie these points together. That, however, tells only part of the story. Perhaps better than words can convey, the accompanying progress sketch points out the essentials.

It is a typical layout of a coastal control scheme. It also indicates the accomplished hydrography, topography and other combined operations dependent upon it. Since the idea behind the method is to bind together and interrelate all of the parts so that they compose a rigid unit with not only all branches equally strong, but the accumulation of error everywhere provided against, a way must be found to step down from the main (second order) scheme at various points along the river. Then finally it is necessary to put in a check at the upper end.

Going into some detail, there must first be a satisfactory starting line. From this the second order scheme proceeds spanning, or adjacent to, the contemporary operations. Meanwhile, parallel to this is set up a separate chain of third order work to provide the immediate control for the hydrography and topography. As the latter becomes weak it must be tied in at intervals by a position check to the second order scheme to give basis for adjustment, eliminating the accumulated discrepancy. These are somewhat similar to sub-stations on a poorer line; they put new "pep" into the system. Then at the upper end, a line check, which is a line common to both schemes, or stepped down from the second order work expressly for that purpose, gives a check on position, length, and azimuth.

THE PRACTICAL PROBLEMS: The difficulties encountered in carrying out this work were numerous:

While there was the necessity always of selecting sites for the second order stations that would satisfy the requirements of strength

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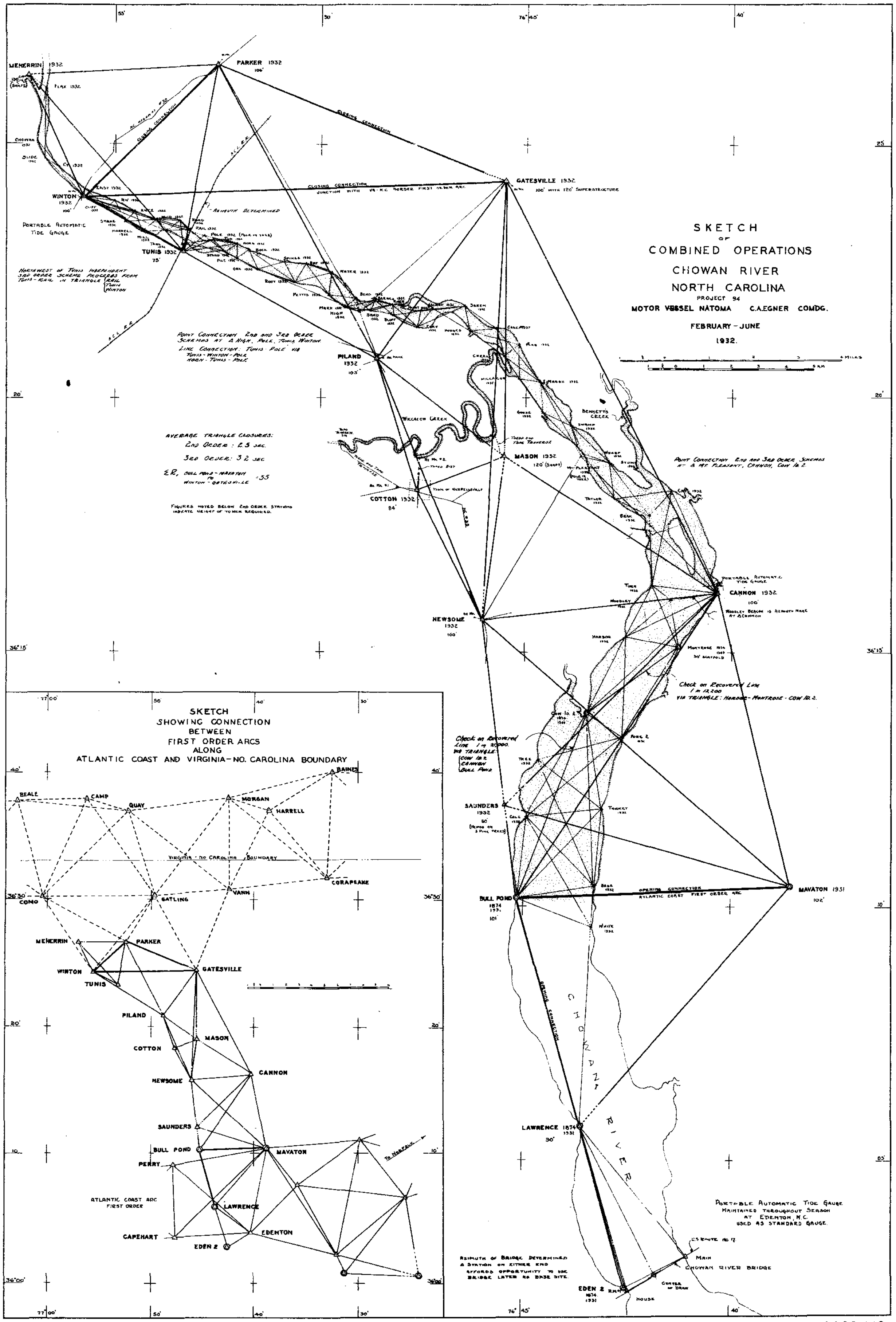

SKETCH
OF
COMBINED OPERATIONS
CHOWAN RIVER
NORTH CAROLINA
PROJECT 94
MOTOR VESSEL NATOMA C.A.EGNER COMDG.
FEBRUARY - JUNE
1932.
MEHERRIN 1932
PARKER 1932
GATESVILLE 1932
WINTON 1932
TUNIS 1932
PILAND 1932
MASON 1932
COTTON 1932
NEWSOME 1932
CANNON 1932
SAUNDERS 1932
BULL POND
MAVATON 1931
LAWRENCE 1874 1931
EDEN 2 1874 1931
CLOSING CONNECTION
OPENING CONNECTION
ATLANTIC COAST FIRST ORDER ARC
PORTABLE AUTOMATIC TIDE GAUGE
WICCACON CREEK
BENNETTS CREEK
CHOWAN RIVER
CHOWAN RIVER BRIDGE
AVERAGE TRIANGLE CLOSURES:
2ND ORDER: 2.5 SEC
3RD ORDER: 3.2 SEC
FIGURES NOTED BELOW 2ND ORDER STATIONS INDICATE HEIGHT OF TOWER REQUIRED.
PORTABLE AUTOMATIC TIDE GAUGE MAINTAINED THROUGHOUT SEASON AT EDENTON, N.C. USED AS STANDARD GAUGE.
SKETCH
SHOWING CONNECTION
BETWEEN
FIRST ORDER ARCS
ALONG
ATLANTIC COAST AND VIRGINIA-NO. CAROLINA BOUNDARY
BEALE
CAMP
QUAY
MORGAN
HARRELL
BAINES
VIRGINIA - NO. CAROLINA BOUNDARY
COMO
GATLING
VANN
CORAPEAKE
MEHERRIN
PARKER
WINTON
TUNIS
GATESVILLE
PILAND
MASON
COTTON
NEWSOME
CANNON
SAUNDERS
BULL POND
MAVATON
PERRY
LAWRENCE
ATLANTIC COAST ARC FIRST ORDER
CAPEHART
EDENTON
EDEN 2
TO NORFOLK

C&GS 442

of figure, and permit such, a scaffold height as could permit the use of wood in the construction, sight never was lost of the fact that these stations were to be useful later as well as new. This is a cardinal point of coastal control, and therefore greater care was taken in the reconnaissance than would be necessary if only the triangulation were in mind. Stations were placed in towns and at prominent crossroads purposely; these were selected in place of others perhaps better suited for triangulation but of little practical future use to anybody. A height of 100 feet turned out to be approximately the standard scaffold. It was found difficult in places to find a site for such a tall tower considering that the guy wires, necessary on this type of tower for support in strong winds, must have favorable leads. This, incidentally, is a drawback not encountered with steel towers which are not guyed. In general, it may be said that a steel tower can be easily placed on a site used for a wooden structure. For this reason, future expansion from the towers will offer no difficulty, for a greater height than that used in this work will not be required; particularly will the sites be satisfactory if steel is used.

The undertaking has been essentially a ship operation. A distinction must be made between the organization of a party suitable for carrying out such a plan to that constituted primarily for first order triangulation, or any one in which only triangulation is done. The personnel and equipment are vastly different. The same officers and crew, when the triangulation has been laid down, must turn with equal facility to topography, launch and ship hydrography, and meanwhile be navigators and seamen. Being permanently organized, when this assignment is completed they may turn to another of a totally different character where triangulation may be altogether absent. A triangulation party which is equipped to work with steel towers requires many trucks which obviously can not be carried as a ship's equipment; this is the prime reason why it is more efficient and economical at this time to build of wood which are not dismantled and moved. As the other operations are carried on parallel with the triangulation in such a project, these towers see service throughout the season. At one time all thirteen of these tall scaffolds were standing.

In the present case high trees to the very river's edge proved quite a handicap. Few opportunities were presented to "step down" immediately to the river banks. As a result all position checks and line checks represent high signals such as poles in trees which can be seen from the main scheme and from the river stations also. All second order stations were unusually tall in contrast with the usual experience of having an occasional small stand to relieve the monotony. There was a total absence of natural objects, such as high water tanks which could be used. Again, it was somewhat unusual to find that in nearly all cases of the third order stations, these had to be placed among cypress trees in waist-deep water where an instrument stand was required, with platform large enough in most cases to be used later for a plane-table set-up.

ADDITIONAL POINTS OF USEFULNESS: In addition to the major advantage of providing rigid control for the work as a whole such a layout serves other ends as well.

(1) It provides one of the second order connecting links between the two first order arcs spoken of above. As such, it is one of the "bridge" arcs which are to be part of the state control system.

(2) It establishes valuable control points with azimuth marks directly on the main highway (N. C. #30) where they are readily accessible for state highway work much desired by the state commission. At these control points the azimuth marks are visible from the ground. For a highway engineer, or local surveyor, to obtain a satisfactory starting point with accompanying azimuth, it is only necessary for him to occupy the station with a transit, orient on the azimuth mark and proceed with his traverse.

(3) Points are established in the county seats of Gatesville and Winton and at prominent crossroads where they are important to local surveyors. It is considered of value to place main scheme stations in the heart of a county seat as being the most useful spot for a county surveyor. Likewise, the selection of prominent crossroads for other stations adds to his convenience because of their accessibility.

(4) The points are selected for facility in extending lateral expansion when further second order work is undertaken in the vicinity. When this is done, it will be found of value to have these stations at such points for the reason that in the great majority of cases these towns and crossroads are higher in elevation than the surrounding region, or are perhaps adjacent to navigable streams, or as the centers of valuable farming communities.

(5) A multitude of control points are located on the Chowan River and its tributaries where, by short traverses, the control can be made available anywhere along this stream, in highway work, in land surveying, or in expanding the triangulation itself laterally.

(6) A three-mile tangent of the A.C.L. R.R., which crosses the river at Tunis, is located in position and azimuth for convenient use to anybody wishing such a starting line.

(7) At the lower end of the working grounds, the Chowan River Bridge, on U. S. Highway #17, has a triangulation station at each end of its two mile length so placed as to locate this bridge in position and azimuth and at the same time available for use, if the need ever arises, as an acceptable second or third order base site.

(8) Tie-ins were made with various lines and stations of Coast Survey work in the wider parts of the river below Cannon Ferry; these furnish a basis for putting earlier work on the same rigid basis and enable a check-up and comparison with such work of long ago in determining tendencies for the river to change its depth and shoreline.

(9) In the future, with the shoreline well tied down to a multitude of triangulation points well referenced to prominent objects, roads, etc., it will be possible to resurvey this area by aerial photography at minimum expense.

CONCLUSION: This layout as a whole, while serving the ends which led to the survey in the first place, i.e., that of providing a basis for a chart of the upper reaches of the river, has at the same time been made to fit in with the larger plan of the state of North Carolina. This latter point really changes somewhat the viewpoint of the survey as a whole, for it justifies the survey of this river in a more thorough manner than the navigator called for.

In the larger aspect, it may be said that whereas a survey may be merely local in character serving some immediate end, such as providing data for chart revision, if carried out in the manner of "Coastal Control" it looks beyond these nearby considerations and can take on permanent value and usefulness.

It would seem, in this connection, that since the principles which govern the method bear a strong resemblance to those instituted for future control of the surveys of a great state, they must have some basis in logic and economy. At least North Carolina has seen fit to heavily back its conviction.

# # # # # # # # # # # # # # # #

GEODETIC CONTROL ESSENTIAL

(Extracts from "Civil Engineering", June, 1932)

I. All of Europe has, within the past 120 years, accepted geodetic control. Even in such distant corners of the continent as the Balkan States, geodesy has been adopted as a foundation for all surveying, whether it is an individual or a public project. South African countries have also introduced geodetic coordinates as contract wherever it is possible to do so. I was personally privileged to test the high quality of geodetic work in Yucatan, and on international and interstate boundary operations in Mexico.

An engineer confronted with a geographical datum made up of degrees, minutes, and seconds, is ordinarily not prepared to make proper use of such information. He will undoubtedly be more familiar with a set of rectangular coordinates. It is, then, the conversion of geodetic data into rectangular coordinates that renders these data acceptable to the average engineer and surveyor,

An almost religious faith in the omnipotence of the time-honored method of chain-traversing apparently holds an overwhelming majority of the engineering profession in a state of hypnosis or paralysis. As a result of this condition, surveying proper, unlike other related branches of engineering, has scarcely advanced a step in this country for at least one hundred years. Barely half a dozen of our numerous colleges and technical institutes include geodesy and practical astronomy in their curricula. This explains the deplorable lack of knowledge, within our profession, of the meaning and value of geodesy. It is desirable, therefore, to create opportunities for enlightening students of engineering on the far-reaching importance of geodesy in municipal, state, and national planning.

E. W. Albrecht.

II. The paper by Mr. Syme on Geodetic Control for North Carolina Highways," in the March issue, has been read with much interest. It shows advance in the right direction, and the state officials and engineers are to be congratulated upon this progressive work. Setting up a central bureau, or general mapping agency, is certainly a necessity if the data obtained are to be available to local engineers and others. This bureau should employ expert computers who can check all data received and make such calculations and adjustments as may be necessary to put the new work on the same basis as previous work. Such computers should have training in U. S. Coast and Geodetic Survey methods.

Judging from the proposed triangulation, as shown in Fig. 1 of Mr. Syme's paper, the second-order work planned by the Coast and Geodetic Survey will be a scheme with lines of from 10 to 20 miles in length, thus leaving many spaces of 40 miles or more between triangulation schemes. Even with lines as short as 15 miles on an average, there will probably be many places where towers will be required to overcome the earth's curvature, standing timber, and other obstacles. In order that such lines may be employed by future observers who wish to use the stations for expansion into new work, similar towers will be necessary, thus increasing greatly the cost of such work and often discouraging the local engineer from making such a connection. It is therefore very essential that more points with shorter lines be located at the same time, practically, as the second-order work.

If topographic maps are to be made, control points should be available at intervals of not more than 5 miles — and preferably at intervals of 2 miles — and many of these points may be located when the second-order work is being executed. If state engineers will erect properly marked signals, at all commanding points, visible from two or more of the second-order stations, and have them ready when the Coast and Geodetic Survey observers occupy their stations, these signals can be observed while second-order observations are being made, thus taking advantage of the large instruments used by the Survey.

Owen B. French,
Professor of Civil Engineering,
George Washington University.

III. Those parts of Mr. Syme's paper in the March issue, which refer to the local engineer or surveyor, were particularly interesting to me.

The average surveyor and engineer can play a large part in helping to extend geodetic control and can, at the same time, derive much personal benefit from his efforts.

Too much emphasis cannot be placed upon Mr. Syme's statement that the survey which has been tied in to geodetic control is indestructible, as this is one of the main reasons for having geodetic control. Although every point of a survey may be lost or destroyed, the survey can be retraced and the old points relocated if the original survey has been tied in to a geodetic triangulation system. Some triangulation points may be lost, especially on coastal control, but they can be relocated, or a new control, fully as accurate as the original survey, can be established. The fact that the original survey can be thus accurately located is extremely important, particularly in title and court work.

That brings up the vital point of the importance of establishing the true meridian for surveys on which surveyors or engineers must give testimony in court. The magnetic meridian used by most surveyors is at the very best only approximate. This is due to local attractions, difference in the needles, and many other causes of error. Any case, involving two or more surveys, each with a different magnetic bearing, is often very confusing to the lawyers, jury, and even to the judge presiding over the case. When the various surveys can be brought into the true meridian and a given system of coordinates, the engineer not only has complete confidence in the accuracy of his work, but is also able to consolidate the various surveys and show clearly to the lawyers, jury, or judge the reasons for overlaps, discrepancies, and variations.

The establishing of the true meridian is also important from the title standpoint. Often the magnetic variations on title surveys are confusing to title searchers and officers. This is especially true when property has been surveyed two or three times within a period of years and each survey shows a magnetic bearing for each particular year. As a general rule, the question of the magnetic declination or variation is of loss importance in cities than it is in country districts, because in the city the old lines are usually so connected with the street lines that their bearings are of minor importance.

Geodetic control is indispensable in sounding and dredging work, particularly for projects that are many miles long. The control points are not only permanently established, but the cost of the work is cut down, and the accuracy greatly increased. Usually the time element is very important, and here again geodetic control is a great help. Precise levels with permanent and easily accessible bench marks are of great value to engineers, particularly in flat country where it is extremely important to have precise levels based on an accurate control.

Wallace H. Halsey,
Wallace H. Halsey, Inc.

GRAVITY OBSERVATIONS IN THE BAHAMA, ISLANDS

Joseph P. Lushene, Jr. H. & G. Engineer, U.S.C. & G. Survey

During the past 30 years many scientific expeditions to the West Indies have been undertaken. On these expeditions all phases of science have been studied except geophysics. It was not until 1928 that the important subject of gravity was considered and observations made to study the formation and structure of the West Indies. Dr. F. A. Venning Meinesz of the Dutch Geodetic Commission, on the invitation of the Carnegie Institution of Washington, came to the United States in 1928 and made gravity-at-sea observations from the Navy Submarine S-21 in the waters of the larger islands of the West Indies.

In 1929 I was assigned to determine values of gravity at 13 land stations in Puerto Rico, Santo Domingo, Haiti, and Cuba. The following year an expedition known as the "International Expedition to the Bahama Islands", under the auspices of Princeton University and directed by Prof. Richard M. Field, proceeded to the Bahamas. The study undertaken was the relation of the stability of the Bahama Block to the origin, migration, and alteration of the sediments deposited on the surface of the islands. The geologists, in studying the islands, realized the value and necessity of gravity observations and requested the cooperation of the Coast and Geodetic Survey, with the result that I was detailed to accompany the expedition and make observations on six islands of the Bahama Group. The results were so promising and interesting that a second trip of the expedition, made in February and March, 1932, was devoted entirely to gravity observations on land and sea. During this trip I established 12 land stations and was later assigned to the Navy Submarine S-48 to assist in the gravity-at-sea observations.

The islands on which the recent observations were made were the Windward Islands of the Bahamas, the most easterly ones in the group. With the exception of Cat Island, these are low, being only a few meters above mean sea level. Cat Island, the highest, has an elevation of 400 feet. The islands are either sandy, marshy, or of coral formation, with a few scattered bushes, palms and shrubs. In general, they are all the same; uninteresting bare islands. As Dr. Ulric Dahlgren of Princeton University quotes, "The first and lasting impression of the entire region was that of an area in which but few kinds, and only a small number, of animals and plants could live."

It is very seldom that one visits these islands, for the only contact with the outside world is through Nassau, New Providence Island, by means of a monthly mail boat. When the mail boat comes to port it is a gala event and a day of celebration for the natives. It was extremely interesting to observe their expressions when the monthly boat arrived in port four or five days late.

The natives are extremely primitive and superstitious and have no means of earning money. They feel that the islands are full of buried gold and treasure for their use. Consequently, whenever a stranger comes to the islands great suspicion is aroused as to his presence. On practically all the islands it was found almost impossible to convince them that gravity work was being considered rather than gold prospecting. At one of the stations it was impossible to convince them that gold was not being sought. This station was an important one and observations had to be made. As a result a native with a double barreled shotgun stood by during the 24 hours of observations. I asked him the reason for the gun, but was informed "duck hunting." As far as I could learn, the nearest ducks were in Florida about 250 miles distant. At any rate, the guard was a good sport and considerable chatting took place. It was realized that he was merely fulfilling the wishes of the populace to guard the buried treasure. It was learned that previous to my arrival, a spirit presented itself to one of the natives, at the exact position of the station, and informed him that gold was buried at that spot.

The yacht "Marmion", an auxiliary yawl of 19-ton capacity and owned by Mr. H. M. Matheson of Miami, was the means of transportation for the party. This yacht proved to be the ideal type of vessel for work in this remote locality where fueling was such a vital problem. A very important factor in the success of the work was Mr. Matheson's knowledge of the region, coupled with his ability as a navigator. He placed his yacht, crew, and himself unreservedly at the disposal of the expedition and also cared for the entire expense of the oceanographic part of the work.

Since it was so difficult to land the gravity apparatus, it was necessary to use a rugged field instrument, and as a result, the Mendenhall invariable half-second (quarter meter) pendulum apparatus was selected. The observations were made in a 9 by 9 center pole tent. In cases where the islands were sandy and low, concrete piers were built to support the instrument. Ordinarily, however, no difficulty was encountered in locating hard coral masses to support it. Due to the intense light during the day, a tunnel, consisting of heavy canvas wrapped around a frame 3 feet in diameter and 6 feet in length, was used. This tunnel was placed between the pendulum receiver and the flash apparatus so that the coincidences of flashes of light could be observed. Working in localities where the humidity differs from that of the base station, it is advisable to place a small amount of a dehydrating salt in the corner of the receiver. The period of a pendulum is lengthened by buoyancy or hydrodynamic affect. The pressure of water vapor is greater in relation to its density than is the case for air and thus the buoyancy effect is less for saturated air than for dry at the same pressure. Ordinarily, no account is taken of the humidity of the air in the receiver for the effect is small when observations are made in buildings or other enclosed structures. But in the open spaces, with a tent, in localities where the change of temperature is appreciable, the question of humidity is important. For example, observations are begun at noon for the first swing of the pendulum when the air is dry and hot. The swing is completed at midnight and a new swing begun. By this time the tent is covered with a heavy layer of dew and the air within is extremely damp and uncomfortable. The buoyancy and hydrodynamic effect is quite different from that of the previous swing, and consequently a larger probable error of the observation will result. The average probable error of the 12 stations observed was 13 parts in 10,000,000. This low probable error was due in a large degree to the use of a dehydrating salt.

Of the 18 stations observed in the Bahamas, 16 anomalies are negative and 2 positive. The two most northerly stations showed positive anomalies. It is a most striking feature that the anomalies on the Bahama Islands are negative. A large majority of the island stations of the world show positive isostatic gravity anomalies. Since most islands are formed of igneous rock, this is thought to be the reason for their positive anomalies. It is certain from the evidence of the gravity observations that the Bahama Islands are not underlaid by igneous rocks and did not originate as the result of submarine igneous activity. They are, without doubt, continental in character and closely related to the continent. There seems to be good evidence that the Bahama Block and surrounding area are in isostatic equilibrium to a marked degree, and that the anomalies at several stations are probably duo to abnormally light material close to the stations. The gravity data showed that, in all probability, the Bahama Block is an old mountain system which has eroded and had its high tops cut off. In some cases these tops were probably eroded slightly below sea level and sedimentation and coral growth brought them to the surface as Islands. The unusually deep bodies of water such as the Tongue of the Ocean, Providence Channel, and Exuma Sound are probably eroded river valleys.

Wherever the crust of the earth is dense, block-faulting or shearing results and in lighter material it is folded, depressed and buckled. To illustrate this condition, let us assume two columns. The first is slender and light, and when compression is applied it buckles, bends, and folds. The other is very massive and dense. In this case shearing will take place. The Bahama Islands, having negative anomalies of gravity, being very light in material, are therefore a folded system. Although the anomalies are of the same sign, they are rather local and the region as a whole is undoubtedly in isostatic equilibrium.

It is hoped that gravity observations will be made in the Lesser Antillios in the near future by the Coast and Geodetic Survey. These would give the geologists and students of isostasy complete and detailed information of the West Indies.

CONVERSION OF RADIO BEARINGS TO MERCATORIAL BEARINGS

A. L. Shalowitz, Cartographic Engineer, U.S.C. & G. Survey

The universal adoption of the Mercator system of map projection for nautical charts and the increasing use of radio directional hearings at sea make it pertinent at this time to consider certain limitations of the Mercator projection in respect to the plotting of such bearings.

As is well known, the most important and useful navigational property of the Mercator projection lies in the fact that on it and it alone the rhumb line or loxodromic curve is represented as a straight line. Hence if any two points on the chart are joined by a straight line, the bearing of this line will represent the course which a vessel must follow continuously in order to go from one place to another on a single true course.

Great circles, on the other hand, unless in the plane of the Equator or of a meridian, are represented on this projection as curved lines, and since radio signals follow the paths of great circles, the correct plotting of radio bearings on a Mercator chart becomes a matter of considerable importance if maximum usefulness is to result from this comparatively new but already valuable aid to marine navigation. (See Radio Beacons and Radio Beacon Navigation by G. R. Putnam, p. 2, note 2)

Obviously, it is impracticable for a navigator to plot such lines on his Mercator chart, so the problem becomes one of applying a correction to the radio bearing, as observed on the vessel or received from the shore station, in order to obtain the rhumb line bearing between the two points. For convenience this bearing will hereafter be referred to as the Mercatorial bearing.

While the theory underlying the practical solution of this problem is simple and based upon established principles of mathematics, its application in practice has probably been limited by reason of the necessity for making certain computations or for referring to certain auxiliary charts for obtaining the corrections.

It is therefore the purpose of this paper to present briefly and simply a self-contained method by which a navigator can quickly determine his Mercatorial bearings from the radio bearings received or observed, and with a degree of accuracy fully commensurate with the accuracy attainable in the present development of radio navigation. The method can be utilized for distances up to 1000 miles, a distance far in excess of that possible with present instruments and technique.

The tables and method of applying the corrections were first prepared by the writer as far back as 1924 and have appeared ever since in all editions of our Coast Pilots. It has since then also appeared in a similar form on the pilot charts of the Hydrographic Office. It is being presented here with some modifications in the belief that with the increasing use of radio bearings it will in its present form find wider application.

TERMINOLOGY: In the following pages the term radio direction finder station means those stations that are equipped to determine the direction of a radio signal transmitted by a vessel. The term radio beacon means those stations (ashore or afloat) that transmit characteristic radio signals at stated intervals and the bearings of which are determined by the vessel's radio compass. The term radio station is used to denote those stations (radio direction finder or radio beacon) whose geographic positions are fixed.

DERIVATION OF FORMULA FOR CONVERSION: The azimuth of a line on the surface of the earth varies from point to point by an amount which closely approximates the corresponding convergence of the meridians. The value for the convergence is derived as follows:

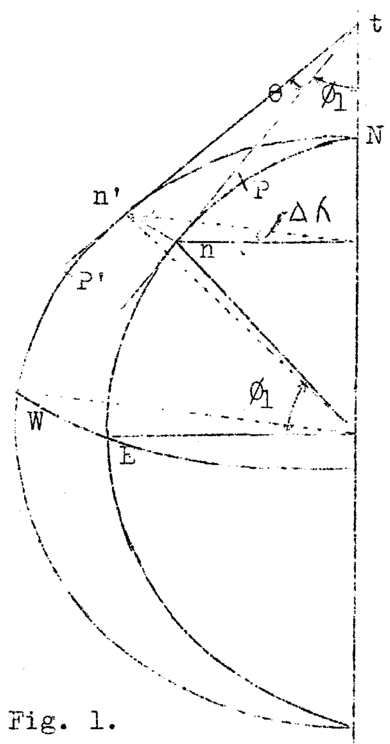


Fig. 1.

In the figure, θ = convergence of the meridians NE and NW for the common latitude ϕ_1. If we assume two points P and P' on these meridians hut not in the same latitude, then the convergence for the middle latitude would be understood. So that in the figure, if n and n' are points on the middle latitude ϕ_1, and ϕ and ϕ' are the latitudes of P and P' respectively, than the convergence θ would be the convergence for the middle latitude ϕ_1, or 1/2 $(\phi + \phi')$. Now if $\Delta\lambda$ = difference of longitude between the two meridians it can be shown from trigonometry that

$$\sin \tfrac{1}{2}\theta = \sin \tfrac{1}{2}(\Delta\lambda) \sin \tfrac{1}{2}(\phi + \phi')*$$

which for the problem under consideration can be reduced with sufficient accuracy to the form,

$$\tfrac{1}{2}\theta = \tfrac{1}{2}(\Delta\lambda) \sin \tfrac{1}{2}(\phi + \phi') \qquad \text{(I)}$$

where θ is expressed in the same unit as $\Delta\lambda$

---

*Proof: In Fig. 1 let no = r = radius of parallel of latitude at n
nt = T = tangent at n

In the plane triangle nn't, chord $nn' = \sqrt{(n't)^2 + (nt)^2 - 2(nt)(n't)\cos\theta}$

Now n't = nt = T, hence $nn' = T\sqrt{2(1-\cos\theta)} = 2T\sqrt{\frac{1-\cos\theta}{2}}$

Now $\sin \tfrac{1}{2}\theta = \sqrt{\frac{1-\cos\theta}{2}}$, therefore, $nn' = 2T \sin \tfrac{1}{2}\theta$

Similarly, $nn' = 2r \sin \tfrac{1}{2}(\Delta\lambda)$

But $r = T \sin \phi_1$

Therefore $2T \sin \tfrac{1}{2}\theta = 2T \sin \phi_1 \sin \tfrac{1}{2}(\Delta\lambda)$,

or $\sin \tfrac{1}{2}\theta = \sin \tfrac{1}{2}(\Delta\lambda) \sin \tfrac{1}{2}(\phi + \phi')$

It will now be shown that equation (1) is also the expression for the correction to be applied to a radio bearing to reduce it to a mean Mercatorial bearing.

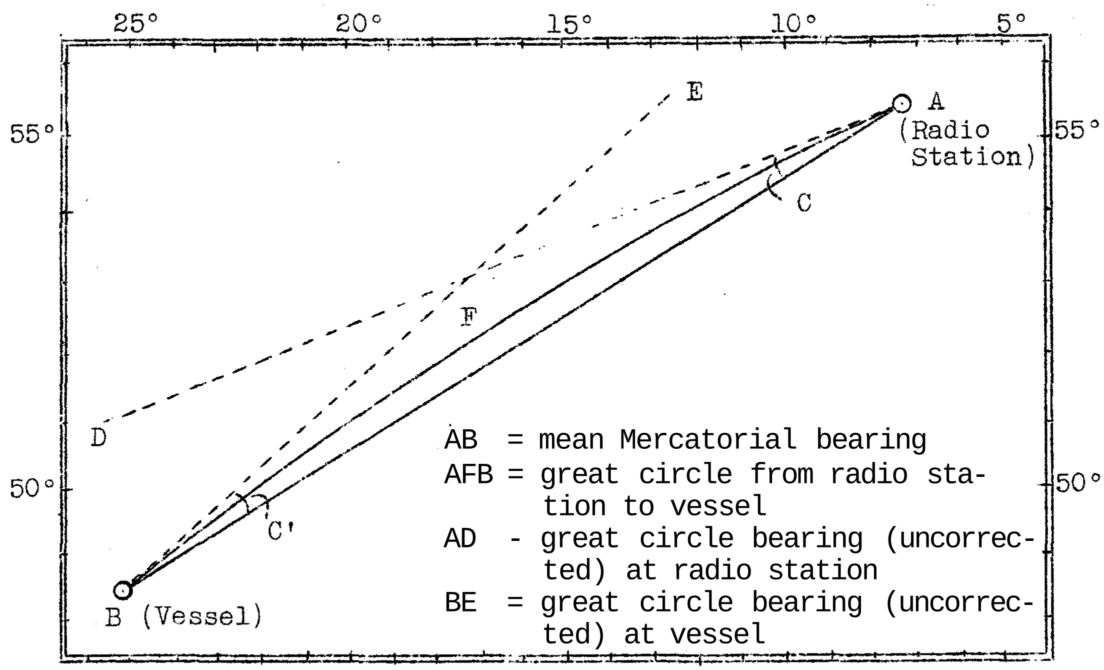


Fig. 2 - Relation of Corrected to Uncorrected Radio Bearings

Fig. 2 represents a portion of a chart on a Mercator projection.

Let T = great circle bearing at A
T'= great circle bearing at B
C = correction to be applied at A to obtain Mercatorial bearing
C'= correction to be applied at B to obtain Mercatorial bearing
θ = convergency of the meridians

From the figure it is seen that the Mercatorial bearing at A = T - C and Mercatorial bearing at B = T' + C'
Or T - C = T' + C'
But T' = T - θ
Therefore T - C = (T - θ) + C'
Or C + C' = θ

That is, the correction to the great circle bearing at one end plus the correction to the great circle bearing at the other end is equal to the convergence of the meridians. Hence, the numerical value of the mean correction at either end = $\frac{C + C'}{2} = 1/2\ \theta$.

RULE FOR CONVERSION: Since radio signals are assumed to follow the paths of great circles on the surface of the earth, we have the following simple rule for conversion:

> To convert a radio bearing between any two points on a Mercator chart into a mean Mercatorical bearing, add or subtract (see Table II) to (from) the radio bearing, one half the convergence of the meridians between the two points.

SIGN OF THE CORRECTION: The sign of the correction will depend upon whether the bearings are observed at the vessel or at the radio direction finder station as well as upon the relative positions of the two. By referring to Fig. 3 and remembering that the curve which represents a great circle on the Mercator projection is in all cases concave toward the Equator, the sign of the correction can readily be ascertained. However, to avoid any possible confusion in the solution of radio navigation problems, the following table has been prepared.

TABLE II
Sign of the Correction to Radio Bearings

North Latitudes		
	Bearings observed at radio station	Bearings observed at vessel
Vessel East of Radio station	+	−
Vessel West of Radio station	−	+

If working in south latitudes the signs in the table should be reversed.

TABLE OF CORRECTIONS

It was shown in equation (1) that $\frac{1}{2}\,\theta = \frac{1}{2}\,(\Delta\lambda)\,\sin\frac{1}{2}\,(\phi + \phi')$ It follows, therefore, that the correction to any radio bearing can be determined if we know the latitudes and longitudes of the radio station and of the vessel by dead reckoning.

Corrections have been computed for values of $(\Delta\lambda)$ ranging from one-half degree to 20 degrees and for values of $\frac{1}{2}\,(\phi + \phi')$ from 5° to 65°, and the results are shown in Table I. It is unnecessary to consider latitudes below 5° since the convergence of the meridians in the vicinity of the Equator is practically negligible and the correction can usually be ignored.

The table is entered with the difference of longitude between the vessel and the radio station as one argument and opposite the corresponding middle latitude, the correction to be applied to the radio bearing is read in degrees and tenths. The correct sign is then determined from Table II.

PRECAUTIONS THAT SHOULD BE OBSERVED

Radio Bearings Observed at Vessel: The method is equally applicable whether the bearings are received from the radio direction finder station or whether observed at the vessel, except that in the latter case, since the position of the radio beacon is fixed on the chart, the Mercatorial bearing from vessel to radio beacon should be increased by 180° and the resulting bearing plotted from the radio beacon. In

TABLE I

CORRECTIONS TO BE APPLIED TO RADIO BEARINGS TO CONVERT TO MERCATORIAL BEARINGS
(Corrections are in degrees)
DIFFERENCE OF LONGITUDE

Mid Lat.	0.5°	1.0°	1.5°	2.0°	2.5°	3.0°	3.5°	4.0°	4.5°	5.0°	5.5°	6.0°	6.5°	7.0°	7.5°	8.0°	8.5°	9.0°	9.5°	10.0°	Mid Lat.
5°	--	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	5°
6	--	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	6
7	--	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	7
8	--	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	8
9	--	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	9
10	--	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	10
11	--	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	11
12	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	12
13	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	13
14	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.2	14
15	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	15
16	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	16
17	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	17
18	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.5	18
19	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5	1.6	19
20	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	20
21	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	21
22	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	22
23	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	23
24	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	24
25	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.0	2.0	2.1	25
26	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	l.8	1.9	2.0	2.1	2.2	26
27	0.1	0.2	0.3	0.5	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.3	27
28	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.2	2.3	28
29	0.1	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	29
30	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.2	2.4	2.5	30
31	0.1	0.2	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.6	31
32	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.8	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6	32
33	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.4	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.4	2.6	2.7	33
34	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.4	2.5	2.6	2.8	34
35	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.0	2.1	2.5	2.4	2.6	2.7	2.9	35
36	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	36
37	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.7	2.9	3.0	37
38	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	8.1	2.3	2.5	2.6	2.8	2.9	3.1	38
39	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.8	3.0	3.1	39
40	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.8	1.9	2.1	2.2	2.4	2.6	2.7	2.9	3.0	3.2	40
41	0.2	0.3	0.5	0.6	O.8	1.0	1.1	1.3	1.5	1.6	1.8	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.1	3.3	41
42	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8	3.0	3.2	3.3	42
43	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.9	3.1	3.2	3.4	43
44	0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.6	2.3	2.9	3.1	3.3	3.5	44
45	0.2	0.3	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.2	3.3	3.5	45
46	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.1	2.3	2.5	2.7	2.9	3.0	3.2	3.4	3.6	46
47	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.3	3.5	3.6	47
48	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	48
49	0.2	0.4	0.8	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	49
50	0.2	0.4	0.6	0.8	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.2	3.4	3.6	3.8	50
51	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	51
52	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.3	3.5	3.7	3.9	52
53	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.3	4.0	53
54	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	54
55	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	55
56	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	56
57	0.2	0.4	0.6	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.6	3.8	4.0	4.2	57
58	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	3.0	3.2	3.4	3.6	3.8	4.0	4.2	58
59	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.1	4.3	59
60	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.2	2.4	2.6	2.8	3.0	3.2	3.5	3.7	3.9	4.1	4.3	60
61	0.2	0.4	0.7	0.9	1.1	1.3	1.5	1.7	2.0	2.2	2.4	2.6	2.8	3.1	3.3	3.5	3.7	3.9	4.2	4.4	61
62	0.2	0.4	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.5	3.8	4.0	4.2	4.4	62
63	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.6	3.8	4.0	4.2	4.5	63
64	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.5	2.7	2.9	3.1	3.4	3.6	3.8	4.0	4.3	4.5	64
65	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.9	4.1	4.3	4.5	65

TABLE I (continued)

CORRECTIONS TO BE APPLIED TO RADIO BEARINGS TO CONVERT TO MERCATORIAL BEARINGS
(Corrections are in degrees)
DIFFERENCE OF LONGITUDE

Mid Lat.	10.5°	11.0°	11.5°	12.0°	12.5°	13.0°	13.5°	14.0°	14.5°	15.0°	15.5°	16.0°	16.5°	17.0°	17.5°	18.0°	18.5°	19.0°	19.5°	20.0°	Mid. Lat.
5°	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	5
6	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	6
7	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	7
8	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	8
9	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.6	1.6	9
10	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.7	1.7	10
11	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	l.6	1.7	1.7	1.8	1.8	1.9	1.9	11
12	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	12
13	1.2	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2	13
14	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.3	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.4	2.4	14
15	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	15
16	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.8	16
17	1.5	1.6	1.7	1.3	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.3	2.9	17
18	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	18
19	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	19
20	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.3	3.4	20
2l	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	3.3	3.4	3.5	3.6	21
22	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.7	22
23	2.1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.3	3.9	23
24	3.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.5	3.4	3.5	5.6	3.7	3.8	3.9	4.0	4.1	24
25	2.2	2.3	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	5.8	3.9	4.0	4.1	4.2	25
26	2.3	2.4	2.5	2.6	2.7	2.3	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.3	3.9	4.1	4.2	4.3	4.4	26
27	2.4	8.5	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.3	4.4	4.5	27
28	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.8	3.9	4.0	4.1	4.2	4.3	4.5	4.6	4.7	28
29	2.5	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.6	3.8	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	29
30	2.6	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5.0	30
31	2.7	2.8	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.2	31
32	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.3	32
33	2.9	3.0	3.1	3.3	3.4	3.5	3.7	3.8	4.0	4.1	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.3	5.5	33
34	2.9	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.1	4.2	4.3	4.5	4.6	4.8	4.9	5.0	5.2	5.3	5.5	5.6	34
35	3.0	3.2	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.4	5.6	5.7	35
36	2.1	3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	36
37	3.2	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	6.0	37
38	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.3	4.9	5.1	5.2	5.4	5.5	5.7	5.8	6.0	6.2	38
39	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.1	6.3	39
40	3.4	3.5	3.7	3.9	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.4	40
41	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	4.9	5.1	5.2	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6.6	41
42	3.5	3.7	3.3	4.0	4.2	4.4	4.5	4.7	4.9	5.0	5.2	5.4	5.5	5.7	5.9	6.0	6.2	6.4	6.5	6.7	42
43	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	4.9	5.1	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.5	6.6	6.8	43
44	3.6	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.0	5.2	5.4	5.8	5.7	5.9	6.1	6.3	6.4	8.6	6.8	6.9	44
45	3.7	3.9	4.1	4.2	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.7	5.8	6.0	6.2	6.4	6.5	6.7	6.9	7.1	45
46	3.8	4.0	4.1	4.3	4.5	4.7	4.9	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.5	6.6	6.8	7.0	7.2	46
47	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.3	5.5	5.7	5.3	6.0	6.2	6.4	6.6	6.8	6.9	7.1	7.3	47
48	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.2	7.4	43
49	4.0	4.2	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.5	49
50	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.7	50
51	4.1	4.3	4.5	4.7	4.9	5.0	5.2	5.5	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	51
52	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.7	7.9	52
53	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	53
54	4.3	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.7	7.9	8.1	54
55	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	55
56	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.3	7.5	7.7	7.9	8.1	8.3	56
57	4.4	4.6	4.8	5.0	5.2	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.3	8.0	8.2	8.4	57
58	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.3	8.1	8.3	8.5	58
59	4.5	4.7	4.9	5.1	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.9	7.1	7.3	7.5	7.7	7.9	8.1	8.4	8.6	59
60	4.6	4.7	5.0	5.2	5.4	5.6	5.3	6.l	6.3	6.5	6.7	6.9	7.1	7.4	7.6	7.8	8.0	8.2	3.4	8.7	60
61	4.6	4.8	5.0	5.2	5.5	5.7	5.9	6.1	6.3	6.6	6.8	7.0	7.2	7.4	7.7	7.9	8.1	8.3	8.5	8.3	61
62	4.6	4.9	5.1	5.3	5.5	5.7	6.0	6.2	6.4	6.6	6.8	7.1	7.3	7.5	7.7	7.9	8.2	8.4	8.6	8.8	62
63	4.7	4.9	5.1	5.5	6.6	5.8	6.0	6.2	6.5	6.7	6.9	7.1	7.4	7.6	7.8	8.0	8.2	8.5	8.7	8.9	63
64	4.7	4.9	5.2	5.4	5.6	5.8	6.1	6.3	6.5	6.7	7.0	7.2	7.4	7.6	7.9	8.1	8.3	8.5	8.8	9.0	64
65	4.8	5.0	6.2	5.5	5.7	5.9	6.1	6.3	6.6	6.8	7.0	7.2	7.5	7.7	7.9	8.2	8.4	8.6	8.8	9.1	65

both cases, of course, the largest scale chart available should be used.

It is important to emphasize here that the corrections that are being considered in this paper are corrections due solely to the characteristics of the Mercator projection, and must not be confused with errors due to distortion of the incoming radio wave. Such errors are determined by calibration and should be allowed for before any other corrections are applied. Similarly, where the rotating coil is mounted directly over the ship's magnetic compass, the errors due to variation and deviation should also be applied in order to obtain the true bearing of the radio wave.

Where Dead Reckoning Position is not Available; If the vessel's position by dead reckoning is not available, its approximate position can be determined by plotting the uncorrected bearings as received or observed directly on the Mercator chart. This will generally give a position considerably in error, but it will serve for obtaining a good first approximation. The tables are entered as before and the proper corrections ascertained. These corrected radio bearings are then plotted on the chart and a new position of the vessel determined which should correspond to a good dead reckoning position. The tables are re-entered using this new position of the vessel and new corrections determined.

Likewise, where the position by dead reckoning differs greatly from the true position of the vessel as determined by plotting the corrected radio bearings, a retrial should be made using the new value as the position of the vessel. Generally the vessel's position will be known with sufficient closeness to make more than one trial unnecessary.

Application in Practice

Example 1 - Bearing observed at radio direction finder station: A ship in latitude 37° 20' N., longitude 69° 20' W. by dead reckoning receives a radio bearing of 64° from a radio direction finder station located in latitude 35° 14' N., longitude 75° 32' W. Find the Mercatorial bearing of the ship from the station.

	Latitude		Longitude
Radio direction finder station	35° 14' N.		75° 32' W.
Vessel	37 20		69 20
(Mid. lat.)	36 17	(Diff.long.)	6 12

Entering Table I with difference of longitude = 6.2° and 36° middle latitude, we obtain by interpolation the correction 1.8°. Since the vessel is east of the radio station and the bearings were observed at the radio station, we find from Table II that the correction is plus. The Mercatorial bearing from the radio station to the vessel will therefore be 64° + 1.8° = 65.8°.

Example 2 - Bearing observed at vessel: A ship in latitude 48° 45' N., longitude 25° 30' W., by dead reckoning, observes a radio bearing of 50° true on a radio beacon located in latitude 55° 22' N., longitude 7° 19' W. Find the Mercatorial bearing of the beacon from the vessel.

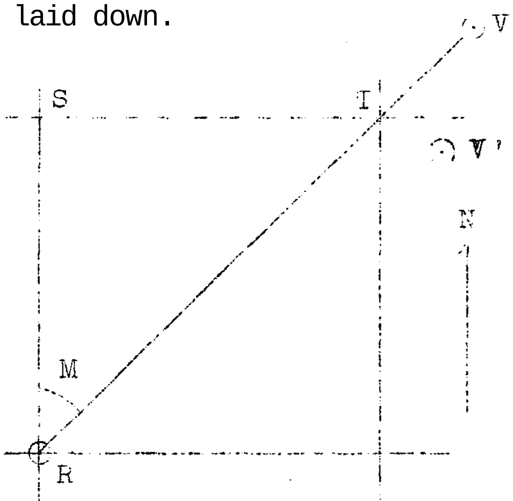
	Latitude		Longitude
Radio beacon	55° 22' N.		7° 19' W.
Vessel	48 45		25 30
(Mid. Lat.)	52 03	(Diff. long.)	18 11

Entering Table I with difference of longitude = 18.2° and 52° middle latitude, we obtain by interpolation 7.2°. Since the vessel is west of the radio station and the bearings were observed at the vessel, we find from Table II that the correction is plus. The Mercatorial bearing from the vessel to the radio beacon is therefore 50° + 7.2° = 57.2°.

To plot this bearing add 180° and lay it off from the radio beacon, that is, 57.2° + 180° = 237.2°, the Mercatorial bearing from the radio beacon to the vessel.

Plotting the Mercatorial Bearings

After the proper Mercatorial bearings have been determined, it becomes necessary to plot these bearings on the chart with a fair degree of accuracy, otherwise the value to be derived from applying corrections will be entirely vitiated. Particularly true is this when long distances are involved. In such cases if accurate means are not available for plotting the bearings graphically, a simple computation will determine a point on the rhumb line which can be joined with the position of the radio station by a straight line and the bearing thus laid down.



In the figure, R is the position of the radio station whose latitude and longitude are known, M is the Mercatorial bearing, V is the true position of the vessel and V' the position by dead reckoning.

The problem is then to determine the latitude of the point T where the Mercatorial bearing crosses a meridian somewhere in the vicinity of the vessel. The meridian closest to the vessel's position by dead reckoning should be used for this purpose.

From the figure, $\frac{ST}{SR} = \tan M$ from which $SR = \frac{ST}{\tan M}$

Now SR = meridional distance between the latitude of the radio station the latitude sought, and ST = the difference of longitude in minutes between those two points. Therefore if we take from the Mercator projection tables the meridional distance corresponding to the latitude of the radio station and to that value add the meridional distance (SR) computed above we obtain the meridional distance for the latitude sought, from which the latitude of T can be determined by again referring to the Mercator tables.

Determination of Mercatorial Bearings by Computation

Any Mercatorial bearing can be computed from the formula

$M = E \pm \frac{D}{2} \sin \frac{(B + B')}{2}$ where

M = Mercatorial bearing required

E = radio bearing received from radio direction finder station or observed at the vessel

D = difference of longitude between radio station and vessel's position by dead reckoning

B = latitude of radio station

B'= latitude of vessel by dead reckoning

Table of Natural Sines

Mid. L.	Sine	Mid. L.	Sine	Mid. L.	Sine	Mid. L.	Sine	Mid. L.	Sine	Mid. L.	Sine
°		°		°		°		°		°	
0	.00000	11	.19081	22	.37461	33	.54464	44	.69466	55	.81915
1	.01745	12	.20791	23	.39073	34	.55919	45	.70711	56	.82904
2	.03490	13	.22495	24	.40674	35	.57358	46	.71934	57	.83867
3	.05234	14	.24192	25	.42262	36	.58779	47	.73135	58	.84805
4	.06976	15	.25882	26	.43837	37	.60182	48	.74314	59	.85717
5	.08716	16	.27564	27	.45399	38	.61566	49	.75471	60	.86603
6	.10453	17	.29237	28	.46947	39	.62932	50	.76604	61	.87462
7	.12187	18	.30902	29	.48481	40	.64279	51	.77715	62	.88295
8	.13917	19	.32557	30	.50000	41	.65606	52	.78801	63	.89101
9	.15643	20	.34202	31	.51504	42	.66913	53	.79864	64	.89879
10	.17365	21	.35837	32	.52992	43	.68200	54	.80902	65	.90631

Errors Resulting from Plotting Uncorrected Radio Bearings

The importance of the problem presented in the foregoing pages will be better appreciated if we consider the error introduced in a vessel's position if the radio bearings are plotted on the Mercator chart without applying any corrections.

The following table gives the errors in nautical miles for various distances from the radio station and for various latitudes. In each case an east-and-west bearing is assumed in order to obtain the maximum correction for that distance from the radio station.

The values given in the table are based on graphical determinations.

TABLE OF ERRORS
(in Nautical Miles)

	Distance from Radio Station in Nautical Miles				
Latitude	100	200	300	500	1000
20°	0.6	2.4	4.5	13.5	53
40°	1.3	4.9	11.0	30.	125
60°	2.5	10.3	23.	64.	262

Conclusion

From what has been said, it should not be inferred that because the paths of radio signals are great circles, any projection, such as the "Gnomonic," on which great circles are represented as straight lines offers a ready solution of the problem under consideration. It does not. What we have been considering here is not the laying down of a great circle between two given points, but the laying down of a true azimuth from a given radio station. This is another problem and would require a set of specially constructed charts on a workable scale with a compass rose at each station or a table of corrections for each station for that particular chart (see Radio Compass Bearings, by Oscar S. Adams, Serial No. 67).

Another projection sometimes mentioned in connection with radio bearings is the "Double or Two-Point Azimuthal Projection" in which straight lines radiating from the chosen points represent great circles in their true azimuths. The limited applicability of this projection for general use in radio navigation is quite obvious. However, in special cases, it might be found a very useful adjunct.

It is this writer's opinion that the method herein outlined for use directly on Mercator charts lends itself admirably to the expeditious solution of present day radio navigation problems.

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WRINKLES AND SUGGESTIONS

USE OF PIPE DRAG ON WIRE DRAG SURVEY
H. E. Finnegan

During the 1931 season the Wire Drag Party constructed and used a short pipe drag for the purpose of investigating the reported existence of a wreck in Northport Channel.

Ten sections of galvanized iron pipe (in lengths of twenty feet) were substituted for ground wire. Shackles were fitted at the ends of each section and the drag was set out in the usual manner with uprights, weights, and drag buoys for support.

At first an attempt was made to tow this drag with pulling boats but very little headway could be made, even with the aid of the current, since most of the effort of the oarsmen was expended in keeping the ends of the drag on line. By attaching the large end buoys and weights it was found that the launches could be used to tow this drag without causing any lift.

This type of drag is excellent for the investigation of narrow channels or areas, where it is impossible to keep a constant strain on the drag. The pipe drag has no appreciable lift or sag. Therefore, in setting the depth of the drag only one variable factor need be considered, the change in tide.

In using the wire drag it is necessary to discontinue a line when the launches stop towing for any reason, because as soon as the strain is removed the toggles or floats lift the ground wire. With the pipe drag, however, no lift occurs when the launches stop towing and the line may be continued with the assurance that the entire area has been dragged to the effective depth.

This type of drag could be operated satisfactorily, in narrow channels and shoal areas, by using small, shallow draft, launches, such as the wire drag tender, and so make it possible to drag many important inshore areas that could not be accomplished by the wire drag and the larger launches.

SPECIAL STATION MARKS, ETC.
Charles Pierce

(Extract from a letter to the Assistant Chief, Division of Geodesy. Mr. Pierce is executing a second-order coastal control scheme on the California Coast, in the vicinity of Monterey Bay, in advance of combined operations of the party on the Ship GUIDE).

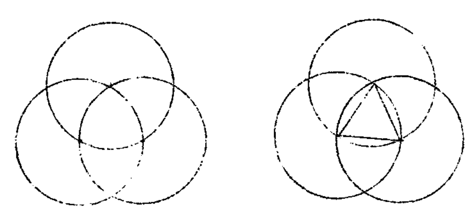
Field work started on this second order triangulation on April 16, 1932, when Lieutenant Bowie had transferred all men and trucks to my party. We have placed through for the first fifteen miles a scheme of approximately first order strength and have stations every two miles along the coast. On the coast side of the scheme many of the stations are on sand dunes, of a type that are fairly permanent as far as can be observed. In order to place marks that would be reasonably certain of permanency we had the choice of using long cast iron pipes or deep marks with wooden forms. No Suitable cast iron pipe could be secured in Monterey so we have been placing both station marks and two reference marks at these sand dune stations as follows: Wooden forms approximately 5.5 feet long were made with an inside cross section 7 inches square. These were set in the sand 4.5 feet below the surface and projecting about one foot above the sand. Although the cross sectional area was reduced the increased length, in my opinion, gives these marks a far better chance for permanency. Especial care is being given to the marking of all the stations and this work is in charge of O. S. Risvold, signalman, with three men for assistants.

We started our field work from three of Lieutenant Meaney's old stations and our angles at these three stations checked his very closely. We have been using an 8-inch Fennel direction theodolite No. 285, with eight positions of the circle and a five-second rejection limit from the mean. For fifteen triangles closed to date we have an average closing error of 1.4 seconds and are naturally quite pleased with this instrument. Many of the lines have been "grazing" lines and the seeing conditions about an average for day observing. We have not been able to figure any side checks as the computations are to be carried backward from a connection with Lieutenant Bean's earthquake triangulation at Monterey, California, but should tie in here in a week or so.

CONSTRICTION OF EQUILATERAL TRIANGLES ON SMOOTH SHEETS, ETC.

Ector B. Latham

In the preparation of progress sketches, smooth sheets, reconnaissance sketches, etc., the equilateral triangle, used to represent triangulation stations, can readily be constructed as follows: With radius equal to the desired length of side, describe a circle. From a point on the circumference, as center, describe another circle, with the center at the intersection of the two circles described, describe a third circle. Then by joining three intersections, the triangle will be obtained.



EFFECT OF CURRENT ON SOUNDINGS

(Extract from Report of R. F. A. Studds on Survey of Cooper and Wando Rivers, South Carolina)

The action of the current on the leadline, when the current is opposed to the direction of the sounding launch, is to indicate too great a depth. It is assumed that, in running against a current, a bight is formed in the leadline. The current acts on both the submerged portion of the line and the lead, but the horizontal motion of the former is greater than that of the lead, so that when the line apparently leads directly down from the leadsman's chains, the lead is slightly aft and a part of the submerged portion of the line is still further down stream. The force of the current puts a strain on the bight so that the leadsman is deceived into believing he is getting a vertical cast.

This condition holds true when sounding from a moving boat which is running against the current and, in a less degree, when running at right angles to the current or when sounding from an anchored boat.

To overcome the discrepancies thus introduced, therefore, sounding should be done only at slack water, or in a boat drifting or running with the current. Cross lines, or lines at right angle to the axis of the river, should be run at slack water and lines parallel to the axis of the river can be run with the current. Since hydrography would usually be done in connection with other operations, the field work should be planned so that advantage can be taken of the stage of the current.

Current may also affect the spacing of soundings between positions and thus introduce another error. If the sounding boat is running at right angles to a current and the helmsman is steering a straight line by ranges, the boat will not progress along that line at a uniform rate of speed, due to the varying force of the current at different places in the river. Directly in the channel the progress across the river is slowest because the current will be strongest and the boat's course must be altered to counteract its effect. This force will diminish near the edges of the channel and there will be some places where there is no current at all.

It is quite often impossible to take a position at every change of course the helmsman makes in holding on his range, especially if working in narrow rivers with small boats, and so an error has been introduced because the distance progressed has varied between soundings, This, therefore, is another reason why it is desirable to run the cross lines at slack water.

Another source of error is the failure to take into consideration the slow speed of the boat at the beginning of a cross line. The sounding at the beginning of a line should be deferred until the boat has attained the rate of speed at which the remainder of the line is to be run. This will usually mean that the first sounding will be somewhat offshore, but the line can end close to the opposite beach, and since a sounding close inshore will be thus obtained on every other line, the information will be sufficient to indicate the depth. If additional soundings are needed close inshore, a line can be run parallel to the beach.

ELECTRIC SOUNDING CLOCK

Chas. K. Green, H. & G. Engineer, U.S.C. & G. Survey

My dear Captain Rude:

Fifteen years ago I rigged an electric sounding clock, as you will recall. Last year I made another one, which we use continuously on the PIONEER. At the above rate of production the next one will be available for use in 1947, and all the larger Coast Survey vessels will have one in 195 years, or on February 14, 2127. However, according to my normal expectancy, I will only be present on this earth for two more launchings of this very desirable device (once before and once after retirement). After that it may become one of the LOST ARTS!

Seems as though something should be done about it.

If you have read this far, I might add that the clock is an extremely useful addition to hydrographic gear, and its advantages are almost too obvious to mention. We have found on the PIONEER that the recorders do not get balled up when "Give me the angles on position so-and-so", is shot at them, and they have plenty of time to read the soundings off to the officer plotting, so that the soundings are always plotted immediately and suspicious ones can be checked at once.

In this day and age when such great strides in hydrographic methods are being made, we are very apt to pass up the more simple improvements, and it is my belief that our Service is overlooking a very useful device in not getting Seth Thomas to incorporate the gear in some of our clocks.

We have two clocks rigged up aboard, and I would be glad to forward one to the office if you are interested. These have contacts for 20, 30, and 60 second intervals (the intervals used on this assignment). There is enclosed a rather poor snapshot of the clock at work. The box is spray-tite, and the interval lever is visible near the second hand on the face of the clock. Chief Jones made the interval lever mechanism for me, and it is an improvement over the one on the old clock, inasmuch as it is more sturdy and convenient. There is an electric jack on the bridge, which when plugged into the clock box causes the bell at the fathometer to ring at desired intervals.

It took spare time for two days to construct and adjust the device, and since that time (6 months ago) the clock has worked continuously without any attention.

While these clocks may be rigged up aboard ship with very satisfactory results, the greatest benefit to the Service will come through a standard assembly by the Instrument Division or the clock makers, and I am sure that the matter will receive your consideration.

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REJECTION OF OBSERVATIONS ON INITIAL WEEK OBSERVING HORIZONTAL DIRECTIONS

H. W. Hemple, H. & G. Engineer, U.S.C. & G. Survey

The following situation recently developed on one of the triangulation parties and apparently caused some confusion. Two sets of horizontal direction observations were obtained at station Mason with the following regults:

	Kirkland	Wrightsville NW Base	Pilgrim
1st set	00°-00'-00".00	232°-25'-10".46	238°-44'-44".70
2nd set	00°-00'-00".00	233°-25'-12".92	238°-44'-49".09

The officer handling the computations rejected the observations to Wrightsville NW Base in the first set and to Pilgrim in the second set. The resulting values were as follows:

Kirkland	Wrightsville NW Base	Pilgrim
00°-00'-00".00	232°-25'-12".92	238°-44'-44".70

Since the triangles did not close within the allocable limits using these values, the original observations were expressed in terms using Wrightsville NW Base as an initial, as follows:

	Wrightsville NW Base	Pilgrim	Kirkland
1st set	00°-00'-00".00	06°-18'-34".24	127°-34'-49".54
2nd set	00°-00'-00".00	06°-18'-36".17	127°-34'-47".08

In the first set, the observations to Kirkland were now rejected, while in the second set, those to Pilgrim were rejected as before. The accepted values as shown below closed the effected triangles well:

Wrightsville NW Base	Pilgrim	Kirkland
00°-00'-00".00	06°-18'-34".24	127°-34'-47".08

The query of the officer was why he has unable to obtain angles of like values when Kirkland was used as an initial. The explanation, of course, is that in the first set, when he used Kirkland as an initial, he rejected the observations to Wrightsville NW Base, while in this same set using the latter station as an initial, he rejected the observations on Kirkland. The correct procedure is to reject the observations on Kirkland under both methods of showing the results. Then since the angle between Kirkland and Wrightsville NW Base is 232°-25'-12".92, and if we accept the directions to NW Base and Pilgrim in the first set, the following values would be obtained:

	Kirkland	Wrightsville NW Base	Pilgrim
	359°-59'-57".54	232°-25'-10".46	238°-43'-44".70
or	00°-00'-00".00	232°-25'-12".92	238°-43'-47".16

These latter values are the same as obtained using NW Base as an initial, and which closed the triangles.

REPORT ON NEW TYPE HYDROGRAPHIC SEXTANT
Kenneth G. Crosby

During the season's work of 1931 on Georges Bank an opportunity- was given to thoroughly prove the superiority of a new hydrographic sextant recently developed in the office. This type differs from the old in several ways. It has larger mirrors, a larger and more powerful telescope and a clamping device to hold the eyepiece of the telescope in focus.

In the course of the season's work a survey was made by the Survey Ship GILBERT on Georges Shoal proper. This survey was made by hand lead sounding and controlled by sextant angles, furnishing a three point fix, that were taken on the usual type of floating hydrographic signals. This new type of sextant was used with much success on the survey of this shoal.

The success of this sextant is attributed to the ease of picking up the signals due to the new features that have been mentioned. The state of the sea was moderately rough, on several of the days during the survey, which caused the GILBERT to roll badly. For this reason, with the old type of hydrographic sextant, I am convinced that the buoy signals could not have been held in the mirrors of the sextant due to the low magnifying power and the restricted field of vision.

With the new type of sextant the signals stood out clearly and, although the ship rolled badly at times, it was still possible to hold the signals in the mirrors. Under these conditions it was not too difficult to reflect the buoy signals at distances of three to four miles.

The users of these sextants are very enthusiastic as regards their performance and consider them very much superior to the old type of hydrographic sextants.

RACK AMD WORM SEXTANT
Kenneth G. Crosby

(Reference: Hydrographic Review, November, 1931, paragraph 7, page 154. "New Standard Sextant of the U. S. Navy.")

During the field season on Georges Bank, 1930, when I was attached to the U.S.C. & G.S. Ship LYDONIA I used a sextant of the rack and worm type to try out thoroughly its features of manipulation. This sextant was used in taking sun sights, star sights and angles when engaged on buoy control hydrography. In all types of work it proved to be highly efficient.

This particular sextant is a navigating sextant of an English make. It has a rack situated below the limb into which a worm gear engaged. This method provides an endless tangent screw, a feature very desirable in buoy control methods of hydrography, as oftentimes the tangent screw "runs out" just before taking a fix with the result that the position fix is lost. By the worm gear and rack arrangement the objects may be kept within the sextant glasses from one end of the limb to the other without fear of jamming the tangent screw.

The index bar or arm of the sextant may be easily moved to any position on the limb by means of squeezing two small nibs. The operation of squeezing the nibs raises the worm gear out of the rack and makes it possible to move the arm with ease. The arm automatically clamps itself by releasing the nibs; this allows the worm gear to engage the rack and the tengent screw is ready for use.

I am informed that this type of sextant has been discussed by the Bureau in the past, but from only a theoretical standpoint. Since I have used this type of sextant under actual field conditions, I thought it advisable to give the Bureau my experiences.

One of the arguments advanced against this type of sextant is the delicate care that must be given to it to prevent injury to the rack. In this particular make of sextant, the rack is well protected by the limb itself, as it is situated below and behind the edge of it. The teeth are of heavy construction. The worm gear is also protected by a guard which is an integral part of the tangent screw and clamping device mechanism. The parts likely to damage are therefore well protected.

This sextant is my own personal property and I could therefore do with it as I pleased. It has been subjected to rough and average use; nevertheless it has not been damaged. It is not as delicate as a theoretical discussion might prove it to be. My actual experience with a sextant of this type is that it is well worth trying a hydrographic sextant of this type in other field parties for their comments.

A group of snapshots accompany my original report (No. 180 - 1931) to illustrate the features of this sextant.

SPECIAL SOUNDING LEAD USED IN MANILA HARBOR, P.I.

(Extract from report by E. R. McCarthy on Hydrographic Sheet No.1375-E)

Because of the very soft bottom, soundings inside of the breakwater were taken with a special lead devised by Lieut. (j.g.) R. C. Bolstad. The lead consisted of a threaded iron rod about one-half inch in diameter and ten inches long with an eye in one end. Below the eye was attached a perforated wooden disk strengthened on its under side by a steel plate. Below the disk was attached the weight, consisting of two and four pound sections of sounding lead drilled through the center so they could be slipped over the threaded rod. The lead and disk were held fast by nuts above the disk and below the lead.

With this arrangement, the disk could be easily changed if necessary and any desired weight of lead obtained. After experimenting with various sizes and weights, it was found that a seven inch disk with a ten pound weight was most satisfactory. The lead line was graduated from the top of the disk as the experiments showed that the disk rested on the mud.

METEOROLOGICAL EFFECTS ON RIVER LEVELS

Paul C. Whitney, H. & G. E. Engineer, U.S.C.& G.Survey
Chief, Division of Tides and Currents

That tidal waters are not alone acted upon by the tide-producing forces of the sun and the moon, but are also affected by meteorological changes is well known. Some of the detailed effects of such changes, however, make an interesting subject for examination, especially so in comparatively shallow rivers and bays. Periods of abnormal weather in the vicinity of Washington during last winter so modified the river level in the upper part of the Potomac River tidewater that it was thought a study of the records from our primary tide station at Washington would be of interest to the members of the Association of Field Engineers.

The general direction of the Potomac River from Washington to its mouth is southeasterly. Therefore, it may be assumed, as a general rule, that winds from the northwest quadrant will tend to blow the water out of the river and thereby depress the river level. As the Potomac River empties into the broad Chesapeake Bay, the direction of which lies north and south, the northwest wind will have a somewhat similar tendency in that body of water, that is, to force the water southward and out of the bay. This tendency is assisted by the fact that this wind is an offshore one along the outer coast, which tendency lowers sea level along the shore. Contrariwise, easterly winds blow the water in the Chesapeake Bay, and if prolonged, raises the level of the rivers emptying into it.

These effects, however, may be modified by either a high or low barometer situated off the coast. A low barometer centered, for instance, near the Chesapeake Bay entrance will raise sea level, the amount depending upon the depth and area of the low; and a well-developed high pressure, similarly situated, will depress sea level. Combinations of these causes can easily produce very complicated changes in the tide curves at any place.

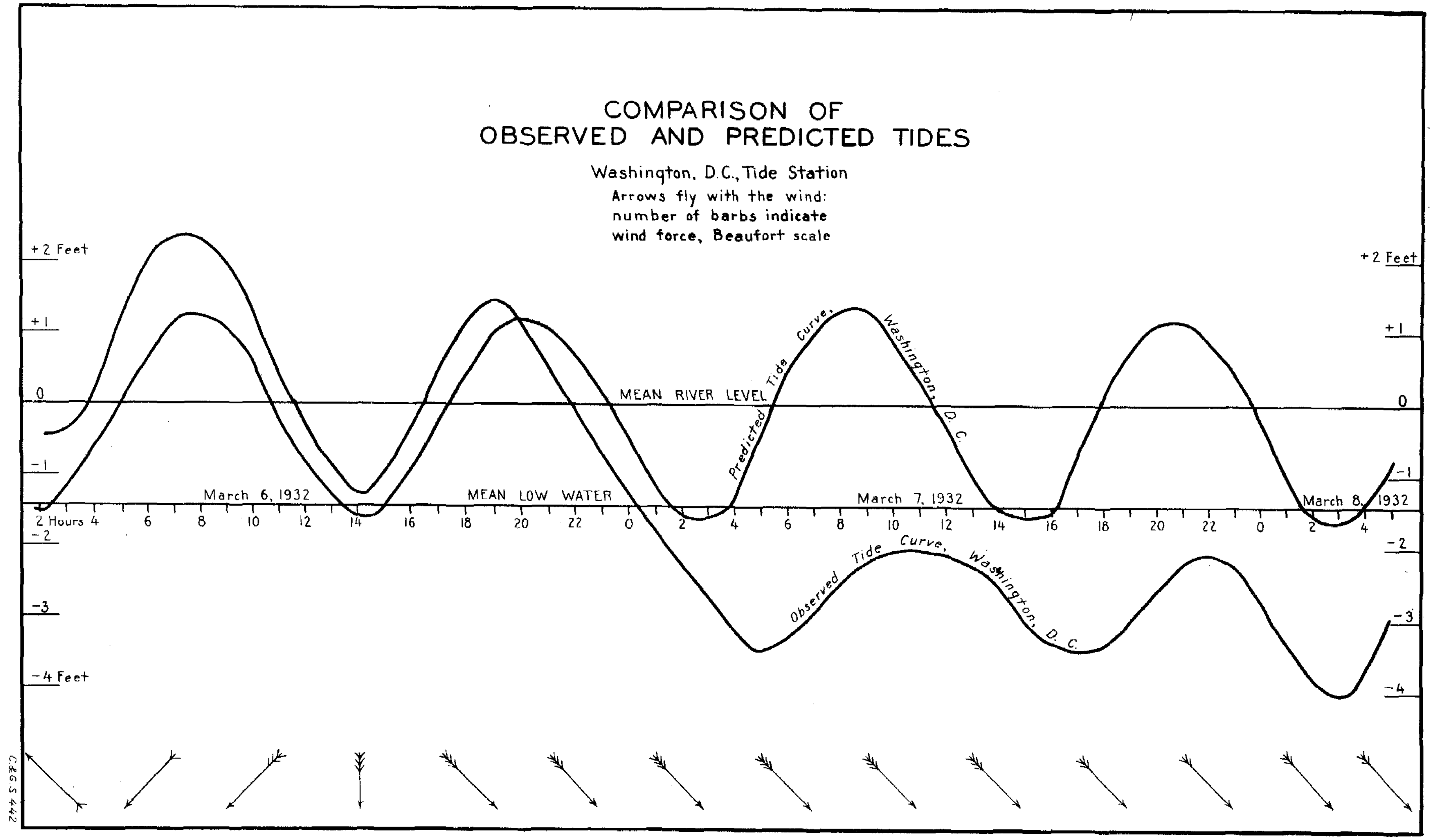
We will now examine the specific cases of interest alluded to. On the morning of December 31, 1931, the weather along the middle Atlantic states was about normal, but an eastward moving low pressure area caused easterly winds to set in that day. Examination of the first illustration shows that the predicted tide curve for Washington during the evening of the 31st coincided very nearly with the observed curve as recorded at the primary tide station there. As this low pressure moved closer to the coast, it was reinforced by a secondary low that formed off the Carolina coast on the morning of January 1, passing over the southern part of Chesapeake Bay that evening. The low barometer and easterly wind from this storm caused the observed tide curve to rapidly depart from the predicted curve with a high water of 4.7 feet about noon of January 1, as compared with the predicted height of 2.8 feet, and a low water of 1.7 feet at 21 hours, or 1.6 feet above the predicted height. As the air pressure increased during January 2 and 3, and the winds became northwest, the tide curve approached the predicted curve and crossed it at high water on the afternoon of the 3rd. From that time it will be noted that the observed curve ran below the predicted curve as the winds continued out of the northwest.

On March 6 Washington was visited by a storm of unusual violence with an extremely low barometer. The center of the low pressure area passed out to sea east of the Delaware Capes, during the afternoon of the 6th, after crossing the lower Chesapeake Bay some hours before. Under the influence of this low, southeast and northeast winds were felt at Washington, followed by shifting fresh north and northwest winds. The easterly winds augmented by the low pressure caused a high water level in the Chesapeake Bay area. The high water at the Naval Base, Hampton Roads, Virginia, occuring at 10 hours on the 6th rose 3.1 feet above the predicted height, or an amount exceeding the spring range of the tide at that place. A high water height of over a foot was recorded at Washington the same morning. With the wind shifting to the northwest quadrant, however, the wind effect overcame the low barometer effect and the water was rapidly driven out of the river, as indicated by the straight line drop of the tide curve from 19 hours on the 6th to 5 hours on the 7th. At the low water, the river was 2 feet below the predicted low. With continued northwest winds and rising barometer, the river level reached its lowest of 2 1/2 feet below the predicted height the morning of March 8.

It will be noted from the second illustration that although the tide rose and fell, its range was decreased and high water did not even reach the plane of mean low water. At times the river level was nearly 4 feet below normal level for those times. Owing to a continuation for several days of westerly winds, the river level did not return to normal for something like ten days.

The feature that is brought out by an examination of the figures is that although the winds and barometric pressure profoundly affect river levels, and to a lesser degree the range of the tide, the times of high and low waters are not changed as much as would be expected.

Predicted tides are based upon average weather conditions. Therefore, during abnormal weather, departures from the predicted values in the tide tables must be assumed. This is an important factor for a navigator to consider when in a vessel where the depth of the channel approaches the draft of his ship.


COMPARISON OF
OBSERVED AND PREDICTED TIDES
Washington, D.C., Tide Station
Arrows fly with the wind:
number of barbs indicate
wind force, Beaufort scale
+2 Feet
+1
0
-1
-2
-3
-4 Feet
MEAN RIVER LEVEL
MEAN LOW WATER
March 6, 1932
March 7, 1932
March 8, 1932
2 Hours 4
Predicted Tide Curve, Washington, D. C.
Observed Tide Curve, Washington, D. C.
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THE TRANSMISSION OF SOUND THROUGH SEA WATER

A. L. Shalowitz, Cartographic Engineer, U.S.C. & G. Survey

(Comments on article by T. B. Reed appearing elsewhere in this bulletin)

Lieut. Reed's comprehensive report on the use of theoretical velocities in R.A.R. hydrography on Georges Bank shows much thought and originality and indicates clearly the many factors that must be considered in the successful prosecution of an offshore survey by the modern acoustic methods. The report, however, is also interesting from another angle, namely: the bearing it has on the further study of the horizontal transmission of sound through sea water.

It is quite evident from a study of the temperature curves submitted by Lieut. Reed that for the Georges Bank area any velocity experiments carried on in depths up to 20 fathoms will add no information whatever on the path of propagation of the sound wave; for the reason that the temperature being the same from the surface to this depth, the same theoretical values would be obtained regardless of the path calculated for. This is essentially what was pointed out in my report on "The Horizontal Transmission of Sound Through Sea Water" (Sp. Report 46, 1931). It was there stated that "where there is little difference between the surface and bottom temperatures, comparisons can be made to fit almost any theory of sound propagation and the results would be within the probable errors of the instruments and methods used."

If we are to find a solution (if only empirical) to the problem of sub-aqueous sound wave propagation we must look to areas where the temperature gradient between surface and bottom is considerable. Accurate tests conducted in such areas would be productive of decisive results and an agreement between measured velocities and theoretical velocities for any assumed path would preclude every other path of propagation, at least as far as the effective sound energy is concerned.

This is well illustrated in the following two tables, both of which have been extracted from a paper by the writer on "The Physical Basis of Modern Hydrographic Surveying."* Table I gives comparisons of experimental velocities with theoretical velocities for various paths, subdivided according to localities and based upon accumulated data between the years 1926 and 1929. Table II gives the average differences between experimental and theoretical velocities computed from all observations, from best observations (this excludes all those comparisons marked with an asterisk in Table I) and from observations made in localities where the temperature gradient is high, such as exists in Alaska and off the coasts of Washington and Oregon.

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*Read before the National Academy of Sciences, April, 1931, and published in the Proceedings of the Academy, August, 1931.

TABLE I.

Experimental Velocity (E)	Surface Velocity (S)	Mean Velocity (M)	Bottom Velocity (B)	E − S	E − M	E − B
		Gulf of Alaska				
1469.8	1490.9	1478.1	1469.2	−21.1	−8.3	+0.6
1467.4	1483.0	1477.2	1470.2	−15.6	−9.8	−2.8
1471.7	1483.0	1480.1	1473.2	−11.3	−8.4	−1.5
1471.0	1483.0	1474.8	1469.2	−12.0	−3.8	+1.8
1470.0	1484.8	1477.0	1469.5	−14.8	−7.0	+0.5
1468.9	1495.1	1476.9	1468.8	−26.2	−8.0	+0.1
1469.2	1483.7	1474.6	1469.3	−14.5	−5.4	−0.1
				Av. −16.5	Av. −7.2	Av. −0.2
		Shelikof Strait				
1470.2	1477.7	1465.5	1464.9	− 7.5*	+4.7*	+5.3*
1470.1	1477.7	1465.2	1465.1	− 7.6*	+4.9*	+5.0*
1474.0	1488.5	1471.6	1466.6	−14.5*	+2.4*	+7.4*
1466.0	1488.9	1470.7	1466.4	−22.9	−4.7	−0.4
1468.2	1477.2	1466.2	1464.9	− 9.0*	+2.0*	+3.3*
1473.0	1477.2	1465.5	1464.5	− 4.2*	+7.5*	+8.5*
1467.8	1488.9	1474.7	1469.1	−21.1	−6.9	−1.3
				Av. −12.4	Av. +1.4	Av. +4.0
		Oregon and Washington				
1477.8	1495.9	1487.6	1479.0	−18.1	−9.8	−1.2
1475.4	1495.9	1480.7	1475.4	−20.5	−5.3	0.0
1478.5	1497.8	1484.7	1477.3	−19.3	−6.2	+1.2
1482.1	1497.8	1486.0	1478.7	−15.7	−3.9	+3.4
1475.2	1497.8	1483.7	1476.2	−22.6	−8.5	−1.0
1475.3	1497.8	1483.3	1475.7	−22.5	−8.0	−0.4
1476.7	1497.8	1480.3	1475.4	−21.1	−3.6	+1.3
1476.1	1497.8	1480.1	1475.7	−21.7	−4.0	+0.4
1477.4	1497.8	1483.7	1476.1	−20.4	−6.3	+1.3
1476.4	1497.8	1484.7	1477.4	−21.4	−8.3	−1.0
				Av. −20.3	Av. −6.3	Av. +0.4
		Northern California				
1479.9	1489.7	1482.8	1479.0	− 9.8	−2.9	+0.9
1477.2	1489.7	1481.9	1478.7	−12.5	−4.7	−1.5
1479.2	1489.7	1482.4	1479.1	−10.5	−3.2	+0.1
1477.2	1489.7	1481.6	1478.6	−12.5	−4.4	−1.4
1480.9	1489.7	1481.7	1478.5	− 8.9	−0.8	+2.4
1479.3	1489.7	1481.3	1478.5	−10.4	−2.0	+0.8
1478.9	1489.7	1481.4	1478.3	−10.8	−2.5	+0.6
1481.1	1489.7	1481.7	1478.3	− 8.6	−0.6	+2.8
1490.1	1497.3	1492.0	1489.3	− 7.2	−1.9	+0.8
1489.1	1494.5	1492.0	1491.2	− 5.4	−2.9	−2.1
1490.6	1494.5	1493.0	1491.7	− 3.9	−2.4	−1.1
1483.7	1497.3	1490.5	1486.7	−13.6	−6.8	−3.0
1488.0	1497.3	1490.5	1486.2	− 9.3	−2.5	+1.8
1489.2	1498.8	1491.7	1489.4	− 9.6	−2.5	−0.2
1485.2	1499.2	1488.1	1485.0	−14.0	−2.9	+0.2
1480.2	1489.0	1485.0	1480.2	− 8.8	−4.8	0.0
1479.7	1489.0	1484.2	1480.4	− 9.3	−4.5	−0.7
1480.9	1489.0	1483.0	1480.3	− 8.0	−2.1	+0.9
1481.0	1489.0	1483.8	1480.0	− 8.1	−2.8	+0.7
1478.2	1489.0	1483 4	1479.9	−10.8	−5.2	−1.7
1479.0	1489.0	1483.8	1480.7	−10.0	−4.8	−1.7
1493.8	1493.2	1487.4	1484.9	+ 0.6*	+6.4*	+8.9*
1487.8	1493.2	1487.9	1485.8	− 5.4	−0.1	+2.0
1490.4	1493.2	1487.4	1485.5	− 2.8*	+3.0*	+4.9*
1486.2	1493.2	1489.6	1486.7	− 7.0	−3.4	−0.5
1489.0	1492.1	1487.4	1483.1	− 3.1*	+1.6*	+5.9*
1489.0	1492.1	1488.8	1485.2	− 3.1*	+0.2*	+3.8*
				Av. − 8.3	Av. −2.2	Av. +0.9
		Grand Average		−12.3	−3.2	+1.0

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TABLE II
(Average Differences in Meters per Second)

	Surface	Mean	Bottom
From all observations (51)	-12.3	-3.2	+1.0
From best observations (42)	-13.7	-4.6	+0.01
From observations in localities of high temperature gradient (17)	-18.7	-6.7	+0.15

Lieut. Reed's observations regarding the rebombing of buoys "Able" to "Cast" (a distance of 70 miles) towards the latter part of the season, when a close agreement was had with the distance as computed from the bombing at the beginning of the season (in each case the theoretical bottom velocity was used) should not be taken as a corroboration of the "bottom velocity theory." A study of his velocity curves shows that the seasonal changes in velocity for the average depth between the two buoys (22 fathoms) is practically the same as it is at the surface. And for any intermediate depth the same difference will prevail. Therefore, regardless of what theory of sound wave propagation is adopted, whether surface, mean or bottom, the same discrepancy in distance between buoys "Able" and "Cast" would be obtained if the same velocity is used for the two bombings. Whereas, if velocities corresponding to the respective temperature conditions existing at the time of each bombing is used, the same agreement in distance would result as was found by the use of bottom velocities. As long as the velocity gradient is the same for the various depths between surface and bottom no conclusions are possible as to the path of the sound wave in the absence of any absolute value for the distance bombed. The use of theoretical velocities for any assumed depth will merely result in either expanding or contracting the control scheme.

The conclusion, however, that is possible is that whatever the assumed path of the sound wave, it is of the utmost importance in computing distances that theoretical velocities based on physical conditions existing at the time of bombing be used if a homogeneous control scheme is to result. Lieut. Reed's paper emphasizes graphically what was stated in Sp. Report 46 - 1931 (above referred to) namely: " ___ if we are to determine the path of the sound wave actually or empirically, we must have a complete picture of the physical conditions encountered by the sound wave in passing from bomb to hydrophone."

The seasonal velocity curves for various depths submitted by Lieut. Reed show clearly what misleading results might be obtained in an area like Georges Bank, if an actual measured velocity was compared with a theoretical velocity based on a mean seasonal temperature curve.

But while Lieut. Reed's paper throws no additional light on the "bottom velocity theory" it suggests to me a possible method of attacking the whole problem de novo. This method would utilize the circumstance that in any given area the seasonal difference in temperature decreases as the depth increases. That is to say, the seasonal temperature gradient decreases as we go downward until we reach a depth where there is practically no variation in water temperature throughout the season. If then two buoys 40 to 50 miles apart are planted in such depth and the distance between them bombed at the beginning and end of the season, the measured time interval should be the same at both bombings if the "bottom velocity theory" is correct. This, of course, presupposes that the positions of the two buoys have remained the same during the two bombings.

If a close agreement is found in the distance between the two buoys at the two bombings when the same theoretical velocity is used that would preclude the possibility of the sound wave having traveled to the hydrophone by any other path than the one calculated for. For the reason that, for any other path, due to the existing temperature gradient, an agreement in distance could only be obtained by the use of different velocities.

From the seasonal velocity curves in Lieut. Reed's paper it will be observed that on Georges Bank the theoretical velocity gradient at 40 fathoms was practically zero for a period of three weeks during the month of June. There are no temperature observations for this depth beyond this date, but if the temperature at this depth should be found to continue the same throughout the season it would make an ideal depth in which to make the experiment.

I am in wholehearted accord with Lieut. Reed in his recommendations that more temperature observations be made in deep water areas and that more experimental data be obtained to determine the path of the sound wave. Regarding the latter I should add that it is particularly desirable that such experiments be made in deep water where the excessive correction for pressure complicates the problem considerably. At the present time there is a conspicuous paucity of workable data bearing on this phase of the problem.

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An Associated Press dispatch from Petersburg, Alaska, dated Saturday, May 14, reads:

> "A marker believed to have been placed in 1792 during an exploration voyage by British ships into this region was found yesterday by Richard Hofstad, a Petersburg herring fisherman. Inscribed on the marker was: 'Capt. Geo. Vancouver, R.N., H.M. Ships Discovery and Chatham.'
>
> "The vessels Discovery and Chatham, under "Vancouver's command, wintered in Conclusion Bay at the end of the expedition which cruised along the Alaskan coast just prior to the nineteenth century."

GENERAL

ADEQUATE AND INADEQUATE SURVEYS

The main steamship tracks in Southeast Alaska have been surveyed and many of them have been dragged. There still remains, however, much work to be done before it can be said that Southeast Alaska is adequately charted. Many localities only slightly removed from the main tracks, where larger vessels might have occasion to anchor or where smaller ones might endeavor to shorten their routes, are inadequately surveyed. The frontispiece in this issue of the bulletin shows a section of chart No. 8160 embracing the region in the vicinity of the Level Islands, Sumner Strait, before and after applying the surveys made by the party on the EXPLORER in 1929. It requires but little imagination to prophesy what would have happened to a navigator who, equipped with the information shown on the earlier chart, attempted to anchor his vessel southwestward of the Level Islands in depths presumably of 10 to 15 fathoms.

WHO'S WHO IN THE U. S. COAST AND GEODETIC SURVEY

Page 78 of this issue shows a copy of the cover page of "Who's Who in the U. S. Coast and Geodetic Survey." The edition is typewritten and limited to exactly three copies, one each in the offices of the Director, the Assistant Director, and the Editor. While not for general distribution, a copy will always be available for the many official reference uses to which it will be put.

The first edition includes all civilian personnel in Grades P-4 and CAF-8 and higher, the commissioned personnel above the grade of Ensign, and those whose names appear in the organization chart printed in the Director's annual reports.

New editions will be issued in December of each year, at which time copies of the pages relating to the members concerned will be forwarded for revision.

The many who have been burdened with such tasks will appreciate the importance of the availability of biographical sketches. Many hours have been spent in researches that would have been unnecessary had this plan been inaugurated years ago.

BROWN GRAVITY APPARATUS

A new gravity apparatus, designed by Lieut. E. J. Brown and constructed under his supervision, is now being successfully used in the field for gravity determinations. The first field test involving 14 stations was completed in May.

In order that there might be no confusion between the old method and the new in the records and computations and in order that the stations determined by the new method could readily be distinguished from the others, it was desirable to adopt a name for the new apparatus and method.

Since the design of the apparatus and many of the original ideas were due to Lieut. Brown, the Director, on June 8, 1932, authorized the Division of Geodesy to call the apparatus the Brown Gravity Apparatus, and the method for its use the Brown Gravity Method.

NORWEGIAN GRAVITY APPARATUS.

The Chief, Division of Geodesy, has recently received the manuscript of a very interesting article written by Captain K. Wold and Engineer G. Jelstrup of Norway. It will be remembered that Captain Wold spent several months in this country a few years ago and made an intensive study of the surveying methods employed by the Coast and Geodetic Survey.

The article describes an improved form of gravity apparatus which was designed and constructed by the authors of the article at an extremely low cost. The old Von Sterneck apparatus belonging to the Norwegian Geographical Service was used as a basis for the new apparatus. Several novel devices are included in the apparatus, as, for example, an aluminum receiver base which serves as an electric heating plate by means of which, and a thermostat, the temperature of the receiver is controlled automatically. Several features are somewhat similar to those employed in the recently improved gravity apparatus of this Bureau.

Anyone interested in the Norwegian apparatus may obtain a mimeograph copy of the article by Captain Wold and Mr. Jelstrup by applying to the Director of this Bureau. The article is included in a Report of the Committee on Improvements of Methods in Gravity Measurements of the National Research Council of which committee William Bowie is Chairman.

AZIMUTH MARKS AT TRIANGULATION STATIONS.

As is well known by the personnel of the U. S. Coast and Geodetic Survey, first order, triangulation parties have, for several years, been establishing an azimuth mark, at a distance of from 300 to 400 yards from the triangulation station, which can be seen from the ground at the station. The object of such a mark is to enable the local engineer and surveyor to start his traverse from a triangulation station. There are very few engineers who have equipment or experience which would enable them to erect towers over stations in order to start from a line of the triangulation.

Parties of this Survey are now instructed to indicate, on the lists of directions and also in the descriptions of stations, those objects which may be seen from the ground. Such objects as church spires, cupolas, water towers, etc., are very valuable for use in local surveying and engineering work as azimuth marks. These objects in first order triangulation are cut in by the observer and, in general, the observations depend on two positions with a 9-inch theodolite. Since the total range of 16 positions on an object is seldom greater than 8", it is reasonably certain that the direction to an intersection station is seldom in error as much as 4". That is of sufficient accuracy for general surveying and engineering work.

Published descriptions of triangulation stations will contain information regarding the objects whose azimuths have been determined, which can be seen from the ground. In cases where there are no such objects, whose geographic positions have been determined, the observers obtain the directions to nearby objects such as chimneys, barn cupolas, etc., which are visible from the ground and which can be used as azimuth marks for local surveys.

There is an increased interest in the triangulation data of the Coast and Geodetic Survey and every effort is being made to meet the demands of engineers and others who use them. It is believed that the furnishing of azimuth data, as outlined above, is a step in the right direction.

HORIZONTAL CIRCLES OF SILVER

Since the Coast and Geodetic Survey has decided to use horizontal circles made entirely of silver for the first order theodolites, it is interesting to learn what has been the practice in making horizontal circles in the past.

A letter was written to Brigadier H. St. J. L. Winterbotham, Director of the Ordnance Survey of Great Britain, asking him whether he had any records in his office which would show what material was used for horizontal circles in the past and when silver strips were first used to carry the graduations. Under date of May 21, 1932, he replied as follows:

> "After a prolonged investigation on this matter of silver theodolite circles we have established that they were introduced by Reichenbach in 1804, and were used in England about that time. Previous to 1804 we had always used solid brass circles, and in some cases silver-brass, and the latter became the more popular, and was used until we heard of Reichenbach's improvements. About 1820 you may say that silver slips were in general use, and I would refer you as confirmatory evidence to Wolf's Handbuch der Astronomi, vol. 3, p. 32."

As far as is known, the Coast and Geodetic Survey has made the first all-silver horizontal circle for a theodolite and it will be interesting to know whether this circle will be superior to the old type, which consisted of bronze with an inlay of silver. The first circle has been made and graduated and it will be placed on one of the new Parkhurst 9-inch theodolites which if being made at the office of the Coast and Geodetic Survey in Washington. It is possible that the now circle can be given field tests within the next two or three months.

AIR-PHOTO TOPOGRAPHIC SHEETS EAST COAST OF FLORIDA.
(Extract from Report of M. H. Reese)

In locating new airway beacons along the East Coast of Florida, called for in instructions dated November 18, 1931, particular attention was paid to the air-photo topographic sheets of that area. The purpose of this careful attention was to determine the accuracy of the sheets, this being the first field check since the compilation of the sheets.

Seven airway beacons were located by triangulation on seven different air-photo topographic sheets. These sheets were well distributed over the entire area, giving a representative check on the compilation of the sheets.

The method used in determining the accuracy of the compilation was by plotting the airway beacons on the air-photo topographic sheets by measurements to topographic features shown on the sheets. The beacons were also located by triangulation and plotted on the air-photo topographic sheets. The amounts by which the positions failed to agree are given below:

Beacon	No.	24,	Sheet	No.	4553,	Difference	3.0	meters.
"	"	17	"	"	4556	"	0.0	"
"	"	16	"	"	4555	"	2.0	"
"	"	11	"	"	4543	"	4.0	"
"	"	10	"	"	4542	"	0.0	"
"	"	6	"	"	4462	"	2.0	"
"	"	2	"	"	4527	"	0.0	"

Four traverses were run on sheets 4530, 4531, and 4458 to locate airway beacons on these sheets. The traverses were run by starting from some point on a road near the center of the sheet and were run along the road across the sheet to beacons which were located near the western limit. The taping was with a 50-meter steel tape and checked with a 300-foot steel tape. The angles at bends of the road were measured with a theodolite. The measured distances checked with the scale distances from zero to 5 meters. The azimuths of the various bends of the road checked very well. The culture shown on the sheets agreed very closely with the topographical features on the ground.

It is my opinion that where it is impracticable to locate landmarks by triangulation, sufficient accuracy can be obtained by relating the objects to topographic features on the air-photo sheets.

The U. S. Engineers have used the air-photo topographic sheets extensively in the development of the Inland Waterway from Ormond to

Miami, Florida. They have used the sheets for a number of purposes. In areas where the sheets were available the preliminary location of the canal was made from data shown on them. In a number of cases the sheets were enlarged to the scale of 1:5,000 for use in plotting the soundings and location of the dredged canal. The Engineers using them state that they find the detail very accurate.

The Engineers state that by having the air-photo topographic sheets available a large sum of money had been saved in surveys of the Inland Waterway. It is thought that the continuance of this work along the coast where inland waterways exist will be found to be very profitable, both to the Coast and Geodetic Survey and the U. S. Engineers.

LEVELING IN TEXAS.

During the month of April, Lieut. James D. Thurmond ran 116.8 miles of first-order leveling along railroads in Texas by walking during actual observations. This work was done during 20 working days and, therefore, represents a progress of 5.8 miles per day of completed double line. This is remarkable progress for any party where the moves from one instrument station to another are made on foot.

SECOND-ORDER LEVELING IN ARKANSAS

There is quoted below part of a letter from Lieut. Gilbert R. Fish, dated May 2, 1932, to the Chief, Division of Geodesy:

"We finished the line of second-order levels from Mammoth Spring to Shirley, Arkansas, last Wednesday and moved to Jasper, Arkansas, on Thursday. The line was 95 miles long and was leveled in one day over three weeks, not counting some rainy days and one day spent in moving. For the entire line the party averaged between 130 and 135 set-ups a day and on April 25 the party made 196 set-ups between 8:25 A.M. and 4:40 P.M., with one hour out for lunch and about 15 minutes for a 'C' shot. The progress on that day was 6.6 miles."

From "Nautical Magazine", Glasgow, Scotland, March, 1932

The Centenary Report of the Association of Field Engineers, U. S. Coast and Geodetic Survey, contains much matter of interest to the seaman. The director's introductory report refers, among other matters, to the waning interest of the American nation in maritime affairs after the clipper ship era, her energies being almost wholly directed to the development of her land and internal resources in general. Coast surveying consequently suffered as a result of the general lack of interest in nautical affairs. In respect of what had actually been done in the surveying of territorial waters, he pays high tribute to the painstaking exactitude of the results achieved in former years by his predecessors working under difficulties unknown to surveyors of to-day. During the last 10 years an enormous amount of leeway in the surveying of territorial waters has been made up. For example, in 1918 only 27 per cent. of the waters off the Californian Coast had been surveyed, whereas in 1931 78 per cent. of this area had been completed; more remarkable still, 14 per cent. around the Oregon Coast had been converted to 100 per cent. fully surveyed during the aforementioned period. An interesting article on the cost of maritime surveying is very revealing; in that the unit cost of this operation has been reduced by 47 per cent. since the development of echo sounding and radio acoustic ranging. The range of multifarious duties performed by this amphibious corps of engineers is shown by the following examples of their activities: Magnetic Surveys; Velocity of Sound in Sea Water; City Triangulation; Earthquake Research; Compass Errors; Tides; Currents, etc., etc., (It might be mentioned that the ubiquitous Nautical Magazine is represented twice in the pages of the report, two short articles from the N.M. being reproduced.) There is a short article on the use of the sidereal chronometer at sea for stellar observations. Such a timepiece was carried in one of the survey vessels (of which they have 13). The contributor of the article recommends the other vessels to try this chronometer out, as it has considerably shortened all his stellar computations. The general get-up of the report is excellent, as it really seems to be a medium through which the personnel of the Department can swop ideas and knowledge.

RECENT LEGISLATION

H. A. Seran, U. S. C. & G. Survey

The work of the Survey for the coming fiscal year will be affected by three bills: First, the Regular Appropriation Bill; second, the Legislative Appropriation Bill, commonly known as the Economy Bill; third, the "Wagner-Garner Relief Bill".

The last has not, at this date, been enacted. At the time this article is being written it is understood from the press that the President is ready to veto the Bill as agreed to by the conferees on the part of the House and Senate, and that immediately upon his veto message being received by Congress, an attempt will be made to change the Bill to meet his objections.

One item in this "Relief Bill" appropriates #1,250,000 for the field work of this Bureau. It is believed that this item will be retained in the final bill. If this appropriation becomes available, present plans contemplate operating a number of shore parties along the Atlantic and Gulf Coasts, a number of control parties in the interior states, and a couple of fairly large parties on the Pacific Coast. The Bureau has set as its goal the employment of about 1,000 men during the fiscal year from this relief money. If this "Relief Legislation" is not enacted, the work of the Bureau will be largely curtailed owing to the reduced appropriations in the regular Appropriation Bill. The various field appropriations, as carried in that bill, are as follows:

Atlantic Coast	$ 150,000
Pacific Coast	200,000
Coast Pilot	5,500
Repairs of Vessels	60,000
Pay, Officers and Men	555,000
Federal, Boundary and State Surveys	150,000
Tides and Currents	20,000
Magnetic work	40,000

The large reductions come in the items far the Pacific Coast; Federal, Boundary and State Surveys; and Pay, Officers and Men. The amount allowed for Pay of Officers and Men will require the discharge of a large number of men and probably complete lay-up of several of the ships.

The so-called Economy Legislation Bill presents a number of problems and questions upon which the Comptroller General will have to rule. As his decision has not as yet been rendered, it is impossible to state exactly what the effects of this bill will be.

You have all read in the papers of the required furlough of all Federal employees. In so far as practicable, each employee of the Government will be required to take a furlough without pay of one month or its equivalent. The Comptroller has already ruled that a deduction of 2-1/2 days' pay can be made each month, but that in case an employee takes more furlough than has been deducted from his salary, a further reduction from that salary payment will be made.

The Bill provides that for those employees to whom the furlough plan can not be applied advantageously, a reduction of 8-1/3 per cent in salary may be made. It is believed that upon the representations of the Bureau, the President will approve this latter procedure in regard to crews of vessels and hands on shore parties. The furlough or reduction of pay applies only to those employees drawing more than $1,000 per year. Allowances for subsistence, rental, etc., are exempt. In other words, the $1,000 applies only to straight salary.

All laws relating to annual leave of absence with pay are suspended during the fiscal year. At this date it is not known whether that includes accrued leave. The Comptroller has been requested to render a decision. It is expected, however, he will rule that no leave can be taken through the year.

The Bill allows no increases of salary on account of promotions, and prohibits filling of any vacancies that may occur unless specifically authorized by the President. An attempt is being made to secure authority to fill any vacancies that may occur in the crews of the ships and organizations of the shore parties.

Mileage is suspended during the year and travel allowances will be the same as for civilian employees. In lieu of actual expenses for subsistence, a per diem of not exceeding $5.00 within the continental limits of the United States is prescribed for everyone.

The Bill prohibits the transportation of an automobile as a part of an officer's effects, although it allows $5,000 each to the War Department and Navy Department for such purpose.

Annual leave is cut from 30 days a year to 15 days. This is permanent legislation and presumably will be in effect after July 1, 1933. Leave is allowed to accumulate for everyone.

There are a number of other items in the Bill, none of which applies particularly to the personnel of this Service. As a final toss of the monkey wrench, there is a provision in Section 111 of the Economy Bill which reads as follows:

> "No court of the United States shall have jurisdiction over any suits against the United States, or (unless brought by the United States) against any officer, agency, or instrumentality, of the United States, arising out of the application of any provision of the title, unless such suit involves the Constitution of the United States."

Not only do we contribute a month's pay on account of the Economy Bill, but, as the official statistics of the Department of Labor showed a drop in the costs of rents and in the retail cost of foods, the President was forced, under the Act of June 10, 1922, (Joint Pay Act) to reduce the rental allowances to commissioned officers from $20 a room to $18 and the subsistence allowances from 60 cents for one allowance to 52 cents. Certainly the uniformed services are standing their share.

THE ASSOCIATION

The recent election of officers of the Association resulted as follows: President, G. T. Rude; Executive Committee, C. L. Garner, A. M. Sobieralski, R. R. Lukens, E. W. Eickelberg and F. S. Borden.

In keeping with the times, the Executive Committee is endeavoring to present a balanced budget at the end of the year. This will not prove difficult provided the comparatively few members who have not paid their dues will help by forwarding a check or money order for the amount indicated on the "Statement of Dues'* enclosed in this issue of the Bulletin.

The Executive Committee welcomes at all times suggestions or constructive criticisms related to the activities of the Association.