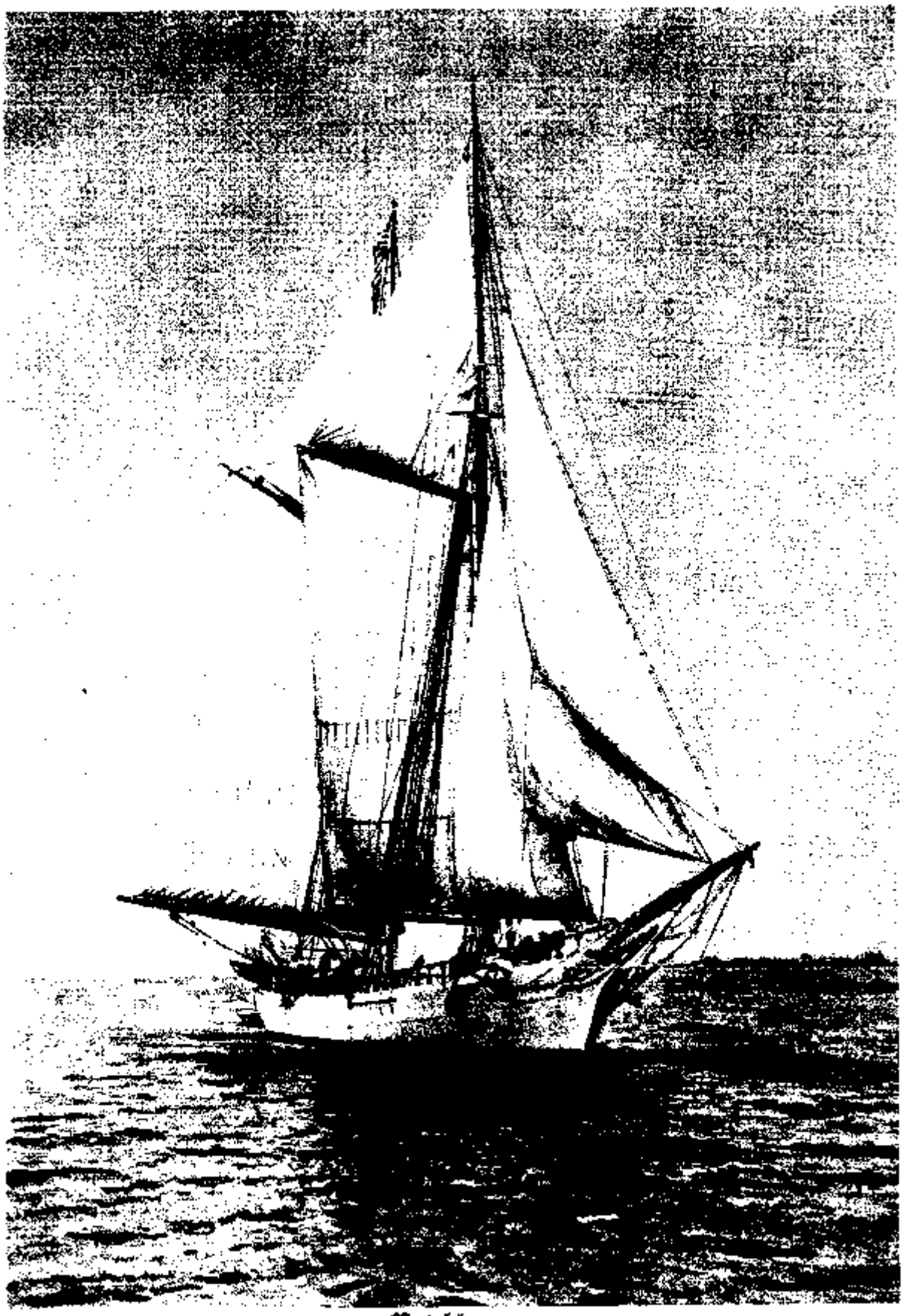
No. 8

FIELD ENGINEERS BULLETIN

U.S. COAST & GEODETIC SURVEY

DECEMBER 1934

U. S. Coast and Geodetic Survey Print



Matchless

EARLY TRAINING SHIP OF MANY COAST SURVEY OFFICERS

INDEX DECEMBER 1934

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EDITORIAL

A New Deal for Surveying and Mapping

Although the subject of mapping was not specifically mentioned in President Roosevelt's recent message to the 74th Congress, it requires but little imagination to see that one of the first requirements for carrying out effectively his vast and far-reaching public works program will be a provision for accurate, basic maps of the entire United States. Dependable maps are essential to the successful accomplishment of the majority of projects proposed to be undertaken. Soil erosion, reforestation, flood control, power and irrigation projects cannot be planned intelligently without them.

That the United States has never had a coordinated mapping policy is unfortunate. The result is that it now finds itself woefully behind the leading nations in respect to basic maps. However, definite advances have been made in recent years. Due to generous allotments from the Public Works Administration, surveying and mapping have assumed more nearly the positions they should have occupied years ago. The results of the last two years alone have had a pronounced effect in educating the public to an appreciation of the value of good maps, and there is every reason to hope that a sound national mapping policy will be adopted.

Don't Cut the Comers

When one looks back over the century and more of accomplishment of the United States Coast and Geodetic Survey, he is particularly impressed with the foresight which inspired the accuracy that was built into the first surveys. It is most significant that they have stood the test of time and the economic advancement of our Nation through the years.

The past several years have seen a growth in surveying activity never before equalled. In this rapid growth there have been times when the maintenance of the standards of accuracy established by long experience in this Bureau has been difficult. It is well in such times to think of the beginning of our first order surveys, over a hundred years ago, and to wonder where we would be now if the first surveys had been made only with such accuracy as was satisfactory at the time. We have discovered many improvements in methods, instruments, and economies in surveying, but it should never be said that these improvements in production have been made at the sacrifice of the original standards. Now, more than ever we should be looking for methods that will lead to greater accuracy and fidelity of results.

There was a period when we considered the third-order accuracy of our coastal triangulation more than adequate to control the detailed surveys of the coasts and contiguous waterways. Only recently have we completed the first order work that ties many of these previous surveys together, and exposes the short-comings of many of them. Time has justified the surveys which occasionally were criticized in some quarters as "too accurate"; on the other hand, there has never been a case, when under some special pressure we lowered our usual standards, that sooner or later we did not regret it. Our good name has always stood for accuracy among the engineers of both the nation and the world. May we perpetuate this enviable reputation.

RODMAN'S REVERIE

R. S. Clark

When Life's last traverse is finished
And the notes are computed and checked,
When angles and levels and chainage
Are purged of the last defect,
We shall turn in the tools and the notebooks
And stamp off the ice and the snow
And take us a good long noon hour
Of a thousand years or so.

Then, when we are all quite rested,
The Chief will announce a plan
For a Galaxydetic survey job
With a trillion miles to span.
Out past the far horizons,
Out past the Pleiades,
To tie in the solar system
With the neighboring galaxies.

All distances chained precisely
With an invar light-year chain.
All levels referred to datum
Of the true ecliptic plane
In twenty decimal places,
Or possibly twenty-one,
With never a doubtful reading,
And never a line re-run.

All angles to accurate fractions
Of a pip on the Zodiac;
Doubled and thrice redoubled;
Repeated forward and back.
Horizons exactly closing,
All pink and purple and gold,
Where instruments read to millionths
And fingers are never cold.

Then rodmen will not be footmen,
Pacing a weary route,
But will ride two weeks in a rocket ship
To set the front target out.
The chain gang will not inch along
With bucks and tension bars,
But will shoot by stadia just like that,
From here to the horns of Mars!

And, 'ere we have measured and plotted
The infinite boundaries of Space,
The rumbling March of the Alphabet
Shall have passed the decimal place,
And each in his separate station
Shall labor as best he can
For the profit of all creation
And the good of the General Plan.

(Mr. Clark is employed on the Local Survey Project in Michigan).

CALIBRATION OF TAUT WIRE APPARATUS
U. S. C. & G. S. SHIP OCEANOGRAPHER

H. A. Seran, H. & G. Engineer, U. S. C. & G. Survey, Comd'g.

(The remarkable consistency of twenty observations made to obtain the apparent velocity of sound in shoal water off the coast of Maryland during the spring of 1933, (see Field Engineers Bulletin No. 7, p. 115) suggested that the limits of the accuracy obtainable with the taut wire apparatus might be increased, and that the calibration used, namely, a direct measurement of the sheave circumference, was open to criticism in that it did not represent the actual conditions encountered during use. Such errors as would result from steering of the vessel, temperature changes in the wire from the time it leaves the sheave until it reaches the bottom, and the possibility of dragging of the wire anchor, all might affect the value of a single revolution as obtained from actual runs, and so give quite a different factor for the sheave than obtained by direct measurement of the circumference.

The report below describes the method used in comparing the two measurements, and this work should be considered from two view points: the accuracy with which measurements can be made with the taut wire apparatus in shoal water and uniform sea bottom, and the coordination of observations as practiced in hydrographic work. It is also something of a criterion of the accuracy with which two observers can determine the position of a moving vessel by observations on shore objects from the ship.) (Editor)

Instructions

Under date of May 1, 1934, instructions for the calibration of the taut wire apparatus installed on board the Ship OCEANOGRAPHER were issued as follows:

"As soon as practicable you will please test the previous calibration of your taut wire apparatus by a measurement of the distance between two points, the positions of which are determined by sextant observations on triangulation signals, using a third angle for checking purposes, and computing the distances between positions. The calibration run should not be less than three miles in length. It should be made over uniform bottom and far enough off shore to permit using the same fix at each end of the line. A third position should be determined about midway along the line as a check. Temperatures of both the air and the bottom, should be taken near the ends of the line, at the time of the calibration. Navigating sextants should be used and, in general, all precautions to obtain the maximum accuracy possible by the method outlined should be taken. This office is of the opinion that a more accurate calibration will be obtained if the positions are obtained as the wire is being paid out at a uniform speed rather than to attempt to measure the distance between the positions of marker buoys."

Location of test

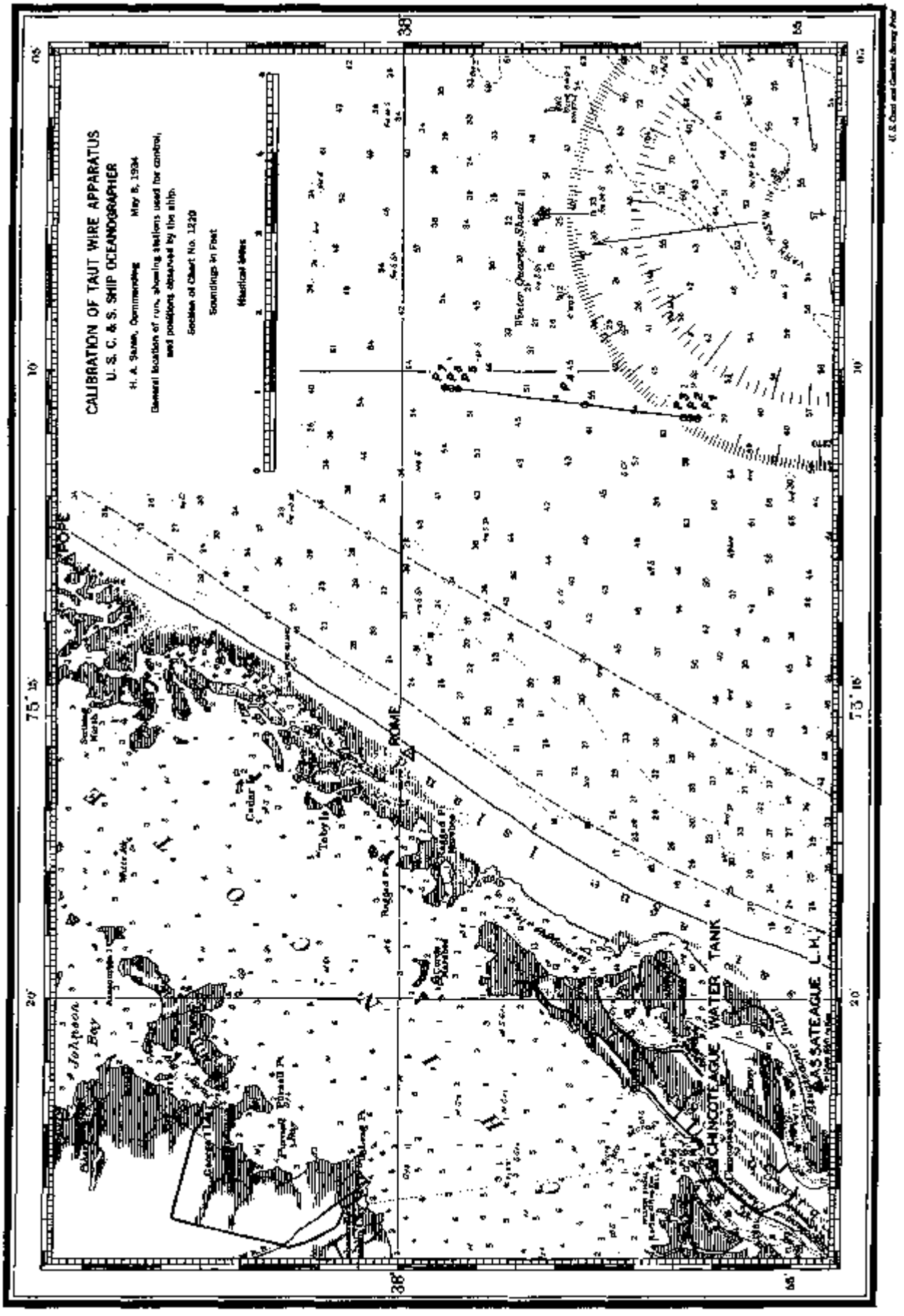
The test was conducted off the coast of Maryland just west of Winter Quarter Shoal in a comparatively even depth of 7 fathoms. Triangulation stations Pope, Rome and Assateague Light House were used as principal stations for the determinations of the fixes, with the water tank at Chincoteague, Va., as a check station.

Operations

The wire was anchored about a mile and a half from the start of the run. The ship steamed at a speed of approximately 9 knots. Four observers were stationed at the apparatus, 1 to observe the right angle, 1 to observe the left angle, 1 to observe the check angle and 1 to read the indicator on the apparatus. Three fixes were taken in quick succession at the beginning and end of the run and 1 fix about the middle of the run. The mark for the fix was given by the observer at the indicator. By this method we obtained 9 measurements of the full run.

Surface, bottom and air temperatures were observed at the point where the wire was anchored about a mile and a half from the beginning of the run and at the end of the run.

The length of the run was a little more than 3 nautical miles.


CALIBRATION OF TAUT WIRE APPARATUS
U. S. C. & S. SHIP OCEANOGRAPHER
H. A. Sauer, Commanding
May 8, 1934
General location of run, showing stations used for control, and positions observed by the ship.
Section of Chart No. 1220
Soundings in Feet
Nautical Miles
Victor Passage Shoal
POPE
ROME
Johnson Bay
Cedar Is.
Tabyle
Ridged Pt.
Ridged Pt. Shoal
Tunnel Pt.
Tunnel Bay
Water Pt.
Sandy Hook
Assateague
CHINCOTEAGUE WATER TANK
ASSATEAGUE L.H.
75° 15'
20'
10'
38°
35'

Computations

The following computations to determine the distances run between the fixes at the beginning and end of the run were made in the order named.

1. Inverse position computation for azimuth and back azimuth between Pope and Rome.
2. Inverse position computation for azimuth and back azimuth between Pope and Assateague Lt. House.
3. 7 computations of three-point problems to determine the angles in the various triangles formed by the points at sea where fixes were observed and the triangulation stations.
4. 7 computations of distances Rome to each of the 7 sea points.
5. 7 position computations to determine geographic positions of the 7 sea points.
6. 9 inverse position computations to determine distances between each of the 3 positions at the start of the run and each of the 3 positions at the end of the run.

Results

As shown by the abstract of distances the mean value of one revolution of the sheave on the apparatus as determined in this manner by the mean of the nine distances is 1.861407 meters. It should be noted, however, that the range of individual values is quite large. A condition to be expected when so many observers are taking part and sextants being used.

Direct measurement of sheave

Three pieces of piano wire, each about 9 feet in length were annealed for about 18 inches on each end. Each wire was lead one turn around the registering sheave, lapped 4 or 5 Inches and drawn taut. A mark with a sharp tool was made across both ends of the wire at the point of tangency. (This point could be estimated closely when the wire was drawn taut. The two ends were parallel for a distance of about one inch.)

After the wires were so marked each was stretched between two nails on a board and the distance between the two marks measured by beam compass and meter bar. A brass plate was secured to the board at the middle point to afford an intermediate marking point.

Three independent measurements of each wire were made with a final mean result, as shown on accompanying abstract, of one revolution of the sheave as 1.860723 meters. The value used in 1933 was 1.86035 meters.

Conclusions

As could have been expected the value of one revolution of the sheave determined by the number of revolutions on a ship's run between two points at sea, the geographic positions of which had been determined, would vary from the value as determined by direct measurement. The impossibility of keeping the ship on a straight line between the two points would tend to increase the number of revolutions of wire and decrease the value of one revolution of the sheave, as would any contraction of the wire due to temperature changes. Incidentally, it is believed temperature changes of the sheave would affect the results more than temperature changes of the wire. On the other hand, any dragging of the anchor or increasing of the tension on the apparatus required for a given speed would tend to decrease the number of revolutions and increase the value of one revolution. The tension on the apparatus will vary from 30 to 40 pounds in making a run. All things considered, the close agreement between the values as determined by these two methods is remarkable and either result could be used in our work without appreciable error.

Abstract of Observations - May 8, 1934.
Calibration of Taut-wire Apparatus
U. S. C. & G. S. S. OCEANOGRAPHER
H. A. Seran, Commander, C&GS
Commanding.

Temperatures Beginning	Air----------11.4°C.	End	Air----------12.5°C.
	Surface---------- 9.3°C.		Surface---------- 9.4°C.
	Bottom (7 fathoms)-- 8.8°C.		Bottom (8 fathoms)----- 8.9°C.

Fix used: Right Angle Pope to Rome — Observer, J. C. B.
Left " Rome to Assateague Lt. H. — " F. N.
Check " " " Chinco. Water Tank — " W. D.

Right Angle	Sextant	c/n	I. o e	30°	- 1'50"	60°	- 2' 15"
Left "	"	"	J.-30"	30°	15"	60°	20"
Check "	"	"	" 20"	30°	0	60°	0

Time	Revolution		Fix	Corrected Fix
8:33	201558	Rt. Angle	36-34-10	36-32-13
		Left "	51-23-00	51-22-48
		Check "	42-22-40	42-23-00
	201667		37-15-00	37-13-02
			51-06-30	51-06-18
			42-05-10	42-05-30
8:36	201766		37-53-10	37-51-12
			50-50-00	50-49-48
			41-46-50	41-47-10
8:45	203008		46-50-00	46-48-01
			45-46-20	45-46-08
			36-28-30	36-28-50
8:58	204592		59-05-20	59-03-06
			35-01-10	35-00-56
			25-55-00	25-55-20
	204680		59-44-10	59-41-55
			34-21-40	34-21-26
			25-15-50	25-16-10
9:01	204764		60-17-30	60-15-14
			33-40-20	33-40-06
			24-37-10	24-37-30

Abstract of direct measurements. Sheave on Taut-wire apparatus
U.S.C. & G.S.S. OCEANOGRAPHER H. A. Seran, Commander, C&GS Commanding.

		Residuals
Wire No. 1	1.86059 m.	+.00013
	1.86070	+.00002
	1.86071	+.00001
Wire No. 2	1.86063	+.00009
	1.86076	-.00004
	1.86059	+.00013
Wire No. 3	1.86076	-.00004
	1.86089	-.00017
	1.86088	-.00016
Mean	1.86072	

Abstract of Results

	Latitude	Longitude	Distance from	to	Distance meters	No. turns of sheave	Factor
P_1	37° 56' 15."5	75° 10' 45."2	P_1	P_5	5641.0	3034	1.859261
P_2	37° 56' 21."9	75° 10' 44."0	P_1	P_6	5820.0	3122	1.864190
P_3	37° 56' 27."9	75° 10' 42."9	P_1	P_7	5961.0	3206	1.859326
P_4	37° 57' 42."4	75° 10' 32."0	P_2	P_5	5441.6	2925	1.860376
P_5	37° 59' 17."2	75° 10' 18."1	P_2	P_6	5620.6	3013	1.865449
P_6	37° 59' 23."0	75° 10' 17."6	P_2	P_7	5761.6	3097	1.860381
P_7	37° 59' 27."5	75° 10' 16."5	P_3	P_5	5254.8	2826	1.859448
			P_3	P_6	5433.9	2914	1.864756
			P_3	P_7	5574.7	2998	1.859473

Mean------1.861407
Mean of individual measurements of sheave------1.860723
Difference------0.000684

Comment by P. A. Smith

It will be noted that there are three very large residuals, all negative in sign and occurring on the values involving position number six. This indicates some error in the observations or the computations at position number six, so the values obtained using this position should be rejected. It should be further noted that such rejection reduces the range in the residuals to about one sixth the amount as shown in the report, and gives a final mean of 1.85971 meters for the value of one revolution of the sheave. The direct measurements gave a result of 1.86072 and this difference is consistent with conditions affecting the wire during use. I believe the experimental determination of 1.85971 meters preferable to the direct measurement, as it represents actual conditions, and should be used until it is necessary to make another calibration. A table of the values obtained by actual run is given below showing the rejections referred to above, in arriving at the value of 1.85971 meters.

FROM	TO	DISTANCE METERS	SHEAVE TURNS	R	V	V_l
P_1	P_5	5641.0	3034	1.85926	+.00215	+.00045
P_1	P_6	5820.0	3122	(1.86419)	-.00278	
P_1	P_7	5961.0	3206	1.85933	+.00208	+.00038
P_2	P_5	5441.6	2925	1.86038	+.00103	-.00067
P_2	P_6	5620.6	3013	(1.86545)	-.00404	
P_2	P_7	5761.6	3097	1.86038	+.00103	-.00067
P_3	P_5	5254.8	2826	1.85945	+.00196	+.00026
P_3	P_6	5433.9	2914	(1.86476)	-.00335	
P_3	P_7	5574.7	2998	1.85947	+.00194	+.00024
			Mean	1.86141		

Mean after rejecting position 6. 1.85971
Direct measurement. 1.86072
Difference 0.00101

LONG-LINE TRIANGULATION IN ALASKA, 1933

A. M. Sobieralski, H. & G. Engineer, U.S.C. & G. Survey

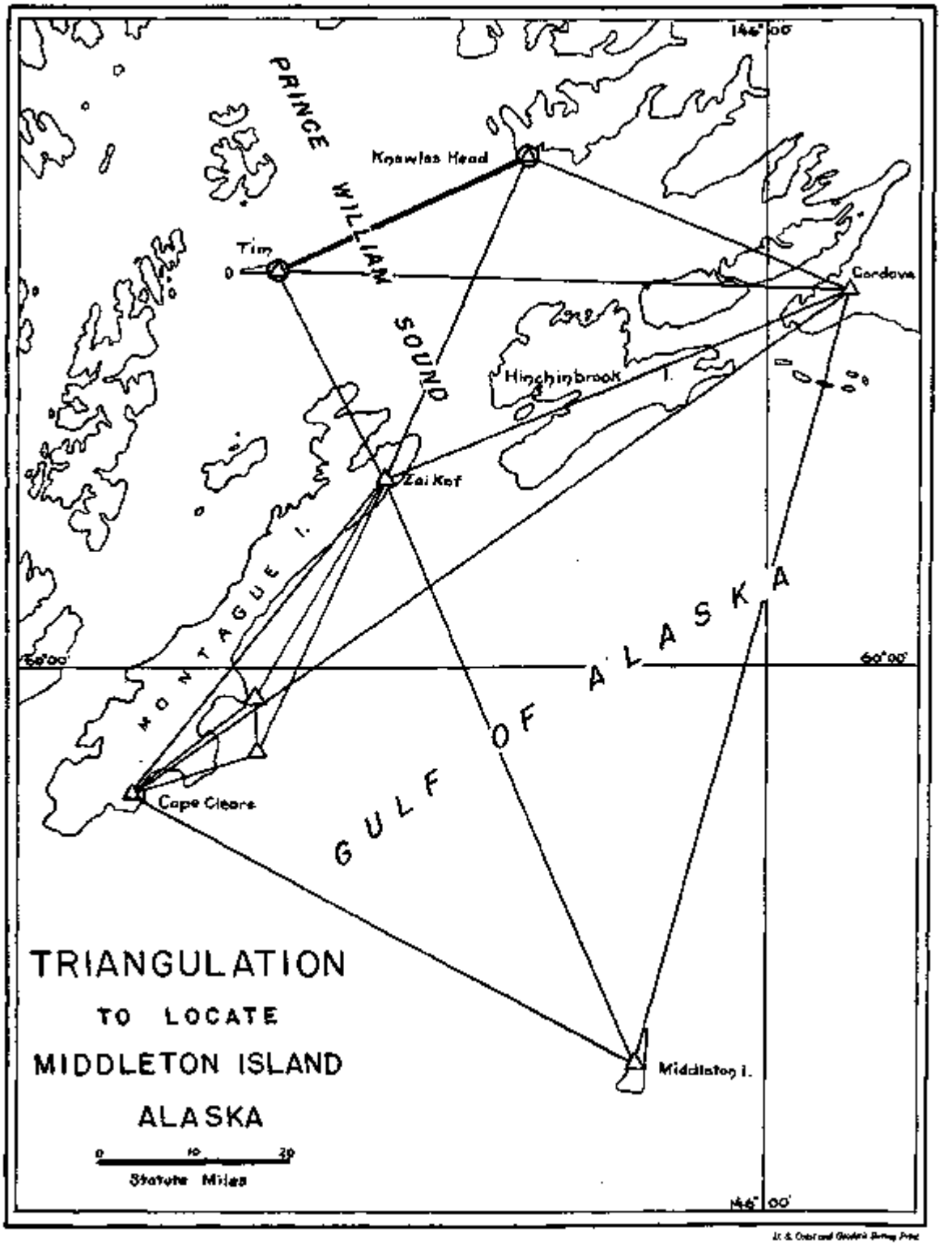
In carrying triangulation along the coast of Alaska, it often becomes necessary to resort to long lines - particularly to locate an off-lying island, or in carrying a scheme along wide channels, such as Shelikof Strait, Dixon Entrance, et cetera. The experience of the party engaged on the triangulation to locate Middleton Island off the entrance to Prince William Sound, Alaska, is therefore given in detail, as it may be of assistance to other parties engaged on such work.

The scheme of triangulation consisted of only two quadrilaterals, extending from an adjusted line Knowles Head - Tim (on Smith Island) 41,600 meters long, to a line Cordova - Zaikof, 76,180 meters long, then to a line Middleton - Cape Cleare 87,317 meters long. The longest line, Cordova - Cape Cleare, was 132,730 meters long (82.5 statute miles). The reconnaissance for the scheme was executed from the ship early in the season. Several possible schemes were discarded because the reconnaissance would require climbing the hills and would thus delay the work. Only two lines in the scheme could not be verified from the ship. The line Zaikof - Cape Cleare passed so close to the slope of an intervening ridge that the intervisibility of the points could be determined with certainty only by ascending the mountain; and the line Cordova - Zaikof, passing over some rather high land, could be positively verified only by actually sighting over the line. Accordingly, as soon as the snow had diminished on the mountain tops, a signal was erected on the peak selected for the station Zaikof and the reconnaissance verified. Of the stations selected, Cordova was the highest (3,141 feet), Zaikof was about 2,200 feet, and Cape Cleare about 1,900 feet. The other stations were comparatively low.

On mountains over 2,000 feet in elevation the snow remains until well into June, even in Southeastern Alaska. While it is not impossible to ascend these peaks before the snow melts, there is considerable difficulty and sometimes danger in traveling, and the additional difficulty in marking stations and finding old marks makes it advisable to wait for the snow to disappear unless it is urgent to complete the work early in the season. In some sections, favorable observing weather is more prevalent in May and June, and under such circumstances it may be advisable to start signal building and observing earlier in spite of the additional difficulties. On long lines in Alaska the observations can be obtained only in the short spells of pellucid clearness which occur two or three times during an average season. If it were possible to predict these spells, the work would be quite simple, but the usual experience has been long and tedious delays and there have been seasons when such spells never occurred. On account of the infrequency of observing weather, it is absolutely necessary to use as many observing parties as practicable. One observing party would probably complete only one station in a season. While it is not practicable to predict such spells of clear weather, with a little experience and considerable watchfulness, one can judge the weather so that there is time to ascend the mountain from a nearby camp before it clears up. I do not consider it necessary to remain continuously at the station, but some light camping equipment sufficient for one or two nights at the station is desirable.

On the work in Prince William Sound, four observing parties were used continuously and a fifth part of the time. Three parties required from two to five hours to reach the stations, but I believe that little if any observing weather was missed on this account. Camps were established at stations Middleton, Cape Cleare, Zaikof and Cordova by July 20, 1933. While some observing over the shorter lines was done on July 23, July 30, August 1, August 13, August 25, August 27, August 30 and August 31, the only days when all four stations were intervisible were August 1 (a few hours) and August 30. Out of some 40 days, only a little more than one day was really suitable for observing over the longest lines and only eight days were suitable for any observing.

Next in importance to the number of observers is the type of instruments and other equipment available. In my opinion, the 7-inch repeating theodolite should be discarded entirely for any observing except supplemental third order work. On difficult long line triangulation I can not help but feel that the use of these instruments is wasted effort. I believe that it would be easier to get first order accuracy with a first order instrument than second order with the repeater. Think of climbing a mountain before breakfast, after weeks of waiting, then grinding out a set of six repetitions, only to find that the


PRINCE WILLIAM SOUND
Knowles Head
Tim
Cordova
Hinchinbrook I.
Zai Kof
MONTAGUE I.
GULF OF ALASKA
Cape Cleare
Middleton I.
146°00'
60°00'
TRIANGULATION
TO LOCATE
MIDDLETON ISLAND
ALASKA
0 10 20
Statute Miles

readings have not returned to zero - half an hour or more of precious time lost, when every minute is so valuable. Under the constant handling with numbed fingers, the instrument gets out of level, most of them drag, the supports are too flimsy, and all in all, it is most discouraging to work with them at all. There is no doubt that some good results have been obtained with them, but I doubt if they were obtained under the hard conditions encountered in Alaska. And if the observations are examined closely, it will be found that in many cases the results are not as good as triangle closures would indicate, there being uncertainties due to widely differing values, large horizon closures, large and irregular differences between D and R readings, et cetera. If only second order accuracy is required, the saving in time alone between observing 4 positions on a first order instrument, and 2 to 3 sets with a repeater, justifies the additional expense, when it is considered that an hour of observing weather lost may mean weeks of waiting. I personally believe that even four positions on a first order instrument would give better results than 2 or 3 sets on a repeating theodolite with the average observer under the difficult conditions in Alaska. The principal object of taking 6 repetitions is to subdivide the 10 second divisions of the circle, but in making these repetitions there is so much handling of the instrument, so many chances of disturbing various adjustments, that the resulting average is frequently misleading. Moreover, if only a partial set is obtained, as so frequently happens, the results are useless. It is possible that with the use of a first order instrument, the observations in Prince William Sound might have been completed on August 1 instead of August 30. On the other hand, if it had been possible to have predicted the fine spell of weather from August 30 to About September 4, the observations could easily have been completed with very little delay with four observing parties.

The final observations gave the following closures in 8 completed triangles: +2".05, -2".40, +5".76, -1".31, +1".12, -1".48, +3".63, +1".03, an average of 2.35 without regard to sign. While these closures indicate good second order results, the several angles are the mean of 2 or 3 sets differing from each other by as much as 10 seconds, introducing an element of uncertainty which would probably not have occurred if a first order instrument had been available. It is probable, too, that the closures would have been reduced. As these stations will undoubtedly enter into any first order scheme extended to this area in the future, it would have been good policy to have prescribed first order accuracy. As these same conditions exist in most places where long lines are necessary, it is suggested that in the future all figures involving lines over 30 miles in length which would probably enter into a coastal first order scheme be observed with first order accuracy. The additional time required to secure this accuracy would save an enormous expenditure in the future, provided that proper equipment were available.

Signals

Most of the observations were made on heliotropes, a few on lights, and a few on center poles. Both triangles with closures over 3 seconds included observations on signal poles. In general, observations on signal poles are not satisfactory, and I should recommend that heliotropes or signal lamps be used on all lines over 15 miles. It is only in exceptional cases that signal poles can be seen clearly at greater distances, and pointings on a white blur, the usual effect seen when pointing on tripod signals, are not likely to give satisfactory results. Small signal lamps, the type rated for lines 25 miles long, gave good results over lines 60 miles long. The weather in Alaska is either so clear that the small lights will show this distance or else so misty that even the largest light will not show. Nothing is to be gained, therefore, in my opinion by using the larger lights in Alaska. The heliotropes give the best results, particularly as the daylight hours are so much longer. It is doubtful whether the usual objections to daylight observing hold true for observations in Alaska, particularly when the lines pass over water at a considerable elevation. It is more likely that different atmospheric conditions along the line of sight might cause horizontal refraction, and such differences are just as likely to occur at night, if not more so. For example, a heavy dew or mist was noticeable around mountain tops, collecting on the object glass and making observations very difficult, when such conditions were not noticeable at the lower stations.

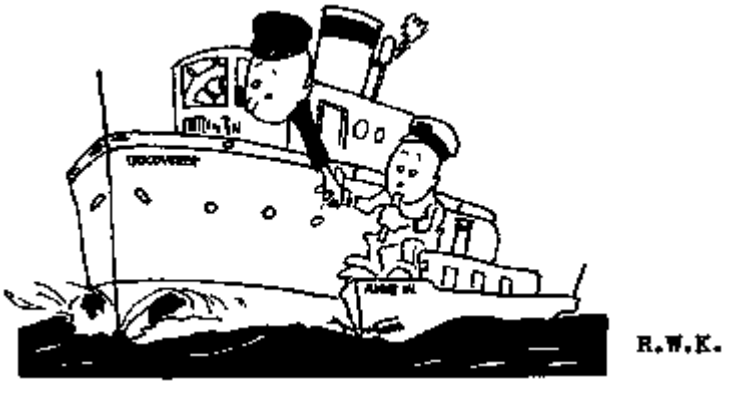
Heliotropes at present in use in Alaska give considerable trouble. In all my experience in Alaska I have not seen one give a steady light over a line even 25 miles long. The flashes usually last only a few seconds and there is then an interval sometimes lasting an hour; in fact, on many occasions heliotropes did

not show when the weather was apparently suitable. As for signaling with a helio, I have never yet known a message to get through. Whether this is due to the instruments, to the personnel or to atmospheric conditions, I have not been able to determine. I believe that atmospheric conditions are mainly responsible. However, the instruments are very crude, and there is room for considerable improvement. The present helio is good enough for short lines, where the object to be pointed on is easily visible, but it is difficult to point on an indistinct object, and once set, it is difficult to replace the instrument in the same position. A support must be built for it and an intricate system of stakes is required to line it in, whereas the terrain in the vicinity of a mountain peak usually makes such methods impracticable. The instrument should be mounted on a tripod provided with a horizontal and vertical circle, with clamps and slow motion screws, thus providing for fine setting and for replacing it in the same position. A good telescope would help, although the pointings can be determined with the theodolite. But most important of all are larger mirrors. I have never known them to be too bright and believe that with larger mirrors observations could sometimes be obtained when it is comparatively hazy. I would recommend the use of larger mirrors, even if it is necessary to prepare an emergency helio as illustrated in the Manual. Of course, great care must be taken in centering or lining in the helio and it is worth while to test the sights to make sure that the light beam is parallel to them.

If repeating instruments are used, cross-hairs are far superior to the glass diaphragms, as the latter absorb so much light that objects appear very faint. I have known several eases where observations were missed on this account at the very time when an observer at the other end of the line was getting good observations. Even with the best of equipment, long delays are to be expected. If the observing can be combined with other work, the delay is not so disastrous. However, the observer must not let other work interfere with the observing, for it is of the utmost importance that he take advantage of every spell of clear weather, for not only his own program but those at the other stations are involved.

Computations

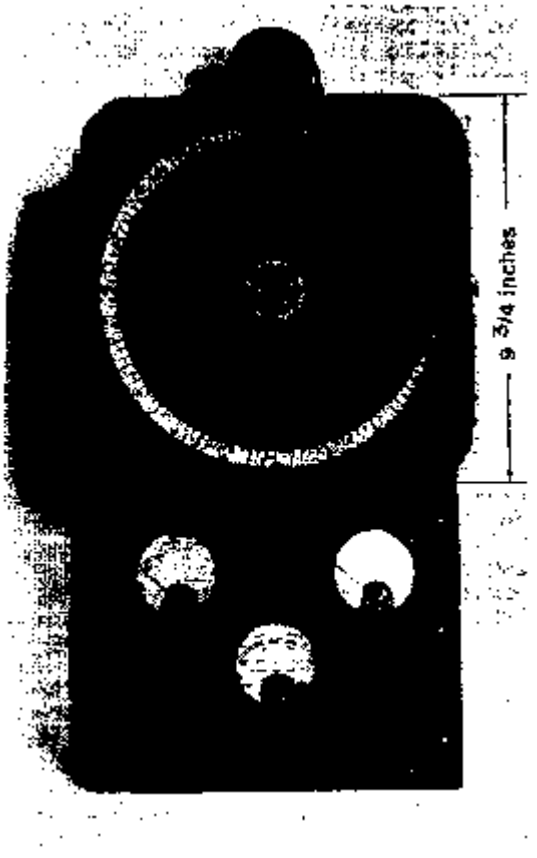
An uncertainty of 4 or 5 meters in the length of a line 100,000 meters long, while indicating an uncertainty of about 1-20,000 and well within the requirements of second order triangulation, creates troublesome problems in the field computations. With smaller figures, the small discrepancies are distributed through the whole chain and do not affect the relative positions of the various stations. But in figures involving long lines, the distribution of these relatively small errors may noticeably affect the resulting positions of the stations. It was found that by carrying the angles to hundredths of a second and using seven place logarithms, many troublesome questions regarding agreement of lengths were simplified. One of the lines, however, which was used to go ahead through some weak figures gave such startlingly different results, depending on which value of the length was selected, that it was important to select the most probable value. Accordingly, a field adjustment of the quadrilaterals was made, and the resulting most probable value agreed very closely with the value computed through the strongest triangles. The comparatively large discrepancies resulting from second order observations indicate the advisability of obtaining first order accuracy in figures involving long lines, as recommended above.



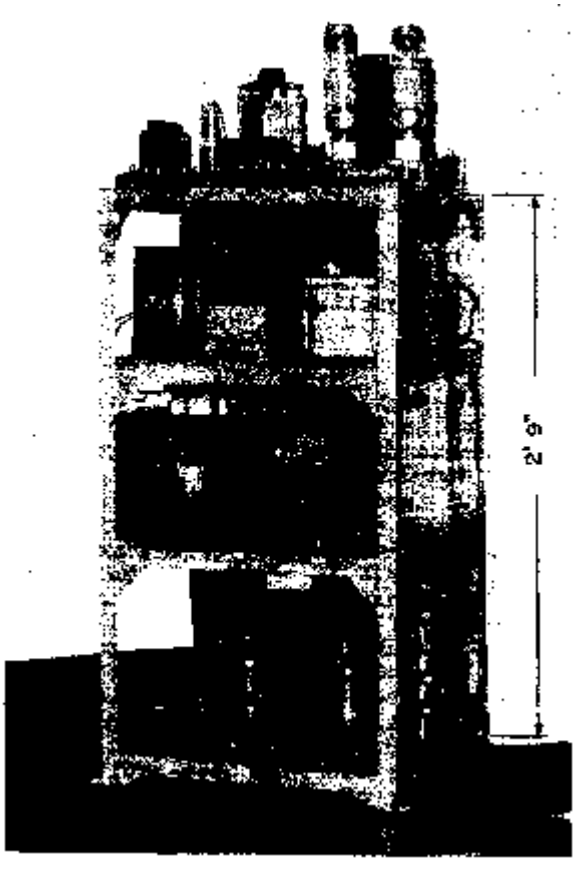
The "Convoy" - Chignik, Alaska to Seattle, Washington. September, 1925.

THE DORSEY FATHOMETER

The Fathometer, for measuring ocean depths by sound waves as developed by the Submarine Signal Company, has been used by the Coast and Geodetic Survey for over nine years. In actual work, this Fathometer has been used to chart all depths from 8 to 3000 fathoms. There are several different models of the Fathometer, as developed by the Submarine Signal Company, different ones having particular uses for different kinds of ships and navigation. No one type was developed primarily for surveying, and there is a small variation in the indication of depth which, having a nearly constant value, produces a larger percentage error in shallow depths than in greater depths. As the usefulness of the Fathometer as a surveying instrument became better known through the care taken by this Bureau in ascertaining all the deviations and consequently knowing the percentage of accuracy to which it could be used, it became apparent that if a Fathometer could be designed primarily for surveying shallow depths,



DORSEY FATHOMETER INDICATOR
Front view of the instrument which visually gives twenty indications of depth per second.

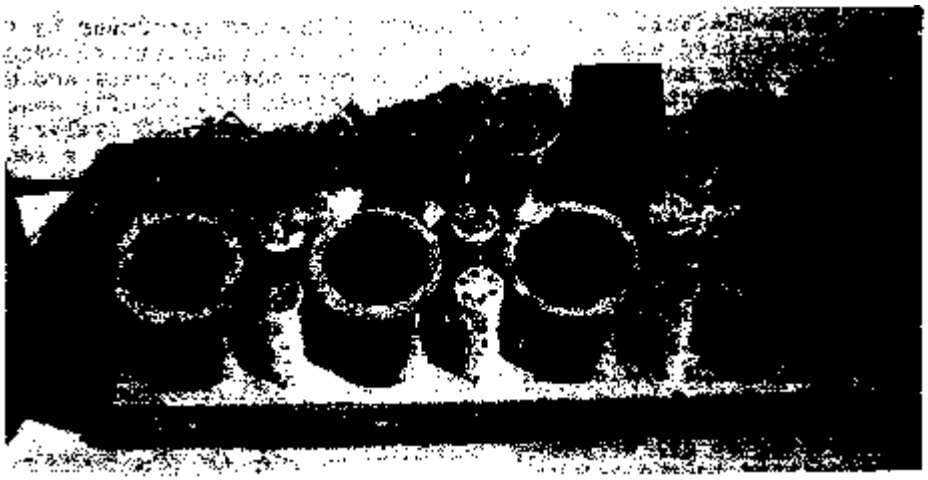


DORSEY FATHOMETER POWER SUPPLY
Thermionic tubes, chokes, condensers, tuning forts and transformers, with which are generated power for the indicator and supersonic transceiver.

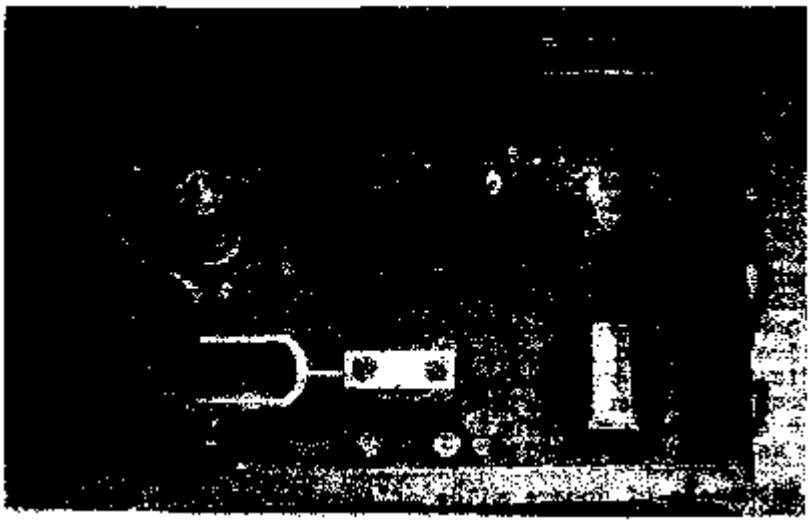
that the range of the instrument could be carried to inshore waters which ordinarily are surveyed only by means of leadline soundings at intervals of about 15 seconds. Such a Fathometer has been developed by the U. S. Coast and Geodetic Survey during the last year and recently has been installed on the surveying ship LYDONIA, which is charting the shallow waters off the Maryland Coast.

The general method of measuring depth by all Fathometers is to produce a sound in the water at the bottom of the ship; this sound then travels to the

bottom of the ocean, returns as an echo which is received in an instrument called a hydrophone and is amplified by thermionic tubes until it produces a single bright red flash in a neon tube. The flash of this neon tube is of such short duration that it serves as a pointer through a slot on a rotating disc. The disc is rotated at constant speed ordinarily controlled by a governor on an electrical motor. This constant speed of rotation gives a method of measuring the time elapsed between the emission of the sound by the sound producer and the reception of the echo as indicated by the neon tube. Since the time of travel of the sound through a depth of one fathom and back is approximately 0.0024 second, if it is desired to measure a depth of one fathom or less, or if it is desired to distinguish between say a depth of two fathoms or two and one-half fathoms, it is necessary that the speed of rotation not only be kept constant, but that the actual speed in revolutions per minute should be accurately known. For this reason, in the recently developed Dorsey Fathometer, it was decided to use as a frequency control the vibrations of a tuning fork, and in order that the speed should remain constant through such relatively short time intervals as a thousandth of a second, it was decided to use a tun-



AMPLIFIER

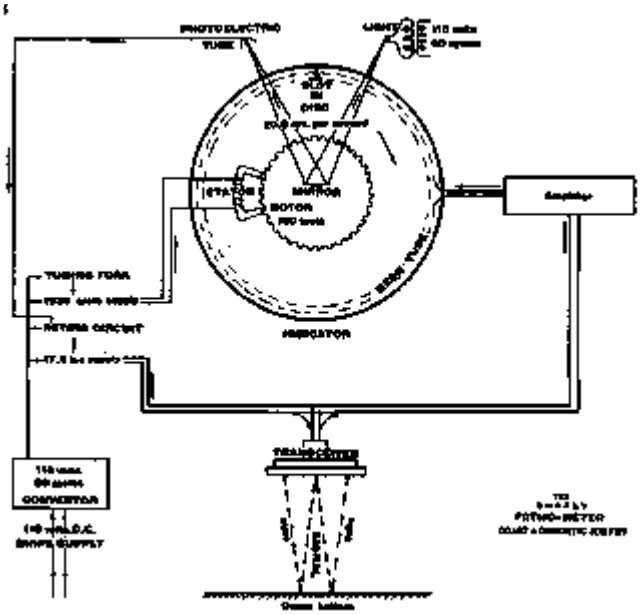


DORSEY FATHOMETER TUNING FORK

The primary control for time measurement in the Shoal Fathometer. The fork has a frequency of 1025 oscillations per second, is made of special steel, non-corrosive and little affected by temperature.

ing fork having a frequency of 1,035 cycles per second. A small amount of power is taken from this tuning fork and amplified to a value sufficient to run a synchronous motor at a speed of 20.5 revolutions per second. This speed of rotation will be maintained constant so long as the tuning fork vibrates; if the motor runs, the speed is correct, since it is controlled entirely by the vibrations of the tuning fork. This speed is chosen to give correct indications for a velocity of sound in water of 820 fathoms per second. The tuning fork is made of special steel having a low temperature coefficient for its modulus of elasticity, and the electrical circuits driving it are such that its frequency is not altered by changes in voltage, et cetera. For each cycle of the tuning fork two impulses are given to the rotor of the motor of the indicator which has 100 teeth; thus there are 200 impulses for each revolution of the indicating flash. The scale is divided into 20 fathoms, which are subdivided into feet so that the indications are readable to tenths of feet, a value even smaller than that ordinarily attained by the leadsman in measuring shallow depths by the usual hand lead method.

In order that the signal may be sent at the proper time, a mirror on the shaft of the rotor, reflects a beam of light from a small lamp and this beam sweeps across a photo-electric tube. The electric impulse generated by this flash of light is amplified and actuates the transmitting circuit to produce the sound in the water. This method was found to be much more accurate and dependable than mechanical contacts. In the ordinary Fathometer, briefly described in the first paragraph, the sound has a frequency of about 1,000 cycles per second, and can be heard easily by anyone on the ship. However, in a sound of this frequency, the duration of one cycle of the sound is a thousandth of a second, a time interval as long as is necessary to obtain an echo in about 2½ feet of water. If as much as a half cycle of this low frequency sound should be lost, it would be the equivalent of having an error of more than a foot in the measurement of depth. Consequently, to avoid any difficulty of this sort, a frequency of 17,000 cycles per second is used in the Dorsey Fathometer so that if one cycle is lost, the equivalent depth would amount to only 3½ inches. The pitch of this sound is so high that it can not be heard by most people, and the instrument, which sends the sound, transmits in a narrow beam toward the bottom so that anyone in the ship can generally hear nothing at all of the sound being transmitted to the bottom or the returning echo.



Since the depth indications occur 20 times per second, the flash of the neon tube appears to be a continuous line of light, showing just what the depth is and how it changes; in fact the indications are so constant that when passing over a flat bottom the motion of the ship on a slight swell is readily observable. In the Dorsey Fathometer the neon tube is in the form of a fixed ring behind the rotating disk, which eliminates the necessity for moving contacts on the older types of fathometers. During the early tests comparisons were made with the hand leadline in depths from 3 to 15 fathoms. The difference has never been more than one foot between the leadline method of measuring and the indications of this Fathometer. There is the further advantage, of course, that except when running slowly, in order to get the checks by the hand lead method, the ship can run at full speed covering almost twice as much ground in a given time as can be done while sounding by the older methods.

There are thousands of square miles of inshore shallow water which can be surveyed by this method. The LYDONIA will continue to use it for the rest of the season and a similar installation has recently been made on the Ship HYDROGRAPHER now surveying in the Gulf of Mexico. By the beginning of next season it is planned to have it on at least two more ships on the Atlantic Coast. The saving by this method will be nearly as great in shallow waters as has been obtained by the regular Fathometer in the greater ocean depths.

IN REPLY ADDRESS THE DIRECTOR
U.S. COAST AND GEODETIC SURVEY
AND NOT THE SIGNER OF THIS LETTER

AND REFER TO No 20—RS
1270 H

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

WASHINGTON

December 13, 1934.

To: Dr. Herbert Grove Dorsey,
Principal Electrical Engineer,
U. S. Coast and Geodetic Survey,
Washington, D. C.

From: The Director,
U. S. Coast and Geodetic Survey.

Subject: The Dorsey Fathometer.

I want to express my appreciation of your contribution to the hydrographic surveying equipment of the United States Government upon the occasion of the recent demonstration of the satisfactory performance of the Fathometer which you have developed in the laboratories of the United States Coast and Geodetic Survey during the past two years.

This Fathometer is in every respect a precision instrument and will enable the Coast and Geodetic Survey to maintain its traditionally high standards of accuracy in the charting of shoal depths, which is most essential to safety at sea and yet has been difficult of attainment. The shoal water Fathometer has thus increased the efficiency of the Bureau in that the quantity of the work can be doubled with a marked increase in the quality.

It is with pleasure that I congratulate you on the successful demonstration of this development, and as a slight token of the appreciation of the Bureau, hereby direct that the instrument shall be designated as the Dorsey Fathometer, United States Coast and Geodetic Survey.

R S Patton

Director.

HISTORY OF THE LOCAL CONTROL SURVEYS PROJECT

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

From Geodetic Letter No. 9

In the fall of 1933 this Bureau was asked by the Federal Emergency Relief Administration to administer as a work relief measure, a surveys project having for its primary object the employment of needy engineers and others. It was expected that some fifteen thousand people might be employed. This Bureau accepted this assignment with some reluctance for it was realized:

(1) That because of the augmented operations in connection with our regular surveying program there would not be available a sufficient number of our own personnel to give adequate supervision to such a project.

(2) Instruments of the type needed for efficient operation could not be obtained on short notice, and in time to be used during the period designated for field operations.

(3) The problem of transportation of personnel and equipment could not be met by purchasing automotive equipment, because most of the funds were to be used for wages and a limit was placed on the amounts to be used for purchase of equipment and materials.

(4) The field work was to be carried on in every state of the Union during the severe winter months which would not make for economical results in the northern states.

This Bureau was interested in such a project from an altruistic motive because of the vast employment possibilities which would be offered to fellow engineers but was faced with the problem of carrying on field operations, in spite of the difficulties mentioned, so that the results obtained would be in accord with the strict standards of accuracy prescribed for our regular surveying program and could therefore be included in the national net of horizontal and vertical control.

The arrangements finally made with the Federal Relief Administration were that this project should be a part of the Civil Works Administration program. Formal approval of the project was granted on November 27, 1933, and employment of personnel, and operations of field parties started as soon thereafter as possible. All wages of personnel were to be paid through the channels of the C.W.A., but all other expenses would be charged to an allotment of $563,120.00 (F. P. 84) made by the Public Works Administration to this Bureau for this specific purpose. The personnel were to be selected through C.W.A. channels, would be paid in accordance with the wage scales, and would be subject to the rules and regulations regarding employment, as prescribed by that agency. Except for the above restrictions, the project was under the control of this Bureau.

This Bureau was given to understand that while the funds available would last only until February 15, 1934, there was every possibility that the Congress would advance additional funds, and the project would almost certainly continue beyond that date.

Employment of personnel proceeded uninterruptedly until January 19, 1934, when the Civil Works Administration issued orders that no further additions were to be made to the payroll. This hampered our project, because in some states the selection of personnel and organization of parties were proceeding slowly and the maximum number of employees authorized had not yet been reached.

On February 15, 1934, Congress passed the law providing for the continuation of the Civil Works Administration program and substantially prohibited participation of Federal Bureaus in such a program after that date. At that time more than 10,000 men were employed throughout the states on these surveys. Each state after February 15th could continue this survey project under its own C.W.A. program if the State Civil Works Administration so desired. As an evidence of the widespread approval of this work, only four states decided not to do so. Our connection with the project after February 15th has been to act in an advisory capacity to insure that the results obtained will be of an acceptable standard. In those states which are continuing, this Bureau assumes the salary of the State Representative and also pays his travel expenses while on official business away

from headquarters. All records are, or will be, sent to this office so that the control may be included in the national net.

On March 31, 1934, the program of the Civil Works Administration ended, and relief measures thereafter were continued under the Work Relief Plan of the State Emergency Relief Administration. Restrictions regarding employment under the new Plan were such that a man to be employed had to be absolutely without resources. Further restrictions limiting the number of hours of work authorized to six and eight hours per week were imposed, so that field work could not be carried on efficiently. As a result, in most states the Local Control Survey project was definitely discontinued after this date.

In fifteen states, however, the work has continued subsequent to March 31st, and at the present time operations are still being carried on in these states although in most of them upon not nearly as large a scale as at first authorized. There are about 1500 men still employed. In some states the project will continue until October 1st, and in Tennessee where work is being done in regions requested by the Tennessee Valley Authority the project will continue until January 1, 1935, with a complement of 320 men. In many of the states still operating, the key employees (that is the instrument men and supervisors) are classed in a supervising status and are not subject to the restrictions regarding employment and small number of hours of work authorized per week, as apply to other employees under the State Emergency Relief.

This Bureau selected a man in each state who acted as our Representative and had general charge of the project in his state. This man was an outstanding engineer, usually a professor in one of the leading engineering schools. He was supposed to devote but part of his time to this project, and it was expected that he would carry on his regular activities at the same time. These men took an active interest in the project, worked hard and put in long hours to make these surveys a success. To them was delegated the job of contacting the State C.W.A. authorities to obtain the necessary personnel. They also made arrangements for borrowing instruments and trucks. The organization of parties was entirely in their hands. They also decided where the surveys were to be undertaken. Too much credit cannot be given to these officials who gave so unsparingly of their efforts, in many cases at considerable sacrifice to themselves, in order that their fellow engineers might be benefited.

To assist our State Representatives, a number of Supervising engineers were selected by them through the C.W.A. channels. In general one supervising engineer had charge of the field work of from five to six parties. These men were usually high grade engineers capable of giving adequate supervision to the field parties.

In each state an office was established where administrative details in connection with the project could be handled. A force of computers, stenographers, clerks and accountants, selected through the C.W.A., were employed in this office.

Each state representative was bonded as a chief of party in order that he might make expenditures of Government funds in connection with this project in his state. His accounting force prepared payrolls for transmission to the C.W.A. offices, where the pay checks were drawn. Vouchers for other expenditures were prepared in his office, certified by him, and forwarded to the Washington Office for administrative examination and payment.

An estimate was prepared for each state of the number to be employed, together with the amount to be expended for the payroll and the amount needed for purchases of equipment and materials. Each State Civil Works Administrator was notified of the number to be employed in his state as soon as this project was approved by Mr. Harry L. Hopkins, Federal Civil Works Administrator.

In order that the project might be of maximum benefit to the employees, work was carried on in localities where the men could live at home and be subject to a minimum of travel. The program of surveys best adapted for such a condition was the subdivision of the twenty-five mile spacing of our first order control by means of traverse and leveling. Some triangulation was accomplished in the western states, but most of the horizontal control was established by traverse.

Had time permitted, it would have been advisable to purchase a sufficient number of theodolites, graduated to ten or twenty seconds, and also tilting levels, so that these surveys could have been expedited and the results obtained much more economically. There is a dearth of high grade instruments available

in this country and as a consequence it was necessary to adopt plans to make use of such instruments as could he borrowed from interested concerns and individuals.

Because of the depression there were many surveying instruments owned by railroads, construction concerns, highway departments and municipalities which were not in use. It was decided that an appeal would be made for the loan of such idle instruments for use on this project. The Survey accepted the responsibility for these instruments while on such use, and agreed to return them to their owners at the expiration of the field work in as good condition as when received. The response to this appeal was very gratifying, and it was unnecessary for this Bureau to purchase any major surveying instruments. Such special instruments as Abney and Locke levels, spring balances, and thermometers, were purchased however. It was also found necessary to purchase a number of 100-foot steel tapes and also a quantity of level rods, as equipment of this nature satisfactory for high-grade work was not available.

Since the transits commonly used by engineers are graduated to 1 minute, or at best 30 seconds, and since these were to be used on this project, specifications were prepared in the Washington Office whereby second-order accuracy could be obtained with such instruments, in connection with the 100-foot steel tape. Forty-eight tapes were standardized at the Bureau of Standards and one was sent to each state to be used as a master tape for comparison with the tapes actually used in the field on the measurements. Taping was usually carried on over portable tripods under a definite tension, and corrections applied for grade and temperature. Four sets of readings were specified for the angular measurements with the criterion that accepted results should agree within eight seconds of the mean. The repetition method was used, and one set consisted of six measurements of an angle with the telescope direct followed by six with the telescope reversed for each angle, including the one to close the horizon. An analysis of the results forwarded to this office shows that acceptable horizontal angle observations in some cases could be obtained with a smaller number of sets than four, but in most cases it was found that this number was required. Had theodolites graduated to ten seconds been available, the required accuracy could easily have been obtained by two sets of 6 D & R. A fair observer can measure one angle 6 D & R in twelve minutes. The consequent saving in time which would have resulted from better instruments is evident. In general no difficulty was experienced in obtaining traverse closures of 1:10,000 when the rigid specifications were followed.

Leveling was carried on mostly with the ordinary Wye level. An accuracy of .05 feet $\sqrt{\text{distance in miles}}$ was specified and obtained without trouble. Had tilting levels been available, this work could also have been done more accurately and expeditiously.

It was realized that many of the engineers out of work owned automobiles which they would furnish for transportation facilities on this work, providing employment were offered to them. Arrangements were made so that these cars would be kept in repair by this Bureau while on such use and whereby this Survey accepted the responsibility for accidents to the cars while in official use, providing such accidents were not due to careless driving. The adoption of this plan made it unnecessary to purchase motor equipment.

Bronze disks somewhat smaller in diameter than the regular marks used by this Bureau were sent to all parties. These disks had the legend "U. S. Coast and Geodetic Survey and State Survey" cast on the face. North Carolina and Pennsylvania had disks cast with legends peculiar to their respective states only. The disks were set in concrete monuments, of a size similar to that specified for our regular operations, or in permanent structures. On the traverse work these monuments were established at intervals not greater than two miles. Marks were established in pairs with the two marks about l/4 mile apart, so that an azimuth would be available at each station for future use. Levels were run over the same lines as the traverse.

Insofar as possible connections were made to first-order work of this Bureau at the beginning and ending of the traverse lines. Where no monuments of this Bureau were available for such connections, it is expected that at some time in the future our regular field parties will connect to such local control work.

The final computations for the horizontal control established in the various states are being placed on the plane coordinate system. The use of this system simplifies the computations for the supplemental control, once the first-order stations of this Bureau to which connections are made are expressed in similar terms. Projection tables and instructions for transferring from geodetic to plane

coordinates were prepared in the Washington Office and sent to each state office. The preparation of these projection tables ranks as no mean accomplishment. It was estimated that under our regular program this work would have taken a year or more to accomplish. Upon the inception of the C.W.A. program these computations were expedited and these tables completed for each state in a few months' time.

Statistics to June 30, 1934 show 14,000 miles of traverse, 20,000 miles of levels, and 1,200 miles of triangulation completed. A number of monuments have been set in some states over which no work has been done because of the abrupt termination of the project. Should further funds not be forthcoming to continue these surveys as a separate project, it is planned to have our own parties run levels over such marks, so that no monuments will be set for which descriptions and data are not available.

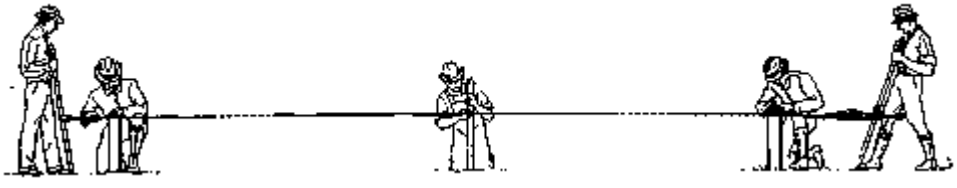
The work done and the monuments established will be of permanent value to those communities where such surveys were carried on. Frequent requests come to this office for information regarding the marks established. Much publicity was given to these surveys through numerous newspaper articles and, as a result, a more wide-spread knowledge of the utility of these marks was disseminated throughout the country.

The project has been of value in acquainting the engineer with the fact that accurate surveys can be obtained when using ordinary surveying instruments. Heretofore many engineers have had the idea that geodetic surveys could be accomplished only with the use of special surveying equipment. This project has taught these men that if certain precautions are adhered to when making surveys, results of a high degree of accuracy can be obtained.

The many letters received at this office from engineers who were employed on this project expressing gratification that they were able in a time of need to work at labor for which they were fitted by training and experience, shows that as a measure to relieve unemployment among a class not reached by other work relief measures, this project was a success. Statistics show that about 75% of those employed were men of college training. These were not necessarily all civil engineers, as mechanical, chemical and electrical engineers and other college men, were employed as rodmen, chainmen, computers, etc. As an indication of the high type of men employed, the following is quoted from a letter addressed to the Director from Mr. John S. Bates, State Representative for California:

"We have as our motto that the good name of the Coast and Geodetic Survey must be maintained and that our privilege to represent the organization carries an obligation to insure good public relations and absolute accuracy of all work done".

For professional engineers, who through no fault of their own, have been without employment, some of them for several years, the Local Control Surveys Project was a Godsend, and was of assistance in keeping up their morale in a time of stress.



THE FOUCAULT PENDULUM EXPERIMENT

Illustrated by the Polyconic Projection for Maps

Thoburn C. Lyon, Assistant Cartographic Engineer
U. S. Coast and Geodetic Survey

In 1851 the French physicist, Foucault, performed an experiment which was hailed as "the first ocular proof of the daily rotation of the earth" on its axis.

From the dome of the Pantheon, in Paris, he suspended a heavy iron ball by a wire two hundred feet long. To the lowest part of the ball a pin was fastened, and under carefully guarded conditions the long pendulum was set in motion. It was found that with each swing of the pendulum the pin traced a fresh mark slightly further to the right (clockwise), in a ring of sand which had been prepared beneath it. This apparent deviation of the pendulum, it was explained, was due to the actual rotation of the earth beneath it, the swinging pendulum (like a gyroscope), maintaining its original plane of oscillation regardless of the motion of its point of support.

The "Foucault experiment," as it has come to be called, has been performed Many times since then, and the long pendulum required for such a demonstration may occasionally be seen in some museum of science today. However, the difficulties incidental to a successful presentation are not small, and as an "ocular demonstration" the experiment is singularly unconvincing.

It is not difficult to understand that if a pendulum, swinging at the pole, maintains its original plane of oscillation for twenty-four hours[1], the earth will in that time make one complete rotation beneath it; with just a bit of mental effort one can even understand that at the equator there would be no deviation at all; but why, between these extremes, the deviation should be proportional to the sine of the latitude is a bit difficult to see clearly. Literature on the subject seems rather scarce, and the writer was long annoyed by inability to visualize the elements involved; finally, however, there came the realization that a simple and satisfying explanation of the whole phenomenon was to be found in the principles underlying the polyconic projection for maps.

The sphere being a "non-developable surface" (that is, one that cannot be spread out in a plane without some stretching or tearing), for mapping purposes it is customary to project the points of the sphere upon some developable surface (one that can be spread out in a plane without stretching or tearing: as a cylinder, or cone).

In the polyconic projection, the earth is considered as made up of the bases of a series of cones (see Figure 1), each of which may be unrolled, or developed, into a plane surface, as indicated in Figure 2.

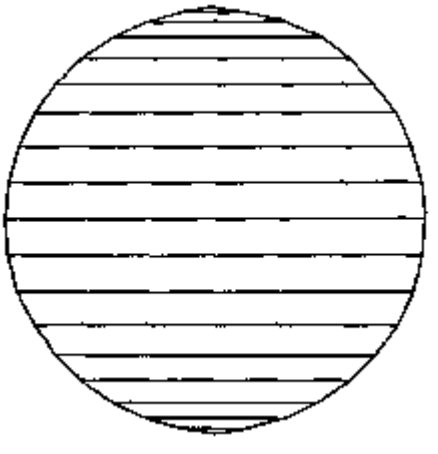


FIGURE 1

Earth considered as formed by bases of cones.

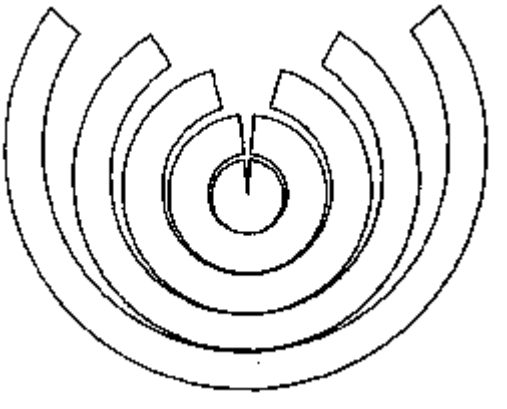


FIGURE 2

Development of the conical bases. As the pole is neared, the bases approach a complete circumference.

Although the base of each cone completely encircles the earth, it is less than a complete circumference when developed into a plane surface: it then becomes a sector with radius equal to the side of its cone, and arc equal to the length of the parallel of latitude which formed the base of the cone. As we near the pole the developed cones approach a complete circle, as indicated in Figure 2; at the pole itself, the altitude of the cone is reduced to zero and the cone becomes a plane - - - a complete circumference[2].

As a most important step in understanding the behavior of the Foucault pendulum, it may be demonstrated mathematically that the portion of a complete circumference represented by any developed cone is proportional to the sine of the latitude of its point of tangency to the sphere.

In Figure 3, let PAA' represent a cone tangent to the sphere at any latitude, φ, the parallel of latitude being represented by the circle AA'A. Figure 4. represents the same cone developed into a plane surface, the length of the arc AA'A being the same as the parallel of latitude AA'A of Figure 3.

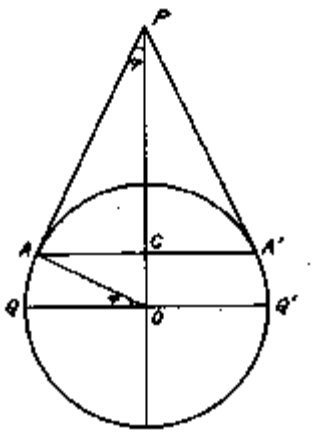
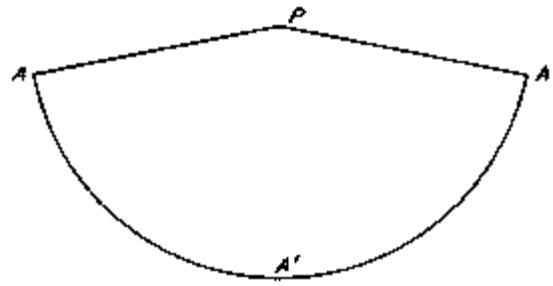


FIGURE 3

Cone tangent to the earth at any tatitude, φ.



FtGURE 4

The same cone develooped into a plane surface.

The parallel of latitude AA'A (Figure 3), is equal in length to

$$2\pi AC. \qquad (1)$$

Now, referring to Figure 4, we may see that if the arc AA'A is four units long while a complete circumference of the same radius is ten units long, then the angle P is 4/10 of 360°. To put this statement-into general terms, the length of the total circumference of which the developed cone is a part is $2\pi AP$; and the angle at P is equal to $\frac{\text{arc } AA'A}{2\pi AP}$ of 360°.

Substituting for the arc AA'A, its value from (1),

$$\text{angle } P = \frac{2\pi AC}{2\pi AP} \times 360^\circ = \frac{AC}{AP} \times 360^\circ.$$

But, referring again to Figure 3,

$$\frac{AC}{AP} = \sin\varphi, \text{ and}$$

$$\text{angle } P = \sin\varphi \times 360^\circ. \qquad (2)$$

Now suppose a pendulum to be suspended at A (Figure 5), and started swinging north-and-south, toward P, along the line AP. As the earth rotates eastward, the point A follows the path of the arc AMA'N to A (24h later).

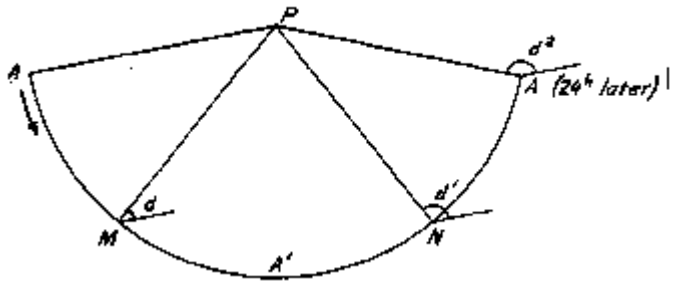


FIGURE 5

The angies d,d[1],d[2], represent the deviation of the pendulum at successive intervals during 24 hours.

When A has reached the position indicated by M, the pendulum, like a gyroscope, will have maintained its original direction, and its path will be represented by the light line drawn from M parallel to AP. MP represents the north-south line at this point, and the deviation up to this time is equal to the angle d.

When A has reached the position indicated by N, the path of the pendulum will be represented by the light line from N parallel to AP; NP represents the north-south line at this point, and the deviation for this period is equal to the angle d'.

Twenty-four hour s[1] later, when the earth has made one complete rotation, A will have reached the position indicated as "A (24h later)," and the total deviation for the twenty-four hour period is equal to the angle d[2] - - - which is equal to the angle P3 which is equal to the sine of the latitude x 360°.

As has been mentioned already, at the poles the altitude of the tangent cone is reduced to zero, and the cone becomes a tangent plane, a complete circumference of 360° (1 x 360°, the sine of the latitude, 90°, being equal to 1).

At the equator we have another special case, in which the altitude of the tangent cone becomes of infinite length, and the cone becomes a cylinder. When unrolled, or developed, into a plane, the edges of the cylinder (representing any desired meridian and its position twenty-four hours later), are parallel, and it is apparent that a pendulum started swinging parallel to the meridian would still be parallel at the end of twenty-four hours. In other words, at the equator the deviation of the pendulum in 24h is zero (0 x 360°, the sine of the latitude, 0°, being 0).

Thus, from the principles underlying the polyconic projection for maps, we have been able to see why, at all places on the earth4, from the equator to the poles, the deviation of the pendulum for a twenty-four hour period is equal to the sine of the latitude times 360°.

1 Strictly speaking, twenty-four sidereal hours.
2 To be exact, the cone becomes a point at the pole itself.
3 By geometry, the sides of the two angles being parallel.
4 Treated as a perfect sphere, with no correction for eccentricity.

IMPRESSIONS OF A MATHEMATICIAN IN THE FIELD

H. P. Kaufman, Assistant Mathematician, U. S. C. & G. Survey

From Geodetic Letter No. 9

Ten years is a long time for one to wait to find out how field triangulation is executed. My office experience had given me an idea of how the work was done, but there was just that element lacking, of not actually having witnessed or assisted in the field observations that kept me from being able to say, "I know how field triangulation is executed". Greatly desiring to get this experience, I made my objective known to Major Bowie, and he gave his kind consent at once to my joining the field party which was executing triangulation from Richmond, Virginia, to Washington, D. C, under the direction of Lieutenant John Bowie, Jr.

I arrived at camp, located at the fair grounds just outside of Fredericksburg, Va., on June 18th. It was a miserable day for it was raining and had been continuously since the night before. I knew only the chief of party and he was not present, but I made myself known to the men and was received very cordially. I was amazed at the size of the party which was composed vf seventy men. Many of the men had their families in camp with them. For the moment I thought I was in a small village. A considerable number of the men live in tents and the rest live in house-trailers, - the ideal home for campers.

The duties of the chief of party, aside from supervision of the actual surveying, are many and varied and call upon all his resources to keep the party going without delays or loss of time. Upon him falls the responsibility of the welfare of a small village. He may be called into a court of law when some of his men are involved in difficulties with the authorities; or he may be required to assist the sheriff in apprehending milk thieves who anticipated the owners in milking cows pastured on the property occupied by the party. The discipline maintained in this outfit is second to none. Orders are immediately carried out with machine-like precision. This is one of the reasons why this party was able to occupy 120 stations during one month on the Jacksonville-Miami arc.

It seemed as if everything happened to this party while I was with it. A tower blew down, cranks would not let us enter their property, and obstructed lines were so numerous that even my patience was sorely tried. Nevertheless, in spite of all these handicaps, the costs per station exceed the average by only a few dollars.

It was a day of blessing when the Office Trailer became part of the field equipment. Heretofore, the field computations had been done in tents and when moving day came, it was a detestable job to move and reestablish the office. Now it is just another day, for in 15 minutes everything is in readiness to be moved. It might be inferred that moving day would be a work-day lost, but this is not the case for the field work goes on, on that day as on any other day. This is an example of the efficient methods which are used to expedite the work.

Actually being present in the field has cleared up many doubtful things in my mind, so that when I look at confusing data in a horizontal direction book today, I can more easily visualize what has taken place. Under the guidance of John Bowie, Jr., Chief of Party, I did each operation myself from reconnaissance and helping to build towers, to observing. Before this, an angle to me was just degrees, minutes and seconds. Today it means days of preparation, hard work, heartaches, cussing, and at times, suffering.

Everybody works hard in this party. The steel men are away by seven o'clock in the morning and, in a few cases, have not returned before ten o'clock at night. This is unusual, however, as they usually complete their tower and are back in camp by four o'clock in the afternoon. The observers and recorders are on the job at ten o'clock in the morning, checking the previous night's work. They leave for their stations about three o'clock in the afternoon and are lucky to return home before ten o'clock of that night. In most instances they come home after midnight. I once came in after one o'clock and I was told that it is not at all unusual for the parties to be out till sunrise. There are many reasons for this, such as obstructed lines, trucks being mired in some out-of-the-way place, etc. Practically the whole day is devoted to carrying on the work, - and indeed, a fine job is being done.

Among the suggestions, which might be made to improve the efficiency of the field work, are:- the use of radio telephone by the chief of party and observers,

regular inspection of the steel towers and the expending of poor ones before they become unsafe or cause trouble in closure of triangles. The observation floor boards should be made fast so that a wind could not stand them up. Unsecured, they form a real hazard to life and property when a strong wind comes along.

I can say without hesitation that, as a result of this experience in field observation, I am better qualified for my work than heretofore, and would like to see all office men get this experience. It would also help the young field man tremendously if he were to spend some time in the office. This understanding of the other man's work would make for a still more efficient U. S. Coast and Geodetic Survey.

MAP OF THE PHILIPPINE ISLANDS

A new edition of the map of the Philippine Islands by Mr. John Bach has just been received in the Washington Office. Mr. Bach has published this edition under the title of "Two Maps of the Philippines, Murillo Velarde, 1734 John Bach, 1954," It is an attractive folder containing the two maps and brief historical notes, as well as a commemoration of the second centenary of Murillo Velarde's original map, a copy of which accompanies the folder. Velarde's patience must have been sorely tried by his political critics of 200 years ago, and surveyors of today will have a fellow feeling for him when they read his own account of the preparation of this map, quoted by Mr. Bach from "Chronicas de la Apostolica Provincia de San Gregoria, por Juan Francisco de San Antonio":

"And in the year 1733 an order came from Our Catholic Monarch that a map be made of these Islands, and the same having been entrusted to my care, it saw the light of publicity in the year '34. In it I put all the pueblos, points, inlets, ports, shoals, reefs, courses, sailing directions, rivers, forts, and distances, as was possible in so difficult a matter within the scale. And in a description of a few lines, and in the margin, as in Egyptian hieroglyphics, I relate the most memorable things therein contained, as extensively as can be done in such concise words and figures, and if anyone deems this boasting, let him undertake the work himself and he will see that it is more difficult to handle the pen and do the work, than to stand by and criticise it."

In spite of the great improvements in cartography during the 200 years between these two maps, we note that our old friend the carabao hasn't changed much.

A further note reads:

"In the year 1901 the United States Coast and Geodetic Survey began a comprehensive survey of the Archipelago. This survey which is now nearing its completion, has been executed by highly scientific hydrographic engineers, whose accomplishment during a continuous period of thirty four years has been published for the benefit of commerce and navigation in the form of one hundred and fifty five nautical charts, accompanied by Coast Pilot publications and Tide Tables for prediction of tides. To serve interior commerce and communication, the Bureau of Coast and Geodetic Survey has also published sixteen topographical maps, three strip-maps for aviation, and two volumes of 'The Triangulation of the Philippine Islands'.

"This important survey work is still to progress, although the fleet of survey vessels, which at the peak of its activity numbered as many as seven, now consists of one only, the good ship 'Fathomer'."

Most of us are familiar with Mr. Bach's excellent map of the Philippines, and this new edition is even more complete than the former ones.

RAPID OBSERVING

From Geodetic Letter No. 9

Moat men just learning to observe in triangulation or leveling are inclined to take a great deal of time in pointing on a light or other object or in reading the rod. They naturally wish to be extremely careful and avoid errors in pointing or reading. Sometimes men of wide experience also are very deliberate in making their observations. If one were required to make single observations only, and that one observation had to be as nearly perfect as possible, perhaps there would be some reason for great deliberation. Where one makes many observations over each line as on triangulation, he should realize that the small accidental errors made on a single pointing will be cancelled out in the mean of all the observations.

If one wishes to learn how rapidly and accurately he can bisect an object by eye, let him try the following: Take a memorandum card about the size of an ordinary envelope and with a pencil or pen try to bisect the card near the top. Cover the point made with a piece of paper and a half an inch lower down, place another dot in what appears to be the center of the card. Let him cover this in turn and keep on making dots until he gets to the bottom of the card. Then, lift the paper that has covered the dots and see how nearly the dots make a straight line. Only occasionally will one be off much more than the width of an ordinary pencil or ink line. Draw a line through the dots, tear the card in half and place one part reversed over the other. This method will show the amount of personal equation one has, if any. Some persons consistently place their dots to the right of the center and others to the left. Only a very few can bisect the card exactly. It is noteworthy, however, that the hand holding the pencil or pen will come to rest almost instantly and if the pencil or pen is moved only slightly to the right or left, the eye tells him that he is off center. Great deliberation in placing the dots will not improve the bisection.

When observing on triangulation, the light should be moved between the wires until the observer does not know which way to turn the tangent screw to improve the pointing. When this has been done, the pointing is a good one. It is just as nearly perfect as if a minute or more were spent in making the pointing. Of course, there are times when the object sighted on is very unsteady. In such a case a few moments are needed to determine whether the object vibrates as much to the right as to the left of the center. Even with unsteady objects, however, it only requires a few seconds to make the pointing.

In leveling, the rod can be read quickly. When the bubble is in the center of the vial the observer should read the position of the wire on the rod almost with the same facility as he would read the position of a line drawn across the centimeter space that might be on a piece of paper lying on his desk. This statement is based on the assumption that the rod is steady. During the middle of the day when the atmosphere is unsteady, there will be an apparent movement of the graduations on the rod. In such a case the rod reading should be the mean of the position of the wire on the vibrating space. In both triangulation and leveling, errors of pointing are accidental. The object of multiplying the observations, three for each rod reading and many more on triangulation, is to eliminate the effects of the accidental errors of the individual readings and pointings.

Hurried observations are never good but it is advisable for everyone to make rapid observations. One should experiment to see just what rapidity of reading will give the best results, both in leveling and in triangulation.

There is one advantage in making rapid observations in triangulation. A number of minutes elapse between the first and last pointing for any one position. If this interval of time is too great, the instrument has a chance to be distorted by changes of temperature or the stand on which the instrument rests may be changed slightly in azimuth. The effect of such changes will be minimized if the observations are made rapidly.

In triangulation it is absolutely essential that the instrument be moved in azimuth carefully. Jerky movements are bad, for they tend to drag the tribach with the alidade.

The chiefs of the triangulation and leveling parties should instruct the observers working under them in the beat methods of observing. It is surprising how quickly a new observer will develop into an excellent one if he is instructed by an experienced engineer in the best practices in observing. Experience, of course,

is the best teacher and each observer should experiment to see what is the best method for him to follow. It is the general concensus of opinion, of experienced observers, that rapid but not hurried observing will, in general, give the best results so far as accuracy is concerned.

APPRECIATION

The Cunard Steam Ship Company Limited

From: Captain P. A. Murchie,
Royal Naval Reserves

R.M.S. Carinthia
New York

To: The Director
U.S. Coast & Geodetic Survey
Washington

18 Sept., 1934.

Sir:

I beg to thank you for your letter dated August sixth and for Chart, No. 3076 (approaches to Nantucket). This is the finest chart, the most complete I have ever seen and approaching Nantucket in foggy weather with the Echo Sounding Fathometer working, I found your sounding absolutely accurate. You have performed a great work for the professional navigator. You are in the van of the worlds hydrographical surveyors and as a British Shipmaster I tender you my grateful thanks. I am Sir

Your obedient servant,

(Signed) P. A. Murchie
Master.

Such appreciation of our work is more than gratifying, especially when it comes from the men who use, and depend on our charts in the routine of their lives. We know that our entire personnel will join the field officers who worked several seasons through the fog and storms of Georges Bank, in thanking Captain Murchie for his kind tribute.

NEW FORM OF CHISELING?

U. S. Coast Survey
Washington, D. C.

July 14, 1933.

Hon. Sirs.

I am a X Sailor? a few years back, off the fla Coask. about 35 miles off Sea in the Clear navigatibe Gulf of Mexico, in 12 fathoms of water, we Ran on to a Rock. I was Sailing on a freight Schooner at the time. in the trough, she caught, on the Scag aft. and almost broke in to. there were only three of us aboard at the time. and the other too are dead. I fully believe I am the only human living who knows of this dangerious Rock.

for a reasonable sum of Money. I will go and Show where it is located. this is a true story there is no Fake about it. this is no Fake to get money.

I am Only Reporting

Please Ans:-

Verry Respy. (- - -)

COAST AND GEODETIC SURVEY, DIVISION OF HYDROGRAPHY AND TOPOGRAPHY - PROJECTS UNDERWAY, COMPLETED, AND PROPOSED
(All projects reported below have been started since 1927)

STATE	LOCALITY	CLASS OF SURVEY: Triangulation Order 1st	2nd	3rd	Hyd.	Aer. Top.	Other Top.	SCALE	AREA SQ.MI.	STATE OF THE SURVEY
Maine	Portland to Eastport.		√						6,900	In Progress
Massachusetts	Boston and Boston Harbor.	√	√						180	Completed
	Cape Cod, Provincetown to Hyannis.		√	√	√	√	√	1:10,000 1:20,000	600	In Progress
N. Y. & Mass.	Newport to Buzzards Bay.		√	√	√		√	1:10,000 1:20,000	100	Completed
Conn. & N. Y.	Wakefield, Conn. to New York.		√	√	√	√	√	1:10,000 1:20,000	750	In Progress
Conn. R. I. & Mass.	Buzzards Bay to Wakefield.		√	√	√	√	√	1:10,000 1:20,000	400	Proposed
New York	Hempstead, Manhasset & Little Neck Bays.		√	√	√	√	√	1:10,000 1:20,000		Completed
" "	Long Island, Orient & Montauk Pts. to New York Harbor.		√	√	√	√	√	1:10,000 1:20,000	2,500	Completed
N. Y. & N. J.	Sandy Hook to Cape May.		√	√	√	√	√	1:10,000 1:20,000	1,450	In Progress
Maryland	Chesapeake Bay, Eastern Bay, West, Rhode & South Rivers, and Baltimore Harbor.		√	√	√		√	1:10,000 1:20,000	175	Completed
Md. & Va.	Offshore hydrographic surveys to the 75° meridian including shore control.		√	√	√		√	1:10,000 1:20,000 1:40,000 1:120,000	15,200	In Progress
Va. & N. C.	Inside Route Chesapeake and Albemarle Canal to Adams Creek.		√	√	√	√	√	1:10,000	600	In Progress
N.C., S.C., Ga., Fla.	Wilmington, N. C., to Jacksonville, Florida.		√	√	√	√	√	1:10,000 1:20,000	2,860	In Progress
Florida	St. Johns River to Sanford.		√	√	√	√	√	1:10,000 1:20,000	340	In Progress
	Biscayne Bay to Key West.		√	√	√	√	√	1:10,000 1:20,000	1,750	In Progress
Atlantic Coast	Nantucket to Delaware River Entrance, offshore hydrography.				√	√	√	1:20,000 1:40,000 1:120,000	30,000	Proposed
" "	Gulf of Maine offshore hydrography.				√		√	1:20,000 1:40,000 1:120,000	28,800	Proposed
" "	Chesapeake Bay to Cape Lookout offshore hydrography.				√		√	1:40,000 1:120,000	16,000	Proposed
" "	Georges Bank offshore hydrography.				√			1:20,000 1:40,000 1:200,000	28,000	Completed
Fla. & Ala.	Apalachicola to Mobile.		√	√	√	√	√	1:10,000 1:20,000	2,700	In Progress
Miss. & La.	Miss. R. Delta, Gulfport, Miss. to Caillou Bay.		√	√	√	√	√	1:20,000	3,060	Completed
Louisiana & Texas.	Miss. R. to Calcasieu Pass offshore hydrography to 100 fm. curve and shore control.		√	√	√		√	1:10,000 1:20,000 1:40,000 1:80,000	26,300	In Progress
Louisiana & Texas.	91st meridian to Galveston, Tex.		√	√			√	1:10,000 1:20,000	4,800	In Progress
Texas.	Galveston to Corpus Christi.		√	√	√	√	√	1:10,000 1:20,000	2,250	In Progress
Gulf of Mexico	Florida Keys to Miss. R. Delta offshore hydrography.				√			1:20,000 1:40,000 1:120,000	64,000	Proposed
" " "	Heald Bank to Rio Grande.				√			1:20,000 1:40,000 1:120,000	23,600	Proposed
California	Mexican Border - San Francisco Bay incl. offshore hydrography to 2000 fm. curve and wire drag.		√	√	√	√	√	1:10,000 1:20,000 1:120,000	56,770	In Progress
"	Sacramento and San Joaquin Rivers.		√	√	√	√	√	1:10,000	900	In Progress
Washington	Puget Sound.	√	√	√	√		√	1:10,000 1:20,000	3,200	In Progress
Pacific Coast	San Francisco to Shelter Cove.				√			1:20,000 1:40,000 1:120,000	14,200	Completed
" "	Shelter Cove to Trinidad Head.				√			1:20,000 1:40,000 1:120,000	6,400	Proposed
" "	Trinidad Head to Cape Flattery.				√			1:10,000 1:20,000 1:40,000 1:120,000	36,000	Completed
" "	Columbia River.		√	√	√	√	√	1:5,000 1:10,000	800	Proposed
Alaska	Southeast, (unsurveyed areas).		√	√	√		√	1:10,000 1:20,000 1:10,000 1:20,000	4,000	Postponed
	Prince William Sound to Kodiak Island.		√	√	√		√	1:80,000 1:500,000	51,500 360,000	Postponed In Progress
	Gulf of Alaska, deep sea, hydrography.				√					
	Aleutian Islands including offshore hydrography.		√	√	√		√	1:5,000 1:10,000 1:20,000 1:100,000	72,000	In Progress
Hawaiian Islands.	Hawaii Id. to Kure Id., T. H. including deep sea hydrography.		√	√	√		√	1:10,000 1:500,000	600,000	Postponed
Philippine Islands	Northeast Luzon.		√	√	√		√	1:10,000	18,800	In Progress
	Balabac Island.		√	√	√		√	1:20,000	2,500	
	Southwest Sulu Sea.		√	√	√		√	1:80,000	6,400	
	Palawan Island, West Coast.		√	√	√		√		12,000	

All the above is field work; results to be published on standard charts of Coast and Geodetic Survey. Copies of standard sheets on scales shown will be available.

M-101

COAST AND GEODETIC SURVEY, DIVISION OF GEODESY - PROJECTS UNDERWAY, COMPLETED, AND PROPOSED
(Period January - December 1934)

STATE	LOCALITY	CLASS OF SURVEY Triangulation Order 1st	2nd	3rd	Miles along Direction of Progress	STATE OF SURVEY
South Carolina	Chester to Georgetown	√			165 st. mi.	Completed
Tennessee	Smithville, Tenn. to Huntsville, Ala.	√			90 " "	Completed
Florida	Dunnellon to Naples	√			250 " "	Completed
New Mexico	Las Cruces to Belen	√			135 " "	Completed
Nevada - California	Las Vegas, Nev. to Niland, Calif.	√			365 " "	Completed
Texas	Langtry through Hot Wells to El Paso	√			430 " "	Completed
Florida	St. Augustine to Miami	√			320 " "	Completed
Florida	Mobile, Ala. to McIntyre, Fla.	√			205 " "	Completed
Virginia	Richmond, Va. to Washington, D. C. to Fredericksburg, Va. to Heathsville, Va.	√			160 " "	Completed
Maryland	Annapolis to Mohjack, Va.	√			45 " "	Completed
Tennessee	Tennessee River Basin		√		1175 " "	Underway
Mississippi	Bay St. Louis to Corinth	√			275 " "	Proposed
Louisiana	Boyce to Mississippi River	√			70 " "	Completed
Louisiana - Arkansas	Jennings, La. to Little Rock, Ark.	√			---	Postponed
Missouri - Iowa	Jefferson City, Mo. to Marengo, Ia.	√			205 " "	Completed
Illinois	St. Louis, Mo. to Havanna, Ill.	√			45 " "	Completed
Indiana - Illinois	Greenville, O., to Mississippi River	√			175 " "	Completed
Oklahoma, Kansas, Nebraska, Iowa, Minn.	Hartshorne, Okla. to Adrian, Minn.	√			565 " "	Completed
Oklahoma - Kansas	Gatesby, Okla. to Anthony, Kansas	√			---	Postponed
Texas - New Mexico	Sierra Blanca, Tex. to Hillsgrie, N. Mex.	√			220 " "	Completed
New Mexico - Colorado	Lordsburg, N. Mex. to Grand Junction, Colo.	√			475 " "	Completed
Arizona	Yuma to Grand Canyon	√			---	Underway
California	Mt. Montgomery to Johannesburg, Calif.	√			175 " "	Completed
California	Campo, Calif. to Yuma, Ariz.	√			105 " "	Calexico to Yuma completed - Rest postponed
California	Johannesburg to San Bernardino	√			175 " "	Completed
Nevada, Oregon, Idaho	Austin, Nev. to Caldwell, Idaho	√			275 " "	Proposed
Oregon	Portland to Astoria	√			60 " "	Underway
Oregon	Portland to Pacific City	√			60 " "	Underway
Maryland	Annapolis to Pocomoke Sound	√			85 " "	Underway
Maryland	Tangier Sound, Va. to Middletown, Md.		√		125 " "	Underway
Pennsylvania	New Freedom, Pa. to Scranton, Pa.	√			150 " "	Proposed
Iowa	Marengo, Iowa, to Spring Valley, Minn.	√			150 " "	Proposed
Wisconsin	Waha sha, Minn. to McAllister, Wis.	√			215 " "	Proposed
Michigan - Wisconsin and Minnesota	Stanbery, Wis. to Princeton, Minn	√			125 " "	Proposed
Minnesota - Wisconsin	St. Paul, Minn. to Ladysmith	√			125 " "	Proposed
Minnesota	Lakefield, Minn. to Alexandria, Minn	√			135 " "	Proposed
Minnesota	Aitkin via. Deer River to Roosevelt, Minn.	√			185 " "	Proposed
N. Dakota, S. Dakota, Nebraska	Sorley, N. Dak. via Westinton, S. Dak. to Ainsworth, Neb.	√			515 " "	Proposed
Georgia - Florida	Augusta, Ga. to Lake City, Fla.	√			250 " "	Proposed
Florida	McGregor, Fla. to Harrisburg, Fla.	√			205 " "	Proposed
Florida	Stuart, Fla. to Sarasota, Fla.	√			70 " "	Proposed
Florida	Miami to Key West	√			70 " "	Proposed
Wyoming - Montana	Burns, Wyo. to Ophein, Mont.	√			465 " "	Underway
Montana	Whitewater to St. Xavier, Mont.	√			220 " "	Proposed
N. Dakota, S. Dakota	Westhope, N. Dak. to Murdo, S. Dak.	√			348 " "	Proposed
S. Dakota, Nebraska	Ideska, S. Dak to Scotts Bluff, Neb.	√			30 " "	Proposed
Montana	Dolebridge to Medicine Springs, Mont.	√			225 " "	Proposed
Montana - Idaho	Helena, Mont. to Headquarters, Idaho.	√			205 " "	Underway
Idaho	Bald Mt. to Fairfield, Idaho	√			225 " "	Proposed
Montana	White Sulphur Springs, to Carlyle, Mont.	√			340 " "	Underway

COAST AND GEODETIC SURVEY

Division of Tides and Currents

Continuous graphic records are being obtained from automatic tide gages at 44 stations distributed as follows: 24 on the Atlantic coast, 4 on the Gulf of Mexico, 13 on the Pacific coast, 2 in Alaska, and 1 in the Territory of Hawaii.

Shorter series of tidal observations varying from a few days to several months in length are constantly being obtained at a large number of secondary stations in connection with hydrographic surveys.

In connection with all tidal aeries observed, bench marks are established to perpetuate the planes secured.

A tidal survey of the coast of Oregon consisting of simultaneous observations for a period of 1 year at 12 different localities has just been completed.

A similar tidal survey of the State of Washington including Puget Sound is now in progress. A tidal survey of the State of Texas is contemplated.

Continuous hourly observations of the velocity and direction of the current are being obtained at six lightships on the Atlantic coast of the United States. Four of these are located in Massachusetts waters, one in Georgia and one in Florida.

A systematic current survey of Nantucket and Vineyard Sounds, Massachusetts, is now in progress. Similar surveys of the St. Johns and Savannah Rivers and the inland waterways between these rivers have recently been completed in the States of Georgia and Florida.

A month of continuous half hourly current observations are now being secured in San Diego Bay Entrance, California. A similar series will be obtained in the near future at Galveston Entrance, Texas.

Numerous series of current observations are obtained each year both offshore and in inland waterways by hydrographic parties of this Bureau.

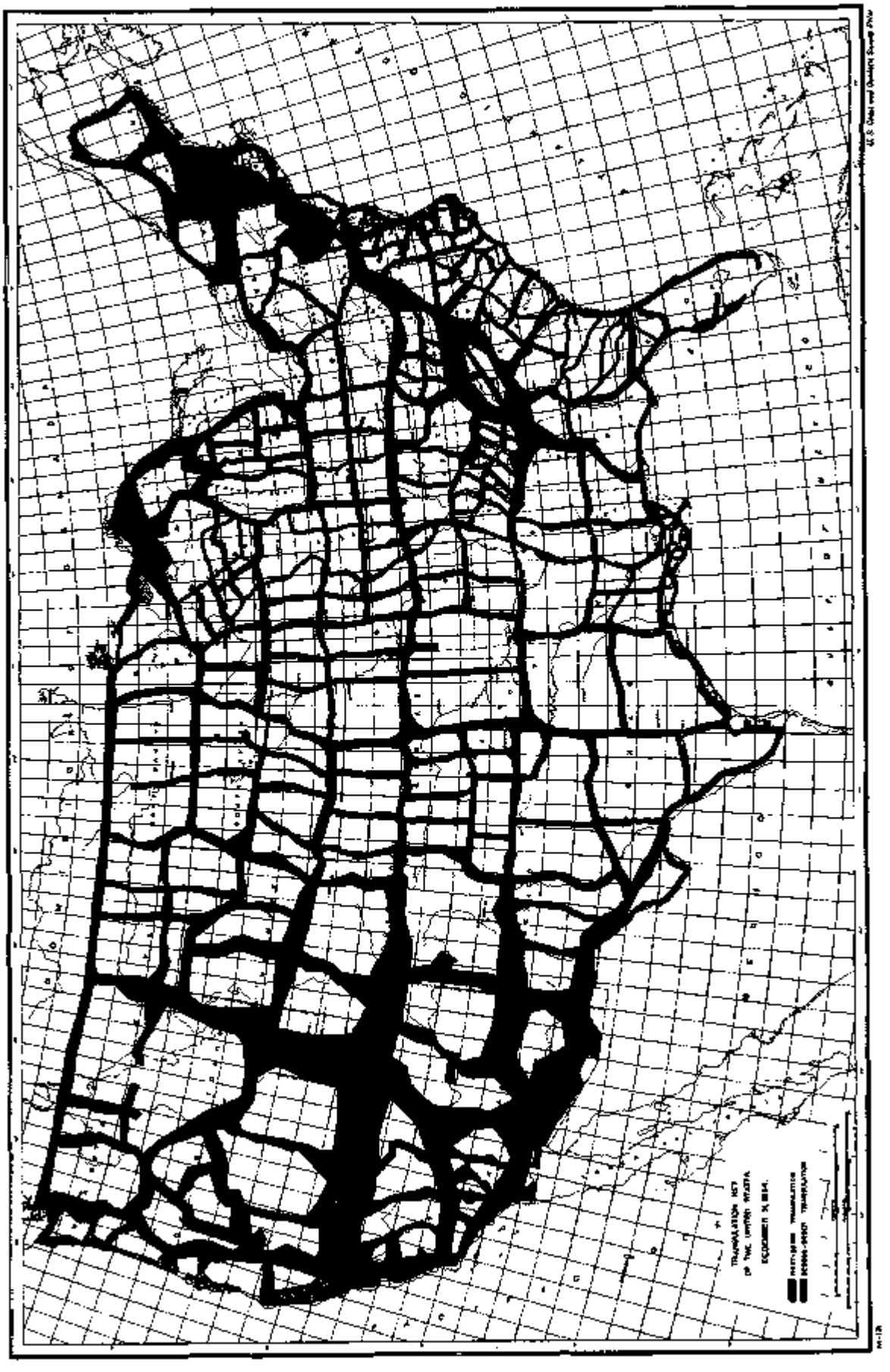
* * * * * * * * * * * * *

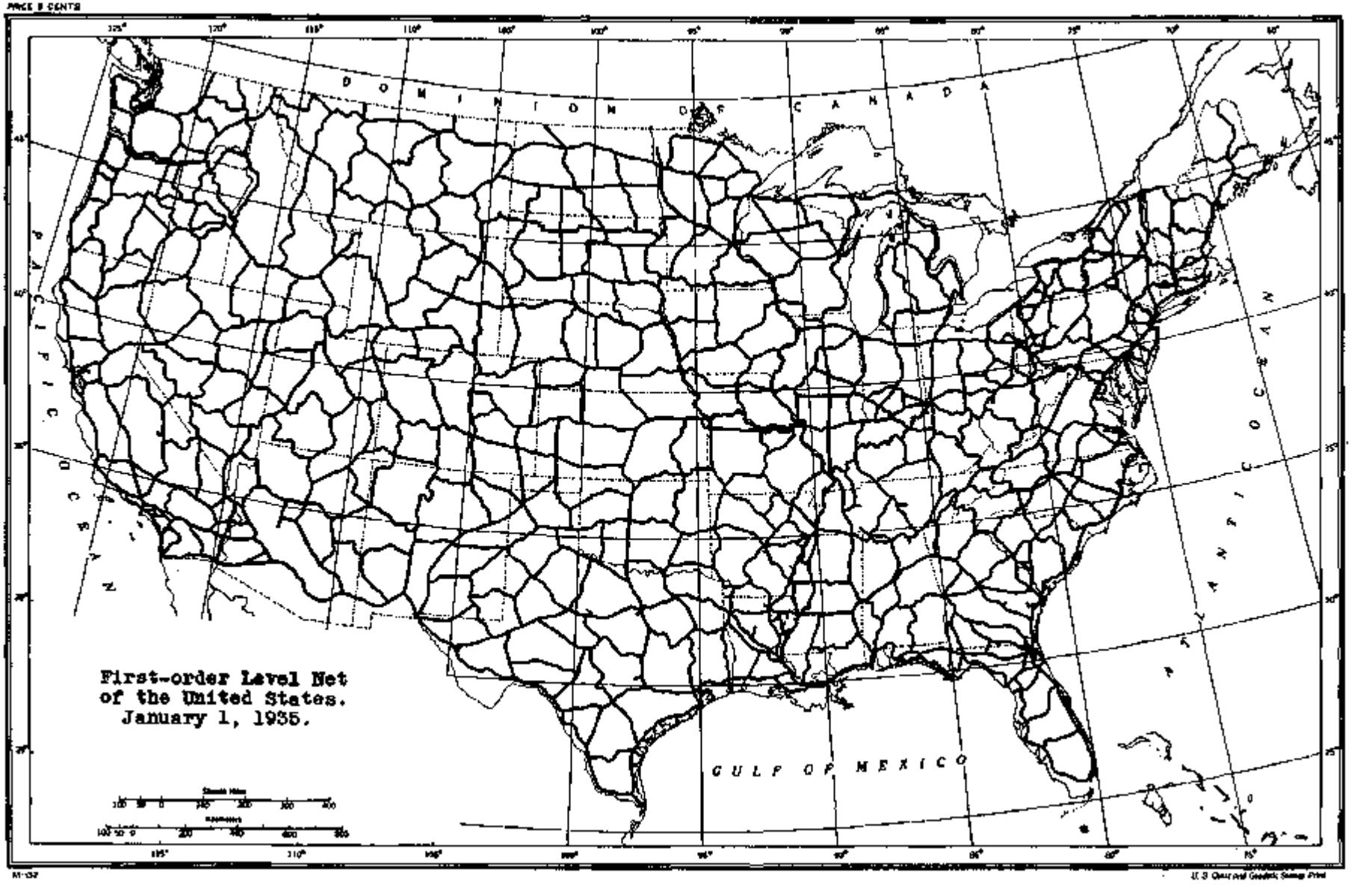
Division of Terrestrial Magnetism

Observations for declination, dip and horizontal intensity are made at intervals of five years at about 300 places distributed throughout the United States.

A similar survey is made in Alaska at intervals of ten years.

Magnetic observatories are operated at Tucson, Arizona, Cheltenham, Maryland, Sitka, Alaska, Honolulu, T. H., and San Juan, P. R., where continuous photographic records are made of the variations of the earth's magnetic field.


TRANSLOCATION NET
OF THE UNITED STATES
ECOSYSTEM IN 1994.
NATIONAL TRANSLOCATION
REGIONAL-SCALE TRANSLOCATION
U.S. Geological Survey


DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
First-order Level Net
of the United States.
January 1, 1935.

DISTRIBUTION AND STATISTICS OF FIELD PARTIES
U. S. COAST AND GEODETIC SURVEY - DIVISION OF HYDROGRAPHY AND TOPOGRAPHY
July 1,1933 -June 30, 1934

Locality	Project H.T.No.	Ship or Party No.	Personnel*	Hydrography Miles	Hydrography Sq. Mi.	Hydrography Sdgs.	Topography Miles	Topography Area	Triangulation Miles	Triangulation Area	Triangulation Pos.
Me., Casco Bay. Me., Penobscot Bay.	149 180	1 1	C. N. Durgin. W. G. Crosby.						55 35	1,012 100	161 36
Mass., Boston and Cape Cod.	145	7	W. T. Adams. P. L. Peacock. E. A. Daily.	850	56	23,769	36	5	30 25	430 300	33 40
Mass., Cape Cod.	145	28	E. A. Daily.	626	41	13,460	31	14	9	45	35
N. Y., Long Island Sound.	134	3	H. A. Cotton, J. T. Jarman, H. J. Seeborg, W. P. Deane, P. E. Chason	616	48	45,252	128				48
Conn., North Shore Long Island Sound.	150	16	O. C. Mattison. W. N. Martin.	756	40	45,005	265*	142*	78	225	360
N. Y., Rikers Island. N. Y., Long Island Sound.	152 186	15 15	I. E. Rittenburg. I. E. Rittenburg.	274 124	9 4	11,640 3,384	20		3	3	6
N. Y., Great South Bay.	132	2	R. F. Hyman, N. O. Witherbee, J. C. Parrington, J. C. Tison, Jr.	1,267	85	54,115	150	25	9	27	86
N. Y., Gardiners Bay.	179	5	W. D. Patterson, G. E. Morris.	1,148	83	26,255	78				
N. Y., Peconic Bay.	135	4	L. C. Wilder, P. C. Doran, R. C. Bolstad, E. B. Brown.	1,781	55	75,932	25	2	12	88	37
N. Y., Moriches Bay.	133	5	A. P. Ratti, J. C. Tribble.	1,820	103	41,659	46	51	30	90	26
N. Y., Jamaica Bay.	178	2	N. O. Witherbee.	667	17	36,564				7	3
N. Y., New York Harbor and Long Island.	121	12	R. C. Bolstad, T. M. Price.				1,175*	450*			
N. J., northeast coast. Md., Eastern Bay.	174 151	14 14	E. R. McCarthy. E. R. McCarthy.	153 704	8 40	6,165 25,504	30 47	16 11	22 16	110 107	143 35
Md., Baltimore Harbor. Md., South, West and Rhode Rivers.	183 186	MI. MI.	John A. Bond[5]. John A. Bond[5].	352 1,812	8 105	17,690 61,262	44 149	10 44	10 18	15 52	62 38
Md., Baltimore to Annapolis.	175	25	J. C. Partington.	No statistics.		Field inspection of air photographs.					
Md., Va., Ocean City to Cape Charles.	170	29	J. C. Tison.								65
Va., outer coast.	142	OC.	H. A. Saran[1].	4,545	3,554	33,309	61		3	5	4
Va., outer coast.	143	LT.	R. L. Schoppe[2].	1,710	235	24,563					
Va., outer coast.	144	OI.	H. Odessey[3].	581	103	14,787					
Va., Tangeand and Back Rivers.	173	OC.	H. A. Saran, D. H. Kondichek.						47	110	106
Ga., N. C., S. C., Wilmington to Savannah.	161	1	C. M. Durgin, W. G. Crosby, G. W. Lovesee.						167	700	273
S.C., Charleston to Beaufort.	162	21	E. H. Kirsch.				1,868*	1,181*			
Ga., Fla., Savannah-Fernandina.	169	18	S. B. Grenell, J. C. Partington.				3,520*	892*			
S.C., Charleston-St. Helena Sound.	154	19	E. H. Rigg, E.B. Brown.	698	53	28,383			3	2	8
S.C., St. Helena Sound and tributaries.	159	WA.	R. P. Hyman[4].	1,898	70	64,323			13	32	31
S.C., Charleston.	155	2	N. O. Witherbee, E. B. Brown.	2,771	54	137,481				30	60
Ga., Broad River to Doboy Sound.	166	23	C. A. Hymen, C. A. Burmister.	2,856	200	88,749			50	90	64
Ga., Fla., Brunswick to Fernandina.	168	26	H. A. Paton, G. W. Lovesee.	1,741	64	71,017			20	13	36
S.C., Broad River and tributaries.	160	15	I. E. Rittenburg.	2,998	77	71,819					
Ga., Doboy to St. Simon Sound.	167	MI.	J. A. Bond[5].	1,635	65	65,107					
Ga., St. Catherine and Sapelo Sounds.	163	OI.	H. Odessey[3].	883	30	30,742					7
Fla., Fort Everglades.	182	22	W. H. Bainbridge.	58	2	2,642	5		4	5	28
Fla., Florida Keys.	158	3	H. A. Cotton, J. T. Jarman, H. J. Seeborg.	2,315	229	104,794	32	2	117	735	167
La., Terrebonne Bay.	157	5	W. D. Patterson.	3,413	380	140,529	31		22	520	34
La., Barataria Bay.	156	4	B. Reed, P. C. Doran, J. C. Tribble.	3,427	416	98,243	58	492*	56	260	83
La., Miss., Mississippi Delta.	164	22	R. L. Schoppe, W. H. Bainbridge.						113	1,030	66
La., Mississippi Delta.	172	24	M. R. Reese.				4,925*	2,422*			

Locality	Project H.T.No.	Ship or Party No.	Personnel*	Hydrography Miles	Hydrography Sq.Mi.	Hydrography Stns.	Topography Miles	Topography Area	Triangulation Miles	Triangulation Area	Triangulation Pos.
La., Mississippi Delta.	165	14	E. R. McCarthy.						142	1,750	108
La. Coast.	123	MY.	W. E. Parker[6]	5,990	5,586	59,676	47	23	35	141	19
La., Lake Charles.	338	6	J. C. Bose.	906	95	42,793	149	80	55	275	51
Tex., Sabine Lake.	116	14	E. R. McCarthy.						4	14	24
Tex., Corpus Christi and Galveston.	118	8	E. G. Heaton, J. S. Morton, W. C. Russell.	6,390	555	189,166	326	78	224	1,230	145
Tex., Matagorda Bay.	118A	20	T. M. Price.				226*	228*	23	150	32
Calif., Mexican Border to Point Hugo.	102	9	R. W. Knox, R. J. Sipe, J. C. Mathiesen.	4,943	342	90,999	227	90	60	129	76
Calif., Point Hugo to Point Conception.	117	10	C. E. Green.	2,040	190	27,412	115	73	16	54	17
Calif., Mexican Border to Monterey Bay.	184 140	OU. OU.	F. H. Hardy[7]. F. L. Peacock[7].	551 6,211	12 5,248	7,502 37,750	12 89	12 43			5
Calif., Southern Coast.	120	PI.	G. W. Swainson[8].	9,912	7,498	67,682	58	46			
Calif., Monterey Bay.	130	27	G. C. Jones.	174	8	3,477	7	9			
Calif., San Diego - Mexican Border.	106	11	C. Pierce.						49	392	100
Calif., Sacramento and San Joaquin Delta.	153	17	L. P. Seymer.	1,416	680	171,663	162* 75	242* 75			60
Wash., Puget Sound.	171	EX.	J. Senior[9].	77	4	2,409	54	22	105	146	222
Wash., Seattle.	148	13	F. H. Hardy, E. E. Smith.						58	210	75
S.E. Alaska, Dixon Entrance.	137	EX.	J. Senior[9].	1,297	140	37,715	222	224	33	33	77
Alaska, Unalaska and Atka Islands.	177	DI.	H. B. Campbell[10].	664	6,640	597	7	8	17	100	56
Gulf of Alaska and Aleutian Islands.	176	SU.	A. M. Sobiaralski[11].	1,609	8,780	6,507	13	10	20	20	19
Alaska, Prince William Sound.	141	SU.	A. M. Sobiaralski[11].	5,196	1,590	58,620	127	151	92	3,061	27
Alaska, Kodiak Island.	139	DI.	H. B. Campbell[10].	6,111	977	76,277	180	164	21	48	43
Philippine Islands, Balabac Island.	P.I.	PA.	C. Shaw, H. A. Karo[12].	9,648	2,628	143,359	59	145	18	293	55
Philippine Islands, East Coast Luzon.	P.I.	PA.	C. Shaw[12].	2,631	2,359	33,048	56	243	30	130	23
			Totals.....	110,045	49,754	2,520,406	14,876	7,725	1,969	14,359	3,373

Field Stations: Manila, R. F. Luce, Director of Coast Surveys; Boston, X. T. Adams, F. L. Peacock; New York, G. D. Gowie; New Orleans, E. T. Crowther, (Clerk in Charge); San Francisco, T. J. Maher; Seattle, R. B. Derickson, F. H. Hardy; Honolulu, J. M. Peters; San Juan, Porto Rico, E. R. Hand, E. H. Bernstein.

1. OCEANOGRAPHER: H. A. Doran Com'd'g, L. D. Graham, H. W. Sample, T. B. Reed, E. J. Brown, J. C. Bose, C. A. Burmister, C. A. George, R. A. Earle, P. Matella, W. P. Deane, E. H. Tryon, J. E. Waugh, R. H. Carstens, J. L. McIver.

2. LYDONIA: R. L. Schoppe Com'd'g, E. E. Roberts, W. H. Bainbridge, G. E. Morris, C. R. Reed, D. H. Konichek, R. C. Overton, C. H. Conover, C. G. McIlwraith.

3. GILBERT: C. A. Egner and H. Odessey Com'd'g, W. H. Bainbridge, S. S. Grenell, J. S. Morton, P. A. Riddell, C. R. Reed, D. H. Konichek, R. H. Carstens.

4. HAYONA: R. P. Eyman and C. A. Egner Com'd'g, J. C. Simmons, J. C. Bull, Paul Taylor, E. R. Giles.

5. MIRAMI: J. A. Bond Com'd'g, F. R. Gossett, C. F. Chamberlin, D. E. Sturmer.

6. HYDROGRAPHER: W. E. Parker Com'd'g, W. D. Patterson, A. P. Matti, H. W. Woodworth, E. G. Crosby, F. C. Doran, G. R. Shelton, E. H. Kirsch, C. A. Schenck, G. B. Hartzog, E. L. Jones, W. E. Greer, C. G. McIlwraith.

7. GUIDE: F. H. Hardy and F. L. Peacock Com'd'g, R. F. A. Studds, I. T. Sanders, W. J. Chovan, L. W. Swanson, A. W. Stewart, G. C. Mast, C. J. Beyma, I. H. Rubottom, H. C. Applequist, F. Seymour.

8. PIONEER: G. W. Swainson Com'd'g, J. M. Snook, P. L. Bernstein, H. J. Healy, C. J. Wagner, O. N. Merchand, R. A. Gilmore, M. E. Wenzenmark, J. C. Ellerbe, E. G. Zimmerman, E. R. Scroggs, J. Ryer, C. G. McIlwraith.

9. EXPLORER: J. Senior Com'd'g, G. L. Bean, H. E. Finnegan, W. F. Malnate, E. E. Lathem, G. A. Nelson, E. E. Lancy, A. W. Stewart, H. F. Garber, G. C. Mast, F. G. Ulm, M. Weidlich C. R. Jones, C. G. McIlwraith.

10. DISCOVERER: H. B. Campbell Com'd'g, G. L. Bean, R. R. Moore, W. M. Sosife, R. J. Sipe, P. L. Bernstein, H. J. Healy, J. H. Epstein, H. G. Fortin, E. G. Bass, G. N. Merchand, M. G. Ricketts, J. H. Jones, R. A. Gilmore, M. E. Wenzenmark, E. A. Marshall, K. S. Ulm, F. J. Soule, K. R. Giles.

11. SURVEYOR: A. M. Sobiaralski Com'd'g, L. C. Wilder, R. H. Moore, R. C. Rouse, J. Bowie, F. M. Quinn, G. A. Nelson, V. M. Gibbens, A. W. Stewart, C. J. Wagner, M. G. Ricketts, H. F. Garber, R. A. Marshall, C. J. Beyma, H. G. Conerly G. E. Johansen, H. W. Healy, W. J. Leary.

12. PATHFINDER: C. Shaw and H. A. Karo Com'd'g, H. E. Finnegan, F. A. Smith, K. B. Jeffers, O. W. Hutchison, D. H. Kruger, A. H. Hunycutt.

PATHFINDER: (Laid up in Pasig River, Manila, P. I.)

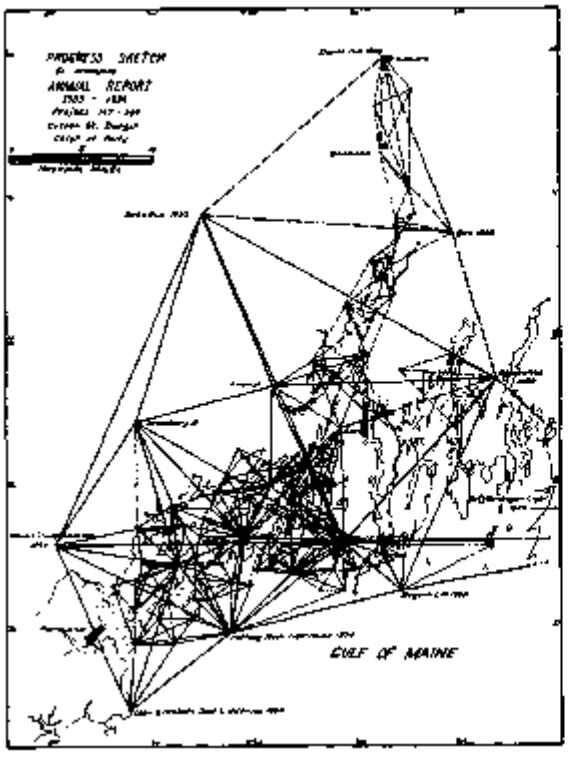
Washington Office: Chief, Division of H. & T., G. F. Rude; Ass'st Chief, H. H. Lukens; Chief, Section Vessels and Equipment, F. G. Engle; Chief, Coast Pilot, F. E. T. Siems; Chief, Section of Field Work, F. S. Borden.

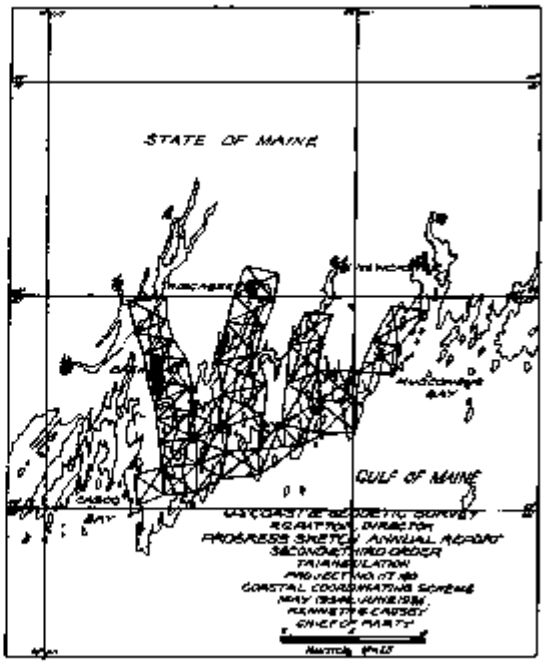
Other officers on duty in Washington office during all or part of fiscal year: G. S. Reading, L. D. Graham, F. A. Smith, C. A. George and F. A. Riddell.

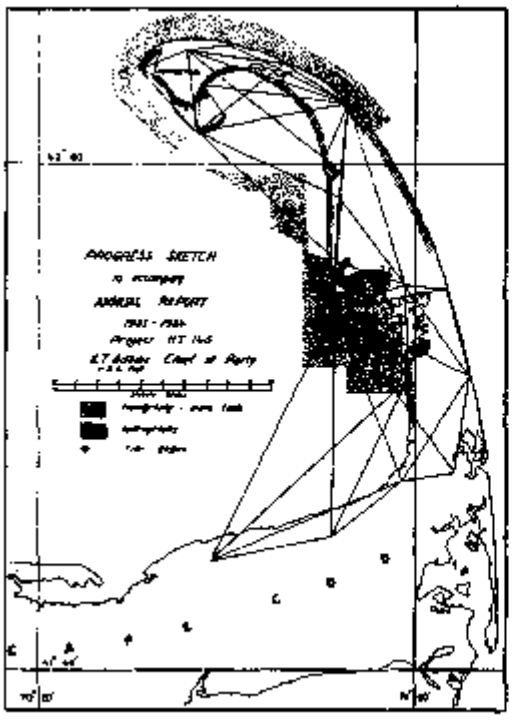
*Air photo topography.

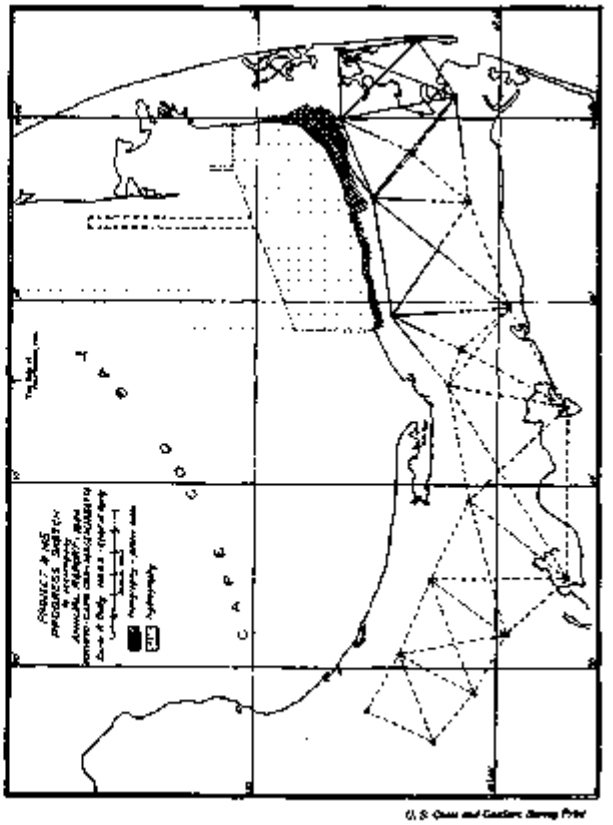
*Personnel conducting operations, including Commissioned Officers, Deck Officers, Chief Marine Engineers, Surgeons, Naturalists, Electrical Engineers.

In addition to the regular field officers listed there were 79 surveyors employed under N.I.R.A. appropriations.

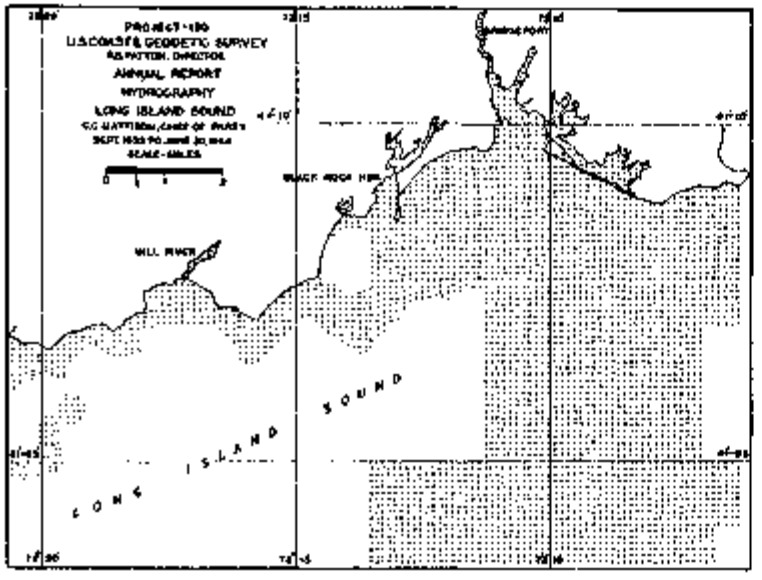


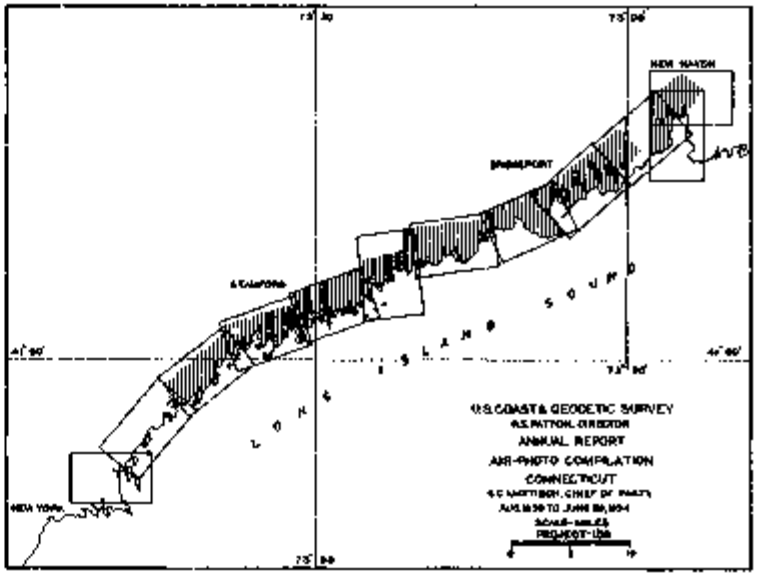






U. S. Coast and Geodetic Survey Print


U.S. COAST & GEODETIC SURVEY
ANNUAL REPORT
HYDROGRAPHY
LONG ISLAND SOUND
LONG ISLAND SOUND


NEW HAVEN
BRIDGEPORT
STAMFORD
NEW YORK
LONG ISLAND SOUND
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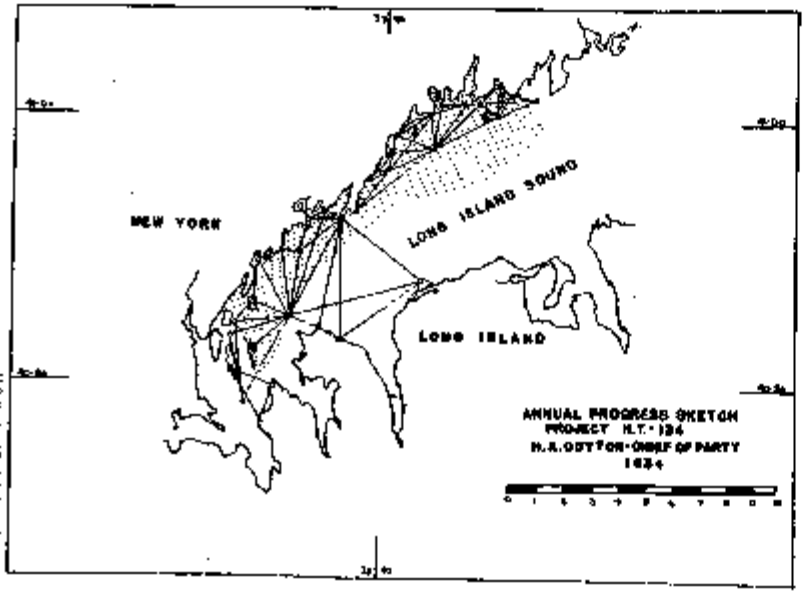
ANNUAL REPORT
AIR-PHOTO COMPILATION
CONNECTICUT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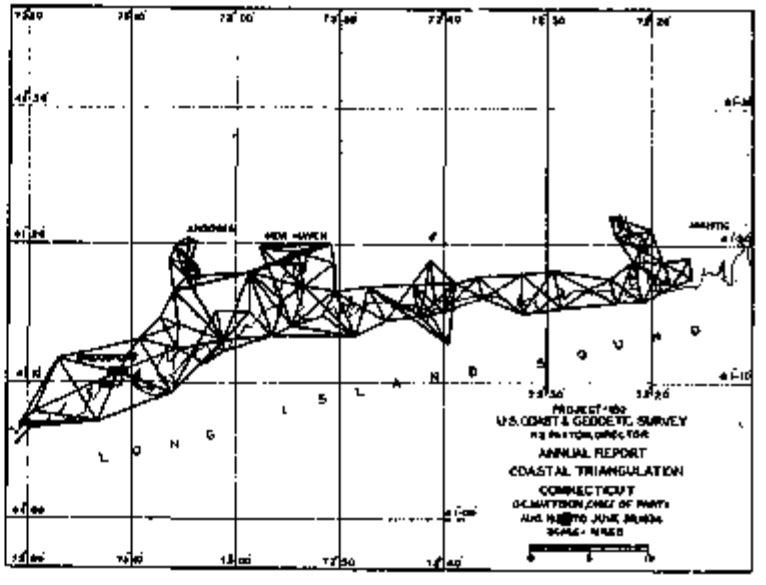
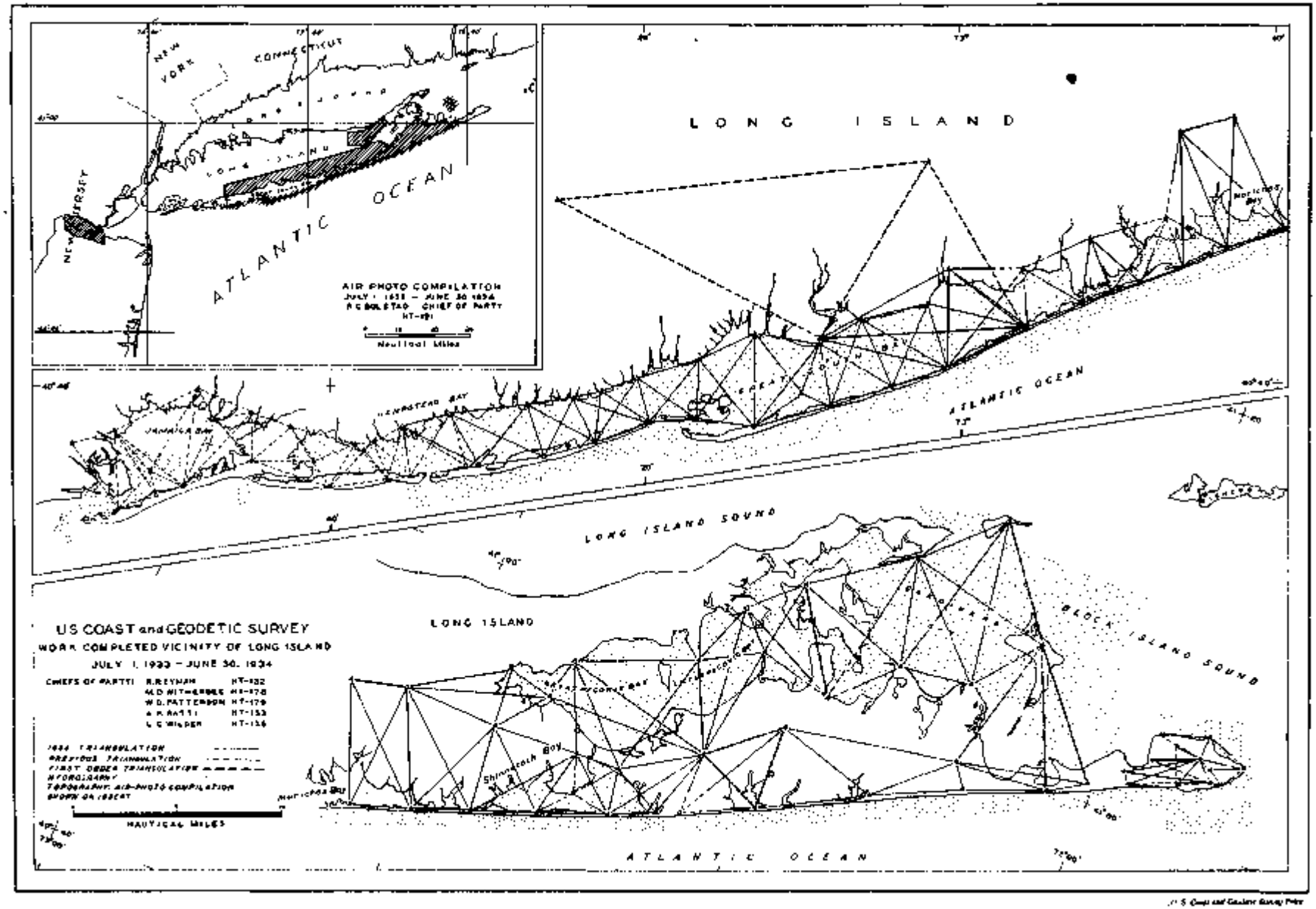
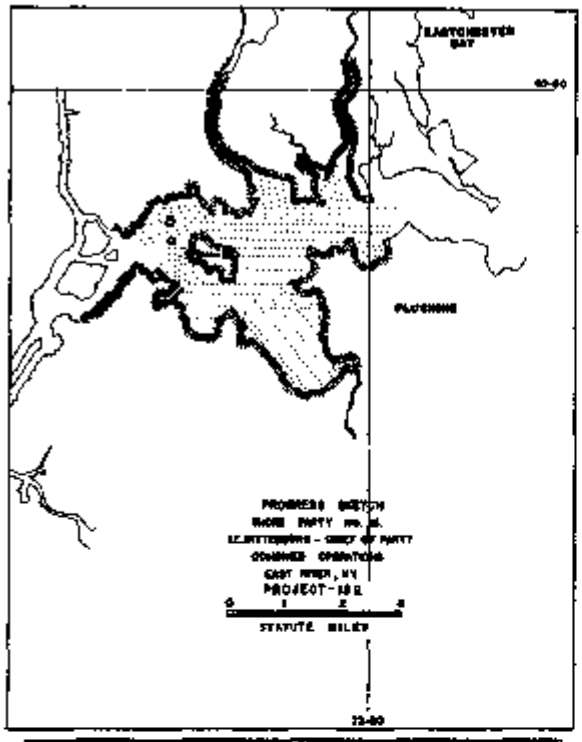
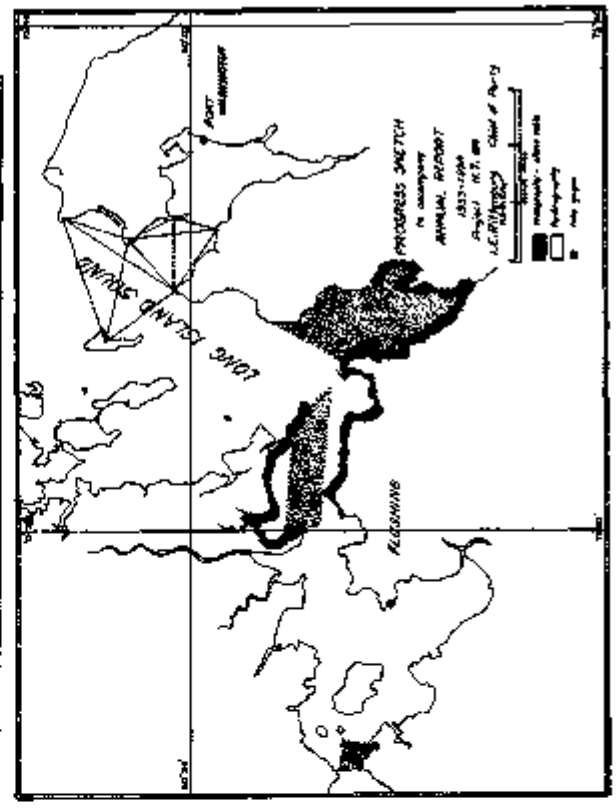
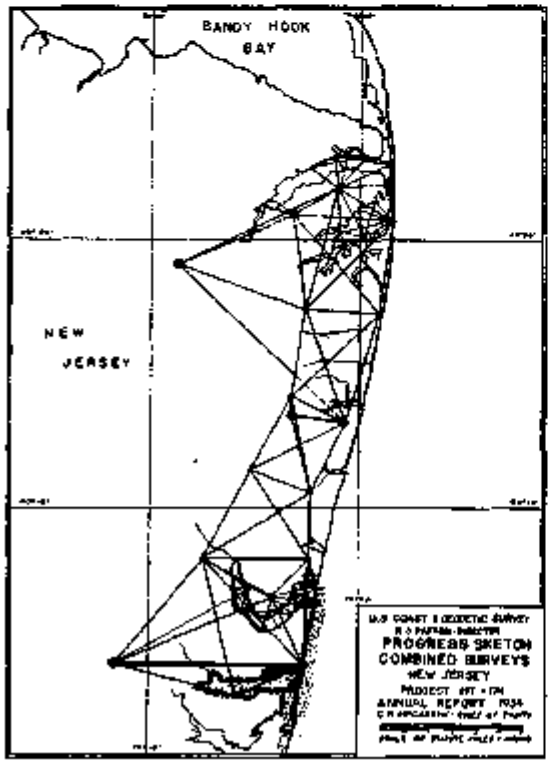
LONG ISLAND
ANNUAL PROGRESS SKETCH
PROJECT H.T.-134
H.A. COTTON-CHIEF OF PARTY
1934

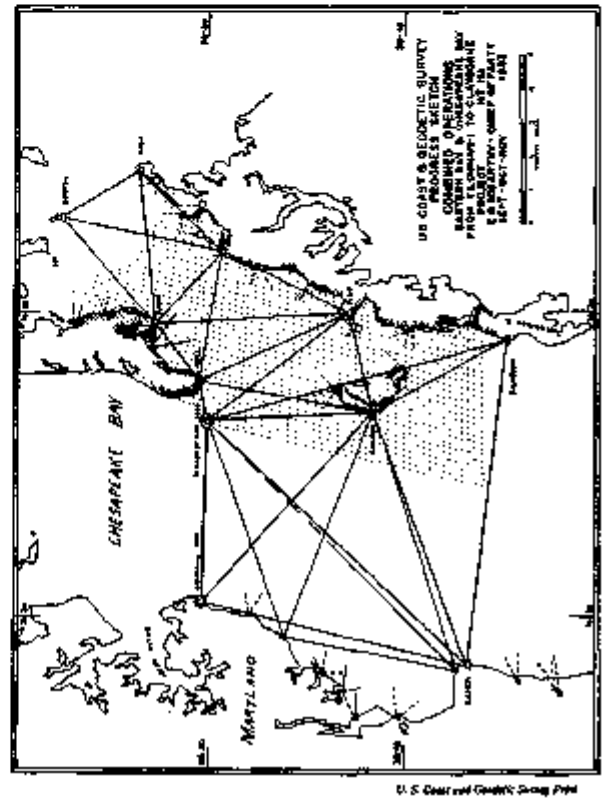

ANSONIA
NEW HAVEN
ATLANTIC
LONG ISLAND SOUND
U.S. COAST & GEODETIC SURVEY
ANNUAL REPORT
COASTAL TRIANGULATION
CONNECTICUT


NEW YORK
CONNECTICUT
NEW JERSEY
ATLANTIC OCEAN
AIR PHOTO COMPILATION
JULY 1, 1933 – JUNE 30, 1934
R.C. BOLSTAD CHIEF OF PARTY
HT-191
Nautical Miles
LONG ISLAND
JAMAICA BAY
HEMPSTEAD BAY
ATLANTIC OCEAN
LONG ISLAND SOUND
US COAST and GEODETIC SURVEY
WORK COMPLETED VICINITY OF LONG ISLAND
JULY 1, 1933 – JUNE 30, 1934
CHIEFS OF PARTY
R.REYNAH HT-132
M.D.WITHERBEE HT-178
W.D.PATTERSON HT-179
A.K.RATTI HT-153
L.C.WILDER HT-136
1934 TRIANGULATION
PREVIOUS TRIANGULATION
FIRST ORDER TRIANGULATION
HYDROGRAPHY
TOPOGRAPHY: AIR-PHOTO COMPILATION
SHOWN ON 1:20,000
NAUTICAL MILES
LONG ISLAND
BLOCK ISLAND SOUND
Shinnecock Bay
ATLANTIC OCEAN

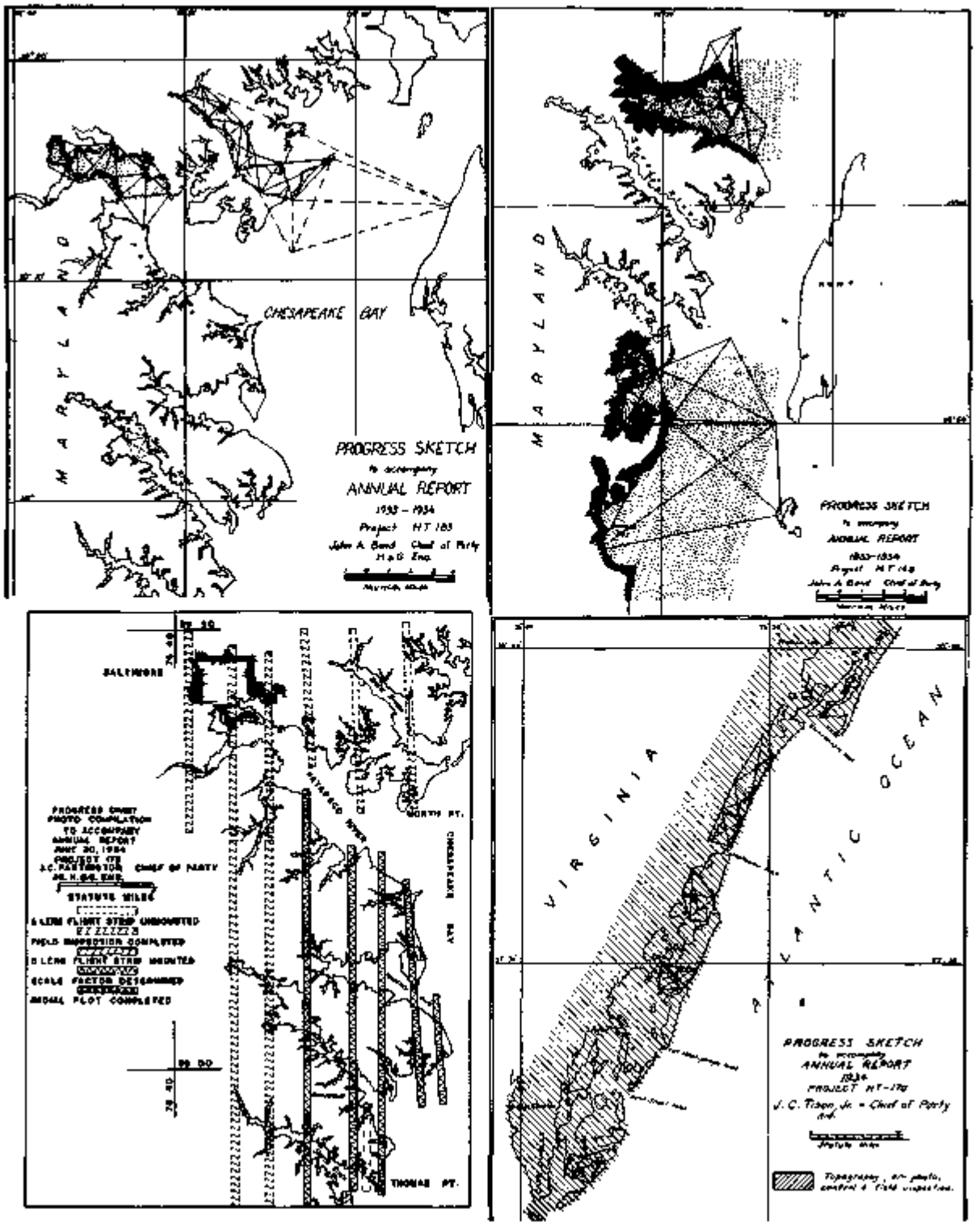




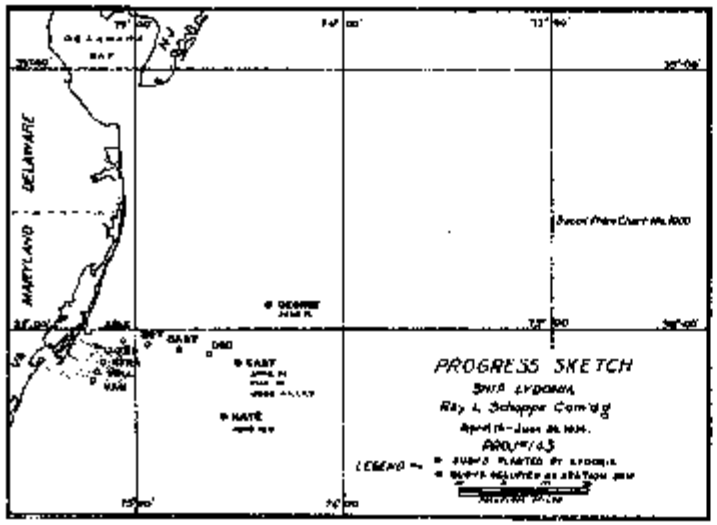


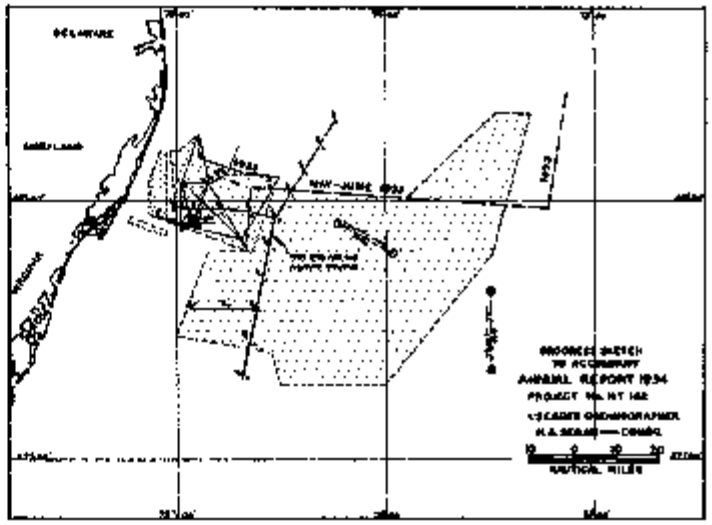


U. S. Coast and Geodetic Survey Print



U. S. Coast and Geodetic Survey Pilot


DELAWARE
MARYLAND
PROGRESS SKETCH
SHIP LYDONIA
Roy L. Schoppe Com'dg
April 14-June 26, 1934.
PROJECT 43
LEGEND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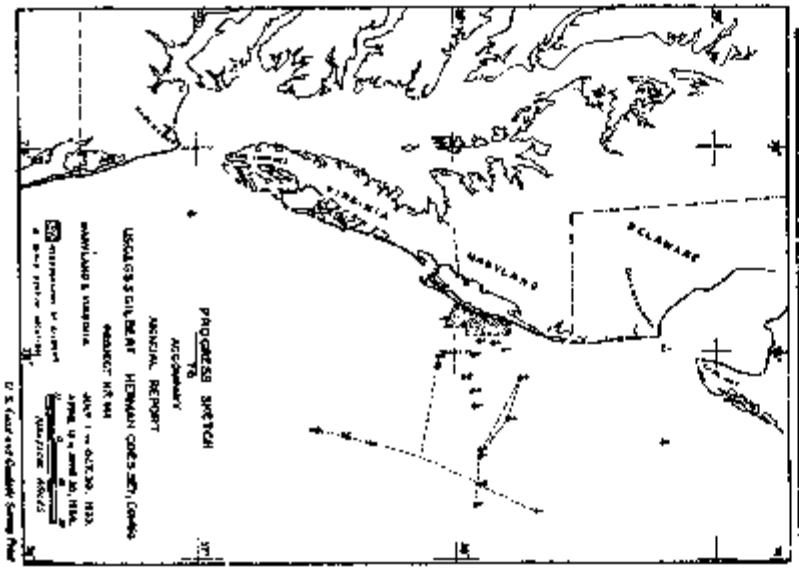
TO ACCOMPANY
ANNUAL REPORT 1934
NAUTICAL MILES


VIRGINIA
MARYLAND
DELAWARE
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TO
ACCOMPANY
ANNUAL REPORT
U.S.C.&G.S. GILBERT HERMAN CORPS OFF. Comdg
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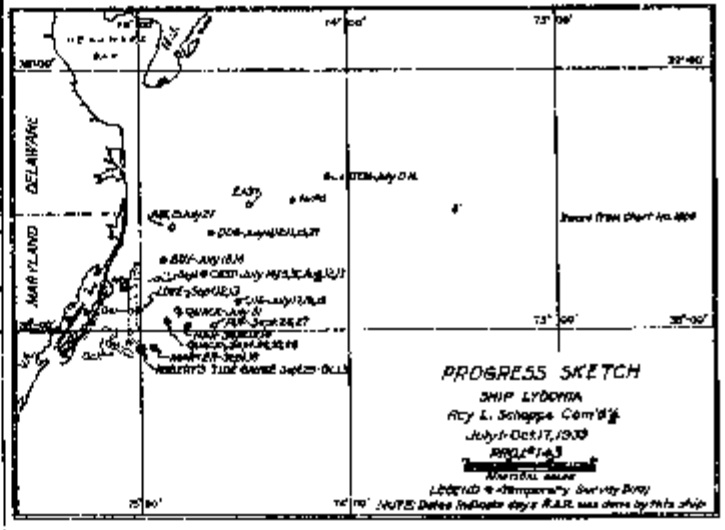
MARYLAND & VIRGINIA
JULY 1 to OCTOBER, 1933
APRIL 14 to JUNE 30, 1934
NAUTICAL MILES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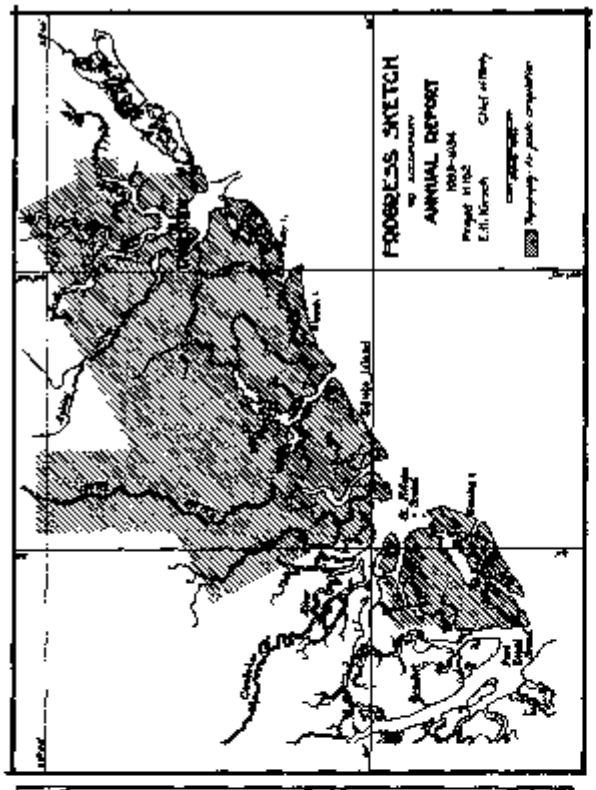
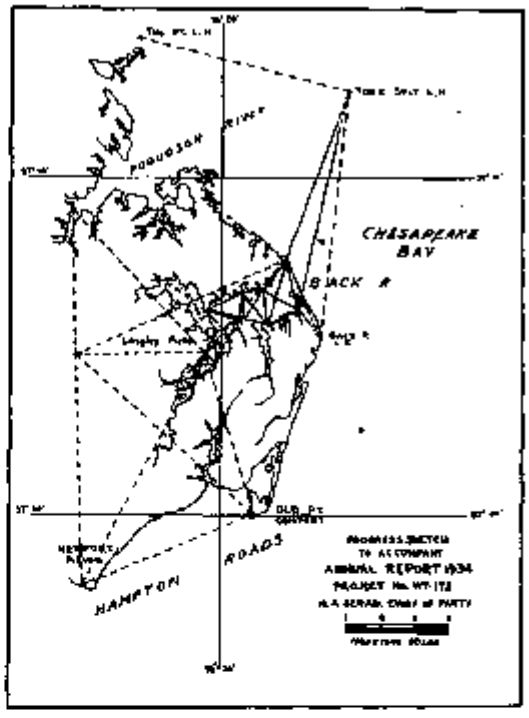
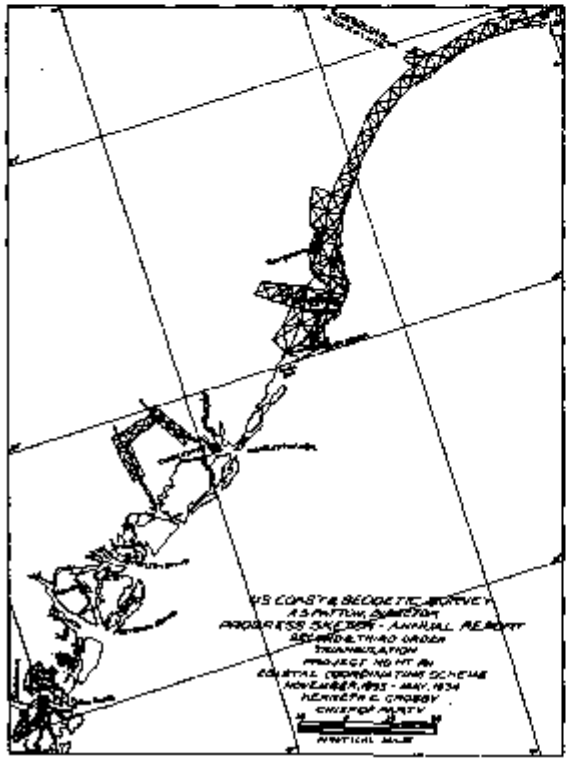
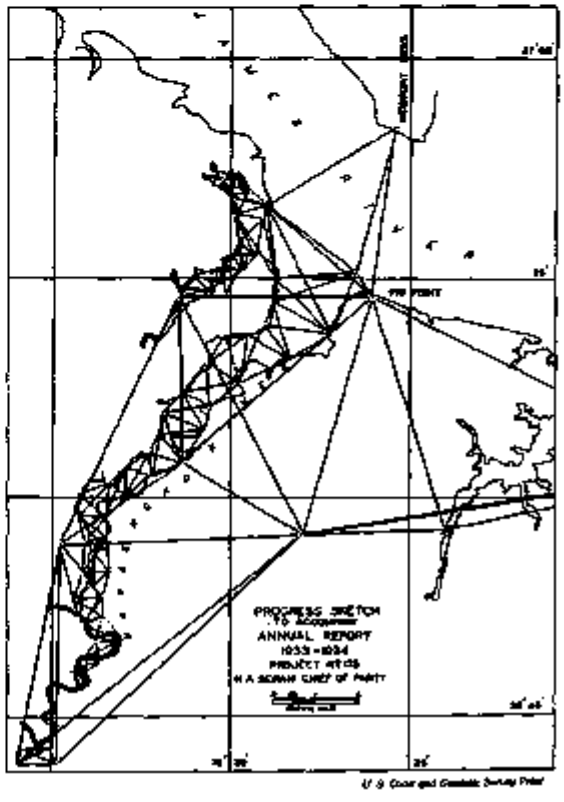
PROGRESS SKETCH
SHIP LYDONIA
Roy L. Schoppe Com'dg
July 1-Oct. 17, 1933
PROJECT 43
NAUTICAL MILES
LEGEND = Temporary Survey Buoy
NOTE: Dates indicate days H.A.R. was done by this ship

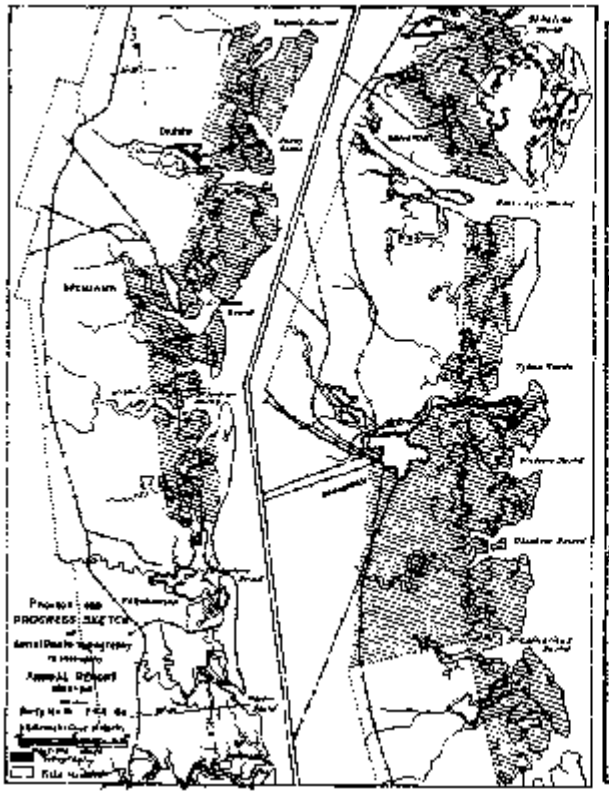


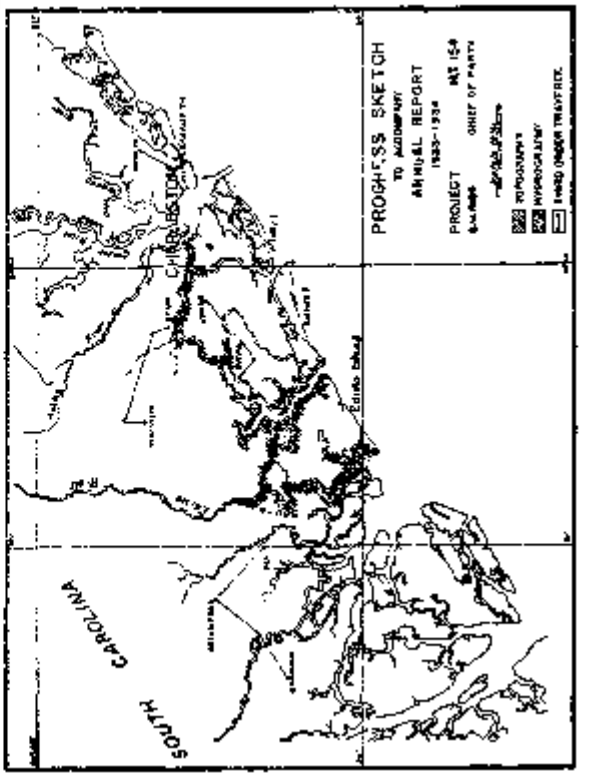


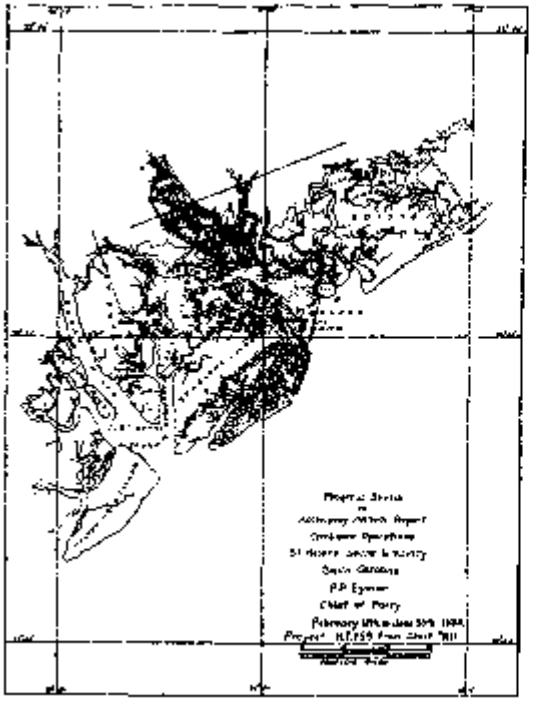


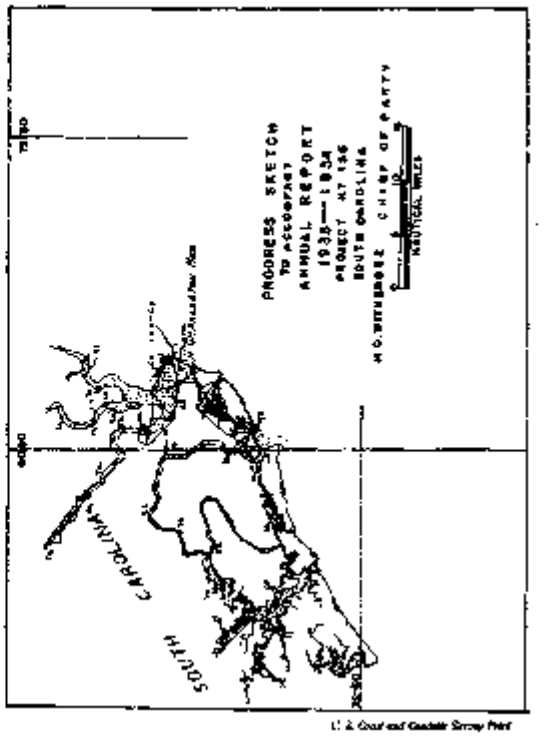


U.S. Coast and Geodetic Survey Print









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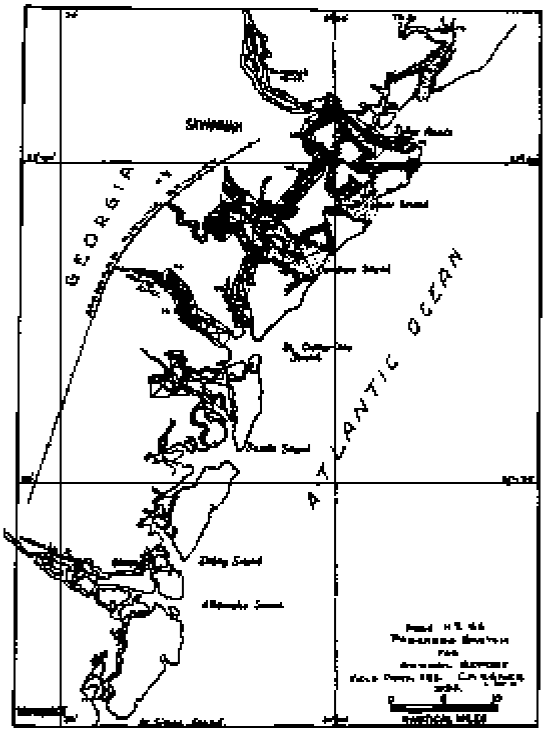

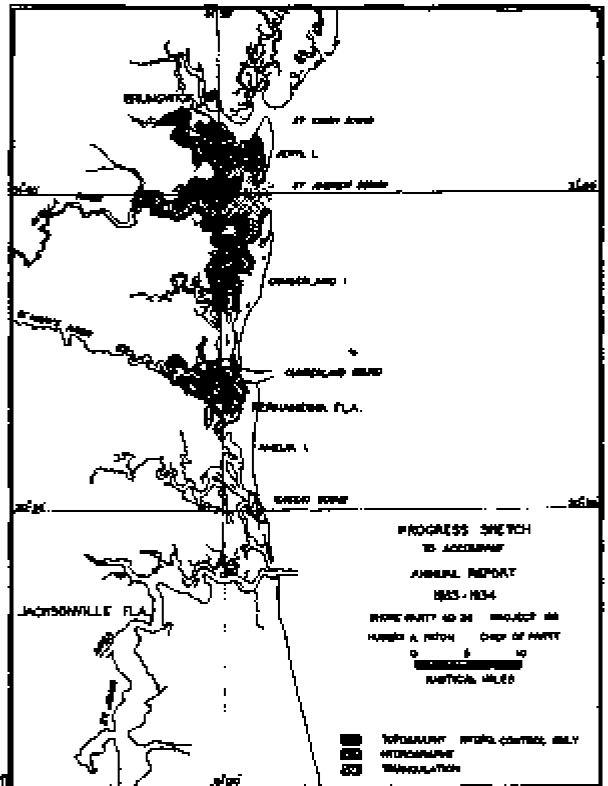

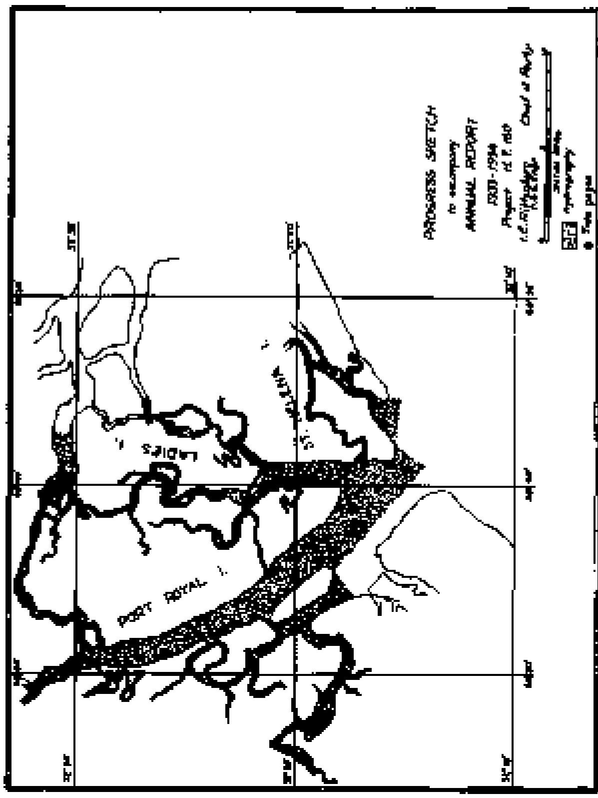

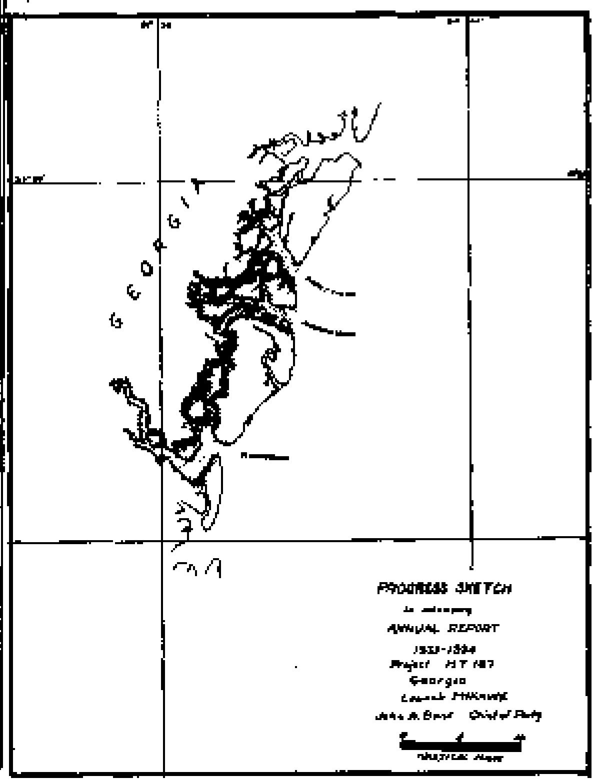

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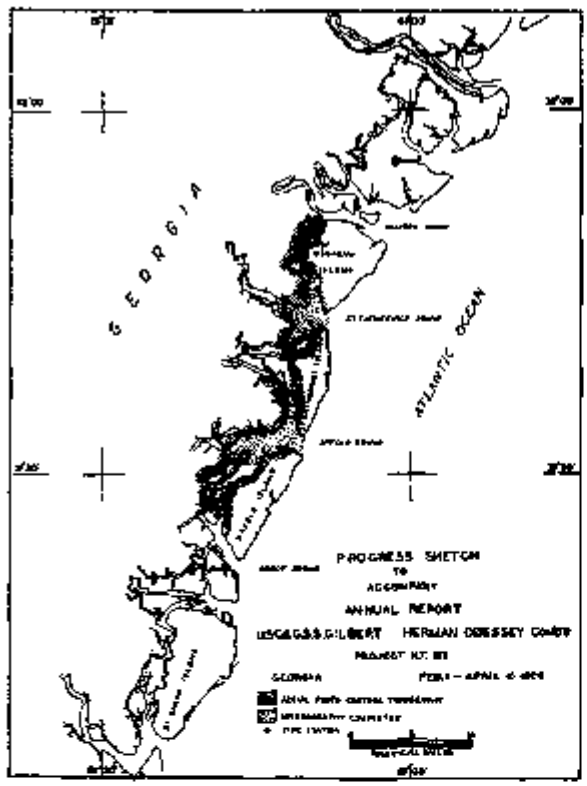

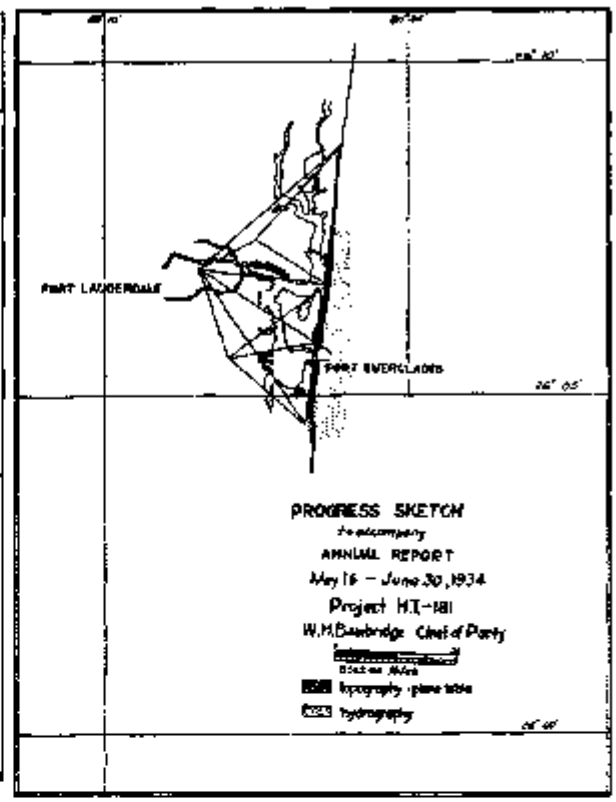

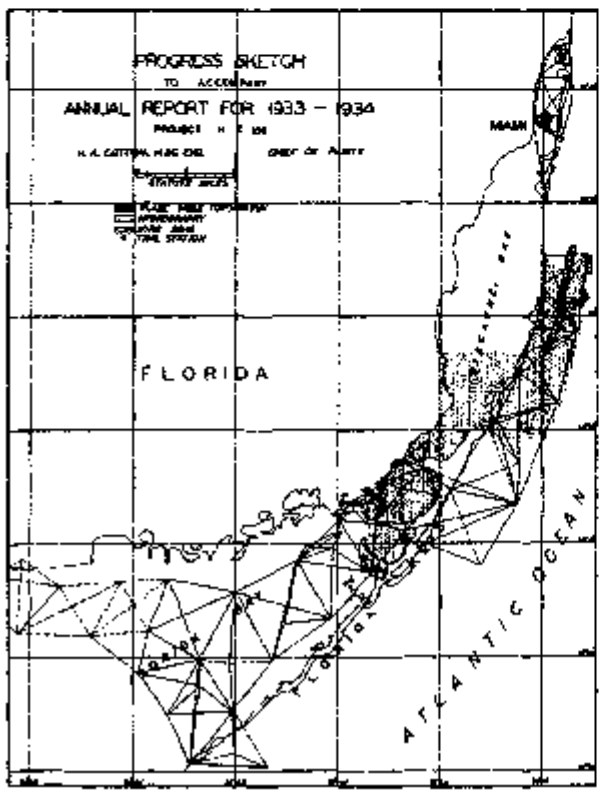

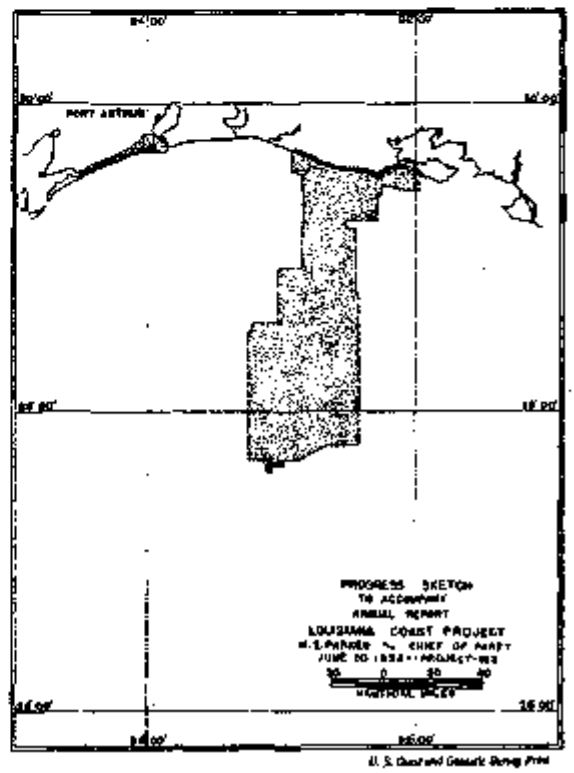

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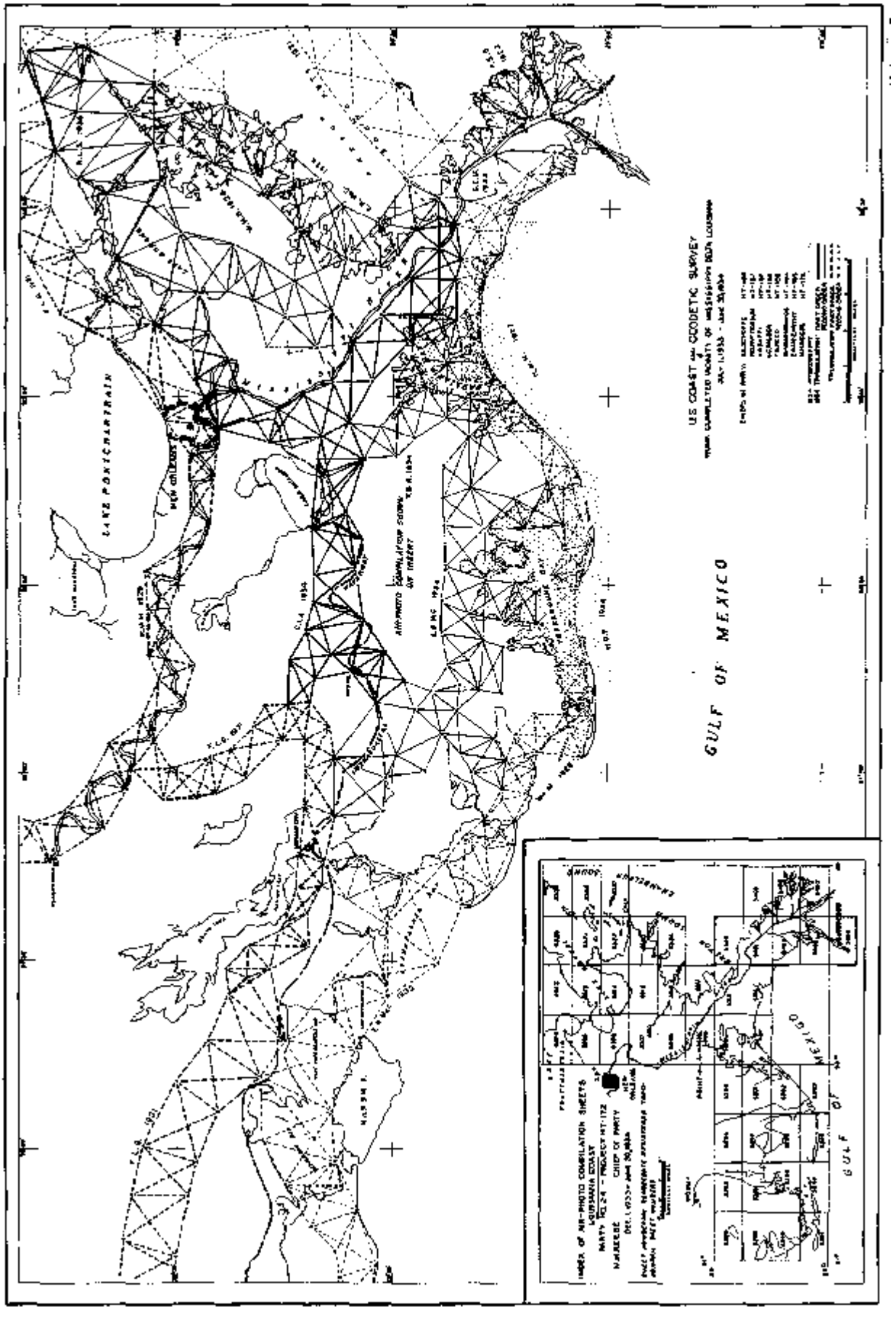
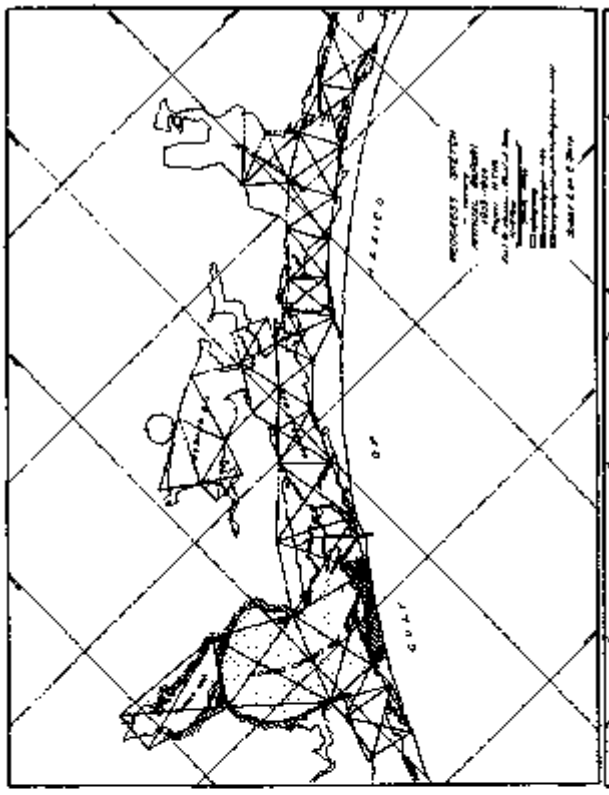

U.S. COAST AND GEODETIC SURVEY
GULF OF MEXICO
LAKE PONTCHARTRAIN
NEW ORLEANS
INDEX OF AIR-PHOTO COMPILATION SHEETS
LOUISIANA COAST
NAVY
CHIEF OF PARTY
GULF OF MEXICO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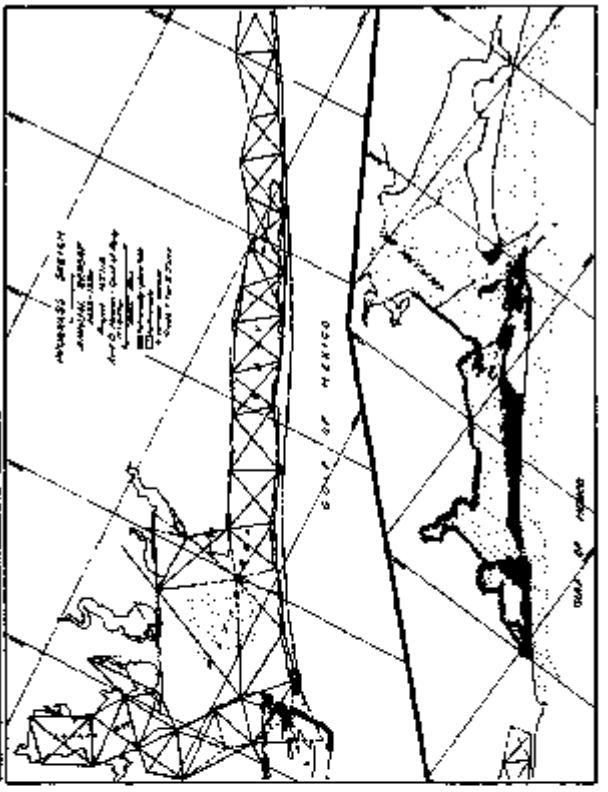
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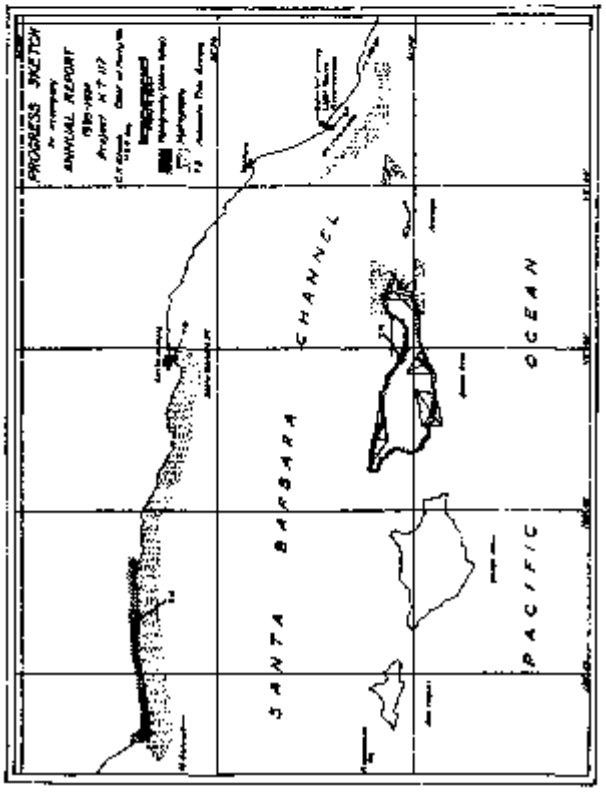
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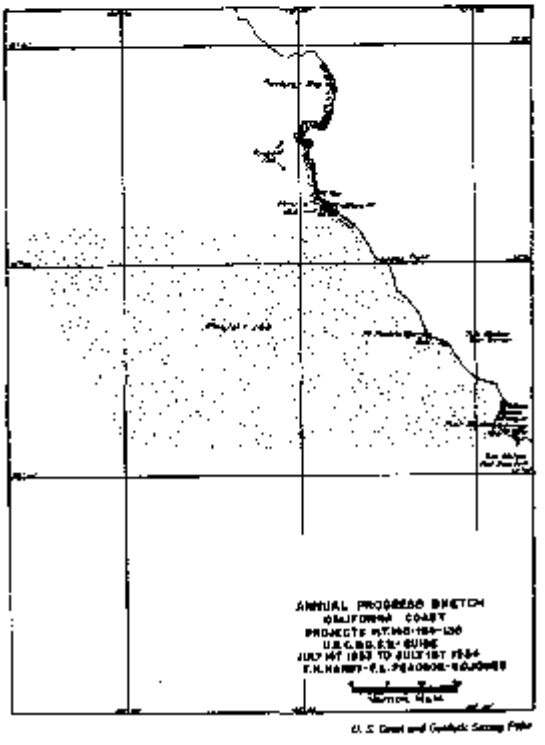
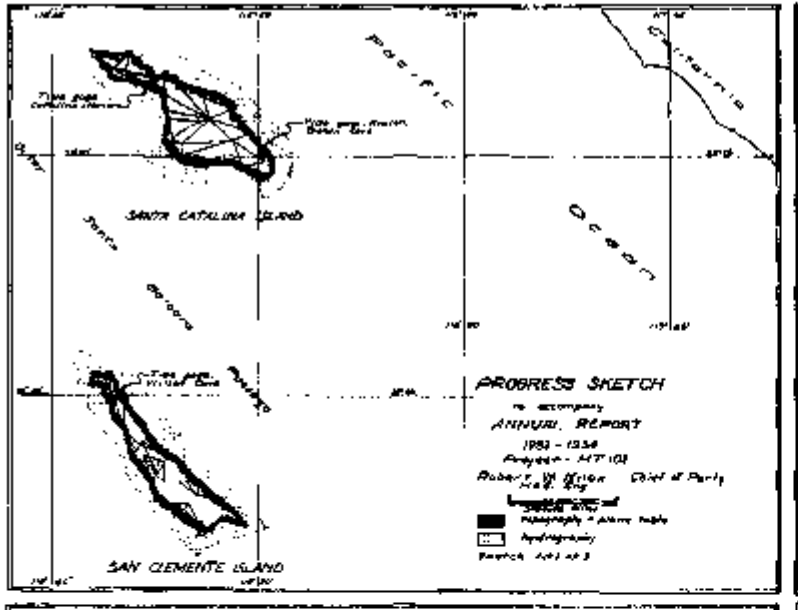
ANNUAL REPORT
SANTA BARBARA CHANNEL
PACIFIC OCEAN


ANNUAL PROGRESS SKETCH
CALIFORNIA COAST
U.S. Coast and Geodetic Survey Photo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OCEAN
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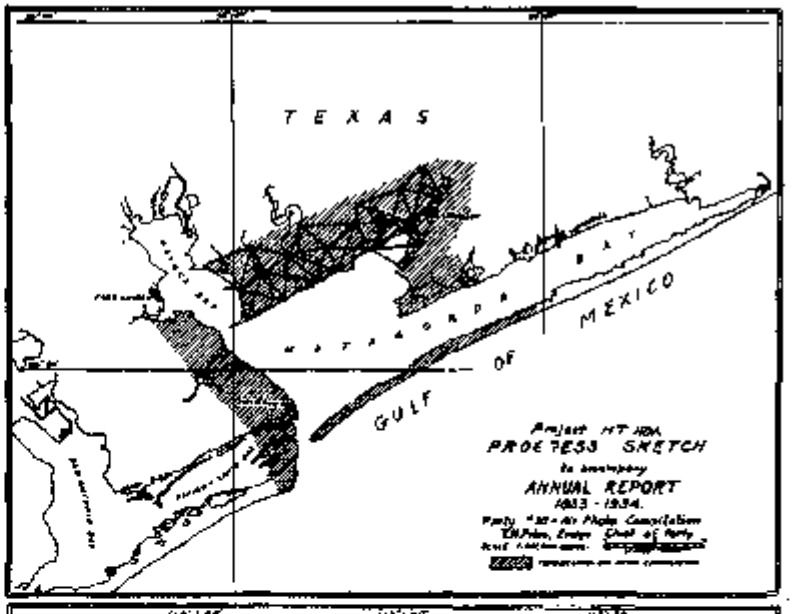
to accompany
ANNUAL REPORT
1933 - 1934
Project - HT 101
Robert W. Knox Chief of Party
Hydrography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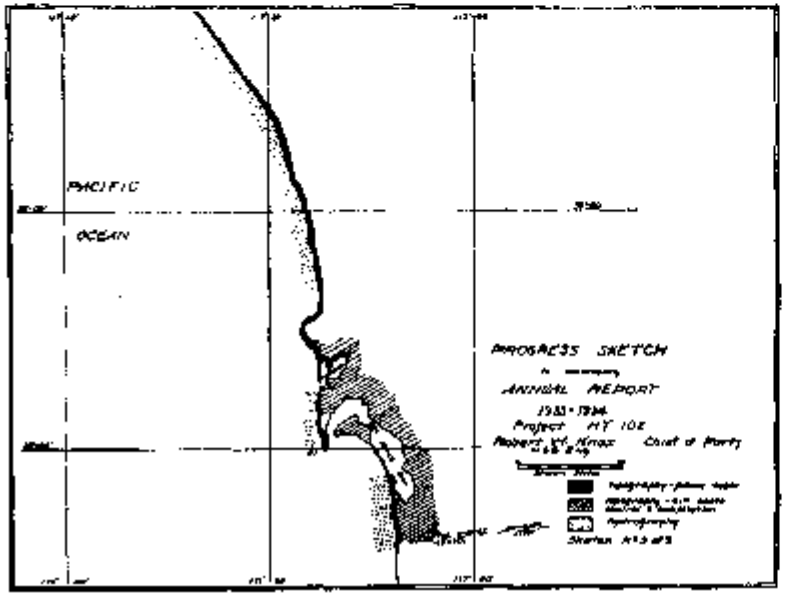
ANNUAL REPORT
1933 - 1934.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to accompany
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1933-1934
Project HT 102
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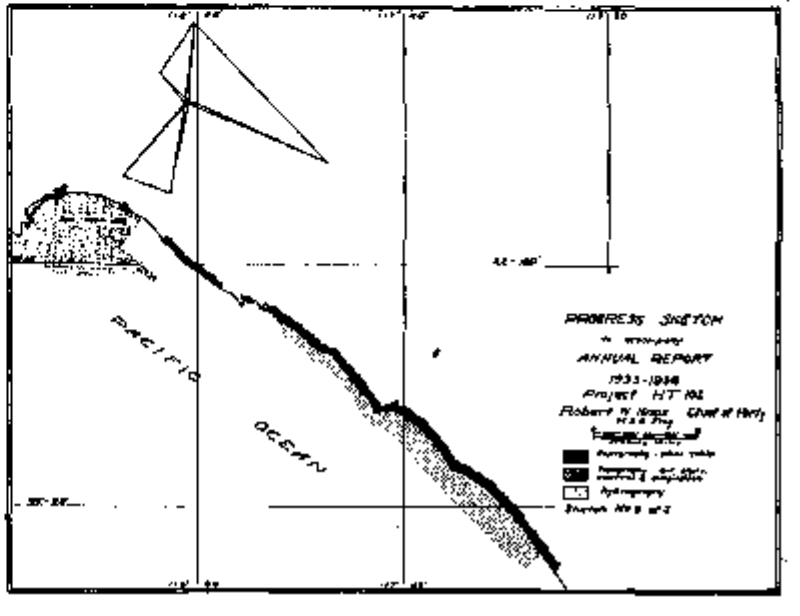
Hydrography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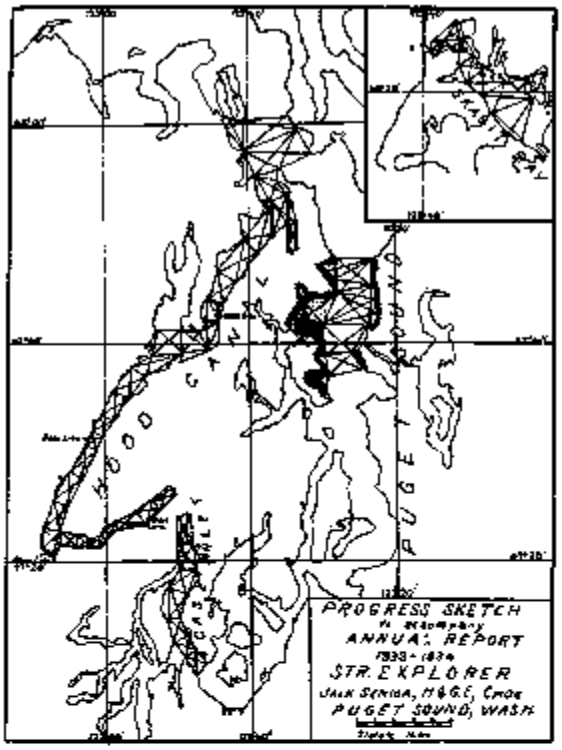
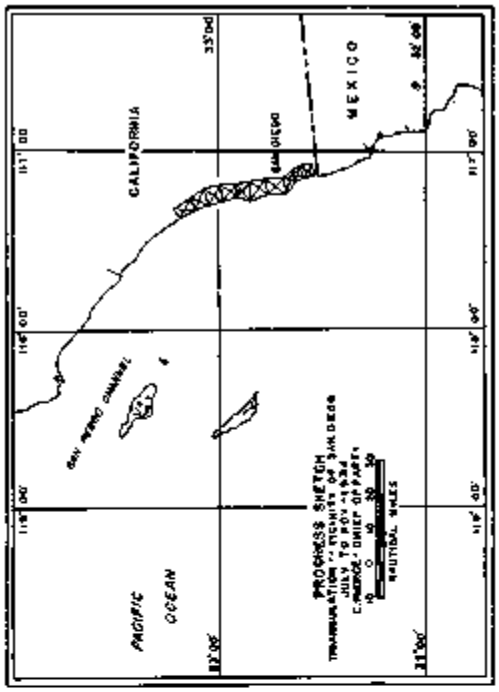
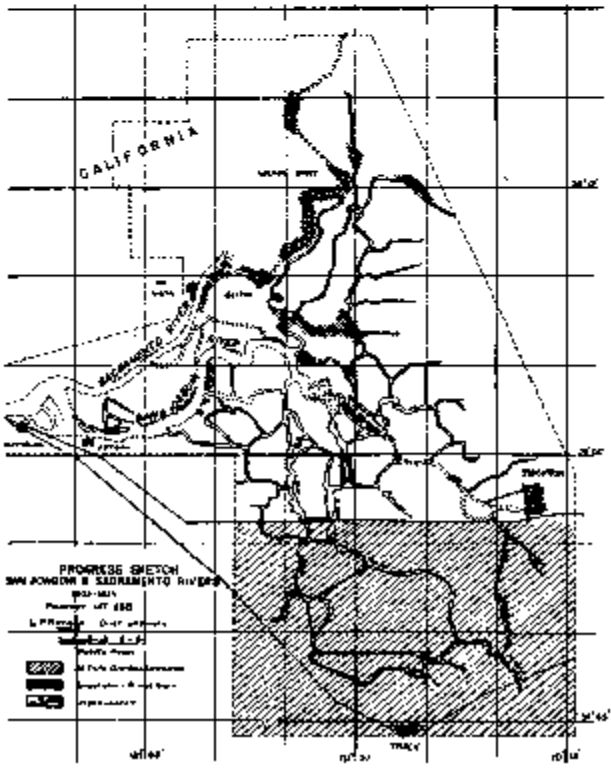
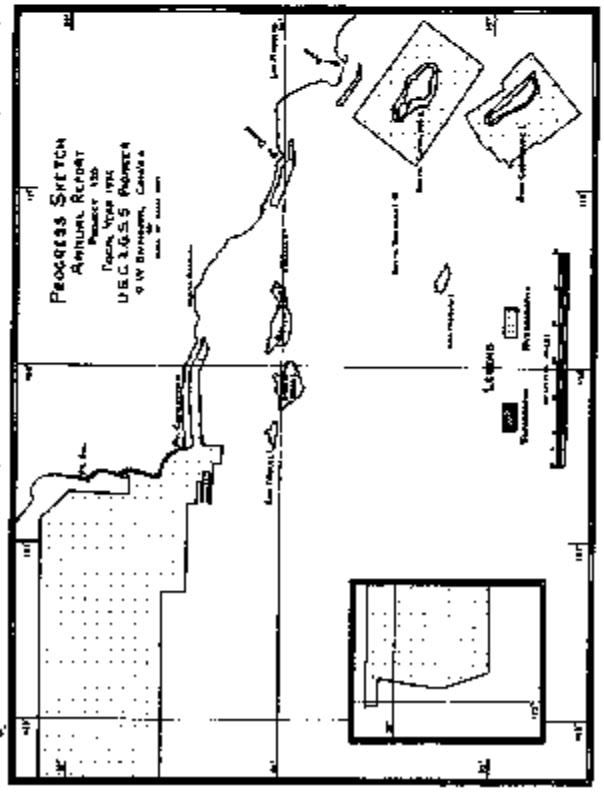
1933-1934
Project HT 102
Robert W. Knox Chief of Party
Hydrography

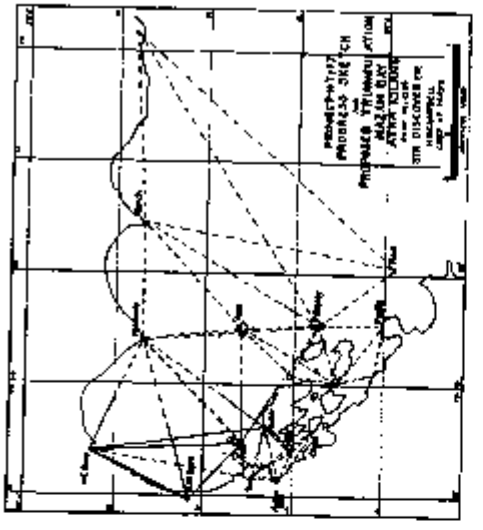


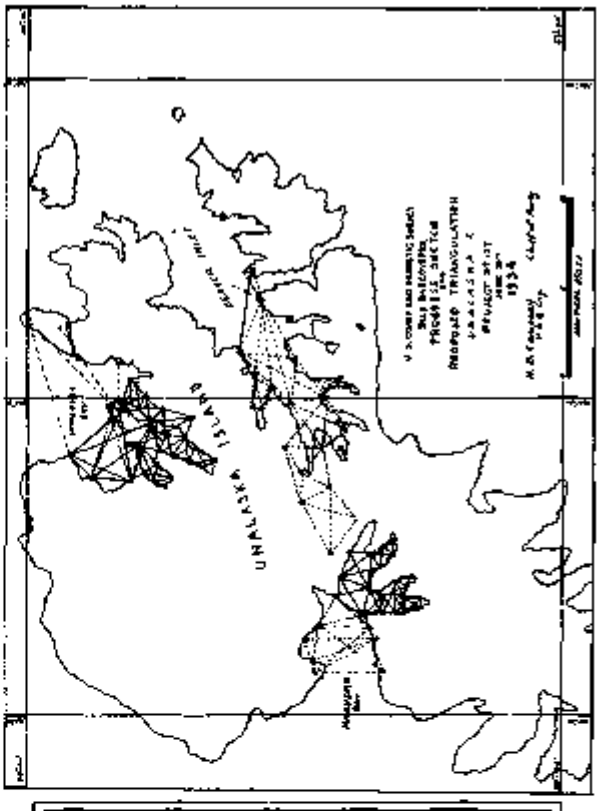






U. S. Coast and Geodetic Survey Ferry

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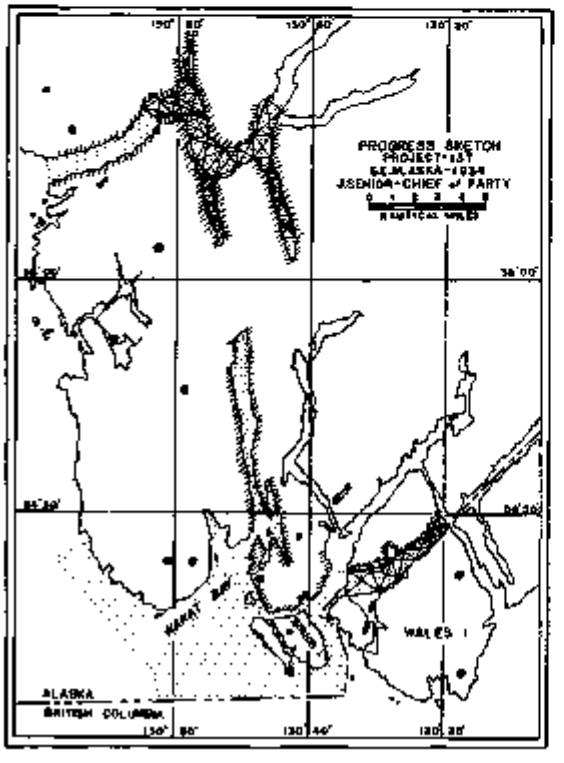
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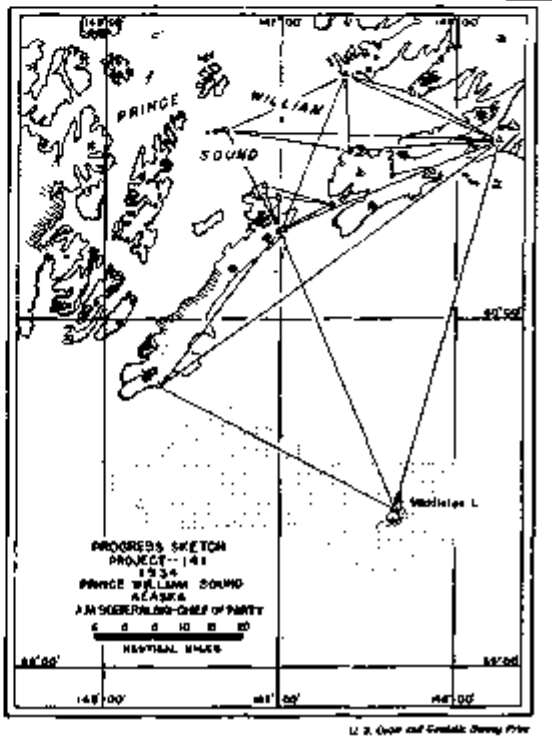
PROJECT-137
SE. ALASKA-1934
J.S.DINOA-CHIEF of PARTY
NAUTICAL MILES
NOME
WALES I
ALASKA
BRITISH COLUMBIA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PROJECT--141
1934
PRINCE WILLIAM SOUND
ALASKA
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NAUTICAL MILES

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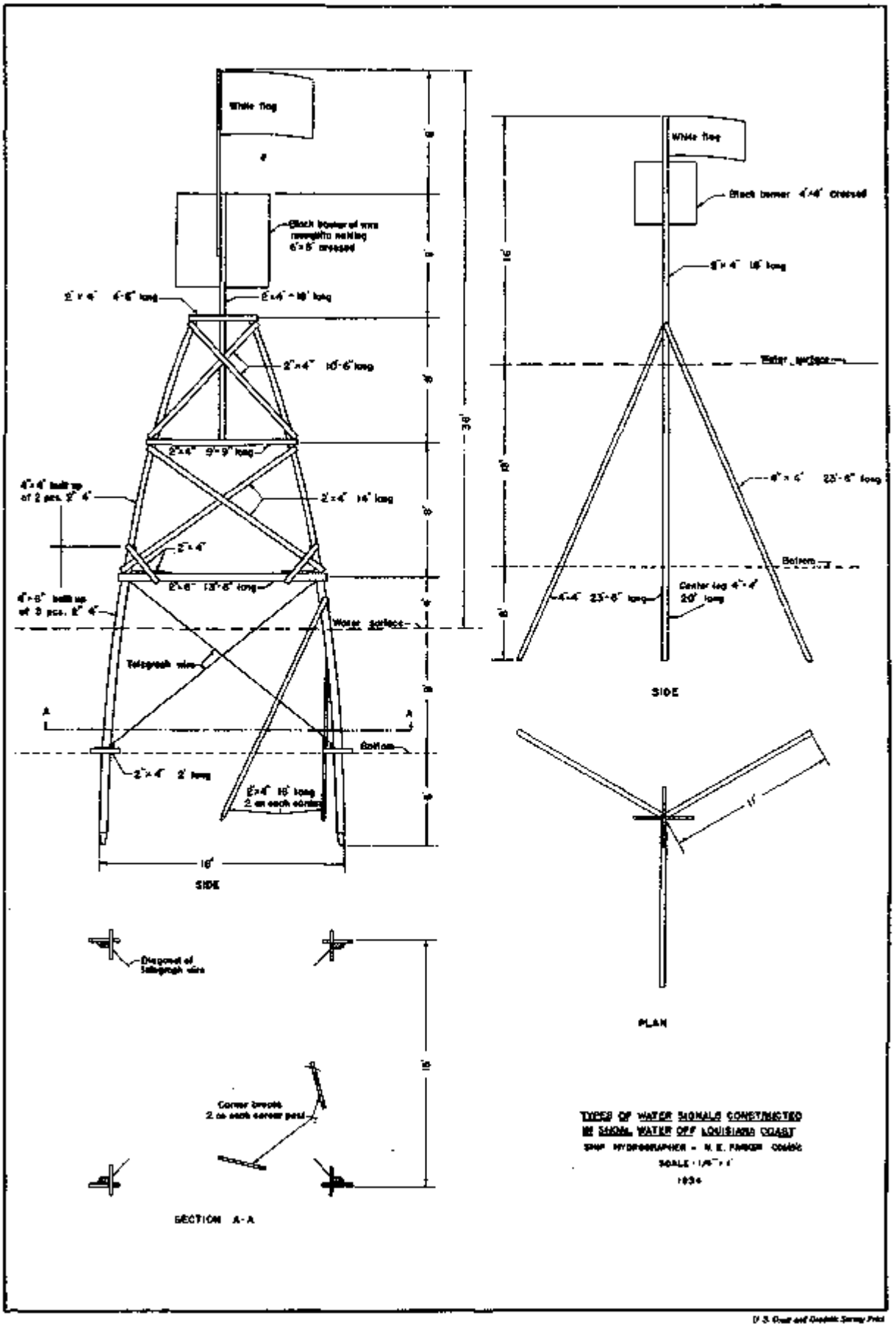


U. S. Coast and Geodetic Survey Print

FRAMING OF WOODEN SCAFFOLDS

G. A. Egner, H. & G. Engineer
V. S. Coast and Geodetic Survey

In the expanded operations of the Coast and Geodetic Survey during recent years practically all parties engaged in combined operations on the Atlantic and Gulf Coasts have been called upon to do triangulation. This has been necessary to span that low area between the higher ground of the first order schemes and the coast itself, and has been largely of a second order coastal-coordinating character supplemented by smaller "breakdown", third order figures, all of which require a fair proportion of tall scaffolds.

While many of these surveys are now completed, future revision work will call for similar control in many localities, and it seems quite likely that this sort of triangulation will always find a place in the routine work of the parties.

In this work, where transportation by truck is in many places impossible, and material must be moved by boat; in cases where scaffolds must remain standing for a considerable time; where the physical problems of availability, handling, stowing of steel is burdensome, and where so few scaffolds are needed as to make the use of steel inadvisable, wooden scaffolds will no doubt continue to serve the major needs of these parties.

The design of wooden towers to give the required stability and strength with a minimum of material and time in construction has been a timeworn subject.

During the summer and fall of 1933, after several seasons of finding this sort of scaffold building an important part of the operations of the "Natoma", during which the published design of scaffold was used with only fair success, particularly with direction instruments, an alteration in design presented itself which was tried out on the Hudson River on wooden towers to a height of 85 feet. In the pa3t season near Savannah, Georgia, several towers of from 50 to 65 feet in height have been built using the same system with much better results than were obtained with the old design. It is believed that others on this coast have used it also with success.

Objections to the previously accepted design of tall wooden scaffolds were not many but hinged around the following considerations:

(1) In heights above 60 feet it was the accepted practice to guy scaffolds with wire, for reasons of safety and to assist in their rigidity. Experience has shown that good results cannot be obtained from observations made on a guyed tall tripod even in light breezes. This is accepted as one of the major advantages of steel towers, which are not guyed, but act as cantilever beams swaying in the breeze. Vibration was too great in the old design of the wooden tripod with long diagonals; guying only increased the vibration and made a "singing tower" of the structure in a light wind. Furthermore, torque was usually introduced by unequal tension on the guy wires, with disastrous results to any observations attempted except in calm weather.

(2) It has been found that with the customary ship's crew inexperienced in this work, there is some hesitation in hoisting heavy l6 foot pieces of lumber into the clear "ozone" to nail a section of leg when working at an elevation of 60 or 70 feet and surrounded by little visible support.

(3) While the sprung "bottle-shaped" type of scaffold of the old framing was rigid enough when built by experienced men because the members functioned according to theory, somewhat less perfection was attained by ship crews in practice, with the result that it was found more expedient to build the legs as straight columns rather than risk a twisted or distorted scaffold after the Hogarthian line of beauty.

Anything, therefore, which lessened inherent vibration, eliminated guy wires (except for safety when not being occupied), reduced danger in construction, and, in general, made an easier, more simple structure to erect, was an improvement.

It is evident that the new scaffolds have less vibration in light winds. None have been subjected to severe storms and none have failed; none have blown

down bodily although no guys have been used to a height of 62 feet on either scaffold or tripod. For greater heights guys have been attached to the scaffold only, to avoid the possibility of failure in strong winds. On some high towers, guys have been attached to the tripod for safety when not being occupied, but loosened for observing. While, therefore, these towers have not been tested to failure as in the case of many towers of the old design, the following considerations are offered in support of their greater strength and rigidity:

In the improved design, by moving the diagonals up half a bent, the unsupported lengths of both diagonals and legs are reduced by half. The diagonals are nailed securely to the horizontals as well as to the legs; they, therefore, actually take compression - or at least a great deal more than formerly - and, of course, take tension better than before. The horizontals remain 2"x 4" lumber as before, but it is worthy of discussion whether this is strictly necessary, as in theory l"x 4"s might serve the purpose. 2 x 4's are retained for general strength and rigidity, and for ease in building, as men must move around the scaffolds and have something substantial on which to stand while going from one corner to another.

It has been argued that the diagonals must take compression in the new design, as stress in the horizontals is practically eliminated. This is true, and in all structures above 60 feet in height the diagonals are 2 x 4 timbers throughout the lower two panels; above that, the diagonals are short enough that 1 x 4 members prove to be sufficiently rigid to do the work. There is no loss, however, in comparison with the old design for similar 2 x 4 pieces were used throughout the lower two panels in similar heights.

For added rigidity in the tripod only, the horizontals of the first two bents have been pulled in slightly by connecting them to each other at their mid-points by 1 x 4 pieces as shown on the sketch.

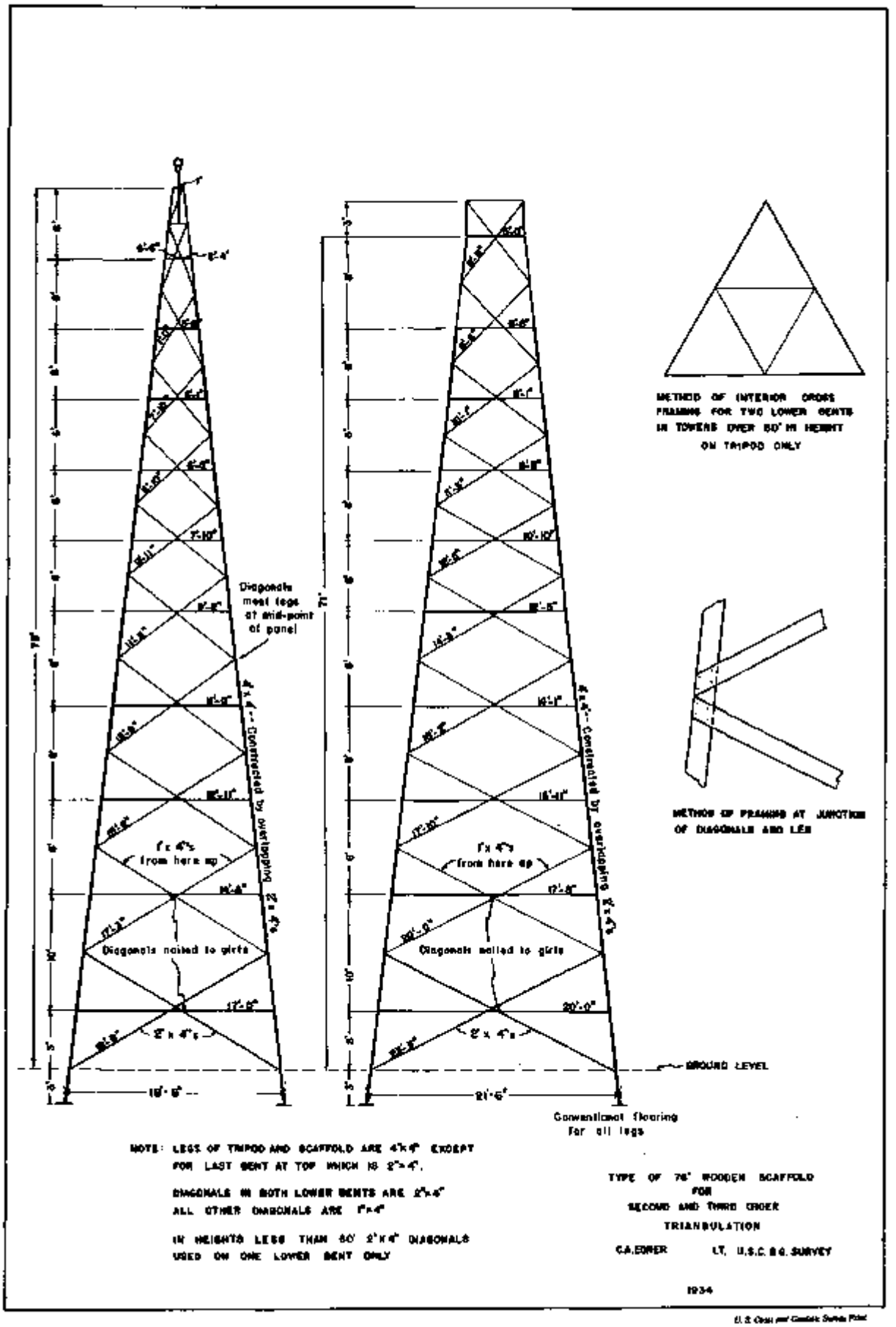
It has been found that this structure can be erected as rapidly as the old one. Indeed, one operation is partly eliminated - that of placing steps on the legs on which a man must stand while raising the next section of unsupported leg into place. On high scaffolds this has always been a serious source of danger to life and limb. Now, on some panels at least, the diagonal may be nailed before the next section of leg is raised, and the man may stand on it while working above.

Another point in its favor is that whereas the first horizontal has heretofore been placed quite close to the ground, the new design permits raising it a half panel higher.

While these considerations are meant to apply only to the erection of wooden scaffolds, it may be that there are points which could be worked out profitably in the design of the Bilby steel tower.

In regard to the theoretical soundness of the design, it has been submitted to the Professor of Structual Engineering, Purdue University, for analysis, who states that it is sound. Supporting this, there is submitted a line diagram of the design of very tall wooden radio towers in Heilsberg, East Prussia, in which this method of framing was used in structures erected to a height of 336 feet. In these, the great size of the lower panels and corresponding length of members made further interior bracing necessary in the lower parts of the structure without, however, altering the basic idea. In these, the open parallelogram in each panel, which has been the cause of adverse comment, is quite evident. These radio towers, in addition to the necessity for strength to withstand high winds, also must carry a severe load at right angles to their length from a heavy antenna.

Reference is made to Vol, 51, 1931, pages 187-191 in the German publication "Zentralblatt der Bauverwaltung". In this article structural details of two towers are given.



NOTE: LEGS OF TRIPOD AND SCAFFOLD ARE 4"x4" EXCEPT FOR LAST BENT AT TOP WHICH IS 2"x4".

DIAGONALS IN BOTH LOWER BENTS ARE 2"x4"
ALL OTHER DIAGONALS ARE 1"x4"

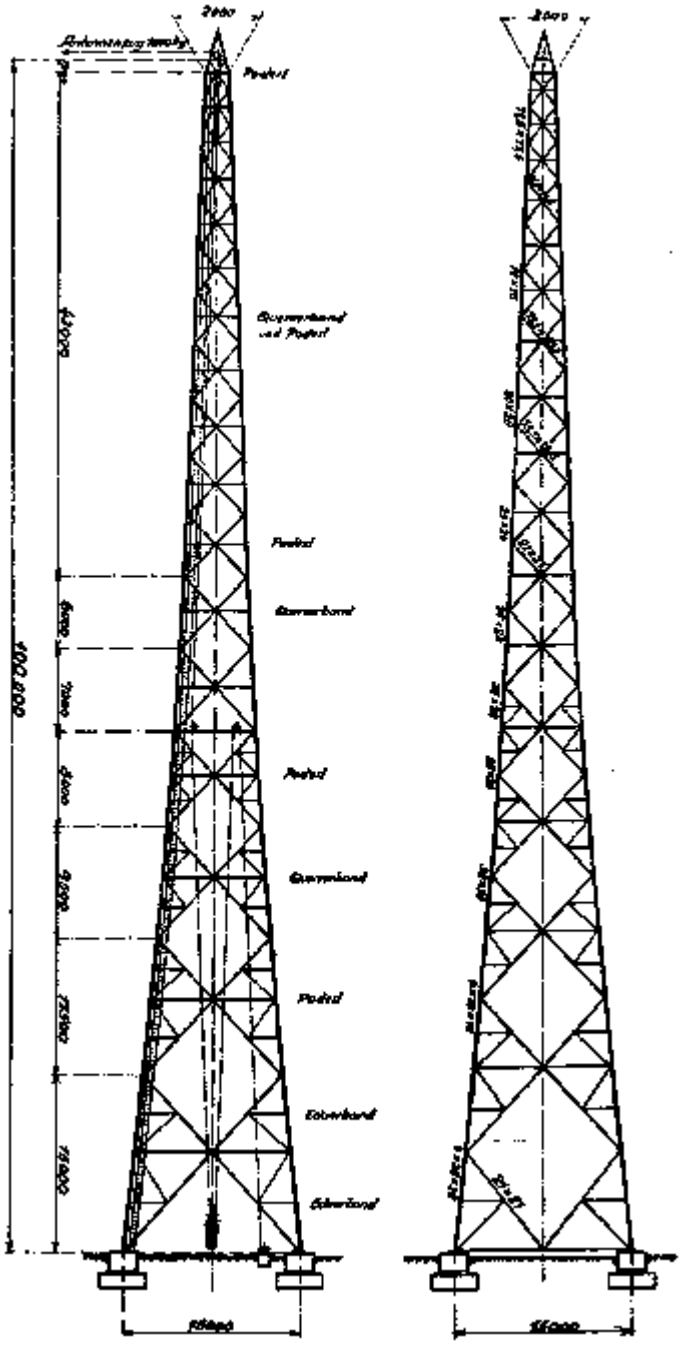
IN HEIGHTS LESS THAN 50' 2"x4" DIAGONALS USED ON ONE LOWER BENT ONLY

TYPE OF 76' WOODEN SCAFFOLD FOR SECOND AND THIRD ORDER TRIANGULATION

C.A.EDNER LT. U.S.C. & G. SURVEY

1934

U. S. Coast and Geodetic Survey Print



WOODEN RADIO TOWERS NEAR HEILSBERG IN EAST PRUSSIA
From "Zentralblatt der Bouverwaltung"

(The wooden radio towers at Heilsberg in East Prussia were built for the 75 kw. station for German broadcasting, and have a height of 102 meters. They were designed for an antenna strain horizontal at the top of 1,000 kg., a wind pressure of 250 kg. per square meter at the top, and 150 kg. per square meter at the base. They are built of wood, American pitch pine unimpregnated, and fastened with "Pressduebel-Holzverbinder" (notched pegs with screw bolts). The framing is shown in the accompanying plate, from which Lieutenant Egner obtained the idea for triangulation towers. It is to be noted that the horizontal members of the Heilsberg towers do not run continuously around the structure, but alternate; the opposing sides are parallel and at the same elevations, but the adjacent sides have the ends of the diagonals at the ends of the horizontal members of the other side. Lieutenant Egner has built his triangulation towers with the horizontal members running entirely around the tower at the same section, and this probably facilitates the building. The method of framing as used in the German towers will probably give greater stability of structure for the same weights of members, and might permit building from a smaller base, which would reduce wind area slightly.

Editor)

WOODEN TOWERS FOR TRIANGULATION

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

The design of towers used by Party No. 14 in the marshes of Louisiana was considerably lighter than that customarily in vogue among other Coast Survey parties. The theory of the design is that with short panels well braced and all diagonals cut to butt against the horizontals, the resultant strength even with a small base is equal to that of a wider, heavier built tower with long horizontals and excessively long diagonals. The signal is not designed for the strongest wind to be expected, nor for permanency. The design was more or less forced on the party as during the 1933 season in Louisiana it was necessary to build a number of towers in remote locations in places where transportation was slow and difficult. A light signal was constructed as an experiment both to save lumber and permit faster progress. It was found to be very satisfactory so far as strength was concerned and it also cut down the time of building as well as the amount of lumber used.

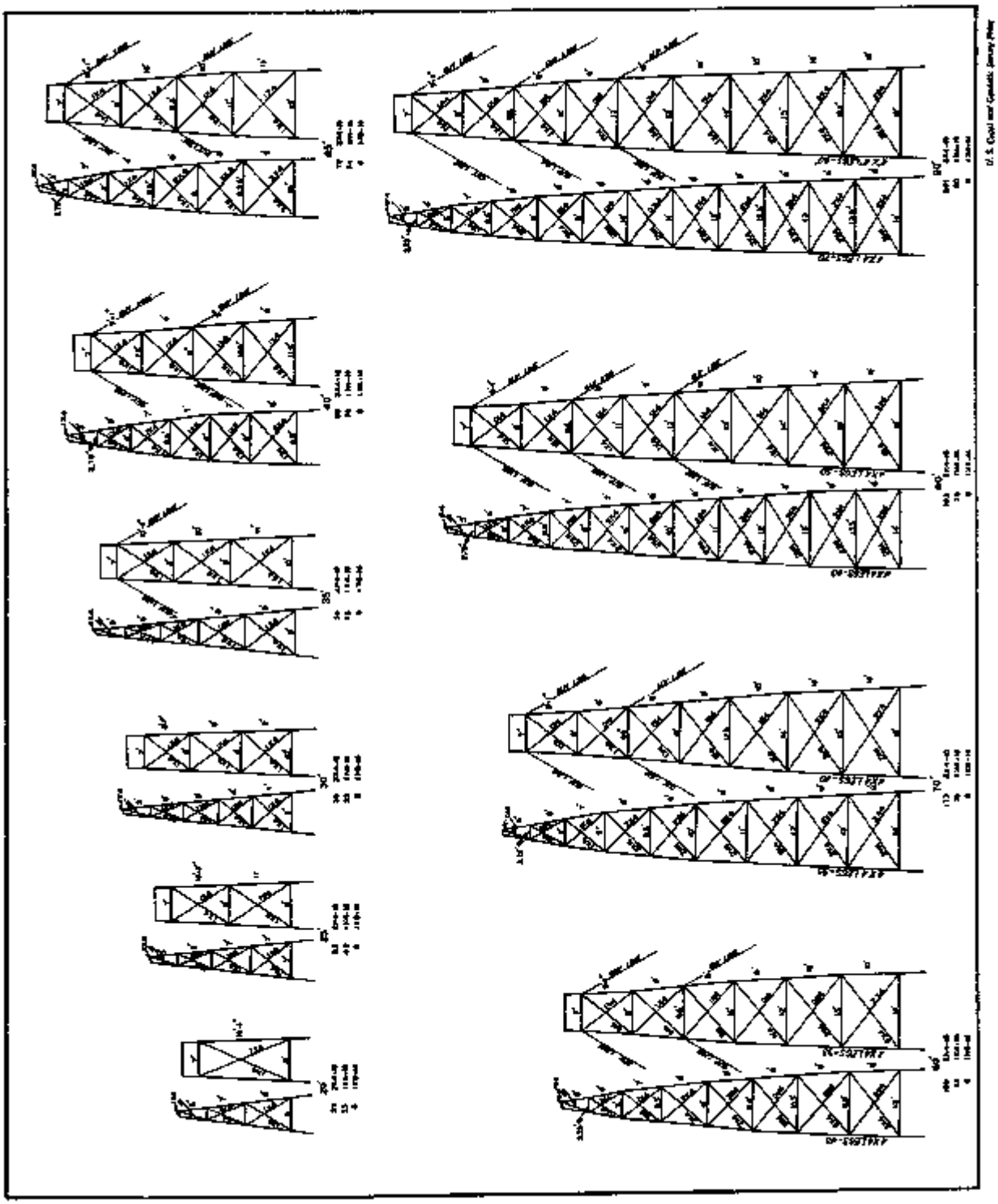
The towers are based upon the use of No. 1 common pine 2 x 4's for legs and horizontals, and No. 1 or No. 2 common pine 1 x 4's for diagonals. With inferior lumber, the legs must be strengthened by increasing their cross sections or by carrying the 4" x 4" legs higher. For diagonals, No. 1 pine is used on signals over 50 feet, and No. 2 pine on signals under this height. For signals under 30 feet, No. 2 lumber may be used safely for all members. The lumber for the legs should be selected in any case. No guys were used on the tripod except in an unusual case where it was unavoidable. No. 11 or No. 12, B. & S. standard gage galvanized iron wire, is a satisfactory size for guys on the scaffold. This wire is rather light for a tall signal but it may be doubled - or a No. 9 wire used if necessary - and it is very easy to handle.

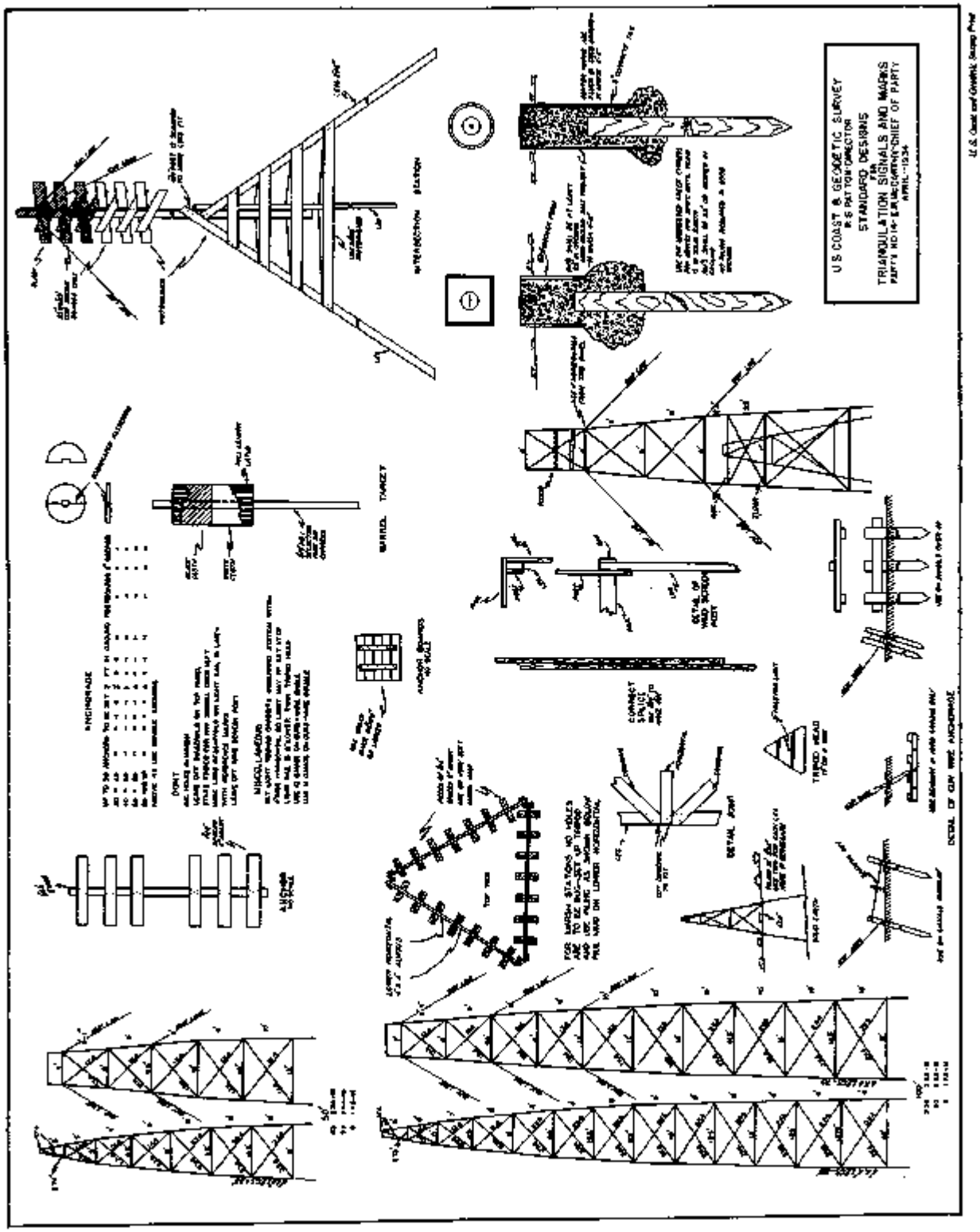
Where it is possible to use anchors on the tripod and scaffold, the depths shown on the plans were used in gravelly soil. For gumbo, they were decreased slightly and for sand, increased or the anchors made larger. For hard marsh and low (under 36 feet) signals, it is usually solid enough to rest the lower horizontal (made of 4 x 4 for bearing surface) on the marsh and pile mud upon it. For soft marsh, cross pieces made of scrap 2 x 4 and 1 x 4 should be nailed to the lower section of the horizontal member, and mud piled over it. It then seems to take a suction grip on the base which makes it very steady. Piling should always be used in addition to the floating foundation. Where the bottom has not been reached at 16 feet, it has been found that the friction grip on the piles is sufficient to hold the signal down. For a 50-foot signal, two piles at each leg and one or two on the horizontal between legs is sufficient. In soft marsh, the base of the scaffold should be increased about two feet in order that the tripod will not be shaken by the observer moving about the scaffold.

The heads of the tripods are designed for lights, but targets may be used by putting a bench about three feet below the top and stepping the target in. Barrel targets were used almost exclusively for day work on main scheme stations. Contrary to the usual opinion, errors of phase were found to be negligible if the observer was experienced, and used the black target as much as possible. The target has the advantage of offering no eccentricity - a source of large errors on short lines - and some observers insist on using the target instead of the center pole when the latter is visible.

Signals up to 35 feet may be constructed on the ground and raised by hand except in marsh where the soft footing prevents anything larger than a 25-foot signal from being erected as a whole. It is best to have one tall, heavy-set man on the party for use as a portable column. Where it is possible to use a truck, signals up to 50 feet may be built on the ground and raised by means of the truck and guy lines. Signals up to 80 feet may be raised as a unit provided a tree is available as a gin pole, and one has a truck for hauling. The hauling line should always be made fast to the forward end of the truck and the truck backed - not so much for the additional power given by the usually lower reverse gear - but that the driver may watch the signal. No additional strength is necessary except that the lower horizontal should be 4 x 4 as should the legs. A brace from the lower diagonal to the bottom of the leg is a precaution but not essential. The blocks should be secured near the top of the signal and at the center to keep the bow out.

Marsh signals above 25 feet must necessarily be built from the ground up. The first two panels are completed, raised, leveled, the foundation put on and the signal built up. The best organization for this method of construction is a six man party, one man on each leg, one to hand up lumber, one to saw and one to




U.S. COAST & GEODETIC SURVEY
STANDARD DESIGNS
FOR
TRIANGULATION SIGNALS AND MARKS
APRIL 1934

direct. A seventh man is useful on the scaffold as It saves time In that one man does not have to shift from leg to leg. In one case a fifty-foot signal was raised by means of a boat. The particular signal was on solid ground on the bank of a canal. The tackle was made fast to the stern of the boat (a 40-foot lugger) and it pulled slowly along the bank of a bayou. When the signal was raised high enough, the boat was run into the bank to prevent the signal from being pulled over.

Marks

It has been the policy of the party to use a 10" x 30" or 36" concrete pipe as a form for center marks and an 8" x 8" box as a form for reference marks. The depths shown on the plans were used in Louisiana but have been increased for New Jersey on account of the frost line. The marks were carefully finished and all bronze tablets set flush with the surface of the concrete.

The design has been discussed with a number of field officers who are all of the opinion that it is too light. However, there have been no failures and triangle closures have been better than the average requirements. As far as wooden towers are concerned, observations - even from a tower of very heavy construction - are impractical in even a moderate wind. It has been found that a narrow base with consequently shorter diagonals cuts down the amount of vibration to such an extent that observations could be made in winds where it was impossible to observe with a standard tower due to the shaking of the tripod from vibration of the lower diagonals.

The design is not considered complete as it is changed somewhat at the end of each season, the changes being the result of experience gained during the season.

FROM NAUTICAL MAGAZINE SEPT. 1934

"The Field Engineers Bulletin, No. 7," of the U. S. Coast and Geodetic Survey, is an unusual type of book. The type used is of an imitation typewriting character and the matter consists of articles appropriate to surveyors and field engineers. In its more than 200 pages it ranges over such subjects as the "Earth's Rotational Force and Navigation"; "The Hurricane of August 1923-1933," "Some Notes on Tidal Observations," "A Submarine Mountain off the Californian Coast"; "Echo Soundings in Submarine Valleys" and "Mapping from the Air." In each case the subject under consideration is treated by an expert and much illuminating information can be obtained. For instance, in "Echo Soundings in Submarine Valleys" we have a paragraph quoted from a letter from Professor P. Shepard of Illinois University, which says: "Recently I have followed *** (See p. 127 Bulletin No. 7)." When it is considered that 54 articles of equal interest and information are comprised in the volume it will be seen that the publication is of no little interest to navigators and engineers. Unfortunately, one is unable to determine whether the book can be obtained publicly. By its appearance one imagines It cannot. If this be so it is a pity, as with the possible exception of the review of the Hydrographic Bureau it is doubtful whether any other publication quite covers the same ground as does this.

CORRECTION

Field Engineers Bulletin No. 7, June 1934.

On the plate showing "Submarine Mountain off the California Coast", p. 123, Bulletin No. 7, change the latitude of the parallel marked 35° 00' to 36° 00', and the parallel marked 34° 20' to 35° 20'.

RECENT ACOUSTIC WORK OP THE U. S. COAST AND GEODETIC SURVEY

Paul A. Smith, Jr. H. & G. Engineer, U. S. C. & G. Survey

During the past generation, the heretofore simple life of a hydrographer who sailed the various seas sounding with lead and wire, and obtaining positions with sextants, has become one of scientific complexity. (Apologies to our professional ancestors). Our ships now are bristling with complicated instruments, radio equipment, sound apparatus, oscillographs, and other such apparatus usually never seen outside a laboratory of physics. In addition to the advent of all these scientific monstrosities, the field officers have acquired the scientific vernacular and toss double-barrelled technical names about with their sea-going expressions in such a manner as to bewilder scientists and disgrace sailors. Nevertheless, the revolution is on, and with modern cargo and passenger vessels equipped with echo sounding devices, and able to sound at 20 knots or more, we have found it imperative to extend our offshore surveys farther from the coasts to assist these high speed vessels in making landfalls. In extending these offshore surveys, the use of radio acoustic methods has made economically possible valuable work that otherwise might have been impossible. In this radio acoustic ranging, with which we all are acquainted, the foundation of the accuracy depends upon a knowledge of the velocity of sound in sea water. The horizontal velocity of sound has been found to be a function of so many factors that in attempting to correlate them all, a vast amount of study is necessary, and many theoretical refinements may not be necessary in practical work. The following is an attempt to describe some of the recent experiments conducted by the Coast and Geodetic Survey, to set down some of the principles and theories which have direct bearing on increased accuracy in R. A. R. work, and to list references which may be of value to any who wish to read further.

We have been reminded many times of the various attempts to measure the velocity of sound in water, of which those of Colladon and Sturm,[1] Lake Geneva 1827, Threlfall and Adair,[2] Australia 1899, are notable. Since the world war, and especially since 1919 there have been numerous experiments made to measure accurately the velocity of sound in sea water by the use of explosives and sensitive hydrophones. It is noteworthy that all of these attempts have been made in shoal water. With the exception of the experiments of Heck and Service, which resulted in a compilation of the first accurate tables for the velocity of sound,[3] all experiments which have been studied by the writer have been made in shoal water, 30 fathoms or less.[4] Another set of tables differing slightly from those of Heck and Service, was published by the British Admiralty in 1923.[5] These two sets of tables have been used in practically all hydrographic work since their publication.

It was obvious soon after the work of radio acoustic ranging was started by the U. S. Coast and Geodetic Survey that the apparent horizontal velocity of the sound was different from the theoretical velocity for the mean conditions of temperature and salinity, and various hypotheses were formulated to explain the difference and to establish a satisfactory working basis. In 1925, Lieutenant Jerry H. Service of the U. S. Coast and Geodetic Survey, recognized that there were other factors to be considered in the application of these theoretical velocities to actual work, and applied the theory of multiple reflections to account for the apparent idiosyncrasies of this elusive quantity. This was, and is the only plausible explanation for the travel of compressional waves in a medium between two reflecting surfaces, bounded by two media of very different elastic and inertia constants, where the velocity varies with the thickness in the medium under consideration, in this case the sea; and Lieutenant Service applied this theory to explain the phenomena he encountered in his experience with hydro acoustics.

[1] Ann. d. Chim. et Phys., 36, pp 113 and 225, 1827.

[2] Proceedings of the Royal Society, London, Vol. 46, 1899.

[3] U. S. Coast and Geodetic Survey, Special Publication No. 108, 1924.
Field Engineers Bulletin No. 5, p. 45, The Start of the Acoustic Work of the Coast and Geodetic Survey, N. H. Heck.

[4] Proc. Roy. Soc., 103, p. 284, 1923. British Admiralty experiments made by A. B. Wood, H. E. Browne, and C. Coohrane.
Annales Hydrographiques, 1919-20.
Field Engineers Bulletin, No. 7, USC&GS, June 1934, p. 115, The Velocity of Sound in Sea Water, T. B. Reed.

[5] Tables of the velocity of Sound in Pure Water and Sea Water for Use in Echo Sounding and Sound Ranging, Hydrographic Department, (British) Admiralty.

If the sound actually travelled by successive reflections between the bottom and the surface of the ocean, it was easy to see that it would not be possible to use one velocity for any given condition of temperature and salinity, as hoped at the outset. Rather, it would be necessary to change the apparent velocity with the changing depths and horizontal distances, as well as with the changing conditions of temperature, pressure, and salinity. Shortly after the publication of the velocity tables referred to, some of the work in shoal water off the Pacific Coast seemed to indicate that the apparent horizontal velocity approximated the theoretical velocity for the bottom temperature and salinity, and it appeared that the sound, in some manner reached and travelled along the bottom, and at the favorable time came up to the surface to actuate the hydrophone. If such a relation between the theoretical velocity for bottom conditions and the apparent velocity existed, it might provide a working formula for use in the shoal waters of the continental shelves of our coasts. A number of experiments were made to investigate this relation, and a careful study of all available data was made by Mr. A. L. Shalowitz, Cartographic Engineer, USC&GS. His work is described in detail in a special report and is summarized in a paper given before the National Academy of Sciences.[1]

For several reasons it is well to quote his conclusion:

"Average differences (in meters per second) between experimental velocities and theoretical velocities for assumed paths.

	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

"This remarkably close agreement between measured velocities and theoretical velocities based on bottom temperatures, would seem to indicate that the peak of the energy reaching the hydrophone has come not by way of the shorter straight line path where the velocity is greater, but by way of the more circuitous path of the bottom layers of water where the velocity is actually less. How is this seeming contradiction to be explained? It has been suggested that it is primarily a question of temperature; that a given amount of energy will travel farther in cold water than in warm water, and though the velocity of sound is greater near the surface, the energy is used up quicker and over long distances fails to reach the hydrophone. Hence the only record we get is of the energy that has come by way of the colder bottom layers.

"While there is considerable evidence to be found in support of this theory, both in the present study and in our experiences with horizontal transmission on the south Atlantic Coast, I believe it is too early to formulate a definite theory regarding the behavior of the sound wave. It will be time enough to consider these possibilities when we have supplemented our present data with experimental work carried out along certain lines which the investigation has shown is urgently needed.

"For the present, the important thing is that a practical working relation has been established between experimental and theoretical velocities that has enabled us to adopt a definite policy for the work on Georges Bank. In addition, the study has shown that any assumption that the effective sound wave travels along the surface or close to the surface is wholly untenable. Other than that, the investigation should be considered in the nature of a preliminary finding and as laying the foundation for a thorough and comprehensive study, both in the field and in the office, of the whole subject of sound transmission in all its ramifications." In spite of Mr. Shalowitz's warning, this fortunate empirical relation has been referred to erroneously by many as a "bottom velocity theory".

Numerous attempts were made to confirm this relation in both shoal and deep water, the most accurate of which was the taut wire determination made by the USC&GS ships OCEANOGRAPHER and LYDONIA in May, 1933, off the coast of Maryland, in a depth of approximately 30 fathoms.[2] The experiments in deep water off the

[1] Proc. Nat. Acad. Sciences, Vol. 17, No. 8, pp. 445-455, Aug. 1931.

[2] Loc. cit.

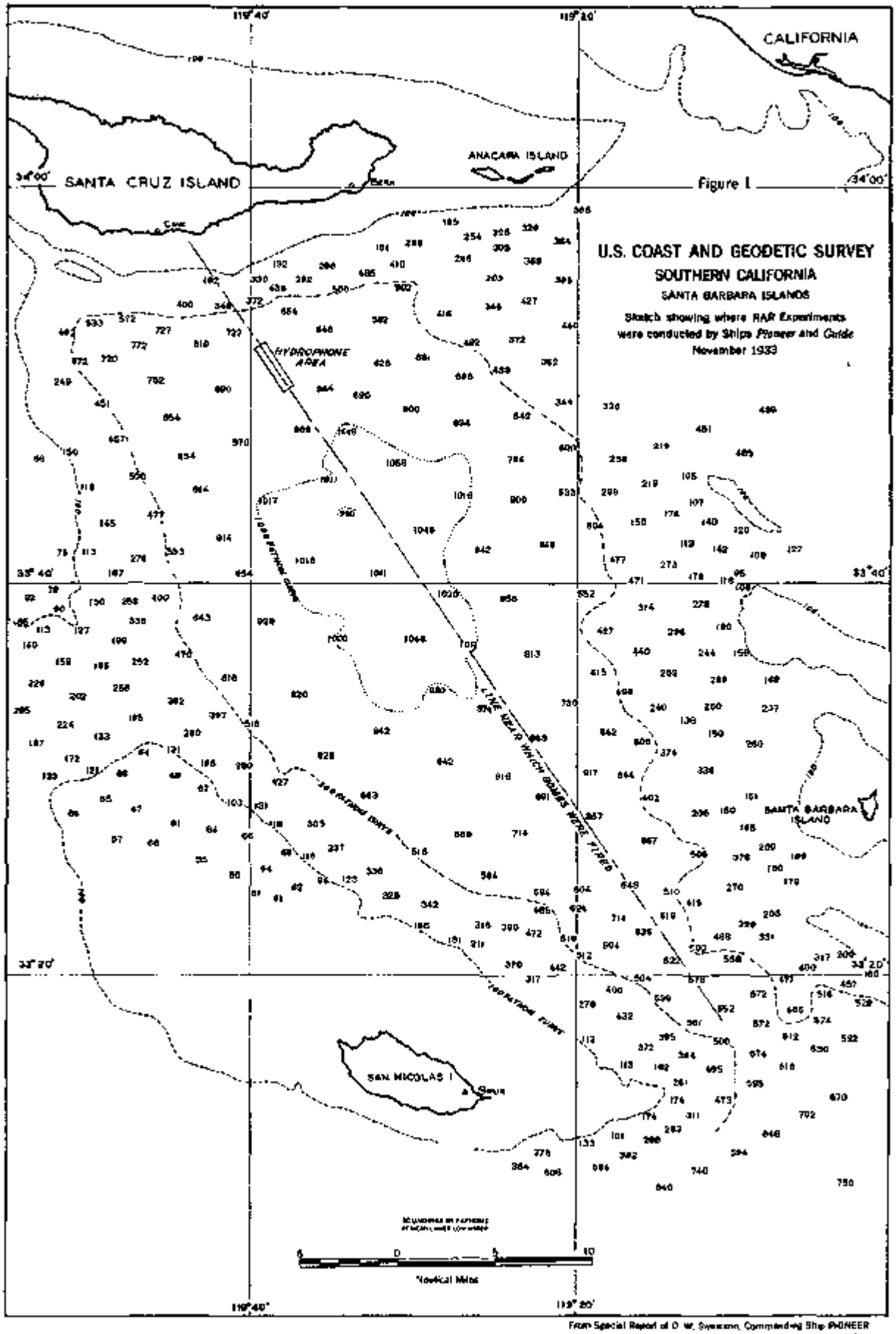
Pacific Coast, up to this time, had given varied and some confusing results. In November, 1933, the first conclusive evidence that the sound waves behaved in conformity with the well known physical laws of geometrical optics, was obtained by the Ship PIONEER under command of Lieutenant-Commander O. W. Swainson, U.S.C. & G.S., assisted by the Ship GUIDE in command of Lieutenant-Commander F. L. Peacock, U.S.C. & G.S. The details of these experiments and the data acquired are contained in Lieutenant-Commander Swainson's Special Report which has been published separately. A digest of this report follows, but for those who wish to study the results more carefully, the original report should be obtained,

These two vessels carried out a carefully planned program. Bombs were fired electrically by the GUIDE at various depths from sub-surface to 600 fathoms. The instant of detonation as well as the instant of explosion was transmitted to the PIONEER automatically by radio, and the arriving subaqueous impulses were recorded on a chronograph as actually done in radio acoustic work, and on an oscillograph from hydrophones at various depths between 30 and 850 fathoms. The GUIDE remained in one location, in deep water, while the PIONEER steamed away and took up stations at various distances approximately between 15 and 58 kilometers. The site selected for these experiments is ideal. It is a large submarine basin between the Santa Barbara Islands, over 1000 fathoms in depth, and due to the formation it should be free from submarine currents. (Incidentally, the temperature curve shows this basin effect, as is found in the Sulu Sea, Red Sea, and the Mediterranean. It will be noted that this curve follows the characteristic form down to 4.2° C, then is vertical below that temperature, which occurs at approximately 550 fathoms depth, the maximum depth of the rim of the basin. See Figures 1 and 2.) Observers at triangulation stations on the islands located the two ships at the instant of firing the bombs as well as at the instant of reception, using triangulation methods and radio communication. The program was arranged, and tests were made to eliminate effects of lag in the apparatus. Difficulties were encountered in firing bombs at depths, and the weather turned adverse, so that only 10 bombs were actually fired at great depths and two accurate distances between the ships determined. There were obtained, however, 140 oscillograms with synchronized chronograph records, and these have furnished a wealth of information. Dr. Karl Dyk, Seismologist, has analyzed these records and the resulting curves of his analysis are shown here. He has made two assumptions:

1. That the first arriving impulse registered on the oscillogram had travelled by reflected paths from bomb to hydrophone. Figure 3.

2. That the first arriving impulse registered on the oscillogram had travelled by diffraction paths down to the constant velocity layer at approximately 150 fathoms, and thence along it to the vicinity of the hydrophone. Figure 4.

The figures are self-explanatory. The full lines are the theoretical or computed paths obtained by using the profile of the bottom and simplified formulae for computing the travel distances by reflection of the wave in the water shell; and the plotted points are actual observations taken from the oscillogram records. Figure 3 shows the close agreement between computed curves and the observed points, and the results seem quite conclusive in confirming the first assumption, namely, that the first arriving impulse had travelled a reflection path. Dr. Dyk attributes some of the discrepancies found with the hydrophone at great depths to slight errors in the British Admiralty Tables of theoretical velocities which tables were used in computing the curves. Although this is a possible source of the error, there are many uncertainties that can be selected which are purely of an observational nature, e.g. errors of depth which will multiply the travel distance errors in proportion to the number of reflections; calibration errors in the fathometer used to determine the depths over which the experiments were made, and errors in wire soundings. Since the fathometer itself depends on the velocities, although the errors in depth are not of the same order, it is apparent that the absolute velocity will be difficult to determine experimentally. Wire soundings in great depths are hardly more accurate than sonic methods; indeed, I believe that our present sonic methods of depth measurement are more dependable and more accurate than the wire methods, due to the difficulty encountered in obtaining truly vertical casts with the wire. The pertinent plates and figures of Lieutenant-Commander Swainson's report are reproduced here with descriptive legends.



From Special Report of D. W. Swanson, Commanding Ship PIONEER
U. S. Coast and Geodetic Survey Print

Figure 10

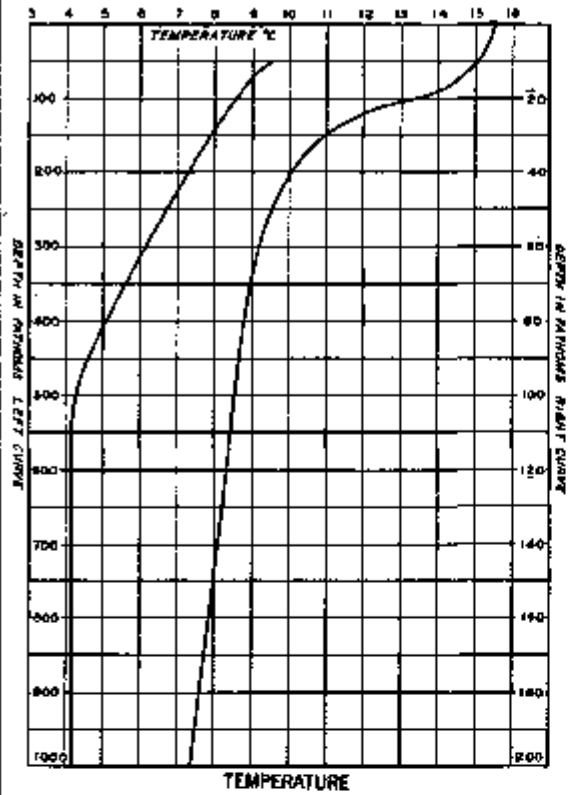


Figure 12

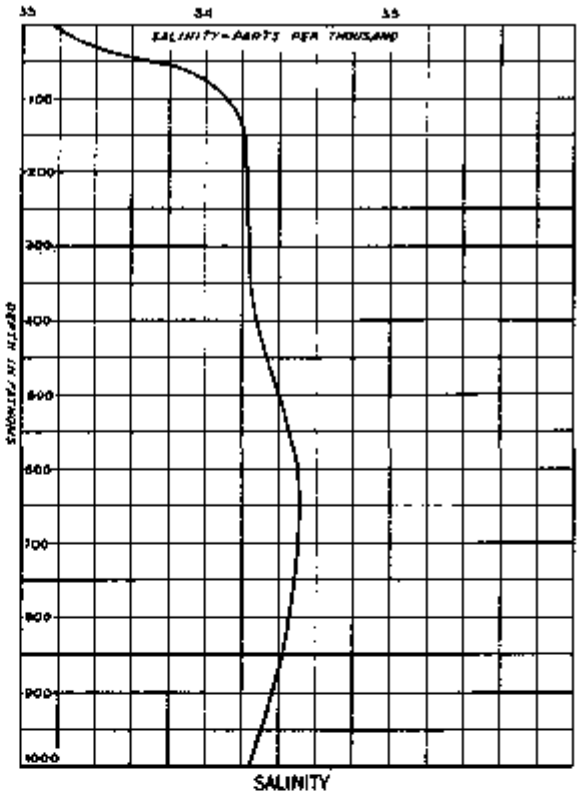
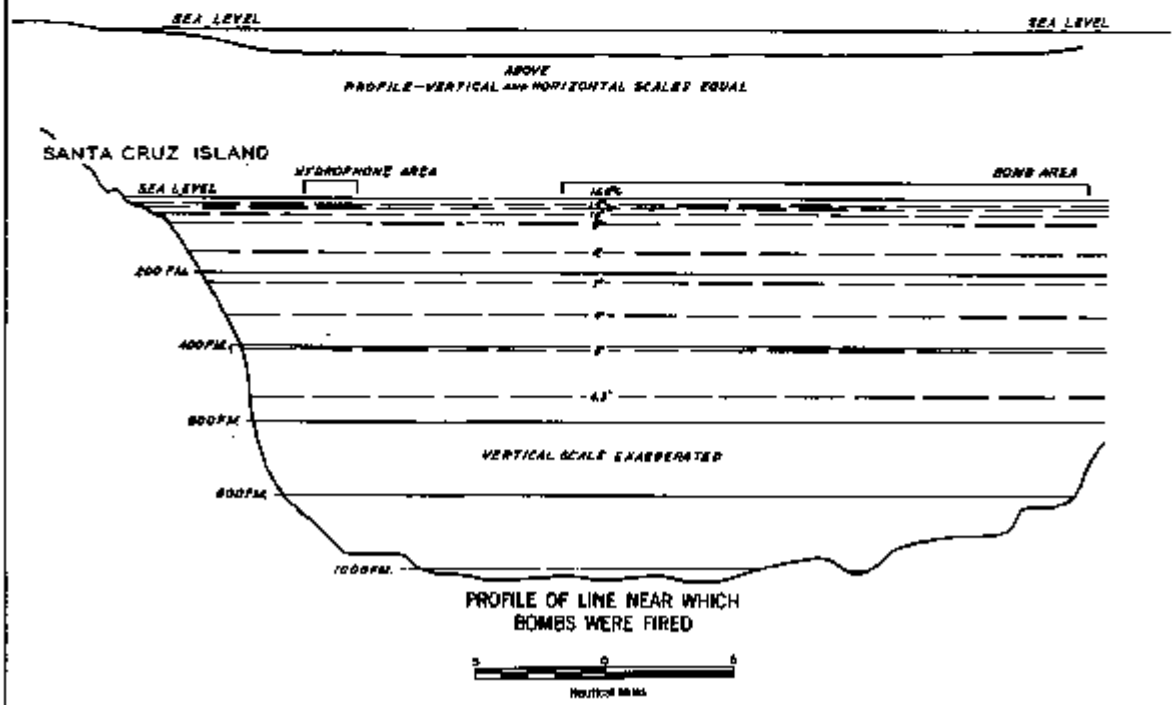


Figure 2



From Special Report of C. W. Swanson, Commanding S.S. PIONEER

U. S. Coast and Geodetic Survey Print

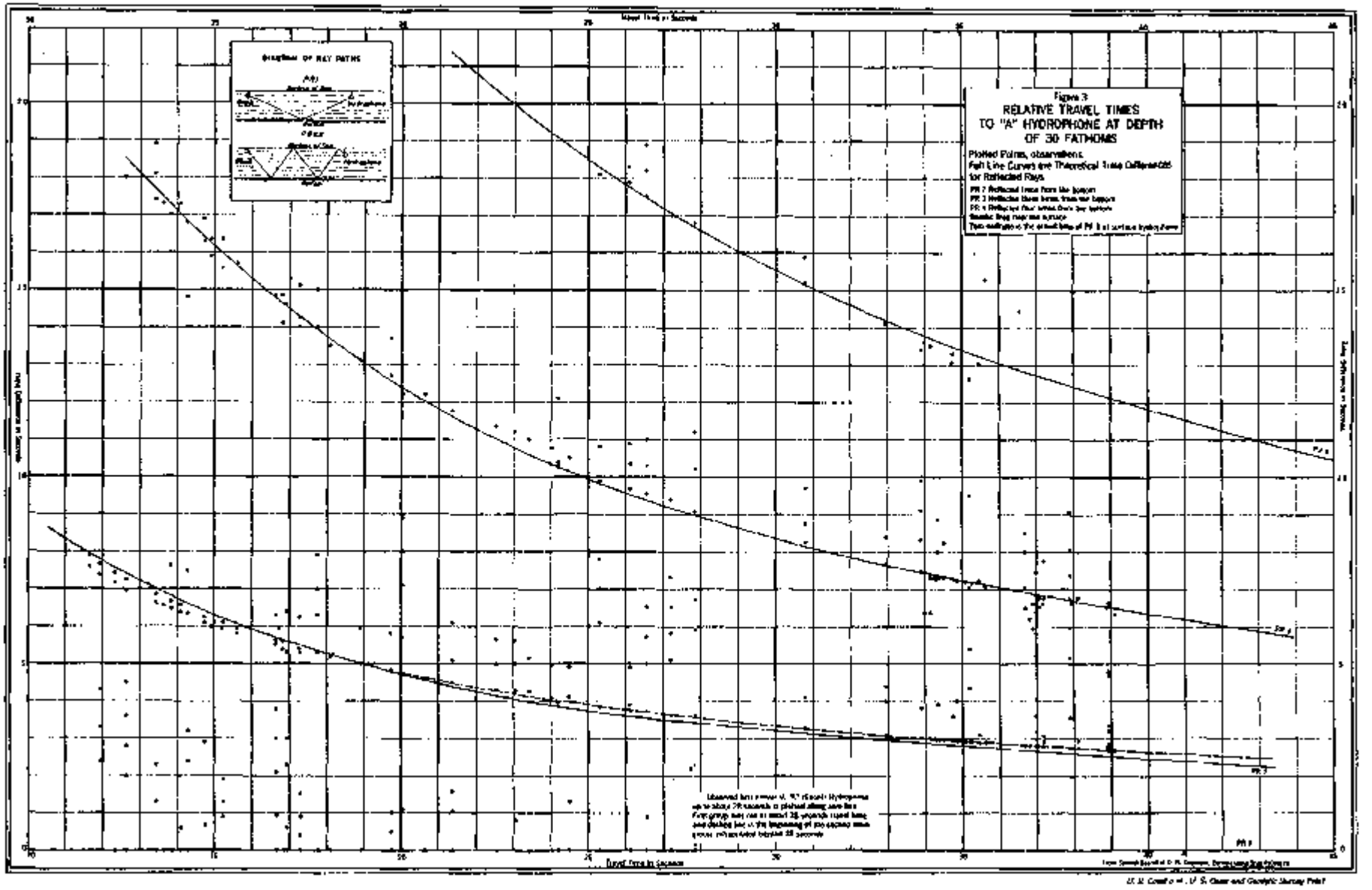


Figure 3
RELATIVE TRAVEL TIMES
TO "A" HYDROPHONE AT DEPTH
OF 30 FATHOMS
Plotted Points, observations.
Full Line Curves are Theoretical Time Differences for Reflected Rays.
DIAGRAM OF RAY PATHS
Travel Time in Seconds
Time Difference in Seconds

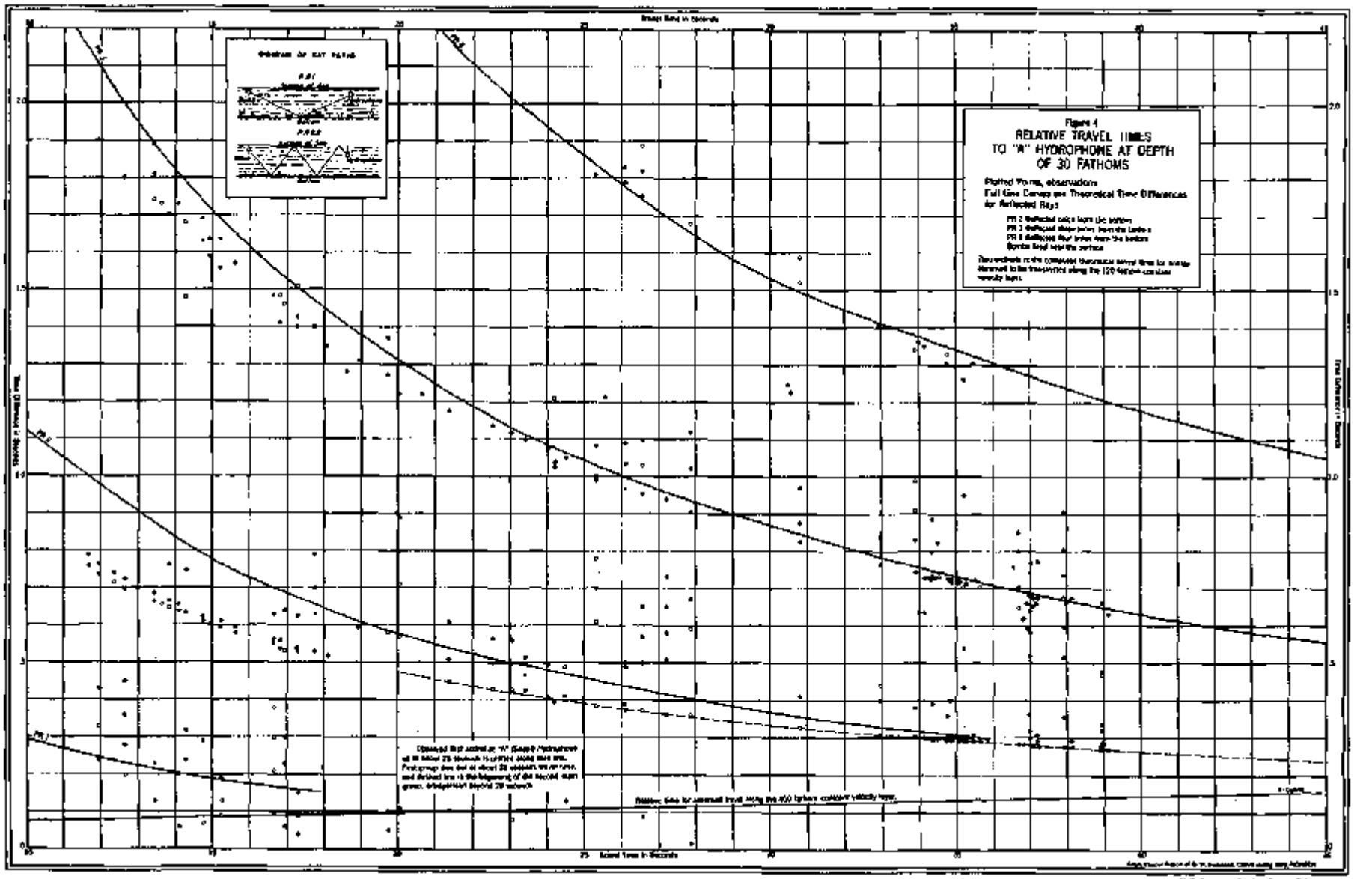


Figure 4
RELATIVE TRAVEL TIMES
TO "A" HYDROPHONE AT DEPTH
OF 30 FATHOMS
Time Difference in Seconds
Scaled Time in Seconds
U. S. Coast and Geodetic Survey

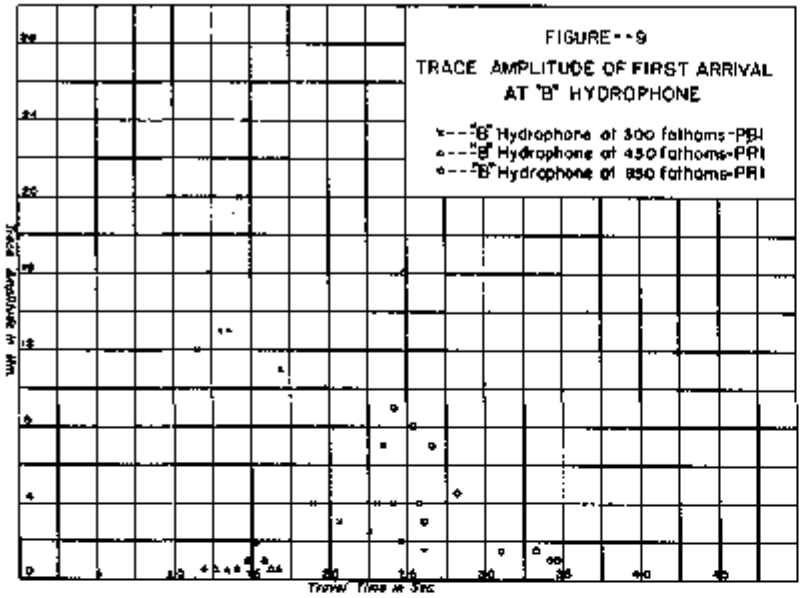


FIGURE--9
TRACE AMPLITUDE OF FIRST ARRIVAL AT "B" HYDROPHONE

x---"B" Hydrophone at 300 fathoms-PRI
o---"B" Hydrophone at 450 fathoms-PRI
◇---"B" Hydrophone at 850 fathoms-PRI

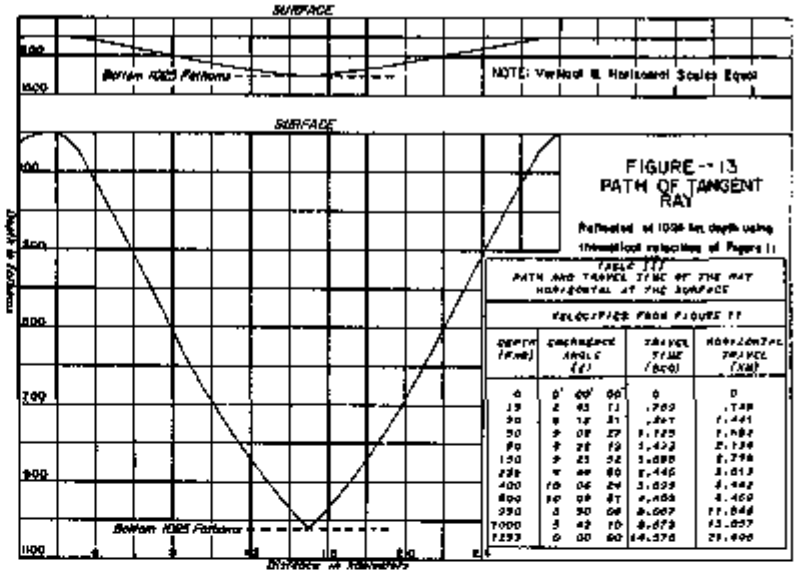


FIGURE--13
PATH OF TANGENT RAY

Reflected at 1025 fm. depth using theoretical velocities of Figure 11

TABLE III
PATH AND TRAVEL TIME OF THE RAY HORIZONTAL AT THE SURFACE

VELOCITIES FROM FIGURE 11

Depth (Fms)	Emergence Angle (ε)	Travel Time (Sec)	Horizontal Travel (Km)
0	0° 00' 00"	0	0
10	2 45 11	.700	.749
20	5 12 31	.867	1.441
30	7 08 27	1.125	1.982
40	8 28 19	1.422	2.134
150	9 23 52	1.688	2.798
200	9 49 00	1.446	3.013
400	10 06 24	3.039	4.442
600	10 09 47	4.466	4.469
850	8 30 08	6.067	11.846
1000	5 42 10	8.673	13.057
1293	0 00 00	14.576	21.496

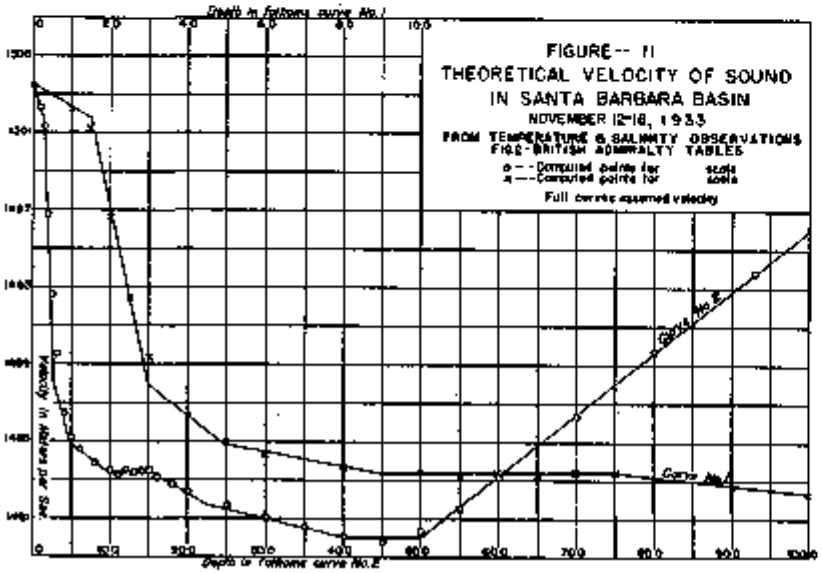


FIGURE-- 11
THEORETICAL VELOCITY OF SOUND IN SANTA BARBARA BASIN
NOVEMBER 12-16, 1933
FROM TEMPERATURE & SALINITY OBSERVATIONS FIGS-BRITISH ADMIRALTY TABLES

o---Computed points for scale
x---Computed points for scale

Full curves assumed velocity

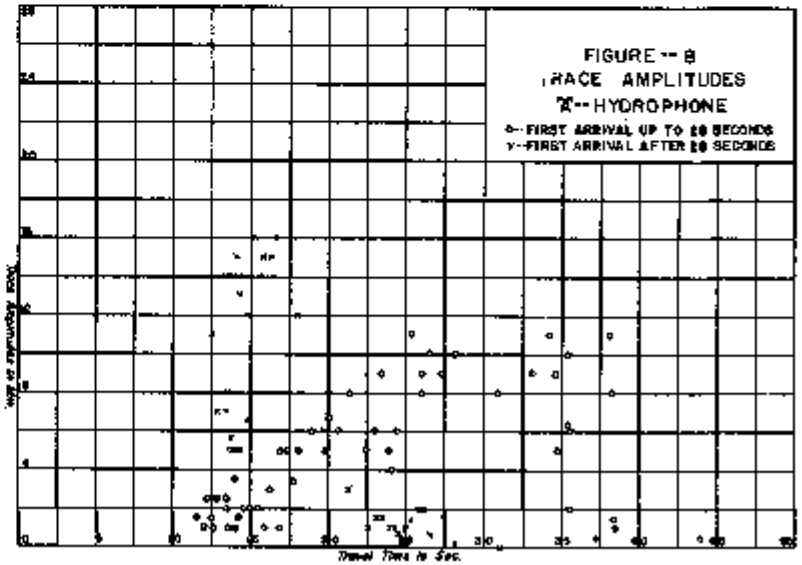
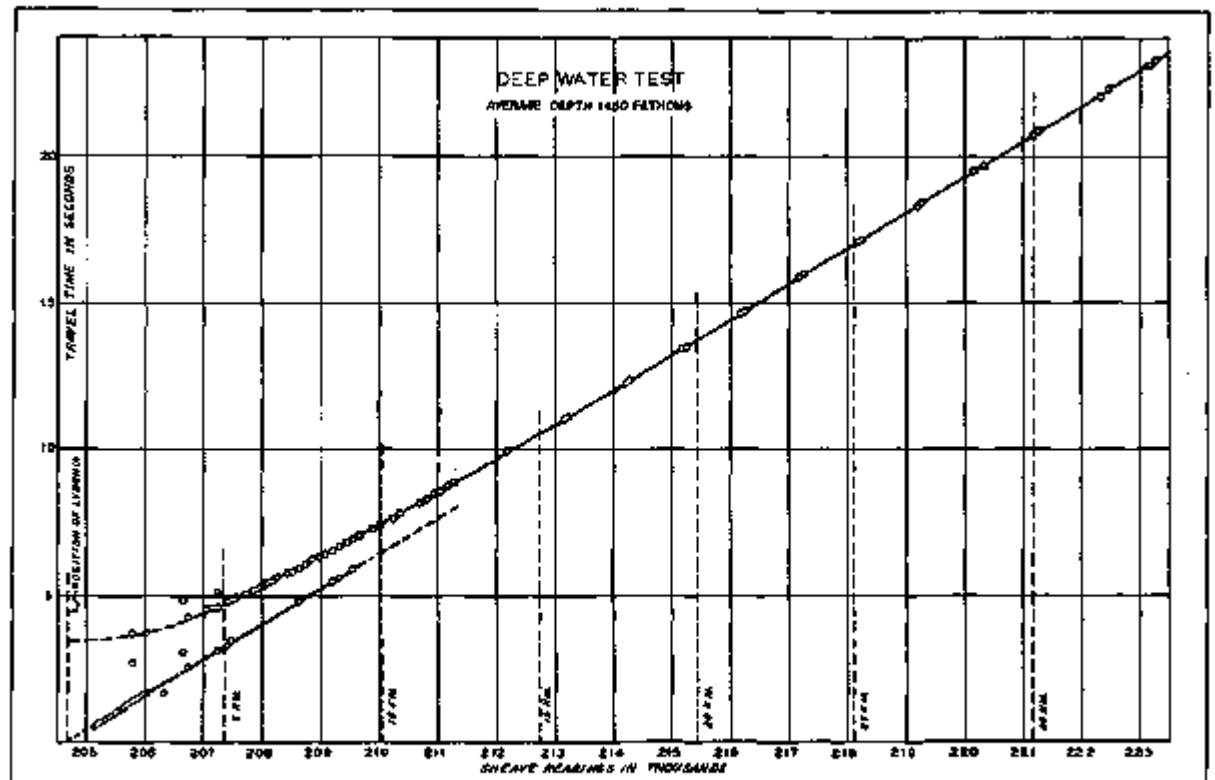
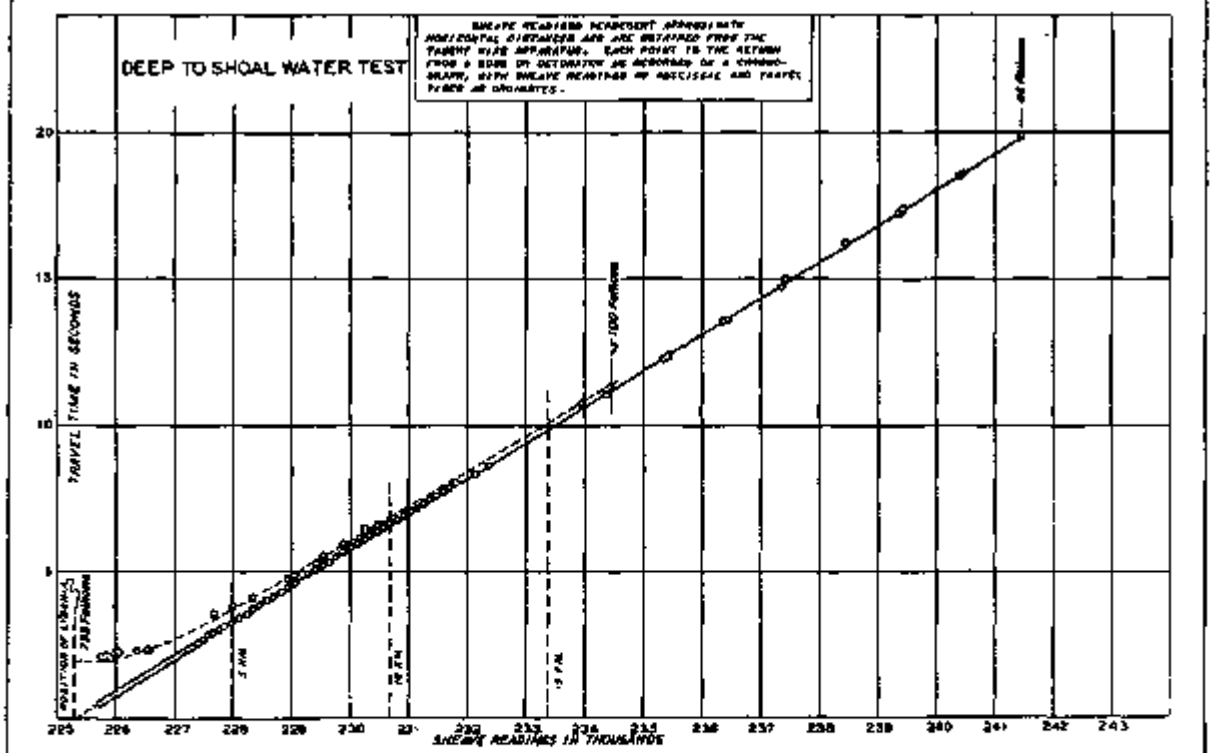


FIGURE--8
TRACE AMPLITUDES
"A"--HYDROPHONE

o--FIRST ARRIVAL UP TO 20 SECONDS
Y--FIRST ARRIVAL AFTER 20 SECONDS





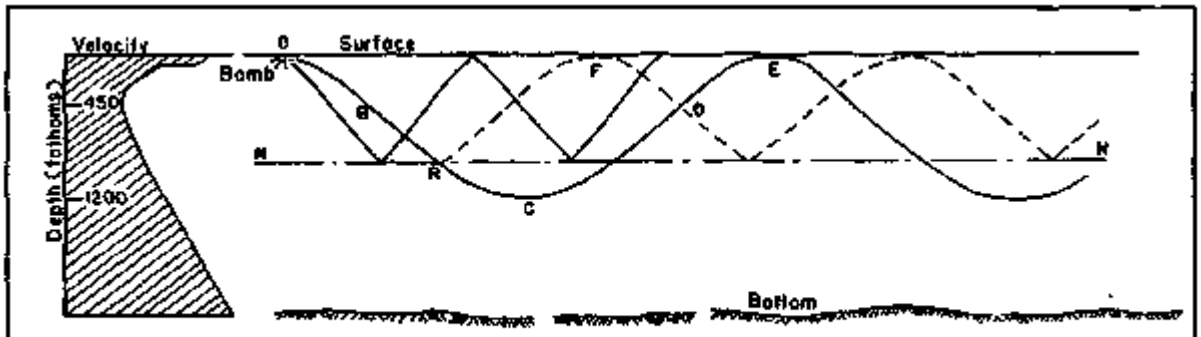
U S COAST & GEODETIC SURVEY
TRAVEL TIME CURVES
For
Radio Acoustic Experiments
Coast of Maryland
Ships: OCEANOGRAPHER, H A. Seron, Com'dg
LYDONIA, R.L.Schoope, Com'dg
May 22,23,1934

U.S. Coast and Geodetic Survey Print

We have additional confirmation of the results of the work of the PIONEER and the GUIDE in the work of the OCEANOGRAPHER (Commander H. A. Seran, USC&GS., Commanding) and the LYDONIA (Lieutenant-Commander R. L. Schoppe, USC&GS., Commanding) accomplished off the coast of Maryland in the spring of 1934. These latter tests, while they do not give absolute velocities, are excellent confirmation through an entirely different method, and in a different ocean of the results of the GUIDE and the PIONEER off the Pacific Coast. The data obtained by the OCEANOGRAPHER and the LYDONIA are shown in Figure 5. In these tests the OCEANOGRAPHER secured the end of the taut wire apparatus to the LYDONIA, and in an area where the depth averaged about 1450 fathoms, with uniform bottom, steamed away from the LYDONIA firing detonators and bombs at intervals of 30 seconds. In another case, the LYDONIA was left in deep water, approximately 800 fathoms, and the OCEANOGRAPHER proceeded in the same manner, running inshore to shoal water. This method was used to obtain results for plotting continuous travel time curves. In both eases, the wire was buoyed with pieces of wood, two by four inches by two feet in length which were fastened on the wire at intervals of about one-half mile. The shape of the curve assumed by the wire is doubtful, and for this reason the results cannot be used for velocity determinations. However, the results, which in this case were recorded only on a chronograph, show the possibilities that might occur in radio acoustic work, and in both tests. there is unmistakable evidence of returns from the first reflection, as well as from diffracted energy. In the all deep water test, the reflected wave apparently predominated, while in the deep to shoal test, the diffracted energy seemed to register throughout the run. This is significant in showing that we have as yet no sure method of predicting which may predominate.

These recent experiments all have been carried out in deep water, and the results are quite gratifying. Before attempting to explain why the theoretical bottom velocities agree so closely with the apparent velocity in shoal water, it might be well at this time to review some of the fundamental concepts of wave motion in an elastic medium. No originality is claimed for this discussion. These principles are simply set down here in brief form for the benefit of those, who possibly like myself have found the need to review the elements of physics to which one is exposed early in eduction, but which principles may have been dimmed by the press of other work. They will be found in any elementary text book on physics.[1]

We know from the fundamental laws of refraction that in the case of a longitudinal wave, or disturbance, traveling in a medium in which the elastic and inertia constants vary with the thickness, or in this case with the depth, the rays will be bent or refracted according to the changing velocity due to the changing constants of the medium. So, if we consider a source of wave motion at



The Propagation of Sound in Deep Sea Water

Figure 6

point 0, Figure 6, at the surface of the sea for instance, the spherical compressional wave will start outward in all directions. As we are primarily interested in that energy which remains in the water, the source will be assumed to lie just below the surface, and we will consider only the energy which remains in the water. The rays of the wave which start vertically downward will of course suffer no re-

[1] Physics for Colleges, Sheldon, Kent, Paton, and Miller.

fraction. Let us trace the limiting ray, the one which starts parallel to the surface. It will be curved downward while the velocity in the medium is decreasing, or in the case of the sea, to the point B, at approximately 450 fathoms depth where a constant velocity layer is found. As the velocity below this point is increasing with the depth, the ray will be refracted upward, and with sufficiently deep water will eventually reach a point where it is again parallel to the surface at C. From the point C, the path will be an image of the path between O and C, for the ray will continue to be refracted upward until it again reaches the constant velocity layer at 450 fathoms (point D), and from D to E it will be refracted downward until it reaches the surface at E where it is again parallel and tangent to the surface. Since the horizontal ray of the wave, for a source at the surface will be the limiting ray of the wave under consideration, it has been referred to as the limiting or tangent ray. The path of this tangent ray is the upper boundary of the parent wave, and is the boundary of the energy traveling on least time paths from point O to any point in the medium to the right of the curve O, B, C. For example, in Figure 6, neglecting diffraction, energy would arrive at point D first by way of the path O, B, C, D, and not by a straight line directly from O to D because the original ray was taken as horizontal. This limiting or tangent ray of course does not constitute a definite boundary, and there is some energy radiated from the parent wave at all points along the tangent ray, or the edge of the wave. Such a spreading of waves from the edge of a wave front is called diffraction. Although the diffracted energy should be weak in comparison with the energy in the parent wave, it is generally strong enough in our problem to complicate matters considerably, as has been noted previously. If the bottom of the sea is at less depth than the depth for complete refraction, reflection will occur. Consider a case, Figure 6, where the bottom is assumed horizontal at N, N. In this case the ray will be reflected at point R, and that section of the ray from R to F will be an image of that from O to R. When reflection occurs at the bottom, the waves that have been reflected only once from the bottom should not be observed at the surface beyond the point F where the tangent ray returns to the surface because this ray is again refracted downward and the path beyond point F is a duplication of this first route. Any energy, except diffracted energy, observed at the surface between points O and F would have arrived by reflection from the bottom. This is what appears on the oscillograms in the experiments of the PIONEER. See Oscillograms Numbers 147 to 152, lower trace. The first reflection, PR 1, becomes very faint on number 149 and disappears completely on number 150 at about 28 seconds travel time. On the same oscillograms, PR2, the second reflection maintains its amplitude through this distance. Dr. Dyk has computed a theoretical path for the tangent ray, Figure 13, and shows that for the depth in which the experiments were made this 28 seconds travel time represents the distance at which the tangent ray will return to the surface. Actually, the difference between a straight line and the theoretical curved path is negligible, so for purposes of computing the travel distances, straight line paths can be assumed without appreciable error.

It is interesting in reviewing the foregoing theory of wave travel in deep water to compare a similar instance in the air where the same theory was applied by a number of physicists. A large ammunition dump exploded at Oldebroek, Holland, in January 1923, and the sound was heard at various distances between 100 and 500 miles, but was not detected between 60 and 100 miles of the explosion. Records of such explosions at long distances show no trace of the audible frequencies which would be the noise of the explosion, but show a pulsation in pressure of about 1 cycle per second.[1] In the case of a meteor which exploded at a height determined to be between 30 and 40 kilometers (20 to 25 miles) a sound similar to thunder was heard up to 60 or 70 kilometers, and was inaudible between 60 and 160 kilometers, after which it was again audible over another zone. F. J. W. Whipple explained this occurrence by a hypothesis similar to the theory used in the under water transmission of sound. His diagram is reproduced here.[2]

Wood explains this phenomenon in air as follows: "The direct wave is steadily attenuated in its passage over the earth's surface, and at an average distance of about 60 miles becomes inaudible. The sound waves reaching the outer zone of audibility appear to have travelled with an abnormally low velocity, but this is not the case. Actually, the sound heard in this zone has travelled by an abnormally long path, via the higher atmosphere and ultimately

[1] A Textbook of Sound - Wood, p. 334.

[2] A Textbook of Sound, Wood, p. 334, and Monthly Notices R. A. S. p. 89, Oct. 1928.

UPPER TRACE B HYDROPHONE
LOWER TRACE A HYDROPHONE

#147 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME 28.10 SEC.

#146 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME 28.7777 SEC.

#148 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME [illegible] SEC.

#149 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME [illegible] SEC.

#150 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME 29 SEC. CA.

#151 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME 30 SEC. CA.

#152 DEPTH A 30 FMS. DEPTH B 850 FMS. TRAVEL TIME 31.02 SEC.

Oscillograph record showing fading out of first reflection at about 28 seconds.

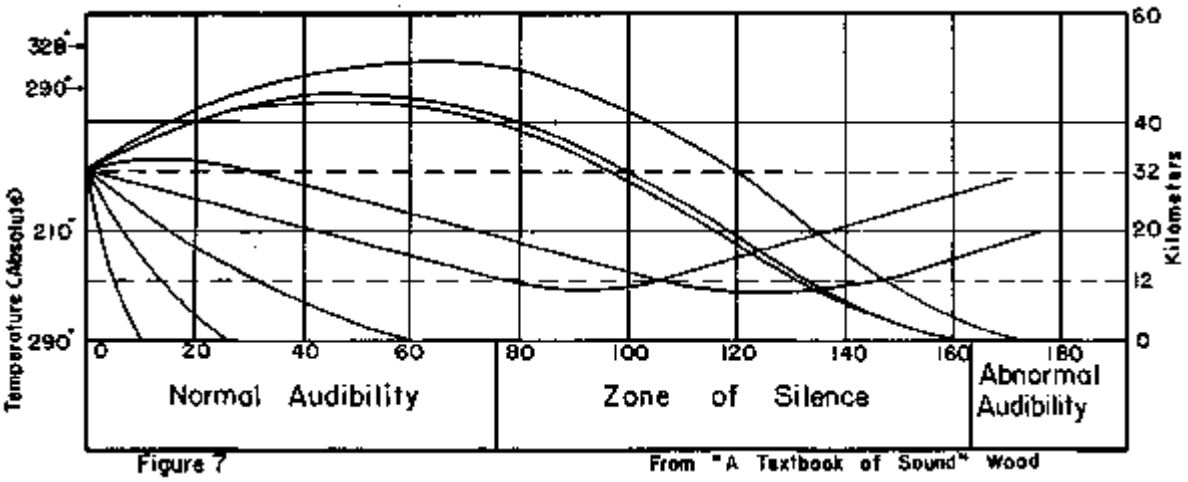


Figure 7 From "A Textbook of Sound" Wood

down to the ground again. There is some divergence of opinion as to the actual mechanism of this abnormal wave, whether it is bent downwards into the outer audible zone by refraction (due to air currents and temperature gradients) or whether it is reflected from a layer of the stratosphere 30 kilometers or more from the ground, at which level the velocity of sound increases with height. The effects doubtless arise as the result of the peculiar meteorological conditions at the time of the explosion."[1]

In our experiments with sound in water we are fortunate in that we are able to determine the physical constants of the medium with considerably more accuracy than we can in the air. The depth of the sea defines the lower reflecting surface, so there are not the unknowns in the problem that there are in the case of sound travel in the atmosphere. It is true the temperatures and salinities vary from place to place and from season to season. This seasonal change is more pronounced in shoal areas of considerable extent than in the oceans of great depths, but the effect of this seasonal change is predictable with more accuracy than is necessary for the present needs.[2]

The agreement of the theoretical velocities for bottom conditions with the apparent horizontal velocity[3] is explainable by this same theory. The depth of the point C, Figure 6, will, of course, vary with the variations in velocity, but it is at approximately 1200 fathoms in the region of the PIONEER'S experiment. If the depth is of the order of 30 fathoms, it can be seen that the tangent ray will fix the minimum number of reflections possible, and at such shoal depths the angle of emergence at F will be very small, about 6 degrees or less. This is an ideal condition for reflection of energy; i. e., there will be very little loss of energy at the bottom, if the bottom is uniform and smooth, and practically total reflection at the surface. The bottom velocity in shoal depths is generally less than at the surface, and as a wave travels by these numerous reflections, hence by a longer route than the true horizontal distance, it has an apparent velocity that is lower than the average velocity as obtained from temperatures and salinities. It so happens that the velocity gradient in shoal depths is related to the distances by reflection in such a manner that within limits the bottom velocity is close to the apparent horizontal velocity.

As an example of the number of reflections that would occur in a case where the depth is approximately 30 fathoms, the runs made by the OCEANOGRAPHER and the LYDONIA in 1933 are taken. (The term "apparent horizontal velocity" is used throughout the article to describe the velocity obtained by dividing the horizontal distance between bomb and hydrophone by the elapsed time between the explosion of the bomb and the reception by the hydrophone.)

Averaging the returns used from the LYD0NIA[4] gives a mean distance of 24,131 meters as the horizontal distance, and a mean travel time of 16.34 seconds.

[1] See Wood - A Textbook of Sound p. 333.

[2] See Field Engineers Bulletin, USC&GS, No. 5, p. 37, T.B. Reed. Theoretical Velocity of Sound in Sea Water and the Practical Use in R.A.R. Hydrography.

[3] Loc. Cit.

[4] See page 119 Field Engineers Bulletin No.7. Velocity of Sound in Sea Water, T.B. Reed.

The average theoretical velocity for the mean depth of 25 fathoms (46 meters) is 1485 meters per second. From these data the distance the sound must have travelled in the water would have been 24,264 meters, or a distance of 133 meters greater than the true horizontal distance. If it travelled by reflections, there would have to be about 28 reflections from the bottom, and 27 reflections from the surface to account for this difference. If this were the case, the first reflection would have been 430 meters horizontal distance from the source and the emergence angle would be about 6°. This distance seems logical, for the tangent ray, according to Dyk's results, would strike the bottom at a horizontal distance of about 670 meters, and the energy which would be carried through a large number of reflections would probably be transmitted by that part of the wave which was reflected from the bottom a short distance ahead of the tangent ray. It may be argued that there is not sufficient energy to stand the losses of the large number of reflections assumed in this case, but when the amount of energy in a half pint of TNT is known to be approximately 660,000 foot pounds, (900,000 kw. for .001 sec), and the 1000 cycle oscillator for a type 312 Fathometer transmits only about 0.2 kw. into the water, it is not unreasonable to believe that so many reflections are possible and quite probable. In some cases such a small amount of energy as developed by the oscillator mentioned has given as many as 13 reflections in 100 fathoms. In the latter case (soundings) the angle of incidence is 0° which is a condition for greatest loss by reflection. There are complicating conditions affecting reflection of compressional waves at varying angles of incidence on surfaces between media of different densities, as between the water and sea bottom, and water and air; due to the lack of data on these factors, we can consider the problem only qualitatively. In this particular case where the sound waves are confined between reflecting surfaces, the usual rate of decrease in intensity is reduced.[1] From the literature of seismology it would appear that an angle of incidence of the order resulting in the above case, namely 84°, would be close to the optimum condition for maximum reflected energy. Another important consideration in the amount of energy transferred by reflection is the relation between the wave length and the irregularities of the reflecting surfaces. The effective frequency of a bomb is undoubtedly low, of the order of 5 to 30 cycles probably, and the wave length will consequently be long in proportion to the irregularities of the sea bottom and the sea surface, which fact also contributes to greater efficiency of reflection. It can be shown that the range of transmission in water will vary inversely as the square of the frequency, and apparently there is also less loss due to heat conduction at the lower frequencies.

Dr. Herbert Grove Dorsey, Principal Electrical Engineer, USC&GS, makes the following comments about the frequencies of bombs under water:

"It is my belief that the frequency of the bomb which actually does the work is rather low, and I would not be surprised but what the frequency may be less than 150 cycles per second. One reason for thinking this is that you can put a condenser across the input circuit from the hydrophone and still get the bomb returns. I have had the operators on the HYDROGRAPHER try different amounts of capacity across the input circuits, then use the same capacity across the same kind of hydrophone during the laboratory tests for measuring the inductance, computing the higher frequencies which would easily come through the combination. By this method I have had them put as much as 4 microfarads across the input to the amplifier using the Baldwin unit in the magnetophone. This combination indicates that the frequencies are probably less than 150 cycles per second.

"I believe that the really effective part of the bomb explosion for our work is just a shove in the water. Of course, by Fourier's theorem, all frequencies must be present from zero to infinity. The higher frequencies undoubtedly are damped out very quickly and the lower frequencies get through more readily. Water noises, such as are made by the waves of the beach, ship noises, et cetera, are probably between 100 and 2000 cycles per second. If the lower frequencies are effective, and especially if they are more effective than the high frequencies, then by using a direct current amplifier we could easily cut out the higher frequencies and still allow the lower frequencies to comethrough and be correctly amplified. By cutting out the higher frequencies, we elimi-

1 Textbook of sound, p. 317, Wood.

nate a large part of the water noises. We had a good example of this on the HYDROGRAPHER when they got out to about 100 fathoms and in the Gulf of Mexico, they heard a peculiar noise in the water at a rather high frequency. It was so bad that they just couldn't do RAR when this noise was at its height, which seemed to be about two o'clock in the afternoon. At my suggestion, they put a condenser across the input and they began to get better results which, of course, was very encouraging. Their standard input circuit includes two microfarads across the input transformer and while this eliminates so much of the water noise that they hang the hydrophone over the side of the launch, they still get the bomb sounds just as easily as before."

The oscillograms of the PIONEER'S experiments show high frequencies, of the order of 170 to 500 cycles or more, but these may be the natural frequencies of the hydrophone diaphragms as mentioned in Commander Swainson's report. On most of these oscillograms there appears to be some interference of frequencies which results in decided nodes and an underlying frequency was suspected. Mr. Frank Neumann, Seismologist, USC&GS has recently had considerable success in analysing seismograms by precise integration, to obtain the displacement curves from the acceleration curves given by an accelerometer having a considerably higher natural frequency than the frequency of the seismic wave.1 Since the suspected bomb frequencies in radio acoustic ranging might be many times less than the resonant frequency of the hydrophone, Mr. Neumann suggested that one of these oscillograms be analysed by his method. This he did, and uncovered a frequency of about 2 per second, and one of about 20 per second, from the particular trace selected. These results are subject to considerable doubt, due to the mechanical structure of the oscillograph used, and it appears that the frequency of 2 per second may be the frequency at which Dr. McIlwraith turned the crank on the camera of the oscillograph, resulting in small flexures of this frequency between the wires of the oscillograph and the film of the camera!

In the future, oscillograms will be made with precautions taken to permit analysis by Mr. Newmann's method, as it may be possible to determine valuable information from the integrated curves.

It might be mentioned that in case magnetophones are used to receive the wave, the resulting curve is probably a velocity curve rather than an acceleration curve, so that a single integration should give a displacement curve. In the case of a carbon button hydrophone, where the impulse transmitted to the amplifier depends on a change in resistance with the motion of the carbon particles, the curve given is probably an acceleration curve, and would then require two integrations to give the displacement.

Another important point in practical radio acoustic ranging is the fact that sources of small intensity and large area are likely to be more efficient than sources of great intensity and small area, because of the serious attenuation of waves of large amplitude. This may partly explain why occasionally it has been possible to record a wave from an ordinary detonator when a larger charge of TNT would not get through.

The two recent tests, the one on the Pacific Coast for which we have oscillograms, and the one on the Atlantic Coast showing the travel time curves to be returns from reflected waves, are sufficient evidence to plan additional experiments for the purpose of finding a practicable method to increase the accuracy of RAR methods and to eliminate some of the small errors in the present methods.

The practical problems of correlating these investigations with actual work are:

1. To determine some method for fixing the apparent velocity to be used in a given area.

2. To determine theoretical velocities more accurately.

3. To find, if possible more economical and efficient methods for radio acoustic ranging.

[1] Analysis of Strong Motion Seismograph Records of the Western Nevada Earthquake of January 30, 1934, with Description of a Method of Analysing Seismograms by Precise Integration,

Our present chronographic record does not permit determining which wave is being recorded, so that it becomes necessary first to fix in some manner this fact. There is also diffraction to be considered, and this is an important factor, especially over short distances. The use of accurate logs combined with profiles of the bottom between the bomb and the hydrophone might indicate when the apparent velocity should be changed. It is of first importance that we be able to recognize in deep water which reflection is recorded, and I believe additional tests should be made with the purpose of acquiring more information on this point. Although it is desirable to increase our knowledge of the theoretical velocities, it is not necessary that the absolute velocity be known in order to increase the accuracy of RAR methods, provided a way can be found to predict the apparent velocity more accurately and to recognize the various reflections when they arrive. With this in mind I believe that a test should be made simulating actual conditions by obtaining oscillograms of the returns received on a hydrophone in shoal water from a series of bombs fired from a ship which steams directly off shore from the magnetophone, into deep water, obtaining a true profile of the bottom as the run is made. By firing the bombs at frequent intervals, similar to the way they were fired in the test described in Commander Seran's report, and obtaining simultaneous chronograph and oscillograph records of each return, it may be possible to devise a way to identify which impulse is recorded by the chronograph; a way to correct the various returns to give the true horizontal distances, and possibly to revise our instrumental equipment. In the test suggested, the ship should, of course, obtain visual positions during the entire run, as well as temperature and salinity data. In a travel time curve thus obtained, the apparent horizontal velocity is given by the slope of the curve, and this relation might be used to advantage.

If it be desired to confirm (or disprove) the accuracy of our present theoretical velocity tables, it should not be attempted by lowering bomb and hydrophone to great depths, for there are no reliable means by which we can determine with sufficient accuracy for this purpose the horizontal position of an object when it is lowered from a ship drifting on the surface, and subject to the vagaries of the wind and currents. Rather it would be better to select a site free from deep currents, and where the bottom is very uniform and smooth; then keep both bomb and hydrophone near the surface, so that their true positions may be obtained with accuracy.

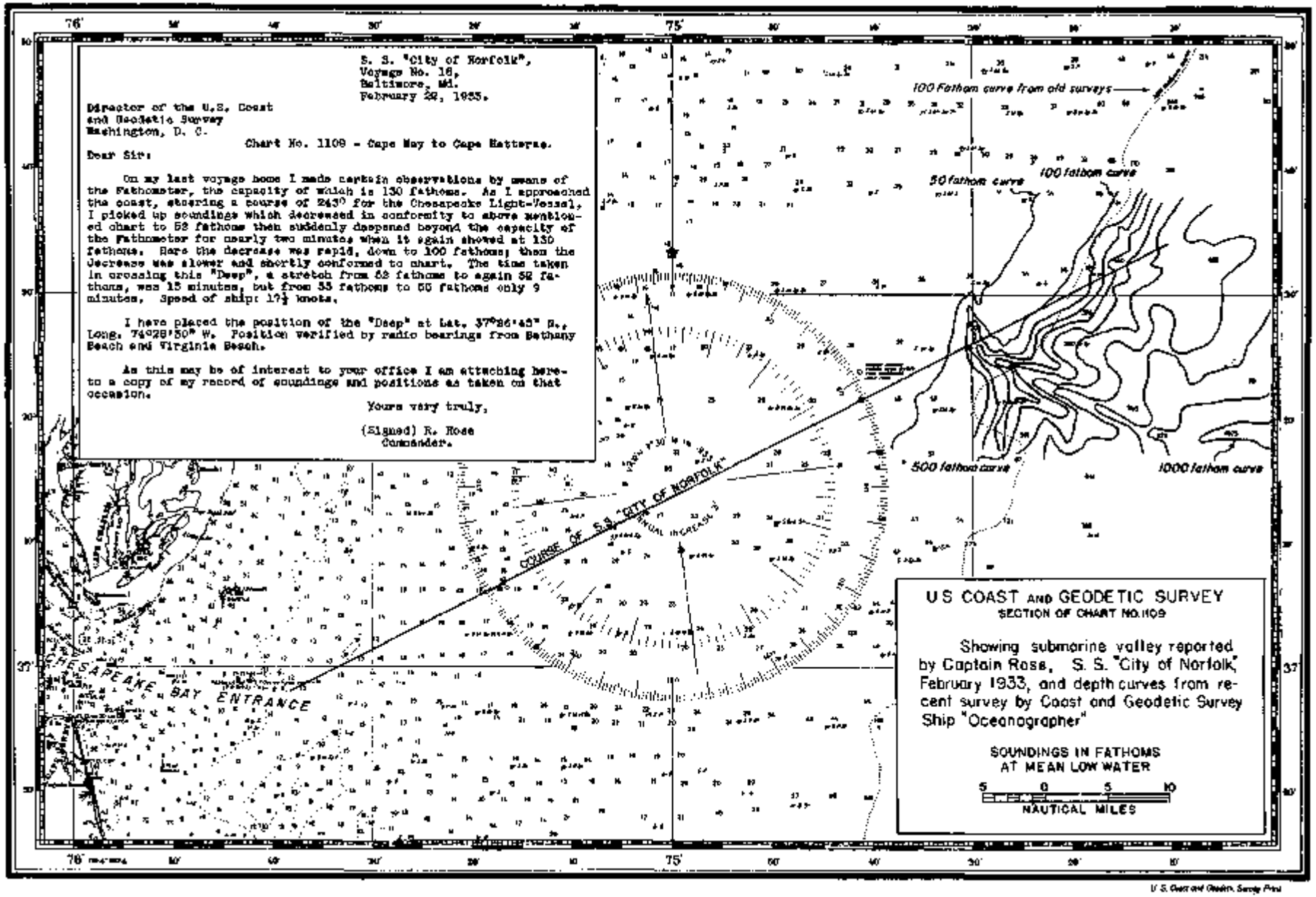
In the meantime, hydrographic parties operating in deep water should understand this source of error in radio acoustic ranging, and by study of the RAR positions obtained, in the light of our recent discoveries, attempt to use such apparent velocities as will give most nearly the true positions of the bombs. Additional experiments are planned and are probably being carried out at this time by the Ship PIONEER, for the purpose of increasing the accuracy of radio acoustic ranging in deep water. This will affect in no way the present practice of using the theoretical velocities for the bottom temperatures in depths less than about 300 fathoms, as the accuracy of this relation has been confirmed.[1]

[1] Velocity of Sound in Sea Water, T. B. Reed - Field Engineers Bulletin No. 7, July 1934.

ANOTHER USE FOR SOUNDING ALARM CLOCKS

A note from Commanding Officer, Ship PIONEER, states that the hydrographic sounding alarm clock is used also for giving the time interval to blow the fog whistle while under way in thick weather. A Bronx high frequency buzzer was substituted for the bell.

Such a luxury recalls the story of the old wind jammer skipper who was caught in the English Channel in a fog without a fog horn. Being one of great resource and quick of wit, he gave orders to put one of the live pigs, which were always carried in those days, up on the bow; and whenever another ship was heard, the unfortunate pig was given a liberal baptism with scalding hot water - and, according to the story - with most satisfactory results.



S. S. "City of Norfolk",
Voyage No. 16,
Baltimore, Md.
February 22, 1933.

Director of the U.S. Coast
and Geodetic Survey
Washington, D. C.

Chart No. 1109 - Cape May to Cape Hatteras.

Dear Sir:

On my last voyage home I made certain observations by means of the Fathometer, the capacity of which is 130 fathoms. As I approached the coast, steering a course of 243° for the Chesapeake Light-Vessel, I picked up soundings which decreased in conformity to above mentioned chart to 52 fathoms then suddenly deepened beyond the capacity of the Fathometer for nearly two minutes when it again showed at 130 fathoms. Here the decrease was rapid, down to 100 fathoms; then the decrease was slower and shortly conformed to chart. The time taken in crossing this "Deep", a stretch from 52 fathoms to again 52 fathoms, was 15 minutes, but from 55 fathoms to 50 fathoms only 9 minutes. Speed of ship: 17½ knots.

I have placed the position of the "Deep" at Lat. 37°26'45" N., Long. 74°28'50" W. Position verified by radio bearings from Bethany Beach and Virginia Beach.

As this may be of interest to your office I am attaching hereto a copy of my record of soundings and positions as taken on that occasion.

Yours very truly,

(Signed) R. Rose
Commander.

U. S. Coast and Geodetic Survey Print

NATURAL RESOURCES

Extract from "Resurveying the Coast of Connecticut" by William Bowie at the 50th Annual Meeting, Connecticut Society of Civil Engineers, New Haven, February 21, 1954.

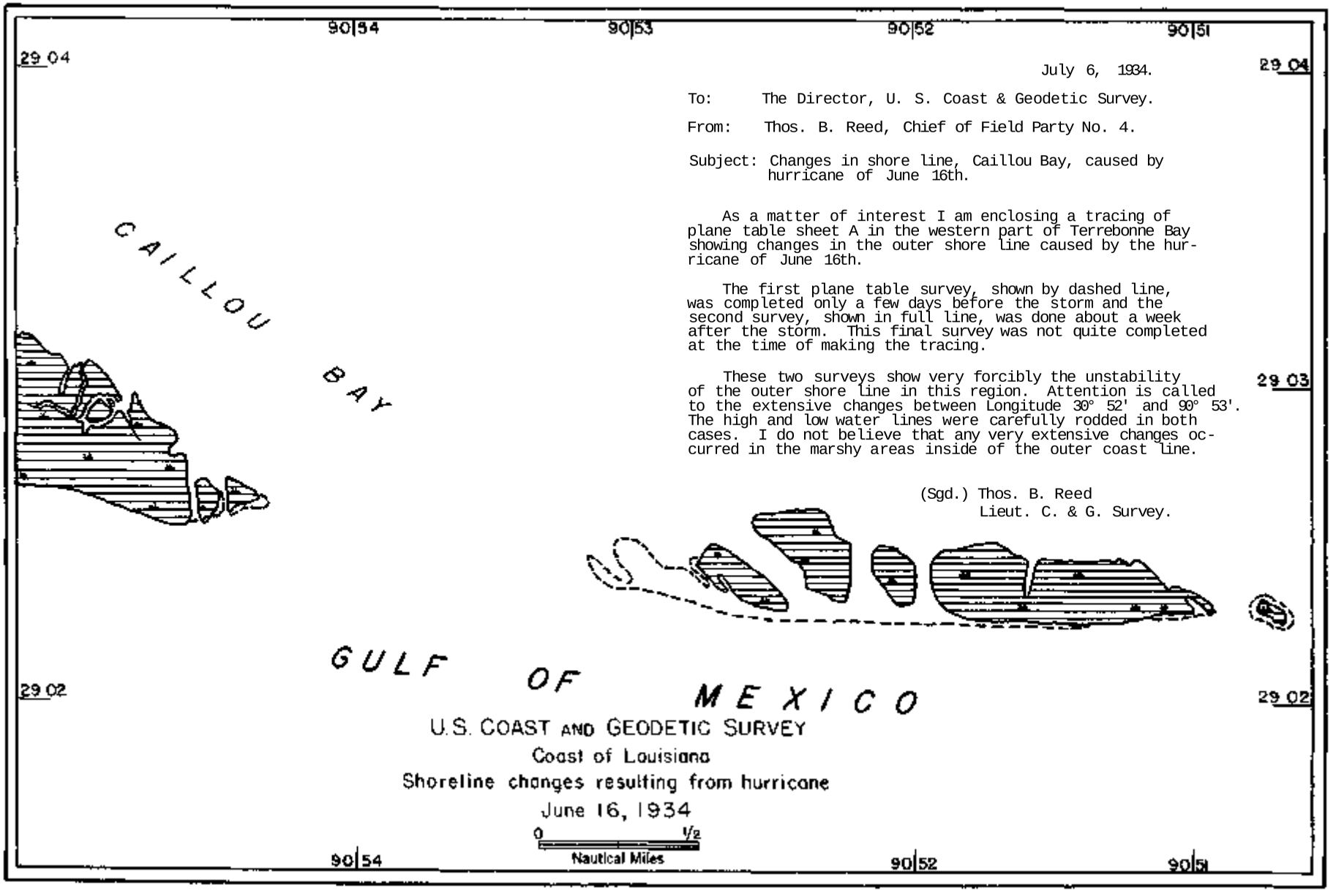
We should consider that we of this generation have inherited this country from our ancestors. It consists of three millions of square miles of area with all the natural resources contained therein. We are not acting as wise inheritors. We are wasting much of our inheritance and we do not really know what our inheritance is. It seems to me that the first thing we should do is to map our area and then make intensive and complete surveys of our natural resources. The resources should be indicated on a series of maps. We should protect these resources and hand them down to the next generation as little impaired as possible. Our descendants will curse us if we deplete this country of the things that are needed for human life and happiness. They will bless us and praise us if we act wisely and give them an inheritance that is worth while.

The natural resources consist of our soil, our forests, our mineral and oil resources, our climate, and other things. Even the beauty of natural scenery is an inheritance that is well worth preserving. We are letting our soil wash down into the valleys and streams. We let our forests burn. We are trying to pump out all the oil that this country has, and we are no doubt wasting much of our mineral resources. Let us change our ways and do things better from now on than we have done in the past.

If we had good maps of our entire area and complete knowledge of our natural resources, we would be able to make super-plans or any other kinds of plans that might be desirable for our various lines of activity and then we could carry these plans out with some degree of success. President Roosevelt is now advocating planning for the future along many lines of endeavor, and I am sure that his plans will be more effective if we can speed up the mapping and also speed up the surveys of our natural resources.

In this public work, involving the surveying and mapping of the country, the Government, through the Coast and Geodetic Survey, and the Topographical Branch of the Geological Survey, is anxious to do its part but there must be sentiment in favor of such work for otherwise funds will not be forthcoming for it. In addition, we hope that the states will also do their part. This may involve merely the supplementing of the control surveys by the running of many thousands of miles of traverse and leveling. With this supplementary work and the many schemes of local control survey, we shall eventually have objects at frequent intervals all over the country from which surveys for engineering and other work can be started. I have in mind that eventually every farm boundary and the boundary of every city lot will be tied into the horizontal control system. Of course, we should have the boundaries of our states, counties, townships and cities accurately surveyed.

The time has long since passed when surveying and mapping were considered non-engineering activities. Years ago surveying was done with the Jacobs Staff and the Gunters Chain. These were crude affairs but they were quite adequate for surveying private and public property when land was plentiful and very cheap. Today land is becoming relatively scarcer. It is fixed in amount while the population of the world is increasing rapidly. Does not this lead us to believe that the boundaries of public and private property should be surveyed with greater accuracy than in the days when we had fertile land in abundance?



July 6, 1934.

To: The Director, U. S. Coast & Geodetic Survey.

From: Thos. B. Reed, Chief of Field Party No. 4.

Subject: Changes in shore line, Caillou Bay, caused by hurricane of June 16th.

As a matter of interest I am enclosing a tracing of plane table sheet A in the western part of Terrebonne Bay showing changes in the outer shore line caused by the hurricane of June 16th.

The first plane table survey, shown by dashed line, was completed only a few days before the storm and the second survey, shown in full line, was done about a week after the storm. This final survey was not quite completed at the time of making the tracing.

These two surveys show very forcibly the unstability of the outer shore line in this region. Attention is called to the extensive changes between Longitude 30° 52' and 90° 53'. The high and low water lines were carefully rodded in both cases. I do not believe that any very extensive changes occurred in the marshy areas inside of the outer coast line.

(Sgd.) Thos. B. Reed
Lieut. C. & G. Survey.

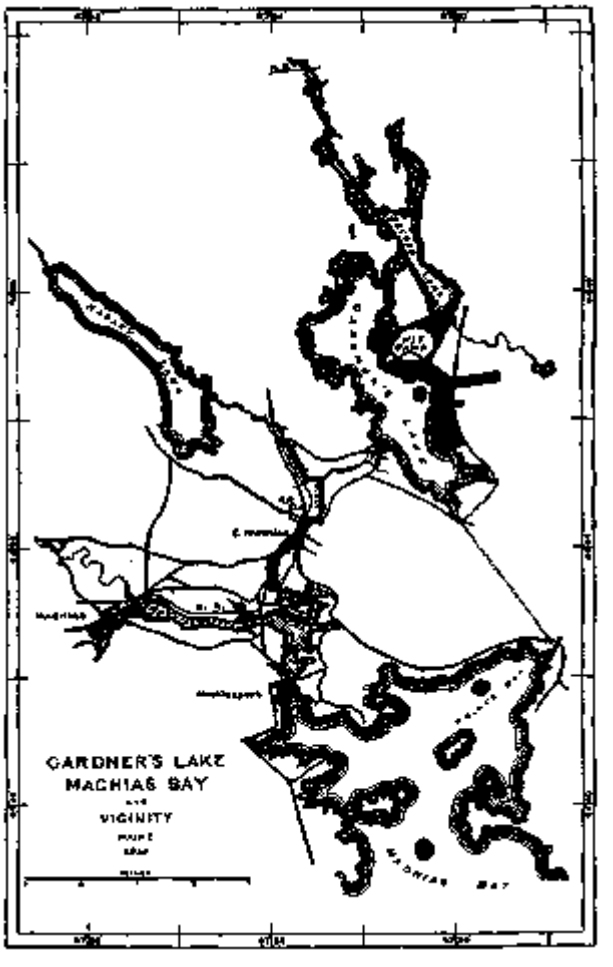
U.S. COAST AND GEODETIC SURVEY
Coast of Louisiana
Shoreline changes resulting from hurricane
June 16, 1934

VISIT TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY SURVEYING CAMP

N. H. Heck, H. & G. Engineer, U. S. C. & G. Survey
Chief, Division of Terrestrial Magnetism and Seismology.

During the summer of 1934 I had occasion to visit the summer surveying camp of the Massachusetts Institute of Technology at Technology, near East Machias, Maine. I was interested in seeing the installation of a Wenner Seismometer which has an important relation to the recording of earthquakes in general but especially those of New England, eastern Canada and in the Atlantic Ocean to the eastward. The records are furnished to the bureau for interpretation and prove a valuable addition.

The visit to the camp brought out many matters of interest to Coast Survey personnel. The camp, which consists of a number of permanent buildings on the shores of a fairly large lake is under the general direction of Professor Charles B. Breed, Head of the Department of Civil and Sanitary Engineering, and more immediately of Professor George L. Hosmer. Both are well known in our bureau either personally, or by reputation through their books on surveying. Unfortunately, Professor Hosmer was incapacitated by an illness during my visit.



On approaching the camp, I saw a steel tower, a tall wooden tower, and several smaller signals, all of which provided a familiar scene. The camp, which has fifty or more students for eight weeks during the summer, gives courses of study in plane, topographic, geodetic and hydrographic surveying, and it provides courses in railroad surveying and limnology (the latter for bacteriological study in connection with water supply). The students in groups of four to six make a topographic survey by standard methods, and eventually a map of the area surveyed. Coast Survey bases are used for the control of all triangulation, and all vertical control is based on Coast Survey benchmarks. Observations for the true meridian are made. Hydrographic surveying includes both stream gauging and sounding in the lake.

From time to time some students take advanced work in geodesy. This advanced work includes base measurement with an invar tape, triangulation of first and second order, first order leveling, and sometimes astronomical observations.

I arrived at the camp in the morning before the students started to work and was asked to address them informally. Since their instruction gave them information regarding our geodetic and simpler surveying work, I told them about the less familiar work, especially that with which I have been personally associated. This included wire drag work in Maine, and some of the results; acoustic work both for depth and position, with especial reference to the survey of Georges Bank and its special problems and features; magnetic and seismological work. I brought out the relation between certain research work at Cambridge of Mr. Ruge, of the Institute, which had to do with safeguarding structures against earthquakes, and our work in this field. The talk and following discussion lasted over an hour, which was taken from the time ordinarily spent in field work. At the close, Professor Breed remarked that people often refer to Government methods as being backward but from other observations and from what had been said, the Coast and Geodetic Survey is keeping up to date in every part of

its work. He later informed me that the effects of the discussion were excellent in that it gave the students some conception of the relation of what they were doing to important Government activity in the interests of the people.

He also called attention to the fact that the Institute has loaned several of its best instruments to the bureau to aid in the emergency work under public works funds.

DISTURBANCE BY EARTHQUAKE WHILE OBSERVING

William W. Kessler (Party of Charles Pierce, H. & G. E.)

On the afternoon of April third, 1934, I was sent to observe Station Obsidian, which is about ten miles northwest of the town of Calipatria, near the Salton Sea, in California. The station is on a low hill, about sixty feet higher than the surrounding country, and composed of loose rock and dirt. A four-foot stand was used.

Arriving at the station about four o'clock, we noticed a rumbling that sounded like blasting, although it seemed to be underground. As we were busy for some time setting up our tent and measuring reference marks, we did not pay much attention to the rumbles. At about four-thirty, I started to observe intersection stations and reference marks, and although I had good targets, I noticed that two positions (on the same signals) did not check within twenty seconds. The first thing I did was to check the tripod, making sure there was no movement on any of the objects and cheeking the instrument. Finding nothing wrong, I again took all marks and objects, and checked the first position very good. We then sat down to wait for the lights to come on and it was just a short time (about five o'clock) until we had a shaking that just about unseated two of the party who were seated on large rocks. We realized then that we were having an earthquake and were quite worried for a while wondering how bad it would be and how long it would last.

From five to eleven o'clock the trembling was regular, at intervals of from five to ten minutes apart, some of them so severe they seemed to shake the whole hill. Although I took twelve positions, between five-thirty and eleven, the runs were from twenty to thirty seconds, instead of the usual three to five that I had been getting with our instrument. The positions were taken in groups of four, from a half hour to an hour apart.

The "OO" party was on a one hundred and thirteen-foot steel tower, about eight miles east of us and did not know there was anything wrong until a resident of a house, near the tower, called to them and told them that they had better get down, as they were having an earthquake. As they did not feel any movement on the tower, they went ahead with their observations and obtained very good runs and very good results.

The movement was also felt by A. L. Lyne, who was keeping light on Station Haubaugh, a fifteen foot wood tower about ten miles north, and F. Coghlan, who was on Station Alamo, a four-foot stand about two miles northwest.

On the "O" party were Roy Sylar, Recorder; H. Graham, reading the "B" micrometer; and J. M. Agnew, lightkeeper.

The station was observed the next night by the same party, the same stand and the same instrument with good results.

INCREASED ACCURACY OF TOPOGRAPHIC POSITIONS ON ALUMINUM MOUNTED SHEETS

The adoption of aluminum mounted topographic sheets by this Bureau has been followed by a notable improvement in the accuracy of positions obtained by conventional plane table methods. In addition to this increased accuracy, the sheets are, in general, considered preferable from considerations of convenience and ease of handling by the topographers, as well as the office personnel.

A recent example of a check on topographic positions, scaled from an aluminum sheet, is given below:

Extracts from Letter from B. H. Rigg

"In connection with the control sheets at Southport, N. C., I thought you might be interested in the following test of accuracy. When Mr. Hall first started work he located a number of beacons, which I later cut in by triangulation, as we found it impossible to get points on them for azimuth, and I also needed an extra station for control of the hydrography. I asked Hall to scale the distances from his topo sheet to use in the reductions to center. Below are the comparisons. When I was up there the other day I told Hall how pleased I was with the results and his letter of comment is also enclosed.

Comparison between Scaled Topographic
Positions and Computed Triangulation Positions

	Scaled	Computed
Cape Fear to Smith	3570 meters	3570.1 meters
" " " BHS R.R.	5675	5674.3
" " " CG Tower	2338.5	2337.6
Bald Head " Smith	4207	4207.5
" " " CG Tower	2340	2338.4
" " " BHS F.R.	1164	1163.5
" " " BHS R.R.	3007	3011.4*

*This station fell on the flattened edge of the topo sheet and I feel that part of the error was due to this."

Letter from Mr. Hall

Dear Mr. Rigg:

In regard to the comparison of distances scaled from the aluminum sheet AB with the same distances computed from triangulation, it has probably occurred to you that this was not a severe test of the accuracy of topographic location, because most of the cuts were taken directly from set ups on triangulation stations.

My experience in making projections and plotting triangulation stations leads me to believe that the limit of accuracy is about ½ meter on a 1/10,000 scale. Any error less Than this is hard to detect and harder to correct. Mr. Nutting might have a better idea of the limit of accuracy in this "office work" than I.

With careful field work, intersections of cuts should determine a signal location within a meter. In pricking the hole for the signal there is nearly always some question as to the "best place". Only occasionally have I felt that the point pricked was correct within ½ meter, even assuming each cut to be the best which could possibly be drawn from the set up to the signals.

If these estimates of maximum errors of ½ meter in the projection, ½ meter in plotting triangulation, and 1 meter in field work are correct, they would combine to give an error which is usually slightly under a meter and sometimes nearly two meters.

My conclusion would be that if my topographic location of a particular station was correct within ½ meter, it was mostly due to luck, that it should generally be correct within 1 meter, and that if it were 2 meters or more in error, something or someone had "slipped a bit".

Yours sincerely,

(Sgd.) Addison S. Hall.

LIFE IN A SURVEYING SHIP

ONE day, one minute, one second in a surveying ship at work on the high seas, any time, anywhere.

"Full-speed astern both!" "Full ahead both . . .!" "Full astern both . . .!" "Why the . . . don't you pick up that beacon?" (etc.)

The ship is engaged *inter alia* in picking up a surveying floating beacon. That contraption (see *E.S.R.*, *No.* 7, 22) is an evil-minded mixture of empty oil-drums, a mast, a little wire, a lot of chain, a 40-foot bamboo and a 10-foot square flag, the whole attached to the sea-bottom by a nasty hard-boiled-looking anchor and popularly supposed to float gracefully in an upright position for month after month.

Observe in every direction the activities in the recovery of the aforesaid beacon. The Captain is in the starboard "chains", coolly and quietly directing the operations, while on the upper bridge can be seen the Navigator, also cool but *not* directing—much! Watch the activities of the platoon on the f'c'sle—the 1st Lieutenant, the Bo'sn, the Chief Stoker and other minions.

Elsewhere we are none the less busy, each on our own work, however varied it may be, from the pilot-balloon being liberated from the after part of the boat-deck for the determination of upper-air currents, down to the echo-sounding gear so accurately portrayed by our artist in the bottom of the ship. Passing through the wardroom, where the Doctor is sitting under the punkah writing up the wine-books, and on by the galley and the Chinese "boys" mess, we arrive in the sailors' quarters—a mess, the canteen store, a stoker (off duty, need I say?); then beyond two closed doors we come ultimately to the paint-room.

Underneath are seen the fresh(?)-water tanks, more sailors, the gym room, the boilers and the main engines. Aboft these come the wardroom wine-store, the "'frig", somebody's cabin and the chronometer room. Can it be the Ship's Steward sitting on the rum-cask next door?

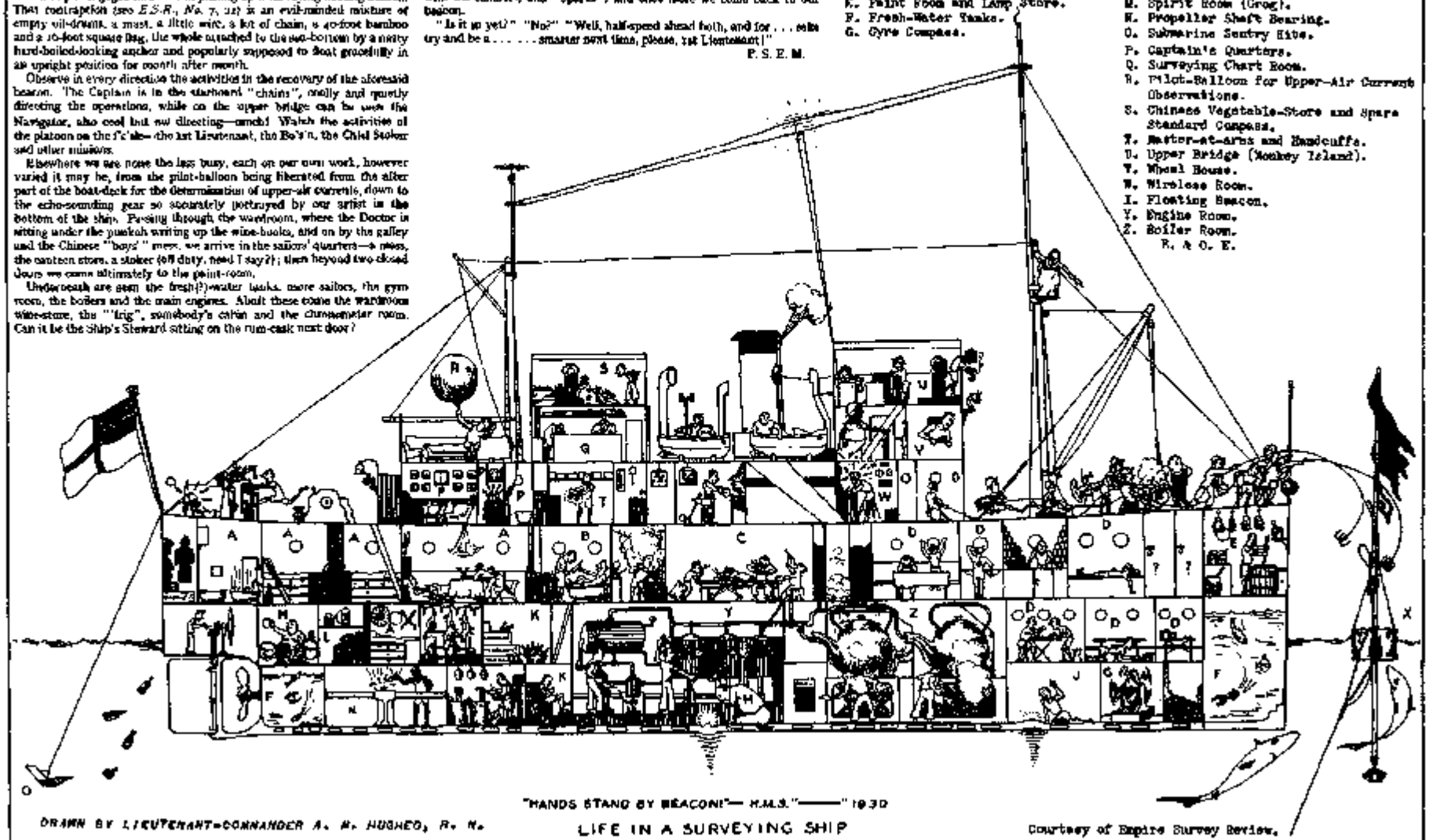
Returning to the upper deck, we find the Submarine Sentry, whose kite, latterly towing astern, has now been tripped by an empty bottle (lime-juice presumably?). Further on as we walk fo'ard we see the Captain's cabin, the Master-at-arms and his shining handcuffs, "Blackie" with his canaries, and "Sparks", and once more we come back to our beacon.

"Is it up yet?" "No?" "Well, half-speed ahead both, and for . . . sake try and be a . . . . . smarter next time, please, 1st Lieutenant!"

P. S. E. M.

REFERENCE TO PLATE

A. Officers' Quarters.
B. Sick Bay.
C. Chinese "Mess".
D. Ship's Company's Quarters.
E. Paint Room and Lamp Store.
F. Fresh-Water Tanks.
G. Gyro Compass.
H. Echo-Sounding Gear (Transmitter).
J. Echo-Sounding Gear (Receiver).
K. Officers' Stores.
L. Chronometer Room.
M. Spirit Room (Grog).
N. Propeller Shaft Bearing.
O. Submarine Sentry Kite.
P. Captain's Quarters.
Q. Surveying Chart Room.
R. Pilot-Balloon for Upper-Air Currents Observations.
S. Chinese Vegetable-Store and Spare Standard Compass.
T. Master-at-arms and Handcuffs.
U. Upper Bridge (Monkey Island).
V. Wheel House.
W. Wireless Room.
X. Floating Beacon.
Y. Engine Room.
Z. Boiler Room.
R. & O. E.



"HANDS STAND BY BEACON!"— H.M.S. "——" 1930

DRAWN BY LIEUTENANT-COMMANDER A. M. HUGHES, R. N.

LIFE IN A SURVEYING SHIP

Courtesy of Empire Survey Review.

U. S. Coast and Geodetic Survey Office

THE CHELTENHAM MAGNETIC OBSERVATORY

Celebration of Completion of One-third Century of Continuous Observations
October 10, 1934

On October 10, 1934, the Cheltenham Magnetic Observatory celebrated the completion of a third of a century or three sun spot periods of continuous observation. The guests, about 175 in number, included personnel of the Coast and Geodetic Survey and of other organizations interested in magnetic work, especially the Bureau of Standards, the Naval Research Laboratory, and the Department of Terrestrial Magnetism, Carnegie Institution of Washington. Special guests of honor included Dr. John A. Fleming, Acting Director, Carnegie Institution of Washington, Dr. J. Bartels, distinguished magnetician of Germany, and Mr. D. L. Hazard, senior mathematician and chief magnetician of the bureau.

The program included addresses, demonstrations of the observatory and field work, and exhibits. The latter included a collection of practically every class of compass in use on land, sea and air, and also pictures of the vessels of the bureau on board of which the magnetic work at sea was established out of which grew the ocean work of the Department of Terrestrial Magnetism, especially that of the CARNEGIE which made magnetic surveys of all the oceans.

Cheltenham Magnetic Observatory, Cheltenham, Maryland, Established in 1901

The program included five addresses, respectively by Captain R. S. Patton, Director, Captain N. H. Heck, Chief of Division of Terrestrial Magnetism and Seismology, and by the three guests of honor.

Captain Fatton's address follows:

"It is a special pleasure to welcome you here this afternoon for a special reason with which you will all sympathize. To me this little group of buildings, simple and unpretentious as they are, stands as a physical symbol of one of the finest manifestations of human aspiration. I can say this to such a group as this because you are here today in direct consequence of the fact that aspiration is the principal motivating force in your own lives. If these structures are the inanimate symbols, some of you are a part of the living reality of what I have in mind.

The aspiration of which I am thinking is that will to penetrate farther into the unexplored regions of infinite truth which manifests itself in fundamental scientific research. I can think of no worthier or more inspiring purpose to which one might dedicate himself. For, intrinsically, I think we may envy any man, whatever his material circumstances, whose dominant passion in life is to know truth. And, extrinsically, I think that man's principal hope for the future, at least in this temporal, mundane sphere, is to be found in progress in that eternal struggle to bring him into closer and more harmonious relation to his environment which is one of the objectives of scientific research.

I am not going to elaborate on this idea or preach you a sermon about it. I mention it at all only because I have sensed that this meeting has an inner significance which lifts it above the plane of a mere pleasant social function. I think such a meeting as this partly would fail of its purpose if it did not enable us to withdraw for a moment to a vantage point from which our view of the forest was not obscured by the trees. We dare not lose that larger vision. The conduct of scientific research demands the exercise of

infinite patience which remains tolerable only for so long as we have the vision before us. To Mr. Hartnell who has devoted more than twenty years to the work of the observatory, the task would have been unendurable if it had ever become merely a day's work for a day's pay.

Our welcome to you today is particularly warm because you have helped us to retain that vision. The stimulating effects of contacts with you, your problems on which you have enlisted our aid, and, conversely, those of our own which you have helped us to solve, all have contributed to that end. We want you to know that we value your friendship and cooperation and that we hope always to give as well as to receive."

Captain Heck called attention to the fact that this might also be considered a centennial since the first magnetic observations by the bureau were made in 1833 in Connecticut. He proceeded to give the history of the observatory, cooperative activities, and to tell of the guests of honor as follows:

"The plan for a magnetic survey of the United States was prepared in 1899 by Dr. L. A. Bauer, then Inspector of Magnetic Work of the bureau and was approved by Superintendent Henry L. Pritchett. The plan included field observations at every county seat in the United States and the operation of a number of observatories throughout the United States and the regions under its jurisdiction. Prior to that time observatories had been maintained at Key West, Florida, 1860 to 1866; Madison, Wisconsin, 1876 to 1880; Los Angeles, California, 1882 to 1889; San Antonio, Texas, 1890 to 1895 - at the last two with the same Adie instrument which is still in operation today - but all the series were too short to be entirely satisfactory.

From the adopted plan came the present observatories at Cheltenham, Sitka, and Honolulu. The observatory, started at Vieques in 1903, was later moved twice, but care was taken to make the necessary observations to insure a homogeneous series for the region. The Baldwin, Kansas, observatory of the original plan, operated for control of field observations in the middle west, was abandoned and the Tucson, Arizona, observatory was established in 1909 under the direction of the late Captain R. L. Faris.

In planning for an observatory near Washington, it was realized that in addition to the regular functions it would be necessary to provide a place for testing and comparing instruments and for carrying on investigations in cooperation with the Washington office.

All these purposes were taken into account in selecting the site and designing the necessary buildings. It was also necessary to find a site free from present and future artificial disturbance, uniformity of magnetic distribution over the area needed, all combined with reasonable accessibility and ease in obtaining supplies. Unfortunate experience at San Antonio, Texas, and at many foreign observatories with the disturbing effects of electric cars made it necessary to give special attention to this consideration.

These conditions have been well met at the present site, leased from and part of the 800 acre farm of the House of Reformation for Colored Boys, a Maryland State Institution. After 33 years of operation the site is as suitable for magnetic work as ever and will probably continue so.

After much investigation of possible sites the one before us was chosen. It is 14 miles southeast of the National Capital and 1-1/4 miles from the Cheltenham railway station, and a mile from the Crane highway.

As a result of this careful selection no serious difficulties have arisen and the site is today as suitable for magnetic work as when it was chosen.

The preparation of plans for the buildings and their erection was assigned to Mr. John A. Fleming, then Aid in the Coast and Geodetic Survey. He had numerous unusual problems in operating two sets of recording instruments in the same building but far enough apart to avoid mutual disturbance. No magnetic material could be introduced and the building had to be insulated against temperature changes at a time when none of the modern means of accomplishing this were available.

The buildings were begun near the end of 1900 and the first observations were made in April, 1901. Their unbroken continuity (except for a few hours) has in itself made an important contribution to the value of the work. Standards

have been maintained during the entire period so that the work of the observatory is known throughout the world and it is frequently referred to in literature on the subject.

There have been only seven men in charge of the observatory during all this time and Mr. George Hartnell has held this duty from 1911 till a few months ago when he was relieved by Lieutenant Commander Eoline R. Hand. Mr. Hartnell will remain at the observatory to continue investigations in instruments and methods which have been productive in the past and should be more so in the future in the absence of conflicting duties.

During the long period of observation, the plant as a whole has had several narrow escapes. A severe bolt of lightning has passed through this highly inflammable variation building without damage except the shattering of a flagpole formerly on the building. A tornado removed part of the roof. The most serious menace developed within the past few years from the activity of an enemy which had no regard for scientific accomplishment. This was the small insect known as the termite. He found the combination of wood and sawdust much to his liking and was well prepared for a comprehensive attack in millions which would soon have rendered the buildings not only unsuitable to their purpose but actually unsafe. Emergency and public works funds were made available. The office building was rebuilt and new foundations were placed under the adjacent variation building. A new comparison and test building replaced a very small one which was moved to another site and which will soon be used for continuous cosmic radiation observations at the request of the Committee of the Carnegie Institution of Washington which deals with that subject.

The pier arrangements of the various buildings were modified to meet present needs with the advice and assistance of Dr. Fleming and his staff.

Much cooperative work is done here. In 1922, the Association of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, asked that each country designate an observatory for making measurements to maintain the international magnetic standard. In 1923 the American Geophysical Union asked that this function be performed jointly by the Cheltenham Magnetic Observatory and the Magnetic Laboratory of the Division of Terrestrial Magnetism, Carnegie Institution of Washington. While the latter organization has the responsibility of establishing the standard and of making international observations to maintain it, it is now necessary to make its observations for the United States almost entirely at Cheltenham because of the encroachment of the city of Washington on its present site. Many observations are made in cooperation with the Carnegie Institution of Washington.

The Naval Research Laboratory has frequently made use of the favorable magnetic conditions at Cheltenham for various investigations.

The Bureau of Standards from time to time makes precise measurements of our instruments in connection with the work in international standards, it has given assistance in problems relating to magnets and has aided in other ways. In return it makes use of the records of the Cheltenham Observatory to control investigations being carried on in its laboratories.

The uses of Terrestrial Magnetism are too numerous to mention here. The exhibits show that needed information is furnished for all mariners' charts and aviation maps. The Cheltenham records are used particularly in connection with radio transmission problems, the records being duplicated weekly for the benefit of the Bureau of Standards and the research department of one of the large broadcasting companies. Other communication companies and the Naval Research Laboratory require similar duplication from time to time. This information is demanded long before we have had time to make use of it ourselves. Cheltenham also furnishes daily the magnetic information for the so-called URSIgram or message giving magnetic, solar and other conditions which may affect radio transmission. The information is compiled by Science Service and broadcasted by the Navy Department. Cheltenham furnishes from time to time, and Tucson, continuously, information of use to geophysical prospectors employing magnetic methods.

We have today three special guests and I wish to say a little about each.

Dr. John A. Fleming started his career in magnetic work in the Coast and Geodetic Survey and built this observatory as well as that at Honolulu. In

this work he showed the efficiency, zeal, mastery of details and executive ability which have characterized his career ever since. He also was the loyal assistant of Dr. L. A. Bauer during the years of establishment of the country-wide magnetic work of the Coast and Geodetic Survey, the organization of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and the development of ocean surveys from the time when Dr. Bauer and our late assistant director, Captain R. L. Faris, established magnetic observations at sea, to the building and extensive voyages of the non-magnetic ship CARNEGIE. His accomplishments are too numerous to mention. His present important duty as acting director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington tells the story in itself. He has always shown a cooperative spirit and the close relations of his organization and our bureau in the field of terrestrial magnetism are in itself responsible for much Joint accomplishment. He played an important part in the participation of our country in the Second Polar year, not only through the work of his own organization but in connection with obtaining necessary appropriations which made possible the participation of our bureau and other Government agencies. He is now president of the Association of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union.

Dr. J. Bartels of Eberswalde, Germany, and research associate of the Carnegie Institution of Washington is present not only as an outstanding figure among world magneticians, but he represents the scientific Germany to which this observatory and magnetic work in general owes so much. The method of obtaining the horizontal intensity was developed by Gauss 100 years ago. A little later Weber developed the earth inductor. The large absolute instruments in this building were built in Germany and also the Eschenhagen variometers of which you will see one set not in use, while the others are closed from view today so that the work of the observatory will not stop. Adolf Schmidt has made many contributions which we utilize daily. Dr. Bartels has made and published many important investigations and not the least of his services has been his contributing with Angenheister an important chapter on the magnetic field of the earth to the Handbuch fűr Experimentalphysik.

Daniel L. Hazard, senior mathematician and chief magnetician of the Coast and Geodetic Survey entered the service in 1892. He served under Mr. Schott in what was then the Computing Division until 1899 when he entered the magnetic work of the bureau with which he is associated not only in Washington, but in the minds of magneticians all over the earth. He has been almost entirely on office work though he spent about a year on field work in early days, made observations during the solar eclipse of 1900 and instructed officers of the PATTERSON, BLAKE and BACHE in magnetic work. He is perhaps best known for his directions for magnetic measurements which are in use throughout the earth. When a revision was called for some years ago he was asked to make the instructions apply to the southern as well as northern hemisphere, the request coming from international sources. One of his great contributions has been in using his ripe judgment to secure the best values of the magnetic elements when the instruments go wrong. They should not do so ordinarily but we are pursuing a very small physical unit, the gamma, and very small instrumental changes make trouble. Little has been lost however, because of Mr. Hazard's ability to deduce the most probable value. His knowledge of magnetism throughout the United States is profound and he has put the information in systematic and convenient form for all citizens who desire to make use of it.

In conclusion I wish to ask you to use your imagination and to look beyond these strictly utilitarian buildings and instruments to the fact that we are dealing with one of the fundamental and elusive forces of nature. In our geodetic work we measure another fundamental force - gravitation - but this once measured remains the same at the same place. In magnetism we cannot predict today what tomorrow will bring forth. In the struggle for a better understanding of this fundamental earth science the Cheltenham Observatory is in the front line of attack."

Dr. Fleming described several amusing occurrences during the construction of the buildings, then in more serious vein stated that Dr. Bauer had from the start emphasized the international character of the work and in this the Coast and Geodetic Survey plays an indispensable part. He also stressed the important results arising from the cooperation of his institution with the bureau which has been especially close during the past few years, and predicted greatly increased results in the future.

Dr. Bartels stated that his notice of the anniversary had been too brief to permit of arrangement for official greetings from across the sea so the audience must accept in lieu thereof his personal good wishes and heartiest congratulations. He said:

"One can never quite get rid of the impression that some very special thing is going on in this place; that is, there is something especially distinctive about the earth's magnetism in this vicinity. This is not true but rather it is one of the places where instruments are available to record it and where measurements are made with care.

In extending congratulations on this birthday, I feel that I can best express the views of scientists across the sea by telling you of our gratitude to the United States Coast and Geodetic Survey for the careful planning and excellent work extending over so large an area of the earth's surface. We also appreciate the fact that you are not jealously guarding the records by keeping them hidden from everyone, but are making them available to all who can profit by them, in the form of excellent publications."

Mr. Hazard's remarks were as follows:

"It is very gratifying to have the Cheltenham Observatory restored to normal operation, after the disturbances incident to repairs and adjustment, and to note the improvements which have been made in buildings and equipment. With the greater opportunity which Mr. Hartnell will now have for the study of the theory of the Instruments and methods of observing, and with the experimental work to be undertaken with the cooperation of the Department of Terrestrial Magnetism and the Bureau of Standards, further improvements may be expected, giving assurance that the work will go on for many years without disturbance and with increasing efficiency and that the future output will be of even higher grade than the very fine results obtained during the first three sun-spot cycles of its existence.

It is also gratifying to note the increasing recognition of the value of its work, of which this gathering is an evidence.

The study of the earth's magnetism by the Coast and Geodetic Survey, implanted by Hassler and kept growing by Schott for nearly fifty years under semi-arid conditions, took on a new lease of life with the more generous appropriation which was provided in 1899, and branched out and developed rapidly under Bauer's careful planning and forceful initiative. It is now beginning to bear fruit and we can look forward confidently to an increase in the value of the crop with every year of its growth."

Part of the exhibit at the Cheltenham Observatory
The non-magnetic stove is at the extreme left

THE A B C OF TRIANGULATION ADJUSTMENT.*

H. P. Kaufman, Assistant Mathematician, U. S. C. & G. Survey.

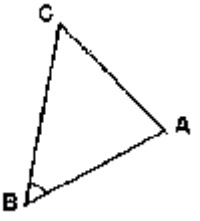
Introduction

In any extensive system of surveys, account must be taken of the curvature of the surface of the earth. In geodetic surveying all calculations are referred to an assumed ideal spheroidal form which is essentially the same as the sea-level surface and closely approximates the actual surface. The position of a point on this ideal surface is determined when it is referred to the system of parallels and meridians, in other words, if its latitude and longitude are known. In the absence of other information the position of a station can be determined only by astronomical observations.

If the positions of two stations are known and the distance between them has been obtained by direct measurement, or is known from previous information, then the position of a third point not in the line joining the other two can be determined if it is observable from both the original stations. It is apparent that the lines connecting the three points form a triangle. The method is known, therefore, as triangulation. It may be extended to include any number of observable stations. By occupying the new stations and observing still other points a system of triangulation is obtained. Such a system may be carried forward to any desired extent and is generally connected with another network. When all determinations are brought into consistent agreement the system is said to be adjusted. The conditions to be satisfied in an adjustment will be considered in connection with the various problems as they are taken up.

Directions

Included in the data obtained by the field parties are lists of directions of occupied stations to observed stations. The direction to a station is the angle taken in a clockwise sense between the line from the occupied station to a station arbitrarily chosen as initial and the line to the given station. There is a list of directions for each occupied station. We shall omit for the time being any discussion of the corrections or reductions which may be necessary and assume that the lists are ready for use. We make use of the directions to determine the angles of the various triangles in a network. In the triangle formed by lines connecting stations A, B, and C, as shown, the angle at B is found by subtracting the direction B to C from B to A. Similarly the angle at C is found by subtracting direction C to A from C to B. It is to be noted that the angle is always taken in a clockwise sense. If the direction to be subtracted is larger than the other, lit is necessary to add 360° to the smaller direction before subtracting.



Directions to main scheme stations of first order accuracy are carried to hundredths of a second, intersection stations to tenths or even to whole seconds, if the object sighted on is not sharply defined. Directions to nearby objects can be given only to the nearest 10 seconds.

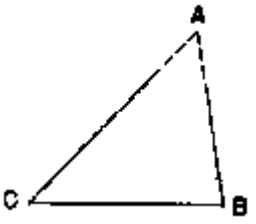
Triangle Computation, no check Point

Suppose we have the following problem: Stations B and C are occupied. At each, observations are made on station A which is unoccupied. Required to find position of A. It is assumed that we know the latitude and longitude of B and C, the distance B C, the azimuth B to C, and the back azimuth C to B. The azimuth of a line, say B to C, is defined as the angle reckoned clockwise between a line extending due south from B and the line B to C. Similarly the back azimuth is the angle taken clockwise between a line extending due south from C and the line C to B. On a plane surface the forward and back azimuths would differ by 180°, but on the earth north and south lines are meridians and are not parallel except at the Equator. Hence the forward and back azimuth differ by slightly more or less than 180°.

*For additional literature see: Geodesy, Hosmer.
U. S. C. & G. S. Spec. Pub. 138.
Practical Least Squares, O. M. Leland.

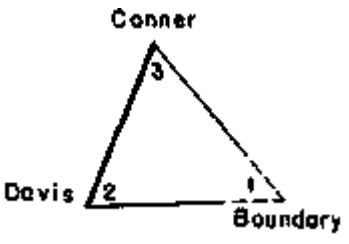
A geodetic line is fixed either by the latitudes and longitudes of both end points or the latitude and longitude of one end point and the length and forward azimuth of the line. That is, if either set of quantities is known the others can be computed.

In the problem suggested let us sketch the triangle, since its form can be deduced from the given data. Lines sighted over in one direction only are shown dotted at the end toward which observation was directed. The angles B and C are obtained from the lists of directions for the points B and C respectively. There is no list for A since the station is unoccupied. Hence the angle A must be concluded. That is A = 180° - (B+C). This is not strictly true since the triangle is not a plane triangle. The sum of the three angles exceeds 180° by a quantity called the spherical excess, the computation of which will be explained subsequently. In the given figure the spherical excess is included in angle A. The spherical excess is computed to as many decimal places as are retained in the directions which fix the angles, in this type of problem usually to tenths of a second. The angles A, B, and C, as determined, are spherical angles. To obtain the sides AC and AB we need to know the plane angles. These are obtained by distributing the spherical excess as nearly equally as possible between the three angles, one third on each angle, or, if it cannot be divided by three, distributed so that the smaller angles will receive their correct share as nearly as possible*[1], and subtracting from each angle its allotted spherical excess. The sum of the three resulting plane angles should be equal exactly to 180°.



The unknown sides BA and CA are next computed using the trigonometric law of sines. This gives us all the data required for the determination of the position of A. The solution of the triangle and the computation of the position of A are carried out on specially prepared forms and will be illustrated by an example taken from actual data.

A rough sketch is drawn to reasonably approximate scale. Following the triangle computation form, the angles are numbered clockwise beginning with the undetermined point. The values of the angles are next entered in the form indicating the concluded angle, which includes all the spherical excess, by parenthesis.



Computation of Triangle

Form 25

NO.	STATION	OBSERVED ANGLE	CORR'N	SPHER'L ANGLE	SPHER'L EXCESS	PLANE ANGLE AND DISTANCE	LOGARITHM
2-3							4.205 406
1	Boundary	(71 07 10.5)		10.5	0.2	10.3	0.024 0190
2	Davis	61 22 16.7		16.7	0.1	16.6	9.943 3673
3	Conner	47 30 33.2		33.2	0.1	33.1	9.867 6947
1-3					0.4		4.172 792
1-2							4.097 120
		180 00 00.4					

The spherical excess is calculated from the formula*[2], a b sin C. x m, involving two sides, the sine of the included angle, and the factor m which depends on the latitude. Since the spherical excess must be determined in advance of the lengths of the sides, we make an approximate preliminary computation of these lengths using the logarithms of the sines of the angles to four places.

*[1] Special Publication No. 138, page 39.

*[2] Special Publication No. 138, pages 32-33.

The steps in the determination of the spherical excess of the triangle, discussed in our example, may be illustrated as follows:

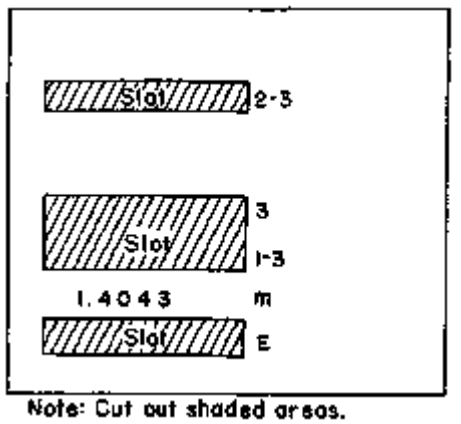
Approximate Computation of Lengths

log (2-3)	= 4.2054
colog sin (1)	= 0.0240
log sin (2)	= 9.9434
log sin (3)	= 9.8677
log (1-3)	= 4.1728
log (1-2)	= 4.0971

Computation of Spherical Excess

log m	- 1.4047	
log sin (2)	= 9.9434	(= log sin c)
log (1-2)	= 4.0971	(= log a)
log (2-3)	= 4.2054	(= log b)
log	9.6506	
	= 0.447	
Adopted	= 0.4	

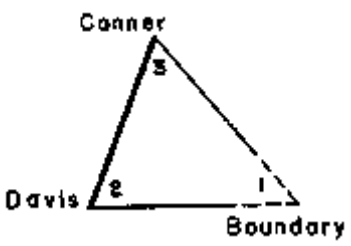
This will give the spherical excess with sufficient accuracy. Where there is no other means of checking, it is advisable to compute the spherical excess in more than one way since we can use any two sides and the sine of the included angle. For convenience and rapid computation, the spherical excess can be computed from the logarithms which are already in the logarithm column of the triangle computation, by placing over them the shield shown at right. This blocks out all but the necessary logarithms to compute the spherical excess. Log m is usually placed as shown, in pencil, and changed when necessary. The shield uses angle 5 and sides 2-5 and 1-3. The shield can be made of bristol board or other similar paper. The plane angles are next determined. The distribution of spherical excess in the example should be noted. The unknown sides of the triangle are calculated by the trigonometric law of sines. Using the triangle computation form numbering system we have:



Note: Cut out shaded areas.

$$\text{line } (1\text{-}3) = \frac{\text{line } (2\text{-}3) \sin (2)}{\sin (1)}$$

$$\text{line } (1\text{-}2) = \frac{\text{line } (2\text{-}3) \sin (3)}{\sin (1)}$$



or expressed logarithmically

log (1-3) = log (2-3) + colog sin (1) + log sin (2)

log (1-2) = log (2-3) + colog sin (1) + log sin (3)

The form is conveniently arranged for this computation.

The logarithms of lengths are carried to six places and those of functions of angles to seven places, in work of the order of accuracy of the example given.

The position of the point Boundary is next computed using a third order position form. The computation follows the formulas given in Special Publication 8, page 8, making use of only as many terms as the order of accuracy requires. It is to be noted that two independent calculations of the position are made. These will check to within one-thousandth of a second or better, if there is no error in the computation.

A brief explanation of the form will suffice. The latitude and longitude of Boundary may be calculated if we know the latitude and longitude of Davis, the length Davis-Boundary and the azimuth Davis-Boundary. We can also obtain the small correction $\Delta\alpha$ necessary to calculate the back azimuth. A similar statement may be made regarding stations Conner and Boundary. The azimuth Davis-Boundary is obtained by adding the angle at Davis (second angle of the triangle) to the known azimuth Davis-Conner. This gives us α , used as the argument for

finding the sine and cosine in the left half of the computation. The constants B, C and D, which are compiled in Special Publication 8, pages 20 to 91, are based upon the latitude φ as an argument.

The right side of the form provides for a similar calculation of the new position using the position of the remaining station, in this example Conner, and the distance and azimuth from it to the new point. The azimuth Conner-Boundary, the a used on the right side, is found by subtracting the angle at Conner from the known azimuth, Conner-Davis. This last statement is made obvious by an inspection of the sketch on page 2. We now have the starting data for both sides of the form. The computation of the increments of latitude, longitude and azimuths, from this point on, follows the same plan on both sides of the form.

In the computation of the increment of latitude $\Delta\varphi$, it is to be noted that substitution in the formula gives $-\Delta\varphi$. If $-\Delta\varphi$ is a positive quantity the latitude of the new station is obtained by subtracting the magnitude of $\Delta\varphi$ from the starting latitude φ . If $-\Delta\varphi$ is negative, the magnitude of $\Delta\varphi$ is added to give us the latitude of the desired position. The sign of the first term of $-\Delta\varphi$ is always the same as that of the sign of $\cos\alpha$. Using the Shortrede Tables this sign is always given, otherwise it must be remembered that $\cos\alpha$ is positive from 0° to 90°, negative from 90° to 270° and positive again from 270° to 360°. The second and third terms are always positive. The rigorous application of the formula for $\Delta\varphi$ requires the computation of a number of terms in addition to the three provided for on the form. Whether they actually need to be brought into the computation depends upon the lengths. The fourth term should be calculated if the logarithm of the length is around 4.0 or more. This term is equal to $-h\ s^2\ \sin^2\alpha\ E$ and is always opposite in sign to the first term. Since the terms are determined to four places of decimals and then adopted to three, the fourth term should always be considered if it amounts to 0".0001. If the values of φ' check within 0".001 the computation is probably correct. The disagreement of 0".001 is arbitrarily removed by adding or subtracting this amount from one of the φ' values. The correction of 0".001 should be applied to that value of φ' for which the corresponding value of $\Delta\varphi$, carried to four places, will be changed least by the correction necessary to alter the value, φ' by 0".001. The determination of $\Delta\varphi'$ is completed after φ' is fixed. Sin a should always be taken out at the same time as $\cos\alpha$. A' is found on the same page of Special Publication 8 as B, C, D and E, but depends on φ' as argument. Since φ' is the same for both sides of the computation, A' and sec φ' are the same in both determinations of $A\lambda$. The formula yields $+\Delta\lambda$. Hence $\Delta\lambda$ is applied with the same algebraic sign as is obtained in the computation, which will be the same as that of sin α. It will be remembered that sin α is positive from 0° to 180° and negative from 180° to 360°. The two determinations of the longitude λ' should also agree to 0".001 or better. Again an additional correction may be required if the triangle is large. This correction, explained in detail on page 18 of Special Publication 8 and known as the arc sin correction, may be determined using the table on page 17 of Special Publication 8, from the value of s and the preliminary value of log $\Delta\lambda$. The correction is applied to the logarithm rather than to $\Delta\lambda$ directly.

The value of the longitude as determined on the right and left sides of the form should differ by not more than 1 in the thousandths of seconds, and, as in the case of the latitude, one of the values is adopted. The same considerations are applied in the adoption of λ' as in the adoption of φ'

The importance of following a fairly accurate sketch becomes apparent when it is seen that it enables one to determine by inspection whether $\Delta\varphi$ and $\Delta\lambda$ have been taken in the proper sense.

The computation of the position is completed by the determinations of $-\Delta\alpha$ necessary to give us the back azimuths. For third order work log $-\Delta\alpha$ = log $\Delta\lambda$ + log sin ½ ($\varphi + \varphi'$). Since we solve for a negative result, $\Delta\alpha$ is always applied with algebraic sign opposite that of $\Delta\lambda$.

After the back azimuths are determined a final check is obtained on the azimuths by adding the angle at the new position to the azimuth 1 to 2. As is apparent from the figure this sum is equal to the azimuth 1 to 3 if correctly determined. We are permitted to adopt one of the back azimuths arbitrarily to correct a discrepancy of not more than 1 in the last place of decimals. It is apparent that the computation is completely self-checking as far as the azimuths are concerned.

In the case of a no-check point the calculation may be entirely correct and

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Form 27
Ed. April, 1929

POSITION COMPUTATION, THIRD-ORDER TRIANGULATION

					°	′	″
α	2	Davis	to 3	Conner	201	54	40.2
2d ∠			&		+ 61	22	16.7
α	2	Davis	to 1	Boundary	263	16	56.9
Δα					+	05	13.7
					180	00	00.0
α′	1	Boundary	to 2	Davis	83	22	10.6
				First Angle of Triangle	71	07	10.5

α	3	Conner	to 2	Davis	21	58	11.8												
3d ∠			&		− 47	30	33.2												
α	3	Conner	to 1	Boundary	334	26	38.6												
Δα					+	02	42.4												
					180	00	00.0												
α′	1	Boundary	to 3	Conner	154	29	21.0												

	°	′	″				°	′	″				°	′	″				°	′	″
φ	38	00	49.798	2	Davis	λ	75	23	16.340	φ	38	08	52.606	3	Conner	λ	75	19	10.404
Δφ	+		47.141			Δλ	−	08	29.242	Δφ	−	07	15.668			Δλ	−	04	23.306
φ′	38	01	36.939	1	Boundary	λ′	75	14	47.098	φ′	38	01	36.938	1	Boundary	λ′	75	14	47.098

	Logarithms		Values in seconds
s	4.097120		
Cos α	9.0680914 n		
B	8.5110016		
h	1.6762130	1st term	−47.″4475
s²	8.19424		
Sin² α	9.99402		
C	1.29774		
	9.48600	2d term	+0.3062
h²	3.3524		
D	2.3792	4th	+0.0001
	5.7316	3d term	+0.0001
		−Δφ	−47.1411

	° ′ ″		
½(φ+φ′)	38 01 13.368		
		Logarithms	Values in seconds
s		4.097120	
Sin α		9.9970083 n	
A′		8.5091681	
Sec φ′		0.1036273	
Δλ		2.7069237	−509.″2416 (+2)
Sin ½(φ+φ′)		9.7895396	
−Δα		2.4964633	−313.6632 (+2)

	Logarithms		Values in seconds
s	4.172792		
Cos α	9.9552857		
B	8.5109916		
h	2.6390693	1st term	+435.″5814
s²	8.34558		
Sin² α	9.26974		
C	1.29980		
	8.91512	2d term	+0.0822
h²	5.2781		
D	2.3797	4th	− 0.0002
	7.6575	3d term	+ 0.0045
		−Δφ	+435.6679

	° ′ ″		
½(φ+φ′)	38 05 14.772		
		Logarithms	Values in seconds
s		4.172792	
Sin α		9.6348723 n	
A′		8.5091681	
Sec φ′		0.1036273	
Δλ		2.4205497	−263.″3055 (+3)
Sin ½(φ+φ′)		9.7901890	
−Δα		2.2106487	−162.4235 (+3)

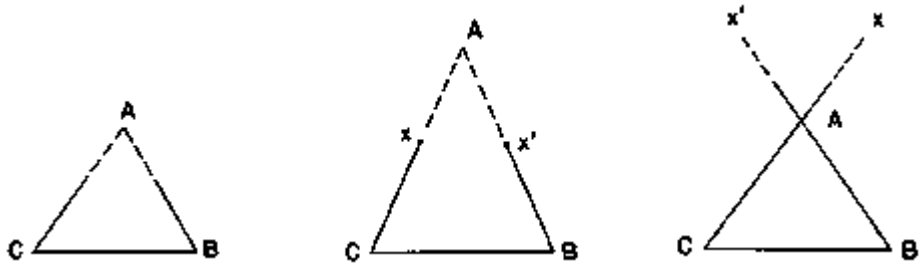
−h	1.6762 n
s²sin² α	8.1883
E	6.0635
	5.9280

arc-sin corr.
− 2.8
+ 4.3
+ 1.5

−h	2.6391
s²sin² α	7.6153
E	6.0663
	6.3207

arc-sin corr.
− 4.0
+ 1.2
+ 2.8

the position yet be spurious. The three adjacent figures illustrate what is meant.

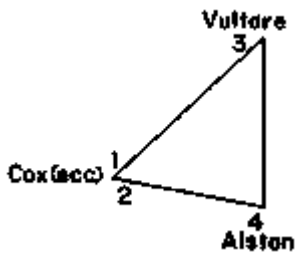


The first indicates a real intersection point at A. Observers at C and B saw the same object. In the other two figures the observers at C and B saw different objects, X and X', identified erroneously as the same. The lines of observation intersect at A and there is nothing in the computation to show that this is a fictitious point. Such an error is liable to occur in a region containing numerous similar objects, such as water tanks or smokestacks.

Check Point with Angle Equation

A point computed from a triangle becomes a check-point, either if the station is occupied and two stations see it or if it is observed from more than two stations. In the first case the three angles of the triangle are determined from observational data and sum to 180° plus the spherical excess with a closing error depending upon the order of accuracy of the work. In the second case the intersection of the lines of observation at a common point may be checked. Furthermore both conditions may be satisfied.

The adjoining figure illustrates the first case. The position of station Cox (ecc.) is to be determined. All stations are occupied. Hence we can determine the error of closure and have one condition to be satisfied in making an adjustment. This condition is called an angle equation. The error of closure is the difference obtained by subtracting the sum of the angles from 180° plus spherical excess. The solution of the angle equation using the theory of least squares gives the most probable distribution of the closure error among the three angles. The numbers placed on the lines leading from the different points are used to indicate the v's or corrections to the directions*. The directions of the two ends of the line Vultare-Alston are fixed by previous adjustment and will receive no correction. Hence no numbers are assigned to this line. The angles are designated as follows; an observer looking into the triangle from any vertex gives the number of the line to the left a negative sign, the one to the right a positive sign. Thus the angle of Cox (Ecc.) is designated - 1+2. At Vultare the angle is +3 since direction Vultare-Alston is unnumbered. Similarly the angle at Alston is designated - 4.



As will be seen more readily from more complicated figures the numbers are taken clockwise about each point beginning with the direction on the extreme left. The scheme of designating angles is consistent with the determination of an angle, that is, the difference between the directions of the lines which form the angle.

FORM 25

NO.	STATION	OBSERVED ANGLE			CORR'N	SPHER'L ANGLE	SPHER'L EXCESS	PLANE ANOLE AND DISTANCE	LOGARITHM
	2-3vultare-Alston								4.139 737
-1+2	1 Cox (ecc)	62	29	26.5	+1.0	27.5	0.1	27.4	0.052 1069
+3	2 VuLtare	42	40	31.6	+0.5	32.1	0.1	32.0	9.831 1311
-4	3 Alston	74	50	00.3	+0.5	00.8	0.2	00.6	9.984 6037
	1-3				+2.0		0.4		4.022 975
	1-2								4.176 448
		179	59	58.4					

*These numerical designations are to be regarded simply as a convenient notation, replacing the familiar x, y, and z, which represent the unknowns in an ordinary algebraic equation. They enter into the equations only as symbols, and their actual values are determined in carrying out the solution.

As soon as the observed angles have been taken out of the list of directions the first three columns of the triangle form No. 25 are filled in. Then the spherical excess is calculated. In the example the spherical excess amounts to 0".4. Since the sum of the three angles amounts to 179° 59' 58.4", the closure is 180° 00' 0.4" - 179° 59' 58.4" or +2.0". We now seek to find the most probable distribution of this closure among the three angles.

The angle equation is:

$$0 = -2.0 - (1) + (2) + (3) - (4)$$

It formally expresses the fact that the sum of the corrections to the angles is equal to the closure. These corrections to the angles are expressed in terms of the corrections to the directions.

The form of the equation is in accordance with the practice of transposing all terms to the right side. This is of no significance in this example, but in cases where several equations are to be solved simultaneously, the constant terms will have the correct algebraic signs, if they appear on the same side of their respective equations as the v's.

The theory of least squares applied to an equation of this type, not solvable uniquely, states that the most probable distribution of errors will be the one for which the sum of the squares of the v's is a minimum. The formal solution is as follows:

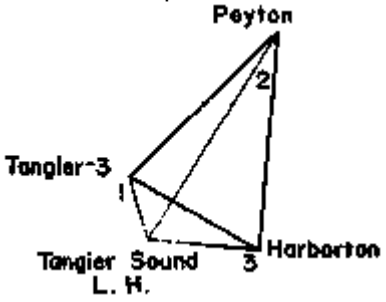
$$(1)\quad 0 = -2.0 - (1) + (2) + (3) - (4)$$
$$(2)\quad 0 = -2.0 + 4C$$
$$(3)\quad 4C = +2.0$$
$$(4)\quad C = +0.5$$
$$v_1 = -0.5,\ V_2 = +0.5,\ \ V_3 = +0.5,\ \ v_4 = -0.5$$

The v's are expressed in terms of a constant C. We see, that the equation, 4C = +2, called a normal equation, is obtained by rewriting the original equation, substituting, for the sum of the v's, the sum of the squares of their coefficients multiplied by C, and equating it to the constant +2.00. The v's are obtained by writing the products of their respective coefficients by C. In an angle equation these coefficients are equal to plus or minus 1. The v's are adopted to the same number of decimal places as the directions in order that the sum of the angle correc tions will be exactly equal to the closure of the triangle. In other words the angle equation is satisfied exactly. No adoption is required in the example given since the v's come out exactly to tenths. The steps in the solution are merely indicated here with no attempt at theoretical justification. The angle corrections are determined by combining the v's as shown on the triangle computation form. These angle corrections are applied to the observed angles to give the spherical angles, after which the distributed spherical excess is subtracted yielding the plane angles.

The determination of the unknown sides completes the triangle computation. The corrections to the directions should be applied to the list of directions. The angles of the triangle obtained from the adjusted directions must check the spherical angles in the triangle. The geographic position is finally computed by the method already described, using the spherical angles.

Side Equation

Another relatively simple problem of adjustment arises when an unoccupied point is observed from three or more stations. If the occupied stations have been adjusted already, we have only the condition to be satisfied that the lines drawn from the points of observation to the new station meet in a point. This condition is known as a side equation and will be illustrated by a typical example.



The triangle, Harborton - Tangier 3 - Peyton, is fixed. Hence no numbers are assigned to the lines forming its sides to indicate corrections. The other lines are numbered only at the ends from which observed, since these constitute the only given directions. The designation given a concluded angle, as may be seen from inspection of the

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Form 25
Ed. Jan., 1929

COMPUTATION OF TRIANGLES

State: Virginia

	NO.	STATION	OBSERVED ANGLE	CORR'N	SPHER'L ANGLE	SPHER'L EXCESS	PLANE ANGLE AND DISTANCE	LOGARITHM
		2-3						4.361603
	-1+2	1 Tangier Sd.L.H.	(53 16 20.8)	+1.4	22.2	0.0	22.2	0.0961007
	+1	2 Tangier 3	122 43 59.7	-0.2	59.5	0.1	59.4	9.9248982
	-2	3 Peyton	3 59 59.6	-1.2	38.4	0.0	38.4	8.8429337
		1-3						4.382602
		1-2						3.300637
						0.1		
		2-3						4.306754
	-1+3	1 Tangier Sd.L.H.	(156 40 27.1)	-1.6	25.5		25.5	0.4023418
	+1	2 Tangier 3	21 05 19.5	-0.2	19.3		19.3	9.5560765
	-3	3 Harborton	2 14 13.4	+1.8	15.2		15.2	8.5915408
		1-3						4.265172 +1
		1-2						3.300637
						0.0		
		2-3						4.526055
	-2+3	1 Tangier Sd.L.H.	(103 24 06.3)	-3.0	03.3	0.3	03.0	0.0119887
	+2	2 Peyton	32 14 29.7	+1.2	30.9	0.4	30.5	9.7271292
	-3	3 Harborton	44 21 26.1	+1.8	26.9	0.4	26.5	9.8445589
		1-3						4.265173
		1-2						4.382602
						1.1		
		2-3						
		1						
		2						
		3						
		1-3						
		1-2						

Do not write in this margin

triangle computation form, is the sum of the designations given the other two angles of the same triangle but with the signs changed.

The data enable us to fill in the first three columns of the triangle form, except for the concluded angles which must include the spherical excess for the whole triangle in each case. The spherical excess for each triangle is computed using the method already described. We can check the accuracy of the result, since the spherical excess of the fixed triangle is known already. The spherical excess is a function of area and therefore the sum of the spherical excesses for each pair of triangles which form the entire quadrilateral must be equal to that of the other pair. Furthermore, the concluded angle Harborton, Tangier Sd. L.H., Tangier 3, must be equal to the sum of the two smaller concluded angles as indicated by the figure. Realization of this condition may require an adoption of the value of the spherical excess to tenths of a second, not exactly in accord with the computed figure carried to hundredths. In any case both the conditions for the sum of spherical excesses and for the sum of the concluded angles must be satisfied, before going on with the problem.

It should be noted also when the computation for spherical excess is made, whether the logarithms of the sides common to the various triangles come out nearly equal in the computation of the triangles. If this check fails, when the angles are known to be taken correctly from the directions, the point whose position is sought is not a genuine intersection point and it is useless to proceed further with the adjustment. If there are directions available from more than three stations it may still be possible to find three lines which give a real intersection, in which case it is necessary to eliminate the spurious direction and work from another set of 3 directions. If, after using all available directions, it is still impossible to find a definite intersection, the point must be rejected altogether.

Assuming that all checks are satisfactory we may proceed with the set up and solution of the condition equation, which assures that the lines intersecting at the point, Tangier Sd. L. H., actually meet at a point. The following equation may be seen to hold between the lines intersecting at the point, Tangier Sd. L.H.

$$\frac{\text{Tangier Sd. L. H. - Tangier 3}}{\text{Tangier Sd. L. H. - Peyton}} \times \frac{\text{Tangier Sd. L.H. - Peyton}}{\text{Tangier Sd. L. H. - Harborton}} \times \frac{\text{Tangier Sd. L. H. - Harborton}}{\text{Tangier Sd. L. H. - Tangier 3}} = 1$$

According to the trigonometric law of sines a side of a triangle is proportional to the sine of the opposite angle. Hence we may substitute sines of angles for the corresponding opposite sides and obtain:

$$\frac{\sin(-2)}{\sin(+1)} \times \frac{\sin(-3)}{\sin(+2)} \times \frac{\sin(+1)}{\sin(-3)} = 1$$

When this equation is expressed logarithmically, the difference between the sums of logarithms in the numerator and denominator, respectively, should be equal to zero. This will be true except for a small residual term, called the constant term, which is to be used in determining the v's. The equation is written on the form especially arranged for the solution.

	1.	2.	3.	4.	5.	6.	7.	8.
			+ Side				- Side	
	-2	3 59 39.6	8.842 9698	+30.17	+1	122 43 59.7	9.924 8978	-1.35
	-3	44 21 25.1	9.844 5558	+ 2.15	+2	32 14 29.7	9.727 1265	+3.34
	+1	21 05 19.5	9.556 0776	+ 5.46	-3	2 14 13.4	8.591 4438	+53.90
			8.243 6032				8.243 4681	

$$\begin{array}{r} +\ 8.243\ 6032 \\ -\ 8.243\ 4681 \\ \hline +\ 1351 \end{array}$$

$$0 = +\ 135.1 + 6.81(1) - 33.51(2) + 51.75(3)$$
$$0 = +\ 135.1 + 3847.3587C$$
$$3847.3587C = -\ 135.1$$
$$C = -\ 0.035115$$

$v1 = -\ 0.2$
$v2 = +\ 1.2$
$v3 = -\ 1.8$

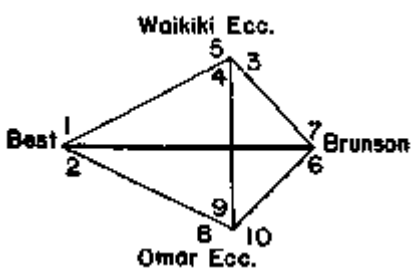
Columns 1 and 5 contain the designations of the angles in the numerator and denominator respectively, columns 2 and 6, the observed angles, column 3 and 7, the logarithms of the sines, and columns 4. and 8 the tabular difference in the logarithm for an increment of 1 second, expressed in units of the sixth place* The sums of the logarithms in columns 3 and 7 are obtained and the difference of the sums, also expressed in units of the sixth place, noted. This difference is the constant term of the equation and is plus or minus depending on whether the left or right column is the greater in magnitude.

In judging whether the constant term is small enough to give a satisfactory-adjustment, account must be taken both of the allowable precision in the angle determinations, and the magnitude of the angles themselves. An error of 1 second in the angle will affect the logarithm and hence the constant term by the amount of the tabular difference for that angle. For small angles the tabular difference becomes very large. In the example shown the constant term is not too large because the equation contains two small angles. The tabular differences in column (4) are written as coefficients of the numbers designating the v's in column (1), the proper algebraic sign being given to the indicated products. Similarly multiplication of the numbers in column (5) by the tabular differences in column (8) is indicated but with algebraic sign changed. The terms so obtained are assembled with the constant term, and the sum set equal to zero. This equation is similar to the angle equation already considered except that the coefficients of the v's in general differ from unity. The solution is handled in exactly the same way. The sum of the squares of the coefficients of the v's multiplied by C is equated to the constant term. After C is solved, it is multiplied by the respective coefficients in the assembled equation to give the v's. The v's are rounded off to the same number of decimals to which the angles are expressed. The values should be adopted to give the most consistent triangle computation and the last figure may not be exactly the same as that arrived at in dropping the extra decimals. This is called adoption of the v's. Because one angle is concluded the sum of the angle corrections is zero for each triangle.

The corrections may now be applied to give the spherical angles and the distributed spherical excess subtracted to give the plane angles. The planeangles should sum to 180° exactly for each triangle. The unknown sides of the triangles are finally computed. Those common to different triangles should be equal or differ in the logarithm by not more than the tabular difference corresponding to 1 in the last decimal place retained in expressing the angles. In intersection work the lengths are rounded off to six places. If common lengths obtained from different triangles are not exactly consistent that one is adopted which is determined from the triangle in which the length is computed from the largest length angles. By length angles are meant the angles of the triangle opposite the sides through which the length is calculated. After the adjustment is completed, the position computation may be made using any one of the triangles containing the unknown point.

Adjustment of a Quadrilateral

The adjustments so far considered have been special cases involving the solution of either a single angle equation or a single side equation. The adjustment of networks involving four or more stations will require, in general, the simultaneous solution of both types of equations. A typical case is that of a quadrilateral with all stations occupied. We choose an example in which two stations have been fixed by previous adjustments. In this case the maximum number of equations are obtained. In the figure the scheme already explained for designating angles has been followed. No numbers are placed on the fixed line. The angles are computed from the list of directions and the first three columns of the triangle form filled out. The spherical excesses are computed and must be the same for the entire quadrilateral using either pair of triangles which form the entire area. The closures are next determined in the manner already discussed. As in the case of the spherical excesses the sum of the closures for the entire area is the same when taken over either of the pairs of triangles which exactly cover the figure. These two checks must be satisfied before proceeding with the adjustment.



A graphical method of determining the number of angle and side equations will be discussed. We shall refer 60 this as the method of building up the figure

* Being plus for angles less than 90° and minus for angles more than 90°.

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 25
Ed. Jan., 1929

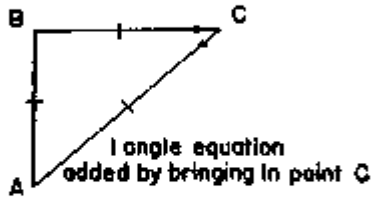
COMPUTATION OF TRIANGLES

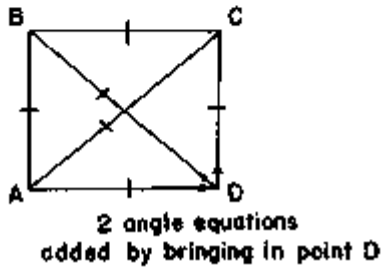
State: Virginia

NO.	STATION	OBSERVED ANGLE			CORR'N	SPHER'L ANGLE	SPHER'L EXCESS	PLANE ANGLE AND DISTANCE	LOGARITHM
	2-3								4.2334927
-8+10	1 Omar Ecc.	113	41	53.60	-0.92	52.68	0.07	52.61	0.03825770
+2	2 Best	20	39	38.75	+0.30	39.05	0.07	38.98	9.54757192
-6	3 Brunson	45	38	29.46	-0.98	28.48	0.07	28.41	9.85429141
	1-3				-1.60		0.21		3.8193223
	1-2			01.81					4.1260418
	2-3								3.8193223
-3+4	1 Waikiki Ecc.	39	47	17.48	-0.79	16.69	0.04	16.65	0.19365517
-6+7	2 Brunson	96	09	51.26	-0.47	50.79	0.04	50.75	9.99748182
-9+10	3 Omar Ecc.	44	02	53.16	-0.52	52.64	0.04	52.60	9.84214728
	1-3				-1.78		0.12		4.0106593
	1-2			01.90					3.8553248
	2-3								4.2334927
-3+5	1 Waikiki Ecc	105	42	42.29	+0.82	43.11	0.08	43.03	0.01653823
+7	2 Brunson	50	31	21.80	+0.51	22.31	0.08	22.23	9.88754872
-1	3 Best	23	45	54.69	+0.13	54.82	0.08	54.74	9.60529383
	1-3				+1.46				4.1375796
	1-2			58.78			0.24		3.8553248
	2-3								4.1260418
-4+5	1 Waikiki Ecc.	65	55	24.81	+1.61	26.42	0.11	26.31	0.03952686
-8+9	2 Omar Ecc.	69	39	00.44	-0.40	00.04	0.11	59.93	9.97201098
-1+2	3 Best	44	25	33.44	+0.43	33.87	0.11	33.76	9.84509062
	1-3				+1.64		0.33		4.1375796
	1-2			58.69					4.0106593

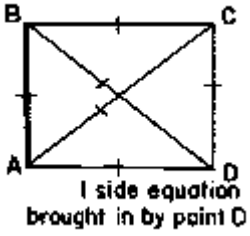
Do not write in this margin

point by point. It is especially advantageous in that it may be applied to a network of any degree of complexity. Suppose two stations A and B are fixed by previous adjustment. Connect these by a heavy line. Next connect the third point C to points A and B. This gives one triangle and one angle equation. Mark each side of the triangle C A B by a short dash. All three sides of the figure are marked indicating that all conditions have been used, which in this case gives one angle equation. Proceeding to the fourth point D, connect it by lines to the three fixed points completing the quadrilateral. Then an angle equation is written in the triangle D B C, the lines B D and C D are marked. This leaves only one line A D unmarked. The last angle equation may be written in either the triangle D A B or D A C to satisfy the last angle condition. Thus two angle equations are added by bringing in the point D, making three in all for the quadrilateral. Stated otherwise the rule is that each new angle equation written in a triangle must contain at least one full line not previously used. It will be noted that the inclusion of a new point permits the introduction of one less angle equation than the number of full lines drawn to the new point from points already used. In practice it is not necessary to actually draw these lines. The figure already drawn should be built up mentally point by point, introducing new lines, but these lines need not be drawn.





Since a quadrilateral with both diagonals drawn consists of four triangles, it is possible to write four angle equations, of which, according to the rule just developed, only three may be retained. The fact that the four equations are not independent may be seen from the example given- Referring ahead to the three angle equations selected, it is seen that if the first equation is subtracted from the sum of the second and third exactly the same equation is obtained as that derived from the remaining triangle. If all four angle equations were retained the solution of the normal equations would fail due to the appearance of an identical equation. Whereas the rule limits the number of equations it leaves us some freedom of selection. In a simple quadrilateral any three of the four angle equations may be retained but is it advisable to omit the one derived from the triangle containing the smallest angle.



The graphical method will now be applied to the determination of the number of side equations. Completion of the triangle C A B will not yield a side equation, since the intersection of three lines is required. Hence we proceed to D and complete the entire figure. Let us choose point D, the point of intersection of A D, B D, and C D as the pole. The angles used in writing the equation are taken from triangles D A C, D A B, and D B C. If the sides of these triangles are marked, there remain no unmarked lines in the figure. Hence only one side equation may be written. Choice of any other point as pole likewise would have exhausted all available conditions. If a figure is built up point by point, it will be found that, for each new point included, there are introduced two less side equations than the number of lines drawn from the new point to points previously used. Each new equation written must bring in one or more lines not previously used.

It is advantageous, as the figure is built up to keep a record of stations added, lines drawn, and resulting equations, in tabular form. In the case of the

example under discussion this table would appear as follows:

1	2	3	4
Name of Station	No. lines drawn	No. angle equations	No. side equations
Brunson	0	0	0
Best	1	0	0
Waikiki ecc.	2	1	0
Omar ecc.	3	2	1
Totals 4	6	3	1

Inspection of this record will indicate either the number of equations introduced with each new point brought into the figure or, by adding the columns, the total number of equations up to the given point. This scheme also gives the most ready-access to the data for substitution in the general formulas for determining the number of equations:

Number of angle equations = n'- S'+ 1
Number of side equations = n - 2S + 3.

in which n is the total number of lines, S' is the total number of stations, n' is the number of lines sighted over in both directions and S' is the number of occupied stations. In order to use these formulas we must include the adjusted points and connecting lines which constitute the starting data in building the figure. The quantity, S, is found by counting the names in the first column, whereas n is the sum of the numbers in the second. The number of angle or side equations is given by the sums of the numbers in the third and fourth columns, respectively, and should check the results given by the respective formulas. It is here assumed that all stations are occupied and all lines sighted both ways so that n = n' and S = S'. Otherwise it would be necessary to indicate unoccupied stations and introduce an additional column for lines sighted both ways. The usefulness of this tabular scheme, is enhanced in the case of extended arcs of triangulation or complex net works.

There is usually some freedom of choice in selecting the side equation or equations to satisfy the rule just given. In a simple quadrilateral with two diagonals drawn the equation may be written in one of four possible ways. It is preferable to choose the pole so that the smallest angles will be used in the side equation.* The angle equations and side equation which were chosen are as follows:

Angle Equations.

1. 0 = -1.46 -(1) - (3) +(5)+(7)
2. 0 = -1.64 -(1) +(2) -(4)+(5) -(8)+(9)
3. 0 = +1.78 -(3) +(4) -(6)+(7) -(9)+(10)

Side Equation

-4+5 -6+7 +2	65 55 24.81 96 09 51.26 20 39 38.75	+ 9.96047172 9.99748170 9.54757063 9.50552405	+0.94 -0.23 +5.58	-1+2 -3+4 -6	44 25 33.44 39 47 17.48 45 38 29.46	9.84508994 9.80614693 9.85429357 9.56553044.	+2.15 +2.53 +2.06

4. 0= -6.39 + 2.15(1) +3.43 (2) + 2.53 (3) -3.47(4) + 0.94(5) +2.29(6) - 0.23 (7)

Correlate Equations

There are thus obtained four equations containing ten unknowns, which are the v's or corrections to directions. The assembly of correlate equations from these four equations, the formation and solution of the normal equations and the final determination of the v's are given completely in the following pages. The steps taken will be pointed out in order and in detail but with no attempt at a theoretical explanation. In the correlate equations are assembled the coefficients of the v's from each of the original equations, for each of which there is one vertical column. There is a horizontal row corresponding to each v. The correlates are filled in vertically one column at a time. It will be noticed that the columns contain the coefficients of the v's each placed opposite its respective v as indicated in the left hand margin.

*Special Publication No. 138, page 35.

Correlate Equations

Equations

	1	2	3	4	z
v_1	-1	-1		+2.15	+0.15
v_2		+1		+3.43	+4.43
v_3	-1		-1	+2.53	+0.53
v_4		-1	+1	-3.47	-3.47
v_5	+1	+1		+0.94	+2.94
v_6			-1	+2.29	+1.29
v_7	+1		+1	-0.23	+1.77
v_8		-1			-1.00
v_9		+1	-1		0.00
v_{10}			+1		+1.00

Normal Equations

	1	2	3	4	η	z
(1)	+4	+2	+2	-3.97	-1.46	+2.57
(2)		+6	-2	+5.69	-1.64	+10.05
(3)			+6	-8.52	+1.78	-0.74
(4)				+41.0098	-6.39	+27.8198

Forward Solution

(row)	1	2	3	4	η	z
(1)	+4.0000	+2.0000	+2.0000	-3.9700	-1.4600	+2.5700
(2)	C1	-0.50000	-0.50000	+0.99250	+0.36500	-0.64250
(3)		+6.0000	-2.0000	+5.6900	-1.6400	+10.0500
(4)	(1)	-1.0000	-1.0000	+1.9850	+0.7300	-1.2850
(5)		+5.0000	-3.0000	+7.6750	-0.9100	+8.7650
(6)		C_2	+0.60000	-1.53500	+0.18200	-1.75300
(7)			+6.0000	-8.5200	+1.7800	-0.7400
(8)		(1)	-1.0000	+1.9850	+0.7300	-1.2850
(9)		(2)	-1.8000	+4.6050	-0.5460	+5.2590
(10)			+3.2000	-1.9300	+1.9640	+3.2340
(11)			C_3	+0.60312	-0.61375	-1.01062
(12)				+41.0098	-6.39	+27.8198
(13)			(1)	- 3.9402	-1.4490	+ 2.5507
(14)			(2)	-11.7811	+1.3968	-13.4543
(15)			(3)	- 1.1640	+1.1845	+ 1.9505
(16)				+24.1245	-5.2577	+18.8667
(17)				C_4	+0.21794	- 0.78206

Back Solution

(row)	4	3	2	1
(1)	+0.21794	-0.61375	+0.18200	+0.36500
(2)		+0.13144	-0.33454	+0.21631
(3)		-0.48231	-0.28939	+0.24116
(4)			-0.44193	+0.22096
(5)				+1.04343

Determination of v's

v_1	v_2	v_3	v_4	v_5
- 1.04343	-0.44193	-1.04343	+0.44193	+1.04343
+ 0.44193	+0.74753	+0.48231	-0.48231	-0.44193
+ 0.46857		+0.55139	-0.75625	+0.20486
- 0.13293	+0.30560	-0.00973	-0.79663	+0.80636
- 0.13	+0.30	-0.01	-0.80	+0.81

v_6	v_7	v_8	v_9	v_{10}
+ 0.48231	+1.04343	+0.44193	-0.44193	-0.48231
+ 0.49908	-0.48231		+0.48231	
	-0.05013			
+ 0.98139	+0.51099	+0.44193	+0.04038	-0.48231
+ 0.98	+0.51	+0.44	+0.04	-0.48

The first three columns of the correlate equations correspond to the three angle equations, the fourth to the side equation while the fifth or Σ column contains the sums of the horizontal rows.

Normal Equations

We now have the data properly arranged for the formation of the normal equations. In this case there will be four equations corresponding to the numbered columns of the correlates. The first term of the first equation is the sum of the squares of the quantities in the first column of correlates. The second term of the first equation is the sum of the products of quantities in the same horizontal rows of the first and second columns of correlates. Thus in the first row we have (-1) x (-1) = +1 in the fifth, (+1) x (+1) = +1, giving a sum, +2. The third term is the sum of the products of quantities in the same horizontal rows of the first and third column, and the fourth term is obtained similarly from the first and fourth column.

Blanks in the correlate columns are treated as zeros. The η term is the constant term of the corresponding original equation. We note that the first η term, -1.k6, is taken from the first angle equation.

The first term written in the second equation is the sum of the squares of quantities in the second column of correlates, the next term is the sum of products from the second and third, followed by the term obtained from the second and fourth columns. The ηterm is taken from the second angle equation. The same scheme is applied to the remaining equations.

The Σterm for the first normal equation is obtained by adding the first horizontal row including η. The Σ term of the second normal equation is obtained by reading down the second column until it terminates then to the right as far as possible, including the η term. The same scheme is applied to the remaining equations. Thus we have -

+4 +2 +2 -3.97 -1.46 = +2.57
+2 +6 -2 +5.69 -1.64 = +10.05
+2 -2 +6 -8.52 +1.78 = -0.74
-3.97 +5.69 -8.52 +41.0098 -6.39 = +27.8198

The Σ terms may be checked independently as follows. For a given normal equation, obtain the sum of the products of quantities in the corresponding column of correlates by those in the same horizontal rows of the Σ column of the correlate equations. This sum should be the same as the sum of the terms of the normal equation preceding the η term. To illustrate for the first equation:

(equation) +4 +2 +2 -3.97 = +4.03, or plus η term = +2.57
(check) -0.15 -0.53 +2.94 +1.77 = +4.03, or plus η term = +2.57

It may be seen that these schemes are algebraically equivalent. This check should always be carried out before attempting to solve the normal equations.

Forward Solution

The forward and back solutions of the normal equations should give us a set of constants from which the v's may be derived. The forward solution is carried out as follows: Write the first normal equation on the first row . On the second row write C_1 followed by the respective quotients, with reversed algebraic sign, of the first term of row 1 divided into each succeeding term. This divided equation expresses C_1 in terms of the other constants and the η term. That is C_1 = -0.50000 C_2 -0.50000 C_3 +0.99250 C_4 +0.36500. The divided equation is checked by obtaining the sum or the terms up to and including η and adding in a -1. This sum should be equal to the Σ term. A horizontal line is then drawn to indicate that this much of the solution is finished.

The solution of the second normal equation may now be carried out. Write the equation, +6 -2 +5.69 -1.64 +10.05 beneath the line in the third row beginning with column 2. To form equation marked (l) which is placed in row 4 beginning with column 2, use the first term of the first divided equation, -0.50000, found in row 2, column 2, to multiply the terms in row 1 beginning with the term, +2, just above the constant factor, and continuing with all subsequent terms to the right. That is, equation (l) is:

-0.50000(+2 +2 -3.97 -1.46 +2.57)

or

-1.0000 -1.0000 +1.9850 +0.7300 -1.2850

Next add the quantities found in the third and fourth rows column by column. We obtain +5.0000 -3.0000 +7.6750 -0.9100 +8.7650, which is written in row 5. The sum of the terms of this equation, added across, up to and including the η term should be equal to the Σ term except for a possible discrepancy in the last figure due to dropping decimals. In row 6 we write C_2 in column 2 followed by the quotients resulting from dividing the first term in row 5, +5.0000, into those that follow, with reversed algebraic signs. This divided equation which completes the solution of the second normal equation is checked by adding the terms across up to and including the η term and adding in a -1. The sum should be equal to the Σ term.

The third normal equation, +6 -8.52 +1.78 -0.74, is written in row 7 beginning with column 3, and just below the line terminating the solution of the second equation. To obtain equation marked (1) in row 8, take -0.50000, found in row 2, column 3, as a constant factor, to multiply the terms in line 1, beginning with column 3. To obtain equation marked (2) in row 9, take +0.60000, found in row 6, column 3, as a constant factor to multiply the terms in row 5 beginning with column 3. Note that in the formation of these multiplied equations, the constant factors are always the terms of the divided equations found in the same column as the number of the normal equation being solved. The terms multiplied are in each case those of the equations found in the respective rows immediately preceding the divided equations from which the constant factors are taken. The multiplication begins in each case with the terms in the column containing the constant factors and continues with all subsequent terms to the right. The equation in row 10 results from the addition column by column of the terms in rows 7, 8 and 9. It is checked in the same manner as the equation in row 5. The divided equation in row 11 is obtained by dividing +3.2000, the first term in row 10, into those that follow with reversed sign. It is checked in the same way as the other divided equations in rows 2 and 6. The horizontal line indicates completion of the solution of the third normal equation.

The fourth and final normal equation, +41.0098 -6.39 +27.8198, is written in row 12 beginning with column 4. The constant factors used to obtain equations (1), (2), and (3), found in rows 13, 14 and 15, are +0.99250, -1.53500, and +0.60312 which are found in the fourth column and in the rows containing the divided equations, viz. 2, 6, and 11. The respective constants are multiplied by the terms in rows 1, 5, and 10, beginning in each case with the term in column 4, that is, the term just above the constant. Rows 12 to 15, inclusive, are added column by column to give the equation in row 16, which is checked in the same fashion as those in rows 5 and 10. The final divided equation beginning with C_4 is obtained by dividing +24.1245, the first term in row 16, into those that follow with reversed sign. As we should expect the first term of the final divided equation, +0.21794 added to -1 gives a sum equal to the last term. The actual value of the constant C_4 is +0.21794. The forward solution is thus completed.

Back Solution

The method of obtaining the back solution should be understood from the following scheme of writing the equations which give the implicit relationship between the constants.

(1) $C_4 = +0.21794$

(2) $C_3 = -0.61375 + 0.60312\ C_4$

(3) $C_2 = +0.18200 - 1.53500\ C_4 + 0.60000\ C_3$

(4) $C_1 = +0.36500 + 0.99250\ C_4 - 0.50000\ C_3 - 0.50000\ C_2$

These equations are obtained by rewriting the divided equations in rows 17, 11, 6 and 2, respectively, of the forward solution, rearranging the terms to read from the η term to the left. It is obvious that these equations must be solved in the order given by eliminating one unknown at a time. The back solution is a formal presentation of the algebraic solution of these equations, consisting of as many columns as there are C's, in this case four, numbered in reverse order. Columns 4, 3, 2, 1 of back solution are exactly the same as equations (1), (2), (3), and (4), written above, except that the indicated multiplications have been carried out. Similarly if we treat the assembly of equations (1), (2), (3), (4) as an array of rows and columns, the column containing the constant terms just to the right of the equality signs, read downward is the same as row 1 of the back solution. The next column containing the products of C_4 is the same as row 2,

etc. The details of setting up the back solution and eliminating the constants follow.

The first row contains the terms of the divided equations found in the η column of the forward solution, rows 17, 11, 6 and 2, read upwards and beginning with C_4. The second row beginning in the second column numbered 3 consists of the products of the terms of the divided equations found in the fourth column of the forward solution, viz. +0.60312, -1.55500, +0.99250, taken in the order written by C_4. The quantities in column numbered 3 are added algebraically to give C_3, -0.48231. C_3 is multiplied by the terms of the divided equations found in column 3 of the forward solution, +0.60000, and -0.50000, and the products placed in columns 2 and 1 of the third row of the back solution. Column 2 is added to give C_2, -0.44193. C_2 is multiplied by the term of the first divided equation found in column 2 of the forward solution -0.50000, and the product placed in column numbered 1, row 4, of the back solution. This column is added to give C_1, +1.04343.

v's

The C's are now substituted in the correlate equations to give the v's.

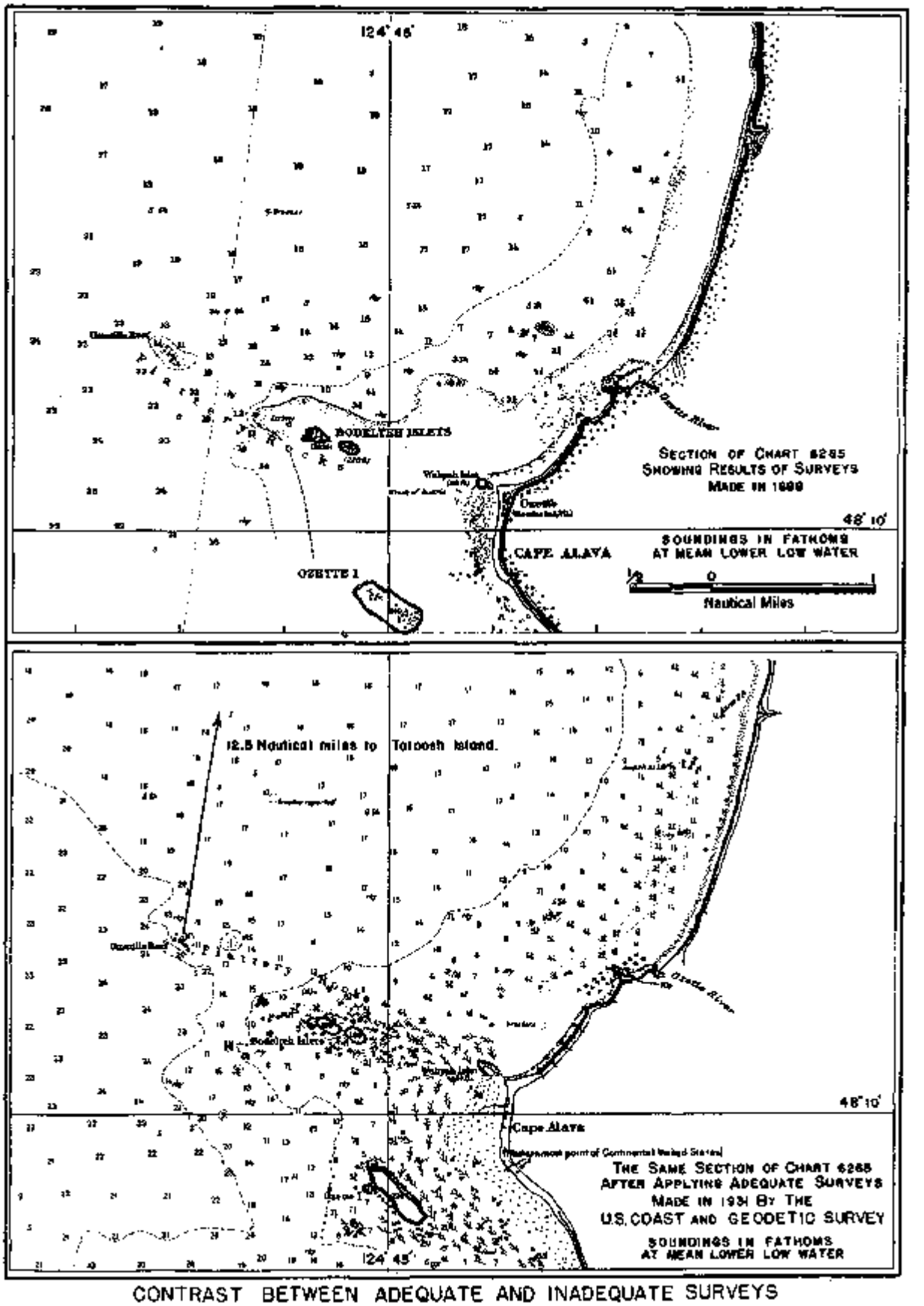
$$v_1 = (-1 \times C_1) + (1-1 \times C_2) + (2.15 \times C_4)$$
$$= -1.04343 + 0.44193 + 0.46857$$
$$= -0.13293$$
$$v_2 = (+1 \times C_2) + (+3.43 \times C_4)$$
$$= -0.44193 + 0.74753$$
$$= +0.30560$$

This work is presented in tabular form, {see page 11) The v's are adopted to the sane number of decimals retained in the observed directions. The adoption is usually simply a matter of rounding off the decimals but the last figure may differ by 1 from the value so obtained, due to the fact that the sums of the angle corrections must equal the closures of the respective triangles. For instance, v_2,+0.30560, is adopted to+0.30 rather than +0.31 as would be expected.

The angle corrections are next determined and entered in the triangle computation. The correction to a given angle is the algebraic sum of the corrections to the directions of the lines which form the angle, taking into account the algebraic signs of the v's, or designations. Let us take as an illustration the computation of the triangle, Omar Ecc, Best, Brunson, as found at the beginning of the triangle form. The correction to the angle at Omar Ecc, designated -8 +10, becomes, after substitution of the v's, —(+0.44) +(-0.48) = -0.92. This correction is entered in column 4, Similarly the correction to the angle at Best, designated +2, is +(+0.30), and the correction to the angle at Brunson, designated-6, is -(+0.98) or -0.98. Note that the sum of these corrections in column 4 is equal to the closure previously determined, -1.60. The closures will be found equal to the sum of the corrections to within the limits of adoption of v's just discussed, if the solution is correct. The spherical angles are then entered and the distributed spherical excess subtracted to give the plane angles which should sum to 180° exactly. The computation of the sides of the triangles is completed. Sides common to different triangles should agree in the logarithms or differ by an amount not exceeding the tabular difference corresponding to 1 in the last decimal place of the smallest angle involved in the calculation. In a first order computation as given in the example the logarithms of the angle functions are carried to eight places and the lengths adopted to seven. In the event common sides differ by an amount within the allowable limit as just discussed, the length derived from the triangle containing the largest length angle is adopted. A satisfactory check in the lengths of common sides is the final criterion of correctness of the whole computation.

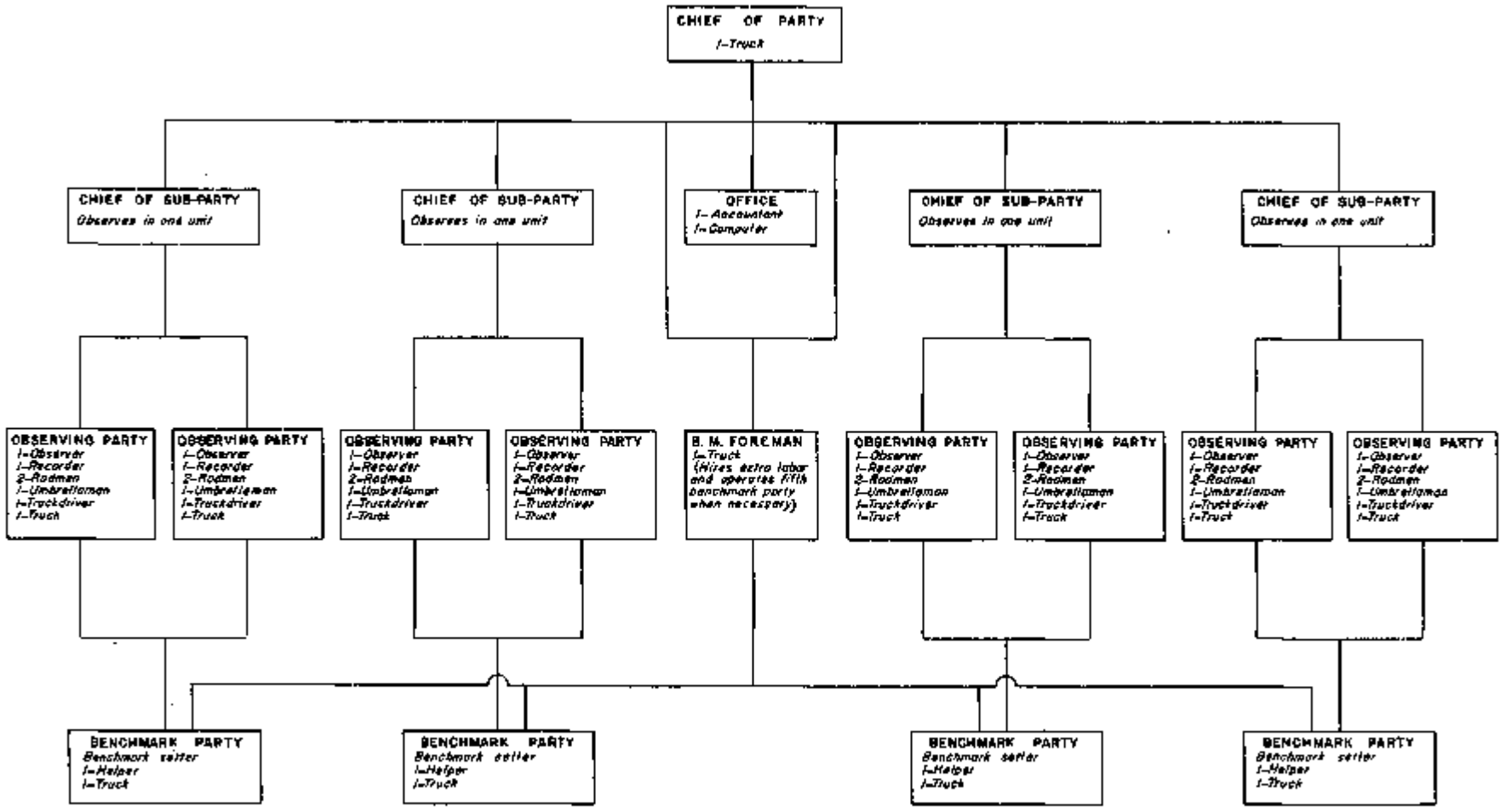
The v's or corrections to directions are finally applied in the lists of directions and the adjusted directions entered. As a final check it should be noted whether the use of the adjusted directions will give the spherical angles in the triangle form. This operation is indicated by check marks on the spherical angles.

The foregoing illustrates the adjustment in detail of a quadrilateral. The reader should now consult Special Publication No. 138 for further development of this problem in seeing how an arc of triangulation is adjusted.



CONTRAST BETWEEN ADEQUATE AND INADEQUATE SURVEYS

U. S. Coast and Geodetic Survey Print

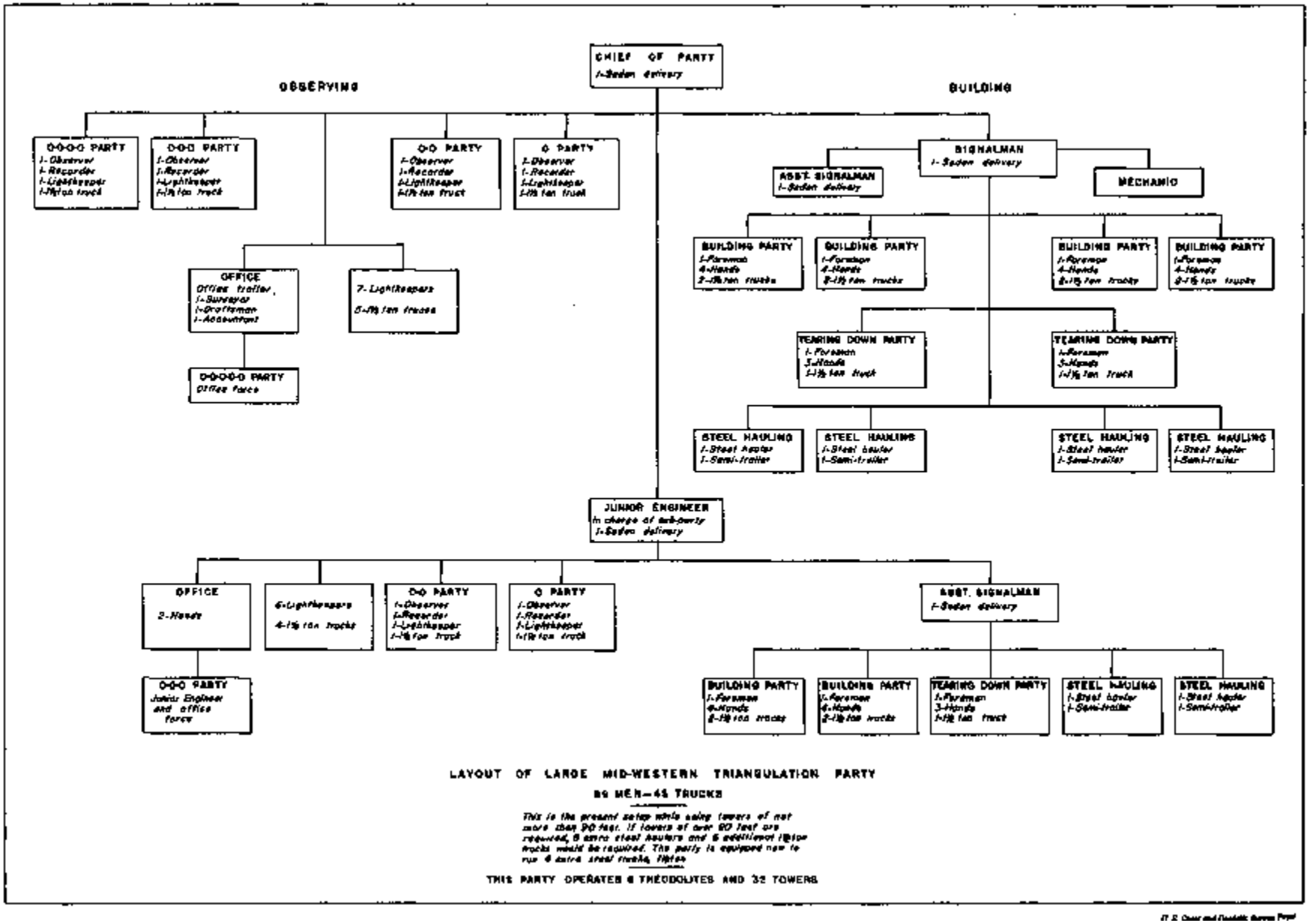


ORGANIZATION CHART OF LARGE LEVEL PARTY

59 MEN-14 TRUCKS

THIS PARTY OPERATES 8 LEVELS

U. S. Coast and Geodetic Survey Print



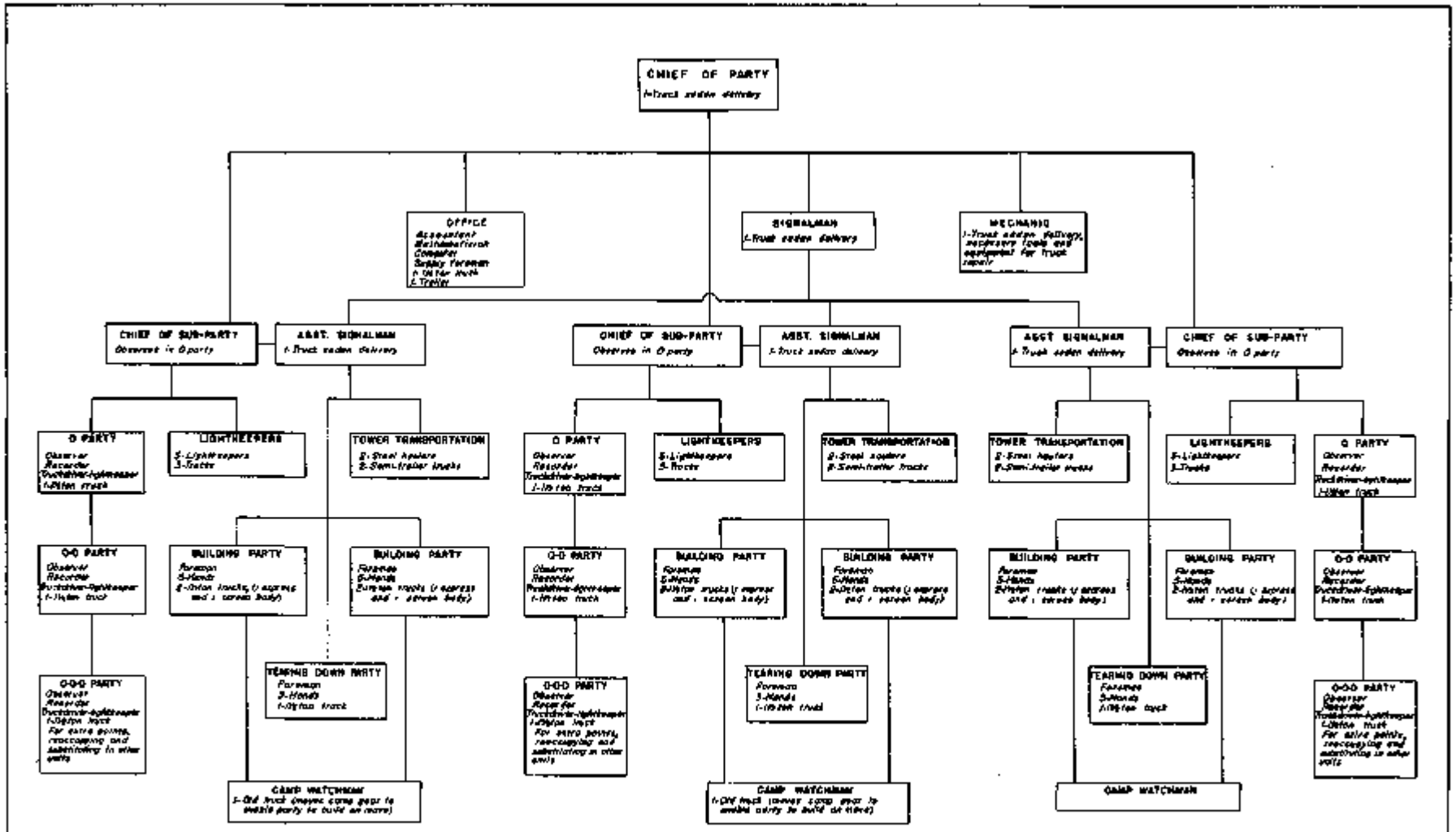
LAYOUT OF LARGE MID-WESTERN TRIANGULATION PARTY

80 MEN—45 TRUCKS

This is the present setup while using towers of not more than 90 feet. If towers of over 90 feet are required, 6 extra steel haulers and 6 additional 1½ton trucks would be required. This party is equipped now to run 4 extra steel trucks, 1½ton

THIS PARTY OPERATES 6 THEODOLITES AND 32 TOWERS

U. S. Coast and Geodetic Survey Proof



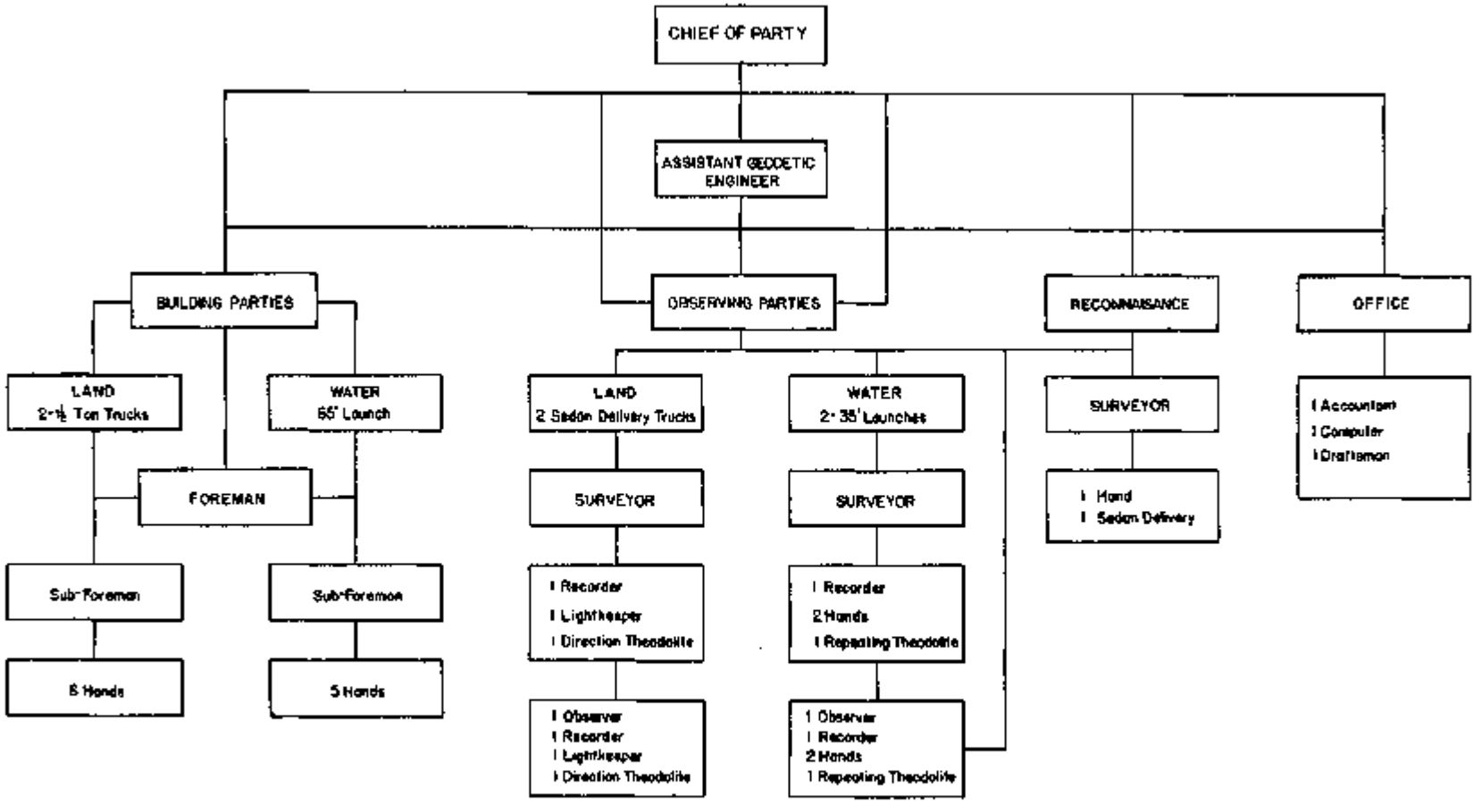
LAYOUT OF LARGE EASTERN TRIANGULATION PARTY

48 TRUCKS—108 MEN

The tower transportation unit can take care of towers up to 80 feet, for towers over this height, 3 more trucks and 2 more drivers are necessary in each of the 3 units

THIS PARTY OPERATES 4 THEODOLITES AND 30 TOWERS

U. S. Coast and Geodetic Survey, Print



ORGANIZATION CHART OF COASTAL COORDINATING TRIANGULATION PARTY-May-1934

Transportation by Launches and Trucks

33 MEN -- WOOD TOWERS

THIS PARTY OPERATES FOUR THEODOLITES

THE PROBLEM OP RECONNAISSANCE

William Mussetter, Senior Geodetic Engineer
U. S. Coast and Geodetic Survey

Since the advent of the Bilby steel tower, the methods and application of triangulation have made radical progress. Since l928, my duties have been almost entirely in the field of reconnaissance. An effort has been made constantly to keep abreast of developments in signal building and observing. However, as the Division of Geodesy is now organized, or rather, up to the appearance of the Geodetic Letter, there has not been a very great opportunity for chiefs of party to talk over various problems, so as to best cooperate in the various fields. As a reconnaissance man, I have had little contact with advances in signal building, these contacts being limited to occasional visits with triangulation parties, and to infrequent letters from triangulation men. Reconnaissance is seldom mentioned in reports, and if there are any comments made to the Office, we seldom hear of them. Hence, I am offering all chiefs of triangulation parties an opportunity to speak up and tell what they like and dislike in the field of reconnaissance, and what suggestions they may have for improving our work. As an opening to any such criticisms, I would like to present some of the problems of a reconnaissance party, and to outline briefly some of the methods of approaching them.

Reconnaissance is essentially design, and as such has a great deal to do with the resulting triangulation. No amount of careful observing can make up for seriously weak figures; no careful management can save the expense of a delay caused by the obstruction of an essential line; and no good mark will be permanent if it is placed in the line of local improvements which will destroy it. Also, the hauling and building of signals of unnecessary height is a needless expense, while the erection of one too short is more so. In extending triangulation between any two localities, there are probably an infinite number of schemes that may be laid out. The duty of the reconnaissance party is to secure the best possible scheme, realizing that its work is a means to the end of completing a satisfactory and economical control survey. The first essential is, of course, the intervisibility of stations. This must take precedence over all other considerations. Next, and in order, I believe, come permanence of marks, strength of figures, wishes of property owners, and accessibility of stations, both for our own parties, and for the use of outside engineers.

In regard to the methods of proving intervisibility of stations, this varies widely with the country, and, on the same scheme, each line will present an individual problem, common to no other one. This is perhaps the reason why no text book has ever been written on the subject, and why college courses pass reconnaissance by with only a mention. The methods used in the sand hills of Nebraska are distantly related to those used in the tall timber of Louisiana.

The simplest reconnaissance is in the mountains, where lines are checked by vision. You either see or you don't, and no amount of signal building will alter it. The question then becomes one of accurately identifying distant objects.

Next comes the Western Plains region, which is nearly treeless, and in spite of the name, contains many hills, breaks and swells. Not all lines in such country can be checked by direct vision, and resort must be had to profiling. In open country, I prefer to set up an instrument with a good vertical circle, and make an instrumental profile, either directly by getting on or near the line, or indirectly, by observing the summits of several obstructing objects from one or more points of vantage. While the altimeter is in wide use, I reserve it for places where the vertical circle cannot be used. In the plains, proper identification is very important, and the observer must train himself to remember small peculiarities, such as a break in a slope, a bent tree, or any detail which might help him find the point in the future. A good observer develops the ability to remember such things without actually concentrating upon them. Otherwise, he will visit a station with a preconceived plan, then move up ahead, find it won't work, and find that he has no stored information with which to develop another plan.

In profile calculations, I use very simple calculations, and usually work them in my head, or in the note book; e.g. the tangent of one minute is 1.6 feet per mile; and curvature is 0.6 foot times miles squared. It should not be taken

for granted, however, that signal heights are carelessly computed, with a few extra panels thrown in for safety. We do figure with a factor of safety, but at the same time hold signal heights as low as practicable.

The next general type of country in order is the so-called prairie regions such as Iowa, Kinnesota and Illinois. Here also, many lines are checked by vision. I commonly make outline sketches of distant groves and buildings to aid in identification, and profile when necessary with instrument or altimeter. Roads are mostly good, and go everywhere in such country, and the altimeter is at its best. Of course, where Geological Survey sheets are available, we use them to lay out a working plan, and then check the lines in the field. The new Geological Survey maps are excellent, but the old ones are not reliable. However, I don't think that more than 10 per cent, of my work in the past five years has been on contour maps, and they seem to grow scarcer as the years go on. On all types of work, it is my habit to consider every line obstructed until I am reasonably satisfied that it is clear. As soon as a man gets optimistic and lets hope govern his calculations, he is bound to have obstructed lines.

The most difficult country for reconnaissance is a heavily timbered, sparsely settled region with a rolling to hilly surface. This sort of territory is usually the least provided with roads or advance information in the form of maps. Much of the South is of this type, as are the cut-over timberlands of Upper Michigan, where we are at present. I have heard remarks to the effect that reconnaissance has been greatly simplified by the steel tower, with its almost unlimited height. It has been, but we are now carrying triangulation into areas where it would never have been thought of ten years ago. Hence, we are working right up against the limit of signal height, with the further disadvantage that the possible obstructions are so far above ground that we can't measure them. An example is the crossing of the Tensas Basin, just west of Vicksburg. The men who were on that job will remember that I called for all the steel they had, up to 149 feet, and yet the lines barely grazed through. Sometimes men are somewhat mystified as to how we arrive at locations and signal heights under such conditions. There is no magic. Down there, I just explored the woods, measuring the height of representative trees, and the distance above ground of the high water marks of the 1927 flood. The regular procedure is to study all available maps, sketch out drainage lines and junctions of divides. Then get such a view of the country as possible from tree tops, water tanks, or fire towers. I have often spent half a day with an instrument on a water tank, measuring heights of distant hills. This will give an idea of the possibilities. Local inquiry is of no value. The natives just don't see their country with the same eyes we do. It is seldom possible to see through a line in such country. Hence, we resort heavily to profiling, almost wholly with an altimeter. All the devices known are used in cheeking these observations, and the result is a pretty good estimate.

It should be remembered that we don't expect to clear high timber more than 10 feet, and that 10 feet in a 10 mile line is a pretty close margin for an altimeter. However, without it, the result would be only a more or less intelligent guess. Any number of methods are used to meet individual problems. Recently, I attempted to check a line from a tentative station to a lookout tower. By plotted positions and compass bearing, the line was obstructed by timber three miles distant, with a plus angle of 15 minutes. This required a minimum of 107 feet at both ends, more than I cared to specify. The only alternative was a much weaker figure. From a tree top, I spotted a ridge that was closer to the line than the bearings indicated, and as the maps were not accurate, I determined to run the line through, to see if it would miss the obstruction. Proceeding from the lookout tower, I found a bare hilltop where I could locate myself accurately by a three-point fix with an instrument. I then set the instrument in the computed azimuth and laid out the course to the other end. This missed the obstructing ridge, indicating the plotted positions were out, and the reversed bearings from the two ends were running parallel courses 1/4 mile apart. As I was not on line, I next computed the azimuth of the point where the true line crossed the defilade. Vertical angles here indicated the line would clear, provided everything was figured correctly. Next, I sketched some outstanding tree on the obstruction, drove as near to it as possible, and ran down the sketched tree. From its top, the compass, on repeated trials read 271-1/2 on the lookout, and 91 on my identifying tree at the east end. I was therefore about 35 yards from being on line, and there was nothing that would obstruct within 100 yards. That is a close margin for clearing a 13 mile line on readings with a 3-inch compass needle, and will indicate why an occasional line will

be obstructed in spite of everything. I believe this one is clear. It took a day but will save the triangulation party's packing a 100-foot signal a mile through brush, as well as leaving an accessible station, and a strong figure.

In making final location of station, if possible, we consult the land owner on future building plans, size up possibilities of road widening, easing of curves, desirability of site for "hot-dog" stands, and anything else we can think of. Then we choose a site that will miss these possible future changes. The yard and barnlots of country homes are among the most permanent places we can find. Hence my reputation for placing stations in pig lots. Where the exact location of a station is specified, and especially if it differs from the obvious, the building party should not take the liberty of changing it. It is specified that way for a purpose which it is seldom convenient to put in the description.

Figure strength has been greatly improved in recent years through careful study by reconnaissance parties. The allowable accumulation between bases is now 80, which allows only l6 perfect quads. Future work may require a strong starting line at any point, and a few years from now, we shall probably be wishing they were still stronger. A strong scheme shows the work of experience.

I believe it hardly necessary to speak to triangulation men about the wishes of property owners, or the value to them of proper approach by the reconnaissance party. We interview or address all owners possible, although, on account of the pressure for progress, it is not always done. The same stands for accessibility of the stations. When they are not readily accessible, the reason is either evident, or dictated by one of the former considerations. In this type of country (Northern Michigan), the visibility gets the lion's share of consideration.

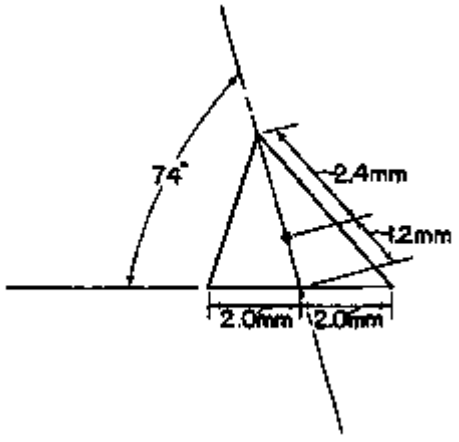
A few years back, a reconnaissance sketch was just a rough outline of the scheme, with a projection and a few large towns located. Then we began adding road sketches and small towns to guide truck drivers. Next, the extensive use of automatic lights demanded a sketch sufficiently accurate for pointings in daylight by map. Recently, we have added prominent objects for cut-ins, so that multiple O-Parties may search for and observe them all, and record them under the same name. And now, as a by-product of profiling, we are attempting to furnish elevations above 1500 feet to save the O-Party from observing vertical angles. This is still experimental, and probably will not entirely eliminate the vertical angles. It is one of the items on which I desire comment from the field.

I do not doubt that there are many things we could do with little extra effort, which would be of aid to triangulation parties, and we will appreciate suggestions along that line. On the other hand, we have a difficult task to speed up to quantity production, and are putting in plenty of overtime.

TRIANGLES AGAIN

A. A. Lockerbie, (Party of B. H. Rigg)

Uniformity of triangulation symbols on plane table and hydrographic sheets adds much to the appearance of the work. While neat, clear-cut triangles can be drawn and accurately centered about a point, it is rather a painstaking job. By cutting a triangle on the left hand end of a LeRoy lettering guide and using the regular LeRoy pen, triangles may be accurately centered and neatly inked on a sheet at a very rapid rate. A pencil point may be substituted for the LeRoy pen point and the triangles applied in pencil to topo sheets. To use, place the guide stylus in the center hole and slide the guide until the station point is directly under the pen point. The triangles may then be inked.



The layout for cutting the guide triangle is shown on the right.

TRANSPARENT DIAGONAL SCALE

Designed by A. A. Lockerbie,
(Party of B. H. Rigg)

The transparent diagonal scale is an instrument designed to replace the beam compass and scale for "taking off" geographic positions from plane table sheets, and for checking the plotting of stations on hydrographic or topographic sheets. Its design precludes its use for plotting purposes.

The scale is an accurately ruled rectangle, 20 x 12.5 centimeters on plate glass. The sides of the rectangle are subdivided into twenty parts. Thus, each centimeter, on the long side, represents 100 meters on the scale of 1 to 10,000. Each 6.25 millimeters, on the short side, represents 5 meters measured to a diagonal having a slope of 1 to 12.5. Thus, when lines have been ruled parallel to the sides of the rectangle, connecting the above points, distances can be scaled utilizing the principle of the ordinary diagonal scale. Direct readings can be made to five meters, the single, or half meters being estimated.

The double line method is used to enable the placing of the index exactly on the meridian or parallel when using the scale. This is one of the most important points of construction leading to accuracy in use. Instead of placing the index line at zero of the scale, two lines are ruled, one 0.20 millimeter above and another 0.20 millimeter below.

The lower edge of the glass is ground parallel to the index lines enabling the placing of the scale against a short straight-edge. By adjusting the scale until the meridian or parallel bisects the index, then sliding the scale until a diagonal intersects the point to be scaled, a reading may be made.

A test of the accuracy of this instrument was made with very pleasing results, considering the equipment with which the sample was constructed. Forty points were plotted on the back of an aluminum, plane table sheet. These forty points were so selected as to come near each end of the diagonals of the scale.

RESULT OF TEST - SCALE NO. 2

Run "A"

Point	True Distance (by beam compass and meter bar)	Scaled Distance	Difference
1	115.6	117.0	+1.4
2	193.7	194.5	+0.8
3	307.9	308.5	+0.6
4	385.2	385.0	-0.2
5	503.3	503.5	+0.2
6	598.2	598.0	-0.2
7	718.5	719.0	+0.5
8	7S3.3	783.5	+0.2
9	909.9	911.5	+1.6
10	995.8	996.5	+0.7
11	1121.1	1120.5	-0.6
12	1193.6	1192.5	-1.1
13	1303.0	1303.0	0.0
14	1398.4	1397.0	-1.4
15	1508.1	1508.0	-0.1
16	1582.6	1581.5	-1.1
17	1719.7	1720.0	+0.3
18	1790.0	1788.5	-1.5
19	1919.9	1921.5	+1.6
20	1988.2	1989.5	+1.3

Stations plotted by Addison S. Hall; scaled by A. A. Lockerbie.
Total time: 17 minutes. (51 seconds per reading.)
Probable error of single observation: .67 meters.

Run "B"

1	11.3	11.7	+0.4
2	89.6	92.5	+2.9
3	218.2	218.5	+0.3
4	296.4	296.0	-0.4

Run "B" (continued)

Point	True Distance (by beam compass and meter bar)	Scaled Distance	Difference
5	410.7	411.0	+0.3
6	488.8	489.2	+0.4
7	603.9	604.0	+0.1
8	697.4	697.0	-0.4
9	809.3	810.0	+0.7
10	888.2	890.0	+1.8
11	1015.6	1015.0	-0.6
12	1089.8	1089.0	-0.8
13	1208.7	1211.0	+2.3
14	1292.1	1290.5	-1.6
15	1406.6	1407.0	+0.4
16	1487.3	1487.5	+0.2
17	1602.4	1602.0	-0.4
18	1685.1	1685.0	-0.1
19	1815.7	1815.0	-0.7
20	1896.2	1897.0	+0.8

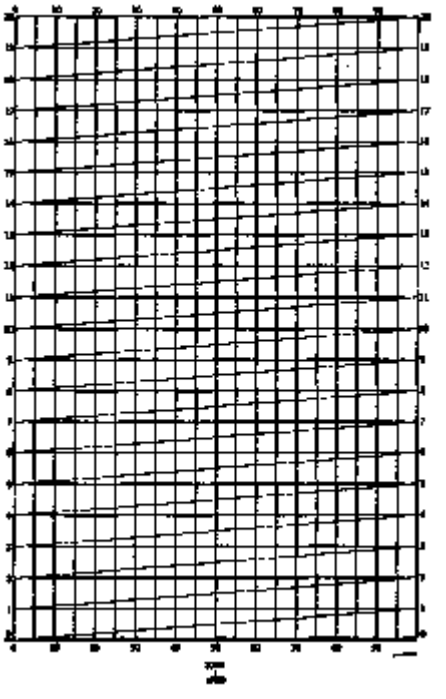
Stations plotted by A. A. Lockerbie; scaled by A. S. Hall.
Total time: 18 minutes. (54 seconds per readings
Probable error of single observation: .69 meters.

It is believed that the results obtained compare very well with those obtainable by the use of scale and beam compass. The best criterion, however, of its accuracy, speed, and smoothness of operation, is found in actual use. If, in checking, distances do not agree within one meter with the listed G. P.'s, it has been found in practically all cases to be some error in plotting the position.

The advantages in using the scale are almost self-evident. A little practice in operation will enable the reading of G. P.'s at a very rapid rate. It is believed that even better speed than shown in the tests could be made under normal conditions. The fact that readings can be made while still looking at the position of the signal will tend to eliminate the mixing of the backward with the forward reading. Needless to say, the scale is less cumbersome than the beam and compass and in inexperienced hands, much less injurious to sheets, not to mention meter bars which receive their hardest use when "taking off" distances. Without a doubt, however, the greatest advantage of using the scale is the elimination of eye-strain attendant to the use of the beam compass.

The only disadvantage is perhaps its limited scope; i. e., it can be used only for checking or "taking off". The vast amount of this rather irksome work more than justifies its adoption as an office necessity.

(These scales have been made photographically on the under side of thin glass and are available for issue to parties in the field. This method of making the scales costs so much less than ruling each scale on glass with the accompanying etching of numerals, that it has been adopted. The photographic emulsion on the under side has been sprayed with a transparent lacquer which should prevent excessive scratching due to the shifting of the scale as in use. Editor.)



THE OPERATION OP A LARGE STEEL TOWER TRIANGULATION PARTY

Carl I. Aslakson, Jr., E. & G. Engineer
U. S. Coast and Geodetic Survey

A great deal of discussion has taken place in regard to the use of central camps by steel tower triangulation parties as opposed to a large number of smaller camps. After having had considerable experience with both kinds of camps, the writer is firmly convinced that the central camp is more economical. The two factors to be considered are the added truck mileage caused by the central camp against the better control of the party in a central camp. There are many occasions when a last-minute change in observing schedule due to obtaining final corrected values of directions will result in saving a day's time. With a party costing around $350 per day, the saving of a single day will pay for a great many additional truck miles. Another factor to be considered is the better inspection of records, computations and equipment that may be maintained by the Chief of Party with a central camp. No loss of time occurs in moving camp. Observing parties are stripped to a minimum and the extra men such as computers, storekeeper, accountants and extra lightkeepers do the moving while the regular observing schedule is in effect.

The writer recommends a camp divided into three units, namely, building parties, observing parties, and tearing down parties. On a very few occasions the building party will be camped with the observing and tearing down parties but usually they will be about 40 miles ahead on the scheme. Usually the tearing down party will camp with the observing parties to receive the 'take-downs' which are posted upon the bulletin board after the return of the observers at night. On some occasions the tearing down party will camp in the rear of the observing parties. The above procedure has been found to be most economical method of handling a large party.

Camp Sites

The selection of a good camp site is an important feature. There are a number of salient points to be considered, namely, shade, water, electric lights, privacy, freedom from insects and dust, room, and camp sanitation.

Shade is an important item in the summer, especially for the observing parties. After a hard night observing if the sleep of the men is broken up by the hot sun on their tents in the morning the morale of the party is soon at a low ebb.

No elaboration need be made on the necessity for convenient access to a supply of good, pure water.

All of the tents on this party are wired for electric lights. The bills for wire and current are prorated among the men. Careful inspection of the wiring is always made and fuses are maintained for safety. It is felt that there is far less danger of fire from this source than from the presence of many oil and gasoline lanterns.

Privacy is desired but seldom obtained. However, the men shortly learn what it means to live like goldfish and acquire a certain immunity. Tents are usually pitched in two rows with a street between, or in horseshoe formation.

Freedom from dust and insects is especially to be desired. Camps immediately on dusty roads or too close to barns or swamps should be avoided when possible.

Plenty of space is desirable so that tents may be arranged in neat rows with plenty of parking space for trucks and cars. There is nothing that looks more slipshod than tents and trucks parked at various angles all over the camp ground.

In general the most important feature in camp maintenance is camp sanitation.

Sometimes camp grounds can be secured which afford toilets and showers. However, in the camps of this party these facilities are always furnished whether or not it is necessary to build them. Toilets are dug to specifications, deodorized properly, and made as fly proof as possible. Lime and chloride are used freely and insecticide is used a number of times each day. Tents are placed over the toilets with the floor tarp arranged as a screen in front of the door. Showers

are easily built. A garden hose is run from the nearest hydrant and the end, which is provided with a sprinkler and valve is led into the shower tent and lashed to the pole. Wooden grating is used on the floor and the floor tarp used as a screen. It is the belief of the writer that these showers have done more to make the party happy and contented than any other single feature. Showers are disinfected and treated with insecticide daily.

Selection of camp sites should be done in advance by the Chief of Party or a Signalman. The local Chamber of Commerce or the Mayor of the city should be contacted at once and usually no difficulty will be encountered in securing the best available camp ground. Camp grounds are carefully policed "before leaving and are usually left in better condition than upon arrival.

Camp Routine

The use of an office trailer is indispensable on a large party. The Split-Coach is used on this party but many changes have been made.

A book case for completed records has been installed. All records are numbered on the ends so that a glance will reveal missing records, A card hangs on a hook below the case showing the numbers assigned to new records so that there is no confusion in regard to volume numbers. The fronts of all the large drawers were sawed off so that they are now cupboards with hinged doors. This provides a convenient place for heavy articles such as blank records, etc. A two drawer steel filing cabinet is installed on one side of the trailer. A convenient set of cupboards was made by cutting through the pillar cabinets on the front of the trailer.

The trailer should be maintained for the use of the office force only. The accountant and Chief of Party work in it. Therefore a computing tent 12 x l4 feet with 5-foot side walls provided with chairs and tables is used as a computing tent for observers, recorders, and computers.

The appointment of a man to act as a storekeeper has been found very advantageous. This man must be one of the most reliable men in the party. He takes complete charge of stores on this party, maintains a check on the inventory, informs the Chief of Party when supplies, such as dry cells, bulbs, etc. are running low, keeps an eye on all of the trucks and equipment, makes necessary repairs to tarps, cots, etc. On this party the storekeeper makes all packsacks and they are better than any that can be purchased. The storekeeper is in general charge of camp sanitation and uses the necessary deodorants, insecticides, and disinfectants. He frequently acts as an emergency lightkeeper.

Observer's Routine

A bulletin board is maintained outside of the office for all notices. Upon this board the daily schedule of observing parties is posted about noon each day. Prom four to six observing parties are operating each night. Five observing parties can nearly match the speed of four building parties. A sixth observing party works on some occasions.

The following routine is now in effect in regard to intersection stations: The schedule assigns certain lightkeepers on observing parties to obtain necessary information for descriptions of available intersection points in certain towns in the vicinity of their operations. These lightkeepers obtain all available data to completely describe the points. The data is then written into one of the triangulation records. The object is given a short name such as "Spire, Wanda"; "Court, Lakefield"; "Sacred, Raymond"; et cetera. After a council among the observers on the following day these names are used exclusively in the record books. Then a "Description of Triangulation Station" is written up for each of these points by one of the computers and checked by the observer in whose volume the description appears. This description card also contains the stations from which the object was located and a reference to the page and volume in which the description appears.

In operating in the vicinity of a large city great confusion will result in obtaining proper cuts unless a single "cut party" is operated. An excellent spread and selection of intersection stations will result if one good observing party is assigned to this work at such a time.

Descriptions of Stations

Due to the lack of an original record book for recording field notes on descriptions of stations it is the practice on this party to completely describe all stations in the "Horizontal Direction Record." The descriptions of stations are then typed by the recorder and checked by the observer.

Training of Men

Every available opportunity is taken to allow lightkeepers and truckdrivers a chance to observe and record under proper supervision. At any one time there are always available enough spare observers and recorders that changes may be made without loss of time.

New lightkeepers are always trained by sending them out with old lightkeepers several times and sending them with an observing party once or twice. This method furnishes excellent results.

One man assists in the office whenever available to familiarize himself with accounting methods thus making a spare accountant.

Progress sketches are turned over to any one of several lightkeepers who are draftsmen.

Trucks

The use of a mechanic for making ordinary truck repairs is a necessity. Trucks are kept in better shape at a much lower cost. One man can be kept busy all of the time on this work. Interest should be created among all truck drivers in regard to low operating costs and appearance of trucks. Most of the men on this party wash their trucks whenever they have time, keep fenders pounded out and painted, wheels painted and make other minor repairs. Many take great pride in the appearance of their trucks.

With a new party very careful supervision of trucks should be maintained to avoid abuse such as fast driving or joy riding. It will always be found necessary to discharge some men for abuse of trucks before the lesson is properly driven home.

For a number of years the use of dual wheels on trucks has been avoided as it was felt that they would not give good service when driven over rutted roads. However, during the past season this party received a number of trucks which had so little clearance that chains could not be used when they were fitted with 10 ply tires. It then became necessary to use dual wheels with 8 ply tires. These trucks have proven very satisfactory. They will travel over soft ground or loose sand which will stop any truck equipped with single drive wheels. It is therefore recommended that all steel trucks and winch trucks at least be so equipped.

The abandonment of semi-trailers as steel trucks is recommended. Trucks of 157 inch wheel base with special brackets on the side for handling the long steel have proven far more satisfactory than Semi-trailers. The use of a semi-trailer as a truck for hauling camp gear on moving day frees most of the other trucks for the use of observers and lightkeepers and is a very valuable aid in proper operation of the party.

Publicity

It is customary on this party to have someone contact the newspapers immediately upon arrival in a city and advise them that a story will be available if reporters are sent to the camp. Every courtesy is shown reporters. If pictures are desired any assistance possible is afforded them. Chiefs of parties may obtain from the Washington Office for distribution copies of a leaflet describing the Survey's activities.

(Photographs, lantern slides, and other material for use by the Chief of Party may be obtained from the Washington Office for this purpose. The value of advance publicity in newspapers of the operations of such a party is usually of great benefit to the economic administration of the party, for an explanation of the work of triangulation in simple terms, with a statement of the general purposes and value to the country will aid the chief of party in many ways.

Editor).

LESSONS OF THE EXPANDED PHOTO-MAPPING WORK OF THE COAST AND GEODETIC SURVEY IN RELATION TO PLANS FOR ACCELERATED MAPPING

by O. S. Reading, H. & G. Engineer, U.S.C. & G. Survey

(Paper read before the American Society of Photogrammetry on September 25,1934)

About a year and a half ago, I was ordered to New York City on what seemed at the time a rather doubtful mission. It was to organize a small photo-compiling party from unemployed engineers. After looking over the many applicants, the prospect seemed still more dubious, for there was not a single topographer or full-time surveyor among them. But I still have a hollow feeling around the diaphram when I think of those men. Clean-cut, intelligent engineers who had been earning three hundred to a thousand dollars a month before the depression. There were also some youngsters, a couple of years out of college, with Phi Beta Kappa keys, all facing a world that had no use for their services. They did not say so at the time, but I learned from later questions that all had long since given up their telephones, and most had seen their life insurance reserves dwindle away. Some had no other means of support for their families except twenty-five dollars every other week for relief "made work" furnished by the City of New York. Since none of the men were specially qualified, I finally selected those who needed the work most and could show by designs of bridges, yards, and building plans they had drawn up in previous years, that they were passable draftsmen.

I was pleasantly surprised to find how readily these men grasped the elements of photo mapping by the radial line method, and when my relief arrived a week or so later, I left for Washington with the hope that we were going to get some good maps for our money. We got the good maps all right; and I was still more surprised to learn, when the reports came in at the end of the fiscal year, that the costs compared very favorably with those of similar maps compiled by experienced cartographers in our Washington Office. As a result of this experience, there was no hesitation, when Public Works funds became available last fall, in starting up seven more such parties to map areas adjacent to the Intra-Coastal Waterway along the Atlantic and Gulf coasts. These parties are all turning in very good planimetric compilations at very reasonable costs at the present time.

As to the lessons we have learned in this work: First of all we prepared a set of notes which briefly described the elements of photo mapping and gave a very detailed description of the technique approved at that time for doing the work. These notes proved very useful in training new men, and a similar procedure is recommended for any large and rapidly expanded mapping program.

A second thing we did was to send each party a set of prints of very satisfactory compilations together with others that were not so good on which had been written in detail just why they were not satisfactory. Most draftsmen need examples more than the printed instructions.

A third point was to organize the parties in some town in the area to be compiled. One of the bottle-necks in an expanding program is to train men to locate the control stations on the photographs with the necessary accuracy and to mark up the photographs with sufficient notes in the field so that there may be no questions of interpretation during the office compilation later. Nearly always there are sins of omission or commission until the men learn through experience the high degree of accuracy and completeness necessary. If the party is located in the area, such difficulties can be remedied at low expense; but if not, there will be many cases of "office surveying" which we all have learned to abhor. As the draftsmen circulate about the country during holidays, they also absorb much that helps them to make their conventional signs depict the country better than would be possible if they had not seen it. By all means, the compiling parties should be established in the localities they are mapping for the equipment needed for radial line methods can be shipped about readily.

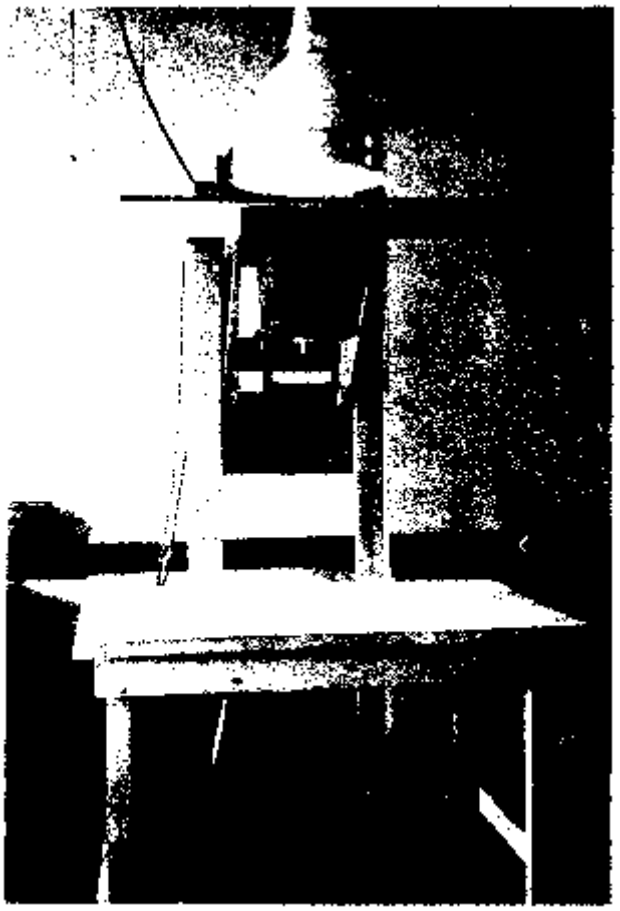
A fourth point was to subdivide and specialize the work as soon as practicable. Ordinarily, a party starts with about eight green draftsmen to one experienced chief of party. After a week or so of organization and instruction, each man does all the work connected with compiling a map by the radial line method. By this time, the chief of party has a good idea of the special abili-

ties of each man and assigns the future work accordingly. One man will do the field inspection and marking up of the photographs (with a laborer helper); another will make the projections, plot the control on them and with a third, make the radial plots. Several neat draftsmen will trace off the information from the photographs, adjusting it to the intersected points. Usually, there is a very careful man who reviews the work before the final review by the chief of party. As soon as such an organization is working smoothly, the party may be expanded safely to fifteen or twenty men, without sacrificing the quality or efficiency of the work. Such subdivision and specialization of the work, of course, promotes production to a marked extent.

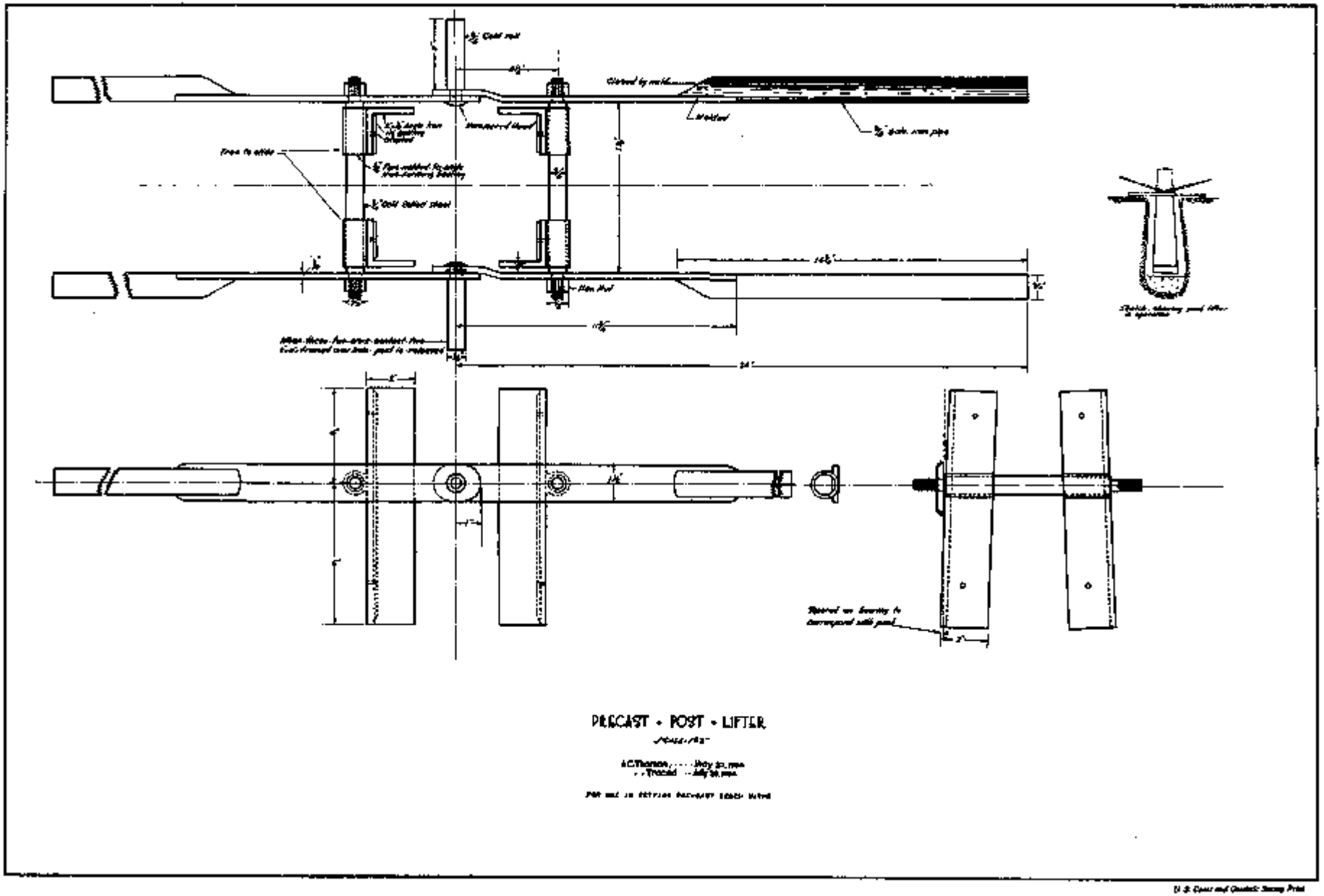
Another point was to check and test the compilations in the field as soon as possible after they are made. One may lecture a draftsman for hours on the importance of carefulness, and he will think that he is doing perfect work, but nothing will put him on his toes or teach him to take the necessary precautions quite so well as having one of his sheets that he thought was about perfect come back from the field to be corrected. We are particularly fortunate in this respect in our work along the coast for practically all our compilations are used in connection with hydrography - often the shoreline is transferred to a boat sheet before the tracing of the detail is completed. If the hydrographer takes a position which plots over on the land, there is a howl to high heaven which is usually heard clear into the Washington Office. In fact, we who have been working with photographs in the Coast and Geodetic Survey purposely have been rather cocky about the compilations, bragging about picking up errors in control positions, exceeding the accuracy of plane table work, etc., etc., until most of the rest of the outfit is quite willing to show us up a bit. It seems to have worked well thus far, and we have a feeling that we learn about any errors, whether important or not.

To sum up, we have learned when confronted by a need to expand photo-compilation work rapidly, to get out a set of notes explaining just what to do and how to do it; to provide a set of satisfactory and unsatisfactory sheets with the reasons marked on them; to organize the compilation work in the area to be mapped; to subdivide and specialize the work as soon as practicable; and to test the compilations in the field as soon as they are made.

But the most important lesson of all is that, given the procedure just described, there are thousands of engineers walking the streets searching for work today who could make during the next few years a beautifully complete and accurate large-scale map of this country; a map we are not likely to have for decades to come if this opportunity is wasted. Mr. Chairman, you may go as far as you like in your Committee on Map Planning. There are plenty of good capable men to put through any plan you make for accelerating the mapping of this country.



IMPROVISED CAMERA FOR TRANSFERING THE SHORELINE FROM SCALE OF PHOTOGRAPHS TO SCALE OF HYDROGRAPHIC SHEETS. -- PARTY OF LIEUT. S. B. GRENELL, SAVANNAH, GEORGIA.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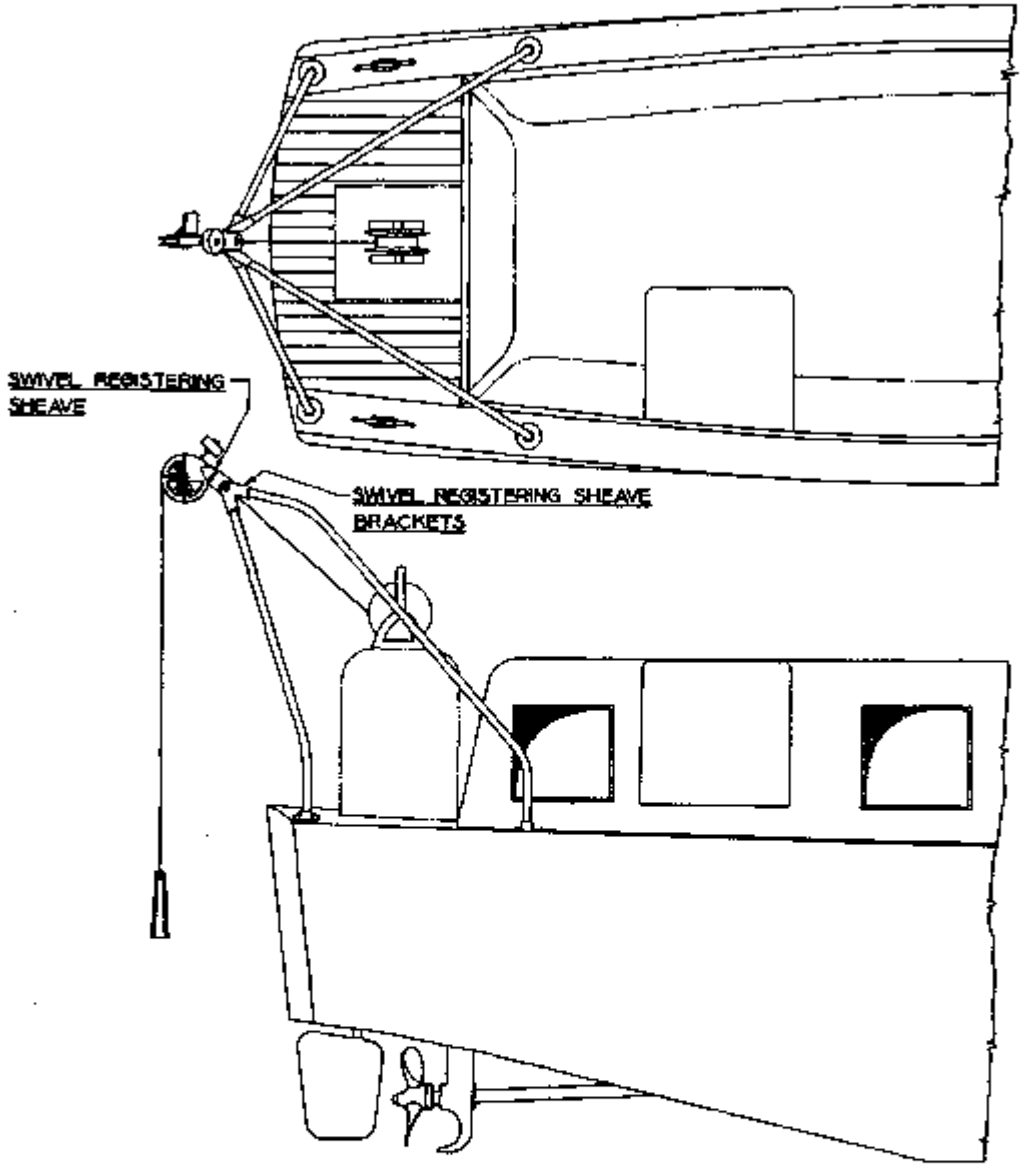
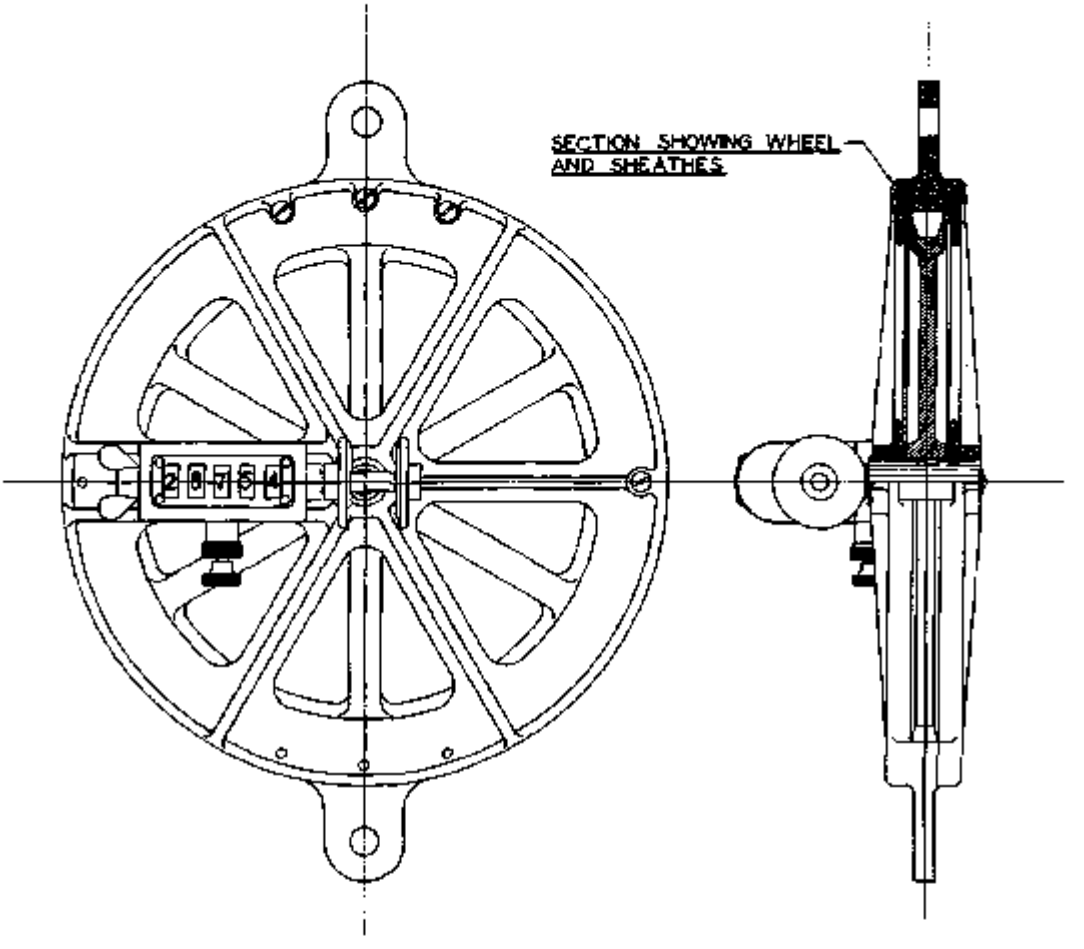


U. S. COAST AND GEODETIC SURVEY

MOUNTING OF SWIVEL REGISTERING SHEAVE

The above is an illustration of the mounting of the swivel registering sheave for use in sounding over the stern of a launch. The drawing shows one of the many possible ways of mounting the sheave, incorporating the brackets into a framework of ordinary iron pipe.

U. S. Coast and Geodetic Survey Print

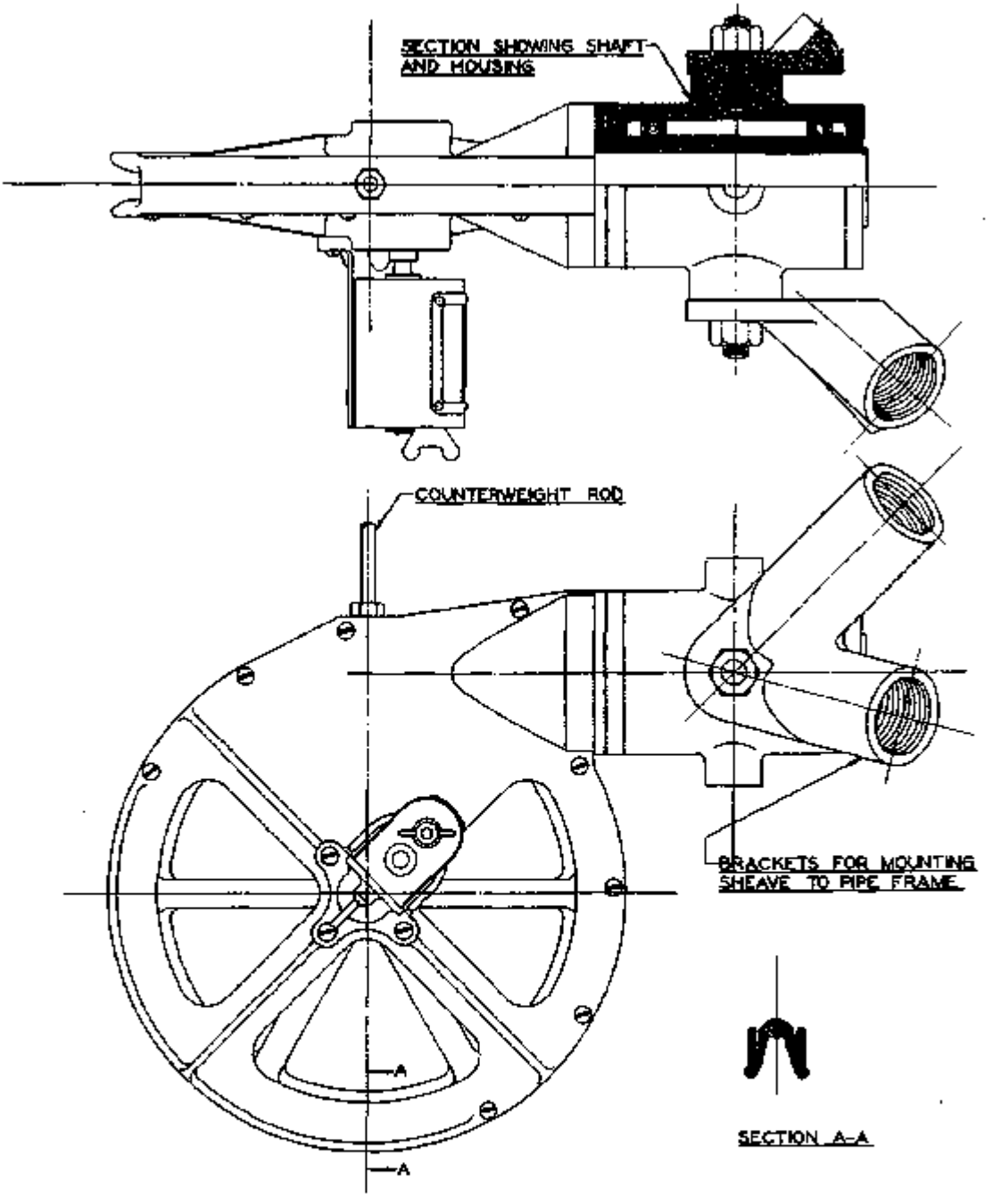


U. S. COAST AND GEODETIC SURVEY

REGISTERING SOUNDING SHEAVE

The fixed type of registering sheave should be used only where the plane defined by the wire is a fixed one. The sheave should be rigidly secured to mountings at both the upper and lower eyes to insure that the wire will not rub against the frame lips in paying out or hauling in. This fixed type of sheave should not be used as an outboard fair leader unless mounted on a counterbalanced swivel, allowing the wire to run free of the frame lip at all times.

As revolution counters cannot be relied upon to subtract accurately when heaving in, the counter shaft of this sheave has been fitted with two bevel gears and the counter mounted as to engage either gear. It can, therefore, be shifted when the lead reachs the bottom so as to add when heaving in the lead, the final reading being double the sounding. A reliable check can thus be obtained on the sounding.



U. S. COAST AND GEODETIC SURVEY

SWIVEL REGISTERING SHEAVE

This type of sheave is to be used only as an outboard fair leader. It is designed so that the sheave will assume the plane defined by the inboard and outboard parts of the wire under a slight tension. The counterweight should be carefully adjusted slightly to underbalance the sheave.

The shaft housing is fitted with threaded sockets and serrated bosses for mounting. Brackets with serrated faces and threaded for incorporation into pipe frame are supplied. They should be rigidly mounted so that the wire will lead clear and not rub against sides of hollow shaft

APPLICATIONS FOR MEMBERSHIP, AMERICAN SOCIETY OP CIVIL ENGINEERS

For the benefit of those in the Service who may wish to join the American Society of Civil Engineers, definitions are given below, based upon a close study of the qualifications for Membership as given in the publications of the Society and on the printed sheet which is sent to applicants and to those named as references by applicants. The Director and the Chiefs of all the field divisions of the office have approved of this interpretation of the requirements of the Society and it is suggested that the definitions given below be closely followed by those in the Service applying for Membership or transfer in the Society, and by those named as references.

Responsible Charge

1. "Responsible Charge" applied to grade of Member includes:-

   (a) The time spent as Chief of Party* in charge of work in the field.
   (b) The time spent as Chief of Party in actively preparing for a season's work (usually this period will not exceed a month at a time).
   (c) The time spent in port or in the office in charge of professional investigations or in writing reports containing the results of such investigations. (Season's reports and special reports by Chiefs of Party included.)
   (d) The time spent in the office or at a field station while assigned to an administrative position designing, directing, or inspecting field work.

2. "Responsible Charge" applied to the grade of Associate Member includes (a), (b), (c) and (d) above and also the following:

   (e) The time spent as executive officer (principal assistant) of a surveying ship engaged on field work.
   (f) The time spent as principal assistant on a first or second order traverse party.
   (g) The time spent in charge of a sub-party, either a launch or shore party, detached from a large surveying party and subject to infrequent inspection and direction from the Chief of Party.
   (h) The time spent in charge of an observing sub-party on first order triangulation.

3. "Responsible Charge" does NOT include:-

   (a) The time spent in charge of a sub-party where the work is subject to frequent inspection and direction (say weekly or oftener) by the Chief of Party or his agent.
   (b) The time spent as principal assistant on a leveling or triangulation party with a single main observing party, or on any other party where the plan of organization does not require that the principal assistant have responsibility for considerable periods of time for one or more surveying units. (See 3 a).
   (c) The time spent in the office or in port either in charge of or making routine computations and reports and in plotting field records.

Design

The qualifications specified for member are that "he shall be qualified to design as well as to direct engineering works". This definition is often difficult to translate exactly in terms of any particular branch of civil engineering. To "design" requires more than the professional knowledge and ability necessary to be in charge of work. Time spent on design in the Coast and Geodetic Survey may perhaps be sufficiently well indicated by saying it includes the satisfactory performance of any of the following operations:

4. Design.

   (a) Preparation of specifications and plans for the construction of surveying equipment, apparatus, structures and instruments.
   (b) Reconnaissance for a project, drawing up plans and deciding upon methods for its execution.
   (c) Executive surveys of such accuracy or complexity that knowledge and experience beyond that contained in the ordinary instructions for such work, and beyond that ordinarily met with in the work of the Survey, is necessary for its successful accomplishment.
   (d) Executing work which requires the application of new and distinctive methods or apparatus for its successful accomplishment.
   (e) Investigating surveying methods or instruments, where the investigations require more than ordinary experience and professional knowledge.

*By "Chief of Party" is meant the officer. who receives from the Washington Office, or in the Philippine Islands from the Manila Office, written instructions for the execution of work.

THE AMERICAN SOCIETY OP PHOTOGRAMMETRY

The first Hews Notes of the American Society of Photogrammetry were issued in September, 1934. These notes announce the new organization, and we take pleasure in extending congratulations and the best wishes for a prosperous future from the Association of Field Engineers to this promising Society. The Officers are: C. H. Birdseye, President, J. W. Bagley, 1st Vice President, O. S. Reading, 2nd Vice President, J. W. Ninneman, Secretary, and M. S. Wright, Treasurer. Several quotations from the first copy of the News Notes, September, 1934, are given here.

Extract from "Proposed Activities of the Society," by O. S. Reading.

"Any one listening to discussions of the relative merits of single lens and multi-lens photographs, of focal plane versus between-the-lens shutters, of plotting machines versus photographs combined with plane table, will be impressed with the resemblance of the present state of photogrammetry in this country to the fable of the three blind men examining an elephant. As I remember the story, one blind man felt the trunk, another the legs, and a third the tail. Each thought the other very stupid and very much mistaken as to the character of the animal. In much the same manner, each one of us has had more or less limited experience with different types of photographs and has compiled different types of maps from them, but few of us are experts in all branches of the art. Each has much to gain from listening to the ideas and experiences of others for we are all feeling our way rather blindly around the tremendous new possibilities of mapping from aerial photographs.

"It is planned that the activities of the American Society of Photogrammetry will serve to unify and make effective the present scattered hopes, aspirations, ideals, knowledge, and experience of its members through its various activities . . .".

Extract from "Random Pacts and Fancies," by W. N. Brown.

"Aerial photography, photogrammetry and mapping is not just a question of the delivery of material. Knowledge, skill and service are involved to such an extent that the material represented by film and print are a very small portion of the delivered product. Given the same films and prints, the quality of the final product will vary just as widely as will the outcome of a surgical operation or a law suit, dependent upon the ability of those In whose hands the matter is placed. The failure of a map to serve Its purpose can be just as costly as the loss of a law suit. In the hands of the inept, the cost of making the map may be many times what it should be. City and Government officials tell us they are compelled to advertise mapping work and that it is next to impossible to let it to any other than the low bidder, even though they know he has failed to deliver on some previous work. It is our task to work for a change of conception in this matter. One method of attacking the problem is to place In the hands of those officials conclusive data showing that the low bid may often the most expensive be when the job is viewed as a whole. This opens up discussion of the means of differentiating a low bid arising from a lack of knowledge and experience from one due to special ability and equipment."

Lieutenant O. S. Reading, U. S. Coast and Geodetic Survey, attended the Fourth Quadrennial Congress of the International Society for Photogrammetry at Paris from November 24 to December 2, 1934. Marked progress has been made in aerial cameras and plotting instruments since the last congress in 1930. It was also evident from the work on display at the Congress that suitable stereoscopes with wandering marks would add considerably to the accuracy with which common points in forests, pastures, and similar featureless areas could be identified on the photographs for the use of the radial line method as practiced in the United States. Lieutenant Reading also, visited the British War Office in London and the Ordnance Survey in Southampton where he was much impressed with the excellent maps he saw there.

THE COAST SURVEY ON THE PACIFIC COAST

T. J. Maher, H. and G. Engineer, U.S.C. and G. Survey
Inspector, San Francisco Field Station

With the possible exception of those who have only had a few years service, I believe that every Coast Survey officer has used or referred to surveys or reports made by those who took part in the work during the early days of the existence of the organization. The normal reaction of any officer who comes in contact with this old work would probably be one of comparison with the work of today, which should naturally lead to a comparison of men and a comparison of methods.

During part of my first years in the service I was under the direction of those who may be referred to as the last of the old school. What impressed me then, and what, upon reflection today, causes a feeling of respect and admiration for these men was their firm adherence to what I believe are the fundamentals underlying the success of this bureau, the success that has rendered it impregnable to all attacks; these are accuracy and attention to detail. They were not in sympathy with the idea that their views might be construed as an indication of narrow-mindedness or of a failure to grasp those so-called broad principles which consider generalization in surveys as a mark of efficiency and economy. These they viewed in their proper light - as a cloak for inefficiency and incompetency. At times, surveys based on such so-called broad principles have been temporarily useful in meeting some urgent need, but they are unsuited for any other purpose and constitute an inferior or class of work. Such attention to accuracy and detail could not help but develop powers of observation, and a perusal of the reports submitted by those of the old school will show this to be so. These men had no patience with those who advocated an adjustment of standards of accuracy to what might be termed the commercial importance of the places to be surveyed at the time the work was to be undertaken. The belief that such an elastic system is conducive to economy or increased output is entirely false, although many specious arguments in support of such a belief have been advanced by the noisy uninformed.

For some years, I had the impression that the work of the present generation of Coast and Geodetic Survey officers was superior to that of those who have preceded us. I now believe that to be a fallacy. This conclusion has been arrived at from a personal comparison of numerous old and recent topographic sheets, sheets which have been used in law suits and legal battles, suits in which the Federal Government was defendant in claims for damages for over a million dollars, and on the outcome of which depended other claims bringing the amounts to over two and a half million dollars. There have been great improvements in our work, but these are almost entirely the result of the development and use of mechanical devices, such as sound ranging equipment, echo sounding machines, power sounding machines, aerial photography, wire drag apparatus, new types of levels and theodolites.

An examination of the history of any progressive organization generally shows that there are certain years or periods which stand out above all others as marking changes in policy, changes in methods, development, expansion or retrogression. This statement is quite applicable to the Coast and Geodetic Survey. That period which marks its first progressive step commenced about 1849 when its first parties appeared on the Pacific coast, as the early history of the Survey will show.

The early years of the Coast and Geodetic Survey really marked a struggle for existence. The development of the organization as we know it today, and the creation of those standards of accuracy which have so well anticipated the needs and demands of a century of the greatest engineering progress that the world has ever seen, may be considered as dating from 1832. The period from 1832 until about 1849 was one of development of personnel and of methods. How well the work was done will be readily seen when we consider and analyze how the bureau was able to meet the great strain thrown on it by the demand for immediate surveys of the Pacific coast, caused by the most spectacular expansion in shipping ever known, resulting primarily from the discovery of gold in California. This growth is well shown by a quotation from a letter dated October 26, 1849, written by William Pope McArthur, then in California: "The increase in population is truly wonderful. Let us estimate San Francisco at 100,000 souls, Sacramento City 40,000 and Stockton 35,000 or nearly. Eighteen months ago there were scarcely 100 people in all three."

Those familiar with navigation will readily appreciate, after glancing over the following statistics, the problem which confronted the Coast Survey

when called upon to furnish charts of an area of which there were no adequate (surveys, and only a few sketchy charts based on the reconnaissance of early explorers: In the first three-quarters of 1849 less than 509 large vessels entered the Bay of San Francisco. At the end of August of that year, there were 62,000 tons of shipping in the harbor. In 1848 the resources, the population and geography of California were almost unknown. At the end of 1855 there were registered, licensed, and enrolled in the Custom House of San Francisco, 702 vessels of a tonnage of 79,309. The amount of gold shipped per manifest from San Francisco In 1849 was $4,921,250; in 1850 - $27,676,346; in 1853 - $57,531,024. The average amount of gold taken from the country from 1850 - 1857 was $55,000,000. The average value (for the United States) of the exported cotton crop for the same period was $100,000,000, and of bread stuffs and provisions $55,500,000. The commerce was water-borne - it was carried in ships. Charts were needed and the Coast Survey successfully met the demand.

The first definite action of the Coast Survey toward making surveys of the Pacific coast was in the fall of 1848, when William Pope McArthur, James S. Williams, and Joseph S. Ruth were ordered by the Superintendent of the Coast Survey to the west coast. McArthur proceeded by way of Panama. The demand for transportation from that place to San Francisco was heavy. No vessels were available, so the ship HUMBOLDT, then anchored off Tobago Island, and used for the storage of coal, was put in commission. McArthur was prevailed upon to accept the position of captain. On May 21, 1849, she proceeded to San Francisco.

The Coast Survey Steamer EWING arrived in San Francisco in September, 1849, and McArthur assumed command. Wages ashore were very high, ranging from five to twelve dollars per day. Sailors were paid very small amounts by the government, and great difficulty was experienced either in keeping or in getting crews. McArthur was faced with insubordination and mutiny. Five men in a small boat attempted to desert, throwing an officer overboard. Fortunately McArthur witnessed the incident and rescued the man. The deserters were captured, tried and punished. For weeks he had been confronted by the discouraging situation of having his vessel lie idle in San Francisco Bay, while the government refused to pay the wages demanded by the sailors, and it was not until April 3, 1850, that McArthur was able to pass through the Golden Gate, headed north for reconnaissance of the coast. He also intended to stop at Georges Ft. (Pt. St. George ?) to secure the bodies of Lieutenant Richard Bache, (younger brother of Professor Bache) and of Lieutenant Robert L. Browning, who were drowned on March 30, 1857, while making some special surveying investigations.

McArthur returned to San Francisco in August, 1850. He made a survey of the mouth of the Columbia River as far as Astoria, and his statements regarding the commercial importance of that section have been fully supported by subsequent events. He made a reconnaissance survey of the coast from Cape Disappointment to San Francisco. Nine tenths of the way was sailed within one half mile of the shore, and every river, bay and headland was visited. This was truly a remarkable piece of work. The three sheets covering that area are on a scale of 1:850,000. The plates were engraved and the charts were printed and published within twenty days after the receipt of the drawings in the Washington office. His Coast Pilot notes of this coast may be considered as the first which furnished the mariner with accurate detailed information.

On November 21, 1850, McArthur received word from Professor Bache that a contract was being signed for a 225-ton steamer for the Pacific coast, and that he was directed to return to Washington to examine the vessel and prepare plans for the season of 1851. He sailed from San Francisco on December 1, was taken seriously ill, and died on December 23, 1850, just as the OREGON was entering Panama Harbor. This was a serious blow to the service, which lost a capable, aggressive and enterprising officer; one who in his short but brilliant career was continually confronted with adverse conditions, but no matter how difficult the situation. He always carried to a successful conclusion any project on which he was engaged. That he was possessed of unusual qualities of leadership may be inferred from the incident at Panama where, within a very short time after landing, he was chosen to suppress a state of disorder and lawlessness with which the authorities were unable to cope. Within forty-eight hours he had the situation well under control. He was succeeded by Lieutenant Commander James Alden, whose name for many years was closely linked with hydrographic surveys along the Pacific coast.

In 1850 a number of young men were sent from Washington, D.C., to the Pacific coast, amongst whom was George Davidson. His biography is really the

history of the Coast Survey work along the Pacific coast from its inception for a period of over fifty years - from the Mexican border to the Arctic. He became one of the foremost men in scientific and engineering circles, and distinguished himself in astronomical work, taking observations for longitude by moon culminations, observations for latitude, and for determination of magnetic declination. At Cape Orford (Cape Blanco] the party was in constant fear of interruption from the natives, and at Cape Flattery it was necessary to entrench and keep a regular watch. Considering the difficulties experienced in traveling, his movements were very rapid.

In 1852 James S. Ruth was drowned through the capsizing of a whaleboat while making a survey of the Columbia River.

In 1853 the Pulgas Base, lying about 35 miles southward of San Francisco, was measured by the party of A. D. Cutts. A brief description of the work may provide the means for an interesting mental comparison with modern methods. "Nearly twelve working days, between June 11 and June 27, 1853, were expended in the actual measurement of 2,627 four-metre boxes, and the final corrected length was found to be 10,512.06 metres. The extremities were marked by permanent momunments. The measurement was executed with two iron rods of a half-inch diameter, each of which was four metres long. The ends were squared and one side of each was plated and marked with the limiting line. Ten comparisons of each with the Hassler two-metre bars E and H were made before and after the measurement. Two inflexible oak-plank boxes and four trestles were employed for carrying and supporting the rods. Previous to each contact, the rod was levelled by a spirit level with blocks and wedges. The alignment was made by a ten-inch Gambey theodolite, from 150 to 300 metres in advance. The contact was observed by means of the silk thread of a plumb-bob suspended in a bucket of watery and when this was correctly adjusted, the advance rod was clamped and the rear box carried forward. The reading of an attached thermometer was recorded for each contact, and Hassler's proportional rate of expansion, 0.000006963535 was used for the temperature reduction. This base was connected through a chain of 17 triangles to the San Jose Base, a preliminary base of a length of 941 metres, with a discrepancy of 0.03 metre." Two facts will probably be noted: First, the means for base measurement were slow and cumbersome; second, persistence and attention to detail produced an accuracy comparable to what we obtain today.

During the following years triangulation was extended from the Pulgas Base to Yolo County, where it was tied in with the Yolo Base, which was measured in l88l. The triangulation from the Pulgas Base gave a length to the Yolo Base which exceeded its true length by 0.35 meter, a difference which is equivalent to about 1/50,000 of the actual length.

The Yolo Base was measured with an exceedingly high degree of accuracy. Compensating bars 5 meters in length were used in the measurement, by placing them end to end. The work was done under a moveable cover or shed. The actual length of the base is 17,486.512 meters. A preliminary measurement had been made by Assistant Colonna in August, 1860, in connection with the spirit leveling of the line. He used a 50-meter steel wire under constant strain, and obtained a length of 17,485.4 meters. A second wire measurement was made in September l88l by Assistant Gilbert, which fell short 0.6 meter of the true length, giving a discrepancy of about 1 in 30,000.

In the measurement of the Yolo Base, there were twenty-four persons on the party including the Chief of Party Davidson, Assistant Gilbert, and Sub-Assistants Dickins, Pratt, and Blair. Three separate measurements were made necessitating the laying of 8,494 bars, and the total number of working days was 46. The value then obtained for this base is the same as that given in the latest publications by the Coast and Geodetic Survey on California Triangulation.

In 1853 the vessel in which Sub-assistant J. S. Lawson was proceeding to Tomales Bay was wrecked on the bar. He succeeded in saving all of the instruments and all of the equipage. The vessel went to pieces shortly after, but through the presence of mind of Mr. Lawson, the work proceeded without interruption.

Lieutenant W. P. Trowbridge, U.S.E., Assistant in the Coast and Geodetic Survey, in charge of tidal observations along the Pacific coast, called atten-

tion to unusual fluctuations on the curve traced by the self-registering tide gage at San Diego for December 23 to 25, l853. An examination of the record from the gage at San Francisco for the same period showed similar irregularities. Reports, which are the basis for the following remarks, were received later from Japan of a very violent earthquake on December 23, 1853. Simoda (Shimoda) suffered dreadfully. Several shocks were felt. The sea rose in a wave four fathoms above its usual height, and when it fell back it left but four feet of water in the harbor. It rose and sank this way five or six times, covering the shore with the wrecks of boats, junks, and buildings. The distance from San Diego to Simoda (Shimoda) is about 4917 miles, and from San Francisco to Simoda (Shimoda) 4527 miles. This matter was not passed over in a cursory manner. The curves were analyzed and all available information was studied. The tide gage at San Francisco had been established in 1852, and irregularities in the records were noted on two occasions previous to that mentioned, but there is no note of their having been given equal attention. These records from the Pacific coast mark the entry of the Coast and Geodetic Survey into what is now one of its most important lines of investigation - Seismology. Earthquake disturbances are frequently recorded by tide gages.

The tidal observations started in 1852 along the Pacific coat were subjects of great interest and study, and may be considered as the stimulus for the intensive study of tidal phenomena which followed. The type of tide experienced, through its great diurnal inequality, differed from that observed on the Atlantic and Gulf Coasts. The results of the studies were communicated to the American Association for the Advancement of Science. In 1855 the Coast and Geodetic Survey published tables by means of which the times and heights of tides at a number of ports on the Atlantic and Pacific coasts could be found.

Lieutenant Trowbridge, in 1855, when endeavoring to make tidal observations in the vicinity of the Straits of Fuca found the natives very hostile. They attempted to sell poisoned provisions to Mr. Russel, and used every strategem to get possession of the schooner used by him for making tidal observations at Nootka Sound; however, the observations were made.

In l854 Davidson wrote a very complete Coast Pilot of the Pacific coast waters of the United States. By 1854. fifty-five surveys, extending from San Diego to Rosario Straits were completed. Many of these sheets, which have been examined by the writer, exhibit, a degree of craftsmanship which is unexcelled. Some have been of inestimable value to the Federal Government, a value arising solely from the fact that only one standard was accepted. Specific instances will be mentioned later.

In the year 1855, William P. Blake submitted a very interesting report on the physical geography and geology of the California coast and the mountain ranges, with reference to the Channel and other coastwise islands indicating the possibility of submerged peaks, a conclusion confirmed by later investigations.

The activities of Coast Survey officers were quite varied. During December 1855 and the early months of 1856, the Coast Survey Steamer ACTIVE took part in the quelling of an Indian rebellion in Washington Territory. Experiments were made in 1856 to determine the feasibility of substituting lunar spots instead of the moon's limbs in transits for determining the difference in longitude.

For many years after the commencement of its work along the Pacific Coast one of the duties of the Coast Survey officers was to make investigations of sites for lighthouses. Their reports were submitted to the Lighthouse Board.

On January 9, 1857, the party of Assistant Greenwell felt a rather severe earthquake which caused long cracks 6 to 8 inches across in the bed of the Santa Clara River. In his report he states: "I was interested to know whether my signals remained unchanged, but in subsequent measurements no difference could be detected in the angles." This is perhaps the first time that triangulation was considered as affording a means for the determination of earth movements. Observations of that nature now constitute a very important part of the Coast Survey work. At that time an examination was also made of the records from the tide gages at San Diego and San Francisco, but there were no indications of any disturbance of the water.

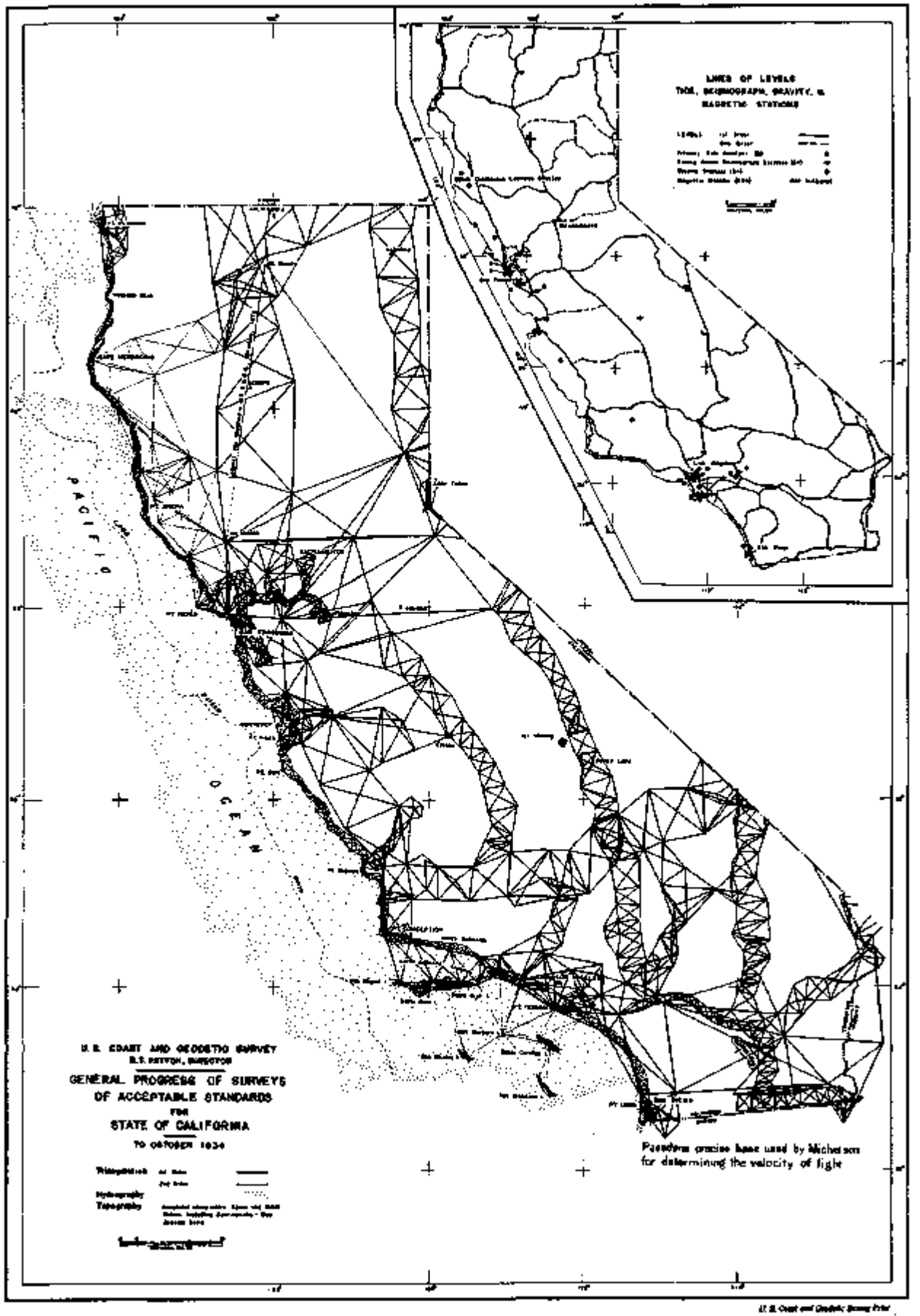
In 1858 the Coast Survey Steamer ACTIVE was placed at the disposal of the State Department for duty in connection with the determination of the Northwestern boundary of the United States. In order to meet the requirements of the Commissioner on the Northwestern Boundary of the United States, sub-assistant James S. Lawson was reassigned to duty in that section. The following is an extract from his report: "In the execution of this work I had to contend against two very severe drawbacks. The very great refraction, and the drawback in the destruction of signals by the Indians - one of the signals twelve miles from the vessel, being thrown down twice in succession, could be reached only by crossing dangerous tide rips and pulling against the strong currents for which these waters are noted." In that year the Pacific Coast Directory by Davidson was published. It is an excellent document, one which perhaps has only been exceeded in value by his own later works. It is one which the layman can read with interest, one which furnishes the navigator with the data he requires, and one which could be well used as a model for subsequent work. In 1858 the list of surveys along the Pacific coast included 110 titles. In 1862 a revised edition of Davidson's Pacific Coast Directory was published.

On May 20, 1867, sub-assistant Julius Kinchelce, together with five of the crew of six hands were drowned as the result of breaking seas which capsized his boat outside of Tillamook Ear. He had completed his survey of the lower part of the Tillamook River, and its approaches, and had waited patiently for an opportunity to verify the soundings by a concluding line across the bar. During a period of smooth water he succeeded, after two vain attempts. His work was done, when by an unexpected breaker the boat was swamped, and by a second breaker it was capsized at a distance of about a mile and a half from land, and within the very sight of his wife. In looking over the records of the pioneers in the service, one cannot fail to note the general prevalence of this spirit of sacrifice.

The work of the Coast Survey along the Pacific coast gradually became established in a well-organized manner, and its progress met fairly well the needs of marine interests of those times. The acquisition of Alaska resulted in an urgent demand for charts of that territory. The Coast Survey promptly proceeded to outfit parties for survey work in that area, although no adequate provision was made for an increased personnel, or for additional equipment to handle this englarged program. George R. Davidson and a party were directed to proceed to Alaska, on reconnaissance. They left Victoria in the cutter LINCOLN on July 29, 1867. Under date of November 30, 1867, he submitted a complete report designated "The Directory of Alaska", which for excellence compares very favorably with his earlier publication - "The Directory of the Pacific Coast." In 1869 his Coast Pilot of California, Oregon and Washington Territory was published.

Another very notable period in the growth of the Coast Survey might be considered as dating from the approval of the Act of March 3, 1871, wherein the extension of the geodetic connection between the Atlantic and Pacific coasts of the United States was authorized. The result of this is the great scheme of triangulation along the 39th parallel of latitude, one of the most famous arcs in the history of geodesy. The need for this was really due to the great commercial development of the Pacific coast region, with the consequent increased valuation of interior lands, the need for control points for surveys and the necessity for tying together the different coastal surveys.

A few details regarding the work of some of those who were engaged on this triangulation in California and a few extracts from their reports may be worthy of attention. George Davidson organized his party and took the field near the end of May, 1874, after arranging to occupy first Mount Lola (9167 feet high) and next Round Top, the summit of which is 10,430 feet above sea level. The route to the last named station was greatly impeded by snow until late in June. The party went to Mr. Lola by way of Lake Independence, and had only 14 miles of teaming in a rise of 1200 feet. The summit was reached by packing and sledding 5½ miles over snow in a rise of about 2800 feet. Much difficulty was encountered in consequence of drifts. Officers, men and animals sank in the snow to their knees. Assistant Davidson went to the summit on the 9th of June, and then encountered a flurry of snow and found the temperature below the freezing point. He selected an azimuth mark somewhat more than 5 miles distant from Mount Lola, and in so doing, guarded as far as possible against the effect of horizontal refraction. For horizontal direction and azimuth, the 20-inch theodolite No. 115 was mounted on the cast iron re-



U. S. Coast and Geodetic Survey Print

peating stand devised by him. Observations were taken and recorded at 23 positions on the limb of the instrument, and the readings were made with three micrometers with circle direct and reversed.

Assistant Davidson, having stationed Assistant Colonna at Mount Shasta, succeeded in measuring two angles in the great triangle Lola - Shasta - Helena, having sides of 136, 169, and 191 miles. The success in getting observations on the Mount Shasta station was due to the persistence of Assistant B. A Colonna. who passed nine days and nights on the summit of Shasta, the elevation of which is about 14,400 feet above sea level. Upon reaching the summit the carriers and packers immediately returned to the valley. The two men retained by Colonna aided him in pitching a tent. Before night one of them was taken ill, and the next morning went down the mountain and did not return. The coldest temperature recorded at the summit was 18 degrees. For azimuth Davidson observed on two stars in 23 positions of the instrument. The observations were referred to an azimuth mark and also to a collimator.

As at Lola, horizontal angles were measured at Round Top during all kinds of weather. Referring to the conditions of the atmosphere late in September, Davidson wrote: "I have stood hours at the instrument to get twenty minutes work, and sometimes to get nothing. The cold was severe, and in the last snow, which was 15 feet deep on the trail, we pulled ourselves up to the station by means of a life line through snow breast high when the air temperature was near zero." Prom Round Top the lines of the triangulation range at 38, 54, 67, 58, 68, 45, 107, 120, 146, and 160 miles. At the two stations, 3,148 observations were recorded for determining the azimuth, and 3,310 measurements of horizontal angles were made.

Davidson made a study of the size of heliotrope required for lines of different lengths, and according to his researches, he found that a heliotrope with a reflecting surface of 77½ inches sufficed for a line of 192 miles. He compared the observed and computed latitudes at Mount Lola, and found a deviation of the plumb line to the north amounting to 5".8, and the deviation at Round Top to be 4".4.

In 1879 Assistant Hergesheimer was sent to the Pacific coast to make a study of the topographic features for use in devising proper symbols for the Manual of Topography. He made a very thorough investigation, and his report indicates that he had a sufficient knowledge of geology to realize that the use of proper symbols would convey valuable information to the engineer.

The following statement made in 1885 is one with which we are all familiar. It describes a condition which existed for years, and I believe that to this failure to make the necessary appropriations may be attributed a great loss of lives and a loss of vessels whose value probably exceeded all that had ever been spent on Pacific Coast surveys. "On the Pacific Coast much difficulty is experienced in executing hydrographic work, for not only is the coast a difficult one to work upon, but the small appropriation permitted only a small portion each year to be spent on actual field work.

"The repair and outfit of the vessels are at a cost almost double what it would be on this coast, (Atlantic), while the wages of men are also much higher, as, for instance, a seaman in the Merchant service gets from $40 to $70 per month, in other branches of the Government service he receives about $40, while seamen on board Coast and Geodetic Survey vessels who are shipped on Naval Rolls receive only #24. This is made up to about $30 under the allowance for subsistence, but as the appropriations will permit it for only four or five months out of the year it can readily be seen that good men do not remain in the Survey for any length of time."

In the 8o's the Coast and Geodetic Survey had several ships operating on the Pacific Coast, generally on a part time basis, as the result of insufficient funds. Amongst these may be mentioned the PATTERSON, GEDNEY, McARTHUR and COSMOS. The PATTERSON and GEDNEY were assigned mostly to Alaskan waters.

While looking through old records, I found an item which describes the passage of the Launch COSMOS across the Columbia River Bar in 1888, during a heavy gale. This Vessel is perhaps one of the most famous in the annals of Coast Survey history, was the home, at some time or other, of nearly every Coast Survey officer of the rank of Lieutenants-Commander and above, and has also been the home of Navy officers who have since reached the rank of Rear Admiral. The

tonnage of the COSMOS was 25, her length 52.5 feet, beam 12 feet, and draft 4 feet and she carried about 4 to 5 tons of coal. I will quote extracts from an item regarding an incident which was often mentioned in the wardroom of Survey ships.

> "The Steamer PATTERSON left San Francisco May 4, 1888, for Alaska, with the new steam launch COSMOS in tow. In immediate command of the COSMOS was Ensign A. F. Niblack. While passing through a severe gale, on May 5, off Cape Gregory (Cape Arago), the hawser used in towing the COSMOS snapped, and the two vessels parted company. The PATTERSON reached Port Townsend on May 11. When the hawser broke, one of the firemen on the COSMOS was disabled, and while crossing the bar of the Columbia River through three miles of breakers, a heavy sea made a clean breach through the deck-house, flooded the engine room and galley, broke the water gauge and stopped the engine. The machinist Maurice Golden, though bruised and stunned, stuck to his post, and by his coolness and bravery further damage to the launch was prevented, and she was enabled to steam under the lee of a pilot tug and so was shielded from the terrible force of the seas. At Astoria every assistance was rendered by the Commanding Officer of the Steamer McARTHUR, and on the morning of the 11th the COSMOS followed that vessel across the bar. That evening, off Destruction Island, a fishing schooner was sighted showing signals of distress. She had on board the shipwrecked crew of the four-masted ship OCEAN KING. The captain, two mates, and crew of 22 men were taken off by the COSMOS and landed at Port Townsend, which place she reached on the night of May 12."

> The story, as I have heard it from those who were in the service at the time, is that one of the crew was seriously injured, and that he required medical treatment so badly that the officer in command of the COSMOS decided on risking his vessel as well as the lives of all in getting her through the breakers to get the necessary medical assistance at Astoria. I was also informed that those in the PATTERSON gave up the COSMOS as lost, and were most pleasantly surprised when she arrived at Port Townsend one day later than the PATTERSON.

In 1889 Davidson's Coast Pilot of California, Oregon and Washington was published. It is a monumental work and stands unequalled as a work of reference for the mariner, for the historian and for the geographer.

In 1891 Assistant A. T. Moseman was appointed one of the members of the International Boundary Commission for the relocation and remarking of the boundary between the United States and Mexico. In 1893 George Davidson was directed to resurvey that part of the California-Nevada boundary line which extends from Lake Tahoe to the Colorado River.

On August 17, 1894, the Coast Survey Steamer McARTHUR anchored about 1½ miles offshore from Jo Creek, which lies about 17 miles north of Gray's Harbor, Washington. That afternoon Lieutenant Crosby, Commanding Officer, with nine men, landed through the surf and started to erect a hydrographic signal. The sea was smooth. On Saturday morning, there was a dense fog, and a long swell. At 7:20 am, the Commanding Officer with nine men in the whale boat left the ship to complete the erection of the signal. When outside the surf line, he directed the men to take all the precautions which are requisite for safety in going through the surf, such as removal of shoes and heavy clothing, casting off of trailing lines of the oars, and unshipping the rudder and substituting a steering oar. He cautioned them that if upset, they should get hold of life preservers or oars, dive under the breakers, and come up when necessary to breathe and make for the beach. They proceeded a short distance, when they were caught by a heavy breaker. The boat apparently broached, and was capsized by a second breaker. Five men succeeded in getting ashore, most of them in a dazed and exhausted condition. They immediately notified the white men and Indians along the beach, who took up the search for the others. The fog was very heavy, and visibility was not greater than 40 to 50 yards. No other landing could be made from the ship, so about 11 am, when the fog began to clear, the officer in charge ran in as close to the shore with the ship as was safe, but nothing could be done from the outside, so he proceeded inside Gray's Harbor and anchored near Damon's Point. C. P. Eaton, the Ensign in charge.

secured a team and with two men drove up the beach to the scene of the disaster. Members of the crew and settlers patrolled the beach. On the way back to the ship, the team ran away while crossing a bridge over swampy land. The occupants were thrown out. The Ensign escaped with a sprained hand and leg and bruised head. One of the men had a bad hole made in front of his left leg, above the ankle, reaching to the bone. The bodies of Lieutenant Crosby and three of the men were washed ashore at various dates, that of Lieutenant Crosby six weeks after the accident.

Triangulation, leveling and topographic mapping, from the early 90's until 1924 or 1925 progressed much more rapidly than the hydrographic work. With the exception of harbor surveys, the surveys of inland waters, and a very narrow strip along the coast, the work which had been done can only be classified as reconnaissance. There are two reasons for this. The methods and instruments employed were entirely inadequate. Proper instruments and equipment had not been devised. Visibility along the Pacific coast of the United States is generally low on account of fog, haze, and forest fires. In Alaskan waters, in Hawaiian Island waters, and Philippine Island waters, sounding lines can be run offshore 10, 20, 50 and even 100 miles, with the location of the soundings controlled by sextant angles to objects onshore. Off the Pacific coast of the United states, there are but few days each year when such control can be carried much more than 10 miles. The second reason is that the Survey ships were entirely unsuited to accomplish the class of work required by the modern merchant marine. To carry on this work, the Coast Survey had two ships driven by single cylinder engines, the GEDHEY and the McARTHUR. The PATTERSON, a slightly larger vessel, had a little compound engine, but sail was relied on to a great extent as a means of propulsion. She, however, was used mostly in Alaskan waters. Had the service been furnished with better vessels, the hydrographic surveys might have been extended a little farther offshore with the instrumental equipment and methods then in use, but the work was really at a standstill, then. The instrumental equipment was inadequate.

The development of radio acoustic ranging made possible accurate and much needed surveys off the Pacific Coast. Much of the pioneering work in the development of this valuable method was done on the Pacific coast in 1924, by the Coast and Geodetic Survey Ship GUIDE.

At a later period of this development, the Steamer GUIDE, ran 206 miles offshore, obtaining fixes by means of its sound ranging apparatus at regular intervals on this line. The introduction of sound ranging apparatus vastly extended the field of hydrographic operations, making the work independent of weather conditions. With the transfer to the Coast Survey of several mine sweepers, that bureau was ready to make hydrographic surveys which would meet all the demands of modern commerce. The result is that modern surveys extend offshore for a distance of about 80 miles all along the coast, from Cape Flattery to the Mexican border, with the exception of two small areas in California, in which work is now in progress. As a means of furnishing additional protection to the mariner, a strip about a mile and a half wide, along the shore, extending from just south of San Francisco Bay to Point Conception is being wire dragged.

One of the longest and perhaps the most accurately measured base line in the world lies in California. It was measured by a Coast and Geodetic Survey party under the direction of Commander C. L. Garner, for the purpose of furnishing a yard-stick for the late Professor Michelson in his experiments for the determination of the velocity of light.

The geodetic work has progressed so rapidly and to such an extent that in California the federal program calling for triangulation stations and precise level bench marks at distances apart not greater than 25 miles, is near completion. This has been made possible as a result of funds allotted by the Public Works Administration, and the excellent organization of the Division of Geodesy, which now has in the field parties approaching in size our large hydrographic units. California presents to the Division of Geodesy what might at the present time be considered as its most interesting problem - control surveys in areas subject to seismic disturbances.

Geodetic control for city surveys will undoubtedly replace all other systems. Los Angeles County and City now use it. The City Engineer of Long Beach has been making inquiries regarding the best procedure to follow for the

coordination of its surveys under geodetic control. Unification and systematization of surveys and aggressive prosecution of the work is exceptionally notable in the state of Oregon, where this work is far in advance of what it is in other western states due to the far-sightedness of its engineers, officials and citizens, amongst the foremost of whom in this work is Lewis A. McArthur, grandson of William Pope McArthur.

The Tidal Division is also confronted with some interesting problems, as a result of the phenomenon known as surge, the magnitude of which at certain places along the Pacific coast is sufficiently great to cause inconvenience to shipping. The operation of a number of gages is also necessary for the proper study of emergence and subsidence of land areas.

The Pacific Coast is also the scene of the most progressive action taken for the determination of the effects of seismic disturbances on engineering structures, a field of investigation entered into by the Coast and Geodetic Survey within the last four years. Other phases of the work in that locality, particularly along seismometric lines, are most energetically studied by members of the faculties of state and other institutions. Some specific instances of the value of many of the early surveys may be of interest. A suit for over a million dollars was brought against the Federal Government over title to land considered as part of Mare Island. The most important evidence that the Federal Government could submit were the surveys made in the 50's by the officers of the Coast Survey, through whose attention to detail and correct delineation of the shore line conclusive evidence regarding the limits of the property was obtained. There were numerous other surveys, but those made by the Coast Survey furnished the evidence required.

A suit was brought against the Federal Government for damages to property, alleged to result from accelerated erosion caused by the construction of jetties at Humboldt Bay. An examination of Coast and Geodetic Survey topographic sheets made from 1851 to 1875, and of U. S. E. surveys of 1801 and later dates, showed that the rates of erosion fluctuated, and that there were periods of greater activity prior to the construction of the jetties. A remark by George Davidson in one of his reports indicated that the geological formation of the area in question might be worthy of investigation, as having some bearing on the rate of erosion. It was found to be stratified, and that the different layers were composed of materials which differed greatly in resistance to erosion, and the indications were that the rates varied according to the layers exposed.

The chart of San Francisco published in 1853 still has a steady sale. It shows the old high water line, defines the marsh area as well as high ground. It is notable for the accuracy of the great amount of detail which is given. It is purchased principally by real estate men and contractors. Limitations of space prevent me from mentioning more than two incidents which illustrate the value of this chart and the features which I believe are the fundamentals of surveying — accuracy and attention to detail. A real estate man, one well versed in land values, made inquiry as to whether it would be possible to superimpose the outline of the present system of streets on that map. That was accomplished. He informed me that he wanted to determine if his property, situated in the old Mission Bay area, was located on the tongue of high land shown on that map as projecting into the marshy area. If it were, its value would be just ten thousand dollars more than if it were on the filled-in ground - the difference in foundation costs of buildings where heavy weights or machinery would be placed.

Many deeds, records and maps were destroyed by the fire which occurred in 1906. One evening, about two years ago, about 5:30 pm a prominent San Francisco attorney telephoned my office and requested me to remain until he called. He informed me that a suit would probably come up for trial on the following day or the day after and he needed evidence to support a claim that a building was on a certain piece of property near the waterfront in the early fifties. The 1853 chart gave him the evidence required, showing the plan of the building in its proper shape. Numerous other instances could be mentioned showing the value of accurate records.

The work of the Coast and Geodetic Survey is progressing at a gratifying rate. The methods developed by the Coast Survey and its work are considered as standards which are seldom or never questioned. There is no higher authority.

That reputation has been built by those who preceded us. In this paper, a few items have been selected at random from a hundred years of history of a service, and of men who have established a record of which anyone might be proud. A few instances have been cited showing the intense interest of these men in carrying on the work, interest which has often resulted in the supreme sacrifice. We have a wonderful heritage. It behooves us to cherish it.

BOMB RETURNS, RADIO ACOUSTIC RANGING

Extract from Season's Report 1934 of Commanding Officer,
U.S.C. and G.S. Ship GILBERT, Herman Odessy, H. and G. Engineer,
U.S. Coast and Geodetic Survey.

Except for interruptions when the "GILBERT'S" party was instructed to assist in taking azimuths between survey buoys, the vessel remained on station ship duty for the entire period from May 1st, to August 30th, 1934. On this class of work the vessel anchored from 250 to 350 yards from the survey buoy; distances from the bridge to the buoy were measured by a range finder; buoy data, including buoy scope, length of magnetophone cable, direction of current, bearing to buoy, etc., were plotted directly on polar coordinate paper, and the resulting values for distance and direction, from the buoy anchor to the magnetophone, were radioed to the "OCEANOGRAPHER" every half hour, or oftener, when required. The strength and direction of the current obtained with a current pole, were forwarded by radio at the same time.

In general, the magnetophone was submerged to a depth of 6 or 7 fathoms, and trailed the ship at a distance of about 60 or 70 meters. Some experiments were conducted to determine at which depth to submerge the magnetophone in order to get the strongest signals from the bomb explosions. These experiments were not extensive enough to arrive at any definite conclusions. There was nothing to indicate that better results would be obtained by submerging the magnetophone to much greater depths than when placed near the surface. It was noted, that the surface noises were more readily picked up, and were more likely to interfere with the reception of the bomb when the magnetophone was close to the surface. This surface effect seemed to disappear at a depth of 5 or 6 fathoms.

Serial water temperatures and salinities were obtained twice daily, and at such other times as distances between survey buoys were being bombed. Surface and bottom temperatures, and salinities were obtained at intervals of two hours during the period when bombing was in progress.

Unusually good results as a station ship were obtained from the very first day on this class of work. There can be no doubt, that the experience of the personnel is one of the most important factors in arriving at this satisfactory situation. It is assumed, of course, that the personnel has been given reasonable time to make adequate preparation for this work, and to put the ship's radio equipment in the best possible working order.

FROM THE SHIP HYDROGRAPHER

A note from Lieutenant-Commander Eyman, commanding Snip HYDROGRAPHER mentions firing 107 bombs without a miss on the reception. They have evolved a new procedure in bombs which they used successfully for distances up to 26 seconds travel time. A half pint can is filled half full of TNT, and the remaining space filled with sand which is packed down on the TNT, and the fuse inserted. The radio operators on the launches say these bombs sound just as loud as though the cans were filled with TNT.

REPORT OF ASSISTANCE RENDERED

(From Commanding Officer U.S.C.and G.S.Ship SURVEYOR)

At 7:20 a.m. on July 31 the SURVEYOR intercepted a message from the Steamer OTSEGO, reporting that she had struck off Cape Mordvinof and punctured all tanks and requesting assistance from the Coast Guard. I immediately communicated with the Commandant Bering Sea Patrol Fleet and with the master of the vessel. As he had over 600 passengers aboard, was doubtful of his position and the extent of the damage was uncertain, he requested that I stand by and pilot him to Dutch Harbor. The Commandant requested that I stand by as only two small patrol boats were available. The weather was foggy with a fresh SW wind with short steep sea. By using the radio compass we sighted the vessel at 11:50 and proceeded to Dutch Harbor, the OTSEGO following. I communicated with the Coast Guard patrol boats as soon as I had sighted the vessel and they arrived in sight at about 1:00 p.m.

The OTSEGO arrived at Dutch Harbor at 6:30 p.m. The damage necessitated transfer of passengers and cargo. The following message was received from the master of the OTSEGO: "I wish to convey to you my sincerest thanks for your courtesy in guiding us to anchor here. Garski, master". The place where the vessel struck is uncertain but probably was close to shore off Cape Mordivnof, Unimak Island, as it was reported that breakers and the shore had been sighted before she struck. The OTSEGO is operated by Libby, McNeill, Libby, and was proceeding from Nushagak to Seattle when the accident occurred.

(Sgd.) A. M. SOBIERALSKI, H. and G.E.
Commanding SURVEYOR

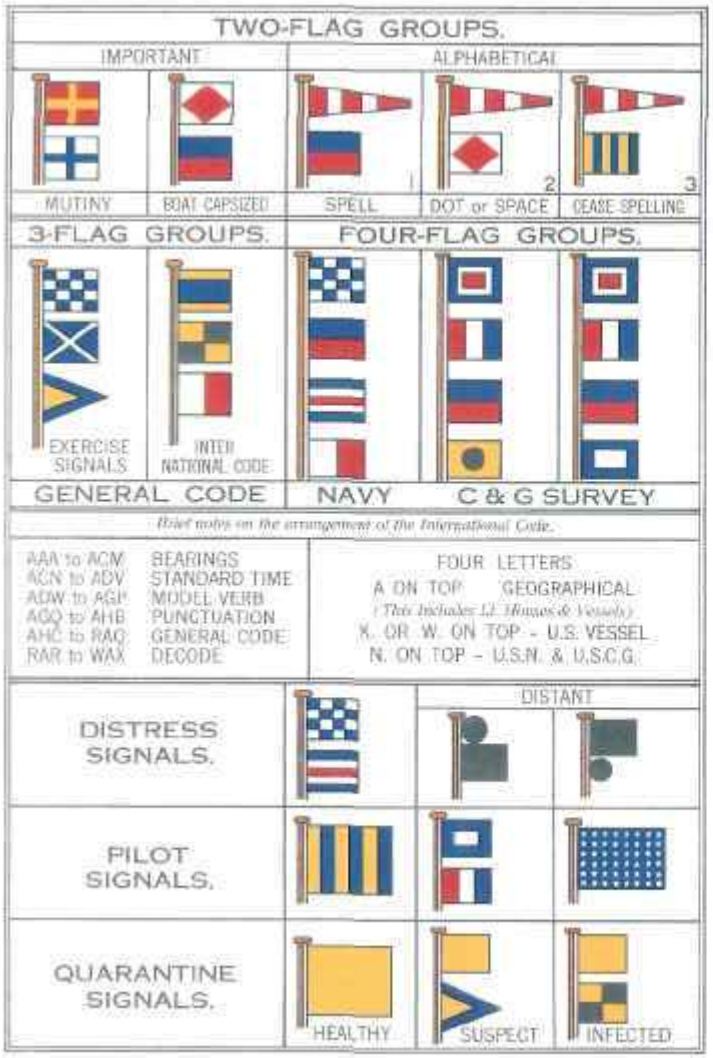
Unalaska, Alaska.
August 1, 1934.

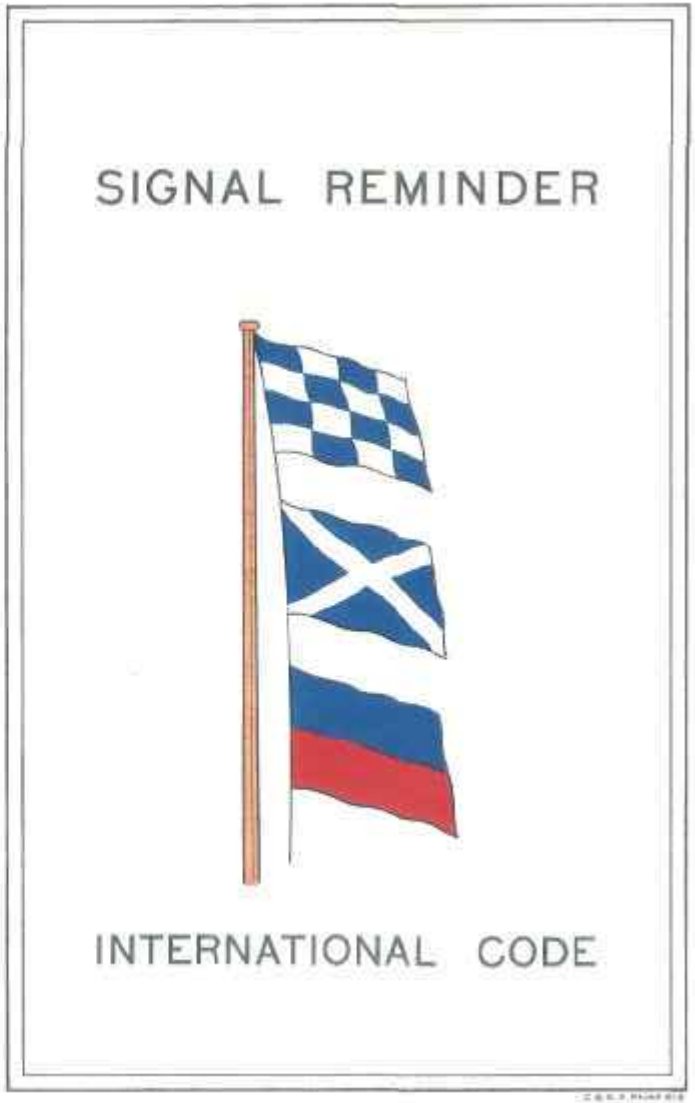
RECORDS FOR FOURTH ORDER CONTROL STATIONS

(Extract from a letter from the Director to a Chief of Party)

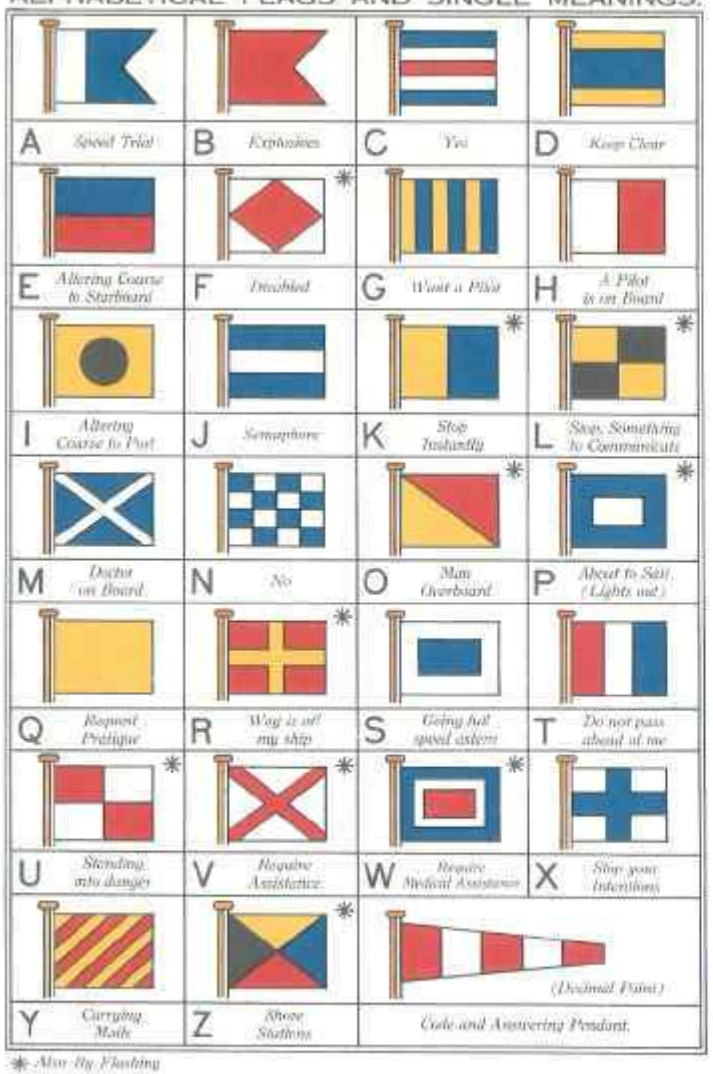
Referring to your letter of June 20, 1934, the descriptions of intersection stations submitted by you on form 524, "Description of Recoverable Hydrographic or Topographic Station", have been filed in this office as descriptions of triangulation stations, the title on form 524 having been changed accordingly. The stations in question are indicated on your triangulation progress sketch, the computations were submitted as triangulation records and the quality of the work seems to indicate that the stations were located with sufficient accuracy to class them as triangulation stations.

It is recognized that frequently a chief of party, engaged on combined operations, will have occasion to locate a station from theodolite cuts which by reason of poor intersection angles, indefinite pointings, partially obstructed lines, abnormal eccentricity, or poor observing may not be considered strong enough to be classified as a triangulation station. The logical treatment in cases of this kind is to consider the station as a topographic or hydrographic station, mark and describe it as such, omit the station from the triangulation sketch and not submit the results as triangulation records. The description of such a station on form 524 should, of course, state that it had been located by theodolite cuts, which were not considered of sufficient accuracy to warrant classifying the work as triangulation.


TWO-FLAG GROUPS.
IMPORTANT
ALPHABETICAL
MUTINY
BOAT CAPSIZED
SPELL
1
DOT or SPACE
2
CEASE SPELLING
3
3-FLAG GROUPS.
FOUR-FLAG GROUPS.
EXERCISE SIGNALS
INTERNATIONAL CODE
GENERAL CODE
NAVY
C & G SURVEY
Brief notes on the arrangement of the International Code.
AAA to ACM BEARINGS
ACN to ADV STANDARD TIME
ADW to AGP MODEL VERB
AGQ to AHB PUNCTUATION
AHC to RAQ GENERAL CODE
RAR to WAX DECODE
FOUR LETTERS
A ON TOP GEOGRAPHICAL
(This includes Lt. Houses & Vessels)
K. OR W. ON TOP - U.S. VESSEL
N. ON TOP - U.S.N. & U.S.C.G.
DISTANT
DISTRESS SIGNALS.
PILOT SIGNALS.
QUARANTINE SIGNALS.
HEALTHY
SUSPECT
INFECTED

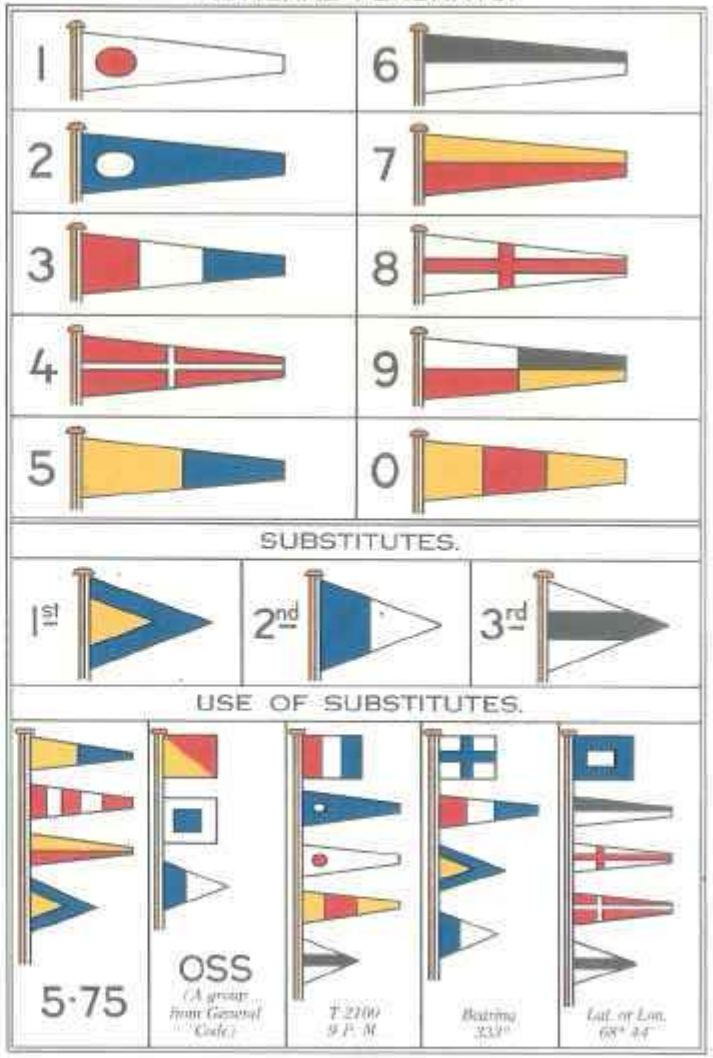

SIGNAL REMINDER
INTERNATIONAL CODE

ALPHABETICAL FLAGS AND SINGLE MEANINGS.



✱ Also By Flashing

NUMERAL PENDANTS.



DIMENSIONS OF INTERNATIONAL FLAGS

U. S. NAVY

SIZE	FLAGS HOIST	FLAGS FLY	PENNANTS HOIST	PENNANTS FLY	REPEATERS HOIST	REPEATERS FLY
2	7'-3"	7'-3"	5'-5"	13'-4"	5'-9½"	11'-7"
4	4'-4"	4'-4"	3'-3"	8'-0"	4'-4"	8'-8"
6	2'-11"	2'-11"	2'-0"	4'-10"	2'-0"	4'-0"

STANDARD

SIZE	FLAGS HOIST	FLAGS FLY	PENNANTS HOIST	PENNANTS FLY	REPEATERS HOIST	REPEATERS FLY
1	6'-6"	8'-0"	5'-0"	16'-9"	8'-0"	10'-0"
2	4'-6"	5'-6"	3'-9"	12'-9"	6'-0"	7'-6"
3	2'-6"	3'-0"	2'-6"	8'-6"	4'-0"	5'-0"

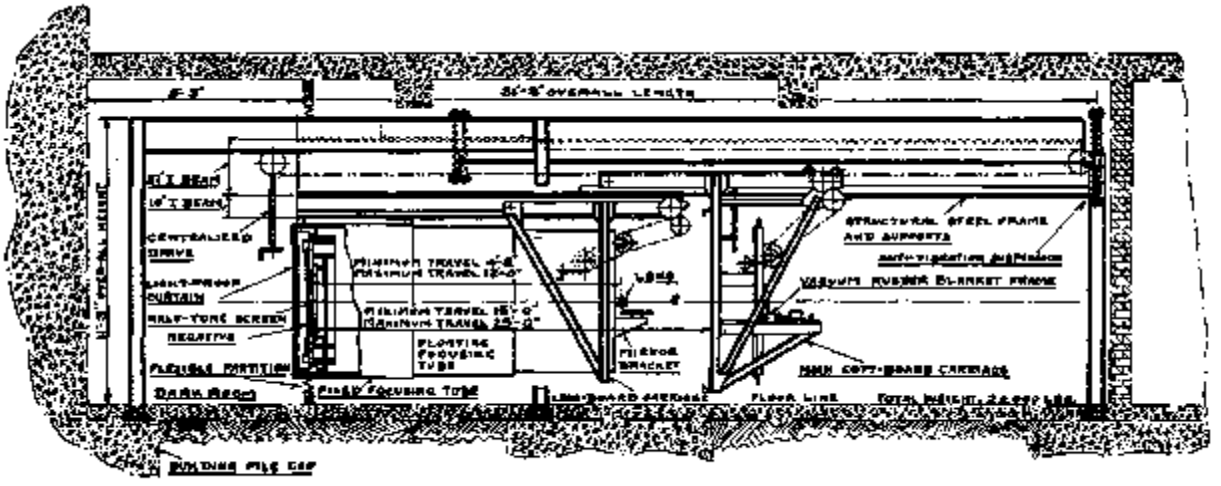
A FIFTY INCH PRECISION COPYING CAMERA

O. S. Reading, H. and G. Engineer, U. S. C. and G. Survey

One of the most important characteristics of modern engineering is its extension of precision machinery into all processes requiring replacement of parts. Parts made with high precision are interchangeable without expensive reworking and adjustment. A 14 ton camera capable of reproducing the largest size charts or survey sheets with an accuracy of one or two thousandths of an inch developed by the U. S. Coast and Geodetic Survey is a recent example of this extension.

Since the paper on which charts and maps are printed changes in dimension (about one part in three hundred) with variations in humidity of the atmosphere, the need for such precision is not immediately apparent. For a number of years the chart compilations have been made upon paper glued to thin aluminum sheets to avoid the extra work of continually allowing for the hygroscopic changes in the paper while plotting. More recently paper mounted, or lacquered aluminum sheets have been used for field surveys to eliminate the errors caused by paper distortion.

Generally the problem of making complete resurveys is much simpler than keeping the surveys revised to date at practicable expense, particularly along



U.S. COAST AND GEODETIC SURVEY 50 INCH PRECISION COPYING CAMERA

a changeable coast with harbors under continuous development. This is essentially a problem of replacement of parts. In order to do this job with high efficiency, it is necessary that the former surveys be reproduced so accurately on the aluminum sheets sent to the field that only the changed areas need be resurveyed to a junction with the unchanged. It is apparent that much time would be lost if it were necessary to allow continually for distortion in the reproduction of the former work. With precise reproduction it is possible to recognize and correct small errors in the former surveys and thus to improve the accuracy of the whole instead of having the accuracy gradually deteriorate as it does when reproductions are made on distorted paper. The new precision camera of the Coast and Geodetic Survey is an important link in this modern development of cartography.

The new camera is one of the largest in the world. It is thirty-one feet long, twenty feet wide and weighs nearly fourteen tons. It is capable of making negatives fifty by fifty inches in size, sufficient to reproduce the largest size chart on one negative. A considerable saving of time will be effected by the use of one negative instead of the two or four which were necessary with the camera used heretofore.

From an engineering standpoint the construction of the camera is interesting because of the difficulty of maintaining the required precision in a machine

31 feet long with copyboard and lens carriages weighing nearly a ton rolling along it. The first thought when considering the design of the camera was not to try to hold the alignment for the widely varying positions, but to provide auto-collimators and adjusting screws by which the camera might be realigned for each setting. This would have been a much simpler design problem but would have greatly handicapped production. Fortunately, the room available for the camera was in the basement of the Department of Commerce Building, and supports could be placed directly on the pile caps of the building foundations. This removed restriction as to weight and permitted the use of simple structural steel beams rather than elaborate truss construction. The main members of the camera frame are twenty-seven inch, eighty-five pound I-beams. They hold the difference in. deflection at the various settings of the one ton carriages to less than one hundredth of an inch. The frame is suspended at three points with groups of chains which free the camera from any effects due to settlement or horizontal vibrations of the building. Provision has been made for cork pads to damp out vertical vibrations. The frame of the camera was placed overhead with the various carriages suspended from it to make them more accessible.

The lens and copyboards run on two tracks fixed to the frame by screws with lock nuts which provide for both horizontal and vertical adjustment of the tracks at intervals of about eighteen inches. The guide track is aligned both vertically and horizontally, and the other track in a vertical direction only. The horizontal alignment of the carriages with the guide track is held by preloaded, opposed ball bearings. Since every piece of steel is a spring, the alignment of the tracks may be considered as straightening one spring by pulling on fastenings to another. The selection of adjusting screws instead of the shims originally considered for this purpose proved fortunate. A bulge worked out in one place often carried over to another and the final adjustment under load was the result of numerous settings which would have been very expensive if each had meant the separate unclamping and clamping of a shim. The guide track was made with vertical sides rather than a "V" for greater ease in adjusting out errors in alignment by vertical and horizontal components. Although there will undoubtedly be seasoning effects which will require readjustment of the camera from time to time, the original adjustment is still practically perfect after six months.

The positions of the copyboards and lens board are set by scales fixed to the guide tracks and read by optical verniers in magnifying periscopes to hundredths of a millimeter. Provision is also made for ground glass focussing by a set of gear and chain controls from the plate end of the camera.

The fixed or plate end of the camera has been partitioned off to form a dark room in which the plates may be sensitized, exposed and developed without bothering with plateholders. One of the limiting errors of the camera is the selection of plate glass sufficiently flat for the photographs. The plates are usually warped about ten one thousandths of an inch or so, being concave on one side and convex on the other. Thus far photographs have been made on selected flat plates but a device is being constructed to press against the unsensitized, convex side of the plates thus holding them to the required flatness. Very little pressure is needed for this.

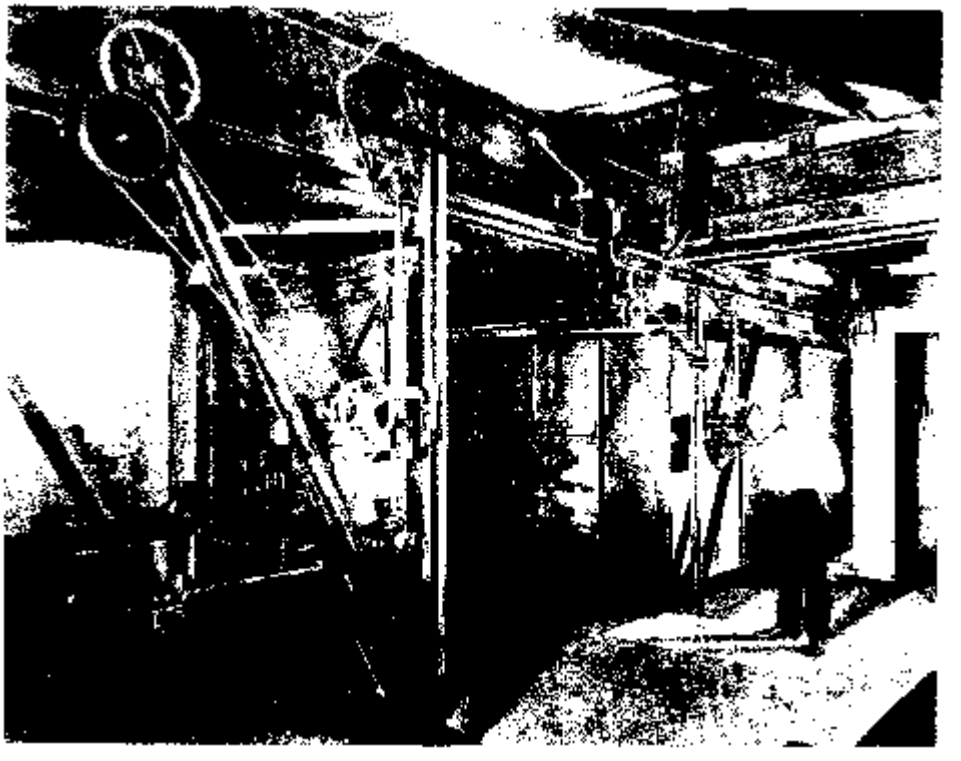
The survey sheets and maps to be photographed are held between a sheet of specially selected water white plate glass and a rubber blanket, A vacuum is created between the glass and the blanket. The atmospheric pressure of the air outside the blanket and glass then holds the copy flat with a minimum deflection of the glass, A system of telescoping sheet steel tubes is used instead of a bellows, both for greater durability and to avoid a varying tension on the lens board which so large a bellows would entail.

Certain processes of map reproduction require a direct instead of the usual reversed negative. An auxiliary copyboard and a reversing mirror of stellite have been provided for this work. The reversing mirror is mounted on a point-line plane support which permits removal and replacement in front of the lens without disturbing the delicate adjustment.

Nearly two years were required for the design, construction, and adjustment of the camera. The original design, sketches and specifications were prepared by Lieutenant O. S. Reading, U. S. Coast and Geodetic Survey, who also had charge of the project. Much valuable information was obtained from the Optical Instrument Section of the U. S. Bureau of Standards. The overhead suspension was adopted from the cameras of the Geological Survey. Preliminary designs were prepared at the Naval Gun Factory Sight Shop. Final design and construction was done under contract by the American Instrument Company of Washington, D. C.

NEGATIVE HOLDER OF COAST AND GEODETIC SURVEY PRECISION CAMERA

The camera may be focussed by eye using a ground glass in the negative holder but usually it is more precisely set by scales along the tracks



MAIN COPY BOARD AND LENS BOARD OF
COAST AND GEODETIC SURVEY PRECISION CAMERA

The 27 inch beams overhead carry these boards with a deflection of less than one hundredth of an inch while the control mechanisms make it possible to set them with the touch of a finger tip.