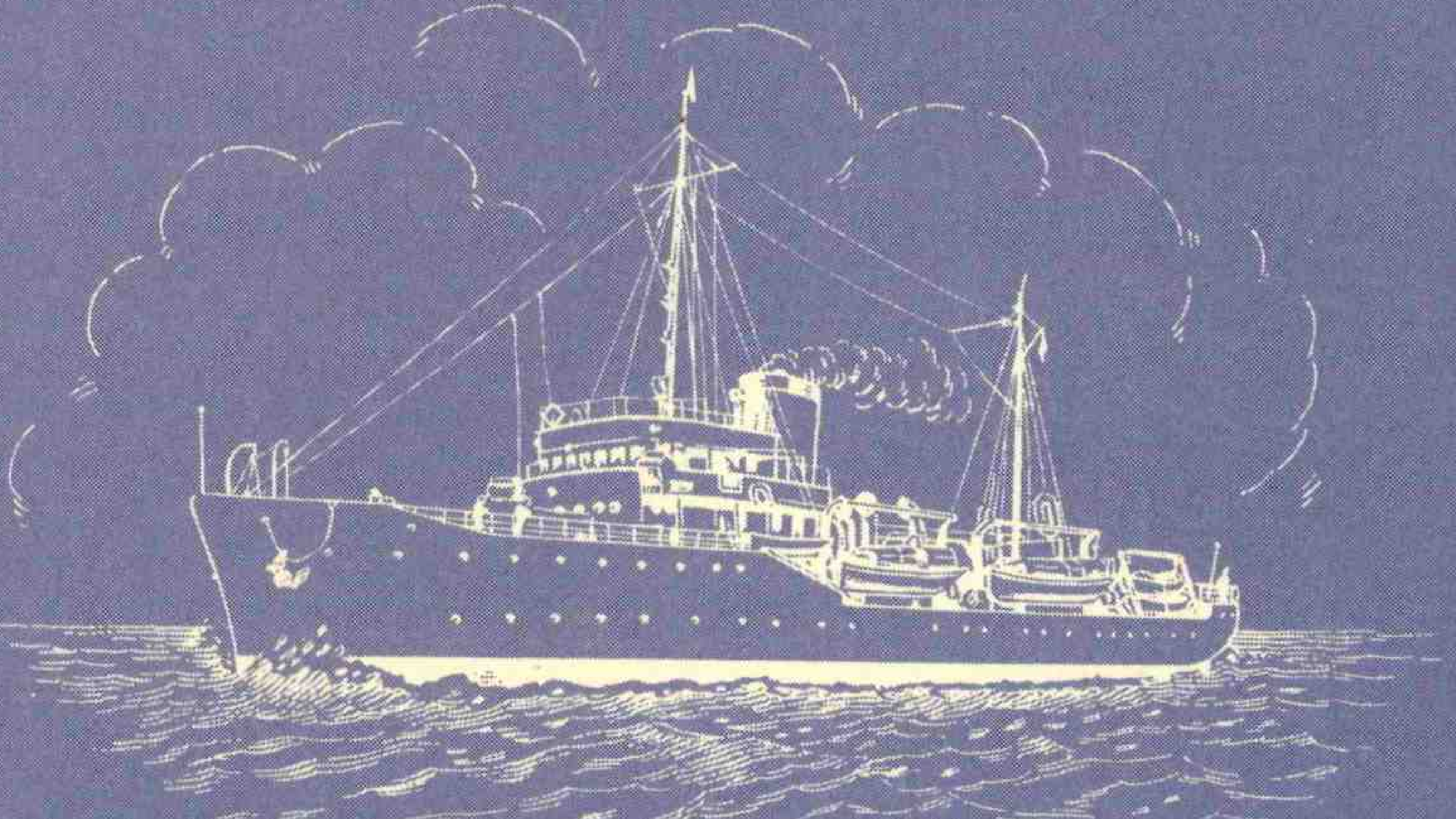
The JOURNAL
Coast and Geodetic Survey



Sesquicentennial Issue

OCTOBER 1957 • NUMBER 7

U. S. DEPARTMENT OF COMMERCE

SCHOONER ***MATCHLESS***, ONE OF THE EARLIER VESSELS USED IN SURVEY WORK

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A. L. SHALOWITZ

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A Sesquicentennial of Public Service

REAR ADMIRAL H. ARNOLD KARO, Director
U. S. Coast and Geodetic Survey

FEBRUARY 10, 1957, marked the 150th anniversary of the founding of the Coast Survey. It is proper that note be taken of such occasion, and that the record, as it stands, be hailed as an achievement. The Survey is proud of what has been accomplished, and in the electronic-atomic age ahead plans an even greater contribution. Within the Department of Commerce the Bureau will continue to serve the best interests of commerce, industry, business, and the defense of the Nation.

The early settlers of this country approached its shores with no knowledge of the waters beyond stout hearts, keen eyes, and an intuitive sailing skill. When independence was won the new democracy had many problems to solve but none so vital as the need for charts to keep maritime commerce moving. President Thomas Jefferson recognized that the prosperity of the infant republic depended upon safety of navigation and the growth of commerce. In keeping with this concept, the Bureau had its beginning along with the very first agencies to be created by our forefathers. Thus was initiated the great undertaking of surveying and charting the coastal waters which has progressively expanded in scope and breadth.

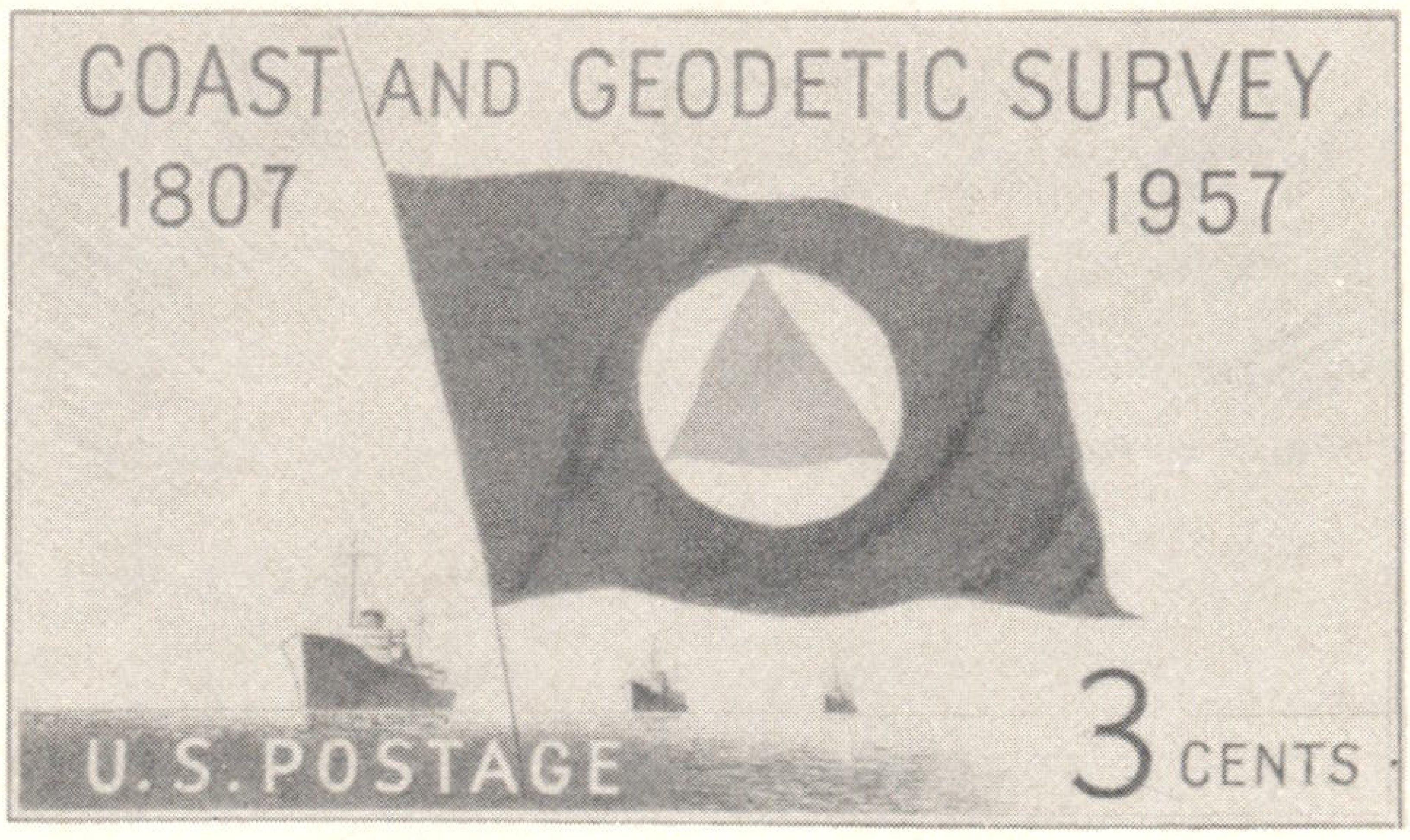
The example set by the Bureau over the years is a constant and ever-present challenge. It reflects the untiring efforts of devoted men and women making diligent application of their intellect, energy, and time. It has steadfastly demonstrated the best in technical proficiency, in devotion to duty, and in an unwavering fidelity to sound scientific principles.

In performing a vital function of Government, the long succession of dedicated public servants who have contributed unselfishly, decade by decade, to our national heritage exemplifies the finest traditions of the Federal service. Their achievements are an inspiration to the present generation and those who will follow. I commend the host of unsung patriots who have demonstrated in a practical way inspired and unselfish labor in the national interest.

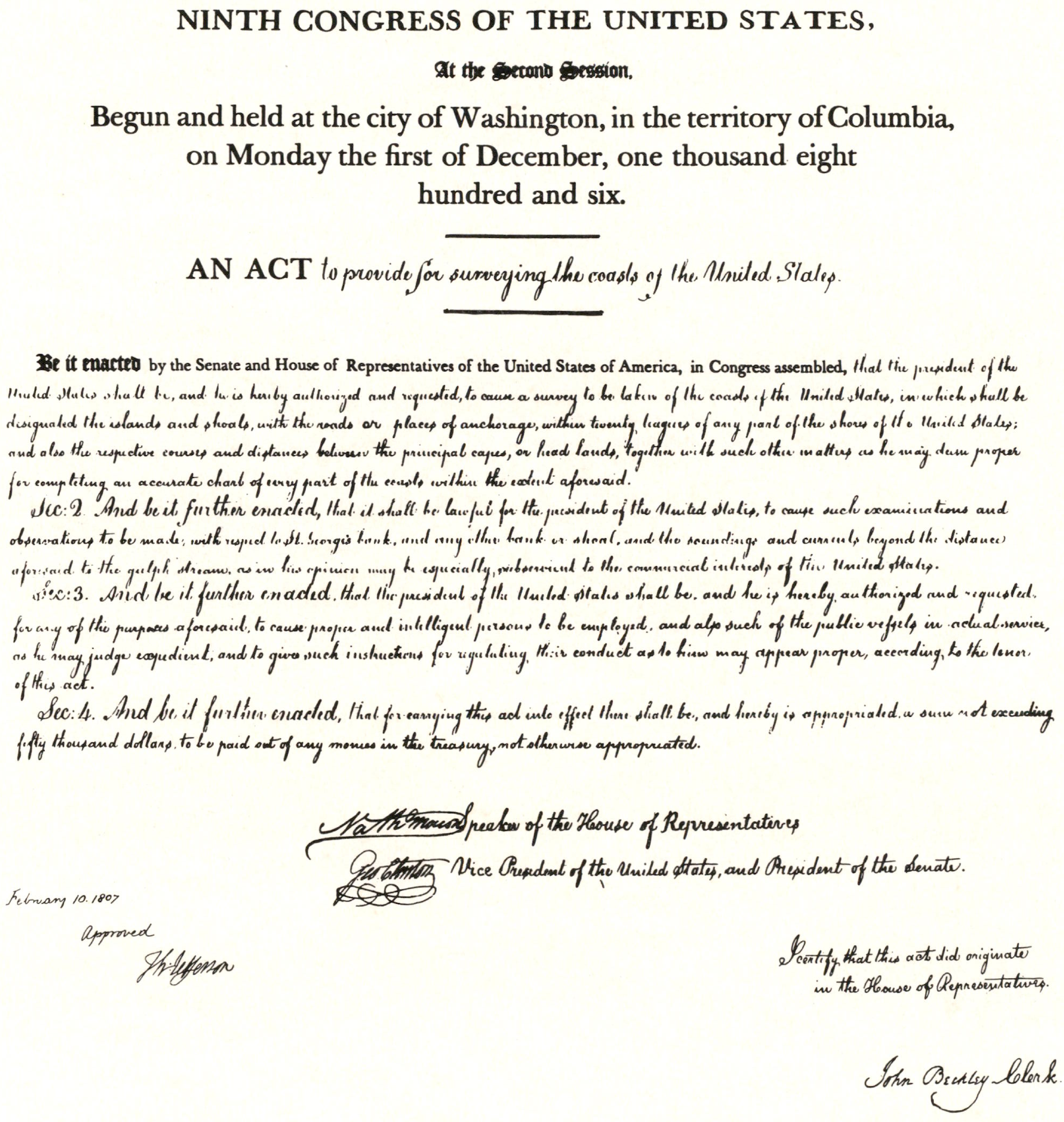
In every generation pioneer personalities of the Survey have been widely known for their practical contributions to science. Bureau scientists have been closely identified with the work in related agencies of Government, both national and international. The great benefits from these efforts which all enjoy today reflect the highest attainments in scientific applications. I am glad that these accomplishments deserve and are accorded the approbation of the leading learned bodies of the world.

The Survey's illustrious history is enriched with dramatic heroism on land and sea, and is resplendent with honored names. Many great men and women share in the honors accorded the Bureau during our Sesquicentennial year. Each period of its existence has produced men who consistently displayed courage, integrity, and sound judgment in carrying out their assigned tasks. They seldom faltered in their missions even when the work took them to almost inaccessible mountaintops, under the very guns of enemy warships; to remote areas of the Philippines, with exposure to tropical diseases; and, in later decades, to the frozen wastes of arctic Alaska.

Always in step with national progress, new applications are found for the unique services of the Bureau. Progressive charting of coastal waters has made safe our maritime commerce, and intensive mapping of air routes has contributed to the safety and advancement of air navigation. The pioneering effort that has expanded in scope and importance, in keeping with national progress, will continue in the decades to come. Plans for the future envision an ever-broadening capacity of the Bureau to serve the American people.



COMMEMORATIVE STAMP



NINTH CONGRESS OF THE UNITED STATES,

At the Second Session,

Begun and held at the city of Washington, in the territory of Columbia,
on Monday the first of December, one thousand eight
hundred and six.

AN ACT to provide for surveying the coasts of the United States.

Be it enacted by the Senate and House of Representatives of the United States of America, in Congress assembled, that the president of the United States shall be, and he is hereby authorized and requested, to cause a survey to be taken of the coasts of the United States, in which shall be designated the islands and shoals, with the roads or places of anchorage, within twenty leagues of any part of the shores of the United States; and also the respective courses and distances between the principal capes, or head lands, together with such other matters as he may deem proper for completing an accurate chart of every part of the coasts within the extent aforesaid.

Sec: 2. And be it further enacted, that it shall be lawful for the president of the United States, to cause such examinations and observations to be made, with respect to St. George's bank, and any other bank or shoal, and the soundings and currents beyond the distance aforesaid to the gulph stream, as in his opinion may be especially subservient to the commercial interests of the United States.

Sec: 3. And be it further enacted, that the president of the United States shall be, and he is hereby authorized and requested, for any of the purposes aforesaid, to cause proper and intelligent persons to be employed, and also such of the public vessels in actual service, as he may judge expedient, and to give such instructions for regulating their conduct as to him may appear proper, according to the tenor of this act.

Sec: 4. And be it further enacted, that for carrying this act into effect there shall be, and hereby is appropriated, a sum not exceeding fifty thousand dollars, to be paid out of any monies in the treasury, not otherwise appropriated.

Nath. Macon Speaker of the House of Representatives

Geo. Clinton Vice President of the United States, and President of the Senate.

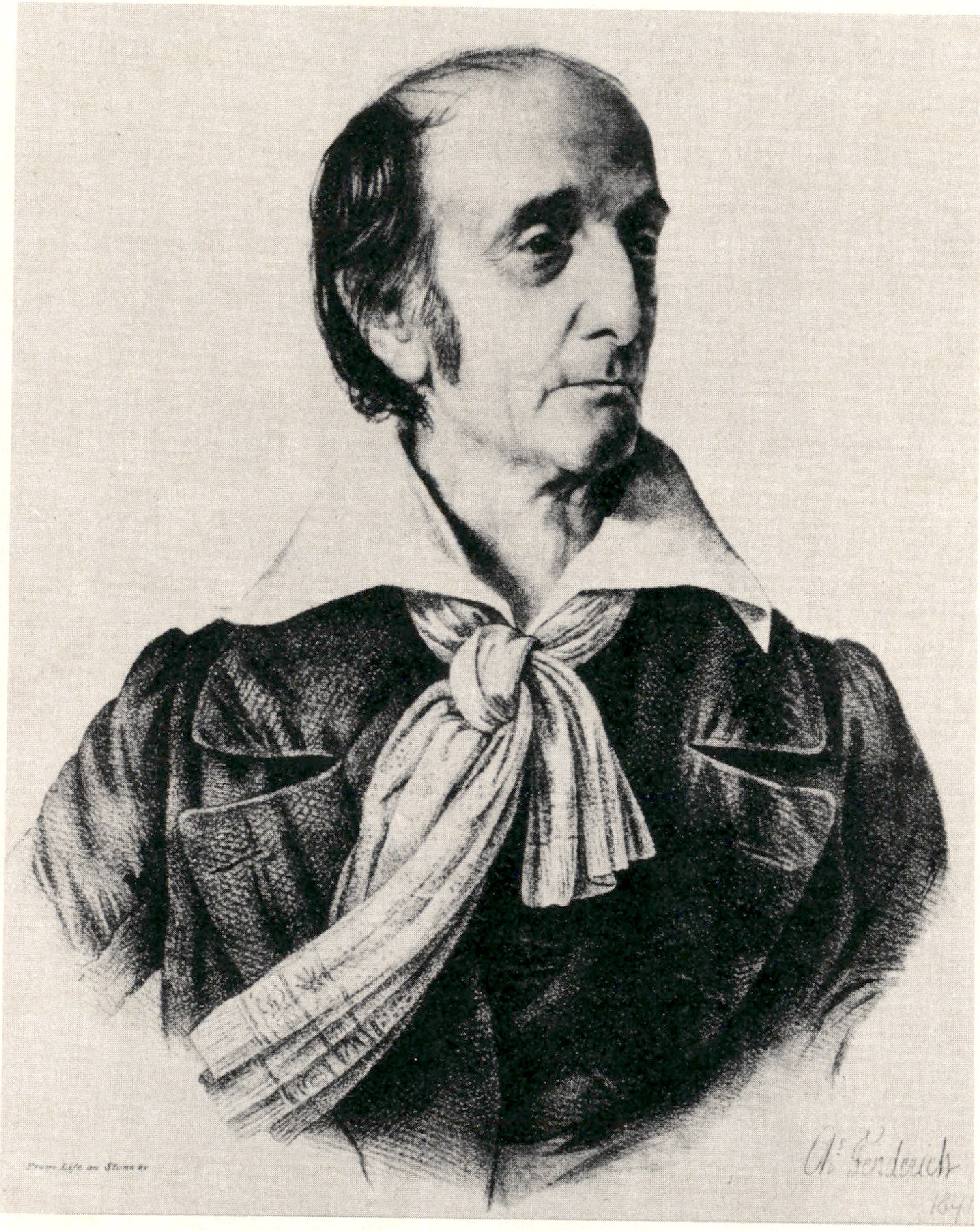
February 10. 1807

Approved
Th: Jefferson

I certify that this act did originate
in the House of Representatives.

John Beckley Clerk.

THE ACT OF FEBRUARY 10, 1807, WAS THE BEGINNING OF THE COAST AND GEODETIC SURVEY



FERDINAND R. HASSLER, THE FIRST SUPERINTENDENT
OF THE COAST SURVEY

The Coast and Geodetic Survey in the Philippine Islands

REAR ADMIRAL EARLE A. DEILY (Retired)
U. S. Coast and Geodetic Survey

(Awarded First Prize in the Sesquicentennial Essay Contest)

This and the following article were adjudged the first and second prize-winning papers, respectively, in the Sesquicentennial Essay Contest held during 1956 under authority of the Incentive Awards Program of the Bureau. The first prize carried with it an award of $100 and the second an award of $50. The panel of judges consisted of Comdr. Franklin R. Gossett, Assistant to the Director, Coast and Geodetic Survey, Chairman; Mr. Henry Scharer, Deputy Director, Office of Public Information, Department of Commerce; and Dr. Henry Birnbaum, Assistant to the Director, National Bureau of Standards. The articles have been condensed for publication.--Editor.

THE SCOPE of the survey operations of Government mapping bureaus always expands with the acquisition of new territories. When Spain ceded the Philippine Islands to the United States the production of nautical charts became the official concern of the United States Coast and Geodetic Survey. Defined by law, its charting jurisdiction covers not only the continental limits of the United States but its territories as well.

Manila was still under martial law and military operations were in progress throughout the islands the September morning in 1900 when the first official of the Survey arrived there to make the preliminary studies needed for inaugurating a systematic survey of the coasts of the Philippines. In fact the times were so unsettled that no one without authority was allowed on the streets of the city after 10 o'clock at night.

Although many maps had been produced in the years since Magellan first visited the islands in 1521, it was found that the American inheritance of nautical information was far from complete. It was contained entirely in a collection of 136 Spanish charts of various dates and in the *Derotero del Archipielago Filipino* or Spanish Coast Pilot. This had last been published in 1879 and was much outdated.

The Spanish colonial surveys and the production of charts were entrusted to a bureau separate from that which exercised the same function in the Spanish continental areas. This "Bureau for the Colonies" was abolished subsequent to the Spanish-American war. Surveys and records were always sent to Madrid and the charts published there. Unfortunately few late records concerning the Philippines were available in Madrid as a great number were lost in the sinking of the survey ship *Argo* at Cavite.

Each particular survey was a unit unto itself and connected to other surveys by only a reconnaissance. Extensive areas had not been explored at all. Above all, there was no general system of triangulation tying the work together as a whole. Such coordination as was effected resulted from observed astronomic latitudes and longitudes for which the designated base point was the Dome of the Cathedral at Manila.

The existing surveys of the large island of Palawan and much of the Sulu Archipelago and Sulu Sea were the product of the British. Some were as recent as 1882. Actually the extensive work along the island of Palawan was only in the nature of an exploration and had been done by a sailing vessel. The British charts which resulted were published on the very large scale of 1 inch to 10 miles.

When one gives due consideration to the methods and equipment used in surveying during the nineteenth century and realizes the large area covered, the Spanish charts were really not too bad. The existence of many errors in the maps was early suspected but it was only in later years when a comparison with the surveys of the Coast and Geodetic Survey would be made that any real evaluation of these discrepancies was possible.

The Spanish positions of the large islands were found to agree relatively in latitude but there were great differences in shapes. There was considerable displacement from true position of the smaller islands, points and bays.

The east coast of Luzon as well as the islands to the northward toward Formosa fell as much as 5 miles to the eastward. At some places the northeast coast of Samar--a large island on the east side of the archipelago--was found to be quite crudely drawn and fell about 5 miles farther inland. Parts of Mindanao also fell 7 miles eastward and the head of Davao Gulf, at the southeast corner of the island, was actually 6 miles to the northward. A group of islets in the Sulu Sea which appeared on the Spanish charts derived from the surveys of 1792-93 actually were nonexistent. The island of Palawan to the west of the Sulu Sea lay 2 miles more to the eastward.

But worst of all, there were innumerable shoals and navigational dangers throughout the island group that were not even indicated.

There are over 7,000 islands and rocks above water in the Philippine group, with a tidal shoreline of 21,000 statute miles. In view of the great area to be charted, it was immediately seen that the work of adequately surveying the islands would be a large undertaking. Remote areas had to be explored for the first time. Four full decades, a considerable force of men, and a number of surveying vessels were required to bring the task to completion.

FIRST COAST SURVEY WORK

The work of the Coast and Geodetic Survey in the Philippines was conducted under a joint agreement between the Bureau and the Insular Government. Each supplied certain personnel and equipment and defrayed particular classes of expenditures. The local administration was conducted through a suboffice in Manila which in turn was under the general supervision of the Bureau in Washington.

The immediate line of action for improving the nautical charts was planned to meet the pressing needs of commerce and of the military whose deep-draft transports were reaching remote and previously unused anchorages. Extension to cover the entire archipelago would come in general course at a later date. Obviously the first surveys would have to be made of detached areas and in such sequence as to take advantage of the periods of good weather alongshore. Hydrographic operations were only possible where sheltered from prevailing winds. The northeast monsoon predominates from November to March and the southwest winds are felt from May to October. Field parties therefore had to be shifted frequently from one side of the islands to the other. Typhoons also could be expected in August and September. The instructions issued to the survey parties made sure that the field work would be done in a permanent and detailed manner despite the urgency for immediate results and would be so rigidly controlled that it could later be incorporated in the over-all survey of the island group.

The Manila office was designed to be a center for directing operations and as a collecting and distributing point for information. Charts and sailing directions were compiled and published there.

Astronomic observations were proposed for the geographic positioning of a number of marked points throughout the islands. These astronomic stations became the base points for the surveys.

Local hydrographic and topographic surveys were to be made of harbors and landing places and of the important approach channels and main routes of travel, in such order as required. Ultimately, the work would be extended until the whole water area of the archipelago would be covered. Tidal and magnetic determinations were of course a necessary phase of these operations.

As soon as conditions permitted during the extension of the hydrography and topography, a coordinating scheme of triangulation was to be observed throughout the islands.

The first field party to reach the Philippines consisted of four officers, one draftsman, and four recorders, with a somewhat limited outfit of instruments. It began field work early in

The Manila Office was located on Engineer Island from 1936 to the beginning of World War II.

Survey party starting for Badoc Island on the west coast of Luzon.

January 1901. For awhile this work was confined to the vicinity of garrisoned posts, but after a few months the general conditions improved so greatly everywhere that survey operations were carried out where desired.

No serious difficulties were encountered because of hostilities of the native population during the insurrection years, although in some instances parties were in towns that were "shot up" during the fighting. The survey parties were armed and this practice was continued for many years during operations in the more remote and primitive areas.

As late as 1922, when the ship *Pathfinder* was in Zamboanga, the commanding officer reported that he made inquiry of the department commander of the Philippine Constabulary concerning conditions in the Sulu Archipelago. He was advised that an armed guard be sent with all shore parties and that the officers be cautioned to use care at all times and keep any Moros at a distance. Arrangements were therefore made to take aboard a party of one sergeant and eight men.

Throughout the long years of operations in the islands there was only one recorded attack on Coast Survey personnel--the brutal butchering of Commander Shaw in Jolo in 1941. By a miracle he survived to be flown to the hospital in Manila, endured the Japanese internment in Bilabid prison while recovering from his ghastly wounds, and was finally brought back to the States where he died in 1947.

TRANSPORTATION PROBLEMS

Transportation was ever a great problem in the Philippines. Many years passed before the island roads supported traffic in the rainy season. Operations of interisland steamers in the early days were irregular and infrequent and even in the late 1930's made scheduled runs only between Manila and the main island ports. Local water travel was by banca, by sailing "prao," or sometimes by small power launch.

Few piers were available except at the major ports and lightering was the usual procedure. Unfortunately there were few lighters. Freight was simply dumped on the beach or on the bank of a river and wagons immediately began to haul it to the town, usually some distance away. Where there were wharves at the little outlying ports of call one reads time and time again in the survey reports: "There is a stone jetty but nothing can go to it but small boats." "Small steamers can go to the wharf." "It is impossible for boats of any size to come near the shore; even rowboats have to lie some 50 feet offshore because of sandy shoals."

There was a railroad between Manila and Dagupan near Lingayen Gulf but the trip of some 125 miles took about 4 hours; a remarkable and terrifying speed for the days of carabao carts and one-horse vehicles. "Sigue Dagũpan" (proceed to Dagupan) was the cry of the conductor to the engineer when the train was ready to start for Dagupan. "Sigue" began colloquially to mean "hurry" but with particular derision when used in the phrase "Sigue Dagupan spera Caloocan" (proceed to Dagupan stop at Caloocan). The train dashed off toward Dagupan and then stopped for an interminable wait in the heat at Caloocan just a few kilometers up the line.

For many years "Sigue Dagupan" was the cry everyone gave the Manila carromatta drives when speed was desired. What speed! The "cochero" yelled wildly and flailed his whip; the little pony jumped ahead; the passengers banged back against the seat; and away the whole thing went careening in and out of traffic and just missing people and bull carts. Autobuses and taxis were far in the future.

Outside of Manila, in the villages and countryside, traffic moved at the slow methodical pace of the carabao, or water buffalo, pulling a lurching cart with wheels of solid planks. Travelers rode horses.

In the wilder sections one walked, and hired "cargadores" to carry the instruments and outfit and to hack a passage through the jungle. In the years of the Survey, such a band on the trail was a somewhat ludicrous string of Filipino sailors from the ship, local residents of the beach, and primitives from the hills. All spoke different dialects.

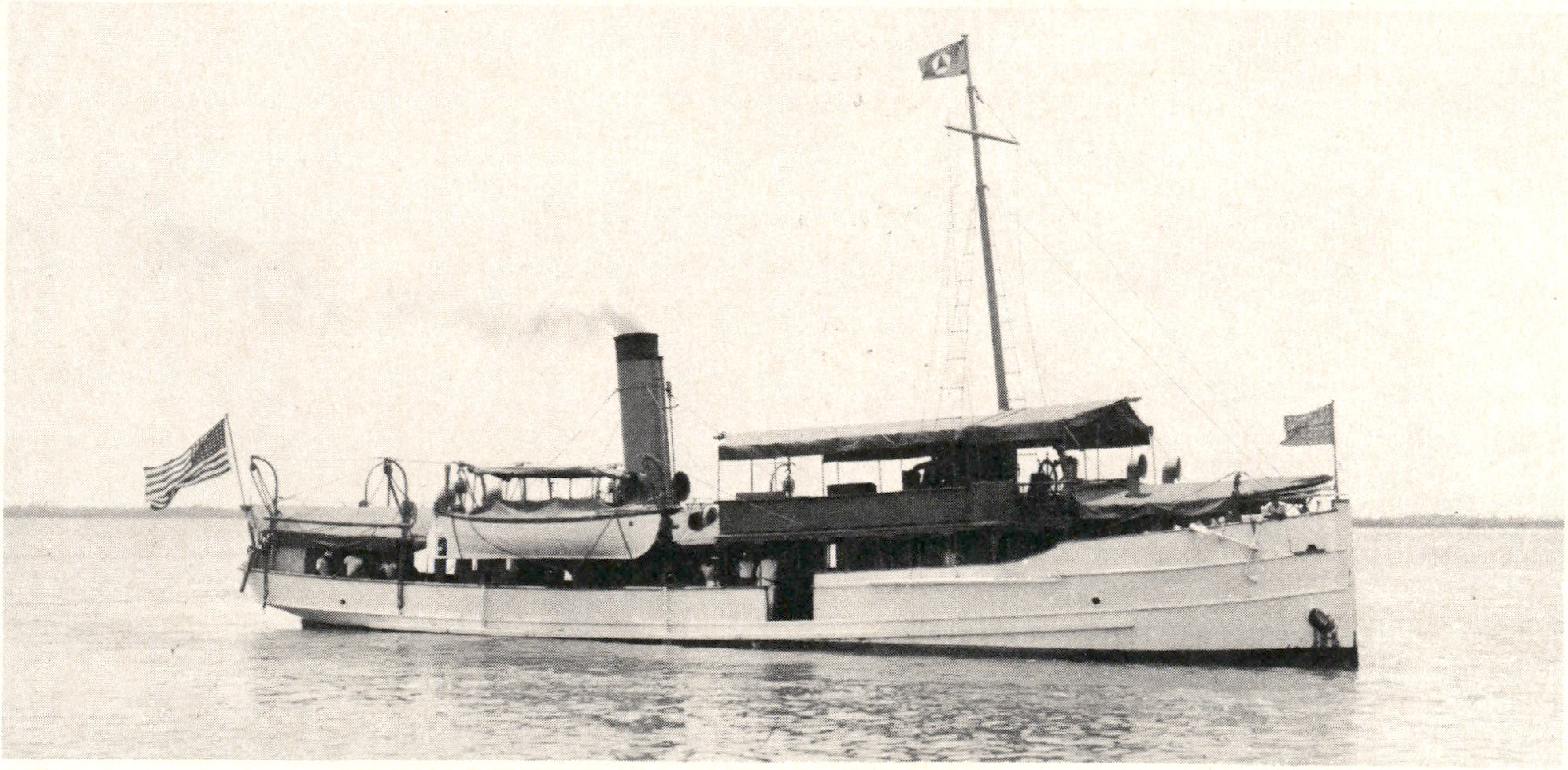
So! The first survey party "sigued" or rather "rushed off" to Dagupan. Then, after arriving there at about 3 o'clock in the afternoon of the same day, it waited 2 more days for transportation to Sual, a then important port of call on Lingayen Gulf.

The observations for latitude and longitude at Sual showed a difference in position from that given by the Spanish and indicated that such disagreement might be expected elsewhere. The latitude differed by 2' 42" from the Spanish chart and 1' 53" from the British Admiralty and United States Hydrographic Office charts. The longitude differed 0' 46" and 0' 25", respectively.

As field work was attempted it was found that launches and boats in any way suitable for hydrographic surveying were only obtainable at the few major ports and then only rarely. Ships were indispensable for carrying on offshore work and to furnish dependable transportation for the field parties. An over-all scheme of triangulation connecting the various islands could not be attempted without ships.

SURVEY VESSELS

The first survey vessel in operation was a small wooden steamer *(S.S. Vitaliana,* renamed *Research)* purchased early in 1901 by the Insular Government. The original agreement for operations specified that the Insular Government supply two vessels and the Federal Bureau one. All ships' officers and other technical force were to be supplied by the Coast Survey. The ***Research*** was 101 feet long, 15 feet extreme breadth, and 95 tons displacement. She had a draft of 8 feet 6 inches and made about 10 knots in smooth water. There were quarters of a kind of 7 officers and 12 men, and an additional 9 men slept



The S. S. ***Research*** was the first survey vessel in operation in the Philippines.

on deck. Boat equipment was a 22-1/2-foot whaleboat, a 19-1/2-foot cutter, and two 16-1/2 foot dinghies. Small-boat hydrography was done under sail or under oars. This small vessel, commissioned in October 1901, gave faithful service throughout the islands until sold in 1917.

The Coast and Geodetic Survey steamer *Pathfinder*, at that time the newest and largest survey unit in the States, arrived in Manila in November 1901 direct from a season in Alaska. She continued at work in the islands until scuttled in the waters of Manila Bay, off the Cavite Naval Station, at the beginning of World War II. This vessel began its work on a survey of San Bernardino Strait and its eastern approaches. Afterwards, as it was a large and thoroughly seagoing vessel, its efforts were usually confined to the more exposed sections of the coast.

Plans for an additional vessel for the Insular Government were drawn up in 1903 and the ship was constructed to Bureau design at the Whampoa Dock Company plant in Hong Kong in 1904. The *Fathomer*, too, reached its end in World War II when it was beached near Corregidor.

The Insular Government made two additional vessels available for survey duty in 1905. These ships, the *Romblon* and *Marinduque*, were twin-screw, composite steamers built in Japan for the Philippine Coast Guard only a short time before. Shortage of officers available for duty in the Philippines made necessary a considerable curtailment of field work after World War I, and the *Romblon* was sold in 1920. The *Mariduque* in later years operated almost entirely among the southern islands and in the Sulu Sea; it was decommissioned and sold in 1932.

Annual reports of the Directors in the Philippines during the first decade mentioned hired steam launches in use by various survey parties. They bore such peaceful names as *Amelia, Filipinas, Comillas, Morven, Evening Star*, and *Teresa*.

With five steamers and a number of shore-based parties continually at work the decade between 1905 and 1915 was one of major effort. It was then that the hydrographic and topographic surveys of the more settled central islands were made. The coordinating triangulation of the same area was also completed. In the year 1911, there were 27 American officers, 12 mates and ship engineers, and 11 recorders on duty in the islands. The ships' crews were composed entirely of Filipinos. By the end of 1915 it was even felt in some quarters that the greater part of the archipelago frequented by shipping had been charted with sufficient accuracy for navigational purposes. Actually much work remained to be done.

As all the vessels consumed coal and had limited bunker space, the matter of obtaining a resupply of fuel was always a problem. Imported coal was available in Manila. In later years, a mine was opened at Liguan near Legaspi and coal of fair quality could be loaded there. Another mine operated for some time at Malangai in southern Mindanao but this coal was of somewhat indifferent quality. At times some coal could be secured from government storage at Puerto Princesa in Palawan.

Long runs to obtain fuel were usual. To eliminate this the Survey at one time built a wharf at Coron in the Calamianes island group and coal was stored there while work was in progress in that area. Coal was also delivered by freighter from Japan.

Vessels operating in the Sulu Sea and along the southern Palawan coasts ran to Sandakan in British North Borneo where local coal was obtainable.

Fueling everywhere was always a long, slow process, as coal usually came aboard in baskets slung on a pole between the shoulders of a couple of men. In Sandakan, many Chinese women were employed in carrying coal. There was always much clatter and much shouting, and much dirt.

Fresh water in quantity at dockside was never available at any but the major ports, and ship storage was so limited that boating water from streams was always common practice. If a convenient waterfall could be found a pipe was sometimes laid and the slow process began of filling a whaleboat and towing it out to the ship. More often a hand pump and a hose was the only way of filling the boat.

HYDROGRAPHY

Practically all of the shoal water hydrography was done by means of the hand lead to the sound of the singing cadence of the leadsman calling off the soundings. They are counted in the millions. The ships always navigated with a lookout aloft searching the sea. Coral shoals are often steep-to and of small area but even at considerable depth show well as discolored water when the sun is right. Ship soundings, like those from the boats, were also made with the hand lead or, in deeper water, by vertical wire casts or by the use of pressure tubes. It was not until the 1930's, when the Fathometer came into use, that it became possible to record a continuous profile of the bottom. The ships were not even equipped with a radio before 1920.

TOPOGRAPHIC MAPPING

Topographic mapping of the shoreline was done by means of the planetable. The fringing coral reefs and mangrove-covered shore presented dif-

Planetable surveying in the Philippines

Sounding with the hand lead was the common method of doing hydrography in the Islands.

ficulties as did the rocky headlands overgrown with dense timber. Much of the work was done with the table set up in nearly waist-deep water. Crocodiles sometimes encountered in the swamp-lined streams of the southern islands were ever a source of anxiety. In places, a portable enclosure was set up about the table and the observer, and a rifleman stood by to guard against the danger of attack.

ASTRONOMIC DETERMINATIONS

The determination of the geographic positions of points throughout the islands by means of telegraphic longitudes and zenith telescope latitudes was of first importance. This work was greatly facilitated by the wide extension of the Insular telegraph system for military purposes. It was fortunate that this Coast Survey work was carried out promptly, as many lines were abandoned with the passing of military necessity. In fact, operation of the telegraph system was always somewhat uncertain. An observer reported in 1901 by letter to Manila that it was impossible to work longitudes at that time between Manila and Aparri at the north end of Luzon as "all messages are now repeated six times by hand and the telegraph line cannot be worked for even half the distance."

Despite such hindrance, 39 latitudes and telegraphic differences in longitude were determined by the end of 1906. The points were fairly well distributed over the archipelago from the north coast of Luzon to Zamboanga. They were marked and described for future reference and a meridian laid out or an azimuth measured at each station. The extension of the cable from San Francisco to Manila, by way of Hawaii and Midway, made possible a telegraphic longitude tie with stations at each of those places and completed a circuit around the world.

Additional work and some repeat stations were observed in later years when radio time signals became available. These were in conjunction with the world longitude determinations made in 1926. Gravity observations were also made in Manila at that time.

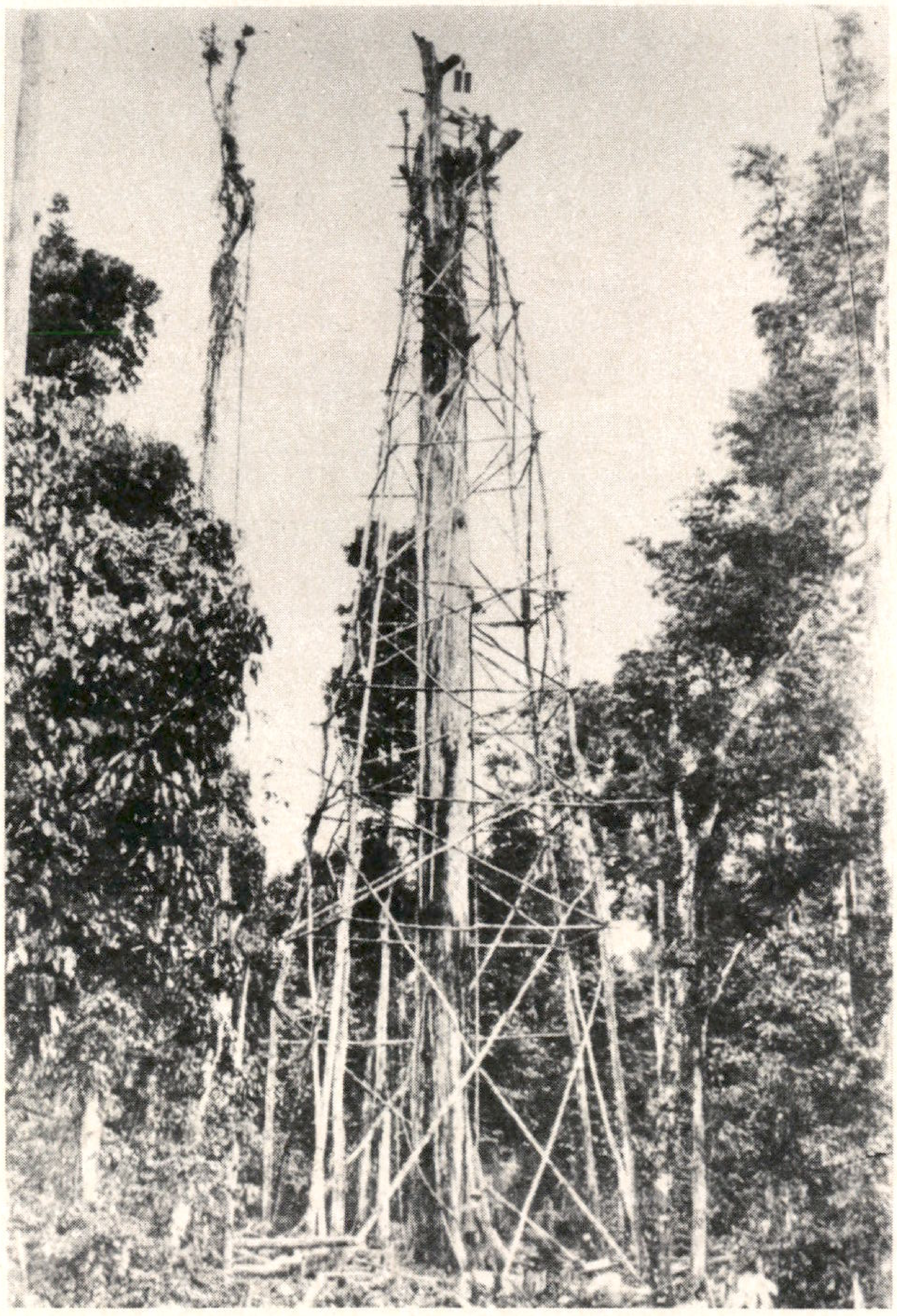
A MEMORABLE ASSIGNMENT

In the absence of more modern surveys, any pertinent information concerning the coasts, sailing routes, and dangers to navigation that might be encountered was invaluable to shipping interests. The Manila office of the Coast Survey always made special effort to gather and supply such data. The nautical expert who was detailed to that office collected much information in a number of cruises to the various ports visited by interisland shipping. He quickly developed a wide acquaintance with ship captains and these seafaring men in turn supplied him with a continuous stream of material which ultimately found its way into the published *Notices to Mariners* and *Sailing Directions*.

Survey operations, as they progressed, also supplied a great wealth of information that could not well be incorporated in the charts, and the *Coast Pilot* grew until there was complete coverage of the archipelago.

After 3 decades there came a very pressing need for a thorough field examination to bring the publication up to date through an actual determination of which parts of the *Pilot* were still correct. New and additional material was also required. This revision was made in 1937, 1938, and 1939--a very opportune time, as the war years found a new two-volume *Pilot* available for use. A running check had also been made of the charts and numerous corrections effected.

This field examination was probably one of the most interesting assignments any one Coast Survey officer ever had. An 80-foot launch was supplied by the Commonwealth Government and a cruise of over 9,000 miles was made throughout the islands. Some 1,600 miles were also covered by automobile. By the time the examination was completed there were only a few portions of the entire shoreline that had not been visited and investigated in detail because of their inaccessibility.



A common practice of erecting a triangulation observing tower was to build it around a tree.

The automobile trip up the Cagayan Valley to Aparri, then westward along the north coast of Luzon and down the west coast of Lingayen Gulf was a venture in itself.

West of Aparri every stream had to be crossed on rafts of bamboo. At one place a carabao hauled the car through a particularly muddy stretch of the road.

Beyond Pamplona it began to rain, and near Pasaleng where the road skirts the mountain side, the officer was informed by a Filipino official that "the bridge is falling down, but if you hurry they will hold it until you get there and you can pass." The little matter of passing meant driving the length of some heavy planks laid to span the partly caved-in mid-section of the bridge. The whole thing collapsed a few minutes later despite all efforts to prop it up.

With darkness, further travel became impossible on the muddy road and in the driving, tropical rain. The night was spent in the car pulled off the highway. Busses, however, driven in the usual carefree native manner, careened wildly by with much shouting several times during the darkness. The government rest house was a really welcome sight when it was reached some hours after daylight.

TRIANGULATING THE ISLANDS

The triangulation operations of the Coast and Geodetic Survey in the Philippine Islands were designed primarily for control of the hydrographic and topographic surveys. In general, triangulation was confined to a relatively narrow strip of land along the coasts, as movement into the interior was quite difficult due to the rough and heavily timbered terrain and the lack of roads and trails. The matter of carrying a general scheme of relatively large figures the full length of the archipelago and from shore to shore across the channels was early decided upon. This coordinating scheme of triangulation was needed to tie all the Philippine mapping together.

A start was made by executing small local networks to control the early detached surveys. In January 1903, the continuous coastal triangulation of northwestern Luzon was started. By the end of 1905, there was a connected scheme all the way to Manila. The overland connection from Lingayen Gulf to Manila, which followed the valley traversed by the railroad, made a good start for the general control of the islands.

By 1913, a connected scheme of triangulation had been extended southward over the intervening water areas to the island of Mindanao, and southwestward to Palawan. This permitted an adjustment upon a uniform datum.

Connection to the south side of Mindanao from Iligan to Illana Bay was held up for some time by the unsubdued Moro tribes in the Lake Lanao region. This work was finally accomplished with the assistance of one company of the 21st Infantry. Difficulty was also experienced by the ship *Pathfinder* in attempting to get triangulation to Baganga on the east coast of Mindanao.

Along the coasts of Mindoro and Tablas, the peaks which had to be used were between 2,000 and 3,000 feet high. Many of them were thickly overgrown with trees and from a half to a day's travel from the shore. It was a real problem to supply the observing parties who often camped from 1 to 2 weeks near the summit.

The extensive triangulation scheme which paralleled the east coast of Palawan in 1917 was a particularly difficult piece of work. The mountain peaks along the backbone of the island are as high as 6,800 feet and each station occupied became an individual journey of exploration. The Palawan country is very wild and covered with heavy undergrowth with no trails or communications whatever. Even the wild hillmen were familiar only with the immediate vicinity in which they lived.

As much as 8 days were required to reach the most difficult stations, and parties were away from the ship as long as 3-1/2 weeks. A party reported that at one place they had "built the longest tunnel in the world." They had cut an actual tube through the jungle from the coast to the station.

It required 9 days of travel from the beach to reach the top of Mount Mantalingajan, westward of Brooks Point. The survey party consisted of an officer and two sailors from the ship ***Romblon*** and 11 Tagbanua natives of the area. Water was scarce, so that after reaching an elevation of 3,000 feet the party had to depend almost entirely on rainwater or on the little water found in pitcher plants. Nights at the top were intensely cold. There was one place where the route, on approaching the final ridge to be ascended, passed through an area covered with scrub hardwood trees so dense that it was practically impossible to cut a trail. When this station was reoccupied in 1930, during the extension of triangulation northward along the west coast of the island, the party cut poles and laid a half-mile long runway 20 feet above ground in the treetops.

Bulanjao Peak to the southward of Mantalingajan and some 3,500 feet in elevation also presented considerable difficulty.

After ascending the Iwahig River to the head of boat travel and using up 3 more days on the trail, the Moros refused to go any further and the party returned to the beach. A new party was formed with one officer and four men from the ship, and four Tagbanuas were induced to accompany the party. The peak was reached in 3-1/2 days.

As the southern end of the Palawan triangulation scheme was approached, taller and taller towers had to be built to get above the trees. The record tower, on Bugsuk Island, was 235 feet high and constructed entirely of poles cut in the forest.

By 1918, the war conditions had so increased the cost of operations that only three vessels continued survey work. A further though temporary curtailment of effort was caused by the influenza epidemic which was so severely felt that at one period the whole company of the *Pathfinder* was incapacitated and eight persons died. On the ***Fathomer*** there was one time when only two men could be mustered on deck. By the end of 1920 and for several years thereafter there was such a serious shortage of officers in the States that resumption of survey work on the islands was impossible on the previous scale.

After the close of World War I, the major effort of the Coast Survey in the Philippines was shifted to the southern islands, but some work was continued along the north and east coasts of Luzon as the seasons permitted.

The triangulation which then began its extension southward through the Sulu Archipelago made final connection with the British work in north Borneo in 1938. This completed a continuous line from the most northern island of Y'Ami as an overland scheme had recently been measured through the Cagayan Valley from the north coast of Luzon to Lingayen Gulf. An extension also ran eastward from this last scheme to a connection with the Luzon coastal triangulation in the vicinity of Palawan Bay.

There was only one place in the Philippines where triangulation was not used for control. This was along the wild south Mindanao coast between Lebak and Sarangani Bay, where a traverse connection was measured along the beach.

Survey work in general was completed everywhere by 1940. The final work off the Borneo coast was ended at the beginning of World War II.

TRAINING PROBLEMS

One of the great problems facing the Survey at its establishment in the islands was that of securing an adequately trained field and office force. Career employees were sent from the States to officer the ships and head the shore parties on definite tour of duty. The difficulty was in enticing persons from the States to duty in subordinate positions in a hot climate so far from home and at the small salaries then prevalent in the Government service.

It was originally hoped that Filipinos could be more completely utilized in the surveying operations than was actually found possible. At the time of the American occupation there were few if any Filipinos with an engineering education. In fact, there was no school in the islands comparable to an American high school. This lack of an engineering education combined with little if any knowledge of English was the great drawback in employing native help. The only recourse was to slowly train a staff of native employees to ultimately replace the civilians brought from the States.

Chart compilation, as an example, requires a high degree of individual technical judgment as well as artistic skill and common sense. Despite early difficulties in securing men with such particular qualifications, there were ten or more Filipino draftsmen working under supervision in the Manila office as early as 1903. The training program for the employees was continued to the point where in later years the office was completely staffed by Filipinos, with the exception of the director--a commissioned officer of the Coast Survey--and his two civilian assistants. A number of men had even been sent to the United States for periods of advanced instruction in the Washington office of the Survey.

Further impetus came to this instruction program with the establishment of the Philippine Commonwealth. Complete severance from any direction in field or office activity was of course contemplated for the day of complete independence. In 1936, a number of Filipino cadets were taken aboard ship to receive specialized training as a nucleus for a future field force. These young officers were the product of the now more mature Philippine educational system and some of them had additional schooling in the United States.

The beginning of World War II found the Coast Survey personnel still engaged in survey work but in an almost entirely advisory capacity. Vessels were captained by Coast and Geodetic Survey officers and there was still a director in Manila. The bombs on Manila which ended all operations also unfortunately ended the life of the director. One officer and the civilian assistant to the director (also an Army reserve officer) were taken at the fall of Bataan and endured Japanese captivity in Korea. Another officer was killed in 1945 in the torpedoing of a Japanese vessel transporting prisoners of war. The officers' wives and the officer succeeding the director in Manila were interned in Santo Tomas until finally freed on recapture of the city.

At the cessation of hostilities there was by good fortune a Coast and Geodetic Survey officer on duty with the Army in Manila. He saw the need for reestablishing the Survey office and was granted permission and assistance in bringing some order out of the chaos. The former employees of the service were readily located but the damage, which included the buildings, vessels and small boats, instruments and equipment, and the reproduction plant, was hard to repair. The records were completely destroyed and much of the information in them was thought lost forever. A thorough search of all possible sources, however, throughout the islands and in the States during these intervening years unearthed as much as 85 percent of the control data. Most of the hydrographic and topographic information was recoverable, as the plotted survey sheets had been reproduced and sent to the States before the war. Only the very recent surveys were lost.

The successor to this reorganizing officer administered the Coast Survey's participation in the Philippine Rehabilitation Program during the years 1947 to 1950. Under the Philippine Rehabilitation Act of 1946, an agreement between the United States and the Republic of the Philippines, the Coast Survey was authorized to continue until June 30, 1950, such survey work as it had conducted prior to December 7, 1941. The particular job of the Bureau was to furnish a commissioned officer as director, to aid in the establishment of a counterpart Philippine organization under their Department of National Defense, and also to train personnel in both the Philippines and in the United States.

Some 50 Filipino trainees were carefully selected from engineering graduates of Philippine Island colleges and sent to the Coast Survey office in Washington for 10 months of intensive instruction in all phases of survey work, including final chart reproduction. These trainees are now the officers of the Philippine survey ships and fill the key administrative and operational positions in the Manila office.

CONCLUSION

What were the positive accomplishments of the United States Coast and Geodetic Survey during the 40 years that it was actively engaged in the Philippines? Surveys were completed of approximately 98 percent of the water and coastal areas. Only a small portion of the west side of Palawan and of the southern Sulu Sea remained unsurveyed. The 136 Spanish charts were replaced by a modern series of 12 general sailing charts and 152 coast and harbor charts. All this was done at an expenditure of approximately $11 million paid jointly by the United States and by the Insular Government. (This, however, does not include the salaries for officers which were paid entirely by the United States Government.) The Republic of the Philippines was left with a trained and organized Bureau of Coast Survey capable of maintaining the legacy left them.

A Century and a Half of Scientific Nautical Charting

A. L. SHALOWITZ

U. S. Coast and Geodetic Survey

(Awarded Second Prize in the Sesquicentennial Essay Contest)

TO A MARITIME NATION such as the United States, the safety of its waterborne commerce is dependent on a full and complete knowledge of the coast, its nature and form, the depths of the water and character of the sea bottom near it, the locations of reefs, shoals, and other dangers to navigation, the rise and fall of the tides, the direction and strength of currents, and the behavior of the earth's magnetism in areas which must be navigated. Such information is furnished by the nautical chart. Without the chart our great ports and harbors would be as effectively closed to maritime commerce as if blockaded by an enemy fleet.

The need for such undertaking was recognized almost from the beginning of our national independence. The young nation was concentrated along the Atlantic coastal plain, fisheries and shipbuilding were important industries, and waterborne commerce between the harbor cities was the medium for the movement and exchange of these and other products. To promote that commerce and to develop trade with foreign nations, President Jefferson, on February 10, 1807, signed into law the Act which set in motion the machinery for surveying and charting the coast and harbors of the United States together with the outlying islands and fishing banks. This was the inception of the Coast Survey, and it is this historic event that we are observing in this year 1957--150 years later.

EARLY PIONEERS

In commemorating this century and a half of charting progress, we cannot fail to take note at the outset of the many men of science and engineering who were associated with the Coast Survey and who, in their respective fields, broadened its horizons--men such as George Davidson, who authored the ***Pacific Coast Pilot*** of 1889, the most complete record of the coast ever to be published for the use of the mariner; Rollin Harris, who pioneered in the field of tidal research and published a voluminous ***Manual of Tides***, in which a new and comprehensive theory of the tides was formulated; Charles Schott, who for 50 years directed all the intricate computations and adjustments of field observations required in the geodetic, magnetic, cartographic, and tidal operations; and John Hayford, whose investigations of the size and shape of the earth resulted in the derivation of a new figure, the International Ellipsoid of Reference. These are only a few in a long roll--a roll of honor in the annals of the Survey. But tribute, in particular, should be paid to two early leaders--Ferdinand Hassler and Alexander Bache--under whose direction the Survey evolved from a mere concept into an organizational entity with a fully developed plan of execution that became easily adaptable to a developing and expanding America. Both bequeathed to the Bureau a heritage of zeal and singleness of purpose that has been an inspiration to those who have followed them.

FERDINAND R. HASSLER

Ferdinand Hassler, may rightly be called the "father of the Coast Survey." It was his plan that President Jefferson accepted for the survey of the coast, and it was he who was later entrusted with its direction. It was fortunate for the country in general, and for the Bureau in particular, that so far-seeing a person as Professor Hassler, with the indomitable will and courage of the pioneer, was chosen to organize and direct the operations of the Survey. Hassler immigrated to the United States in 1805, at the age of 35, after filling a number of the most important official positions in his own land, Switzerland--among them those of head of the Geodetic Survey, Attorney General, and member of the Supreme Court.

Hassler's fundamental plan provided for a division of operations into three great branches--the geodetic, the topographic, and the hydrographic. Of these, he considered the geodetic operation to be the most important, for it affected the accuracy and final value of the other two. Hassler's plan had the approval of the most eminent scientists of Europe and of this country. It is a tribute to his farsightedness and his genius that his original plan of organization, broadened and thoroughly worked out in succeeding years, is still the fundamental directing plan of the Bureau a century and a half after its adoption.

The difficulties that faced Hassler would have

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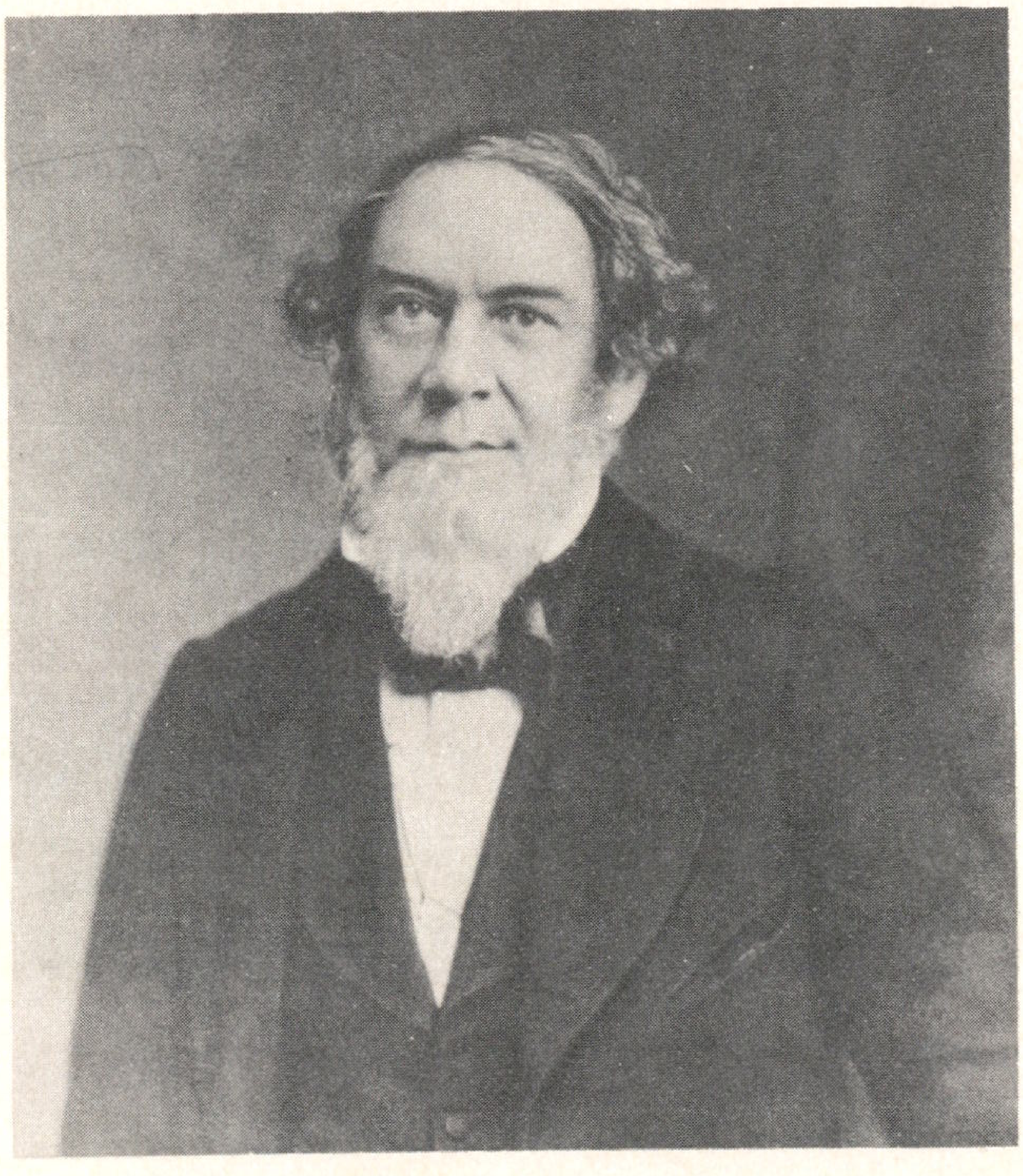
completely discouraged one of less strength and fortitude. Instruments such as those necessary for a geodetic survey were not available in this country at the beginning of the 19th century. Hassler had to prepare his own drawings and designs, and some of the more important ones, such as theodolites and chronometers, that were eventually constructed for him bear the impress of his inventive genius in the shape of modifications and improvements that he devised. It is an interesting fact that not a single working observatory for the training of astronomers existed in this country at that time, and there was not a single college that included a course in geodetic surveying in its curriculum.

Although the need for results was urgent, the level-headed Hassler fortunately did not allow himself to be stampeded into haphazard decisions. Instead, he approached the great task scientifically and never deviated from the high standards he set for the work. He knew that the survey of the coast, if it were to have a lasting value, could not be attacked as a problem of ordinary surveying. The operations were to be bound together by a trigonometric survey with long lines, and executed by the most accurate instruments and the most refined methods. The best of foundations was thus laid for the geodetic operations of the Bureau. This was Hassler's great contribution. Had he planned to meet only the needs of his time, he would have effected but a negligible saving, and his work would have had to be done over at greater expense in later years. Instead, the first Hassler surveys meet modern requirements and, today, form part of the permanent primary network of the country.



Alexander Dallas Bache, under whose superintendency the nautical chart was given considerable impetus.

ALEXANDER DALLAS BACHE

When Hassler died in 1843, the foundation for the survey of the coast had been laid, and the detailed surveys of the ports and harbors were begun with a survey of the approaches to New York Harbor. The building of the superstructure fell to his successor in office, Alexander Dallas Bache. Bache was the great-grandson of Benjamin Franklin and a grandson of Alexander Dallas, Secretary of the Treasury under President Madison.

During his lifetime, Bache held many responsible posts, any one of which might have been considered the successful culmination of a life's work and ambition. His rise to positions of prominence in the fields of education and science was meteoric. As a West Point cadet he distinguished himself by his scholastic excellence, graduating at the head of his class at the age of 19. At 22 he was named to the faculty of the University of Pennsylvania as professor of natural philosophy and chemistry. In addition to his 8 years at the university, his service to American education included the presidency of two of our foremost schools--Girard College and the Central High School of Philadelphia; the general superintendency of a city school system; and the publication of a monumental work on European education, the result of 2 years of intensive study abroad.

Bache attained preeminence while serving as head of the Coast Survey. His selection to this important scientific and technical post had the concurrence of all the principal scientific and literary institutions of the country. It was said that no such weight of recommendation was ever brought at any time, in support of a candidate for office on purely intellectual grounds.

In original concept, the plan for the Survey of the Coast was Hassler's, but Bache gave it form and direction. Hassler built on a rigid scientific foundation; Bache adapted that plan to an expanding America. (Texas, California, Oregon, and Washington were added during his tenure.) His determination that the maps and charts of the Coast Survey should be carried to every man's door having an interest in commerce, navigation, geography, or science, was an indication of his broad vision of the scope and purpose of the Survey. Under Bache's careful guidance and sympathetic understanding, the Coast Survey not only kept pace with the progress in art and science but many notable and original contributions were made in the fields of practical astronomy, physical hydrography, and cartography.

THE MODERN NAUTICAL CHART--END PRODUCT OF SYSTEMATIC SURVEYS

In assessing the contributions of the Coast Survey to the development of nautical charting, cognizance must be taken of the fact that what had previously been called a chart was largely the result of exploration or of limited surveys, and was generally the work of individual effort and private undertaking. The Portolanos of the 14th century, the Cosa chart of 1500, and the Atlantic Neptune charts of the late 18th century are all examples of this exploratory period. These, like all the early charts, suffered from two great defects--the want of detailed surveys and the lack of a rigid system of connection between the various ports.

Not until the early part of the 19th century did governments begin to recognize the wisdom of systematically charting their coastal waters as a necessary prelude to their commercial intercourse with other nations. This marked a new era in chart making and was the beginning of the accurate chart of today.

The modern nautical chart is the end product of all the field operations. Into its construction enter the results of the geodetic, topographic, hydrographic, tidal, and magnetic work of the Bureau. Progressive improvement in the nautical chart is, in the main, coextensive with the development of systematic surveying and of surveying techniques, including instrumentation and equipment. A consideration of these components is therefore essential in any evaluation of the nautical chart proper.

A GEODETIC BASE FOR CHARTING

That good and reliable charts can be made only from correct surveys is a truism that need not be belabored to the engineer and the scientist. No one appreciated this more than Hassler. From the very beginning he insisted on a strong triangulation as the backbone for all the harbor and coastal surveys, but the need for this was not so obvious to others, and, as a result, Hassler was subjected to much humiliating criticism. His scientific approach, nevertheless, prevailed, and the tradition of accuracy which he inaugurated has been steadfastly maintained through a century and a half of progressively increased activity.

Triangulation is to the nautical chart what the steel framework is to a building--it gives it rigidity and knits together all portions into a harmonious whole. Without this framework of control, our charts would be subject to the same deficiency that characterized the charts of the Colonial period and exemplified by the Atlantic Neptune of Des Barres.

The nautical chart is the end-product of all the field operations of the Survey. This shows the many records that go into the making of a single chart.

If a survey, or group of surveys, on which a chart is based, were to be positioned with respect to the astronomic latitude and longitude of an initial point, it would soon be found that discrepancies exist in the overlapping portions of adjacent charts, and scaled distances between points spanning two charts would not be true, nor would the geographic relationships be correct. Because of the varying density of the earth's crust and its effect on the plumb line, such results are inevitable if surveys are based solely on astronomic determinations.

In any engineering or scientific undertaking involving a large area, it is important that full coordination and correlation exist in the surveys, maps, and charts of the country. A hydrographic or topographic feature on the earth can have but one latitude and longitude, and it must be the same on every map or chart on which such feature appears. This can be accomplished only through the adoption of a single geodetic datum for the entire area; that is, by taking the position of a single point in the country as the initial or datum to which all other stations are referred. In the United States, this initial is station *Meades Ranch* in central Kansas. Its latitude and longitude on the spheroid of reference were fixed by mathematical adjustment based on a study of numerous astronomic stations throughout the country that had been connected by a continuous system of triangulation. Today, the whole of the United States, through Canada and Alaska to the Bering Strait, is coordinated on this single geodetic datum--the North American datum of 1927. The establishment of this datum has resulted in the complete coordination between nautical charts of the Atlantic and Gulf coasts and those of the Pacific coast and Alaska--a most enviable position for any country to be in.

Recently, the distant, offshore islands in the Bering Sea were connected for the first time with the triangulation network on the mainland of Alaska by a system of trilateration, in which the sides of the triangles were measured by electronic methods, the longest line being 501 statute miles. The successful completion of this project furnishes a control net for hydrographic surveys from which accurate charting of this vast, strategic area can proceed with minimum danger to men and ships.

THE ADVENT OF PHOTOGRAMMETRY

An important feature of the nautical chart is the land area, with its characteristic shore forms, landmarks, elevations, and depressions. In close, inshore navigation, a mariner relies a great deal on prominent shore objects to fix his position and sometimes even uses the configuration of the shoreline for identification.

From the beginning, the principal instrument used in the Coast Survey for topographic surveying was the planetable. The introduction of the telemeter rod, about 1865, for measuring distances with the alidade, greatly facilitated the surveying of complex shorelines and gave the chart increased fidelity. With proper precautions, a remarkable degree of accuracy is obtainable by this method of surveying.

The years preceding and following World War II saw the emergence and flowering of the new science of aerial photogrammetry--the greatest advance in topographic mapping since the prototype of the modern planetable was developed by Johann Praetorius, in 1590. Ground topographic methods are rapidly giving way to this more economical and more expeditious method of mapping from the air. The wealth of information and fullness of detail embraced in an aerial photographic survey cannot be matched by any other practicable method of surveying.

The design of a nine-lens camera by the Coast Survey--together with transforming, rectifying, and stereoplotting equipment--gave considerable impetus to our topographic survey work in Alaska, where difficult and inaccessible terrain could be bridged by this camera with a minimum of ground control.

Recently, a low-distortion, wide-angle, single-lens precision aerial mapping camera, which uses an infrared lens cone, was acquired. The use of infrared photography for mapping the high- and low-water lines will result in greater charting accuracy of these tide lines, particularly in areas that are difficult of access for identification of shoreline. Techniques are being studied for use of this type of photography, in conjunction with tide observations, for charting riparian boundary lines based on tidal definition.

The advent of photogrammetry in the Coast Survey has had two salutary effects on the nautical chart: (1) It has further increased the accuracy of the chart, particularly in inaccessible areas; and (2) it has brought within practicable scope the immediate revision of areas where natural or man-made changes have occurred--an important factor in safeguarding our sealanes.

HYDROGRAPHIC ADVANCES

From the standpoint of the nautical chart, the greatest advances made, since the early days of charting, have been in the field of hydrographic surveying. The chart can be likened to a map of the water area on which elevations above the bottom (depth soundings) are shown. Hydrography is thus the principal visible characteristic of the chart. By it the navigator is guided into the safe lanes and can avoid the known dangers.

Hydrographic surveying for charting purposes consists essentially of two simultaneous but independent operations: the measurement of depth and the determination of the survey vessel's position at the time the depth is obtained. The revolutionary advances made in this field during the past three decades have had a profound effect on the accuracy and usefulness of the nautical chart. Depth measurement by sound--better known as echo sounding--has superseded the hand lead and the wire machine, and electronics has replaced all previous, less accurate methods of position determination.

Echo sounding is based on the principle that a sound impulse sent out by the survey vessel will be reflected from the ocean bottom and will return to the vessel as an echo, just as echoes are received in air from distant objects. From the elapsed time interval and a knowledge of the velocity of sound in sea water, the depth can be determined. Echo-sounding equipment is designed to produce the sound, receive the echoes, measure the elapsed time intervals and convert them into depths, and register the depths on a dial or in the form of a graphic profile. The Coast Survey developed a precision, dial-type echo instrument (the Dorsey No. 3), which had a probable reading accuracy of 1/10 foot for soundings up to 100 fathoms.

Methods of positioning the sounding vessel in latitude and longitude, and, in turn, the soundings, have undergone more radical changes during the life span of the Coast Survey than perhaps any other activity. The early hydrographers, who operated close inshore, located their positions by sextant angles on shore objects. When out of sight of land, observations were made on the heavenly bodies, or "dead reckoning" was used. Although refinements were made in the latter methods, their application to hydrographic surveying still left much to be desired, and an accurately coordinated offshore survey was the exception rather than the rule. The first major change occurred in the late 1920's with the development, in the Coast Survey, of Radio Acoustic Ranging (RAR) for measuring horizontal distances over the water by means of underwater sound transmission. This was, in reality, an adaptation of echo sounding in which the horizontal path of the sound wave was used to measure the distances from the survey vessel to two or more known stations on shore or in the water.

While RAR is no longer in use, having been superseded by later developments in position determination, it is noted here because of its influence on the nautical chart. Together with echo sounding, it gave us a new conception of accuracy, as applied to offshore hydrographic surveys, and laid the foundation for the development of a new type of nautical chart.

World War II ushered in the electronic era. It is well known that electronics played an important role in the prosecution of the war. Shoran, a form of radar, was developed for strategic aerial bombing. The Coast Survey was first to adapt this technique to the accurate location of a survey ship's position.

Shoran is based on the principle that electromagnetic waves travel through the atmosphere at a nearly constant rate of speed--186,000 miles per second. In the familiar radar, dependence is placed on the reflection of such waves from natural objects. In shoran, this reflection is strengthened and specialized by use of responding stations set up at known points which return intensified signals.

Shoran constitutes no new principle in hydrographic surveying, but it does apply a new and more effective technique for determining distances from control points. Shoran does the job quickly, accurately, and independent of adverse weather conditions. Being a line-of-sight system, it is limited, under practical operating conditions, to distances of 50 to 75 miles with a probable error of 8 meters in a single measurement.

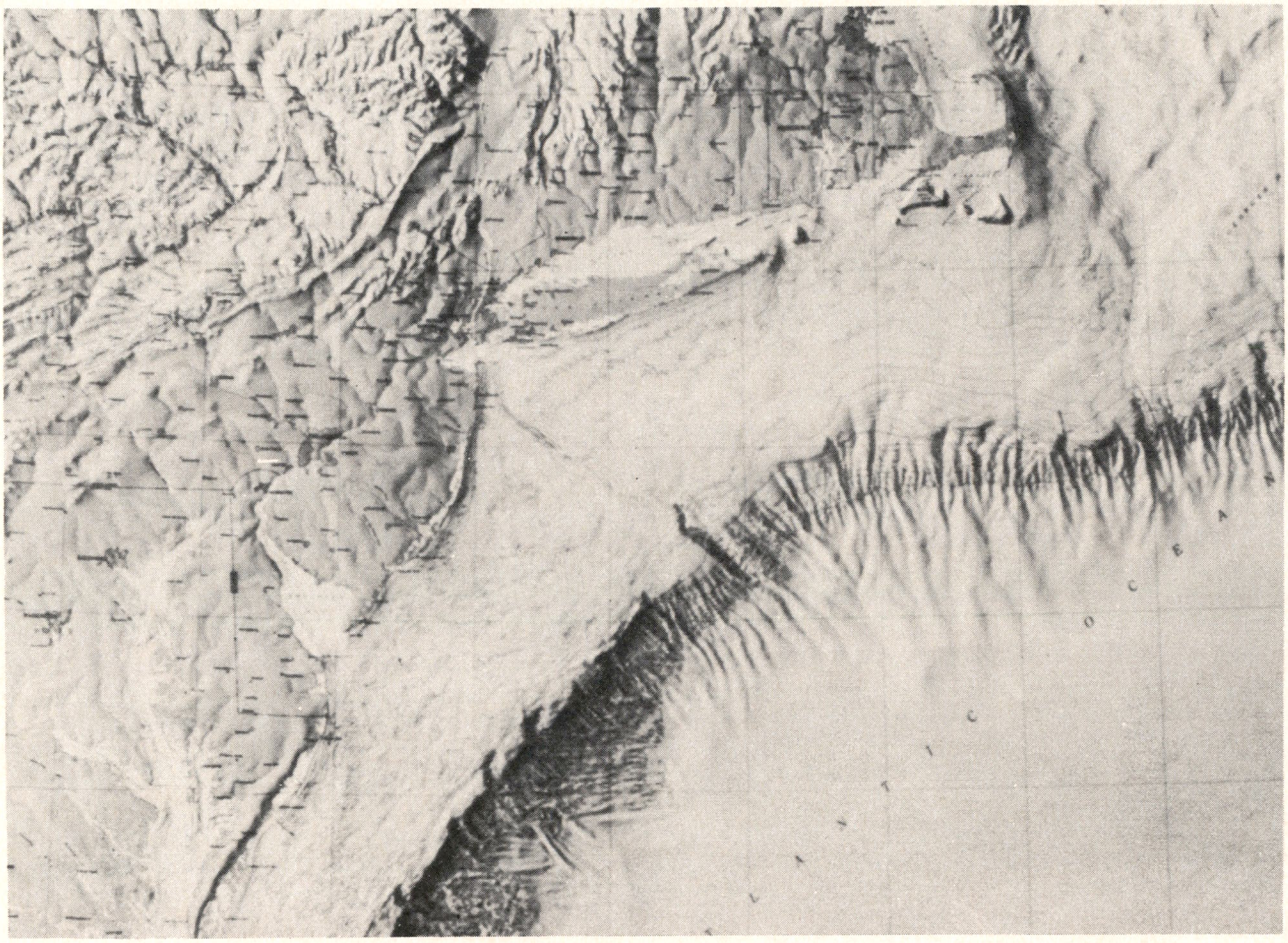
To extend the operating limits of shoran, a new electronic device, called the Electronic Position Indicator (EPI), was developed by the Coast and Geodetic Survey. This system combines the long-range characteristics of loran with the distance-measuring features of shoran and thus makes possible the measurement of distances in excess of 300 miles. EPI operates in the low-frequency range of about 2 megacycles per second and utilizes the ground wave, so that its distance range does not depend upon the elevation of the control stations. The principles of position fixing with EPI are essentially the same as with shoran; both involve the measurement of small time intervals of the order of one ten-millionth of a second. The overall accuracy of the system is about 75 meters and is independent of distance from the control stations. The maximum distance offshore to which EPI has thus far been carried is 550 statute miles.

The acoustic and electronic methods have steadily pushed seaward the frontiers of accurate hydrographic surveys. They have made feasible the exploration of the intricate patterns of our continental shelves and slopes with an accuracy and completeness undreamed of by the early methods, and thus have added to the safety of life and property at sea. The rapidity with which great depths can be measured by echo sounding (a matter of seconds compared to the hour or more required by the older method) has made it possible to take thousands of soundings in areas where formerly only a few scattered ones were economically feasible. This has increased immensely our sum total of geographic knowledge. And it is a gratifying circumstance that nearly all the Bureau personnel who have had a part in this revolutionary change-over are still alive today.

SCIENTIFIC CHART MAKING

What has been the impact of these developments in surveying techniques on the navigational chart? Mention has already been made of the lack of coordination that characterized the charts of the Colonial period. The first chart published under the auspices of the Coast Survey was in striking contrast to anything that had previously been called a chart of our coast. The outstanding improvements were high accuracy of geographic position, more thorough hydrography, and complete topography.

With each accession of new data, resulting from surveying developments, the nautical chart improved in accuracy standards and in coverage. But the chart also developed in its own right, cartographically. Since publication of the early



Submarine topography of continental shelf and slope along northeast coast of the United States.

charts, there has been a progression of improvements both in the character of the chart and in the methods of reproduction--all designed to enhance its value to the navigator.

CHART COMPILATION

Chart making is a combination of the work of the cartographer, who prepares the engineering drawing, and the engraver or lithographic artist, who translates the drawing into a finished product for reproduction. The nautical chart, unlike many other cartographic efforts, is intended for serious use in the solution of navigational problems; hence, all the rules of engineering must be meticulously observed in its preparation.

Chart compilation is a process of selection. The usefulness and accuracy of the chart depend not only on the material entering into its construction but also on the critical appraisal of such material and the intelligence with which the essentials are portrayed. "Easy reading is hard writing" may well apply to nautical charts. The skilled cartographer must sift, from the mass of data before him, the important from the unimportant, the strong from the weak, the stable from the changeable. Some data he rejects entirely, some in part, and he coordinates and selects from the rest the information that is to appear on the finished chart.

In addition to these engineering elements, the chart compiler must be ever conscious of the importance of artistry in the chart. There must be no crowding of matter to confuse the navigator, and there must be no haphazard arrangement to throw the chart off balance. It is just as important to make proper and effective use of various forms of graphic presentation in the chart as it is to study the values of different methods of verbal or written presentation.

A NEW TYPE OF NAUTICAL CHART

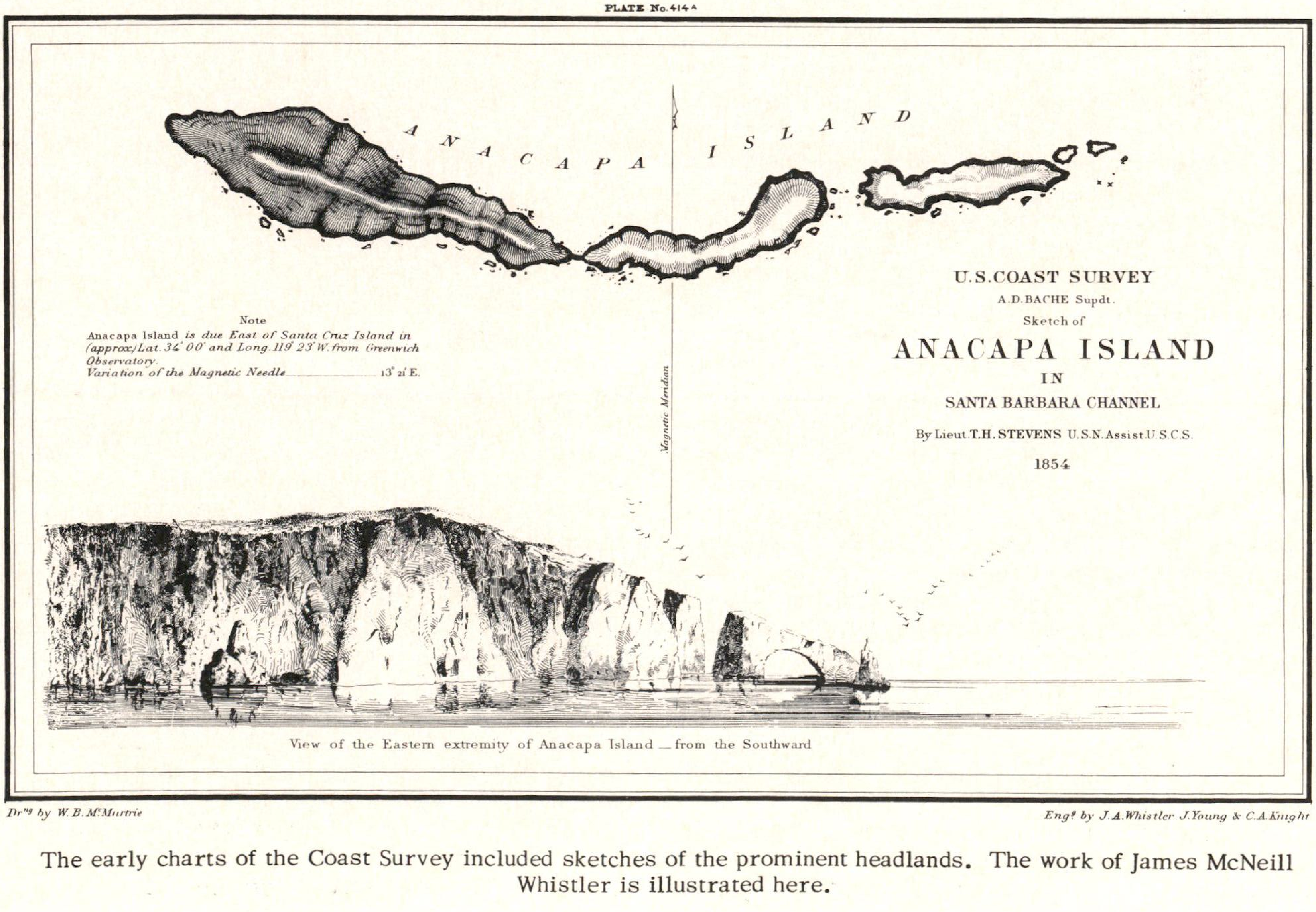
The most significant advance in nautical chart design--since the introduction of colors--was made in March 1939, when the Coast Survey published the first chart in which special emphasis was given to depth contours. The installation of echo-sounding apparatus on our naval and merchant vessels signaled the need for a new type of chart—one that would enable the navigator to utilize fully this new sounding technique for fixing his position at sea. It is axiomatic that the more faithfully the chart portrays the submarine relief, the greater will be its usefulness to the navigator. The answer was not found in an increase in the number of soundings charted; this was already a characteristic of the conventional chart. What was called for was a method that would utilize the wealth of submarine detail provided by modern hydrographic surveys, and that would portray this detail in a simple and useable manner. The new chart was the result.

In this chart, depth contours, which are equivalent to land contours on a topographic map, are given special emphasis. In the drawing of the contours, full use is made of all the soundings obtained on the hydrographic survey. Characteristic features of the ocean bottom are brought into prominence. These features are comparable to permanent landmarks and provide the navigator with a simple method for identifying his position by comparing a line of echo soundings with the charted depth contours.

Another significant innovation in nautical charting took place after World War II, when the United States Coast Guard established loran stations along our coasts as an aid to navigation. Lines of position in this electronic system are families of hyperbolic curves that do not lend themselves to ready plotting by the navigator, as is the case with a circular system such as shoran. To facilitate the navigator's use of this new aid, the Coast Survey, after experimenting with several methods of applying loran information to the charts, has evolved a form that combines the hydrographic information with the loran information without confusion and in a manner that makes the chart of maximum use to the navigator. Loran charts now include coverage of the Atlantic, Gulf, and Pacific coasts.

THE REPRODUCTION PROCESS

On the reproduction side, we have indeed traveled far from the early days of copper engraving and plate printing. Charts of this period were entirely engraved by hand--every line, every figure, and every letter. Many were artistic masterpieces. The fineness of detail that was made possible by this method of reproduction af-



The early charts of the Coast Survey included sketches of the prominent headlands. The work of James McNeill Whistler is illustrated here.

forded the engraver an opportunity for artistic expression seldom equaled by any other method. These early charts were all black and white reproductions. Many were embellished with elaborate views of harbor entrances and headlands for the guidance of the mariner. One of the finest of these was the view of Anacapa Island, off the southern California coast. This was engraved by James McNeill Whistler, who later achieved world renown as an artist. Whistler's stay in the Coast Survey was brief but hectic. The rules of the office he soon found too exacting for his artistic temperament, and he became an habitual late-comer. When chided about it in later years, his biographer tells us, he invariably replied: "It was not that I arrived too late in the morning, but the office opened up too early."

Photolithography paved the way for the introduction of colors and offset printing. Each rotary lithographic press in the Coast Survey today is capable of printing 3 to 5 thousand impressions an hour, as compared with the 100-a-day maximum that was possible with the older method of printing directly from engraved copper plates.

NEGATIVE ENGRAVING (SCRIBING)

The greatest single contribution the Survey has made in the reproduction process has been the development of negative engraving (now commonly referred to as "scribing"), around the turn of the century. This technique was first used as a more economical means of revising nautical charts. Revisions were applied directly to the wet-plate glass negatives using the conventional engraving needles then in use. Later, entire nautical charts were reproduced by this method. The compilation manuscript was photographed on glass negatives. These were then coated with an emulsion that was pervious to light and so afforded the engraver a facsimile of the manuscript. In 1935, the first engraving tool for specific use on glass negatives was designed. A special assignment for reproducing maps for the Tennessee Valley Authority gave impetus to the design of additional tools, and by 1940 all the basic instruments and techniques in universal use today had been perfected in the Bureau. Both glass and plastic are now used for negative engraving.

In the Coast Survey, the direction is toward complete conversion from drafting to scribing of final copy, in both the chart production and reproduction stages, so as to realize all of the inherent quality and economy of the technique.

AIDS FOR SAFE NAVIGATION

The modern nautical chart is thus a synthesis of the utilitarian and the artistic, suitable for meeting present-day demands for quantity and quality reproduction. It is a scientific achievement, the evolution of which has kept pace with the economic development of the Nation and with the progress in science and engineering.

It is of interest to examine the latest Coast Survey chart of the approaches to New York Harbor (Fig. 1) and note the variety of data which the navigator has available to fix his position as he enters or leaves the metropolis. (Tints and colors--not shown in the illustration--to accentuate the land topography, shoal-water areas, depth contours, etc., provide him with additional cartographic aids.)

At *A*, he has a range for a line of position through Ambrose Channel.

At *B*, he has a danger warning and channel marker--buoy with radar reflector by day, and light of fixed characteristics by night.

At *C*, he has radio beacons on the lightships and on shore for obtaining bearings by radio compass from the vessel.

At *D*, he has the height and visibility of lights for determining position.

At *E*, he has landmarks for taking angles and bearings--structures and natural objects by day and lights by night.

At *F*, he has depth contours for use with an echo sounder.

At *G*, he has Loran lines of position for use with his Loran receiver by day or night.

At *H*, he has isogonic lines (lines of equal magnetic declination) to be applied to his magnetic compass.

One rightly wonders how the ancient mariner, without any of the modern navigational aids and contrivances, ever managed to reach his destination. Perhaps the answer is that very often he didn't!

THE FUTURE

Thus, the work which Thomas Jefferson launched a century and a half ago, when our coastline was confined to the Atlantic seaboard and to a small stretch along the Gulf of Mexico, has been patterned through the years to a developing and expanding America. The cession of Florida and the Pacific coast states, the annexation of Texas and the Hawaiian Islands, the purchase of Alaska, and the stewardship over the Philippines, all added to the charting responsibilities of the Bureau.

The Coast Survey views with gratification and pride the contributions it has made to the overall program of surveying and charting our coastal regions. But its mission is not yet ended, nor will it ever be, as long as changes wrought by man and nature leave their impact on our shores. Change and not stability is the order of nature. This finds significant expression along the seacoast and the littoral. Breakwaters and jetties are built, channels and harbors are dredged, and new paths of commerce are opened. Rivers

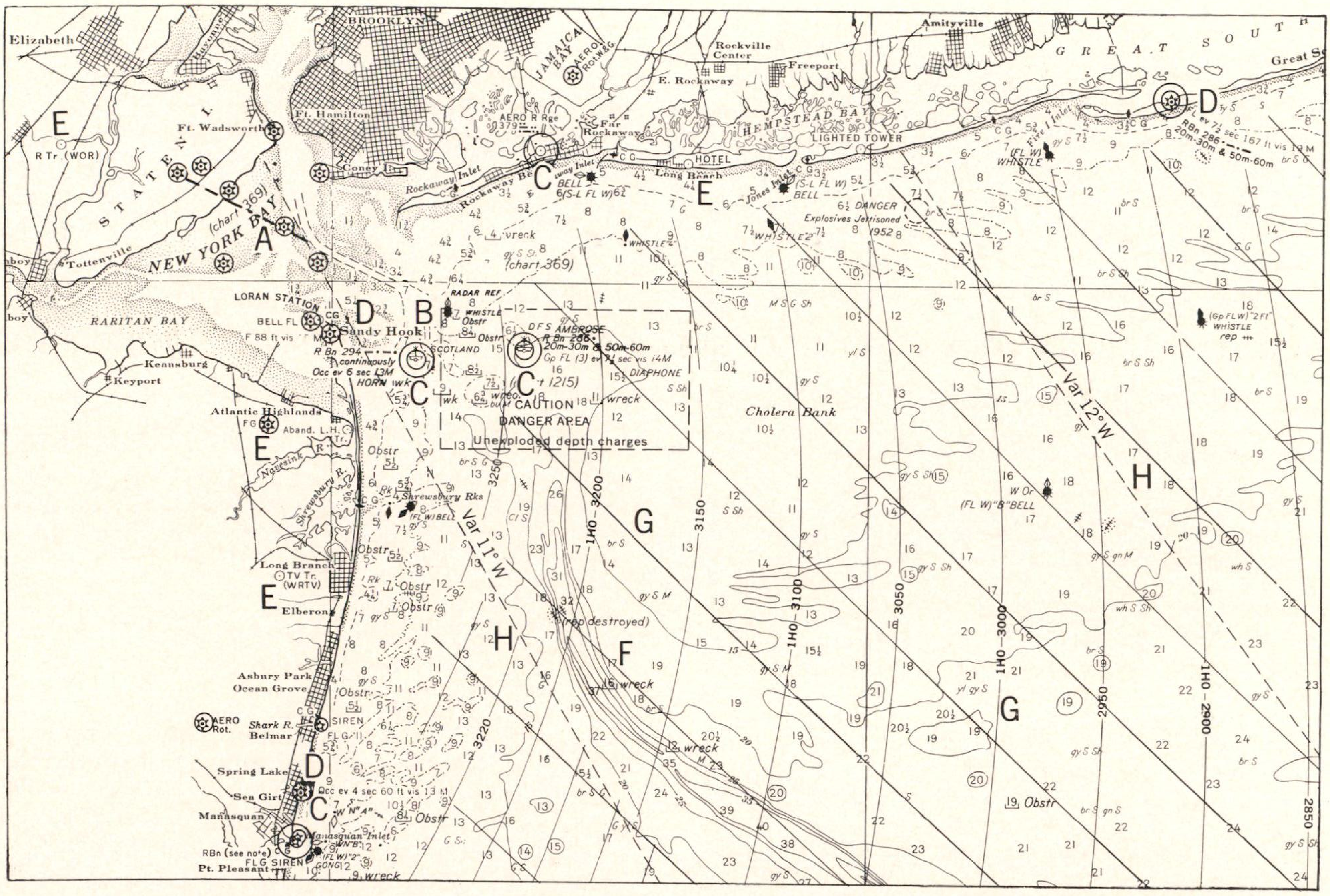


FIG. 1.—Section of Chart 1108 (reduced) showing aids to navigation available to the navigator in leaving or approaching New York Harbor. Tints are used to accentuate the land area and the shoal-water areas.

empty vast quantities of sediment near their mouths to build out the coastline and change the underwater configurations. The safety of navigation depends on an accurate representation of all these changes on the published nautical chart

Offshore, there are large areas, sparsely or inadequately surveyed, that require resurveys to insure the safety of submarine operations and to meet the exacting requirements of modern surface craft. As a byproduct, these surveys of the continental shelves will increase in importance as technology advances and makes practicable the recovery of resources the shelves are known to contain.

In Alaska, much surveying and charting remain to be done in support of the strategic defense of the Territory and in anticipation of increased commercial activity there.

As for the chart proper, it is fair to assume that its design has been stabilized, although not necessarily permanently fixed. Changes that do occur will be more in the techniques of compilation and reproduction, rather than in the character of the finished chart. "Navigation with safety and assurance" has been the guiding principle of the Coast Survey in its program of nautical charting. This will continue to be its motto in the days ahead, and it will fashion its charts to the needs of maritime interests.

We who are privileged to look back upon the first century and a half of the Bureau's existence are justly proud of the record that has been written in its promotion of commerce, industry, and the national defense. Those who will have the task of carrying forward this work will derive inspiration from the great heritage of public service that has been bequeathed to them.

LIGHTERING STEEL TOWER MEMBERS ASHORE REQUIRED MANY TRIPS

Louisiana Coast and Offshore Triangulation

COMMANDER ROSS A. GILMORE

U. S. Coast and Geodetic Survey

FOR THE MOST PART, the Louisiana coast consists of flat marsh of only a few feet in elevation, and in some places only a matter of inches. The eastern three-quarters of the very irregular shoreline is broken up by numerous islands, shallow bays, and inlets backed by a myriad of bayous and miscellaneous waterways. For years, due to its inaccessibility and general undesirable nature, the area was mostly used only by fishermen and trappers who traveled about in pirogues or other shallow-draft boats. Several places such as Grand Isle, just west of the Mississippi Delta, and Cameron, near Lake Calcasieu, are of sufficient elevation to warrant occupation. But on the whole, except for a few so-called islands, most of the area adjoining the coastline for a width of about 25 miles lay practically dormant until quite recently.

Since the closing days of World War II, the tidal waters and marshes of Louisiana--and more recently the adjacent offshore areas--have become a beehive of industry due to the ever increasing search for oil, gas, and sulphur. This has resulted in a need for geodetic control in this area. It soon became apparent that much of the former control no longer existed. This situation became increasingly serious to the various geophysical and oil companies when they undertook offshore exploration and oil well location work, particularly when their operations began reaching farther and farther offshore from very meager initial control.

The last major triangulation surveys by the Coast and Geodetic Survey along the Louisiana coast were made in 1927 and 1933. Since then, due to storms and other causes, many of the monumented stations have been lost. This has been true in particular of the seaward side of the coastal schemes, where storm and tide action caused changes in shoreline.

The loss of such horizontal control is not generally considered too serious until new hydrographic or other mapping work is undertaken, or until some area becomes commercially important from a development standpoint. Then, the need for control is keenly felt. This was the case along the Louisiana coast during the last few years.

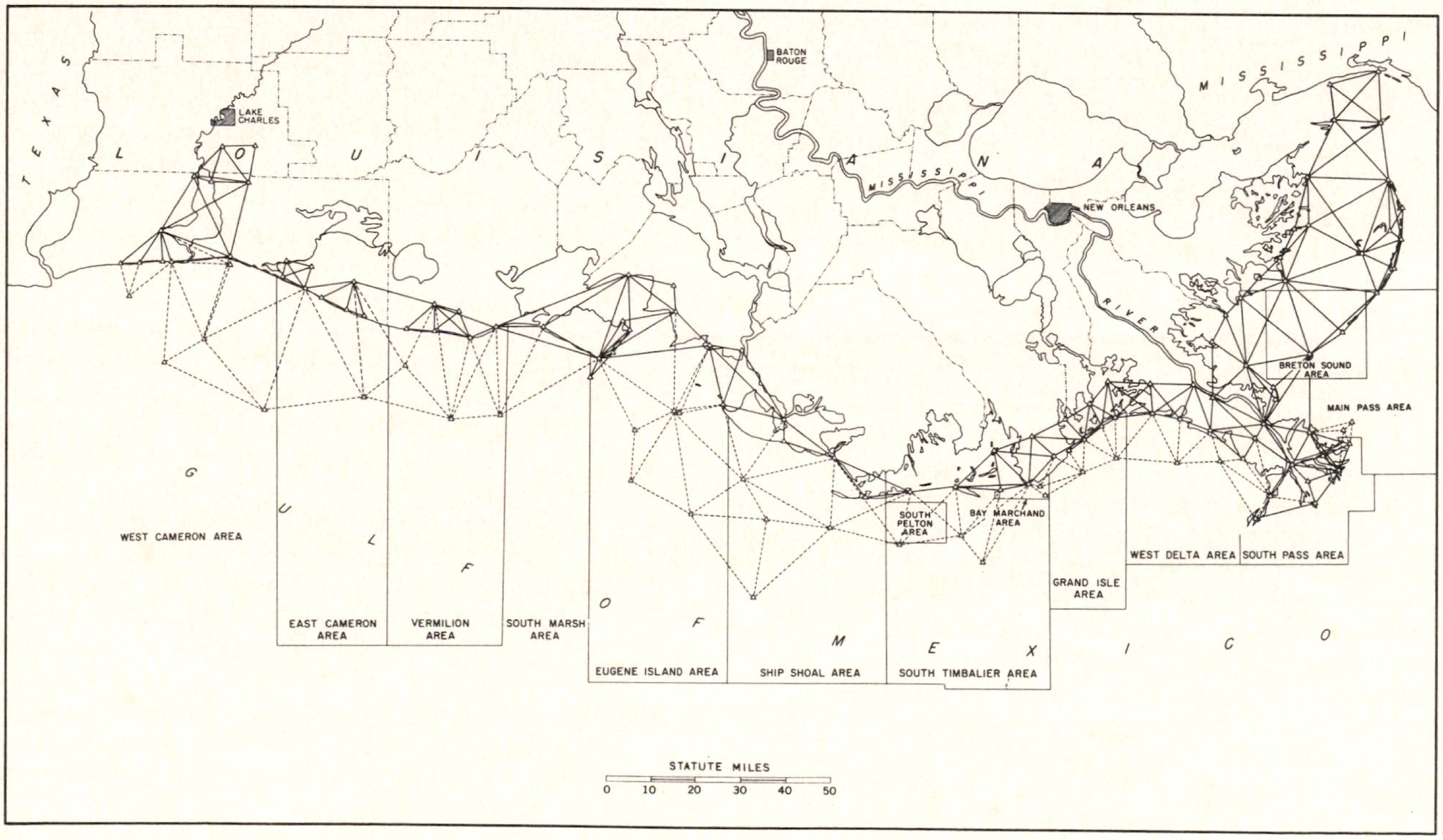
THE PROJECT

The establishment of a new arc of triangulation along the Louisiana coast was of considerable interest to the oil companies operating there, as the precise locations of their wells were tied up with the leasing rights and royalties and represented investments running into the millions of dollars. It was because of this that representatives of 15 of the larger oil companies--organized into an Engineering Subcommittee of the Offshore Operators Committee--approached the Coast and Geodetic Survey in 1954 for cooperation in establishing the necessary control along the coast and to tie in to the triangulation scheme the offshore platforms (called Texas towers) so that they could be used by the companies in the future to carry control farther offshore. The work was done on a partially reimbursable basis. In addition, the companies were to assist the survey parties by furnishing water transportation to the offshore stations and any other services applicable to that phase of the work.

Two reconnaissance and two triangulation parties, supplemented by two 2-man photogrammetric parties, were assigned to the work--a total of approximately 67 officers and men. A unit of each of the foregoing parties began simultaneously at the east and west boundaries of the State and worked to a common junction in Atchafalaya Bay. Work began early in February 1955 and was completed in 5 months. The necessary alongshore control was reestablished and all specified permanent offshore platforms were located, plus a few additional ones. In addition to a considerable number of intersection stations, several secondary points for use in photogrammetric mapping were established. A total of 134 marked triangulation stations were built and occupied. Of these, 97 were new stations--established to replace lost ones or entirely new stations strategically located to provide better control coverage. Of the latter, 30 stations were established on offshore platforms, or similar installations. One hundred and three intersection stations were located--radio towers, stacks, tanks, permanent navigation lights, etc. These intersection stations are of inestimable value to the engineer for azimuth purposes, for obtaining 3-point fixes, or for air-photo mapping.

Observations along the main scheme were held to second-order specifications. Supplemental stations for photogrammetric purposes and intersection stations were of third-order. Most observing was done with Wild T-3 and T-2 theodolites. Wooden stands 4 to 24 feet and steel observing towers up to 126 feet in height were used. Lines in some instances were as much as 32 miles long. On the western half of the project where the offshore platforms to be located were at considerable distance from shore, Bilby towers as high as 90 feet were erected on the platforms, which in themselves were 30 to 50 feet above the water surface. The longest land-to-platform line was approximately 28-1/2 statute miles.

Considerable difficulty was experienced in observing these long over-water lines due to haze and spindrift, as even with the elevation obtained by the use of towers, the water clearance of the longer lines at mid-point was generally only 10 to 15 feet. It was noted that as long as the over-water lines were less than 10 to 12 miles, not too much difficulty was experienced in observing on most nights; however, once the lines became longer than 12 miles, considerable delay occurred in getting the lines through. In order to do so, it took a complete change of weather in which the wind, due to a general meteorological disturbance, had shifted to the northwest for at least 24 hours from its usual southerly direction. Then, the atmosphere cleared and the prevailing offlying haze was either dispersed or driven farther offshore. This condition would last for about 48 hours and the trick was to be on station at the proper time.

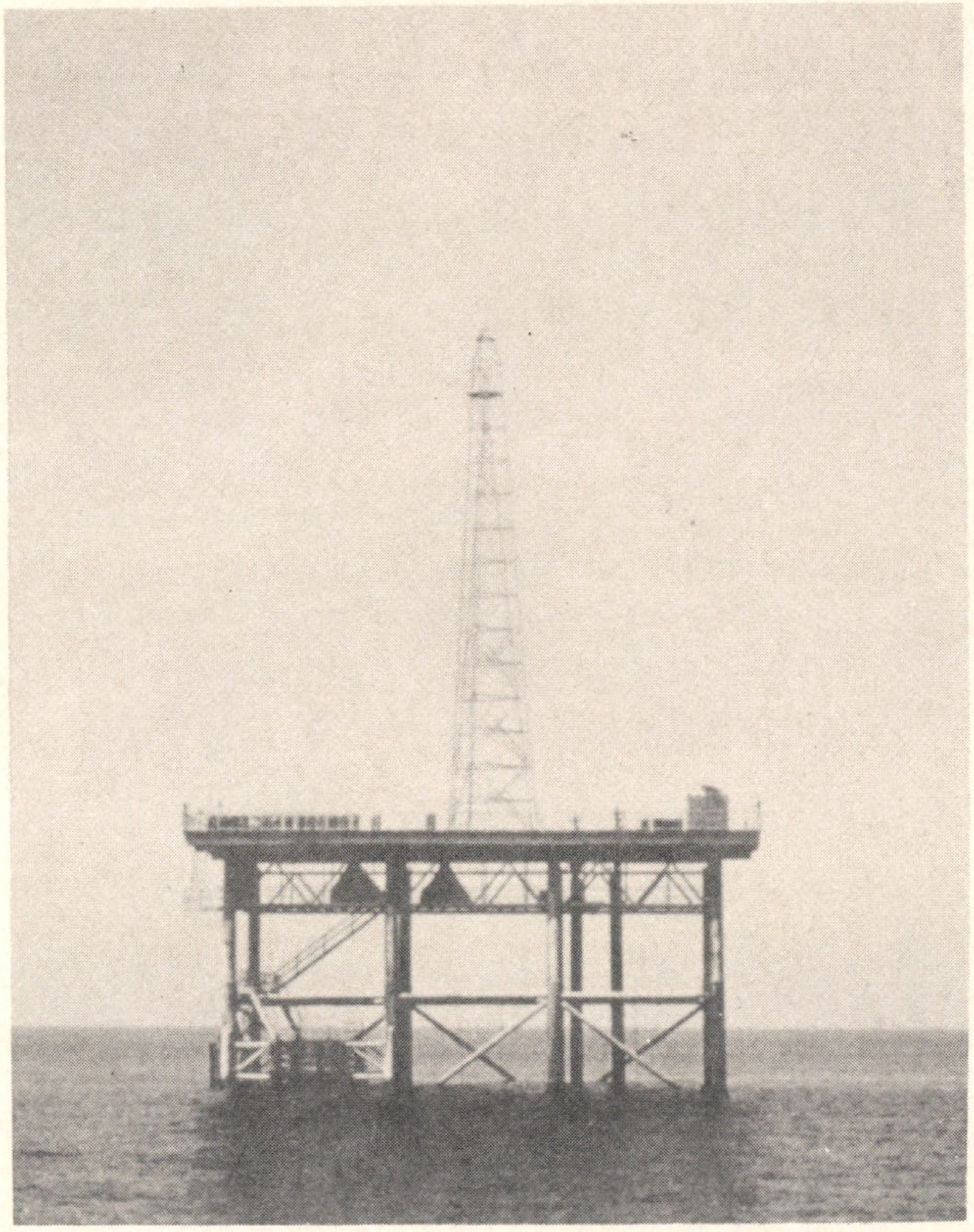


COASTAL AND OFFSHORE TRIANGULATION ALONG LOUISIANA COAST

TOWER BUILDING

Considerable difficulty was encountered in building steel towers along the shore due to the soft or unstable nature of the marshy ground. It was found that it was best not to break through the marsh or dig holes for the tower footings, as mud and water would be encountered almost immediately and no real support could be obtained. The best procedure was to crib the tower footings by laying 16-foot 3" by 10" planks on top of the marsh at each footing location to serve as anchor boards, and then nail the regular tower mud sills to these planks. Sixteen-foot 2" by 4" pieces of lumber were then driven along each side of the planks and cross boards nailed between the 2 by 4's thus locking the anchor boards in place. Oftentimes the 2 by 4's could be driven practically their full length by just forcing them down by hand. A cribbing was next built at each corner of the tower which covered the planks placed on top of the marsh and the cribs were filled with mud, or sandbagged, to hold the anchor boards in place. It was difficult in most cases to use guy wires on the towers due to the poor holding nature of the guy supports, but various types of "deadmen" were devised--depending on the local conditions--with varying degrees of success.

Completed wood stand at a recovered station. Tide is high, but area around station is only a few inches above sea level.



Steel survey tower on offshore platform.

Erection of steel towers on the offshore oil well platforms presented new problems. In the first place, getting onto the platform was hazardous. The usual method was to grab a dangling rope and swing "Tarzan" fashion over to a small landing at the bottom of a stairway. This was no small stunt for men not used to being on a boat to begin with, and to have it moving up and down while trying to disembark was quite disconcerting. Also, getting the steel up on the platform, which was as much as 50 feet above water, from a pitching boat was a problem in itself. The steel in most cases had to be handpassed from the boat to someone standing on a small landing and then carried up a stairway or ladder to the platform deck. Sometimes, a small davit was available at one corner of the platform that could be used for hoisting the tower parts, but extreme care had to be exercised not to lose any pieces overboard in hoisting nor to foul them underneath the platform bracing and supports. At best it was a hazardous job and very tiring.

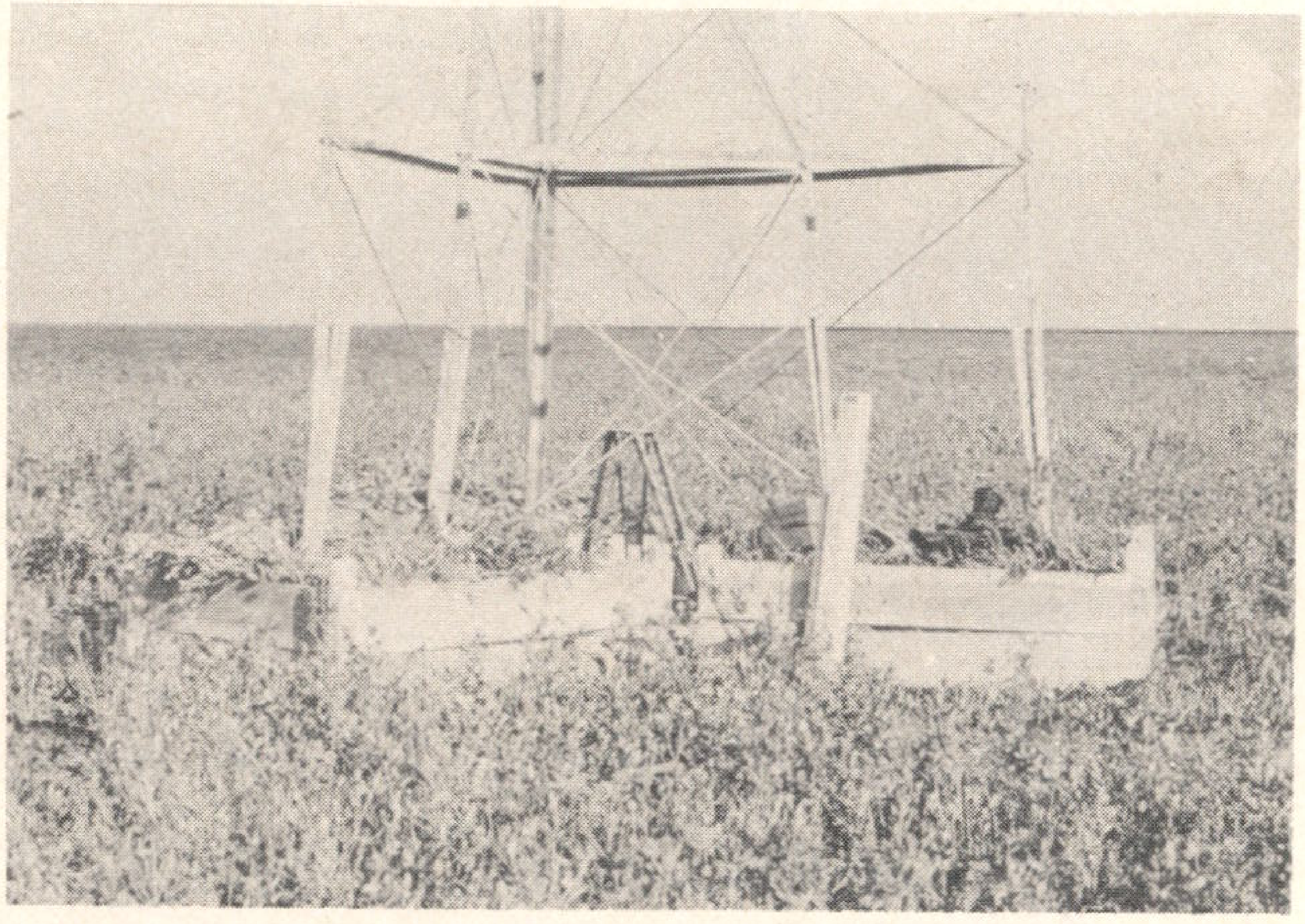
In erecting the towers it was found that the best method of anchoring the footings on the platform deck was to lay down long 3" by 12" planks (usually gum wood), which were spiked to the wooden deck. The tower mud sills were then U-bolted to the planks and the deck, and finally 3/8-inch wire rope was tightened around the mud sills, planks, and the steel platform beams underneath. The towers were found to be very solid after erection. Only one steel tower failure was experienced on a platform. This occurred during a local squall with 70-mile winds, when a tower leg sheared the supporting rivets to the mud sill upright, and the entire tower toppled into the sea. No one was at the station at the time.

On the whole, very good results were obtained from towers erected on the offshore platforms. No observing was attempted from platforms on which drilling operations were in progress and only those platforms on which most oil well activities had been completed were occupied. However, considerable care had to be exercised when on the offshore platforms, as some were of small dimensions, often only 40 by 50 feet, and most all of them were heavily greased and treated against corrosion and deterioration. Crowded conditions on these platforms were normal even after the drilling derrick and equipment had been removed.

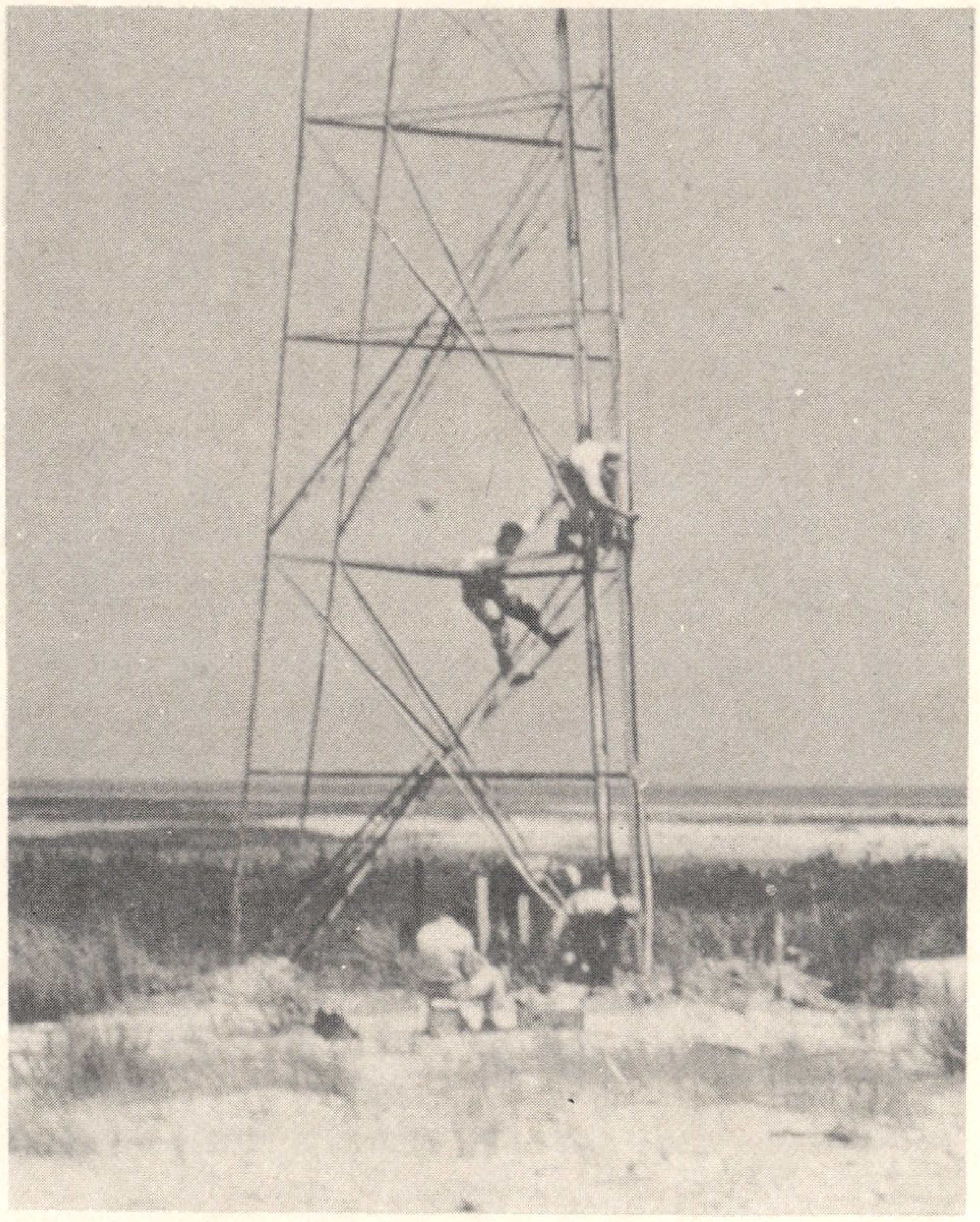
MARKING STATIONS

Marking stations in the marsh areas presented problems not usually encountered on regular triangulation projects. The two methods found advantageous were: (1), a 10-foot section of 3-inch pipe, on which the survey disk had been brazed, was forced into the marsh and left projecting 10 inches, then an 8-inch diameter tile, about 3 to 4 feet long, was telescoped down over the pipe mark and cement poured into the tile to at least a depth of 18 inches, with the surface flush with the top of the pipe and disk (at some of the firmer marsh stations a shorter section of the iron pipe was used); and (2), an 8-foot length of fiber sewer pipe (Orangeburg Pipe) was forced into the marsh except for about 10 inches, filled with cement, and the survey disk set in the top.

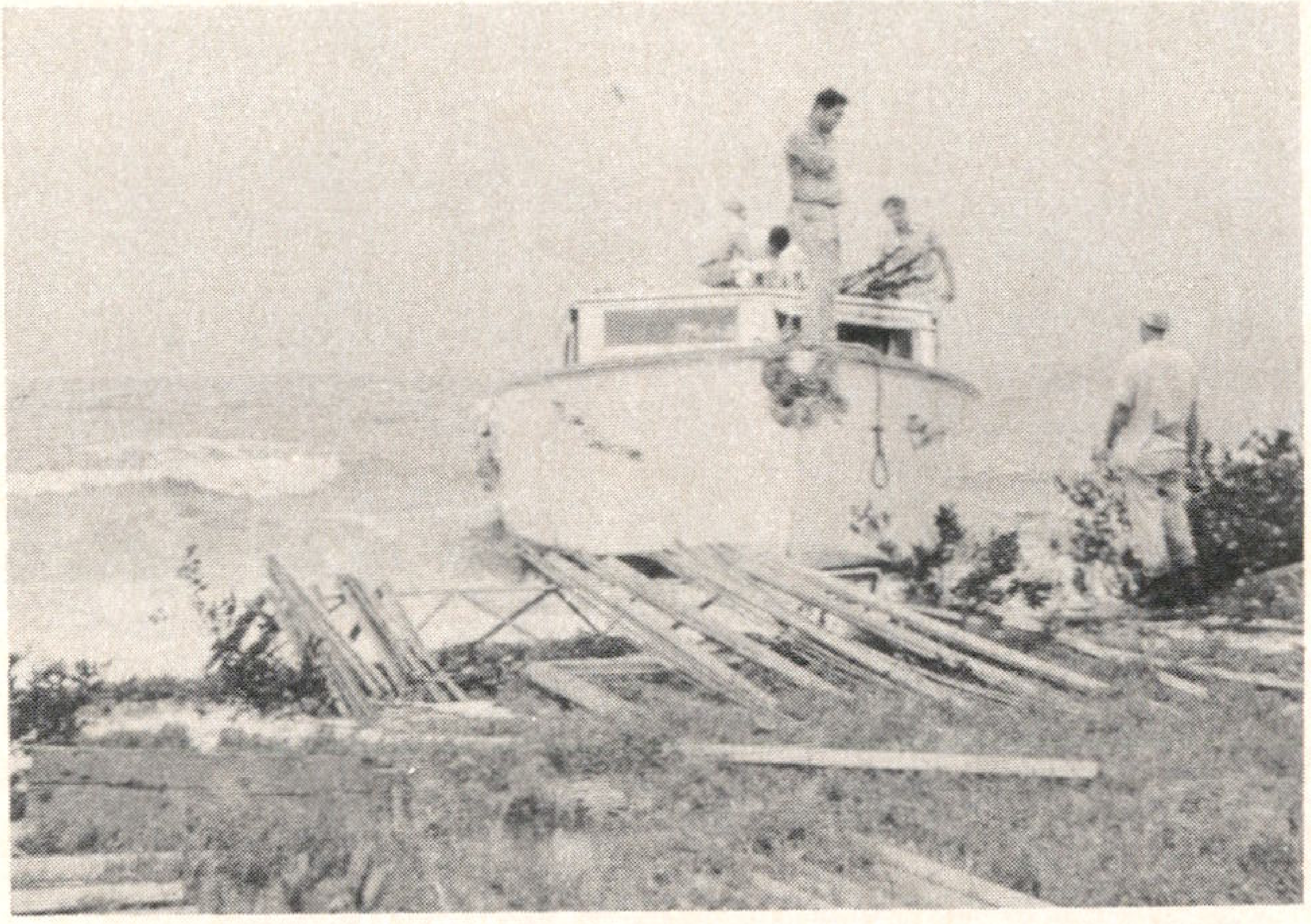
Marking stations on the offshore platforms presented a new problem. As most platforms are decked over with 4-inch thick wood planking, in some cases it was necessary to remove a section of the deck to reach a steel beam to establish a permanent mark. The best means of marking was to make a substantial center-punch hole as the station center in the steel I-beam, cut a fair-sized triangle (about 1-1/2 inches on a side) around it with a cold chisel, and then stamp the letters USC&GS with steel dies, followed by the station name and year, around the triangle. Sometimes a regular station disk, with the shank removed, was cemented directly over the above type of mark, which in effect became an underground mark. The disk was stamped prior to cementing to prevent disturbing the cementing compound, a resinous type substance that was prepared just prior to using. Generally, a platform has two steel I-beams, known as skid beams, on



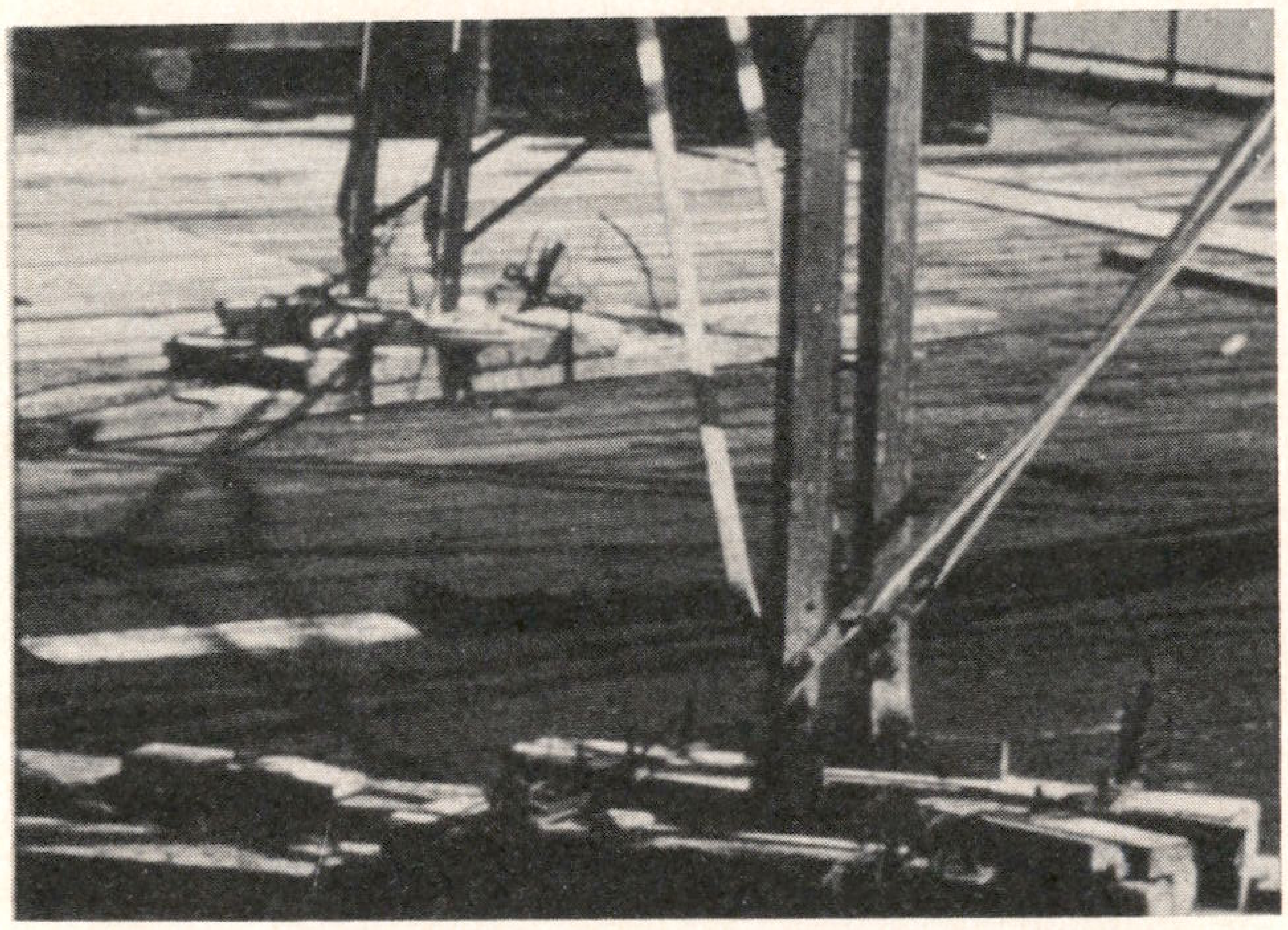
Mud-filled cribs built on top of plank foot boards. Note level of the water.



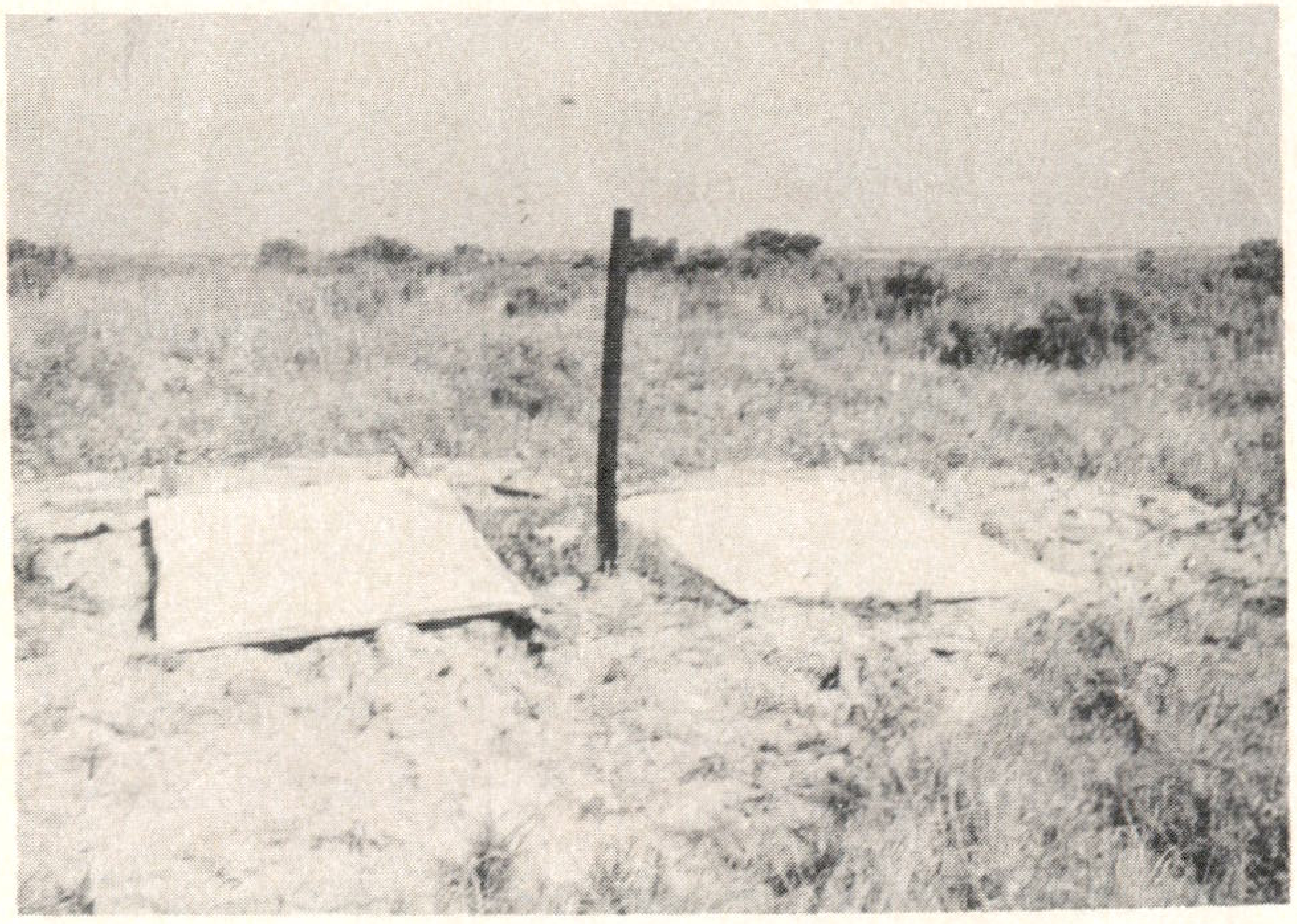
On shell banks such as this, the tower footings could be dug down about 1 foot.



Unloading operations of tower members. Note roughness of water and boat being completely aground.



Tower anchors on offshore platform. Note cables around anchor boards which were placed around steel girder of platform. Cable guys were placed on outer towers.



Tower station after teardown operations, showing witness post and paneling for aerial photography.

which the drilling rig and other equipment are skidded into position. Usually the tops of these beams are exposed and flush with the top of the wood decking. In some cases, the station mark was established on one of these.

TRANSPORTATION

The majority of the stations on this project were difficult to reach. Consequently, transportation was the all-important item. Most stations had to be reached by some form of water transportation which varied from small mudboats, that could negotiate the narrow bayous and drainage ditches, to 35- and 40-foot launches and speedboats, for longer runs in the inside bays and shallow water areas, to 85- to 100-foot offshore vessels. The latter were generally under charter to the oil companies for transporting their work crews and equipment in connection with the offshore work. Steel towers and other building equipment were either transported in the company boats or in various types of hired or chartered ones.

On the east end of the project, particularly in the very shallow Chandeleur and Breton Sound areas, very shallow-draft boats and barges were used. Self-propelled barges were employed to transport several steel observing towers at a time; but, even then, most of the steel had to be shuttled to the station by skiff or back-packed a considerable distance through the mud and water, once the barge grounded off the station site. Oftentimes, the steel had to be carried as much as three-fourths of a mile. Speedboats were of assistance in getting the observing parties around in the Chandeleur area, but the rental rates on such craft were found to be very high and most of the better craft were already under lease to the oil companies for their own operations. The Coast Guard and Air Force supplied some transportation on the extreme east end of the project, which was the only government transportation available. All other water transportation was either hired by the month on contract or on an "as needed" basis at a daily rate.

Transportation to the offshore platforms was furnished by the oil company to whose platform the survey party was going. As this transportation was by the regular company "crew-change" boats, we had to coordinate our programs with the company schedules. Due to the fact that some boat trips took 6 to 7 hours to reach the platforms, the survey personnel frequently had to start for their offshore station at 3 or 4 o'clock in the morning, observe until midnight or later, and then wait until morning to go ashore on the next boat. Consequently, the surveyors had to put in extremely long hours, and generally under adverse conditions. This was particularly true on the platforms which were no longer being used, except as a capped-off well, and only visited once a day to check the navigation lights or the pumps, if it was in production. On the platforms where crew quarters were still in use, arrangements were made with the oil companies for the surveyors to be fed and housed, and they were well taken care of.

Various methods were used to get to shoreline stations between Marsh Island and Cameron on the west end of the project. It was considered impracticable to approach these stations from seaward because very favorable conditions had to exist in order to get personnel and material ashore. To reach the stations from the land side was also quite difficult, but the better of the two. Sometimes the steel and lumber were loaded on small, shallow-draft, catamaran-type barges and towed by equally small mud-boats down through the various drainage ditches and bayous to the station site on the coast. In most cases, these stations were purposely selected with some such idea in mind. In one instance, a jeep was barged down to a station and used on the beach to go both directions to two other stations—for building operations and later during the observing phase.

CAMPING

Camping was necessary for the Chandeleur Island stations, but this was hazardous at best due to the very low ground elevations. Even a minor storm floods across most of these low islands and the campers often found themselves completely surrounded by water.

The problem of mosquitoes was one that also had to be considered. There is no place in the United States where this condition is any worse than in the Louisiana marshes. Consequently, camping at the mainland marsh stations was practically prohibitive. The men often preferred to spend long hours traveling, even at night, to get away from the mosquito infested marshes. During the daylight hours, while building, the situation wasn't too bad, but in the evening hours, during the observing phases—particularly while using lights—it was almost maddening to remain in the marshes. Until someone has actually experienced such conditions, it is hard to realize how bad they can be. For sheer viciousness the Louisiana salt water mosquito has no equal. Various types of insect repellents were tried and the most effective was found to be "6-12," a formula developed during World War II and now sold commercially.

On the west end of the project, camping was held to a minimum. Some overnight camping on the boats by the observing parties was necessary due to the danger of getting lost in the numerous bayous at night. Usually the boats that could negotiate these waterways were very small and quite inadequate for staying out. Observing camps were set up on some of the offshore platforms in order to get the long lines through. In some cases, the parties were able to be housed on a nearby platform that had living quarters and they were shuttled back and forth by the oil company boat on its regular scheduled run. In several instances, camping on platforms extended for as long as a week. The oil companies are not allowed to leave any of their personnel on a platform unless a boat is in attendance at all times. Our men, however, were often left unattended for periods of 48 hours without contact. This wasn't considered a good practice but certain chances are always taken in engineering and the men had long since been accustomed to being on their own for long periods of time.

CONCLUSION

Field computations were kept up with the field work so that shortly after its completion the unadjusted field positions of all stations were furnished the New Orleans district office and made available to the interested engineers. Priority was given to the adjustment of this work in the Washington office and within 4 months of the final field work, the adjusted positions—including both geographic and plane coordinates, the applicable station descriptions, and sketches—were published and made available to the public.

As has been pointed out, water transportation was the keynote of this project and practically all of the stations had to be reached by water. Procuring such transportation, whether by charter, daily rental, or other means, was time-consuming and took considerable patience, foresight, and good judgment—patience to withstand the lack of boats at times and their breakdowns, and foresight and good judgment to anticipate the need for the various types of water transportation at the proper time and place. The other phases of the project more or less took care of themselves because there is no substitute for experience and "know-how," and that is what our geodetic field men are "long" on.

Oftentimes in geodetic work, when horizontal control is being established in some remote or inaccessible place, the members of the field parties are prone to question the need for it or give very little thought to its ultimate use. This was far from the situation in coastal Louisiana. Occasionally during the field work before the station was even built, we would be contacted regarding its position by some geophysical or surveying party. It is doubtful if there is another place in the United States today where the work of the Coast and Geodetic Survey is in more demand or is in more use than along the Louisiana coast.

Accuracy Limitations in Vector Airborne Magnetometer Surveys

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U. S. Coast and Geodetic Survey

THE Vector Airborne Magnetometer, when operated in conjunction with accurate and reliable navigational devices, completely defines the magnetic vector in space in terms of absolute values. One of the most versatile instruments yet devised for this purpose is known as the VAM-2A. This instrument was largely designed and developed at the Naval Ordnance Laboratory prior to 1953. It is described in NOL Report No. 1187, *NOL Vector Airborne Magnetometer, Types 2A and 2B.*

Correlating the magnetic data gathered by the VAM-2A, with respect to an absolute datum, is of prime importance in the types of survey operations conducted by the Coast and Geodetic Survey, and it is the opinion of the writers that the methods and procedures employed in the current aeromagnetic survey program are the nearest approach to absolute control yet put into practice for a survey program of this nature.

The absolute level of total intensity depends on the main bias or nulling current, or on the voltage across a series resistor. The proper voltage must be determined at a place where ***F*** is accurately known. The voltage is then the calibration value for field operation.

The high degree of angular accuracy commonly achieved on the ground with field-type instruments is extremely difficult, if not absolutely impossible, to achieve in flight with the VAM-2A or any other type of airborne instrument that depends upon a pendular vertical reference as does the VAM-2A. However, certain refinements have largely overcome the major sources of error, and accurate angular data should be obtainable with this instrument.

Merely knowing the magnetic vector without knowing the exact geographic coordinates, altitude, and time at which the vector quantity was determined would be of little value; therefore, precise navigational data accurately synchronized with the magnetic data are essential.

Normally, in routine travel by air it is unnecessary to know the aircraft's position closer than a mile or more, especially over water; hence, only a few specialized aircraft have been equipped for precise position control. In order to assure the greatest position control obtainable, the aeromagnetic survey aircraft currently in use is equipped with an electronic device (Hiran) primarily developed for geodetic survey aircraft.

The position data are photographically recorded and synchronized with the angular and intensity data by synchronous electronic timers with reference to Greenwich Mean Time.

DESCRIPTION OF THE VAM-2A

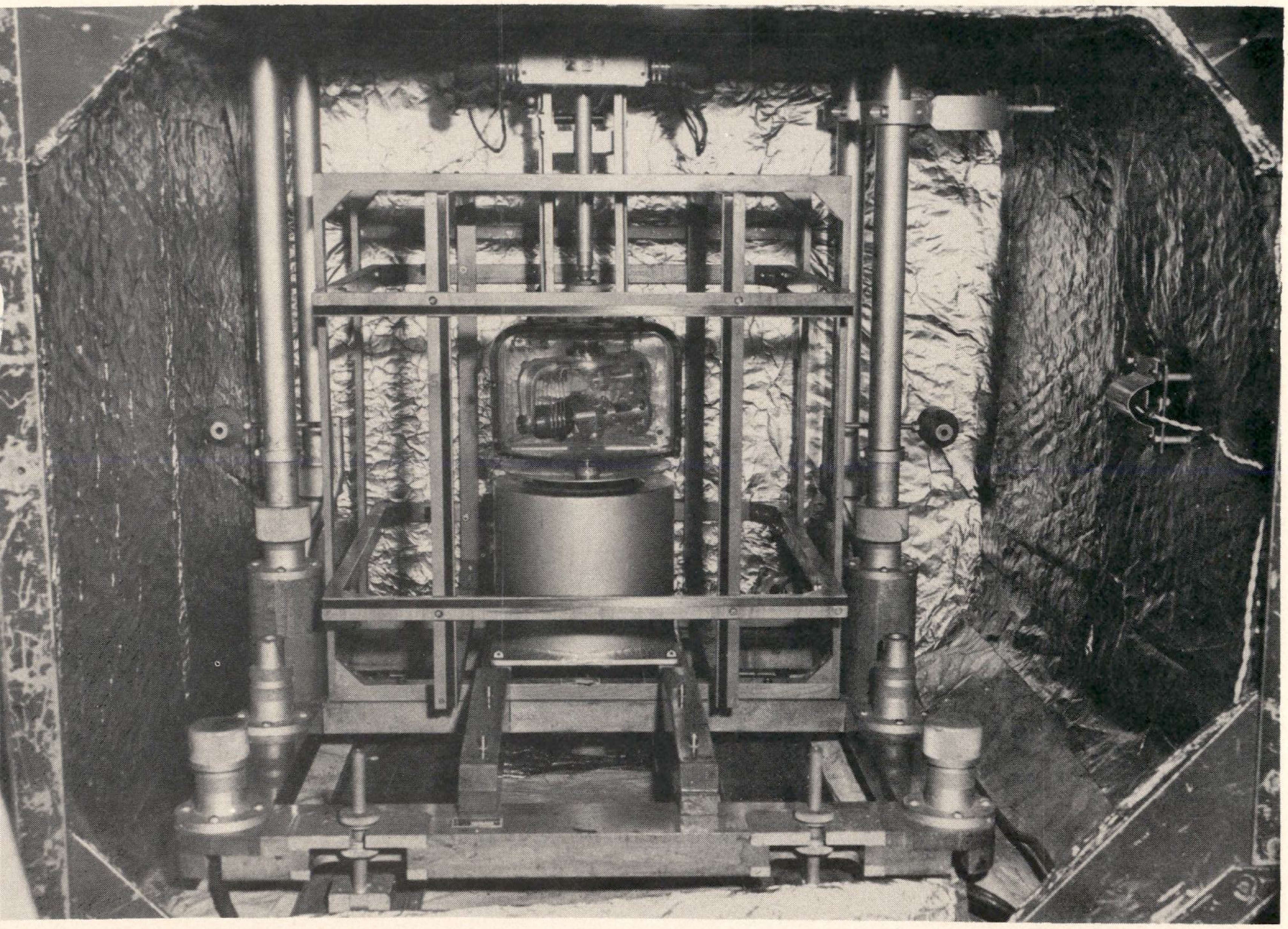
The VAM-2A employs three orthogonally oriented sensing elements of the saturable inductor type. Two of these inductors feed signals to a servo-system that keeps the third constantly aligned with the magnetic field. By utilizing a precisely calibrated nulling current in the third inductor, variations in the magnitude of the magnetic field are detected and recorded on an Esterline-Angus strip chart as the aircraft progresses along its course. The angular components of the magnetic vector--inclination and declination--are obtained from circuits associated with the two aligning inductors and an auxiliary component of the magnetometer system, the relative bearing component (periscopic sextant). The three sensing elements are suspended in a pendular manner from a delicate gimbal mechanism with a damping unit attached. Reference planes are thus established by this arrangement.

MAGNETIC INTENSITY CONTROL--ADJUSTMENTS AND SOURCES OF ERROR

Although the intensity circuitry is essentially free from acceleration effects during flight, certain other sources of malfunction and maladjustment errors do exist and require very close monitoring. The most important of these functional, adjustment, and operational sources of possible error are: (a) compensation of the aircraft, (b) establishment of the calibration voltage level for indicating absolute intensity, (c) drift of the established voltage during a survey mission, (d) wide temperature ranges during a survey mission, and (e) 'errors due to the acquisition of permanent magnetism by the inductors.

Compensation of the Aircraft

Complete and accurate compensation of the aircraft is a long and tedious process and will not be discussed in great detail except to point out

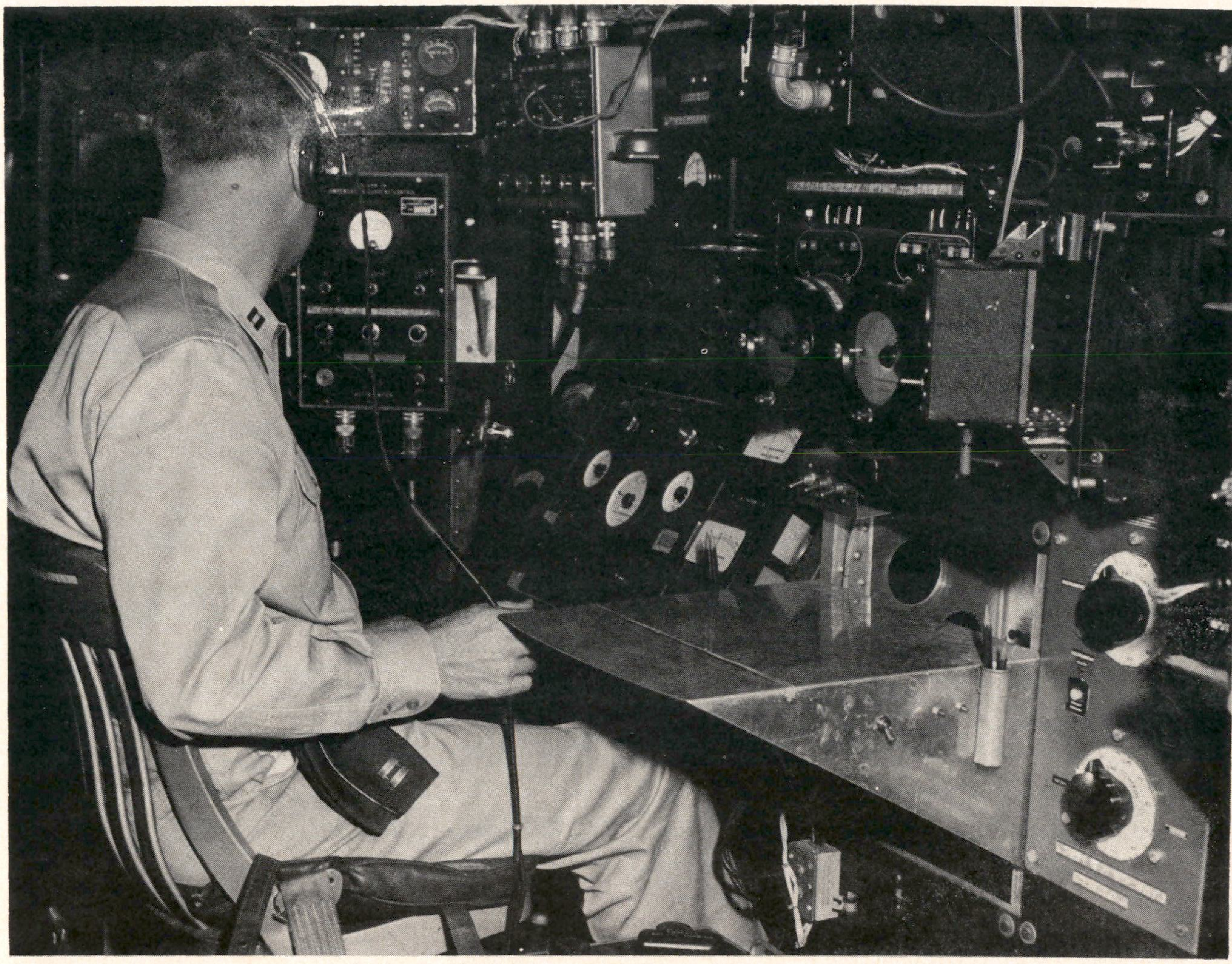


Vector Airborne Magnetometer 2-A installed in plane. View shows gimbal suspension.

the general procedure and the importance of frequent checks to insure continued satisfactory compensation. Absolute and complete compensation is only approached and never attained.

The procedure for compensating the aircraft employed by the Coast and Geodetic Survey is essentially as described in NOL Report No. 1187. It consists of (1) removing from the general vicinity of the sensing elements all ferromagnetic material that can possibly be eliminated, (2) twin-leading the aircraft's electrical system, thus reducing the magnetic effect which results when the aircraft structure is used as the ground return, (3) counteracting the remaining permanent fields set up by the aircraft's electrical system and ferromagnetic material with counter fields produced in a helmholtz coil system which surrounds the sensing elements, and (4) counteracting the induced magnetic effects from the ferromagnetic materials of the aircraft with specially designed and strategically located magnetically soft masses. Thus, with a sufficiently compensated aircraft, true magnetic readings can be obtained with the VAM-2A independent of magnetic latitude and of aircraft heading. It is quite obvious that temperature variations, vibration, and hysteresis may change the parameters of the aircraft magnetism. Accurate design and location of the induced compensators for complete induced compensation at wide variations in magnetic latitude are difficult to control outside the laboratory, but errors from these sources are generally small and insignificant.

After initial complete compensation has been effected, however, this phase cannot be forgotten at any time during a magnetic survey project, because any changes such as the position of ferromagnetic material, addition or removal of aircraft components containing ferromagnetic material, major changes in the current drawn by the aircraft's electrical system, and lack of balance of the electrical load among the aircraft generators have a definite influence upon the maintenance of satisfactory aircraft compensation. Therefore, in view of these considerations a systematic procedure for testing the com-



The operator continuously monitors the equipment.

pensation of the aircraft before and after each survey mission is necessary, and serious changes in the aircraft's compensation can thereby be detected and corrected.

Establishment of Calibration Voltage

The magnetometer control box circuitry is provided with a precision resistor across which the calibration voltage drop may be adjusted--by bringing the nulling current to a level that the magnetometer indicates the absolute intensity value at the location and time when this measurement is made. In order to establish this level accurately, a location for the initial determination of the proper adjustment is chosen where the earth's magnetic field is precisely known, preferably at or near a magnetic observatory. (A nuclear precession magnetometer will provide the best control.) The procedure followed is to set up the magnetometer with the sensing elements at the desired location, adjust the nulling current until the known field at that location and time is indicated by the magnetometer, measure and record for future field adjustments the voltage drop across the precision resistor. Once this voltage has been determined, its value is set into the instrument by use of a Lyndeck potentiometer standardized against saturated standard cells prior to each survey mission.

Drift of Established Voltage

Since the calibration voltage is close to 1 volt, an error of 20 microvolts produces an error of 1 gamma in a field of 50,000 gammas. The calibration voltage can easily be checked to this accuracy before each mission. Experience has proved that voltage drift during a mission is reasonably small except in cases of extreme temperature ranges. Should the drift become excessive, it might be advantageous to prorate the indicated error over the entire mission.

Temperature Range

Although the magnetometer intensity circuitry has been temperature compensated through reasonable ranges, it has been observed that extreme temperature deviations during a mission are a source of indicated intensity error. As a result of this fact, missions should be flown only when the aircraft heating system is capable of maintaining reasonable temperature control over all magnetometer components. Special electric heaters are provided on the survey aircraft to aid in maintaining a favorable temperature level in the inductor compartment when it is located outside the aircraft's pressurized section. Unfavorable temperature ranges are encountered more frequently when operating at extremely high altitudes—20,000 feet or more.

Permanent Magnetism of Inductors

This possible source of error is favorably eliminated by deperming the inductors with alternating current prior to each survey mission.

ANGULAR CONTROL

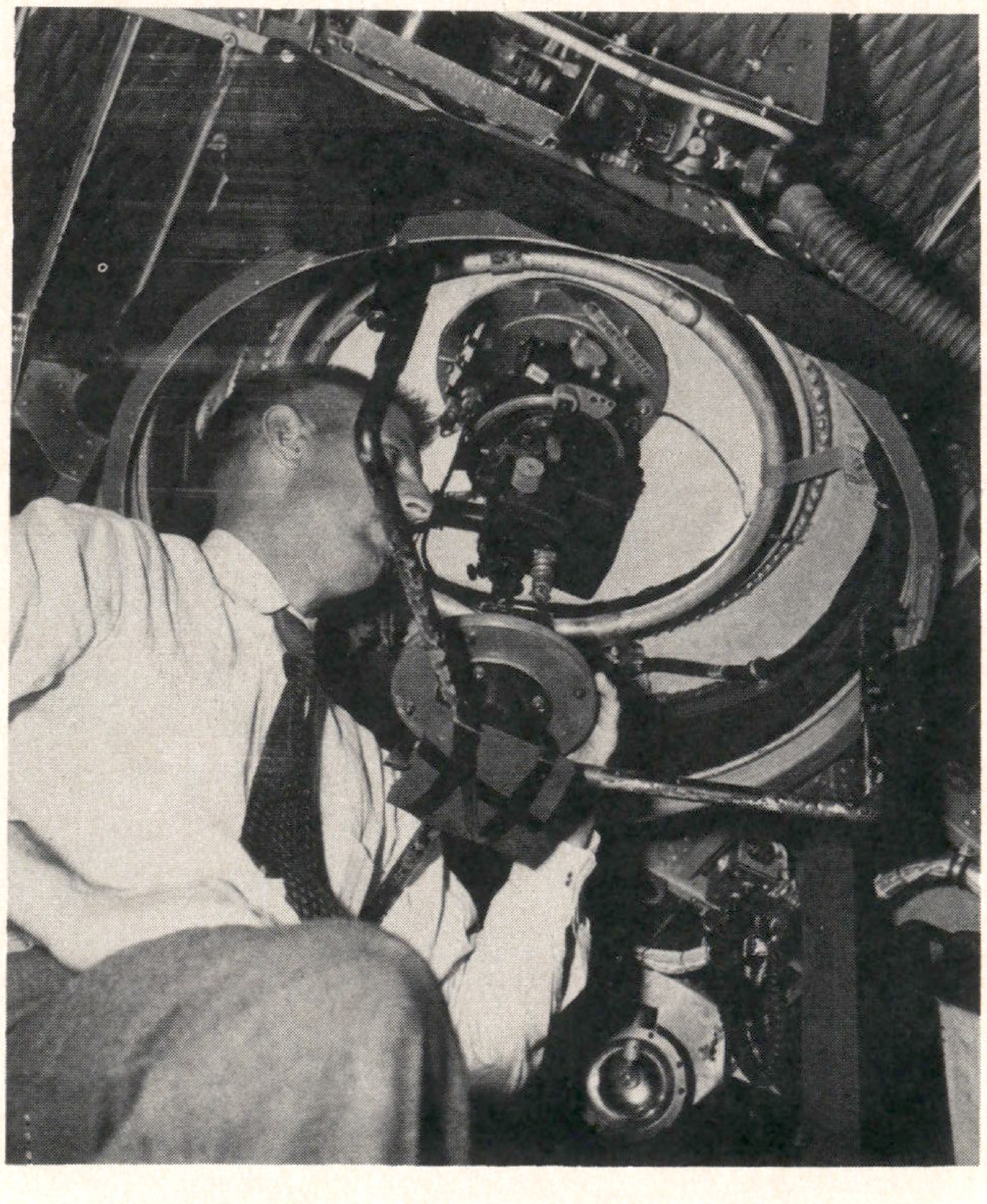
The angular data are sensed by synchro-transmitters geared to the reference planes of the VAM-2A. This information is received by synchro-control transformers in index boxes which are calibrated in 5° intervals. A phase detector circuit measures the small angular differences in minutes of arc between the transmitting and receiving units. This difference is continuously recorded on Esterline-Angus charts. One records the inclination while the other records the detector heading relative to the aircraft. In order to determine declination, the true heading of the aircraft must be known. This is derived through celestial observations with a modified Kollsman periscopic sextant also fitted with the synchro-angle system.

The accuracy derived from this system is dependent upon the respective precision of the synchro units, the calibration of the index boxes, the calibration of the phase detector, the compensation of the aircraft, the minimizing of aircraft accelerations, and synchronizing of the data with the ground control observatory. It is also necessary to determine the lubber-line errors of the magnetometer and sextant, or at least to determine the net error.

POSITION CONTROL

Pilot experience and skill in flying the type of mission peculiar to geomagnetic surveys, coordinated with the specially trained Hiran navigators, insure accurate position control of the aircraft. A 2-man team is required to operate the navigational equipment. In addition, 2 ground stations must be operated in conjunction with the airborne units.

The Hiran simultaneously measures the distance from the aircraft to each of the ground stations and indicates to the pilot his position with reference to a predetermined line of flight. There are, however, several limitations in range, position, attitude, and altitude which can be effectively dealt with only by experienced operators and very careful flight planning. Although the actual coordinates of the aircraft are finally determined through data reduction of photographic Hiran records to accuracies well within 100 feet, the predetermined flight line, obviously, cannot be duplicated with that kind of accuracy because of (1) the small scale of the straight line overlays, (2) the fact that the pilot can make heading corrections only during periods of no observations (alternate 100-second periods), and (3) varying atmospheric conditions requiring adjustments in indicated altitude, a factor that can be dealt with more effectively in the process of data reduction.



Celestial observations are made to determine true heading of aircraft for use in declination computations.

PROCEDURES

In the case of the Coast and Geodetic Survey installation, extreme care is exercised in the calibration of the index boxes, compensation of the aircraft, and so forth, details of which can be found in NOL Report No. 1187. A check on the phase detector circuitry, adjustment of meters, and so forth, is a routine part of each survey mission. Ground observatory control is obtained by operating at the home base a full-time observatory in which continuous variation records are photographically recorded with weekly absolute baseline control. All of these data accompany the flight data for final processing in the Washington Office.

The effect of aircraft accelerations is minimized by the use of integration circuits which give average angular values over 100-second intervals. This particular interval was primarily chosen to cover two phugoid oscillations of the aircraft. Coriolis is corrected for in data processing. Also, during the integration period the aircraft is flown on auto-pilot with no heading corrections being applied throughout the period. This assures the most stable platform obtainable in flight.

SYNCHRONIZATION OF DATA

Careful synchronization of all the data is of major importance and extreme care must be exercised in coordinating the position data, magnetic flight data, and the ground control data obtained from the observatory at the operations base. Automatic synchronous timing is employed both in the aircraft and on the ground, and is supplemented by operator monitoring.

When speaking of synchronization, it cannot be overemphasized that accurate and reliable data depend not on any one part of the equipment or personnel but, rather, upon a completely synchronized team operation. Therefore, considerable skill must be developed by all participants in their specialty and in coordinating their work with other members of the flight crew.

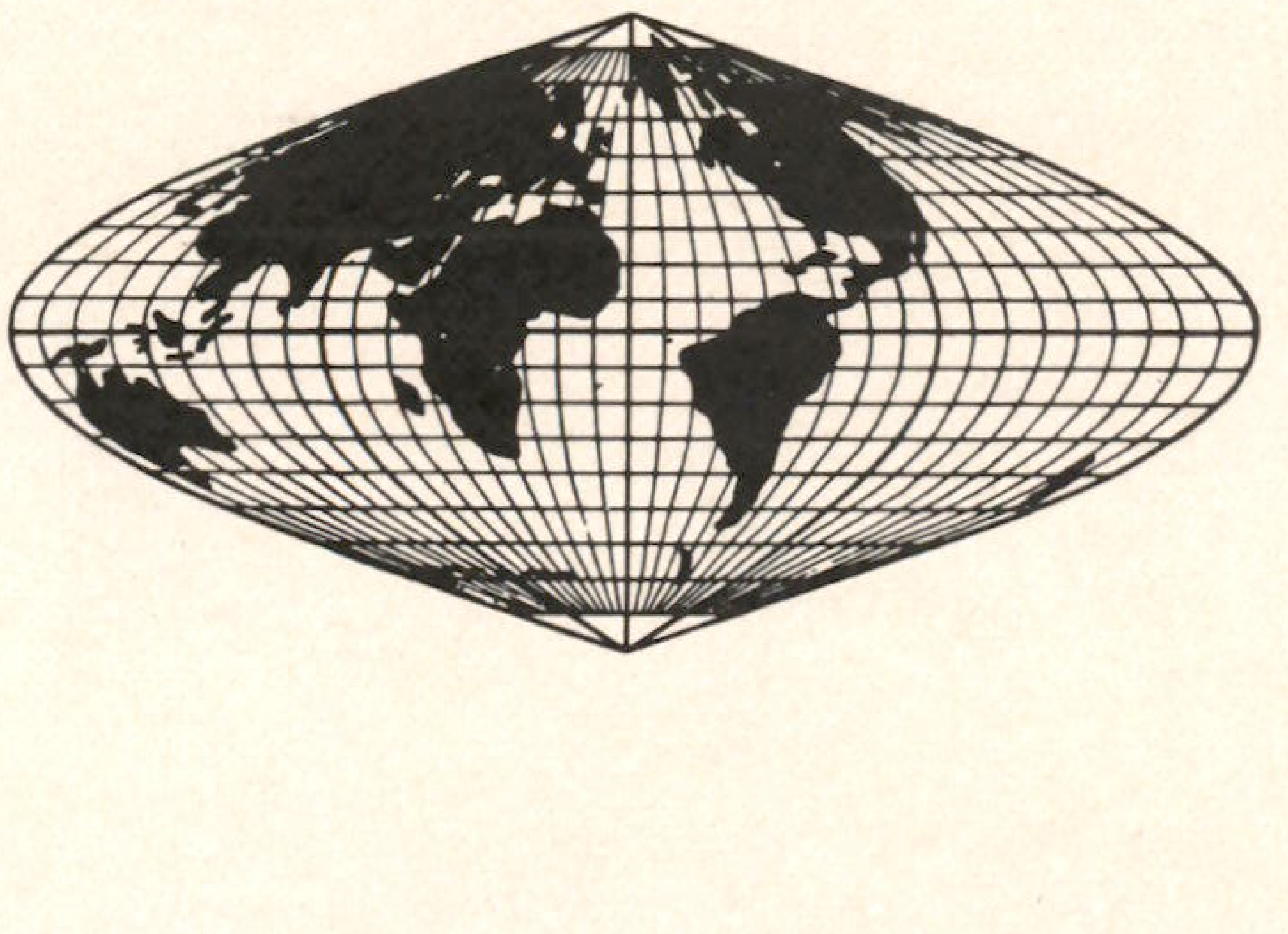
Because of the many modifications of the B-29 aircraft required by the aeromagnetic survey program, an alert and highly conscientious maintenance and flight crew is essential to successful operation.

Magnetic Observatory

A magnetic observatory operated near or in the area in which the survey is being conducted is essential for correlating the airborne data to predetermined epoch. In cases where long flights over extended areas are made rather than concentrated flight lines in a relatively small area, it would definitely be advantageous to have the ground observatory located at the base from which the aircraft operates.

The observatory is particularly useful, if not absolutely necessary, for control purposes during the compensation phase of an operation and is very advantageous for data comparison of compensation checks which are performed before and after each survey mission. The observatory is of further aid in the scheduling of survey missions, as flights, during periods of magnetic storms, can sometimes be prevented through close monitoring of the magnetograph records.

To make full use of the inherent accuracy of the total intensity data, accurate reduction-to-epoch values are required. This can only be achieved if the observatory is close to the survey area.



Hydrographic Work of the Coast and Geodetic Survey

COMMANDER KARL B. JEFFERS
U. S. Coast and Geodetic Survey

LONG before the beginning of recorded history, seamen began to assemble information about the sea routes then in use. Most of the data collected were disseminated by word of mouth and illustrated by crude sketches. Today all the maritime nations of the world produce nautical charts which present in graphic form a vast amount of precise information. Even the so-called "backward" nations are establishing surveying and mapping bureaus which are comparable to those of more affluent nations. International cartographic symbols and practices have been adopted so that mariners of any nationality can understand and interpret the charts of foreign nations.

The conduct of surveys necessary for the production of nautical charts is recognized as one of the essential functions of government. In 1807, Congress authorized a survev of the coasts of the United States. The plan of operation submitted by Ferdinand R. Hassler was adopted, and this eminent Swiss scientist was engaged to carry out his plan.

The plan of operations proposed by Hassler was based upon the establishment of geodetic control of a very high degree of precision. The charts and maps were rigidly tied together under this system. Topographic surveys were made by planetable and alidade. Hydrographic surveys were controlled by sextant angles on signals located by triangulation or planetable. Aids to navigation were located precisely, and soundings accurately positioned in order that the mariner could be provided with a complete chart. The basic concepts of responsibility set forth by Hassler are valid today. Although instrumentation and procedure have changed in the ensuing 150 years, it is surprising to note that many of his methods are still in use.

FIRST HYDROGRAPHIC SURVEY

Hydrography is that branch of surveying which defines the depth and configuration of the bottom of the ocean and of lakes, bays, rivers, and other bodies of water. To be of value, depth measurements, or soundings, must be fixed in geographic position and precisely related to geodetic or topographic positions on the adjacent shores. It is quite easy, in many places, for a mariner to determine his position at sea by comparison of echo soundings with charted soundings. There are many landmarks under the surface of the water which are as recognizable as those apparent to the eye.

There are more than 8,300 hydrographic surveys in the vault, the oldest being numbered H-44. This is a survey of Great South Bay, Long Island, done at a scale of 1:10,000 in 1834 by Lt. T. R. Gedney. A channel in New York Harbor is named for this early hydrographer.

When the Coast Survey was first organized, it was responsible for charting the harbors and coastal waters from Maine to the western limit of the Louisiana Purchase in the Gulf of Mexico. Today, the area of responsibility has been extended farther seaward to the continental shelf and includes waters bordering our Territories and possessions in addition to our own coastal zones. The total area of responsibility is estimated at 2,500,000 square statute miles.

Waterborne commerce in the early days was vital to the young nation and the ports were jammed with shipping. The sealanes were particularly important before the construction of the railways. This commerce has grown steadily and will undoubtedly continue to increase for years to come.

COASTAL SURVEYS DIVISION

In the organizational plan of the Bureau, the hydrographic work is under the supervision of the Coastal Surveys Division, which is subdivided into three branches. The Coast Pilot Branch compiles and publishes ten volumes of *Coast Pilots* which supplement information printed on nautical charts. The Vessels and Equipment Branch is responsible for construction, maintenance, and repair of all survey ships and floating equipment. The Hydrography Branch is responsible for project planning and writing orders and instructions for hydrographic and planetable topographic surveys. This paper deals primarily with the work of the Hydrography Branch.

At present, the survey fleet comprises four major ships and ten auxiliary vessels. One ship is engaged in special offshore surveys for the Navy; two major units and three auxiliaries work in Alaskan waters; and one small unit is engaged in resurveys in the San Juan Island area of Washington. Only one major unit remains of the

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Commander Jeffers is Chief, Hydrography Branch, Coastal Surveys Division.

East Coast fleet and is assigned to duty in the Gulf of Mexico, except when needed for more urgent work in the Atlantic. Four auxiliaries operate in the Atlantic and one on the west coast of Florida. The tenth is a small vessel assigned to Coast Pilot work in the Atlantic and Gulf coast areas. Field work is generally in progress from early spring to late fall when the fleet returns to assigned bases for processing of records, overhaul and repair, and preparation for new projects.

Since the principal function of the division is field work, only 4 officers and 12 civil service employees are assigned to the office staff. The field force is variable, but generally has in excess of 100 officers and 400 men during the field season.

SURVEY PROGRAM

The program for hydrographic survey operations is based upon the following:

(1) Requests for surveys in support of civilian pursuits.
(2) Military survey requirements.
(3) Requirements for new charts and reconstruction of old charts.
(4) Completion of surveys in all the area of responsibility.

A 4-year plan of operations has been laid out after consultation with representatives of the Chart Division. This plan is extended and adjusted each year to reflect changing circumstances. An example of this is found in the 1957 program: The ship *Hydrographer* had been scheduled to continue surveys in the Gulf of Mexico and Florida Straits. The New England Fishermen's Association requested a new survey of Georges Bank, in view of many reports that shoals and banks have shifted to such an extent that the present fishing chart is obsolete. A new chart is needed to help reduce the loss of fishing gear. The establishment of Texas Tower 2 on Georges Shoal has introduced a requirement for a detailed survey of the approaches to the tower, and construction of a large-scale approach chart. Similar changes have taken place on Nantucket Shoals, creating a danger to coastwise shipping. The urgency for resurveys in these areas is such that the *Hydrographer* is being assigned to this project to be completed in 1958.

After it has been decided to make a hydrographic survey of an area, a project plan is drawn up. Each operating division is notified of the plan and requested to furnish information as to its requirements in the area to be surveyed. All existing information is reviewed, and copies of pertinent data are assembled for transmission to the field. The Chart Division prepares a "presurvey review," in which all questionable soundings, or points requiring further investigation, are indicated. Basic instructions for the project are written and circulated for amendment, or approval. Although methods and requirements for hydrographic surveys are completely described in the *Hydrographic Manual*, it is customary to include in the instructions specific reference to the scale of the surveys, line spacing, crosslines, location of tide stations, current stations, magnetic stations, triangulation, and photogrammetric surveys.

THE HYDROGRAPHIC SURVEY

On receipt of instructions for a survey project, the chief of party is responsible for laying out the work program. Boat sheets are constructed on which all critical soundings and obstructions are plotted, and a few other charted soundings are plotted for comparison purposes. Control stations, if any, are plotted, and shoreline details are transferred to the sheet.

Each hydrographic survey unit has as its primary function the determination of subsurface contours by means of soundings. Much preliminary work must be done before sounding operations can begin. Triangulation control must be established first. Shoreline surveys must be made and topographic signals located. In recent years, much of this work has been done by photogrammetric methods. Each project presents its own problems for organization of the party and execution of the field work. Solution of these problems rests with the chief of party.

Soundings

For centuries, all soundings were obtained by the use of a marked line attached to a weight and suspended in a vertical line. The hand lead is still used extensively to examine shoals and submerged rocks, and to verify least depths obtained by echo sounders. Great depths have been measured by use of a fine steel wire running over a calibrated registering sheave. The wire-sounding machine is now used to obtain bottom samples, water samples at various depths, and for comparative soundings. Pressure tubes were used for a time in an effort to speed up sounding operations in water too deep for hand-lead sounding.

Since World War I, the echo sounding instruments have come into common use. This is a device which measures the time required for an emitted signal to travel from the hull of the sounding vessel to the bottom of the sea and be reflected as an echo. The elapsed time is converted to depth in feet or fathoms, and recorded graphically as a continuous profile of the bottom under the vessel as it proceeds on its course.

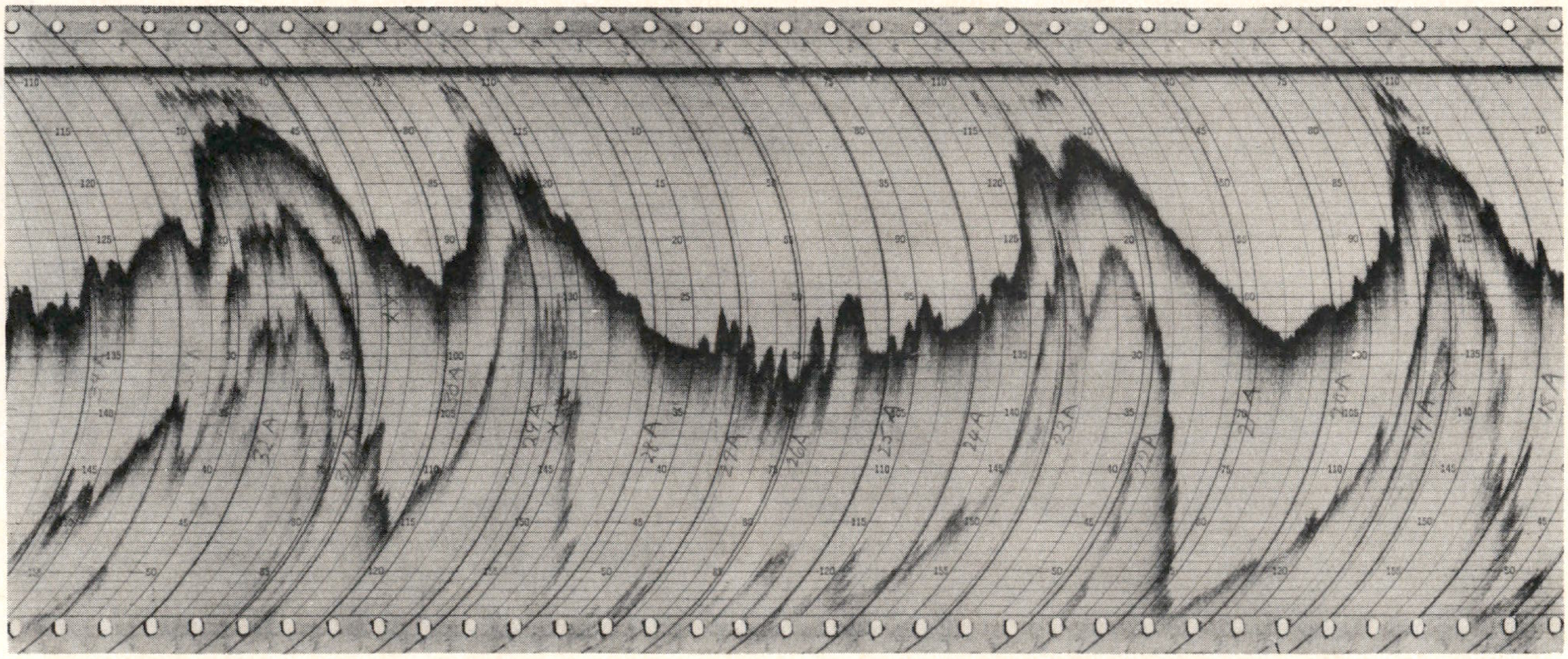
With the previous system of wire sounding, the individual soundings were widely spaced and it frequently happened that dangerous pinnacle rocks were not discovered. All indications of shoals are investigated. Least depths on rocks and shoals are verified by hand-lead soundings. Questionable echo soundings in kelp are also investigated by the hand lead.

Control of Hydrography

From the beginning of hydrographic surveys in this country, the position of the sounding vessel has been determined by sextant angles on signals ashore or afloat. The system is still used for inshore surveys. In offshore areas some sounding lines were fixed by astronomic sights. Prior to development of modern electronic systems, the Bureau developed and made extensive use of radio acoustic ranging. This system also depends on the speed of sound through water. The time elapsed between the instant of explosion of a small TNT bomb and the return of a radio signal keyed through a hydrophone is converted to distance from the hydrophone station, and plotted as an arc. The intersection of two or more distance arcs determines the position of the vessel.

World War II brought tremendous advances in the electronic field, among which were the development of Shoran and Loran. Shoran measures a line-of-sight distance which limits its area of use; however, it permits continuous surveys within its range regardless of visibility, and is particularly valuable in areas where fog is prevalent. It is sufficiently compact to permit

Type 808 portable graphic-recorder revolutionized sounding methods.



The echo-sounding instrument records a detailed and accurate profile of the bottom.

The sextant is still essential after more than 150 years of use.

its use in small boats. The Electronic Position Indicator (EPI) was developed for control of hydrography beyond the limits of Shoran, and its use is restricted to ships. This equipment is not limited to line of sight and yields excellent results in measuring distances up to 300 miles. It has been satisfactorily used for distances in excess of 500 miles. EPI does not lend itself to large-scale surveys and is used exclusively for small-scale offshore operations. Corrections to observations are based on calibration tests over known distances. The EPI correction is generally constant regardless of distance, whereas, the Shoran correction varies with distance and is sometimes erratic. Both equipments yield results within the limits of precision required for hydrographic surveys. It is probable that one, or both, will be replaced by even better equipment as advances are continued in electronic development.

FIELD WORK

As previously stated, a hydrographic survey is generally a combined-operations project. Several operations are carried on simultaneously by a major survey ship. Before actual sounding operations can begin it is necessary to establish control for the hydrography. Signals are built and located by planetable, or photogrammetric methods, and fitted into a framework of triangulation which has been established in advance. If part of the survey is to be controlled electronically, it is necessary to build Shoran or EPI stations ashore and locate them precisely. At least one tide gage must be established and the staff referred to three or more tidal benchmarks.

Inshore hydrographic surveys are made in launches operating from the ship, or from a base camp ashore. The ship will accomplish the offshore surveys as time permits and is able to keep abreast of the launch work. Since the inshore work progresses rather slowly every effort is directed to its accomplishment, full advantage being taken of favorable weather conditions.

A system of parallel sounding lines is run, usually normal to the depth curves. The line spacing is a function of depth-of-water and character of the area. Channels, anchorages, and shoals are developed much more intensively than areas of similar depths along an open

EPI Mast in Alaska.

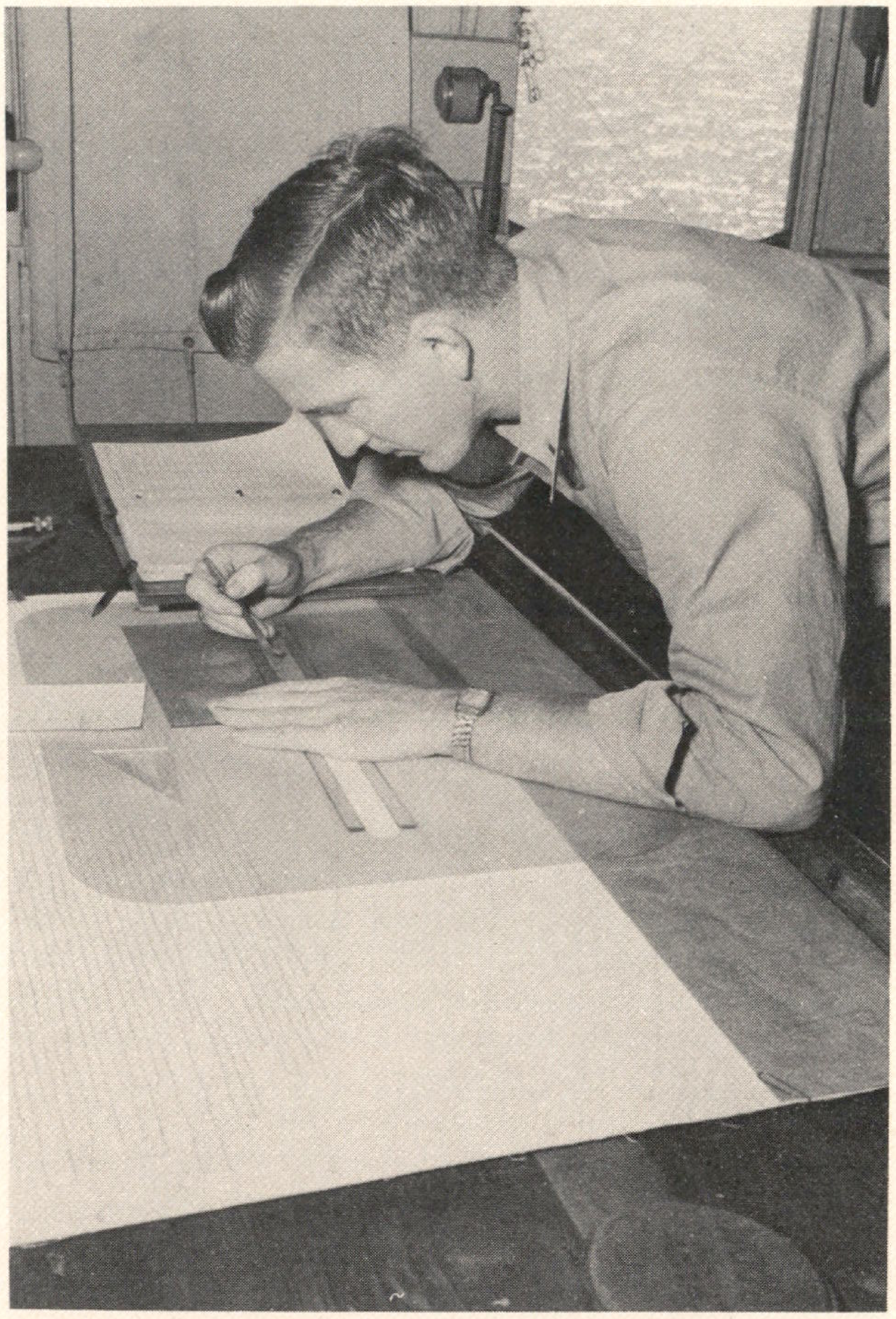
coast. For example, a harbor being surveyed on a scale of 1:10,000 will have a general line spacing of 100 meters, with closer spaced lines in critical areas such as channels and anchorages. Sounding lines are several miles apart in open ocean areas where depths exceed 1,000 fathoms.

Random crosslines are run in addition to the regular system of sounding lines. These serve to detect errors in the operation of the echo sounder, or positioning of the soundings. A position fix is observed and plotted at regular intervals. The distances between fixes should not exceed 1-1/2 inches on the scale of the projection. Soundings are recorded at regular intervals ranging from 10 seconds to 5 or more minutes, depending on the scale of the survey. Soundings are also scaled from the fathogram at irregular intervals where necessary to provide data for plotting shoals and deeps in order that a true profile can be drawn. The hydrography is plotted on a boat sheet as the work progresses. Soundings are usually corrected for tide as they are plotted on the work sheet. Each day's work is carefully examined to make certain that any indication of a shoal, or obstruction, which could be a danger to navigation is detected and examined.

As a further safeguard, many areas are swept with a wire drag to eliminate all risk of missing a pinnacle rock. A wire drag is a small cable towed by two vessels and maintained at a predetermined depth by a system of weights, floats, and buoys. Many such rocks have been found which exceed 200 feet in height. Typical of such a danger is a shoal with a least depth of 2 fathoms found in the Bay of Waterfalls in the Aleutian Islands. This pinnacle lies in the approximate axis of the bay and projects from general depths of 35 to 40 fathoms.

THE SMOOTH SHEET

When the field work for a hydrographic survey has been completed, the sounding records are processed for final plotting. The boat sheets are forwarded to the Washington office for preliminary review, and pertinent information to correct existing charts is recorded and frequently published in *Notices to Mariners* as advance chart information. The fathograms are scaled to verify recorded soundings; the soundings are corrected for instrumental errors, such as echo sounder phase, draft of the transducer, and drift of the initial setting. The soundings are finally reduced to the tidal datum plane used for charts of the area--mean low water in the Atlantic and mean lower low water in the Pacific. [illegible] fixed positions are carefully replotted on a "smooth sheet," using final positions of control stations. The soundings are plotted and depth curves drawn in pencil. The completed smooth sheet is transferred to the Washington office, where the smooth plotting is verified and inked. The final result, as shown on the finished smooth sheet, is reviewed to determine the adequacy of the survey. If there are any doubts on this score, appropriate note is made and further investigation is ordered at the first opportunity.



Smooth plotting of positions and soundings is frequently carried on as field work progresses.

THE CHART

The ultimate objective of the survey is the publication of a nautical chart of the area. The smooth sheet provides the necessary information as to depth of water, location of dangers and obstructions in navigable waters, and location of floating aids to navigation. Other field work performed by the survey party provides details of shoreline, position of fixed aids to navigation, information as to time and range of tide, direction and velocity of tidal currents, variation of the compass, names of important features, and information to be published in the *Coast Pilot*, which supplements the chart.

Occasionally, a survey is made to determine the amount of dredging required in a channel, or to determine the quantity of material removed by the dredge. Hydrographic surveys along shores characterized by accretion or erosion are valuable records frequently used in the courts to resolve cases involving land ownerships and riparian rights. These surveys are essential tools used by engineers in laying cables, and in constructing piers, jetties, bridges, dams, and tunnels. Combined with tide and current data, they are used in studies of water pollution, waste disposal, and beach erosion problems. Special surveys have been made in southeast Alaska to facilitate location surveys for paper mills and logging operations. Photostat copies of all hydrographic surveys are available to the public at a nominal fee.

The collection of oceanographic data is rapidly assuming greater importance in the field operations. Information is needed on a worldwide basis regarding temperature, salinity, mineral content, plankton density and type, surface and subsurface currents, and bottom core samples. The Bureau processes very little of this information, and the observations are turned over to interested oceanographic laboratories, such as the Hydrographic Office.

Tide and current observations are analyzed and used to supplement the data published in *Tide* and *Current Tables*. Magnetic observations are processed and add to the store of information on the earth's magnetic field.

SOME MAJOR ACHIEVEMENTS

The annals of the Coast Survey contain many stories of triumph, such as is to be found in the history of the ship *Surveyor*. As a convoy ship in World War I, she was credited with damaging a German submarine so severely that it was forced to put into a Spanish port where it was interned. Or the ship *Patterson*, which rescued some of the crew of the Revenue Service cutter *Tahoma* in the Aleutians. There are also stories of tragedy and disaster, such as the loss of Lieutenant Bache and ten men from the brig *Washington*. These are isolated instances of a dramatic nature. The real import of the service performed during the past century and a half can only be visualized after careful study of accomplishments.

The most urgent reason for undertaking the original surveys was the need to reduce the number of shipwrecks, which were so costly in lost lives, cargo, and ships. Marine insurance and freight rates were prohibitive until adequate charts were compiled and published. Only a few years ago, an oil company refused to send a tanker into a small bay in southeast Alaska until a complete hydrographic survey had been made. History is replete with such cases.

Incomplete records show that from 1867 to 1917 approximately 425 vessels were wrecked in Alaska with the loss of more than 500 lives (Special Publication No. 50, *Safeguard the Gateways of Alaska*). More than half of these wrecks were losses to which the lack of surveys and accurate charts were a contributing cause. Far too many hidden dangers are named for ships which lie buried beside them.

Nautical charts are essential prerequisites to the opening up of new areas for trade and development. Outstanding examples of this fact are the Philippines and Alaska. When the United States assumed stewardship over the Philippines in 1898, there were very few charts of the islands. The Coast Survey began work at once, and when the islands were granted complete independence in 1946 a series of 165 charts were available. The growth to economic, as well as political, independence was fostered by the commerce made possible by nautical charts.

The labyrinths of southeast Alaska were similarly opened up by nautical charts. These deep-water channels are infested with pinnacle rocks. In order that mariners could be assured that no danger had been missed by leadsmen, a complete wire-drag survey was made of all the principal channels.

When Fathometers and radio acoustic ranging were developed after World War I, the survey ships were able to extend their operations farther seaward. The general belief that the great ocean floors were flat was quickly disproved. One of the major accomplishments was a detailed survey of Georges Bank--a vast shoal area east of Cape Cod. A fleet of four survey vessels was engaged in this work from 1930 to 1932. The surveys were extended to the continental shelf, where a number of canyons were discovered. In later years, as the work was extended southward to Chesapeake Bay, other great canyons were discovered, the most spectacular being the Hudson River gorge.

Detailed hydrographic surveys along the coasts of Louisiana and Texas disclosed underwater domes which lead to the search for and development of the offshore oil deposits. Since World War II, the northern portion of Alaska has become of great strategic importance. A search for oil reserves in the northern plains contributed to the need for charts. Shore-based units carried on combined operations on the Arctic coast from 1946 to 1952 to provide charts for resupply expeditions. Some of the methods used have been previously described in this Journal.

FOUR-YEAR PROGRAM, 1957-1960

One major and six minor vessels are now in operation on the Atlantic and Gulf coasts. Surveys are planned for the coast of Maine, Georges Bank, vicinity of Nantucket Island, Narragansett Bay, Chesapeake Bay, Florida Straits, west coast of Florida, and Gulf of Mexico. Three vessels, the ***Parker***, ***Bowen***, and ***Stirni***, are being retired from service. Wire-drag work to locate wrecks between Cape Hatteras and Cape Canaveral will be deferred until these vessels can be replaced.

One small vessel will continue surveys in the San Juan Island and Puget Sound areas. A shore-based party operating on the west coast will finish projected work plans in 1957. One ship will continue surveys in the Aleutian Islands and should complete this project in the next 3 to 4 years. Surveys on the north side of the Alaska Peninsula will be continued. Three minor vessels will be engaged in survey operations in Prince William Sound and southeast Alaska. The ***Pioneer*** is at the disposal of the Navy and will continue operating under plans originating in the Navy.

FUTURE PROGRAM

There has been a periodic repetition of the question first posed in 1818--"When will the survey of the coast be completed?" After nearly 150 years of hydrographic surveying, there are still thousands of square miles of unsurveyed areas, particularly in Alaska. The adoption of the echo sounder as an aid to navigation made it necessary to resurvey vast areas previously considered adequately surveyed. Many areas on the Atlantic and Gulf coasts must be resurveyed periodically to chart the changes in shoreline, channels, and shoals which occur naturally, or are caused by human interference with natural conditions.

The survey fleet has been gradually reduced from 8 to 4 major units. A number of smaller vessels placed in service after World War II are rapidly becoming obsolete; in fact, 4 such vessels have been retired. The fleet now consists of 4 major and 10 minor vessels. A 10-year replacement program has been proposed to provide a fleet of 7 major and 10 auxiliary vessels. If this program is carried out, it is believed that the present survey program can be completed in approximately 25 years.

The introduction of echo sounders and electronic-positioning devices has greatly increased the rate of production of completed hydrographic surveys. Survey sheet No. 5000 was registered in 1930, almost 100 years after the first survey was made. As of January 1957, there are over 8,300 surveys. Further increase in productivity can be expected as modern survey vessels join the fleet. Advances in survey techniques have created major problems in processing field data and publication of new material. New methods and procedures must be devised to keep pace with survey production.

No one can tell what future chart requirements will be. Ships are being built which will draw 60 feet; oil wells are being drilled in deep water; nuclear-powered submarines have requirements differing from previous models; the fishing fleet is becoming more exacting in its demands; electronic aids to navigation permit more accurate positioning of vessels in offshore areas; and military requirements continue to grow. As the science of oceanography grows and the world's population increases, there is no doubt that man will turn more and more to the sea as a source of raw materials.

The hydrographic work of the Coast Survey is thus a never-ending job. It is probable that future years may see a diminution of the work, but chart-maintenance surveys will be required as long as currents flow, storms beat on the coast, and man continues the development of the ocean shores.

Ship ***Pathfinder***, a modern survey vessel.

Stereotriangulation Adjustment

G. C. TEWINKEL, Photogrammetric Engineer
U. S. Coast and Geodetic Survey

STEREOTRIANGULATION or bridging in photogrammetric mapping is the technique of operating where only a relatively sparse distribution of images of known horizontal and/or vertical position exist. In the simplest application of topographic mapping by means of aerial photography, two overlapping photographs are oriented in a stereoscopic plotting instrument so that the common area forms a three-dimensional model which agrees with at least two plotted horizontal control points in azimuth and scale, and with at least three vertical control points insofar as levels are concerned. Thereafter all the topographic information, including contour lines and spot elevations, is compiled on a drafting medium with a known degree of accuracy.

Inasmuch as the next model is composed of the unused portion of one of the photographs which is already oriented to fit control, the detail of the second model can be compiled to agree with the first one in azimuth, scale, and level without any additional ground data. Moreover, succeeding models can be attached in the same manner *ad infinitum*. If further ground control points are eventually encountered, it is reasonable to expect that an error of closure will be present. This discussion treats of an appropriate method of adjusting all intervening photogrammetric positions and elevations in accordance with the errors of closure.

GENERAL APPLICATION

In this application, the instrument consists of a first-order stereoscopic plotting device, such as the Zeiss stereoplanigraph C-5 or C-8, with which it is possible to record the instrumental coordinates in three dimensions to the nearest 0.01 mm. for any image, as well as to plot the position graphically on a map sheet. The map details and contour lines are compiled at a later time by instruments of lower order to fit the adjusted image positions that are obtained originally from the stereoplanigraph. To make the system flexible, it has been found unnecessary to specify the exact location of the control, other than its general distribution throughout the flight strip, without any concentration in any model.

The specific application consists of small-scale 1:200,000 mapping from 1:60,000 photographs, with a manuscript scale of 1:30,000. Many of the bridges are 40 photographs in length. Thus, each photograph shows an area 8.5 miles square, the distance between photographs is 4.2 miles, and a 40-model bridge spans 168 miles. The minimum quantity of control required to maintain the specified accuracy is approximately 1 horizontal station every 10th photograph and a pair of vertical stations on opposite sides of the flight line in every 8th photograph. It is also required that 4 or 5 horizontal points and 4 or 5 pairs of vertical points be present in each strip, as 3 points do not furnish a check on the operation. This control is required only in alternate strips as the other strips are oriented by the detailing instruments to fit common points on the 2 sides without a separate bridging operation. This control arrangement ordinarily allows the use of existing primary triangulation and level nets. In practice, it has been necessary to establish no new horizontal points, and only a relatively few elevations in the immediate vicinity of existing level lines. All control requires identification on the photographs in the field.

The adjustment of the values of the instrument coordinates to fit control consists of two principal phases: (1) a linear transformation by an International Business Machines (IBM) automatic calculator to agree with values near the ends of the strip; and (2) a graphic analysis of the residual discrepancies which become evident after the IBM step. The method of solution of the former phase and the use of IBM is believed to be unique with this Bureau. The second phase is a direct adaptation of the graphic practice developed by the Army Map Service (AMS).[1] The contribution of the Coast and Geodetic Survey probably lies in the utilization of a moderately priced automatic calculator which is used primarily for other Bureau activities, such as geodesy, into which the photogrammetric operations have been programmed with little or no interruption of schedule.

ORDER OF OPERATIONS

As scant vertical control exists in the mapping area, the first pair of photographs is horizontalized with a shop level after which the cus-

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[1] The AMS also utilizes a method which combines the two phases into a single UNIVAC computation that includes the application of least squares.

tomary visual routine of relative orientation by successive approximations is employed. The model is only approximately scaled to agree with other photography of the area, or with the reported flight altitude.

The first pair of a strip are placed in the instrument in such manner that the progress is eastward or northward which, for convenience, allows the instrument coordinates to increase in the same directions as the ground coordinate system--the Universal Transverse Mercator (UTM).

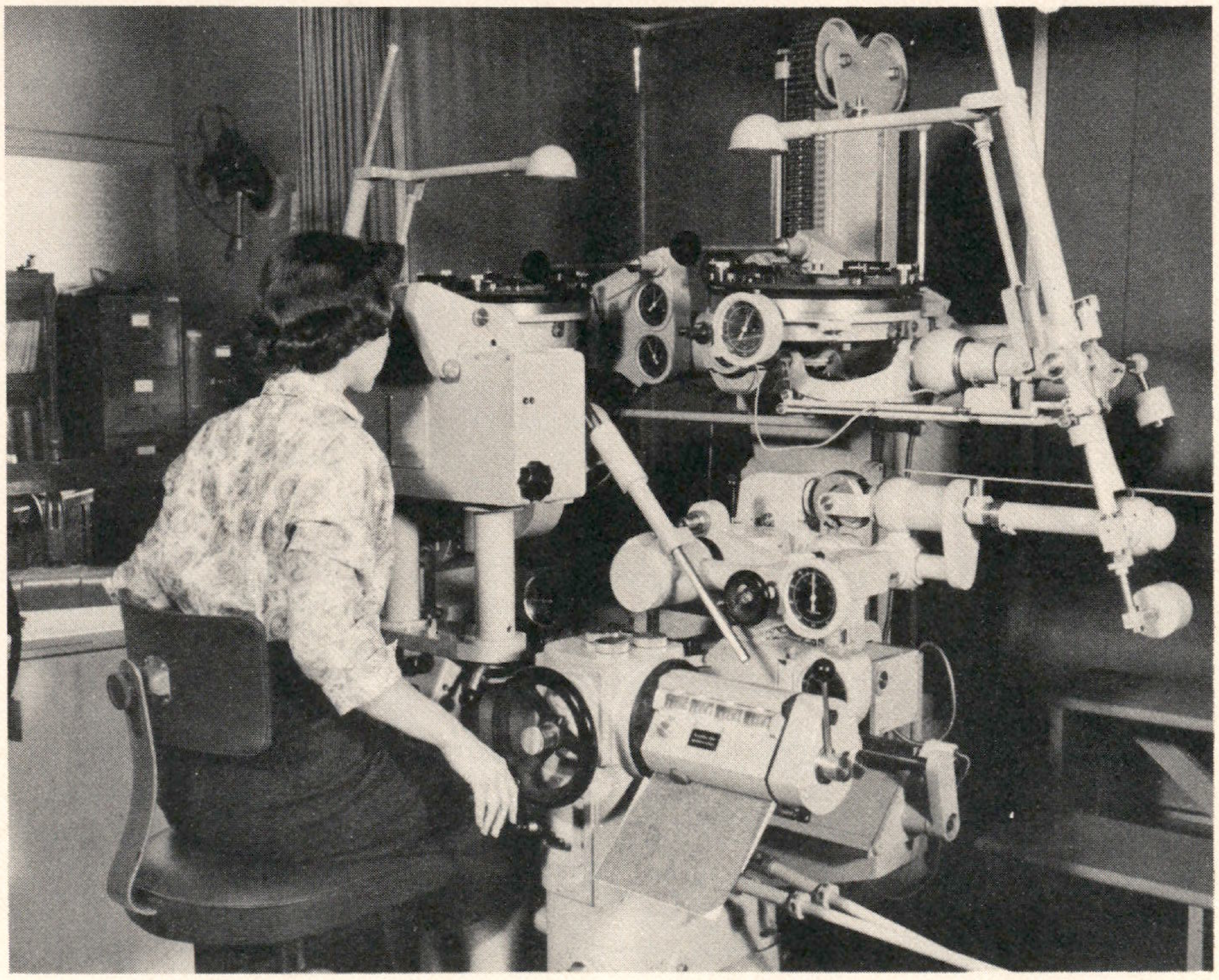
The instrument dials are set so that the initial longitudinal coordinates are near zero, and also so that the transverse coordinates are zero on or near the flight lines. The *x* and *y* notations are reversed if necessary to agree with the ground coordinate system. These items are merely expedients which tend to simplify the system in the minds of the operators and reduce the frequency of large arithmetical mistakes.

After the orientation of the first model is complete and the coordinates of the necessary points are recorded, the first plate is removed and the third one is put in its place. The stereoscopic model can be seen by a convenient reversal of the optical system and a change from the ***base-in*** to the ***base-out*** condition. The third plate is then oriented relative to the second without disturbing the position or orientation of the second, using the customary *BY-BZ* method. The scale or base is adjusted until the elevation of a point near the center of the second photograph is equal to that obtained in the first model. The elevations of the outer points are also observed and adjusted if necessary by minute changes in orientation until a general agreement is obtained. This completes the connection of a photograph to the existing system, adding, as it were, another link to a rigid chain of tetrahedrons.

The *x*, *y*, and *z* coordinates of at least 6 points in each model are recorded. These include the side pass points and images near the principal points. They are selected and carefully identified on contact prints of the photographs for the subsequent use of the compilers. An additional set of side points is selected, if they are needed to supply the corners of the models on adjacent strips. This occurs frequently where the photo centers of two strips do not lie directly opposite one another. Horizontal and vertical control points are recorded in the same manner as the pass points, no effort being made to fit to them at this stage.

In addition to recording the coordinates of all the points, their positions are also located or plotted on tracing paper or vellum as a graphic record. The vellum consists of a long roll, accommodating the entire strip on one sheet. Any convenient scale is selected for plotting as it need not be that of the photograph or of the compilation. The principal use of the graphic record is the analysis of systematic errors.

The constants of the transformation equations are determined by desk calculator based on the



The Zeiss Stereoplanigraph C-8 is used for stereo-triangulation and for map compilation from aerial photographs.

instrumental and geodetic coordinates of control points near the ends of the strip. The constants are also applied to all the other control points of the strip by desk calculator to check the numerical operations and to yield the data for plotting the correction curves. Ordinarily, the instrument coordinates for each point observed are punched on a regular IBM card, and the constants punched on a master card. The cards are put through the IBM calculator and through the tabulator which prints the transformed coordinates--the *X*'s and *Y*'s in meters on the UTM system and *Z*'s (elevations) in feet. A set of wired panels are kept for this work.

The tracing-paper record is laid on a table, 24 feet long, which has been covered with cross section paper having 10 divisions per inch. The differences (closures) between the IBM and the geodetic values are plotted as ordinates opposite the graphic location of the control stations and smooth curves drawn connecting corresponding points. The corrections to the IBM values for any other point are read from the curves passing opposite the point, and added or subtracted as indicated.

The adjusted values are then plotted with a Haag-Streit coordinatograph on appropriate sheets or grids for compilation with multiplex or Kelsh plotters.

THE NUMERICAL TRANSFORMATION

As insufficient control will occur in the first instrumental model for complete absolute orientation, it is evident that (1) the scale of the model will not be known exactly, (2) the geographic direction will not be known for any line, and (3) the reference plane of the instrument will not represent a horizontal datum plane. Consequently, the entire strip will be propagated at an unknown scale, in some unknown northerly or easterly direction, inclined slightly upward or downward and toward the right or left. As the strip progresses, a sufficient number of control points will be encountered and observed so that all the unknown elements can be rigidly determined and corresponding corrections applied. The mathematical process for changing the observed instrument coordinates into corresponding corrected or oriented ground coordinates is called a *transformation*.

The transformation employed here is purely linear, derived to fit control near the ends of the strip.

The complete transformation is represented by the equations

$$X=ax-by+c \tag{1}$$

$$Y=bx+ay+d \tag{2}$$

$$Z=e(x-x_3)+f(y-y_3)+gz+h \tag{3}$$

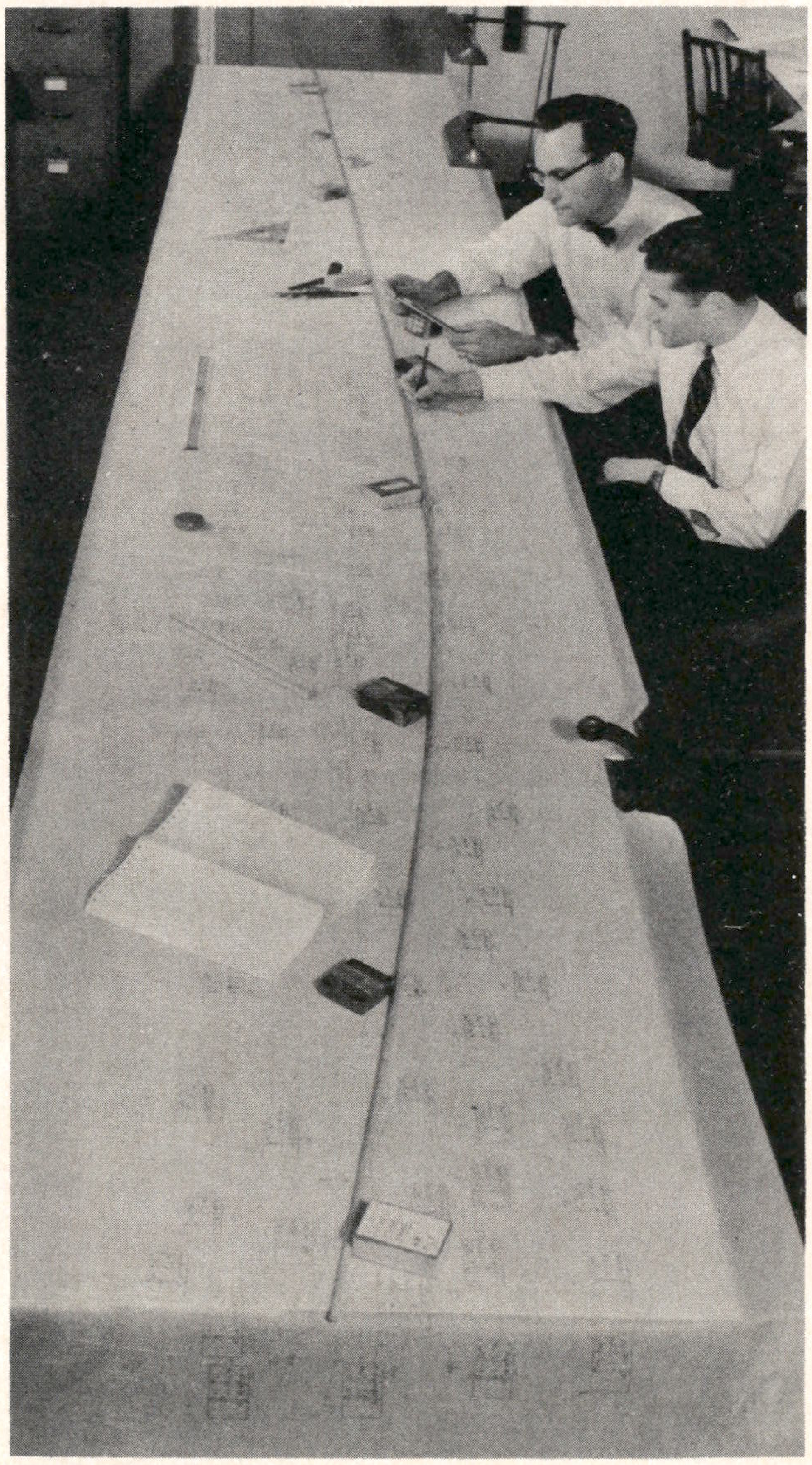
The values of the constants for the horizontal coordinates are given by the equations

$$a=\frac{(X_1-X_2)(x_1-x_2)+(Y_1-Y_2)(y_1-y_2)}{(x_1-x_2)^2+(y_1-y_2)^2} \tag{4}$$

$$b=\frac{(x_1-x_2)(Y_1-Y_2)-(y_1-y_2)(X_1-X_2)}{(x_1-x_2)^2+(y_1-y_2)^2} \tag{5}$$

$$c=X_1-ax_1+by_1 \tag{6}$$

$$d=Y_1-bx_1-ay_1 \tag{7}$$



LAYOUT TABLE FOR THE GRAPHIC ADJUSTMENT

Items of particular interest include the graphic stereoplanigraph record on the long sheet of tracing paper, the fiberglass rod, the printed calculation forms stamped beside the image points, and the IBM record to which the adjustment values are applied.

The constants, *e, f, g, h,* for the vertical equation (3) are derived from the following equations from three vertical control points, which are presumably different points (but not necessarily) than those used in the horizontal phase:

$$e=\frac{k_4(y_5-y_3)-k_5(y_4-y_3)}{(x_4-x_3)(y_5-y_3)-(x_5-x_3)(y_4-y_3)} \qquad (8)$$

$$f=\frac{k_5(x_4-x_3)-k_4(x_5-x_3)}{(x_4-x_3)(y_5-y_3)-(x_5-x_3)(y_4-y_3)} \qquad (9)$$

$$g=3.2808(a^2+b^2)^{1/2} \qquad (10)$$

$$h=Z_3-gz_3 \qquad (11)$$

where,

$$k_4=Z_4-gz_4-h \qquad (12)$$

$$k_5=Z_5-gz_5-h \qquad (13)$$

The subscripts refer to the number of the control points used, presumably five in all, consisting of two horizontal and three vertical. Vertical control point number 3 is supposedly near one end of the strip, and points 4 and 5 are on opposite sides of the strip at the other end. *X* and *Y* are used to indicate the UTM ground coordinates of the horizontal control stations in meters, and *Z* represents the elevation above sea level in feet; the lower case letters, *x, y,* and *z* represent the instrument coordinates in millimeters. If *X* and *Y* are in units other than meters, then the factor 3.2808 in equation (10) must be changed accordingly.

As a check on the computation of the constants, the transformation is applied to all the control in the strip by desk calculator. The values of the discrepancies between ground and transformed coordinates should form smooth progressions becoming zero at both ends. This condition can usually be verified by scanning the results.

GRAPHIC ANALYSIS OF SYSTEMATIC ERRORS[2]

Inasmuch as the numerical transformation is based only on control near the ends of the strip, the graphic corrections are based on the discrepancies between the computed and the ground surveyed values for all the intervening control points.

A photogrammetric bridge is considered to be an interconnected chain of solid geometric figures. In any such system it is realized that unavoidable, repeated, instrumental errors will cause the chain to deviate gradually from its intended straight course in several ways: (1) by increasing or decreasing in size or scale from photograph to photograph, (2) by curving to the right or to the left, (3) by bowing upward or downward, and (4) by twisting clockwise or counter clockwise like a screw thread. Moreover, it is realized that these deviations occur in a smooth, or gradual, unabrupt manner.

In practice, therefore, curves are constructed on the graphic vellum record, connecting points whose ordinates represent the residual errors. Because of the nature of the numerical transformations, the curves pass through the zero points in the terminal control areas. The curves are actually constructed by using a flexible spline.

Six separate curves[3] are constructed showing:

(1) Scale, or correction in *x*.
(2) Bearing (azimuth), or correction in *y*.
(3) Elevation, or correction in *z*.
(4) *Y*-scale, a secondary element of the *x*-scale error affecting the *y* coordinates.
(5) Swing, a secondary element of the horizontal bow affecting the *x* coordinates.
(6) Twist, applied to the *z* coordinates of all points not on the centerline.

The first three curves are considered to be quadratic, whereas the last three are regarded as linear.

The literature[4] indicates that the first or *x*-scale curve is actually cubic rather than quadratic, whence the fourth curve is theoretically quadratic rather than linear. The method of constructing the curves eliminates the requirements for this distinction as no attempt is made to form the curves as purely second degree or exactly straight. Instead, the curves are drawn to fit most nearly all the points of the strip without undue strain or abrupt bending.

It can be shown that the fourth correction is the first derivative of the first curve and the fifth correction is the first derivative of the second. Thus, once the first and second curves are constructed, the value for the fourth and fifth at any point is the slope of the first and second. The value can be measured readily with a scale and plotted directly. The total correction in *X* is the algebraic sum of (1) and (5); that for *Y* is the sum of (2) and (4); and that for *Z* is the sum of (3) and (6). The data for the construction of (6) are obtained from the discrepancies of

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[2] Discussed also in "Photogrammetric Surveys for Nautical Charts," by Bennett G. Jones, in *The International Hydrographic Review*, November 1955.

[3] Two additional minor types of systematic deviations include: (a) the effect of the vertical deviation on the orthogonal projection of the horizontal coordinates, and (b) the small differences in elevation usually evident for the common points of two adjacent models.

[4] See also "Some Theoretical and Practical Problems in Photogrammetric Bridging," by Dr. J. M. Zarzycki in *Photogrammetric Engineering*, December 1955.

elevations of pairs of points on opposite sides of the strip.

Curves (4), (5), and (6) are "rate" curves which indicate for each point a factor which must be multiplied by the distance the point lies off the flight axis. The corrections derived from these curves are normally only about one-fifth the size of the first three corrections.

In practice, the cross-section paper, which can be seen through the vellum, forms the basis for plotting the discrepancies and constructing the curves. The various corrections are noted and added algebraically alongside the graphic location of the point itself, from whence the sum is added to the tabulated values obtained by the IBM.

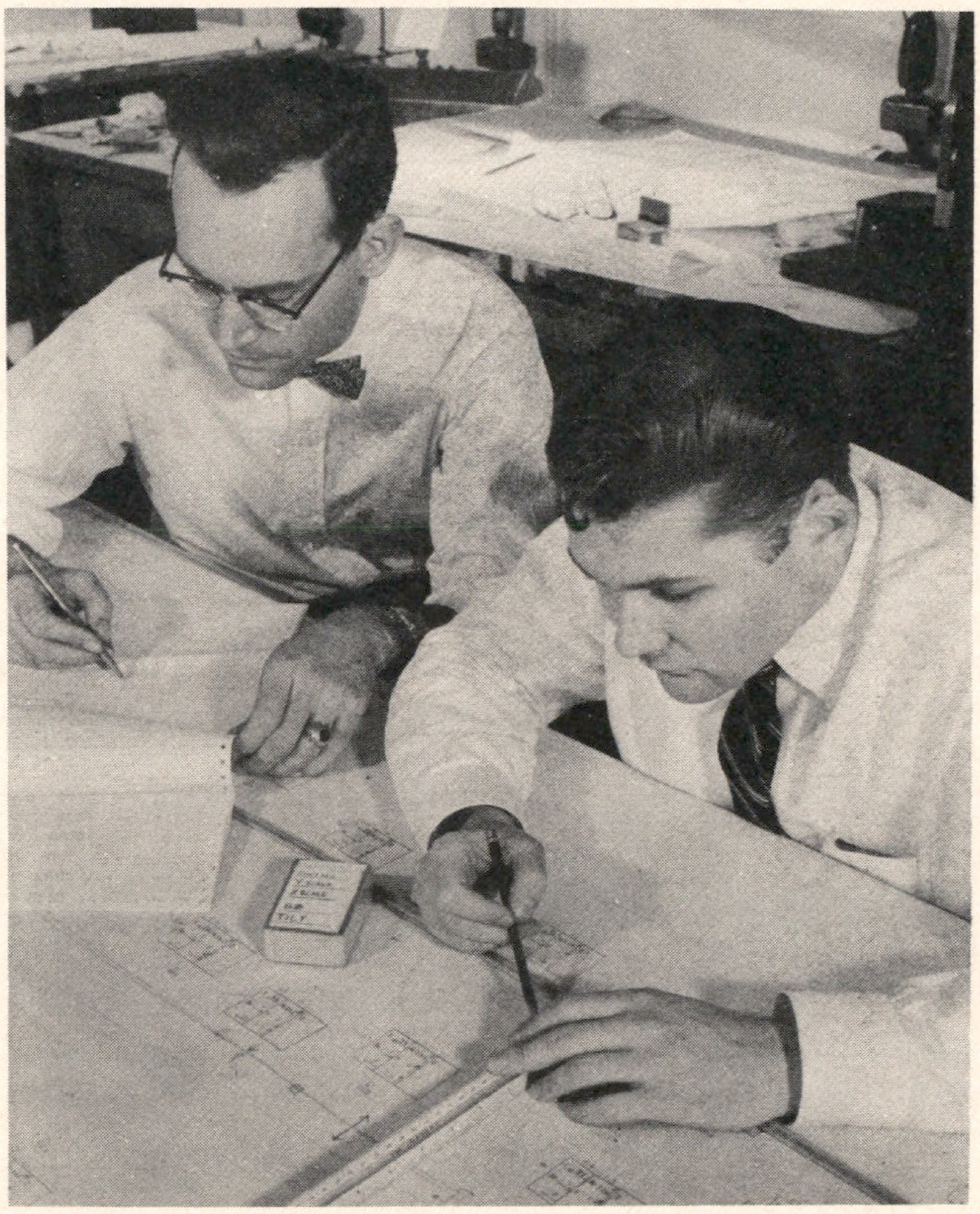
RESULTS

The accuracy of the results is indicated only in a relative way by the residual differences occurring between corrected instrument values and known survey coordinates of control points, and also by the failure of smooth curves to pass through all the ordinates. The differences have been sufficiently small to warrant no hesitation in mapping at 1:200,000. In the few instances where extra control existed, the errors have been remarkably small. Moreover, in every instance where the graph did not form a smooth curve of normal magnitude, the cause was later determined to be due to human errors, such as the misidentification of control, and was never due to the photogrammetric procedure, the instrument, or the method of adjustment.

As an example, one exceptional strip showed a maximum residual error of 5 meters horizontally and 5 feet vertically, although the graphic corrections were 270 meters and 2,470 feet, respectively. Another more typical example showed maximum residuals of 10 meters and 20 feet where the maximum corrections were 21 meters and 1,300 feet. Although extensive data are not yet available as to the absolute error, these values indicate the validity of the assumption of the systematic and regular nature of the discrepancies.

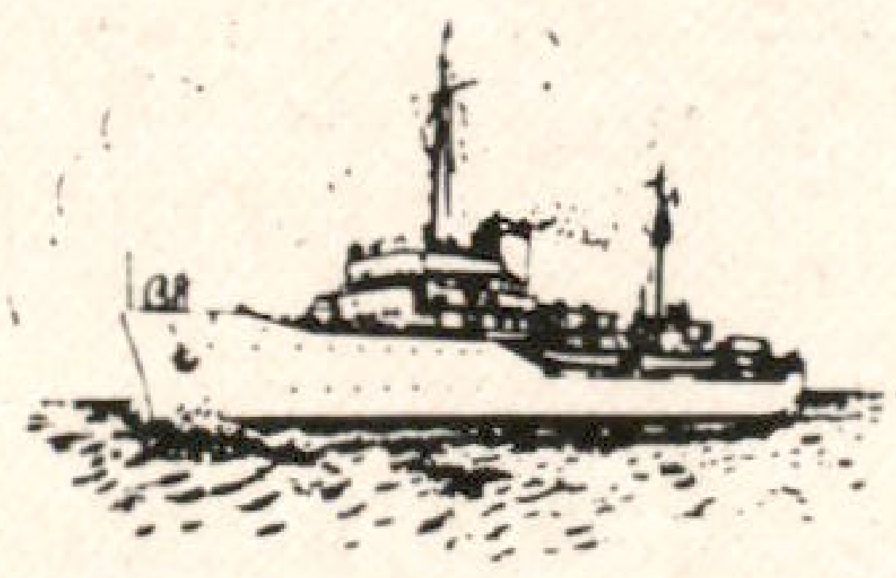
The system has not yet been applied broadly to large-scale mapping, but several projects have been planned to utilize the principles of stereotriangulation adjustment within the next year, one of them having already been started. It is recognized that the accuracy requirements for the larger-scale mapping are more exacting than for the small-scale maps, which we have produced thus far. Inasmuch as the Bureau does its own photography, the flight altitude and the flight lines are designed to be consistent with accuracy requirements. By utilizing ample existing control in the first model, if it is available, the numerical transformation is not required, thus simplifying the adjustment procedure. Accuracy can be improved further by employing an appropriate system of numerical relative orientation, which has not been seriously attempted in this office.

The bridging techniques which were formerly used have been significantly improved by the experience gained with the small-scale mapping. The bridges may now contain more photographs than formerly; the amount of ground control can be reduced; the distribution of control can be more haphazard; and yet equal, or even higher, accuracy can be maintained.



CLOSEUP VIEW OF THE GRAPHIC ADJUSTMENT

Note the IBM record on left to which the graphic adjustment values are applied.



ER-Type Raydist System of Position Control

IN MANY AREAS, not too far from shore, it is difficult to determine the position of the survey vessel by visual means, nor are electronic means, such as shoran, sufficiently accurate for the large-scale surveys in these areas. The west coast of Florida, for example, has many miles of coastline so low that shore signals only a few miles off cannot be distinguished.

For some time, the Coast and Geodetic Survey had been following the commercial development of various phase-comparison, survey-navigation systems, one of which is known as Raydist. This system is capable of outstanding accuracy at moderate ranges. One of the outbranches of this development, an ER-type Raydist, appeared to be quite adaptable to hydrographic surveys. The Coast Survey decided that only by its use on an actual hydrographic survey could this system be properly evaluated. Arrangements were made to rent this equipment for 3 months. After the company technicians put the system in operation, the Coast Survey took over its operation and studied the system.

Due to the importance of phase-comparison systems to precision navigation, Part I of this article describes phase-comparison systems in general and the technical aspects of the ER Raydist in particular. Part II describes the actual tests and their results.

(This article is an objective appraisal of the ER-type Raydist system as used on a hydrographic survey project. It is not intended as an endorsement of this system of position determination over any other electronic system.)

Part I—Technical Aspects of Phase Comparison Navigation Systems

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U. S. Coast and Geodetic Survey

The ER-type Raydist is a phase-comparison electronic-navigation system employing two shore stations from which a ship, electronically equipped, can position itself. Shore stations are located on the beach as close to the water's edge as possible to assure strong signals on the ship. They are placed 5 to 10 miles apart, and it is desirable to have a fairly clear path between them. The placing of the shore stations depends on the strength of the control in the area to be surveyed. Unlike shoran, Raydist is not seriously dependent upon antenna height for strong offshore signals.

Shore station units are so cased that they may be exposed to the weather and are only housed to prevent molestation. Following the initial adjustment, the equipment is self-operating for the remainder of the project. When using a dependable power supply, the shore stations may be unattended and need not be visited for long periods.

While the shore station antenna system is complicated, requiring several antennas and a ground plane, the actual time of its installation is no longer than that required to set up a shoran station. However, as there is less need to elevate the antennas, Raydist installation may be simpler, especially when shoran instruments must be transported to high ground.

Raydist ship-equipment is comprised of a transmitter, three receivers, and the indicating device or phasemeters. Four antennas are required on the ship. The equipment is packaged in several containers that may be located in different parts of the vessel. Their volume, weight, and complexity slightly exceed those of shoran, but the installation is not significantly more difficult. Like the shore station, no instrumental adjustment is necessary after installation adjustment. No special skill is required in reading the phasemeter; it is as simple as reading a clock. It is difficult, however, for one person to read the two phasemeters when the craft is moving fast while on certain courses.

The plotting of fixes is similar to shoran, but the distance circles are numbered in lanes to correspond with the phasemeter scale. Before plotting the fix from one of the stations, it is necessary to make a simple computation using the readings from both phasemeters. The distance from

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the other station is read directly from the phasemeter.

The range and area coverage of this system is more a function of the power of the transmitter than the elevation of the antenna systems. The ER Raydist used in these tests employed 10 w. transmitters. With such power, the day and night dependable range is 12 miles. Under favorable conditions of noise level, a distance of 16 miles is then considered a dependable range.

GENERAL CONSIDERATION OF ALL PHASE-COMPARISON SYSTEMS

The phase-comparison principles are important in navigation systems. They are inherently capable of a high degree of accuracy. Their signals occupy a comparatively small portion of the radio spectrum, therefore causing little interference to other services. Pulse systems occupy many times the radio space. Conversely, due to this narrow bandwidth, they are not as easily interferred with by either other radio signals or atmospheric static. Once started and adjusted, the system is self operating, no longer needing manual operation at either the ship or shore stations. No special operating skill is required.

These systems go by other names, the most common being the continuous-wave (CW) system. The better known have trade names of Decca, Raydist, and Lorac. Basically they resemble each other, but employ different techniques. None have any marked difference in the accuracy; however, in certain details, each has advantages over the others.

Phase-comparison systems transmit continuous waves which have a linear length in space. The counting of the number of wavelengths and fraction thereof makes it possible to measure distance over the surface of the earth. The actual phase measurement is made on a phasemeter, designed to make one dial rotation for each half wavelength (known as a lane) the vehicle traverses. As any half wavelength looks like the next to this meter, totalizing dials add or subtract the number of lanes traversed by the vessel, depending on its direction with respect to the shore station.

The entire area is covered by these phase patterns, or lanes, which are fixed in space. Navigation is accomplished by knowing the starting point and keeping track of the position by the readings of two phasemeters. Each meter keeps track of the lane count with respect to one shore station or pair of stations, and gives one line of position. Position data appear continuously; the vessel's position is fixed as fast as the phasemeters can be read and the positions plotted.

Two common types of phase-comparison systems are the hyperbolic and the range; the former is the more common of the two. Generally, hyperbolic systems employ three shore stations; the center one being the master, and outer stations the slaves. Each slave and the master station transmitters are either phase-locked or use some other device to keep their phase pattern fixed. The ship equipment is usually quite simple, requiring only the necessary receivers and phasemeters. The range system needs only two shore stations; the distance is measured directly from the ship to these stations. The ship also carries a transmitter in addition to the receivers and phasemeters. As such, it resembles the master station to which the two shore stations are slaved. The phase patterns appear concentric with the shore station. The ER Raydist is a variation on these two systems.

In many respects the phase-navigation system appears ideal, but certain shortcomings somewhat offset the many advantages. Prominent among these is the need to eliminate a possible ambiguous ship position by requiring a secondary means of fixing the position of the vessel. Or, before the hydrography can begin, the location of the ship must first be set into the phasemeters at a known position. After that, the electronic circuits will hold the positions as long as the ship remains within range of the shore stations. This requirement poses another problem: should power or equipment fail at any of the units of the system, or should there be sustained interference, the ship may lose its position and must return to a known point to reset the phasemeters. While this may occur infrequently, when it does, it causes considerable annoyance and loss of time to a survey unit.

Lane-identification can be added to phase systems which will make it possible to reset the phasemeters at any time; some of these lane-identification modifications are more successful than others--all are complicated. Lane-identification is prohibitive for the present survey-type systems, as more equipment, more frequencies, and additional shore stations are required. It is practical for general navigation systems. With lane-identification, the phase-comparison system has the same flexibility as the pulse systems, and some of the principal objections are removed.

When the signals between the ship and shore stations are entirely over salt water, free of large reflecting objects, and receiving the ground wave, all positions are essentially true and need no correction. On the other hand, when the signal path is over considerable land, or if large reflecting objects are near the ship or ground station, then the phase pattern is distorted and corrections must be applied for true positioning.

Also, in the fringe area, and more especially at night, a combination of the ground and sky waves can make navigation in distant areas impossible. Part II of this paper also illustrates how phase distortion, caused by the directivity of the antenna system, results in an error.

COMPARISON OF THE HYPERBOLIC SYSTEM WITH THE ER- OR SURVEY-TYPE RAYDIST

Much of the foregoing discussion considered the hyperbolic pattern, since that system is most common. The ER-type Raydist differs in many respects from the pure hyperbolic system although the phase-comparison principles hold exactly the same as the other systems.

The high degree of accuracy and other desirable features strongly indicate that a phase-comparison system fulfills many of the requirements of an electronic hydrographic survey system. As a survey instrument, hyperbolic systems have two objectional features: first, the difficulty of preparing the hyperbolic grids for the survey sheet. As surveys move along the coast or to new areas, new survey sheets are required and when the system is short based, a great many may be needed. Second, the conventional hyperbolic system, as used for navigation, requires at least three shore stations. This involves the expense of setting up the third station, and, in some cases, additional personnel to man it, plus the difficulty of procuring the additional station site. Sometimes it is impossible to locate three stations to give area coverage.

Two features in favor of the three-station hyperbolic system over the two-station arc or circular system are: first, the number of ship stations that can operate from the shore stations is not limited. Second, a transmitter is not needed on the ship, so the ship equipment is very

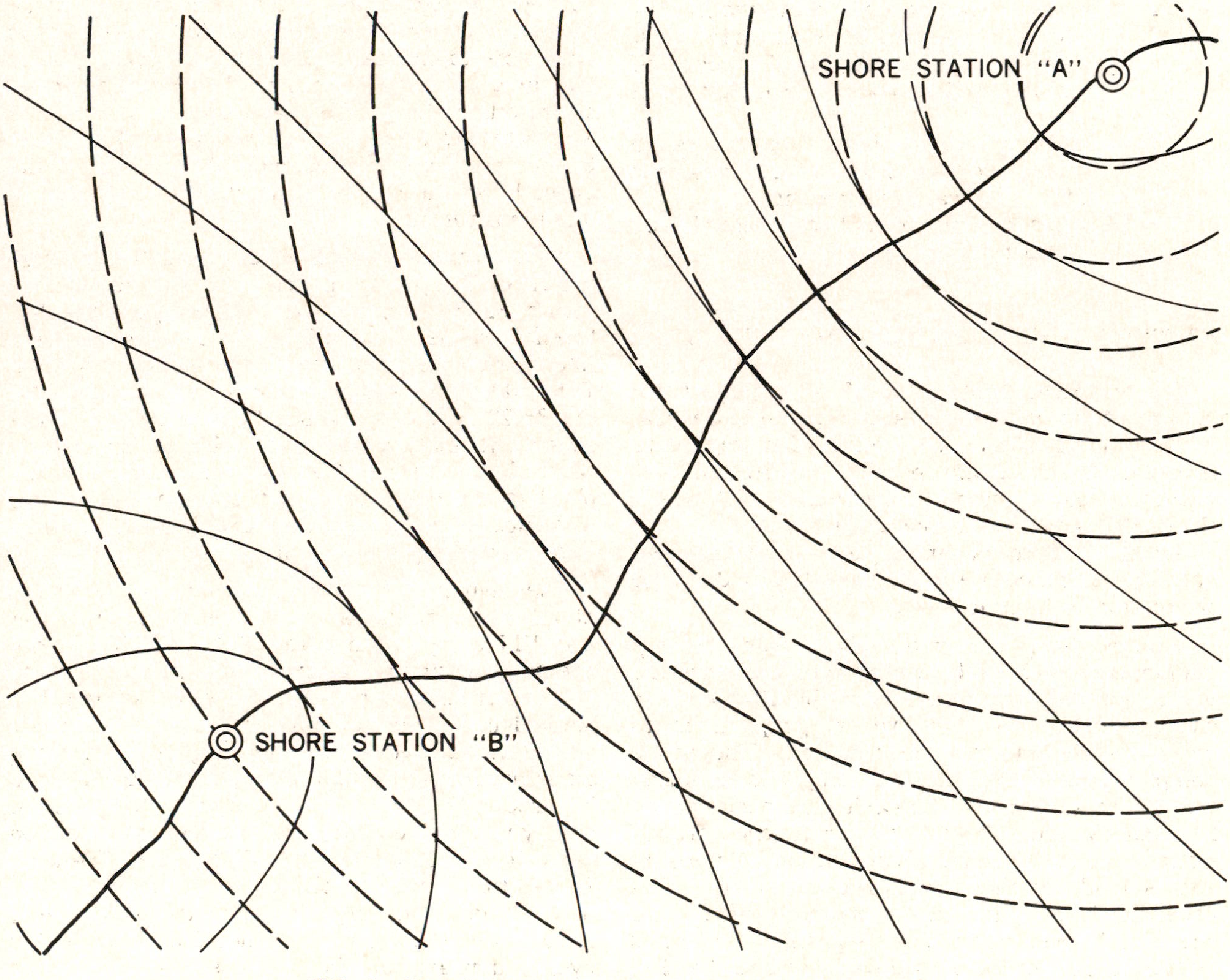

FIG. 1.--Hyperbolic grid superimposed on the circular grid.

simple and may be transported on the smallest vessels.

In order to create the ER-type Raydist system, some components of the standard Raydist navigation system were redesigned. By so doing, the objectional features characteristic of the hyperbolic systems were overcome. The ER Raydist requires only two shore stations and the phase-lane pattern is a range-hyperbolic system. Range part of the name implies that the ship measures its distance directly to one shore station, while the 2 shore stations acting together produce a hyperbolic phase-grid superimposed on the circular grid (*see* fig. 1). Range concentric circles from each shore station are drawn on the survey sheet; the hyperbolic grids are not used when surveying. The reading of the range phasemeter is plotted directly. To convert all hyperbolic dial readings to range readings for plotting, the following formula is used:

$$h = d + r - 2H$$

where h is the range distance from the hyperbolic shore station to the ship in lanes,
d is the computed distance between the range and hyperbolic shore stations in lanes,
r is the range distance from the range shore station to the ship in lanes read from the range phasedial,
H is the reading of the hyperbolic phasemeter.

ER-TYPE RAYDIST USED ON THE SHIP *SOSBEE*

The technical description of system operation is that of the equipment used on the ship *Sosbee*. This is particularly important with regard to lane widths, which are partly fixed by the frequency of the system's transmitters. Figure 2 shows this system schematically.

Briefly, the operation of the system to measure the distance between the ship and range shore station is as follows:

Assume the phase of the signal from the ship transmitter T-1 is known at both the ship and the range shore station. Then, the difference in phase at these two points will be proportional to the distance between these points. The phase comparisons at the ship and range shore station are accomplished by comparing the phase at the two points with respect to a reference transmitter T-2 at the range shore station. Comparison is made at the ship in receiver R-1, and in receiver R-2 at the range shore station. The phase difference between the signals T-1 and T-2 at the range station is relayed back to the ship through transmitter T-3 and receiver R-3, and thence to one side of the range phasemeter. The importance of this process is that there is no change in the comparative phase between the phase difference in T-1 and T-2 while being relayed back to the ship.

Now, consider the comparison of T-1 and T-2 on the ship. This phase-comparison value will differ from that at the shore station because T-1 signal must travel the distance to the shore station resulting in phase difference by reason of travel-time. The comparison between T-1 and T-2 at the ship is furnished to the other side of the range phasemeter; the difference between the phase on each side of this meter is a measure of distance between ship and range shore station.

On the ship, it should be noted in figure 2 that the signal from the range station transmitter T-2 on 4135.0 kc. is mixed in receiver R-1 with 4135.2 kc. signal from the ship transmitter T-1. The difference between these two signals will be 200 cycles in the output of receiver R-1. Any change in phase between these two signals will be represented by an identical change in phase of their difference frequency of 200 cycles. This 200-cycle signal is doubled to 400 cycles, to be the same as the frequency to which it is compared on the other side of the phasemeter. Transmitter T-1 radiated on 8270.4 kc.; the 4135.2 kc. signal for comparison in receiver R-1 is from the crystal oscillator that controls the frequency of this transmitter.

At the range receiver R-2, the 8270.4 kc. signal from T-1 is compared with the second harmonic 8270.0 kc. of T-2. Here again the difference frequency of 400 cycles carries the phase information between the two signals compared. This 400-cycle signal frequency modulates (FM) the 36.22 mc. transmitter T-3, which relays the phase information back to the ship receiver R-3. When demodulated, this 400-cycle signal is applied to the other side of the range phasemeter to compare with the phase of the signals discussed in the preceding paragraph.

The hyperbolic shore station is somewhat simpler. It contains only a relay receiver R-4 and FM relay transmitter T-4, and, in all respects, functions exactly as the relay receiver R-2 and transmitter T-3 in the range station. The ship signal from transmitter T-1 on a frequency of 8270.4 kc., along with the signal from range transmitter T-2 on 4135.0 kc., are received at the hyperbolic receiver R-4. This receiver has the ability to receive two signals at the same time on two different frequencies (4135.0 and 8270.4 kc.). Inside this receiver these two frequencies are heterodyne to nearly the same frequency, and, after detection, their difference frequency of 400 cycles appears at the receiver output. This 400-cycle difference frequency modulates the relay transmitter T-4, which transmits on 38.22 mc. to the ship receiver R-5. The demodulated 400-cycle frequency from this receiver is then applied to one side of the hyperbolic phasemeter. The 400-cycle frequency for the other side of the hyperbolic phasemeter is from the output of ship receiver R-1, produced from the beat of the 4135.2 kc. signal from the crystal oscillator of the ship transmitter T-1, and 4135.0 kc. from the reference transmitter T-2.

The hyperbolic phase difference is developed as follows: The 8270.4 kc. signal from ship transmitter T-1 travels to both the range and hyperbolic shore stations. The difference in phase, at the time this signal reaches these stations, will depend upon the differences in distance between the ship and these two shore stations. The method of resolving this phase difference at the two shore stations is by comparing the phase at these two stations with that of the reference transmitter. If this reference transmitter were located exactly halfway between the range and hyperbolic shore stations, the signal from this transmitter will have exactly the same phase at these two stations. Then the phase difference of the ship signal and the reference signal at the two shore stations is also the difference in distance the ship signal must travel in reaching these two stations. As discussed earlier, this phase difference is relayed back to the ship by relay circuits at each shore station and is presented on the hyperbolic phasemeter. The actual reference transmitter is T-2,

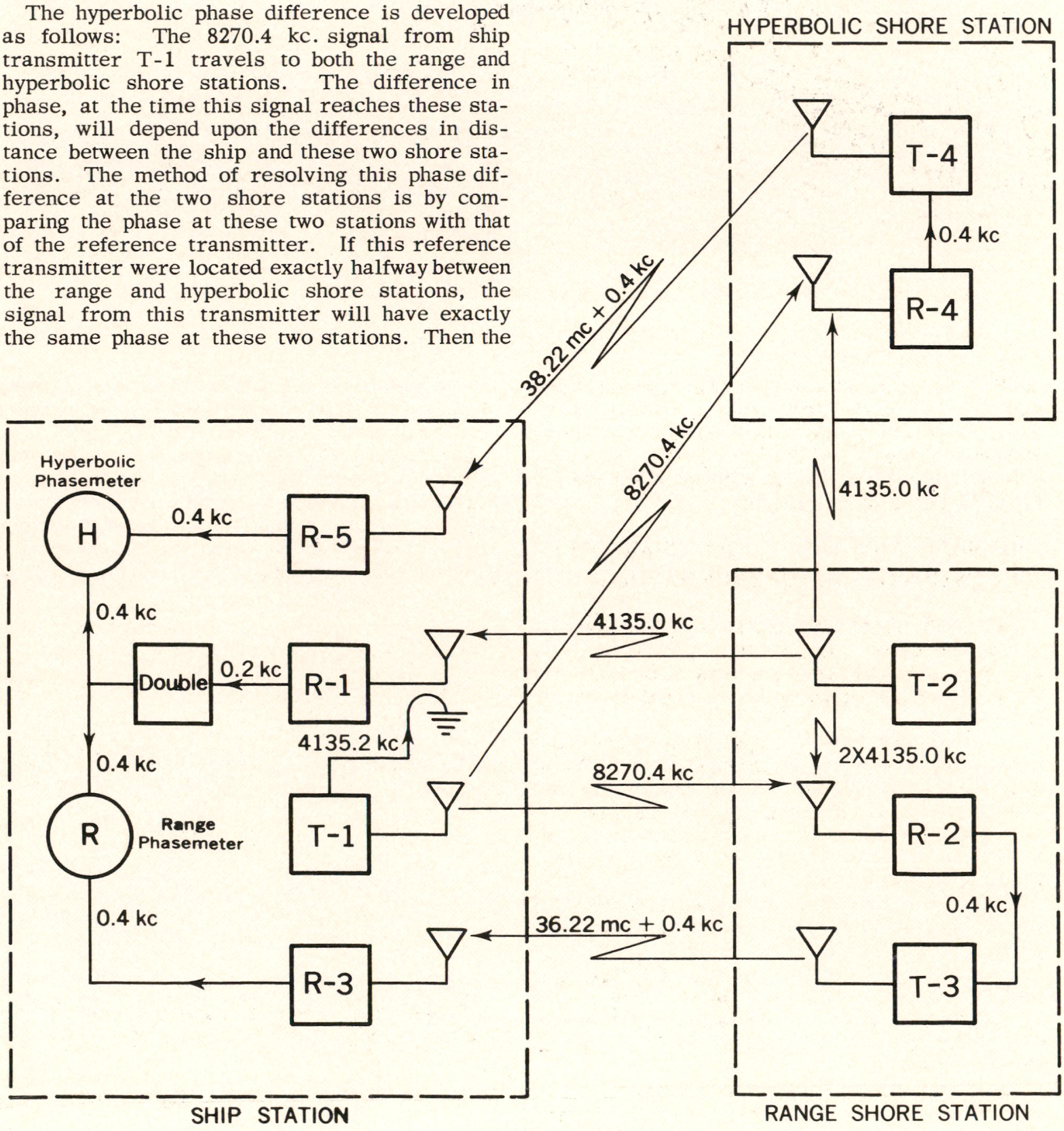

FIG. 2.--Diagram of ER-type Raydist system.

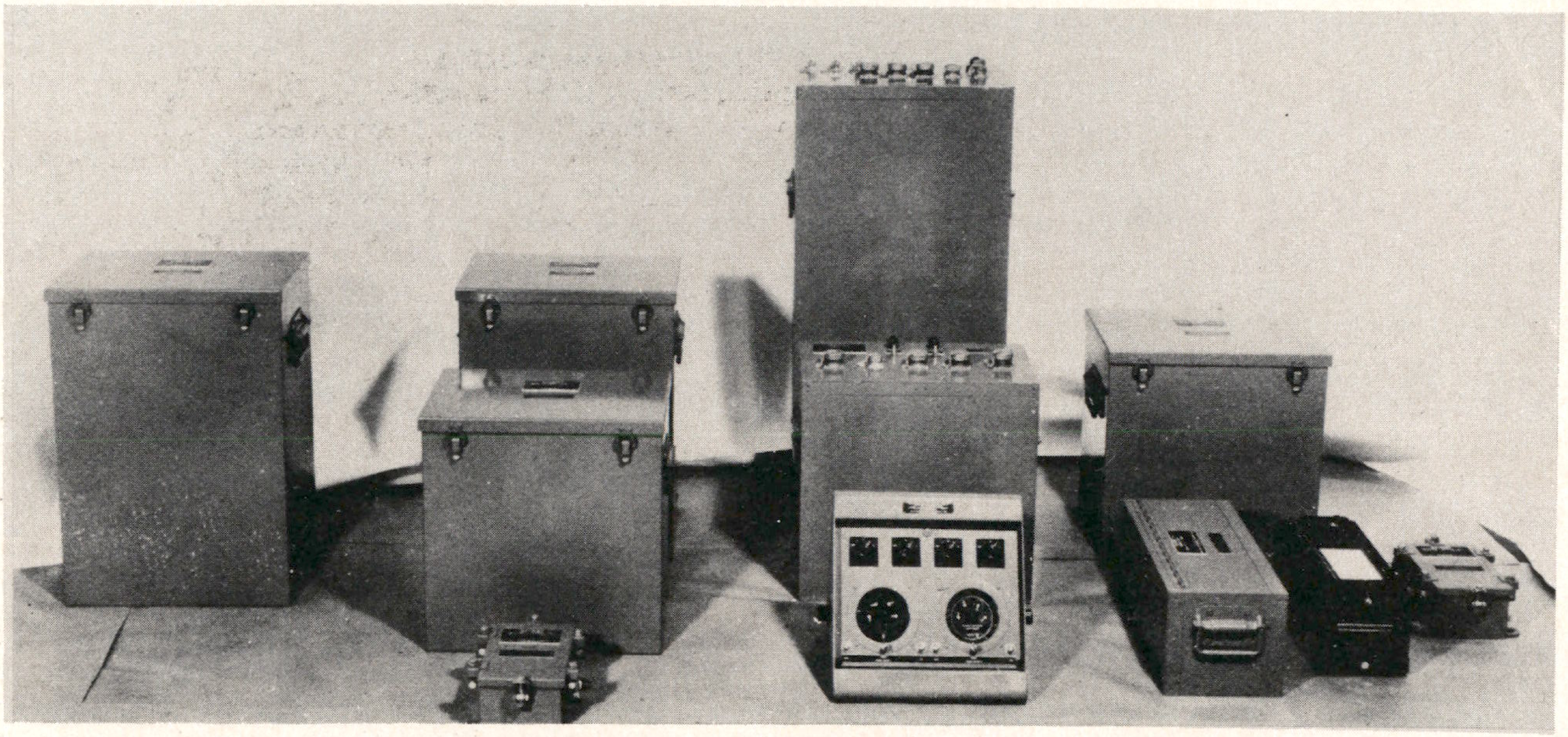

FIG. 3.--Complete electronic equipment for ER-type Raydist except antennas.

and is not located at the midpoint between the shore stations, but at the range station instead. However, since the distance between the two shore stations is known and fixed in length, the effect will be the same when allowances are made for the differences in path length.

PHYSICAL AND ELECTRICAL CHARACTERISTICS OF THE ER-TYPE RAYDIST

Figure 3 shows the entire ER-type Raydist equipment except the power supplies, antenna systems, and instrument shelters. No single unit is so large that it cannot be carried by one or two men.

The maximum power required to operate the shore station is 500 w. at 115 v., 60 cycles. While this may be furnished from a gasoline-driven generator, more satisfactory results are obtained when dependable commercial power is used. Power for the ship equipment is from a 3-kw., gasoline-driven generator.

Four Raydist antennas are needed on the ship, two 35-foot Premax whips, and two 12-foot dipoles used for the FM relay circuits. While it is not necessary to elevate the whip antennas, the dipoles should be as high on the ship as its structure will permit. Elevation of these antennas is not as important as the elevation of shoran antennas.

The range station antennas require two 35-foot Premax whip antennas, separated by 5 feet (fig. 4). A 12-foot dipole is mounted 40 feet away from the whip antennas. A ground plane, required for the whip antennas, is made by laying out twelve 30-foot radials of chicken wire fencing, with the center between the whip antennas.

The hyperbolic shore station has one whip antenna and one dipole antenna spaced 40 feet apart. The whip antenna requires a ground plane similar to the range station ground system.

All transmitters are rated at 10 w. Automatic gain controls compensate for changes of signal

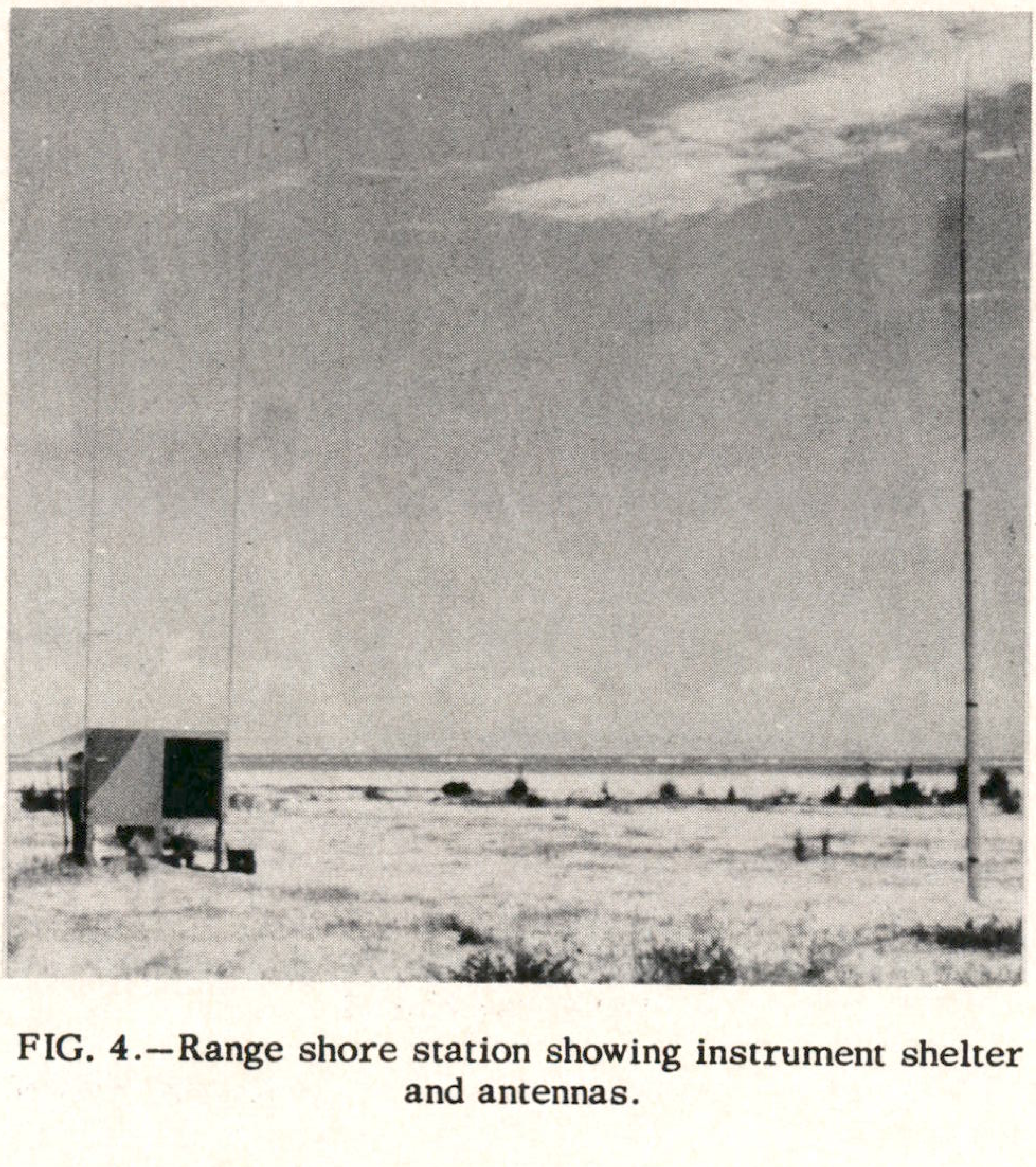

FIG. 4.—Range shore station showing instrument shelter and antennas.

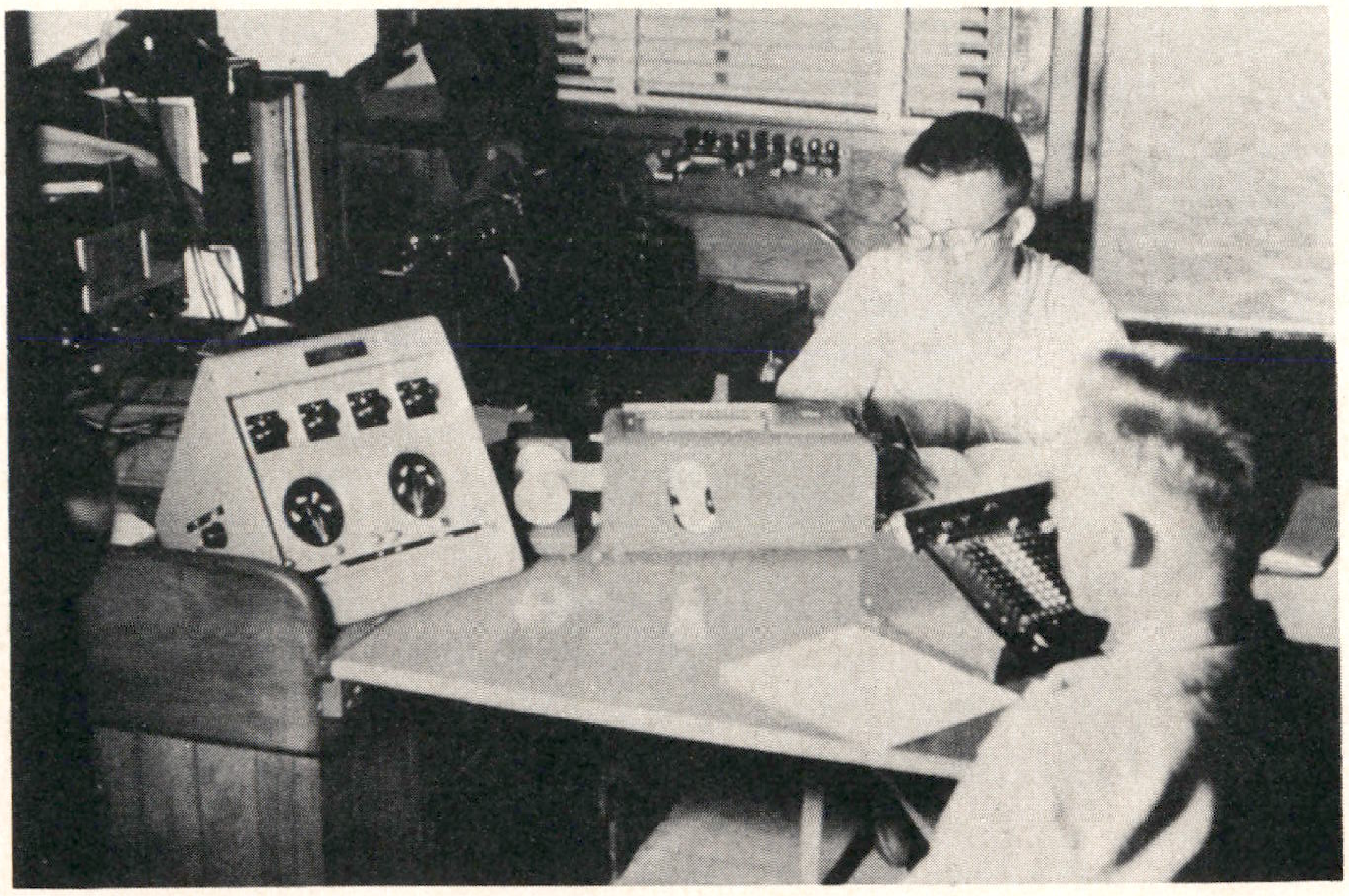

FIG. 5.—Ship station equipment set up for observation and computation of results.

intensity due to the change in the ship's position with respect to the shore station.

Figure 5 shows the ship recording equipment set up for observation and computation of results.

IMPROVED ER-TYPE RAYDIST SYSTEM

Since the ER-type Raydist tests on the *Sosbee,* several improvements have been made to the system to make it more adaptable to hydrographic surveys. Some of these resulted from those tests. The modifications are as follows:

(a) The power of all transmitters has been increased from 10 to 100 w. It is estimated that the dependable range has been increased to about 50 nautical miles, or more.

(b) The relay transmitters which were on very high frequencies (VHF), are now on high frequencies (HF). The former are a little better than line of sight, while the latter do not depend upon the elevation of the antenna, as propagation is by the ground wave which follows the curvature of the earth.

(c) The phasemeters are designed to read the range or direct distance to both stations, and it is no longer necessary to compute the distance to the hyperbolic station. A mechanical computer is built into the phasemeter to perform this conversion automatically and continuously.

(d) A left-right indicator, or zero-center meter, is placed in front of the helmsman to help him steer the vessel on an arc, which is a convenient method of running hydrography lines with Raydist.

(e) Automatic printing of the phasemeter readings for a permanent record and quick and easy reading of lane count.

(f) By proper adjustment to the system, two or three vessels may operate from the same pair of ground stations.

(g) The system has been converted from range-hyperbolic to range-elliptical. This change has several electrical advantages, but no particular advantage because of the geometry of the phase-lane arrangement. It was the result of a redesign of the receivers, which makes multiship operation easier, and will allow operation in the presence of stronger disturbing signals.

(h) Due to the number of changes in the system, it is now designated as type DM.

Part II—Hydrography With ER-type Raydist

CAPTAIN ROSWELL C. BOLSTAD
U. S. Coast and Geodetic Survey

During the summer of 1954, the ship *Sosbee* was assigned the project of conducting evaluation tests for hydrographic surveys with the ER-type Raydist System. The *Sosbee* was then operating out of Sarasota, Fla., engaged in visually controlled hydrographic surveys in the Gulf, offshore

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Captain Bolstad was the Commanding Officer of the U.S.C.&.G.S. ship *Sosbee*.

FIG. 6.—Range shore station showing instruments set up in shelter.

to a distance of approximately 10 miles. Terrain, humidity, high electrical disturbances, and the opportunity afforded to complete offshore hydrography heretofore hampered by poor visibility, were influencing factors in the selection of the *Sosbee* and locale for the tests. It was believed that if Raydist proved practical under these extreme conditions, it would have demonstrated its capability for the Bureau's hydrographic operations elsewhere.

Since the contract for rental of the Raydist equipment provided for a maximum usage of 3 months, it was essential that the contract time be utilized to the fullest extent. Prior to arrival of the equipment and the two company technicians several weeks were devoted to preliminary preparations. Sites for the three unattended shore stations were selected in accordance with instructions issued by the manufacturer. Although not strictly complying with all requirements, these sites were considered the best available in the locality and capable of controlling the hydrography in the selected test area. The exact location for the antennas at each site (designated ***Albert***, ***Baker***, and ***Charley***) was marked and triangulated in. As it was planned to carry on the hydrography simultaneously with the evaluation tests, the computed positions were plotted on both 1:10,000 scale projections on aluminum-mounted sheets for the evaluation tests and a new 1:20,000 scale boat sheet of the uncompleted offshore hydrography. On all sheets, 100-lane (1,812.2m.) arcs were inked in from stations *Albert* and *Baker*, the first pair of sites to be used. (The lane values for the hyperbolic system vary with distance and therefore are not given in all cases in this paper.)

During the ***Sosbee*** tests, a 4' by 4' by 4' plywood shelter, housed each shore station equipment (fig. 6). Shelters are bolted together, and can be easily taken apart for transportation to a new site.

For the purpose of the evaluation tests, and in order to set the two phasemeter dials to correctly represent the ship's position, it is necessary to know the position of the vessel at several locations. For this purpose, and also in order to determine the necessity and frequency of additional check-points required in the hydrographic test area, four Dial Calibration Stations (DCS) were established and triangulated in (*see* fig. 7). DCS 2A, 4A, and 6A were ship stations in open water alongside fixed navigational aids. DCS 3A was a fixed position of the vessel alongside the mooring pier. The correct lane settings of both ***Albert*** and ***Baker*** dials were computed for each DCS.

PRELIMINARY TESTS

Upon completion of the ship and shore installations at ***Albert*** and ***Baker***, the first tests were carried on in Sarasota Bay. With the vessel on station at DCS 3A, both dials were set to their correct readings. The vessel then proceeded to each DCS in the bay and dial readings were observed and compared with the computed (true) values. The results were as follows:

DCS	Difference (Computed reading minus actual reading)		
	Albert (Hyperbolic)	*Baker* (Range)	
	(Lanes)	*(Lanes)*	*(Meters)*
	Going Out		
3A	0.00	0.00	
2A	0.00	+0.20	+3.6
4A	-0.06	-0.24	-4.3
6A	+0.23	-0.16	-2.9
	Coming Back		
6A	+0.23	-0.16	-2.9
4A	-0.06	-0.24	-4.3
2A	+0.03	+0.20	+3.6
3A	+0.07	+0.09	+1.6

The equivalent linear distance in meters is shown in the above tabulation for *Baker* dial only, as this dial read range values direct. Since the hyperbolic reading of *Albert* dial represents a difference in distance involving both *Baker* and *Albert* dials, the conversion to meters has no particular significance for this preliminary test.

The ship cruised off station and back on again at DCS 6A prior to making the return run. The total time consumed for the test was approximately 4 hours. These results showed that the Ray-

FIG. 7.--Chart of northern or first test area.

dist is capable of repeatability within close tolerances. Since these differences at each DCS represent corrections of the dial readings for the respective locations at that particular time, it was evident that several offshore check points in the hydrographic test area would also be required at intervals of time in order to secure true positions. This was later confirmed by results secured at DCS 2A on 5 different days.

To obtain these required offshore check points in the hydrographic area devoid of stationary objects for the ship to come alongside, it was necessary to compute the dial settings for points on each of three ranges (broken triangles, fig. 7). To reset or check dial settings at these points it was only necessary to run the ship on the range and with the observers stationed up the mast between the antennas, "mark" at the time the preselected angle would occur on the sextant. The three successive readings obtained on each range furnished a necessary check for rejections and reruns. This method was adopted after attempting to use sextant fixes taken on triangulation stations, plotting on an aluminum sheet, and scaling the required lane values directly from the sheet.

INITIAL OPERATING PROCEDURE

The method of running ranges combined with preselected sextant angles was therefore adopted as normal operating procedure for dial calibration and evaluation of instrumental error of the Raydist equipment during the period in which hydrography was in progress on hydrographic sheet No. H-8043.

At the start of each day's operations while the ship's engine was warming up alongside the pier on DCS 3A, both ***Albert*** and ***Baker*** dials were set. From the beginning, and up to the morning of July 8, the dial settings were made to agree with the computed values. The vessel would then proceed out of Big Sarasota Pass checking the hyperbolic dial reading when the baseline extension was crossed; the reading was nearly always close to its correct value of 0.00. Sometimes high electrical disturbances would cause the dial to jump or oscillate in this vicinity, therefore, to safeguard against loss or gain of a lane, an additional check was made at station ***Out***. The vessel then proceeded to the offshore check stations where the dial readings were compared against their computed values. At times, all of the check stations would be visited, but more often only a few would be occupied while the vessel was completing the offshore hydrography. In all cases, the operations would again be conducted in reverse procedure as the ship proceeded back to its berth at DCS 3A.

DIAL CALIBRATION

Initial Hydrographic Test Area

An analysis of the results obtained at these offshore check stations lying in the initial hydrographic test area for the period July 2 to 8, inclusive, (with the initial dial settings at DCS for ***Baker*** on 233.43 and ***Albert*** 50.06) showed from an average of 38 values that the ***Baker*** dial was reading 0.17 lane (3.1 m.) too low and ***Albert*** 0.16 lane (2.7 m.) too high, hyperbolic. The maximum divergence from these values were 0.39 lane (7.1 m.) for ***Baker*** and 0.13 (2.3 m.) hyperbolic for ***Albert***. These values could have been reduced by setting an appropriate rejection limit.

Therefore, starting on July 9 the initial dial settings at DCS prior to departure were changed accordingly with ***Albert*** dial set on 49.90, and ***Baker*** dial on 233.65 as influenced by a weighted mean. These initial dial settings were unchanged from July 9 to 19, inclusive. For this period the average of 36 values showed that ***Baker*** dial was still reading too low by 0.08 lane (1.4 m.), and ***Albert*** too low by 0.06 (0.7 m.) hyperbolic reading.

On July 20 the locations of the ship AM-whip antennas were changed to remedy jumping of the dials thought to be caused by improperly grounded ship components. DCS 3A (***Pier***) could then no longer be used for initialing the dial settings, consequently a new calibration station, ***Term***, was established for the vessel alongside the pier. For the period July 20 to August 4, inclusive, the initial dial settings were made with the ship on station ***Term***; ***Baker*** dial was set on 233.83 and ***Albert*** on 49.99. During this period the average of 45 values at the offshore check stations showed that ***Baker*** dial was reading 0.16 lane (2.9 m.) too low and ***Albert*** hyperbolic reading was 0.09 lane (0.3 m.) too low.

Ship Distortion Patterns

On July 12th, prior to the start of hydrography, there appeared to be slight deviations in the dial readings for different headings of the ship, when on station. This was evident alongside the dock and also while running the check stations on the offshore ranges in both directions. To determine the extent of this deviation for the various ship's headings, a series of tests were run at four ship distortion pattern stations, three of which were in the initial hydrographic test area.

The tests were made at survey buoys planted with special short-scope anchoring gear. The vessel proceeded to pass close alongside the buoy on both port and starboard sides at every 45^0 heading. Readings of both dials were taken when abeam the steering wheel; this point was considered to be in the center of all four an-

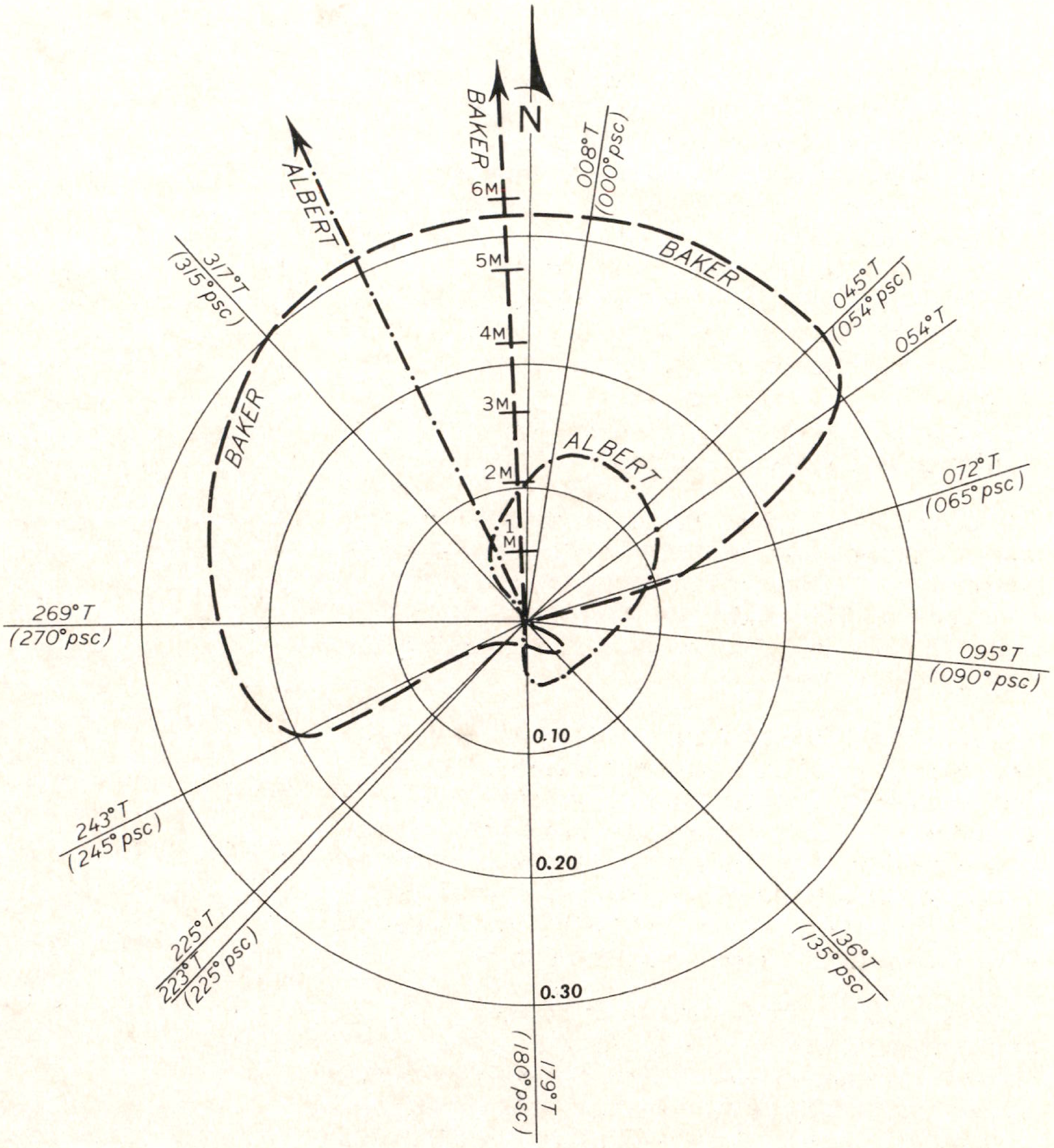


FIG. 8.—Typical ship distortion pattern showing difference in dial readings for various ship headings.

tennas. By holding the lowest dial reading as zero, the ship distortion patterns were plotted (fig. 8 is an example); for *Albert* dial the readings are hyperbolic differences while for *Baker* dial the readings are range differences. At all four stations, it was noted that *Baker* dial readings were greater by approximately 0.3 lane (5.4 m.) when the ship's heading was towards *Baker* shore station; they were at a minimum when on the reverse heading. These tests showed that the "electrical center" of the ship installation was actually about 9 feet aft of the steering wheel, rather than at the previously assumed physical center.

Inasmuch as these four ship distortion patterns were fairly consistent, it was, at first, surprising to find a departure in the pattern taken September 13 at station 5 at the close of the season's work. Dial readings for the range station then read up to 0.4 lane (7.2 m.) greater when the ship's heading was 45^0 left of its shore station, than when on an opposite heading. The hyperbolic dial read 0.5 greater (or 12 m. less in range) when the ship heads 90^0 to the right of its shore station (or directly towards the range station), than when on an opposite heading. In analyzing, it is noted that in the first tests taken at stations 1 through 4 in the earlier part of the summer, the angle between the shore stations was less than 60^0, whereas in the test at station 5 the angle was in excess of 90^0. In all five patterns, when the angle between the shore stations increased so did the maximum hyperbolic correction increase; this is reasonable and shows consistency.

On the ship distortion pattern, the Raydist coefficients have been plotted as differences of dial readings in lanes (range and hyperbolic). An equivalent scale in meters has been shown for the range station only; the hyperbolic station varies in metric scale with orientation, and therefore is omitted.

Second Hydrographic Test Area

Upon completion of the initial tests and offshore hydrography from Sarasota Key to Longboat Key, shore station *Albert* was dismantled and moved southward to the new site where it was placed in operation as *Charley*. Thereupon, the combination of *Baker* (range station) and *Charley* (hyperbolic station) were utilized similarly to previous procedures. Dial readings were also observed at the two test buoys placed in the new area to be hydrographically developed to the southward. This method established an interlocking tie-in of the Raydist control between these adjoining hydrographic surveys.

Shore station *Baker* was then dismantled and moved to the new site where it was placed in operation as *Del*. Thereafter, hydrography on boat sheet H-8152 and tests were resumed in this southern area with *Del* (range station) and *Charley* (hyperbolic station).

To obtain dial settings which would be truly representative of this hydrographic working area, and to minimize corrections to the dial readings, a series of seven calibration test stations were established in the offshore area where the hydrography was to be performed. The use of such a series permitted rejection of "wild" readings and establishment of accurate mean values.

On the first day of hydrographic operations in this southern area, the dials were set to the computed values at *Term* prior to departure from the Sarasota City Municipal Pier. Going out, the reading of *Charley* (hyperbolic), in crossing the baseline extension in Big Sarasota Pass, checked well with the computed value. Readings of both dials were taken at computed station *Out* and at Big Sarasota Pass Entrance Buoy No. 1, for the purpose of verifying the correct lane count. The scope of the buoy prohibited placing too much reliance on the readings, although they were helpful as a rough check. Proceeding southward to the working grounds, it was found in checking in on test buoys Nos. 1 and 2, that dial readings did not agree with computed readings; therefore, both dials were reset to the correct computed values at test buoy No. 2. Although test buoy No. 2 was placed with short-scope anchor gear, and therefore restricted to small horizontal movements, the sextant angles determining its position were rechecked prior to runs on the buoy. Runs were then made on the fixed-location test stations and correct dial settings were confirmed. Immediately thereafter, a series of dial readings were taken on a more sensitive range at five points, using fixed sextant angles on a conspicuous house cupola. These dial readings, although not computed, were used as a standard in checking the dial readings at subsequent periods and determination of applicable corrections.

DISTRIBUTION OF SHORE STATIONS FOR HYDROGRAPHIC CONTROL

Only two shore stations were used to control the hydrography on each of the hydrographic sheets H-8043 and H-8152. This is not advocated where intersecting range arcs are less than 15°. However, the time limit set on use of the Raydist equipment, and the method of overlapping with strong control from the adjoining sheet, justified the procedure. All intersecting arcs are strong throughout the area except at the inshore southeast corner of each sheet, where they approximate 10°. A quarter of a lane error in protracting would result in 1.3 mm. error in position along the range station arc. Since the development of the hydrographic areas on both sheets was attained by running range arcs, the plotted position from the hyperbolic dial readings are time intercepts producing very nearly constant distances. These were extended as checks into the progressively weaker area from the strong intersection area.

On field sheet H-8043, this weaker area has been well overlapped by the strong intersecting arcs of sheet H-8152. No discrepancies in the applied soundings resulted, showing that the method is practical for this locality, and is within hydrographic requirements.

CORRECTIONS FOR HYDROGRAPHY

Since approximately 2 mm. represents the space covered by a two-digit sounding on a 1:20,000 scale hydrographic sheet, it would appear that one-third of this amount, 0.7 mm. (representing 14 m. or about 0.8 lane) could well be tolerated without unduly influencing the horizontal position of the plotted sounding. Moreover, the inherent error of the plotted arcs, plotted under most favorable conditions, will amount to about half this value, which combined with the error in plotting a Raydist position would also justify disregard of aggregate corrections below 0.8 lane, or 14 m.

The analysis of corrections to the dial readings for the period starting with the first day of hydrography on June 29, 1954, "B" day on boat sheet H-8043, until August 4, inclusive, is contained in the preceding section *Initial Hydrographic Test Area*. These corrections did not take into account the influence of the ship's distortion pattern for various headings of the ship. If the two distortion patterns, obtained on August 3, are considered representative of the hydrographic area of that sheet, the maximum divergence from the mean values will amount to ±0.11 lane hyperbolic (±6.7 m.) for *Albert* and ±0.15 lane (±2.7 m.) for *Baker*. The effect of applying these values for hydrographic purposes was considered impractical and unwarranted; they were, therefore, disregarded.

On the last day of hydrography on H-8043, checks at three offshore calibration stations showed that *Baker* dial was reading too low by 0.11 lane (2.0 m.) and *Albert* too low by 0.04 hyperbolic (0.5 m.), all values being close to the means. Therefore, on hydrographic sheet H-8043, since the sum of corrections for either dial reading was never in excess of 0.8 lane (14m.), no corrections to the original dial readings were applied.

For hydrographic sheet H-8152, the average correction obtained over a period of 10 days showed a 0.0 lane (0.0 m.) correction for the range station and +0.34 lane correction to the hyperbolic station readings. Since the hyperbolic reading is not used for plotting, the converted range correction of -0.68 lane (-12.3 m.) was applied in the sounding volumes in order to improve plotted position accuracy, especially where the intersecting range arcs are weak in the southeast inshore area. For the determination of these corrections, mean values of 0.25 lane for *Charley* and 0.20 lane for *Del* were used as determined at ship distortion station No. 5.

STANDARD OPERATING PROCEDURE

Although it was not so apparent during operations in the first test area, at the start of work on the second hydrographic sheet, it became evident that dial readings were sometimes appreciably inconsistent with their computed values at various localities. This variance, of over 1 lane, appears to be caused by differences of topographic detail along the wave paths. Over water areas the differences are small. Therefore, in applying the ER-type Raydist System to hydrographic surveys, the following standard operating procedure has been successfully used by the ship *Sosbee:*

(1) After ship and shore stations have been adjusted for maximum antenna loadings, ship distortion patterns should be secured at two separate representative locations in the hydrographic area. Port and starboard runs on a buoy for every 45° ship's heading will suffice for a good determination. The distortion patterns are then plotted. Where the variance is appreciable, a new electrical center of the ship should be selected from which point the fixes are secured. This will result in an improved pattern to avoid the necessity of requiring the application of these ship distortion corrections.

(2) The ship is then run on a range for which dial readings have been computed for successive sextant angles to visual-control objects. If possible, more than one series of dial calibration stations should be secured at different localities in order to be representative of the hydrographic area. The settings of the dials are made to correspond to the computed readings which have been adjusted to the mean accepted value of the ship's distortion.

(3) Once the dials have been set correctly for the hydrographic area, the vessel proceeds to at least two localities where a test buoy with short-scope anchor gear is set out. Passes are made on each buoy at several ship's headings which are recorded along with the distance off the buoy and dial readings. This information is used for future reference in the event it is necessary to reset or check the lane count against the dials during the course of hydrographic operations. These buoys have proved valuable to reset the lane count after the ship generator has either failed or has been temporarily shut down.

(4) The vessel then proceeds to its mooring pier, taking readings at points en route which can be reoccupied by the vessel. In crossing the baseline extension, the hyperbolic reading is taken as well as readings alongside the dock. It is unnecessary for the dial readings to be computed to these points; they are used only to again set the dial count prior to departure to the hydrographic area. Such conditions may not prevail as favorably elsewhere, although suitably placed test buoys will serve equally well.

(5) During the course of hydrography it should be unnecessary to check-in each day on the dial calibration points. Frequent checks are made in this area for test information. The frequency of required checks will depend upon variance of readings for the locality of operation. In Florida, during the summer months, conditions are probably more unstable, with variations of temperature, humidity, static, and storms, than will normally be encountered elsewhere.

(6) For the practical and most economical coverage of an area, hydrography with the Raydist system is best accomplished by the vessel traversing the arcs rather than attempting straight lines (*see* fig. 9). When a voltmeter is connected into the system the pointer can be made to center at each half-lane dial reading of the range station used as the "arc" station. With the meter before him, the helmsman is then able to follow along the selected half-lane arcs within a few meters; once placed on the arc with an approximate course at the start of each arc line, no further attention need be directed to the helmsman.

EVALUATION

On the basis of the test data and over 1,600 miles of hydrography obtained with the ER-type Raydist System from the middle of June to the middle of September, 1954, the following evaluation is concluded:

(1) The system is dependable. There are few moving parts subject to wear. Components used have several hundred percent safety factor. In general, the circuits are conventional and familiar to most radio technicians. Instrument operation was very satisfactory. No time was lost due to equipment failure except portable generator trou-

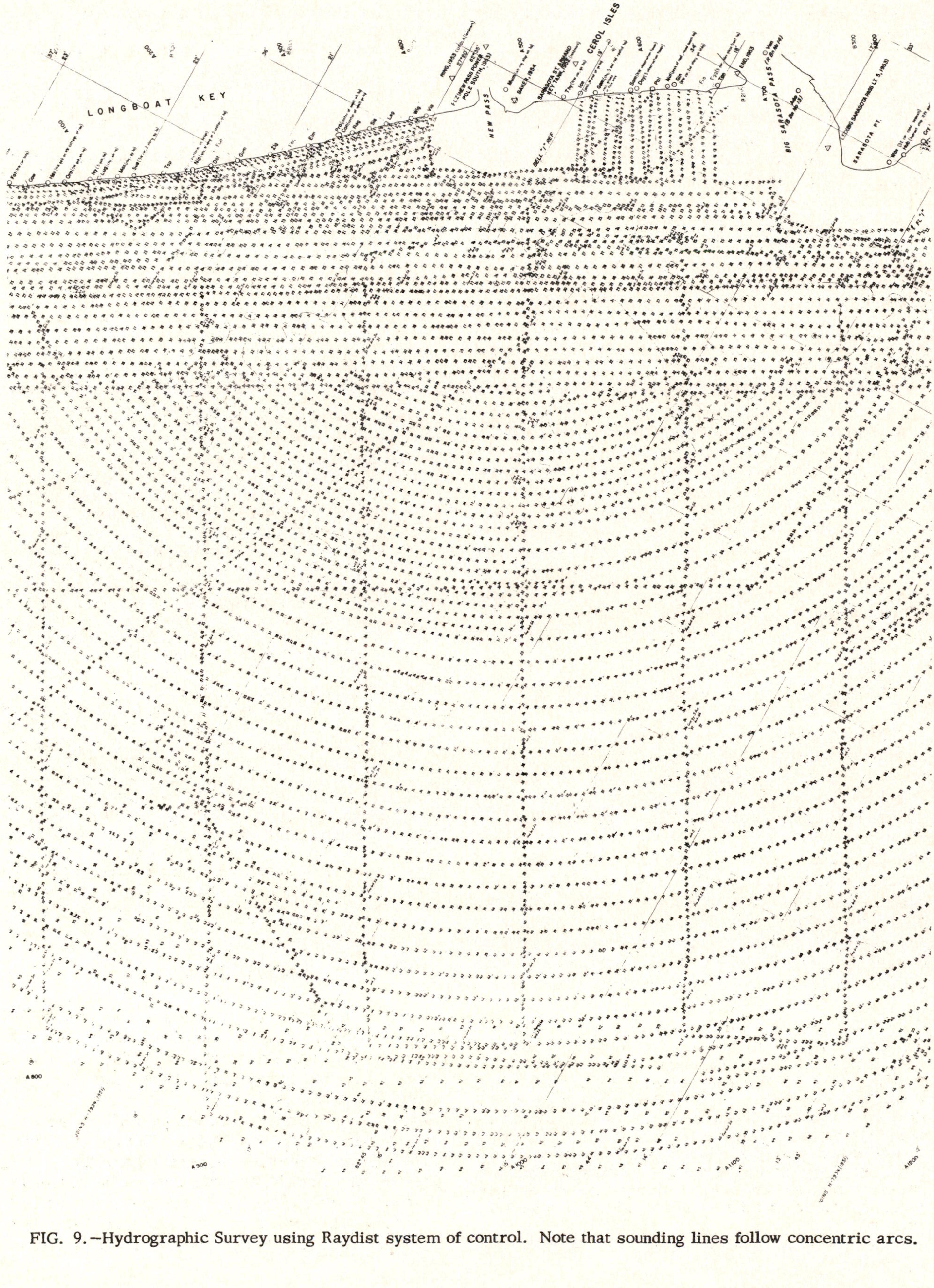


FIG. 9.—Hydrographic Survey using Raydist system of control. Note that sounding lines follow concentric arcs.

ble; this was later minimized by periodic overhauls. It is essential that the ship power be as dependable as the power used for the shore stations.

(2) The accuracy of the system is well within requirements for hydrography. By following the standard operating procedure outlined, corrections to dial readings in the hydrographic area can be minimized to the point of disregard. As the system is more accurate than shoran, it could be best used for inshore surveys of harbors, bays, entrances, and so forth, where accuracy is paramount.

(3) The system operated during periods of both good and bad weather. Lightning had less effect on dial fluctuation than high static level. Only three times during unusually bad electrical storms was it necessary to discontinue operations.

(4) Operation of the unattended shore stations was reliable. Both stations *Del* and *Charley* were in continuous operation for over a month. No adjustments other than slight adjustments of antenna loadings were made; this was not essential except to give peak output performance. All shore stations (10w.) were unattended for their entire duration; standard 110-volt a.c. commercial power was used. If gasoline-driven generators are used, attendance ashore is necessary, and there would be little advantage of the Raydist shore station over the shoran shore station. It would be possible to run the system from chargeable-type batteries.

(5) Aboard ship, the time to install Raydist is about the same as that of shoran. While it is not as essential that the antennas for Raydist be elevated as high as those for shoran, it is still important, for better operation, that the FM relay antennas be as high as possible.

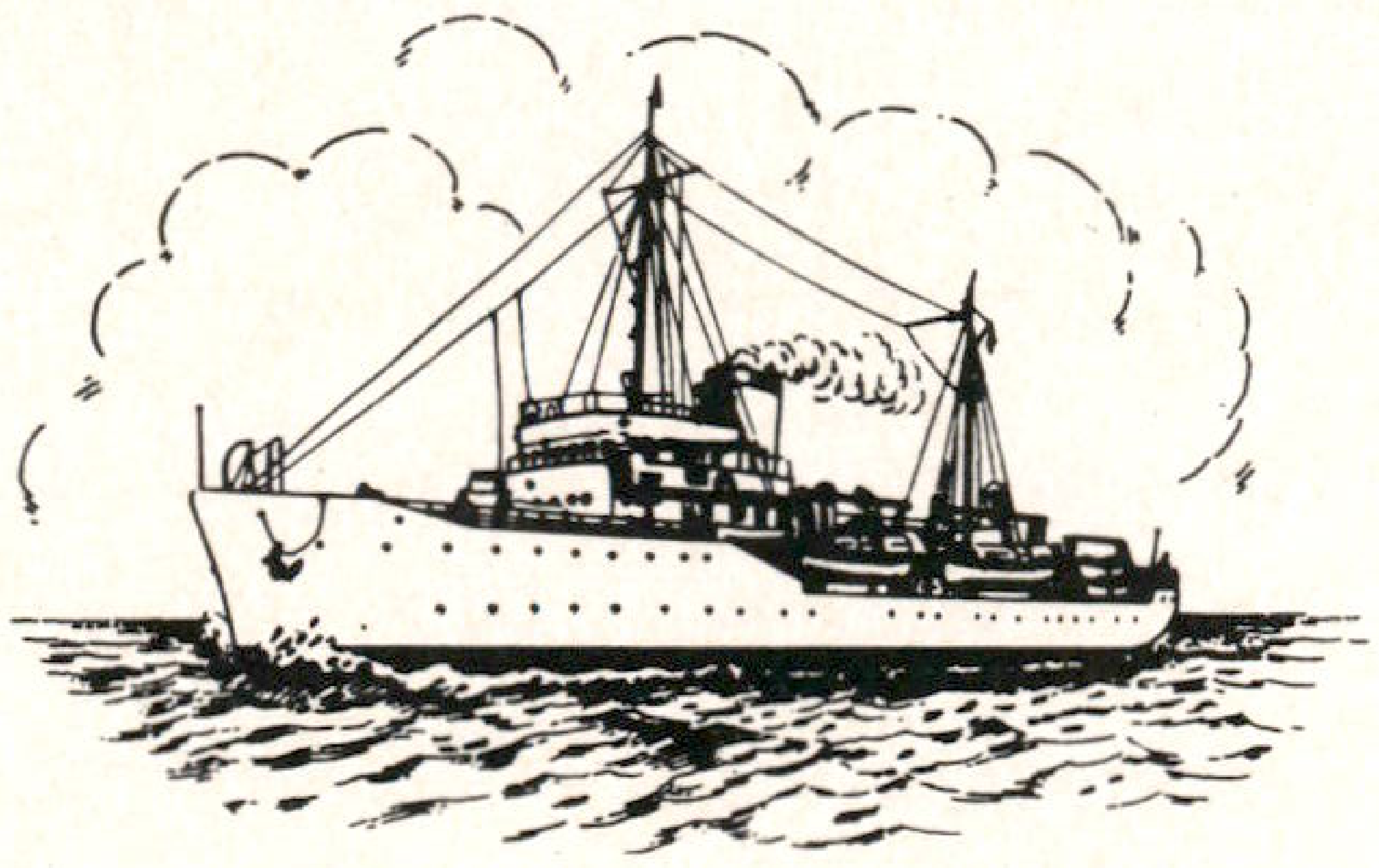
(6) A little less time is required in setting up the ground station for Raydist than for shoran. Assuming the shelter problems about the same, the time of erecting the shoran mast is nearly offset by the time to put in the Raydist ground system. The Raydist has the advantage where a shoran personnel shelter is required.

(7) Although tests for maximum range of this system were never concluded due to storms, the following distances in nautical miles were obtained aboard ship from the range and hyperbolic shore stations, respectively, on three different occasions: 11.1, 13.9, and 14.1 and 18.6, 14.2, and 16.0. It is believed this low power Raydist system is capable of operation up to 20 miles, provided the atmospheric noise level is low.

(8) While the ER-type Raydist controls hydrography well, it has certain unsatisfactory features which make operations difficult.

(a) At fix time both range and hyperbolic phasemeters are read. These readings, along with the baseline distance, are used to compute the range distance to the hyperbolic station. Range and hyperbolic station range distances are then used by the hydrographer to plot the position in the same way as EPI and shoran. The time required to make these computations and to pass the data along to the hydrographer is about 30 seconds. This loss of time can be serious in controlling the vessel on a large-scale survey, unless arc-hydrography is used. The manufacturer recognized this weakness and has revised the system with a new DM-type Raydist which is not hyperbolic, but furnishes position data from both dials directly in terms of range.

(b) Two men are required to read the phasemeters at fix time. This is primarily because of the fast moving dials. Due to their size and arrangement, the small dials are difficult to read. Even with two men reading the instrument, it is only possible to estimate the reading from the range phasedial; therefore the method of conducting hydrography on the range arc was used to overcome this. If the system operated on a lower radio frequency, wider lanes would result and dial speed would be reduced. Also, the wider lane spacing requires less accuracy in the fix used to set the phasedials or checking the lane count. It is only necessary to identify the whole lane; the phasemeters actually indicate the fractions of the lane. The lowest frequency now obtainable would mean that the dials would turn only about one-half as fast as they now move, which is still too fast for one man to read. It has been proposed that the dials be geared down to move slower, with corresponding loss in reading accuracy. Also, it was proposed that the phasemeters print out their readings.



Subtense Bar Traverse

CAPTAIN GILBERT R. FISH
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The subtense method of tachymetry is distance measuring obtained through measuring the horizontal angle subtended by a horizontal bar of a precisely known length. A great deal of work has been done by this method in India, but it has not been used to its fullest extent due to the lack, until recently, of small direction-theodolites reading to 1 second. This and the following article are presented for the purpose of showing the advantages that can be derived from the use of the subtense bar and the Wild T-2 theodolite.

Essentially, the subtense bar is a short base line, which may be from 2 to 20 feet in length between the sighting targets. As the bar is held horizontally and the angle is measured in the horizontal plane, no slope correction is necessary, which makes it admirably suited for rough terrain.

The subtense bar as an accessory to the Wild T-2 theodolite is 2 meters long and consists of an invar wire inclosed in a metal casing, which controls the distance between two sighting targets. One end of the wire is fastened to a target with a spring tension. In this way the expansion and contraction of the metal casing have no effect on the distance between the targets. The coefficient of expansion of invar is so low that temperature corrections can be neglected entirely for the order of accuracy obtained by this method. A range of temperature of 100° F. could have the effect of changing the subtense base by only about 1 part in 20,000.—Editor.

SUBTENSE BAR TRAVERSES do not require taping as do "transit and tape" traverses but in lieu of the taping an increased number of instrumental observations are required. In the first type of traverse the distance measurement causes more trouble than the angle measurement for azimuth and the same condition applies to subtense bar traverses in that inaccurate measurement of the angle subtended by the subtense bar causes more trouble than does the measurement of the azimuth angle.

Available literature on running subtense traverses indicates that the angle subtended by the bar can be satisfactorily measured with two positions with a Wild T-2 theodolite, and that with this number of positions the assumption can be made that the angle is measured with 1 second accuracy. The literature also states that distance accuracy can be increased by using more and shorter traverse legs. It is easy to show that short distances can be measured with more accuracy than long distances but how the accuracy obtained on a number of short distances combine to form an accurate measurement of a long distance is not explained except on the basis of probability curves.

Since the measurement of the angle subtended by the 2-meter subtense bar (fig. 1) is the most important feature of such a traverse, a study of what happens when a number of observations are combined appears warranted. In making this study the amount by which distance will be affected by an angle error of 1".0 is necessary. This information is shown in figures 2 and 3: where the abscissas show the length of the measured distance, in meters; the ordinate values of figure 2 show the distance error, in meters; and the ordinate values of figure 3 show the proportional error represented by the distance error.

Figure 3 shows that 82 meters is the maximum distance that can be measured with 1:5,000 accuracy if the angle is in error by 1".0. Accuracy better than 1".0 is difficult to obtain without an excessive number of observations. Figure 3 of the companion article *Angle Measurement With Wild T-2 Theodolite*, by Gilbert R. Fish and William N. Martin, shows that four positions with a Wild T-2 theodolite will give 1".0 accuracy only about 90 percent of the time. Also traverse legs of 82 meters are too short for economical operations. From this it appears that the only way subtense traverses can be run in an economical manner is for the accuracy on each distance to be less than 1:5,000, and to expect these distances to combine to form an overall accuracy of 1:5,000, or better.

If the overall traverse accuracy is to be better than the accuracy of the individual legs of the traverse the errors must partially compensate each other. To get some idea of the amount of compensation that is necessary, it will be beneficial to study a hypothetical traverse wherein all traverse legs are of equal length, so that the bar will subtend equal angles at all stations, and the traverse is straight and has no errors in the azimuth angles. Since all of the subtense angles are equal, the errors in the individual angles can be combined to form a mean error, with sign considered, for the entire traverse. For small changes in the subtense angle, the distance change will be proportional to the angular change, and the mean angle error will be proportional to the mean distance error. If each traverse leg were to be measured with an angle which was in error by the same amount

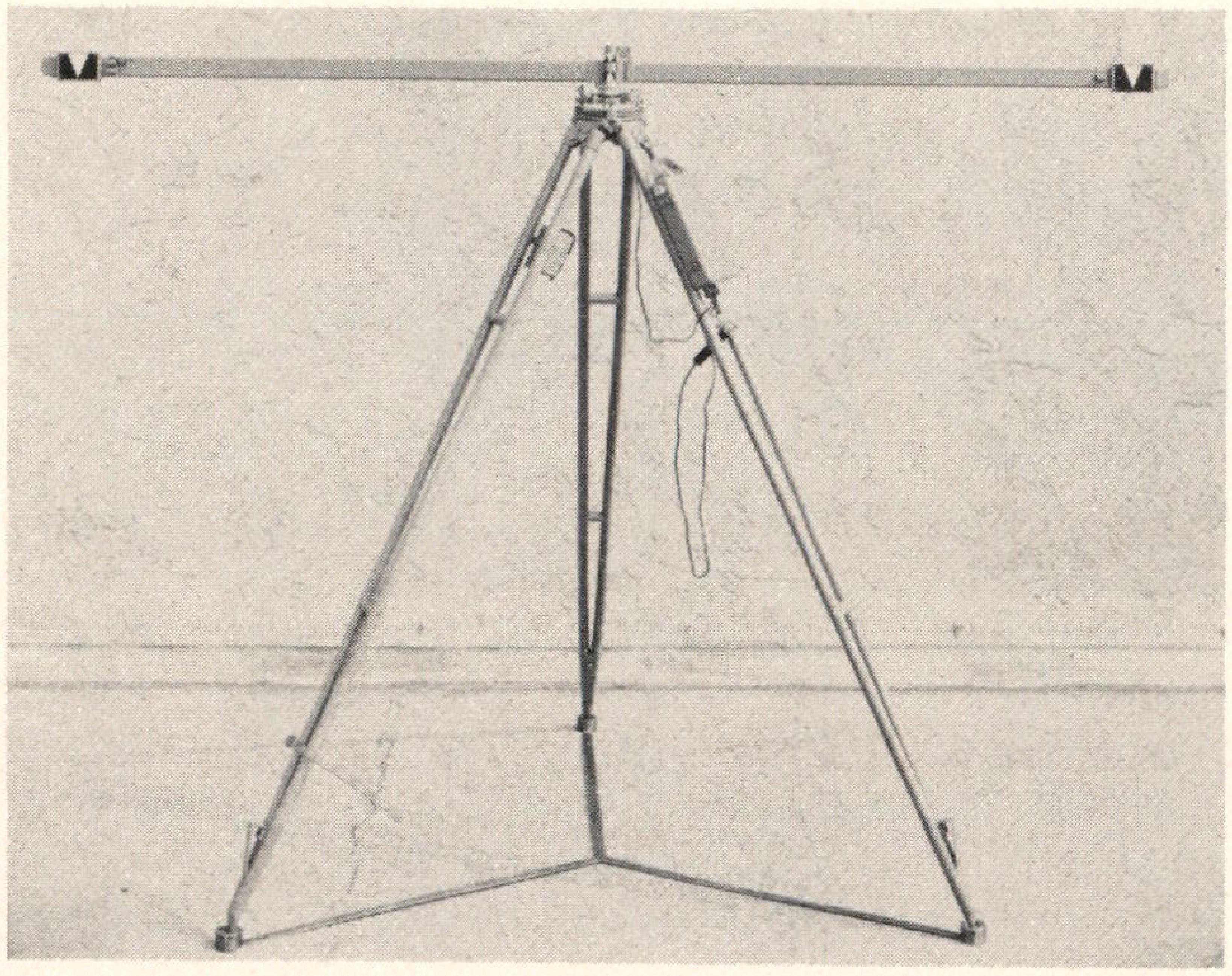


FIG. 1.—Wild 2-meter subtense bar

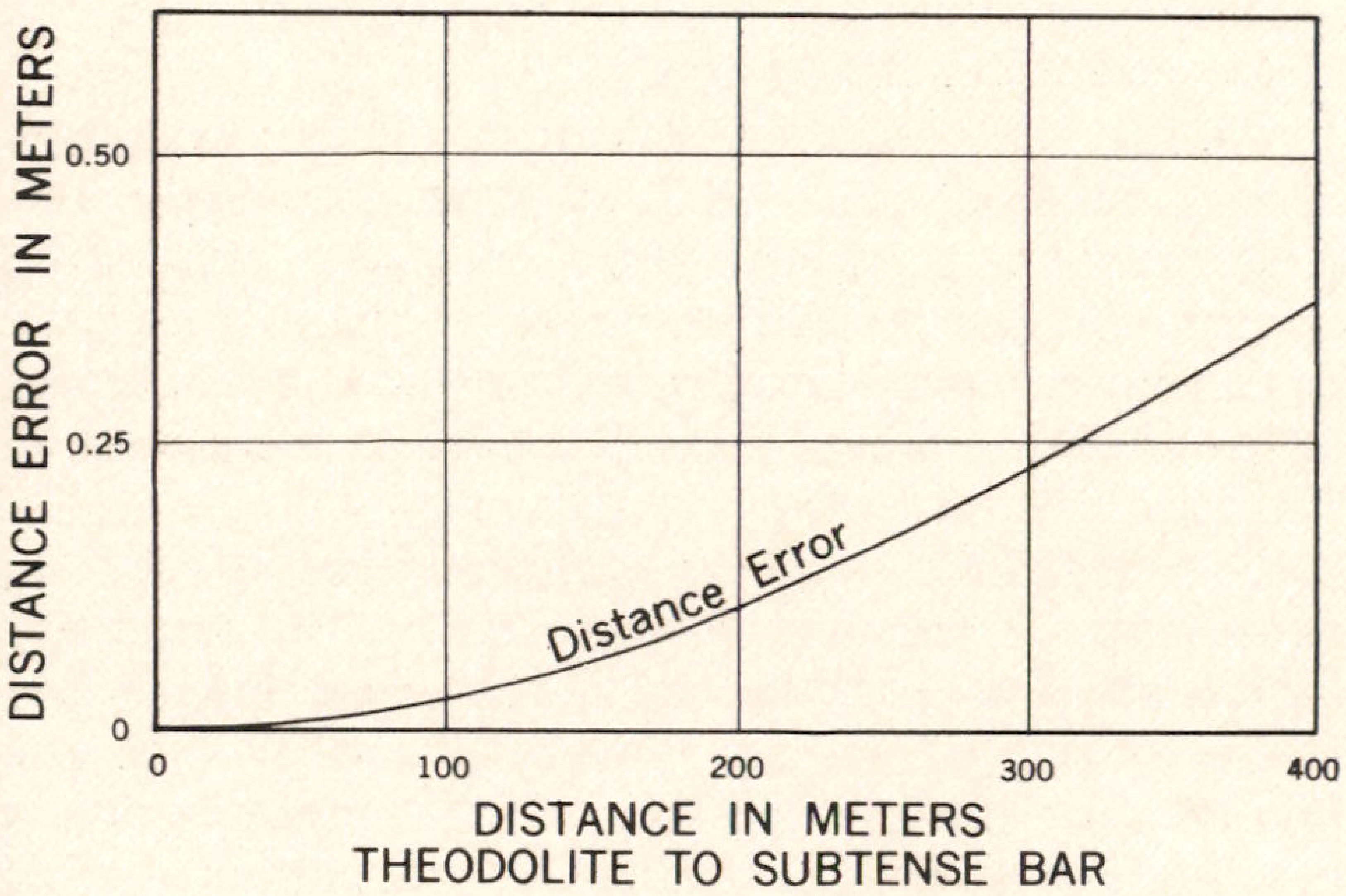


FIG. 2.—Distance error caused by 1 second error in subtense angle

as the mean angle error, the distance errors would be identical in sign and size for all legs, and the proportional accuracy for each leg would be the same as for the entire traverse. The angle accuracy necessary to give 1:5,000 distance accuracy is shown in figure 4, where the abscissa shows the distance being measured and the ordinate shows the maximum angle error which can be tolerated if the distance is to have 1:5,000 accuracy.

Since it would be practically impossible to run a traverse without some error in the azimuth angles, the permissible subtense angle error as shown by figure 4 should be decreased to allow for errors in the azimuth angles. For purposes of this article it can be assumed that a 10 percent reduction in the error of the mean subtense angle will be sufficient.

The application of the information in figure 4 to traverses can now be considered. If it is assumed that the legs in a traverse will be 200 meters long, the maximum and not the average length, the curve in figure 4 shows that the mean angle error cannot exceed 0″.40 if third-order accuracy is to be obtained, and when this figure is decreased by 10 percent the allowable mean angle error becomes 0″.36. The length of the traverse now needs to be considered for it will determine the number of angle stations, and hence the number of angle errors which will be available for determining the mean angle error. In practice, traverses will not have equal subtense angles but this will not materially affect the consideration of the errors unless there is a wide difference in the lengths of the various legs.

With the permissible mean angle error determined and the number of stations at which subtense angles will be measured known within reasonable limits, the next question to be answered is the observing program to be used to measure the subtense angles. For purposes of discussion it will be assumed that the traverse

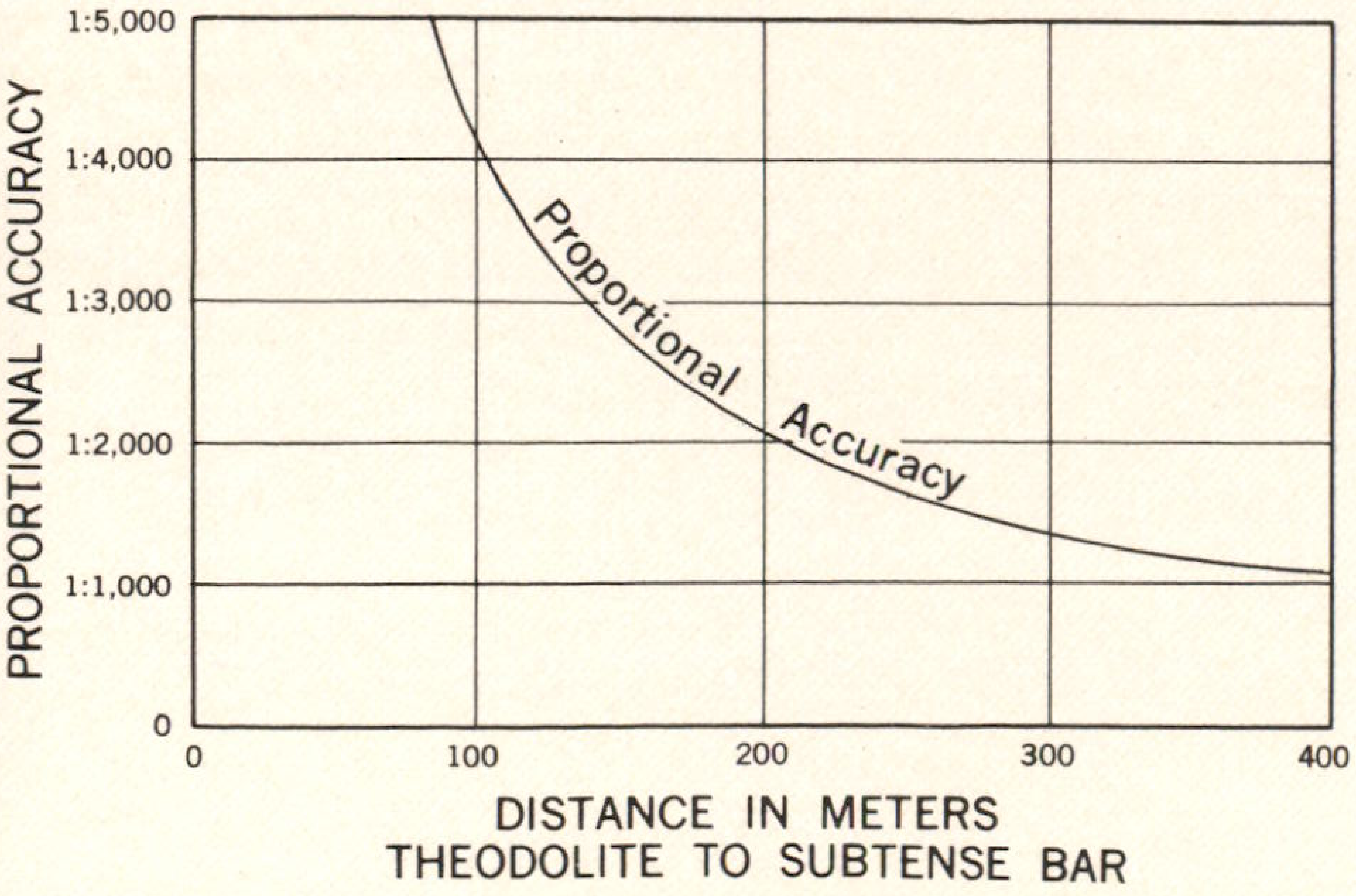


FIG. 3.—Accuracy with 1 second error in subtense angle

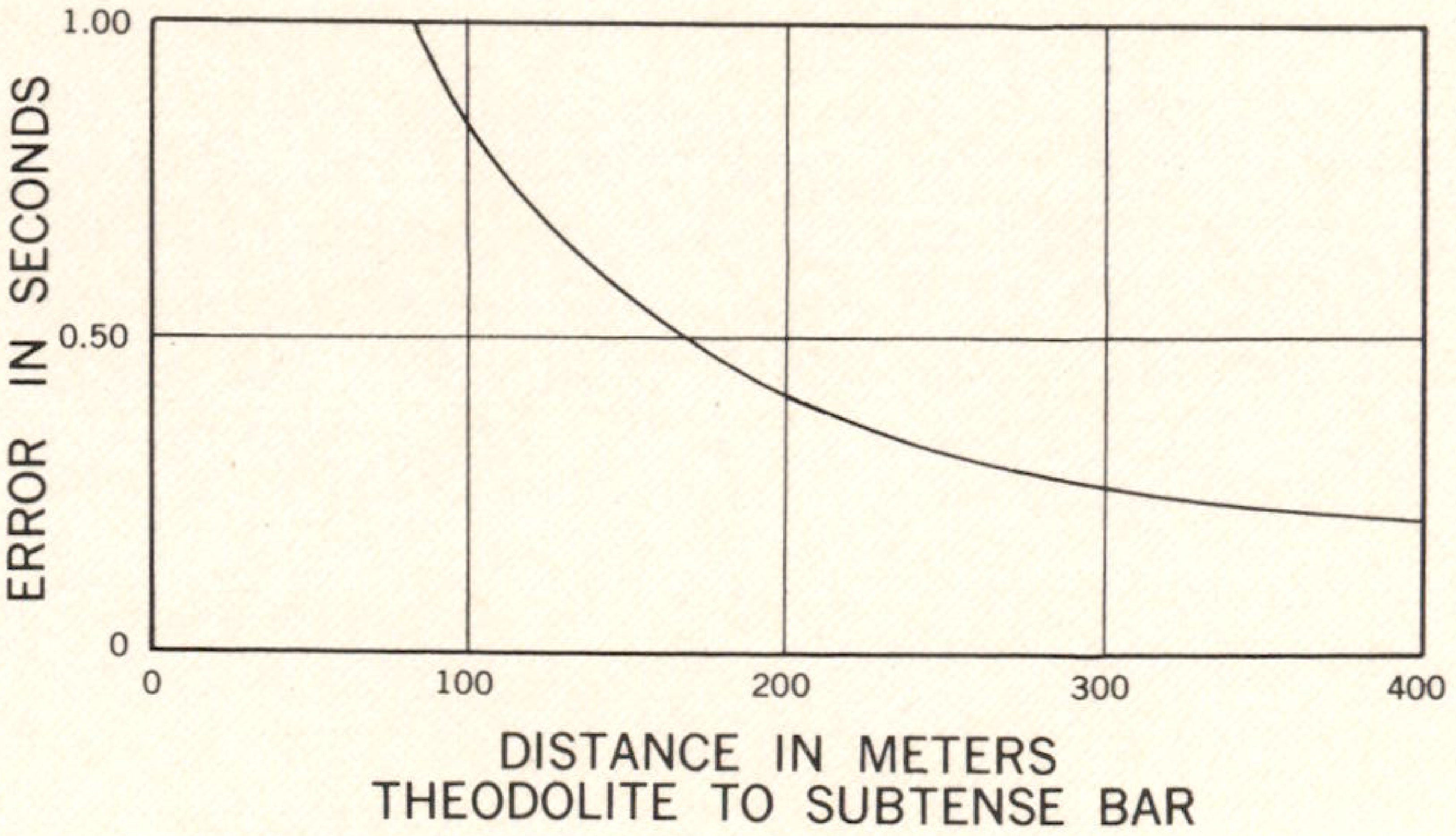


FIG. 4.—Maximum error in subtense angle which will still give 1:5,000 distance accuracy

will have about 20 to 25 angle stations. With this information reference is again made to the companion article. Table 1 of that article has useful information in the columns of algebraic means, and in the means for these columns.

For the first theodolite listed in table 1, 18 sets of observations were used to make the compilation. The mean angle error for four positions is +0".2, which is acceptable, but the mean errors for angles obtained with two positions are -0".2 and +0".6, for positions 1 and 3 and positions 2 and 4, respectively. Before considering whether observations with two positions are acceptable table 2 of that article should be consulted. This table shows that when the observed angles are corrected for micrometer scale error the mean angle error becomes +0".3 and +0".1. These results are acceptable and indicate that two positions with this theodolite will give good results when the observed angles are corrected for micrometer scale error. If corrections are not applied the angles will have errors which tend to be of one sign for all distances, and this will reduce the chances of the mean angle reaching an acceptable figure.

The second instrument listed in table 1 of the companion article has a mean angle error of -0".4 for 19 sets of positions with four directions each. This value is slightly more than the 0".36 requirement and indicates that the results when using four positions with this instrument may be questionable when the traverse legs are 200 meters in length. The mean errors of -1".8 and +1".0 for positions 1 and 3 and positions 2 and 4, respectively, indicate that this instrument is unacceptable when two positions are used. A micrometer scale correction curve was not available to correct the angles obtained with two positions with this theodolite, but the application of corrections would most likely improve the angle errors to an acceptable value.

The third theodolite listed in table 1 has a mean angle error of -0".5 for 37 sets of observations with four positions each, but if only distances of 90, 120, and 180 meters are considered, and for which 25 sets of observations were used to make the compilation, the mean angle error is -0".2. For angles measured with two positions the mean angle errors are too large to be acceptable. With this instrument two positions will not give acceptable results unless the angles are corrected for micrometer error, and corrections may also be necessary with four positions to increase the probability of the mean angle having an acceptable value.

When traverses have more than about 25 angle stations it will not necessarily follow that the increased number of observations will reduce the size of the error obtained by meaning all angle errors. This may be due to factors inherent in the instrument used and to other causes. There is also, in general, a minimum number of observations which will be required to reduce the mean angle error to a reasonable value. When there are fewer angle stations in a traverse than this minimum the number of observations at each station will have to be increased, or the traverse legs will have to be shortened, a procedure which will increase both the allowable mean angle error and the number of sets of observations used to obtain this mean. For traverses with few angle stations it will probably be more economical to increase the amount of observing at each station rather than to obtain all increase in accuracy by a decrease in the lengths of the distances measured.

As the lengths of the distances to be measured are increased over 200 meters, the angle requirement gets more rigid and the observing conditions get poorer, especially when there are heat waves. It would appear that about 200 meters is the maximum distance that should be measured if third-order results are desired.

The azimuth angle in subtense bar traverses need not be measured with the same accuracy as the subtense bar angle. This angle will usually be measured with sufficient accuracy with one position of the Wild T-2 if the angle between the forward and back stations is measured as well as the angle between the back and forward stations.

The running of successful subtense bar traverses depends on the mean angle error in the subtense bar angle. In order to measure the subtense angle with two positions with a Wild T-2 theodolite the observed angles will, for most instruments, need to be corrected for micrometer scale error. With some T-2 theodolites, micrometer scale corrections may also have to be applied to observations obtained with four positions to increase the probability of obtaining acceptable angles.

* * *

Angle Measurement With Wild T-2 Theodolite

CAPTAIN GILBERT R. FISH and COMMANDER WILLIAM N. MARTIN
U. S. Coast and Geodetic Survey

THE WILD T-2 THEODOLITE, shown in figure 1, is an excellent instrument for measuring angles with sufficient accuracy for second-order triangulation where the required triangle closure is an average of 3".0 and a maximum of 5".0, and sometimes they are used on first-order triangulation when first-order theodolites are not available. The Wild T-2 is also used on subtense bar traverses, but here the requirements are somewhat different than for triangulation since the large increase in the number of stations precludes taking as many observations at each station, and therefore the results are not always as satisfactory.

To increase the knowledge of the accuracy that can be obtained in measuring angles with various numbers of directions with the Wild T-2 a series of tests were made in the Canal Zone during February 1954 by personnel of the Inter-American Geodetic Survey. It was believed that the best information could be obtained by measuring known angles and then comparing the known and the observed angles. As a 2-meter subtense bar set at accurately measured distances from the theodolite will provide known angles with a minimum of work, this method was chosen. Distances of 90, 120, 180, 270, 380, and 390 meters were measured with standardized invar tapes using second-order base measuring methods. The computed angles for these distances were: 90m. = 1° 16' 23".5, 120m. = 0° 57' 17".7, 180m. = 0° 38' 11".8, 270m. = 0° 25' 27".9, 380m. = 0° 18' 05".6, and 390m. = 0° 17' 37".8.

The site selected for the tests was a level grassy plot alongside a series of warehouses and adjacent to a surfaced road (fig. 2). The tests were made during the dry season when, in general, the weather was bright and sunny in the early part of the day and partly cloudy in the afternoon, with relatively high temperatures and heat waves on some days. Any breezes were usually parallel to the line of sight which was approximately north-south.

The angles were measured with three theodolites. The instruments, while not especially selected, were all in good condition. All observing was done by experienced observers who were considered to have equal ability. Most of the observations were made with the instrument shaded from the sun, but some were made with the sun on the instrument and those have been rejected when indications were such that the results had been affected by the sun's heat. Part of the observations were made with the micrometer scale illuminated with reflected light and part with electric light. The latter made coincidence readings easier but no difference could be noticed in the angles obtained by the two methods of illumination, so the methods have not been separated in the results.

The angles were measured in sets which consisted of 4 positions, with a direct and reverse pointings on each end of the bar for each position. The T-2 theodolite micrometer scale has a range of 10' and the initial settings were 00' 40", 03' 10", 05' 40", and 08' 10" for positions 1 to 4, respectively. The degree settings for the

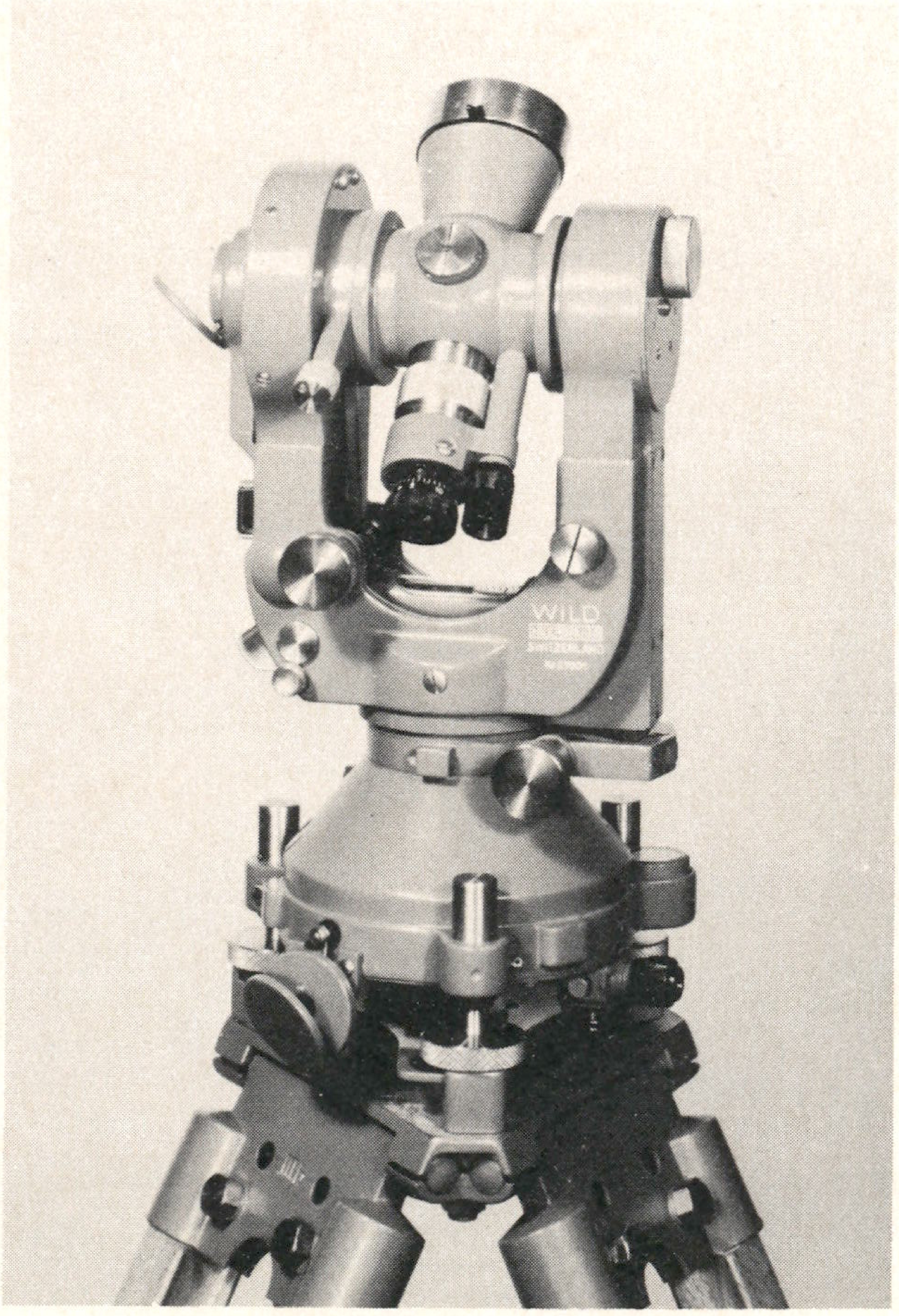


FIG. 1.—Wild T-2 theodolite

4 positions were 00, 45, 90, and 135. With one theodolite, and for one distance only, 8 directions were taken in each set. For these observations the micrometer scale settings given above were repeated twice and the increment in the degree settings was half as large as for 4 positions. In order to use these observations in the tabulation of the results, each 8-position set was divided into two 4-position sets.

The mean angle in each set was subtracted from the computed angle and the resulting errors were arranged in groups designated by theodolite and by distance. No differentiation was made between work of the various observers. Distances of 90, 120, and 180 meters were grouped together and distances of 270 and either 380 or 390 meters were placed in another group. This differentiation was made, since the heat waves were more noticeable on the longer distances and it was believed that this would affect the accuracy of the angles. Besides using the mean angle from sets of 4 positions the same directions have been used to compute means for (a) sets of 4 half-positions, in which the first pair of pointings on the bar were used as the first half-position and the second pair of pointings as the second half-position, (b) sets of 2 positions using positions 1 and 3, and (c) sets of 2 positions using positions 2 and 4. For the sets with 4 half-positions, 2 angles were obtained with the telescope direct and 2 with the telescope reversed.

The errors from the above computations were arranged in subgroups with errors of 0″.0 to 0″.5, 0″.6 to 1″.0, etc. The relationship of the number of values in each subgroup to the total number in the group was then expressed as a percentage and the results used to draw curves which are shown in figure 3. The abscissa shows the deviation, in seconds of arc, of the observed from the computed angle, and the ordinate shows the percent of the observations with errors less than the abscissa reading. The *A* curves are for regular four-position sets, the *B* curves are for sets of 4 half-positions, and the *C* and *D* curves are for sets of 2 positions obtained from positions 1 and 3 and positions 2 and 4, respectively. The superscript (') refers to distances of 90, 120, and 180 meters and the superscript ('') refers to distances of 270 and either 380 or 390 meters. The number of full 4-position sets which were used to compute the curves for each set of distances and for each theodolite were: No. 14406--10 for the short distances and 8 for the group of long distances; No. 14426--11 and 8; and No. 17796--25 and 12.

The A' curves of figure 3 indicate that with 4 complete positions any one of the theodolites will give an accuracy of 1″.0, or better, approximately 90 percent of the time when the distances do not exceed about 180 meters, and that very infrequently will the error be as large as 2″.0. The B' curves show less accuracy than the A' curves due to the lesser number of telescope pointings in each set, and with one instrument 1″.0 accuracy is obtained only 65 percent of the time, and the maximum error increases to 3″.0. The *C* and D' curves, in general, show a further decrease in accuracy; with one instrument 1″.0 accuracy is obtained only 25 per-

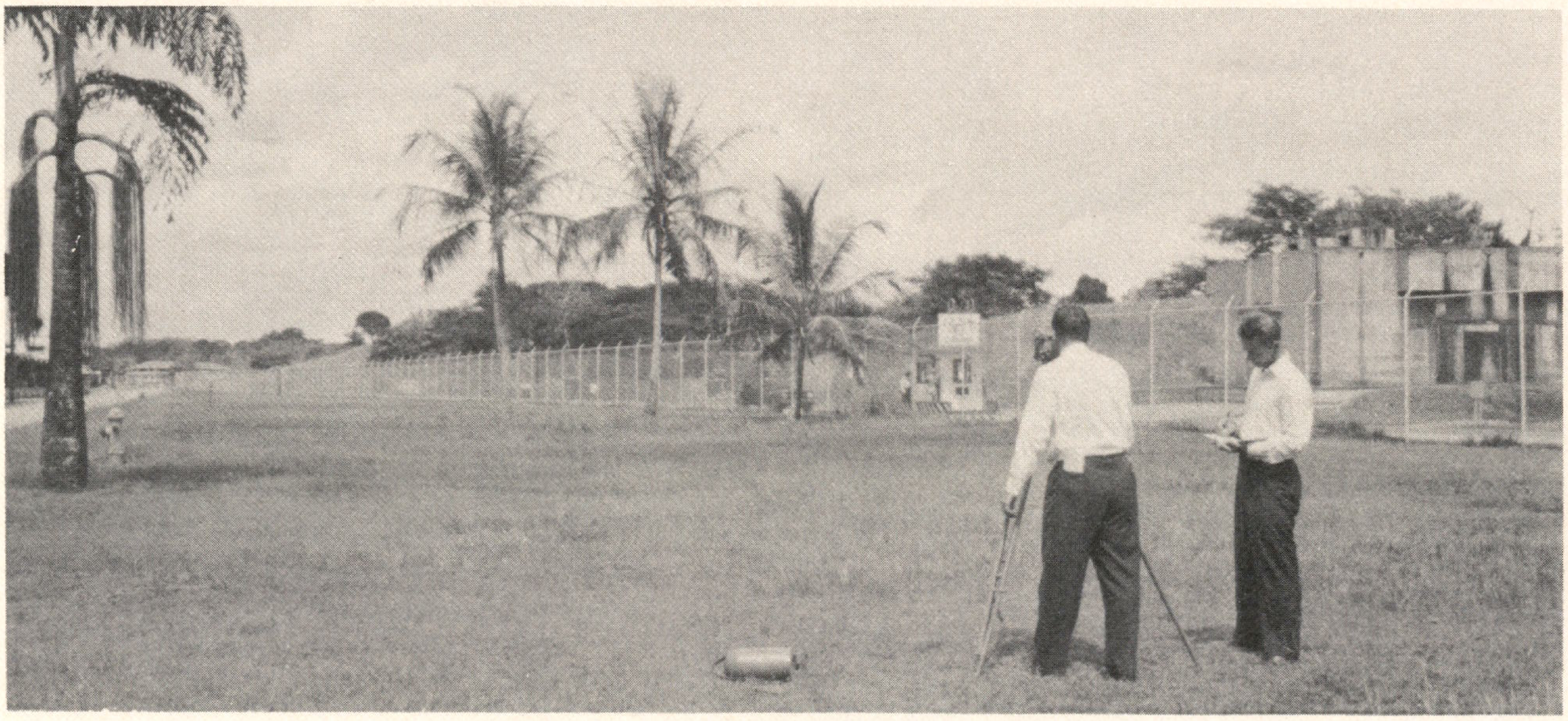
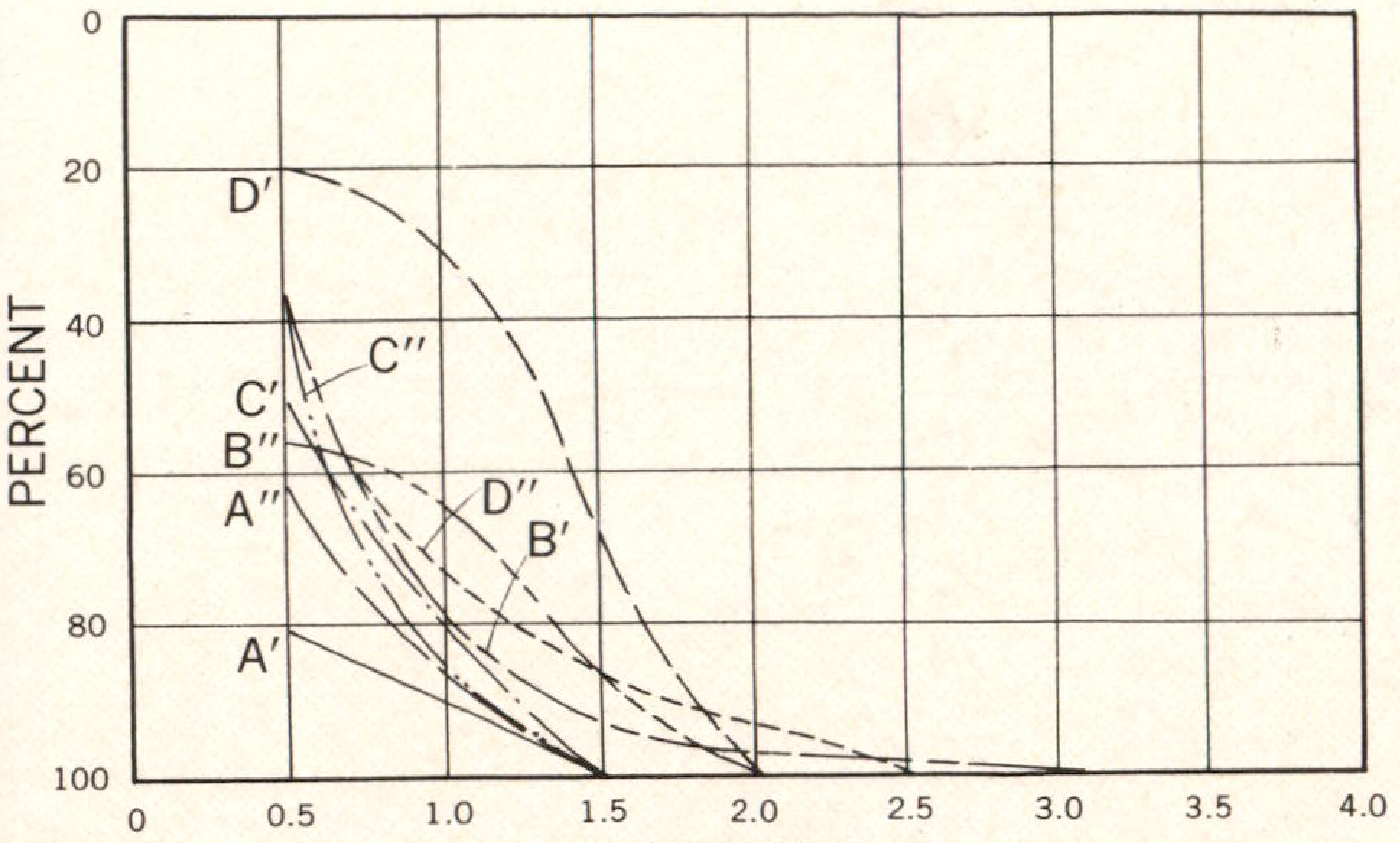
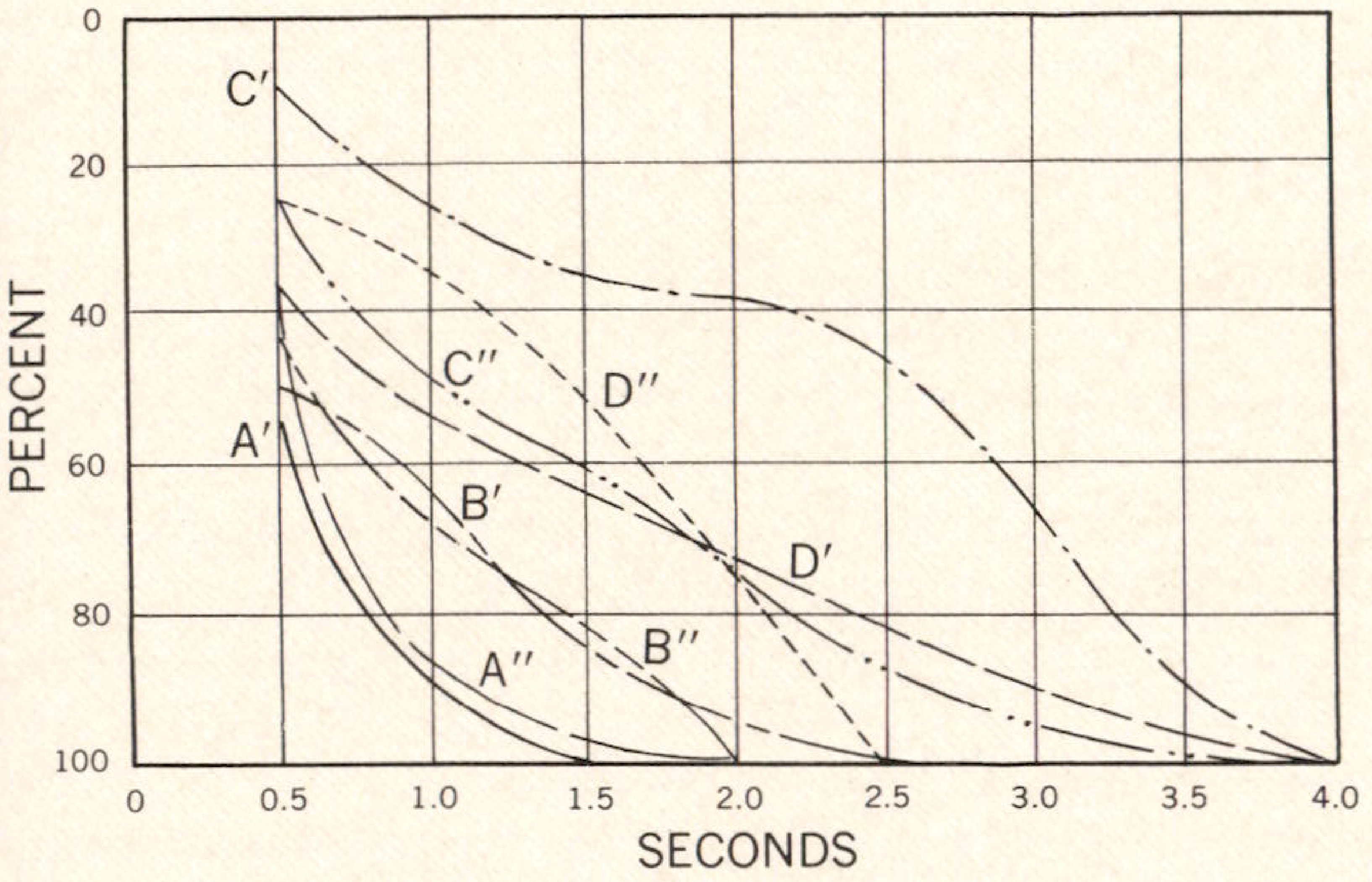


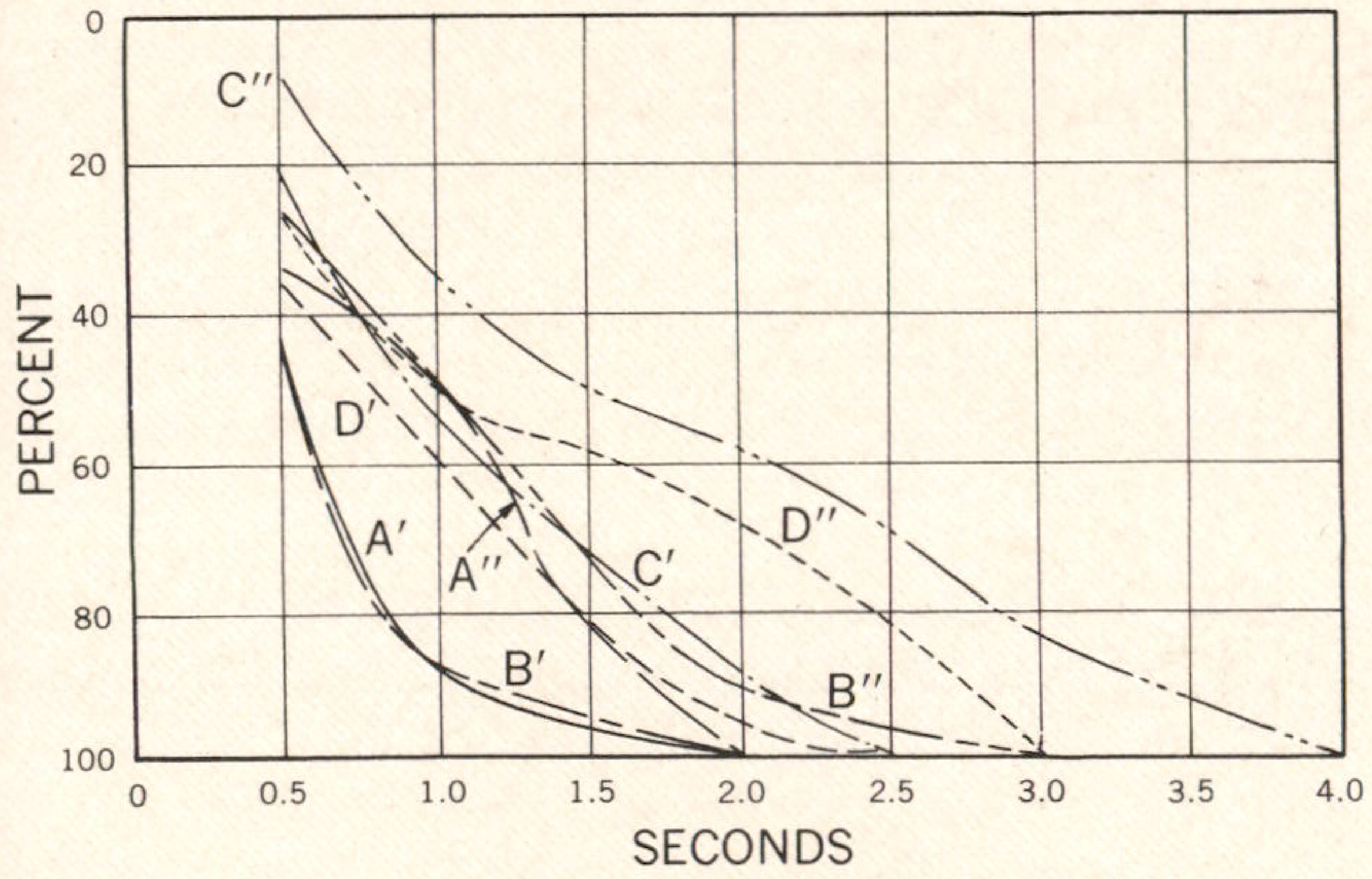
FIG. 2.—Testing site in the Canal Zone



(a) Theodolite No. 14406



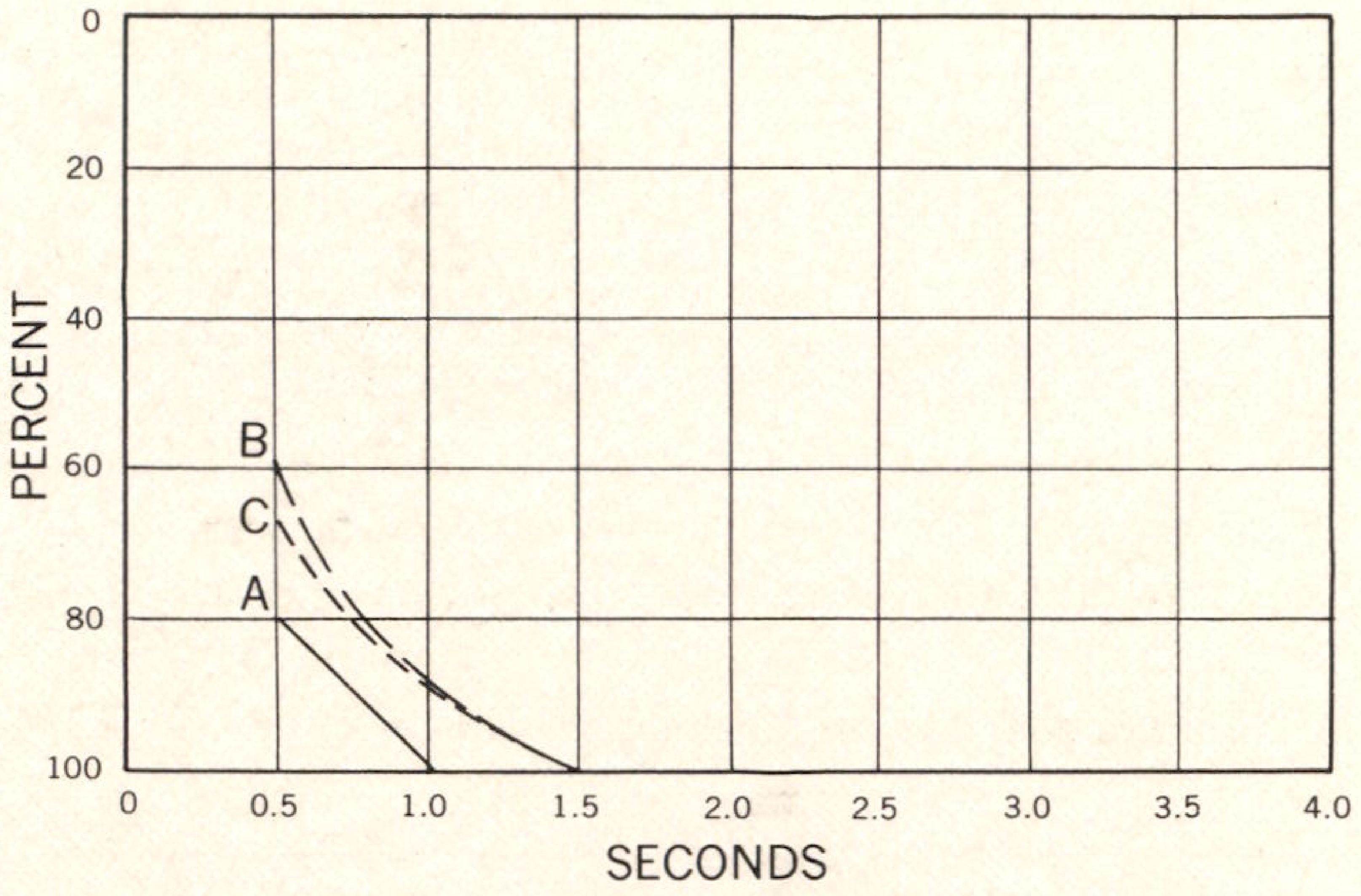
(b) Theodolite No. 14426



(c) Theodolite No. 17796

FIG. 3.—Accuracy of subtense bar angles

(Two or four positions of circle)



Theodolite No. 17796

FIG. 4.—Accuracy of subtense bar angles

(Four or eight positions of circle)

cent of the time, and the maximum error increases to 4″.0. For the *A* and *B* curves the accuracy at the longer distances was less than for the shorter distances, reflecting the increased difficulty of making accurate pointings at the longer distances under ordinary field conditions. The general pattern of decrease in accuracy with increase in distance is not reflected in the *C* and *D* curves, so it can be assumed that this trend is masked by factors other than distance.

During the observing 5 sets of 8 positions each were observed with theodolite No. 17796 at a distance of 120 meters. The results of these observations are shown in figure 4. The *A* curve shows the results obtained by 8 full positions, the *B* curve by 8 half-positions, and the *C* curve shows the results when the observations are used as sets of 4 positions. This particular test shows that 8 positions will give an angle accuracy of 1″.0, or better, 100 percent of the time.

The cause of the lesser accuracy of the *C* and *D* curves as compared to the *B* curves in figure 3 must lie in some instrumental factor that affects the angles due to the method of observing. The initial settings used to measure the angles for the *B* curves divided the micrometer scale into 4 equal parts while the initial settings for the *C* and *D* curves were only 2 in number and divided the micrometer scale range in half. This points to non-linearity of the micrometer scale as the probable cause of the error.

To check the accuracy of the micrometer scales a curve was prepared for each theodolite using the observations made during the tests and following the method described in Special Publication 247, *Manual of Triangulation*, on pages 38 to 42, but considering all errors as originating in the micrometer instead of the horizontal circle. The resulting curves are shown in figure 5. The abscissa is in minutes of arc and corresponds to the micrometer reading on the T-2 theodolite, and the ordinate shows the error, in seconds. Since two directions are necessary to measure an angle, the correction to an angle is the micrometer error in the right hand pointing

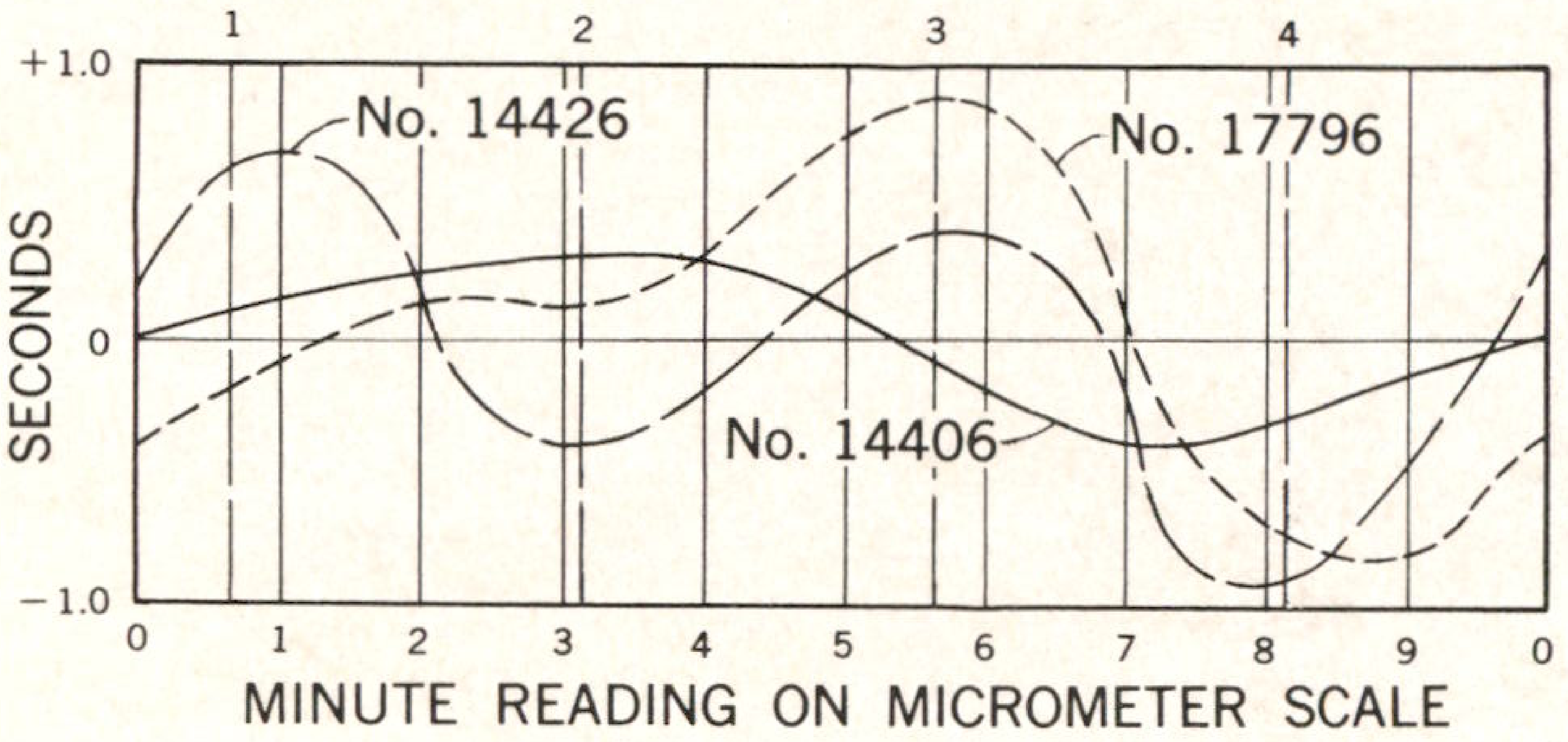
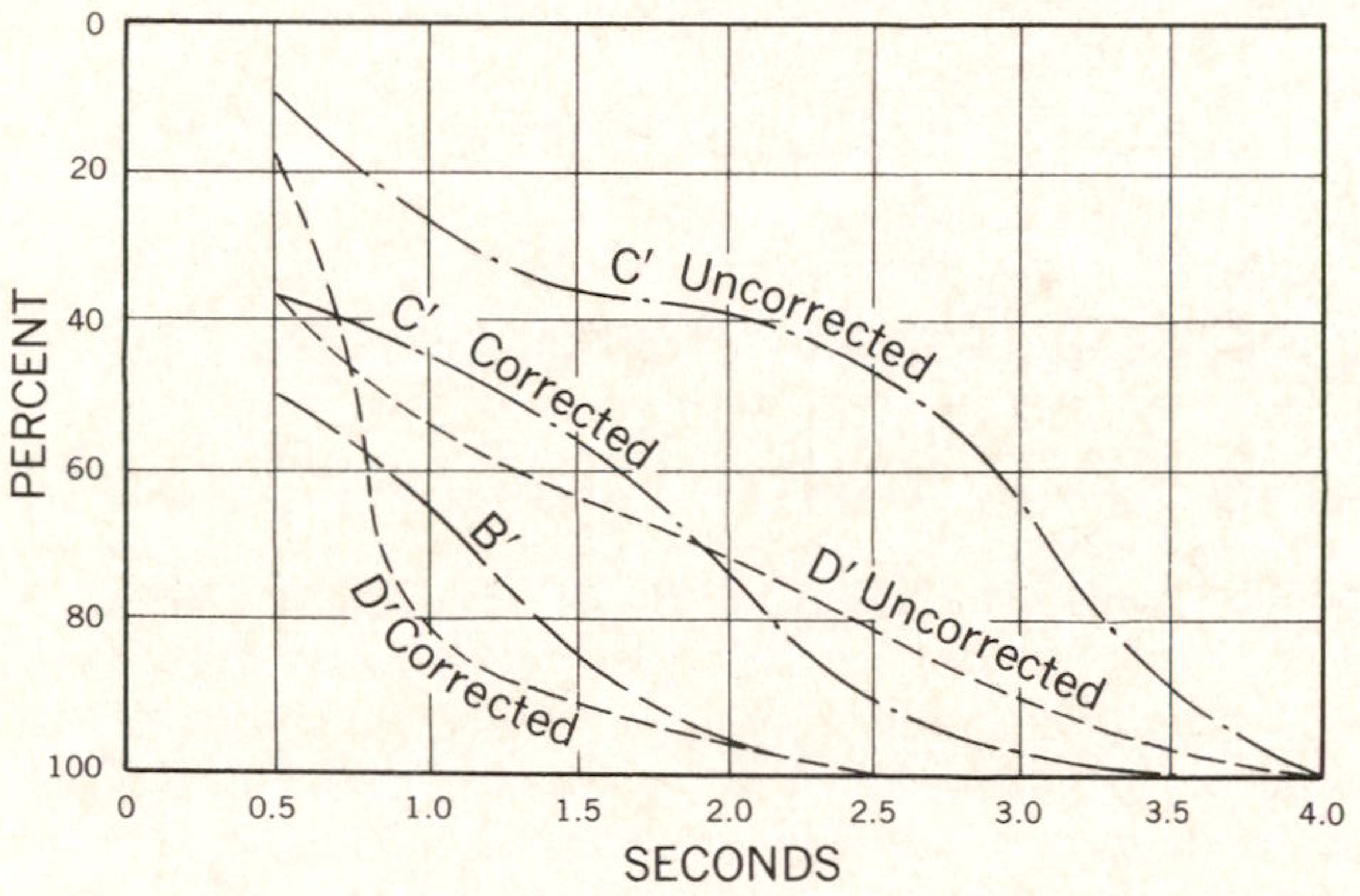
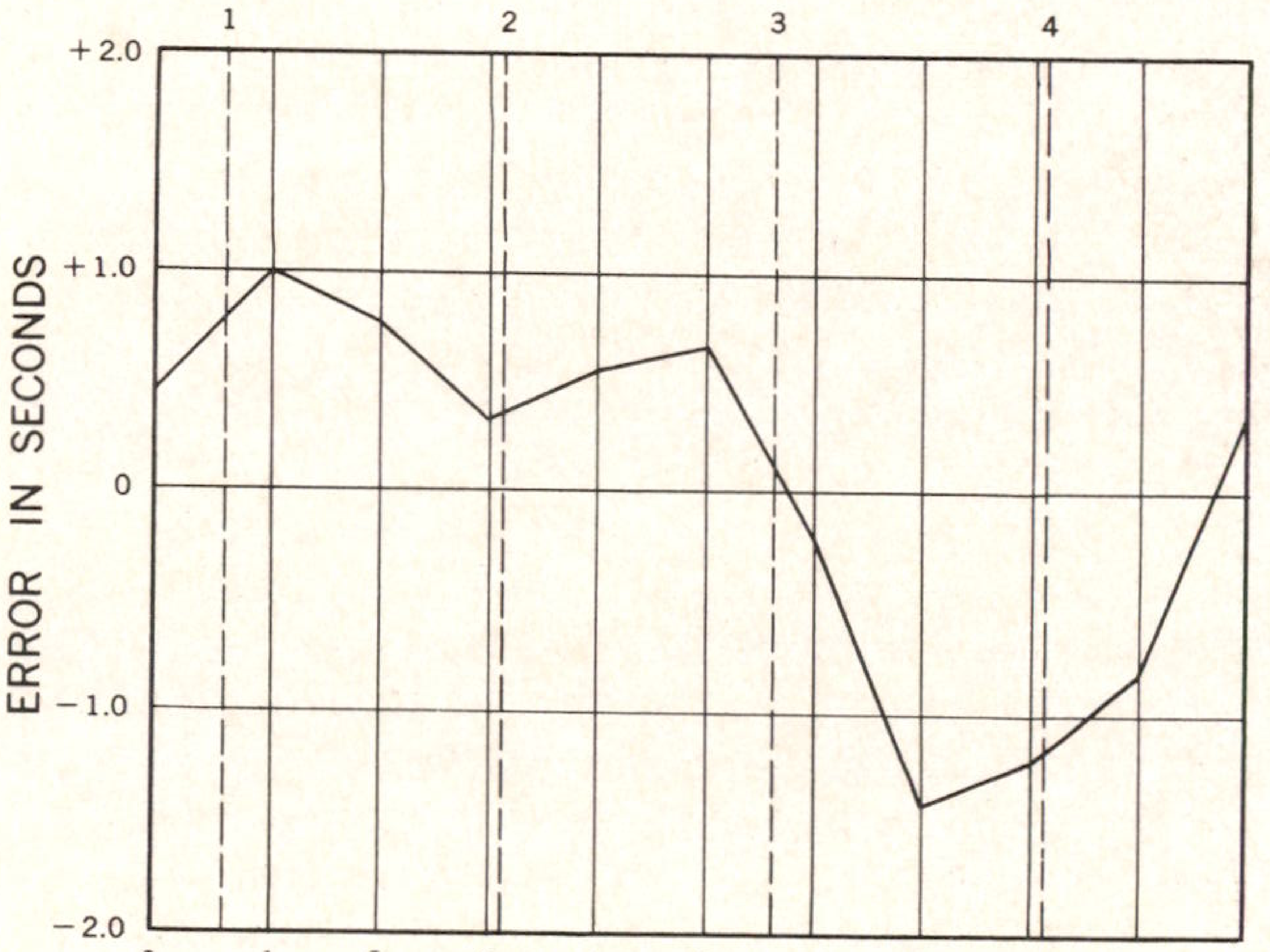


FIG. 5.— Micrometer scale error curves



Theodolite No. 14426

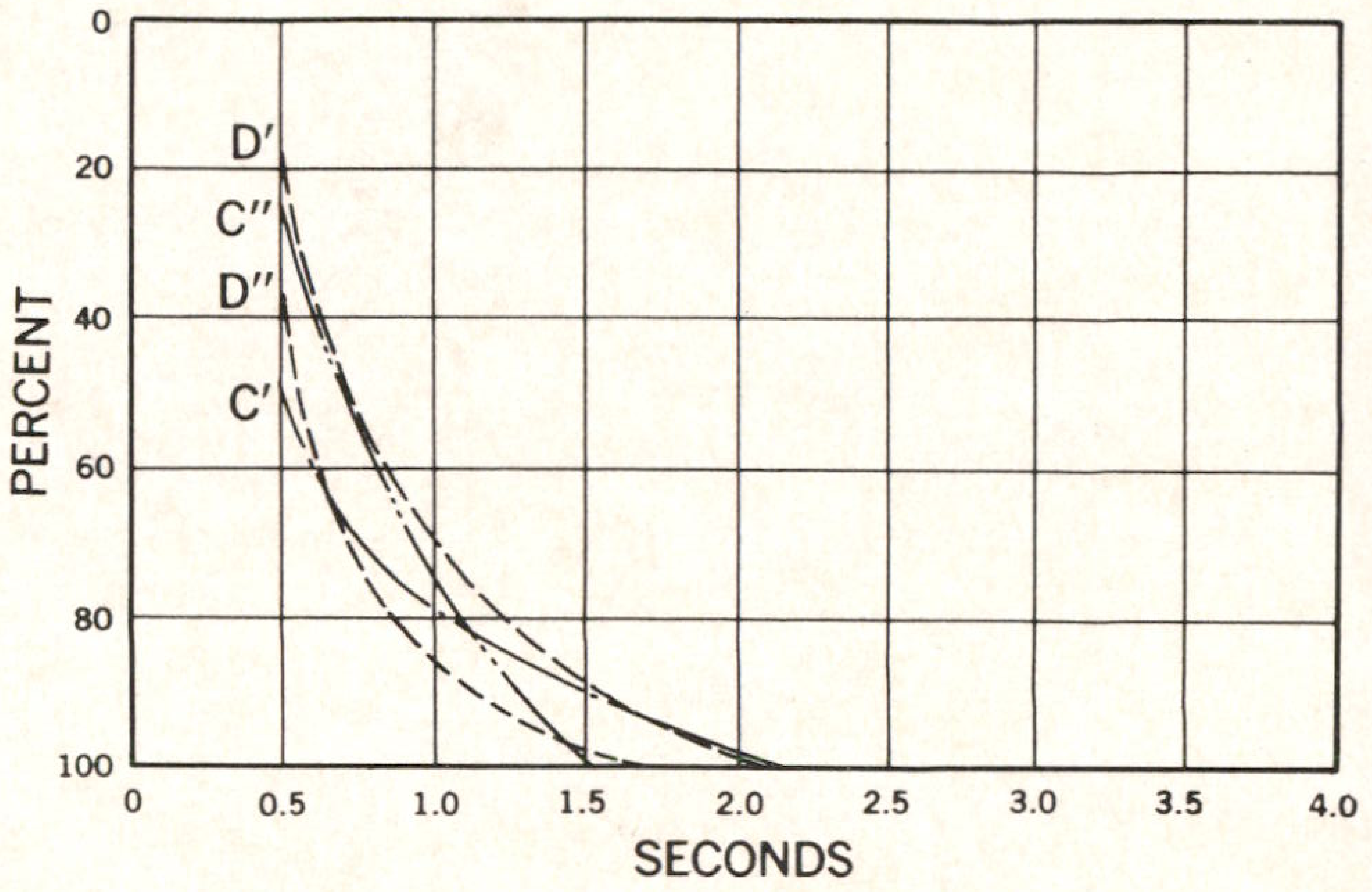
FIG. 6.—Angle accuracy with corrected angles



Theodolite No. 14406

FIG. 7.—Micrometer scale error curve

plus (with change of sign) the error in the left hand pointing. The vertical lines numbered 1 to 4 indicate the initial settings normally used with four positions.



Theodolite No. 14406

FIG. 8.—Angle accuracy with corrected angles

If corrections obtained from the curves in figure 5 are applied to the angles from which the *C* and *D* curves of figure 3 (b) were prepared, the curves shown in figure 6 result. These corrected curves show considerable improvement over the uncorrected curves.

The data on which the curves in figure 5 were based were not complete enough to allow the preparation of reliable curves, so that several months after completion of the original field tests, several sets of observations were made especially for the purpose of calibrating the micrometer scale on theodolite No. 14406, the only one of the three instruments used in the tests which was in the Canal Zone at that time. The calibration observations were made by placing a geodetic level rod in a horizontal position on top of a tripod and using rod markings two centimeters apart as signals. For the first set of observations the rod was placed about 85 meters from the instrument, twelve rod markings were used as signals, the angle between adjacent signals was about 51", and the angle between the outside pair of markings was about 09' 30". For the second test the rod was placed about 70 meters from the theodolite to reduce the effect of heat waves and to make the instrument pointing easier. At this distance the angle between adjacent signals was about 01' 10". Nine signals were used and they subtended an angle of 09' 30". Both sets of observations had ten positions with initial settings on the micrometer scale of 00' 00", 01' 00", etc. to 09' 00". For the first set the degree settings on the horizontal circle were kept at 00°, but for the second set the circle setting for the first position was 00° and the setting was advanced 18° for each following position.

A geodetic level rod was used to supply the targets because a short section of a salvaged rod was available. In lieu of the level rod, equally spaced markings of a suitable nature could be placed on a board, or on any surface which will not be subject to rapid changes due to humidity or other causes. The marks should be about 0.8 inch apart and should be about 10 in number. The targets should be placed at a distance from the theodolite which will make the angle between the outside markings about 10'.

The curves for each set of test observations were computed in the same manner as those for figure 5. The curves for both sets of observations were nearly identical even though the readings fell on different parts of the micrometer scale. The curve for the second set of observations is shown in figure 7. A comparison between this curve and the one in figure 5 for the same instrument shows a considerable difference. This is the result of the more evenly spaced observations used to compute the curve in figure 7.

If the curve in figure 7 is used to correct the angles obtained with two positions with theodolite No. 14406 the accuracy increases as shown by the curves in figure 8, which should be compared with the curves in figure 3 (a). The curves in figure 8 tell only part of the story of the change in accuracy, as they do not reflect the change that has taken place in the signs of the angle errors when the corrections are applied. Due to the shape of the micrometer scale error curve the sum of the corrections for positions 1 and 3 tend to have the same sign regardless of the size of the angle being measured, and the same is true for positions 2 and 4 but with a change in sign as compared to positions 1 and 3. Table 1 shows the angle errors, with and without regard for sign, for the sets of angles in the test. An inspection of this table shows the similarity of signs in the columns listing the results of sets with two positions.

If the angles obtained using 2 positions with theodolite No. 14406 are corrected by use of the curve in figure 7, the values shown in table 2 are obtained. There is no general improvement in the algebraic mean values in the positions 1 and 3 column and several of the errors are considerably larger than those in table 1. The mean for this column changes 0".5 but due to shifting past the point of zero correction the new value is only 0".1 larger than the uncorrected value. In the column for positions 2 and 4 the uncorrected values were rather large and the values in table 2 show considerable improvement, the maximum

Table 1.--*Average angle error*

[All values are in seconds]

Distance in meters	Four positions		Four half positions		Two positions (Nos. 1 and 3)		Two positions (Nos. 2 and 4)	
	Mean (no sign)	Algebraic mean	Mean (no sign)	Algebraic mean	Mean (no sign)	Algebraic mean	Mean (no sign)	Algebraic mean
				Theodolite No. 14406				
90	0.4	+0.2	0.5	+0.2	0.5	-0.5	1.2	+1.0
120	0.3	+0.1	0.7	+0.1	0.7	-0.2	1.2	+0.3
180	0.6	+0.6	1.1	+0.6	0.7	+0.2	1.3	+1.1
270	0.3	-0.3	0.7	-0.2	0.7	-0.7	0.8	0.0
380	0.4	+0.4	0.8	+0.4	0.4	+0.4	0.7	+0.4
Mean	0.4	+0.2	0.8	+0.2	0.6	-0.2	1.0	+0.6
				Theodolite No. 14426				
120	0.4	-0.2	0.8	-0.2	2.5	-2.4	1.8	+1.8
180	0.7	-0.6	0.9	-0.6	2.2	-2.1	0.7	+0.7
270	0.7	-0.4	1.0	-0.5	1.1	-1.1	1.5	+0.3
380	0.7	-0.3	0.6	-0.3	1.8	-1.8	1.4	+1.1
Mean	0.6	-0.4	0.8	-0.4	1.9	-1.8	1.4	+1.0
				Theodolite No. 17796				
90	0.5	-0.4	0.6	-0.3	1.1	-1.0	0.6	+0.4
120	0.7	+0.4	0.6	+0.4	0.8	-0.5	1.4	+1.4
180	0.7	-0.6	0.9	-0.6	1.8	-1.8	0.6	+0.6
270	1.2	-1.2	1.4	-1.2	1.1	-1.1	1.6	-1.6
390	0.7	-0.7	0.9	-0.8	2.7	-2.7	1.1	+1.1
Mean	0.8	-0.5	0.9	-0.5	1.5	-1.4	1.1	+0.4

error changing from +1″.1 to +0″.6. The mean for this column changes from +0″.6 to +0″.1. The means of both columns are now within 0″.1 of the mean for sets of 4 positions, as shown in table 1, instead of the 0″.4 for the uncorrected values.

As previously mentioned theodolites Nos. 14426 and 17796 were not available for the making of accurate micrometer scale correction curves. Had these curves been available the large errors shown for sets of 2 positions in table 1 would be decreased in size and would have a smaller mean value for the column.

The use of 4 initial settings evenly spaced around the range of the micrometer scale will practically eliminate errors due to non-linearity of the micrometer scale if the error curve is reasonably regular in shape. For theodolite No. 14406 the maximum error on any of the four position test angles due to this cause was 0″.1. When the micrometer scale error curves are not regular in shape four equally spaced settings may not entirely eliminate errors due to this cause. With theodolites Nos. 14426 and 17796 the algebraic means for angles obtained with four positions tend to have the same sign for all distances, and this may indicate that some micrometer scale error is still present.

Micrometer scale errors also affect the divergence of the individual directions from the mean of a set. For theodolite No. 14406 a 3″.0 rejection limit could be used when obtaining the mean of sets of four positions, but this had to be increased to 4″.0 for the other two instruments. In a few instances a 5″.0 rejection limit had to be used for theodolite No. 17796 since a retake position was not available, and to reject the value which varied widely from the mean would have caused a much larger error than when the value was retained and used in computing the mean.

Table 2.--*Average angle error when using corrected angles*

[All values are in seconds]

Distance in meters	Two positions (Nos. 1 and 3)		Two positions (Nos. 2 and 4)	
	Mean (no sign)	Algebraic mean	Mean (no sign)	Algebraic mean
Theodolite No. 14406				
90	0.5	0.0	0.7	+0.3
120	0.9	+0.6	0.9	-0.5
180	0.9	+0.7	1.2	+0.6
270	0.6	-0.6	0.8	0.0
380	0.9	+0.9	0.5	-0.1
Mean........	0.8	+ 0.3	0.8	+ 0.1

The relationship between the angle accuracy and the divergence of individual directions from the mean of the set is shown in table 3. In this table the values in the "average" columns are the means of the maximum divergences for each set in a group. The values in the "maximum" columns are the largest single divergence for the groups. Several interesting conclusions can be drawn from the table. The maximum divergence in a set apparently has no direct bearing on the accuracy of the mean angle; in general, the maximum divergence is larger for angles obtained with one telescope pointing than when direct and reverse pointings are made on each object; and the maximum divergence increases with an increase in the number of positions comprising a set. The latter conclusion is amplified when the observations used to compute the curves in figure 4, five sets of 8 positions each with theodolite No. 17796, are considered. All of the mean angles were accurate within 1″.0 yet the maximum divergence varied from 3″.4 to 4″.7, with four of the values being over 4″.0.

In the T-2 theodolite the range of the micrometer is changed by moving a lens which is located on the vertical axis of the instrument. When fixing this lens in position the coincidence reading at the lower end of the micrometer range should have an average reading of less than 00' 01″.5, and when the coincidence is shifted to the upper end of the micrometer range the average reading should be more than 09' 58″.5. The error curve shown in figure 7 for theodolite No. 14406 indicates that this instrument has the lens set within the permissible range. Any change in the position of this lens will cause a change in the micrometer error and any time this lens is moved, during cleaning of the instrument or for other purposes, a new curve should be computed.

The foregoing has pointed out the errors which can arise when directions measured with the T-2 theodolite are not equally distributed over the range of the micrometer in sufficient number to allow the errors to compensate. Four equally spaced micrometer settings for the initial direction will be sufficient to give the accuracy required for second-order triangulation, but enough systematic error may remain to make correction advisable when some theodolites are used to measure subtense bar angles with four positions. Of the three theodolites tested only one could be considered to have even fair accuracy when angles are measured with two directions. It appears that the only solution for this condition is to correct the angles obtained with two positions for micrometer error. Where angles are interdependent, as are the azimuth angles on a traverse, and it is not considered practical to apply corrections, better results will be obtained by alternating the initial settings for positions 1

Table 3.--*Divergence from mean direction*

[All values are in seconds]

Error in mean angle	Divergence from mean of set							
	Four positions				Two positions			
	Full positions		Half positions		Nos. 1 and 3		Nos. 2 and 4	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Theodolite No. 14406								
0.0 to 0.5...............	1.7	2.7	2.4	3.8	1.2	2.2	1.5	2.5
0.6 to 1.0...............	2.2	2.8	2.1	3.2	0.7	1.2	0.6	1.5
1.1 to 1.5...............	1.4	1.5	1.3	2.5	0.6	0.8	0.5	0.9
1.6 to 2.0...............	....	....	2.0	2.0	....	....	0.8	1.2
2.1 to 2.5...............	....	....	2.0	2.0				
2.6 to 3.0...............	....	....	2.0	2.0				
Theodolite No. 14426								
0.0 to 0.5...............	2.5	4.1*	2.6	4.3	0.6	0.7	1.2	2.5
0.6 to 1.0...............	2.7	3.9	3.0	5.0	1.0	1.2	1.3	2.1
1.1 to 1.5...............	2.7	2.7	3.2	4.6	1.1	2.3	0.5	0.9
1.6 to 2.0...............	1.7	1.7	3.3	4.5	....	....	0.8	1.1
2.1 to 2.5...............	....	....	3.2	3.2	1.1	2.4	0.7	1.1
2.6 to 3.0...............	....	....	....	....	1.8	3.4	0.1	0.1
3.1 to 4.0...............	....	....	....	....	1.1	2.0	0.2	0.2
Theodolite No. 17796								
0.0 to 0.5...............	2.9	4.0	3.0	4.9	0.8	2.8	1.4	3.0
0.6 to 1.0...............	2.8	4.0	3.2	5.0	1.3	2.7	2.1	2.9
1.1 to 1.5...............	2.6	4.8	3.0	4.5	1.2	2.1	2.0	3.2
1.6 to 2.0...............	2.1	2.4	2.8	4.0	1.2	2.1	1.6	1.9
2.1 to 2.5...............	....	....	2.6	2.6	1.2	1.5	1.4	1.6
2.5 to 3.0...............	....	....	2.9	2.9	2.4	3.8	1.8	1.8
3.1 to 4.0...............	....	....	....	....	1.1	1.5		

*The direction which gave this value was retained even though it was over the rejection limit of 4″.0, since a retake position was not available and to reject it would have increased the error.

and 3 with those for positions 2 and 4, rather than using the same initial settings for all stations.

In conclusion, the accuracy with which angles can be measured with the Wild T-2 theodolite is dependent on the errors in the micrometer as well as the errors in the horizontal circle. To obtain accurate angles it is important that the observations in a set be well distributed around the range of the micrometer as well as around the horizontal circle.

Comment

The subtense bar method, when used in connection with traverse surveys, has a definite place in surveying which has not received proper recognition in this country. Good judgment must be exercised as to just when the method should be employed. In areas that are relatively level and over which taping can be conducted without too much difficulty, little is to be gained by the subtense method. It is particularly adaptable to rugged terrain and to projects where relatively low accuracy is sufficient. A case in point would be the determination of position and elevation of picture points in photogrammetric control.

One of the principal arguments for the subtense method is its simplicity and speed. Anything that can be done to reduce the number of observations of a small angle and still maintain the accuracy required is quite desirable. For example, it is stated that, due to the irregularity of the micrometer scale, four positions, direct and reverse, are required. Two positions appear to be adequate if the readings are corrected for scale irregularity.

It is proposed as an optimum program that two positions, direct and reverse, be observed using four settings of the micrometer scale by advancing it at the middle of each position. Thus, the micrometer scale settings would be as follows:

(1) 0' 40" for first position direct.
(2) 3' 10" for first position reverse.
(3) 5' 40" for second position direct.
(4) 8' 10" for second position reverse.

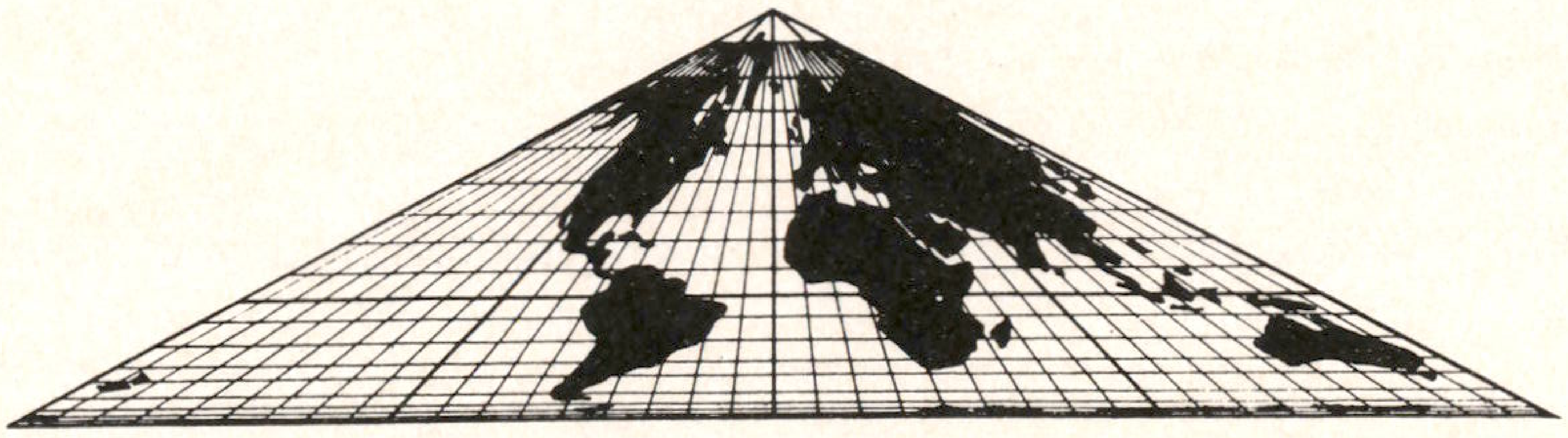
For ease in computation, perhaps settings (1) and (3) should be used for the first position and (2) and (4) for the second position. It is not important that the readings be distributed over the main circle, since any periodic error in the graduation of the circle is not great enough to affect small angles.

Mr. Millard L. Cutler of the Geodesy Division has recently conducted a rather extensive experiment with the subtense bar method for the purpose of obtaining data on accuracies. He has concluded that the minimum requirements for third-order traverse can be met for lines up to a length of 200 meters provided extreme care is exercised throughout and provided also weather conditions are favorable. In most of his tests he used 8 positions, direct and reverse, for the measurement of a small angle and states that his experience in a limited number of tests indicates that the smaller instruments, such as the Kern DMK 2 and the Wild T-2, will give about the same accuracy as the Wild T-3.

This is hard to understand and I believe that a more exhaustive test would prove the superiority of the Wild T-3. This instrument has a larger magnifying power permitting finer pointings, and its micrometer scale ranges only 2 minutes as against 10 minutes for the T-2 theodolite. Although the T-3 theodolite is a rather large and expensive instrument to be employed in the subtense bar method, if it is available for other purposes, it might well be used for this purpose in order to cut down the number of observations to obtain a given accuracy.

I do not believe that it is desirable to furnish our regular triangulation parties with subtense equipment under normal conditions. The few times it is necessary to employ such a method, any short base application would be satisfactory. In the Coast and Geodetic Survey, the Photogrammetry Division would probably be most interested in the subtense method.

Lansing G. Simmons,
Chief Mathematician



Army Engineers Develop Radar Presentation Restitutor

A Radar Presentation Restitutor, a device which removes as many as six different distortions simultaneously from radar plan position indicator photography, has been developed by the U. S. Army Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Va. The corrected photos may then be used for radar mapping.

Using novel optical and mechanical principles that require only setting three dials, the Restitutor quickly removes all the distortions including slant range, which must be changed to true ground range; sweep delay; aircraft motion during scan time; non-uniformity of electronic sweep; lens distortion in the recording camera; and curvature of the cathode ray tube (radar scope) face. The first three are major distortions while the other three are minor in the present state of the radar mapping art.

The Restitutor corrects each sweep of the radar photo separately, thus paralleling the manner in which the photograph was originally formed in the radar set. Prior to development of this equipment, distortions were removed graphically and by computation for a finite number of points in each photograph.

The Radar Presentation Restitutor is compact (10 cubic feet), weighs 200 pounds, and is rugged in construction. It can be transported in the field.--From a release, Engineer Research and Development Laboratories, Department of the Army.

Deflection of the Vertical Above Sea Level

HYMAN ORLIN, Mathematician

U. S. Coast and Geodetic Survey

IN RECENT YEARS, considerable attention has been given to the determination of the deflection of the vertical at points above sea level. At sea level, the deflection is defined as the angle between the normal to the reference ellipsoid and the normal to the geoid. Above sea level, the deflection is defined as the angle between the normal to the level surface determined by the theoretical gravity field for the adopted reference ellipsoid and the normal to the level surface determined by the actual gravity field. Just as the normal to the geoid indicates the direction of the gravity vector at sea level, so the normal to the level surface at the elevated point represents the direction of the gravity vector at that point. Thus, for a body above sea level, a knowledge of this latter direction in conjunction with the intensity of gravity completely determines the effect of the earth's attraction on the body at a point in its orbit or trajectory.

Procedures for determining the deflection at sea level are the astrogeodetic, gravimetric, and topographic-isostatic methods. It is usual to designate the deflection in terms of its two components--in the meridian and in the prime vertical. As the astronomic position, reduced to sea level, is determined with respect to the normal to the geoid and the geodetic position is determined with respect to the normal to the ellipsoid, a simple computation establishes the two components of the deflection. However, the choice of the reference ellipsoid and datum is not unique and one should expect the deflections to depend upon this choice. The gravimetric method, based upon the free air anomalies, is a modification by Vening Meinesz (1) and de Graaff Hunter (2) of a problem proposed by George Stokes (3). An advantage of this method is that the deflections are practically unaffected by the choice of the reference ellipsoid and refer to the angles between the normals to the best fitting ellipsoid and the normals to the geoid. Thus, from a knowledge of the astronomic positions and the deflections determined gravimetrically one may compute the directions of the normals to this ideal ellipsoid.

Although the direction of the normal to the best fitting ellipsoid is desired at sea level for geodetic purposes, the emphasis in orbit and trajectory problems has been on the direction of the gravity vector at points above sea level. Essentially, astronomic coordinates are needed for these elevated stations. Without adequate instrumentation to establish these astronomic positions a substitute technique must be devised. Generally, one can obtain the direction of the gravity vector at the elevated point for the reference ellipsoid from theoretical considerations and then determine the change in this direction due to the variation of the earth's figure from that of the reference ellipsoid.

Where adequate gravity coverage is available, a suitable technique giving this change in direction has been proposed by Hirvonen (4). However, in regions of sparse gravity coverage, where the free air anomalies do not represent the area considered, the application of this procedure to the free air anomalies would give spurious results. This would be particularly true for large ocean and mountainous regions where the gravity coverage, at this time, is especially inadequate. This situation can be partially remedied by applying Hirvonen's technique to the isostatic anomalies, which generally are more representative of large areas, and supplementing this computation with the effect of topography and compensation under the isostatic theory.* Where gravity information is practically nonexistent the topographic-isostatic method is the only one available. It is this method that is primarily discussed in this paper.

Any theoretical method for determining the deflection of the vertical must consider the irregularities in the distribution of the masses comprising the earth. These irregularities may be due to the topography (land and water) or to a variation from the normal density beneath the surface of the earth or to both. Assuming a density of 2.67 gm./cm.^{3} for the land masses and a density deficiency of 1.643 gm./cm.^{3} for the oceans, the effect of the topography on the deflection may be computed (topographic deflection). If a suitable theory determines the variation from the normal density beneath the solid surface of the earth, its effect can also be computed. Hayford (5) in 1912 developed such a method.

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*When determining the deflection of the vertical from gravity anomalies one generally considers a gravity field of radius less than 400 kilometers due to the lack of gravity data. This implies that outside the 400-kilometer radius the effect of the average anomalies approximate to zero, which assumption applies more generally to the isostatic anomalies than to the free air anomalies when the available gravity data are inadequate.

Simply stated, the theory of isostasy implies that the mass (volume times density) in any column from the surface down to some depth (depth of compensation) is equal to the mass in a column from sea level down to the same depth. A consequence of this assumption is that the topographic mass in a column is equal to the deficiency or excess of mass beneath this column. This deficiency or excess of mass is attributed to a variation from the normal density in the column. As the topographic mass is determinable and a depth of compensation is adopted, the variation in density may be evaluated. With this knowledge, the effect on the deflection due to the deficiency or excess of mass may be computed (isostatic compensation deflection). These two deflections, due to irregularities in the topography and variation from the normal density, represent the topographic-isostatic deflection of the vertical.

Of the two well-known sources, neither Hayford (6) nor Darling (7, 8) considers the determination of the deflection at points far above sea level. This problem may be resolved by extending the tables in these sources. Another approach depends upon the approximation of the horizontal component of the attraction of spherical laminae. A numerical integration will then determine the total effect of columns h kilometers in height or depth. Actually, both procedures were tried with satisfactory agreement. The results indicate that the topographic-isostatic deflection at an elevated point is a function of the topographic deflection for a station at sea level.

Both Hayford's and Darling's methods require that the average elevations or depths of compartments (defined by radial lines and concentric circles centered at the station) be estimated from maps. To facilitate this process, transparent templates (*see* fig. 1 of Coast and Geodetic Survey Special Publication No. 243, ***Fundamental Tables for the Deflection of the Vertical)*** are prepared upon which are drawn the circles and the radial lines. The radii depend upon Table II of ***Special Publication No. 243***, and upon the scale of the map. The consecutive azimuths, a_1 and a_2 of these lines are chosen so that

$$\sin a_2 - \sin a_1 = 0.25 \tag{1}$$

The average topography is first estimated with the reference line in the meridian for the meridian deflection and then with the reference line in the prime vertical for the prime vertical deflection.

Hayford initially assumes that the topography is condensed to the horizon of the station and then corrects this assumption by applying a "slope" correction. The radii of successive circles (consecutive circles form zones) are in the ratio of 1:1.426. Under these conditions the effect of each compartment is

$$D_T = 12''.44 \frac{\delta}{\Delta} h (\sin a_2 - \sin a_1) \log_e \frac{r_2}{r_1} \tag{2}$$

Evaluating equation (2) we find, when h is expressed in feet for land areas,

$$D_T = 0''.0001012h \tag{3}$$

and when h is expressed in fathoms for water areas,

$$D_T = 0''.0003735h \tag{4}$$

(These values differ slightly from those used by Hayford due to a revision in the density factor for the earth from 5.576 gm./cm.^{3} to 5.517 gm./cm.^{3})

After the average topography has been estimated for all compartments, the topographic deflection is easily computed by equation (3) or (4) and corrected for the "slope."

Hayford found that the effect of isostatic compensation on the deflection was a function of the topographic deflection and the depth of compensation. He prepared a table of factors similar to those in Table III of ***Special Publication No. 243*** which are applied to the topographic deflection to obtain the topographic-isostatic deflection.

RECENT PROCEDURES

Topographic Deflection

With the advent of more rapid computing equipment the most time-consuming aspect of these determinations is the estimation of the average topography, which has to be done twice. By increasing the computing load we may eliminate one set of estimations for each station. To accomplish this, the sector azimuths are chosen so that the angular aperture of each sector is a constant.

Evaluating equation (2) under this assumption we find, when h is expressed in feet for land compartments,

$$D_T = 0''.00040464 \ (\sin a_2 - \sin a_1) \ h \tag{5}$$

and, when h is expressed in fathoms for water compartments,

$$D_T = 0''.0014940 \ (\sin a_2 - \sin a_1) \ h \tag{6}$$

The accompanying template (fig. 1) has been prepared with the azimuths of the radial lines differing by 22°.5. The reference line is oriented to the south. The first zone for which the topography is estimated is the farthest zone on the same grade or slope as the station. The estimation is carried out for all zones to the antipodes.

All readings are expressed in the same unit (feet or fathoms). From equations (5) and (6) we note the following relationships:

D_T for 369 feet of land = D_T for 100 fathoms of water

D_T for 27.1 fathoms of water = D_T for 100 feet of land

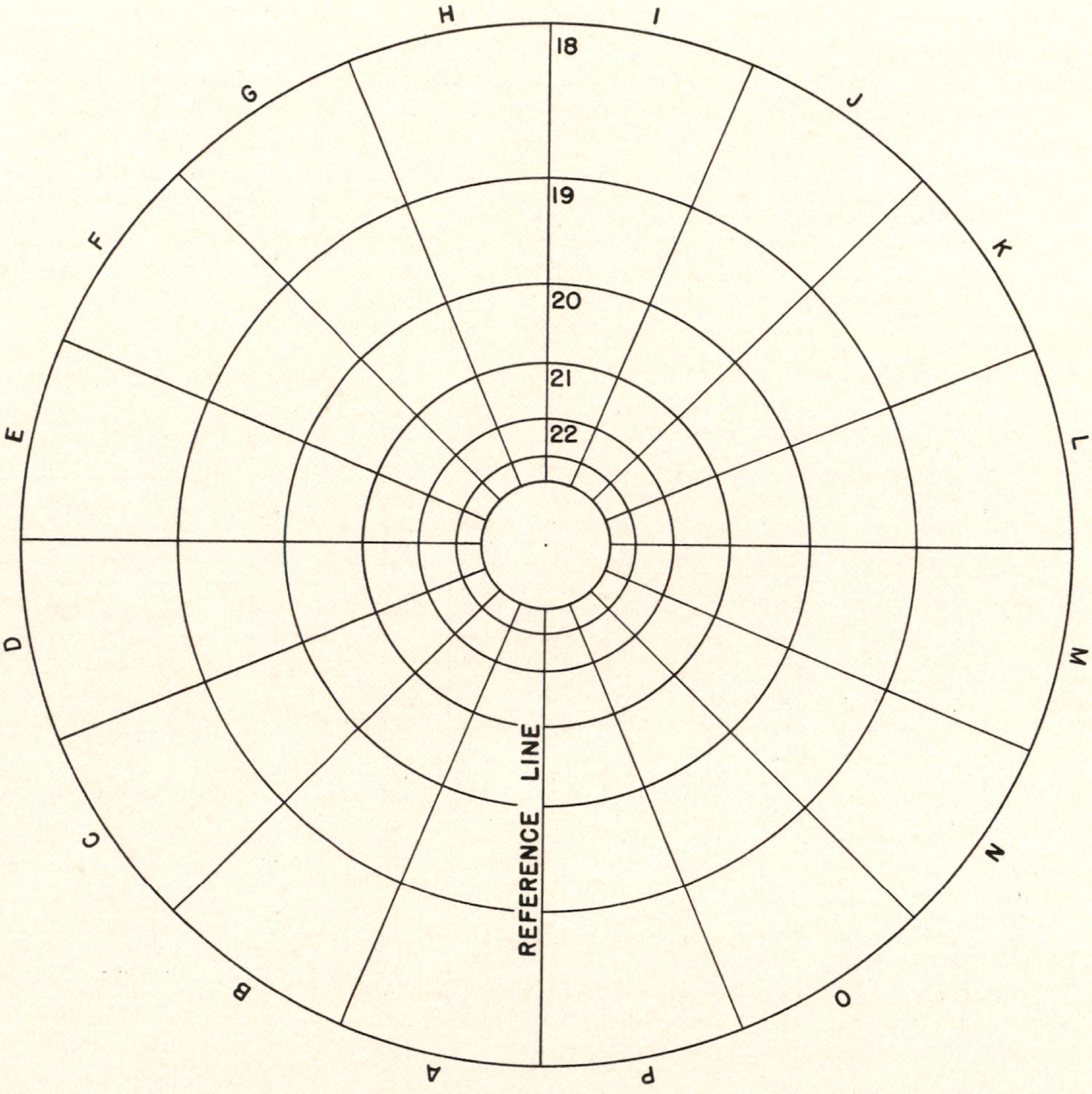

FIG. 1.—Circular template. The number of zones shown on a template depends upon the scale of the map for which the template is designed.

Thus, when all the topography is to be estimated in feet, water compartments are estimated in negative "equivalent feet," and when the topography is to be estimated in fathoms, land compartments are estimated in positive "equivalent fathoms." These "equivalents" produce the same deflections in the horizon of the station, but introduce a small error after the "slope" correction is applied. This error is never more than a few hundredths of a second of arc for 15-degree grades near the station and is practically nonexistent for zones 15 and beyond.

The topographic deflection is computed by equation (5) or (6) corrected for the "slope" as indicated in equation (7) or (8) below, for a station at sea level. For a station on the earth's surface above sea level, the topographic readings should be reduced by the elevation of the station before applying equation (7) or (8). If the readings are not so reduced, a small error is introduced for the near zones when the grade is greater than 15 degrees.

Slope-correction factors S are found by comparing the deflection determined by equation (3) or (4) with the values obtained from Darling's tables (8). The ratio of Darling's value to equation (3) or (4), as a function of h and the particular zone, may then be applied to the values obtained by equation (5) or (6), respectively. Thus, to determine the correction factor for a depth of 4,500 fathoms (8,230 meters) in zone 21, we find by equation (4),

$$D_T = 1''.680$$

and from Darling's tables for a depth of 8,230 meters in zone 21,

$$D_T = 0''.324 \times 1.643 = 0''.532$$

and the ratio,

$$S = \frac{0''.532}{1''.680} = 0.32$$

which is applied to the deflection computed by equation (6) for a depth of 4,500 fathoms. In practice, these quantities do not change rapidly with height or depth and the same factor can be used for a range of 300 fathoms or 1,000 feet.

Table 1 gives the factors for all possible elevation differences for zones 21 through 14. The factors differ by less than 3 percent from unity for large elevation differences in the remaining zones.

Table 1.—*Slope correction factors S*

Elevations	Zone							
	21	20	19	18	17	16	15	14
Fathoms (In units of 100)								
3	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.93	0.96	0.98	0.99	1.00	1.00	1.00	1.00
9	0.86	0.92	0.96	0.98	0.99	1.00	1.00	1.00
12	0.78	0.87	0.93	0.96	0.98	0.99	0.99	1.00
15	0.71	0.82	0.89	0.94	0.97	0.99	0.99	1.00
18	0.64	0.76	0.86	0.92	0.96	0.98	0.99	1.00
21	0.58	0.71	0.82	0.90	0.95	0.97	0.99	0.99
24	0.53	0.67	0.78	0.87	0.93	0.96	0.98	0.99
27	0.49	0.62	0.75	0.85	0.91	0.96	0.98	0.99
30	0.45	0.58	0.71	0.82	0.90	0.95	0.97	0.99
33	0.41	0.54	0.68	0.79	0.88	0.94	0.97	0.98
36	0.39	0.51	0.65	0.77	0.86	0.92	0.96	0.98
39	0.36	0.48	0.61	0.74	0.84	0.91	0.95	0.97
42	0.34	0.45	0.59	0.72	0.83	0.90	0.95	0.97
45	0.32	0.43	0.56	0.69	0.81	0.89	0.94	0.97
48	0.30	0.41	0.54	0.67	0.79	0.88	0.93	0.97
51	0.28	0.39	0.51	0.65	0.77	0.86	0.92	0.96
54	0.27	0.37	0.49	0.63	0.75	0.85	0.92	0.96
57	0.26	0.35	0.47	0.60	0.73	0.84	0.91	0.95
60	0.24	0.34	0.45	0.59	0.72	0.83	0.90	0.95
Feet (In units of 1,000)								
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
3	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00
4	0.91	0.95	0.98	0.98	0.99	1.00	1.00	1.00
5	0.88	0.93	0.97	0.98	0.99	1.00	1.00	1.00
6	0.83	0.91	0.95	0.97	0.99	0.99	1.00	1.00
7	0.79	0.88	0.93	0.97	0.98	0.99	1.00	1.00
8	0.74	0.85	0.91	0.95	0.98	0.99	1.00	1.00
9	0.71	0.82	0.90	0.94	0.97	0.98	0.99	1.00
10	0.67	0.79	0.88	0.93	0.97	0.98	0.99	1.00
11	0.63	0.76	0.85	0.92	0.96	0.98	0.99	0.99
12	0.60	0.73	0.84	0.91	0.95	0.97	0.99	0.99
13	0.57	0.70	0.81	0.89	0.94	0.97	0.98	0.99
14	0.54	0.67	0.79	0.88	0.93	0.97	0.98	0.99
15	0.51	0.65	0.77	0.87	0.92	0.96	0.98	0.99
16	0.49	0.63	0.75	0.85	0.92	0.96	0.98	0.99
17	0.47	0.60	0.73	0.84	0.91	0.95	0.98	0.99
18	0.45	0.58	0.71	0.82	0.90	0.95	0.97	0.99
19	0.43	0.56	0.69	0.81	0.89	0.94	0.97	0.98
20	0.41	0.54	0.67	0.79	0.88	0.94	0.97	0.98

Thus, for water compartments, or land compartments expressed in "equivalent fathoms," the deflection is determined by equation (6), modified by the factors in Table 1 as a function of *h* and the particular zone.

$$D_T = 0\overset{''}{.}0014940\ (\sin a_2 - \sin a_1)\ hS \qquad (7)$$

The deflection for land compartments, or water compartments expressed in "equivalent feet," is determined by equation (5) modified by *S*.

$$D_T = 0\overset{''}{.}00040464\ (\sin a_2 - \sin a_1)\ hS \qquad (8)$$

The coefficients of *hS* for the sectors *A* through *P* are given in Table 2. The following conditions determine the algebraic signs:

1. Elevations are considered as positive quantities and depths as negative quantities.
2. Deflection is given in the sense of astronomic minus geodetic (*A* - *G*).
3. Deflection in the prime vertical (η) is for west longitude.
4. Deflection in the meridian (ξ) assumes that latitudes increase algebraically from the South Pole to the North Pole.

Table 2.—*Topographic deflection factors (without "slope" correction) for each sector of a zone*

Compartment	Coefficients (in units of 0.001)			
	Equation (8)		Equation (7)	
	Meridian	Prime vertical	Meridian	Prime vertical
A	+0″.15485	−0″.03080	+0″.57172	−0″.11372
B	+0.13128	−0.08771	+0.48470	−0.32385
C	+0.08771	−0.13128	+0.32385	−0.48470
D	+0.03080	−0.15485	+0.11372	−0.57172
E	−0.03080	−0.15485	−0.11372	−0.57172
F	−0.08771	−0.13128	−0.32385	−0.48470
G	−0.13128	−0.08771	−0.48470	−0.32385
H	−0.15485	−0.03080	−0.57172	−0.11372
I	−0.15485	+0.03080	−0.57172	+0.11372
J	−0.13128	+0.08771	−0.48470	+0.32385
K	−0.08771	+0.13128	−0.32385	+0.48470
L	−0.03080	+0.15485	−0.11372	+0.57172
M	+0.03080	+0.15485	+0.11372	+0.57172
N	+0.08771	+0.13128	+0.32385	+0.48470
O	+0.13128	+0.08771	+0.48470	+0.32385
P	+0.15485	+0.03080	+0.57172	+0.11372

We must now consider the effect of the plane area within the nearest zone for which the topography has been estimated. In this plane region the elevation of a compartment in a sector is a function of the distance from the station. As the radii of successive rings are in the ratio of 1:1.426, the mean elevations of successive compartments in a sector will be in the same proportion. Hence, from equation (2), if the deflection for the first zone computed is represented by D_O, the zones nearer to the station will contribute the following deflections:

$$D_1 = \frac{1}{1.426} D_0$$

$$D_2 = \frac{1}{1.426} D_1 = \left(\frac{1}{1.426}\right)^2 D_0$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .$$

$$D_n = \frac{1}{1.426} D_{n-1} = \left(\frac{1}{1.426}\right)^n D_0$$

where each D_i represents the deflection for a zone nearer the station than the zone with deflection D_O, and *i* is taken from 1 to infinity.

The sum of these deflections is an infinite geometric series. Therefore, the effect of this plane region is given by the equation

$$\Sigma \left(\frac{1}{1.426}\right)^{i} D_0 = 2.35\ D_0 \qquad (9)$$

Isostatic Compensation Considered

The deflection D_C, due to the compensating mass, is computed by means of equation (2) with the logarithmic term replaced by

$$\log_e \frac{r_2 + (r_2{}^2 + h_1{}^2)^{1/2}}{r_1 + (r_1{}^2 + h_1{}^2)^{1/2}} \qquad (10)$$

considering the effect as a negative quantity. Hence, the ratio of D_C to D_T is the negative of *(B)*, the ratio of (10) to the logarithmic term in equation (2). Therefore,

$$D_C = -D_T B \qquad (11)$$

$$D = D_T + D_C = D_T\ F \qquad (12)$$

where

D = total deflection

$$F = 1 - B \qquad (13)$$

The factors **F** for each zone and for various depths h_1 are given in Table III of ***Special Publication No. 243.***

The total topographic-isostatic deflection is the sum of the products of the topographic effect for each zone by the appropriate factor for each zone determined by equation (13).

DEFLECTIONS ABOVE SEA LEVEL

A preliminary investigation indicated that the effect of a zone on the deflection at points far above sea level was approximately proportional to the effect of the same zone on a station at the earth's surface. To determine these proportionality factors, the ratio of the deflection at the elevated point to the deflection at the sea level station was computed for various average elevations for a compartment in each zone. The direct computation of the deflection for each compartment was replaced by a numerical integration of the effect of spherical laminae on the elevated point. (*See* fig. 2.) For comparison with existing tables, the same procedure was used to obtain the deflection for a compartment in each zone for a station at sea level.

In order to determine the topographic deflection, laminae were taken at heights of 2 and 4 kilometers, at sea level, and at 2- and 4-kilometer depths. The deflection due to compensation depended upon the numerical integration of the effect of spherical laminae at sea level and at depths of *n*, 2*n*, 3*n*, and 4*n* (where *n* =28.425 km.). Greater accuracy could have been achieved by determining the effect of laminae at additional points between sea level and the depth of compensation. However, the numerical integration over the values considered compares favorably with those obtainable from Darling's tables for a station at 32 kilometers, and closer agreement can be expected at higher elevations.

The laminae herein considered are surface areas of unit density. Those at sea level lie on the sea-level surface of the earth treated as a sphere with a radius equal to the mean radius of the International Ellipsoid (6371.2km.), and coincide with the surface areas of the compartments used by Darling to determine the deflection of the vertical at sea-level stations. The remaining laminae are assumed to lie on spheres of radii (6371.2+*h*) kilometers, where the linear radii for each zone are defined by $\frac{6371.2+h}{6371.2}$ times the radii of the zones as given by Darling, and *h* is the height (positive) or depth (negative) of the laminae with respect to sea level. As the desired ratios are independent of the angular aperture of the compartments, and as it was desired to compare the effects computed in this way with those given by existing tables, and as these tables are based upon an angular aperture satisfying the condition that the difference in the sines of the sector azimuths be equal to 0.25, this latter condition was adhered to. In addition, with little loss of ac-

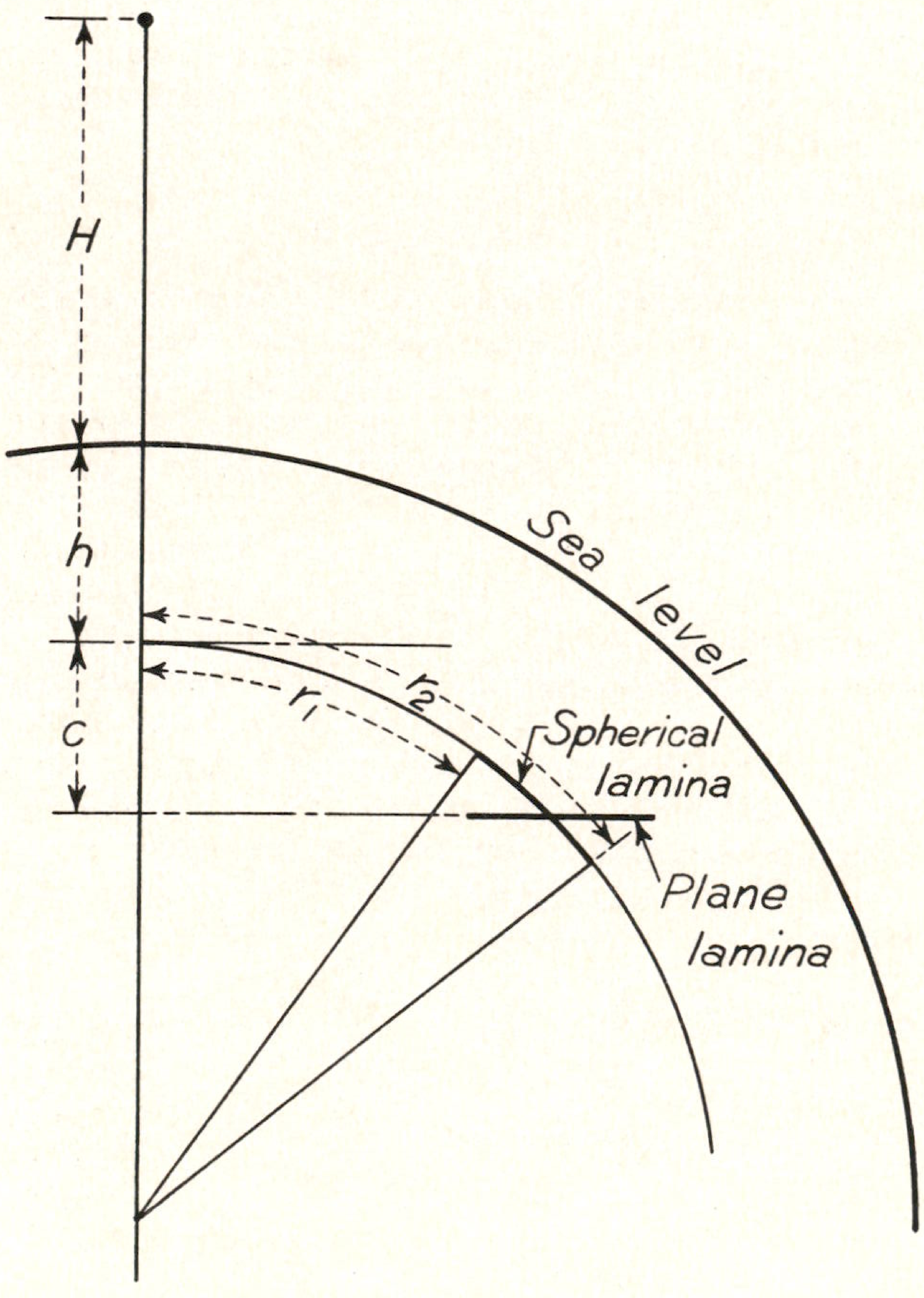

FIG. 2.—Plane and spherical laminae.

curacy, the spherical laminae could be assumed to be plane laminae which lie *c* kilometers below the plane tangent to the sphere of radius (6371.2 $+h$) kilometers. This distance *c* is the average depression of the spherical laminae below this tangent plane.

Thus, the formula for the deflection at *H* kilometers due to plane laminae of unit density is

$$D_h = A \left| -\frac{r}{(r^2+R^2)^{1/2}} + \log_e \left[r + (r^2+R^2)^{1/2} \right] \right|_{r_1}^{r_2} \tag{14}$$

where

$A = \dfrac{6.673 \times 206265 \times 10^{-3}}{4G_H}$

$G_H = \dfrac{(6371.2)^2}{(6371.2+H)^2} \times 982.03$

r_1 and r_2 = inner and outer radii of a zone on a sphere of radius $(6371.2+h)$ kilometers

$R = H - c - h$

H = elevation of station in kilometers

h = height (positive) or depth (negative) of spherical laminae with respect to sea level

c = average depression of spherical laminae below tangent plane (a negative quantity)

The preceding radii maintain the mass of the spherical laminae but they exaggerate the distance from the normal to the sea-level surface at the station. To maintain this distance these radii may be redefined by

$r = \dfrac{r_i \sin \theta_i}{\theta_i \text{ in radians}}$, where r_i is as defined above and θ_i is the angular radius corresponding to r_i. The distance is maintained at the expense of the mass. This difficulty can be overcome by introducing a fictitious density factor equal to the difference in the radii as originally defined divided by the difference in the radii as herein defined. The resulting deflection will again be in terms of unit density for the mass of the spherical laminae.

Equation (14) was used to compute the effect of plane laminae on stations at sea level and at elevations of 32, 64, 96, 128, and 160 kilometers. Thus, for plane laminae in zone 6 for a station at 32 kilometers the following table gives the data used and the deflections (D_h) computed:

$H = 32.00$ $c = -25.82$ $A = 0.353927$

h km.	r_1 km.	r_2 km.	D_h ″
+4	471.07	672.13	0.12406
+2	470.92	671.92	0.12393
0	470.77	671.71	0.12380
-2	470.62	671.50	0.12366
-4	470.47	671.29	0.12351
$-n$	468.67	668.71	0.12137
$-2n$	466.57	665.72	0.11808
$-3n$	464.47	662.72	0.11403
$-4n$	462.37	659.72	0.10934

The deflection due to the topography could be obtained by applying a numerical integration process such as Simpson's Rule to the values from D_{+4} to D_{-4}. With suitable accuracy the average D_h times the *h* for the compartment may be used.

The deflection due to the compensating mass is obtained by a numerical integration. A general quadrature formula derived from the integration of Newton's interpolation formula for equidistant intervals is used (9). The effect of a column of 113.7 kilometers at unit density below sea level is given by

$$\int_{-4n}^{0} D_h\, dh = 1.26333 \left[7\, D_0 + 32\, D_{-n} + 12\, D_{-2n} + 32\, D_{-3n} + 7\, D_{-4n} \right] \tag{15}$$

The effect of a column, equal to a depth of compensation of 113.7 kilometers at unit density, below the compartment** can be obtained from equation (15) and the values D_0 and D_{-4n} as follows:

$$\int_{-4n+h}^{h} D_h\, dh \cong \int_{-4n}^{0} D_h\, dh - (D_{-4n} - D_0)\, h \tag{16}$$

A better approximation can be obtained if one uses $\frac{D_{+4}+D_0}{2}$ for land compartments and $\frac{D_0+D_{-4}}{2}$ for water compartments in lieu of D_0, and $\frac{D_{-3n}+D_{-4n}}{2}$ in lieu of D_{-4n} in equation (16). However, the added refinement is rarely warranted.

A comparison of the deflections computed by equations (14) and (16) with the deflections determined by an extension of Darling's tables indicates very small discrepancies. Under the most unfavorable theoretical conditions, this discrepancy does not exceed 0″.03 per compartment for the compensating masses and 0″.06 per compartment for the topographic masses for a station at 32 kilometers. But, more probable values of the total discrepancy at a station are ± 1″.0 and ± 2″.0 for all the compensating and topographic masses, respectively. These errors merely indicate computational accuracy and not the probable error of the computed deflection. This latter quantity will depend upon the adequacy of the isostatic theory.

An examination of the topographic deflection at sea level and elevated stations indicated that the latter was nearly proportional to the former for all *h*, the proportionality factor being a function of the zone. The effect of the compensating masses showed the same tendency. These factors differed by less than 1 percent in any zone for all values of *h*. In the following table these pro-

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**The compensating mass column of 113.7 km. is assumed to start at the height of the compartment for land compartments and below the depth of the compartment for water compartments.

portionality factors are obtained by dividing the effect at elevation *H* by the effect at sea level:

Variation in effect in zone 6 from sea level to 32 kilometers for various h

h	Station at	Effect at unit density	Proportionality factor
		Topography	
±4 km.	sea level	0″.4964 (1)	
+4 km.	32 km.	0″.4957 (1)	0.9986
-4 km.	32 km.	0″.4946 (2)	0.9964
		Mean	0.9975
		Compensation	
+4 km.	sea level	13″.701 (3)	
+4 km.	32 km.	13″.426 (4)	0.9799
-4 km.	sea level	13″.617 (3)	
-4 km.	32 km.	13″.310 (4)	0.9775
		Mean	0.9787

(1) $\frac{D_{+4}+D_0}{2}$ h as computed by equation (14).

(2) $\frac{D_{-4}+D_0}{2}$ h as computed by equation (14).

(3) As given in Darling's tables.

(4) Computed by equations (14) and (16).

Thus, for zone 6 one can obtain the total topographic-isostatic deflection at 32 kilometers by applying the factors 0.9975 and 0.9787 to the topographic and compensation effects, respectively, at sea level.

The computation of the deflection at altitudes is considerably facilitated by taking account of these factors of proportionality. For if

D_{OT} (D_{OC}) = deflection due to topography (compensation) for station at sea level

D_{HT} (D_{HC}) = deflection due to topography (compensation) for station at elevation H

and

$$R_{HT} = D_{HT} / D_{OT}$$

$$R_{HC} = D_{HC} / D_{OC}$$

the total deflection is

$$D_H = D_{HT} + D_{HC} = D_{OT}\ R_{HT} + D_{OC}\ R_{HC} \tag{17}$$

but by equations (11) and (13)

$$D_{OC} = D_{OT}\ (F-1)$$

hence (17) reduces to

$$D_H = D_{OT} \left[R_{HT} + (F-1)\ R_{HC} \right] \tag{18}$$

Where the average elevations for compartments in a zone indicate large variations, mean values of R_{HT} and R_{HC} in equation (18) can introduce errors of ±1″.0 and ±2″.0 in the total topographic and compensation effects, respectively, at 32 kilometers. If the topography in the vicinity of the station is predominantly land or water, this error may be reduced by determining these factors for land or water columns only. Thus, for an ocean region the coefficients of D_{OT} in equation (18) were determined from the ratios of the effect of water columns at altitude *H* to that at sea level. These quantities for zones 21 through 6 for a depth of compensation of 113.7 kilometers appear in Table 3. The table could be extended to the antipodes for all elevations.

The total topographic-isostatic deflection at the elevated point is the sum of the effects due to all the zones.

Table 3.—*Factors for computing isostatic deflections at elevations*

$(R_{HT} + (F-1)\,R_{HC})$

(To be applied to the topographic deflection at the sea level station)

Zone	H (in kilometers)					
	0	32	64	96	128	160
6.......	+0.016	+0.035	+0.050	+0.061	+0.072	+0.079
7.......	+0.036	+0.068	+0.092	+0.108	+0.120	+0.122
8.......	+0.073	+0.125	+0.157	+0.172	+0.168	+0.156
9.......	+0.136	+0.213	+0.236	+0.221	+0.188	+0.152
10.......	+0.231	+0.317	+0.292	+0.225	+0.160	+0.111
11.......	+0.356	+0.405	+0.289	+0.175	+0.104	+0.062
12.......	+0.490	+0.432	+0.221	+0.105	+0.053	+0.029
13.......	+0.615	+0.376	+0.133	+0.051	+0.023	+0.011
14.......	+0.719	+0.262	+0.065	+0.022	+0.008	+0.005
15.......	+0.798	+0.148	+0.028	+0.008	+0.003	+0.001
16.......	+0.857	+0.070	+0.009	+0.003	0.000	0.000
17.......	+0.899	+0.029	+0.004	0.000	0.000	0.000
18.......	+0.929	+0.011	0.000	0.000	0.000	0.000
19.......	+0.950	+0.004	0.000	0.000	0.000	0.000
20.......	+0.965	+0.001	0.000	0.000	0.000	0.000
21.......	+0.975	+0.001	0.000	0.000	0.000	0.000

CONCLUSION

The deflections thus computed must be augmented by the deflection due to the isostatic anomalies using a technique such as Hirvonen's. A knowledge of these anomalies within a radius of 600 kilometers of a station at sea level would be adequate for an accuracy of ±2″.0 at all stations on the basis of available gravity information. Although this effect is small it does not reduce rapidly with height.

This total deflection will be referred to the level surface passing through the elevated point. The level surface is defined with reference to the International Ellipsoid.

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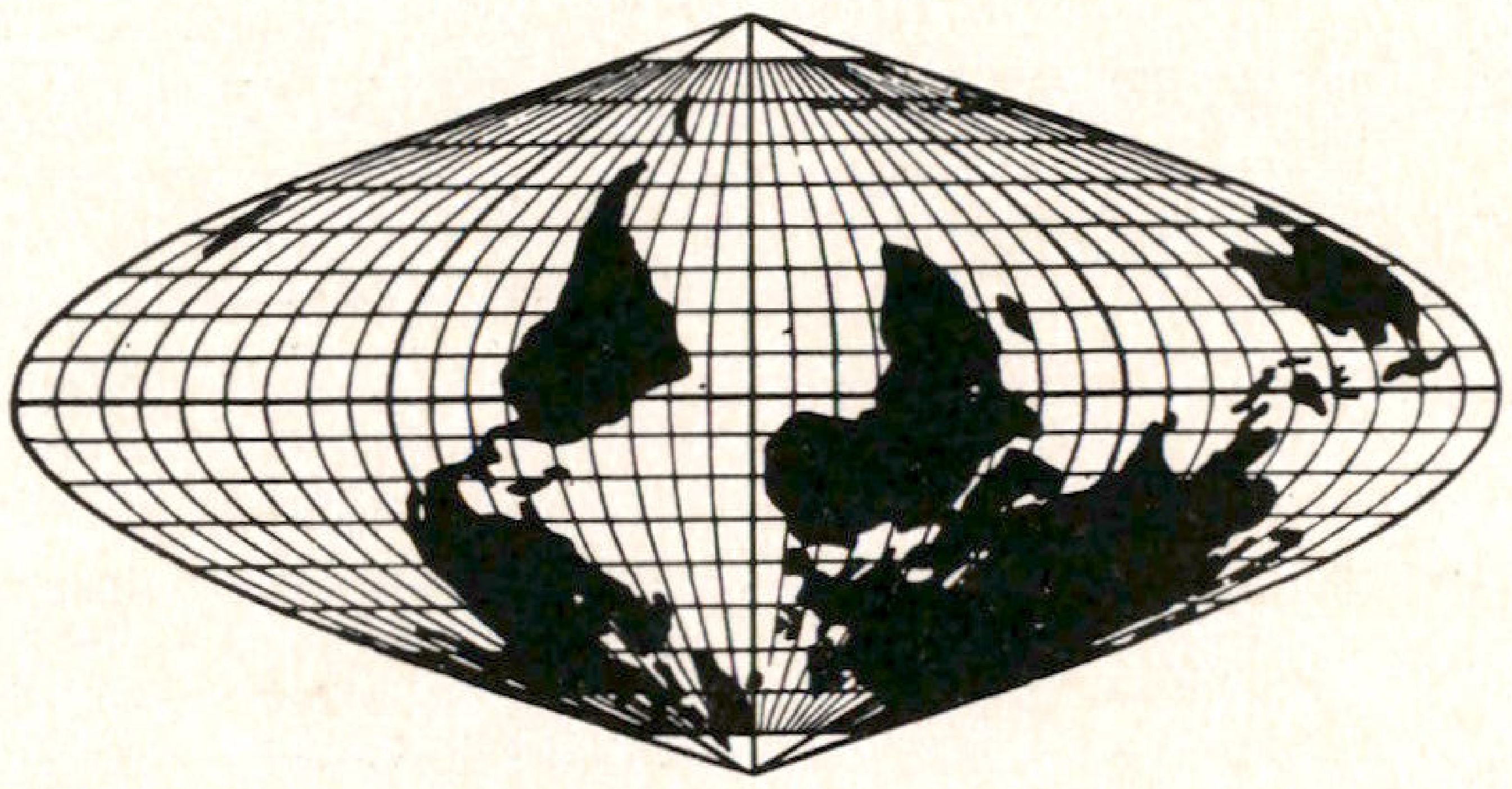

Rate of Postglacial Rise of Sea Level

The results of careful studies of peat and shell material from Velsen in North Holland reported by van Straaten, and radiocarbon measurements on this material by deVries and Barendsen have led to a fairly adequate knowledge of the approximate sea stand as a function of time for the Dutch coast over the past 8,000 years. These authors represent their results by a figure showing radiocarbon age of shell and peat versus depth of the sample horizon relative to the present strand line. The same is shown in this report (Contributions from the Scripps Institution of Oceanography, new series, No. 856); we have added measurements from other localities for comparison. Most of the added measurements were made by the Magnolia Petroleum Laboratory, Houston, Tex., on material that was obtained from bays, barrier islands, and the continental shelf of the Texas and Louisiana coasts.

With the exception of several dates that were determined by the Lamont Geological Observatory, the measurements appear to show approximately equal rates in the rise of the sea level at the various localities. This may indicate that the observations reflect the actual eustatic change that accompanied the melting of the last ice sheets rather than the effects of local tectonic movements or compaction. It is obvious, however, that many more measurements from a variety of locations must be made before it will be possible to distinguish conclusively between eustatism, tectonic movements, and compaction.

A possible temporary halt in the rise of the sea level some 7,000 or 8,000 years ago seems to be indicated by samples from both North Holland and the Gulf coast. Such a halt may conceivably correspond to the Cochrane halt in the retreat of the ice.

The picture becomes confused prior to the last 10,000 years, which may be due to imperfection of the data, or, possibly, to an oscillation of the sea stand connected with the Mankato readvance of the ice sheets around the Great Lakes. Evidence for or against changes in the rate of eustatic rise in correlation with oscillations of the ice sheets might prove helpful in determining whether or not glacial readvances were synchronous on different continents and in the two hemispheres.

Perhaps the most interesting question connected with these observations is that of the supposed postglacial higher sea stand during the "climatic optimum." Neither the samples from the Gulf coast nor those from North Holland give any indication of a postglacial sea level higher than that of the present. As yet no evidence from carbon-14 measurements has been produced that would prove such a high sea level, and a sample of shells from one of the low terraces from Western Australia (+10 to 12 feet), which was expected to date this sea stand, gave an age of more than 30,000 years.--F. P. Shepard and H. E. Suess in *Science*, June 15, 1956.

Application of Electronic Position Indicator to Long-Line Geodetic Measurements

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SEVERAL DEFENSE AGENCIES have been exploring methods of positioning remotely located areas such as scattered islands. As the Coast and Geodetic Survey used the Electronic Position Indicator (EPI) in 1951* for locating islands in the Bering Sea, it was natural that they would show interest in this system.

The Coast Survey used the line-crossing method for measuring lines ranging from 100 to 500 statute miles. These measurements were made by placing an EPI ground station at each end of the line to be measured, then the survey vessel with an EPI ship instrument aboard steamed across the line between stations, measuring, at frequent intervals, the distance to each ground station. When the ship is on the line between the two ground stations, the sum of the EPI distances measured is at the minimum, which is the distance between the two EPI ground stations.

An alternate method of using EPI for line measurements is to place a ground station at one end of the line to be measured and a ship station at the other end. The ship-station operator can then make a direct measurement to the ground station. Some of the advantages of this method over the line-crossing method are:

1. A large expensive ship is not needed to make the measurements.
2. The program is not governed by the vagaries of weather and other factors affecting the movement of the ship.
3. When the line to be measured is entirely over land, this is the only method that can be employed.
4. In any single line measurement using the direct method, only two operators and two instruments are needed; hence there is less source of error, whereas, in the line-crossing method, three operators and three instruments contribute to the total error.

The line-crossing method has the following advantages:

1. For equal transmitter power, it is possible to measure lines 30 to 40 percent longer.
2. Calibration of the equipment by line crossing is simpler; at least, the techniques for calibration by the line-crossing method have been established. After further study, however, it may be found that calibration by the direct method is simpler.

COOPERATIVE TESTS CARRIED OUT

The mutual interest of defense agencies and the Coast and Geodetic Survey in extending the applications of EPI resulted in a conference held at the Navy Department on January 4, 1956 to discuss a test experiment, using EPI for direct-line measurements. In the adopted program, the Coast and Geodetic Survey supplied the EPI instruments, formulated and conducted the tests, and evaluated the results. The Navy Department furnished the sites at the ends of the line to be measured, which included shelters for the equipment, EPI antenna system, and power to operate the equipment.

These tests are not considered as an evaluation of EPI for line measurements. More precisely, they are a study of how to adapt the existing EPI designed for hydrographic control of survey ships, for measuring long lines. However, it is hoped that sufficient evidence has resulted from these tests to tell whether the present system can be used, with slight modifications, or whether considerable development will be required.

In these tests the following factors were studied:

1. Value of the method of calibrating the system.
2. Stability of the system.
3. Operator's error.

The answer to some of these items is still incomplete, but further study is being made.

PROCEDURE

The test line selected was between Monomoy Point, Mass., and Cape May, N. J., a distance of about 300 statute miles. These points were chosen because the Navy had EPI stations at these locations, and thus much of the difficult and time-consuming part of the installation was circumvented. The antenna and ground system, housing facilities, and power supply from the EPI stations were used. The EPI and communication equipment used in the line measurements were supplied by the Coast and Geodetic Survey. It was originally intended to measure a second line between Monomoy Point and Cape Charles, Va., but, because of the difficulties in both the

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*"Datum Connection to the Bering Sea Islands," by Capt. Charles Pierce, and "Preliminary Adjustment of Shoran and EPI Observations in the Bering Sea," by B. K. Meade, in Journal No. 5, June 1953.

scheduling of personnel and in establishing this third station, that part of the program was abandoned.

Before the line could be measured, certain instrumental corrections had to be determined and applied as an arithmetical correction to the line measurement. They are uncompensated delays in the system, which are essentially constant both with regard to time and distance. These corrections were established by measuring the EPI distance over a known distance. Correction measurements were made both before and after the test line was measured, using a test circuit between Cheltenham, Md., and Fredericksburg, Va., a distance of about 46 miles.

Except for the antennas, the same equipment used in the calibration was used in the line measurements. It was assumed that the antenna systems would be the same at all locations since an attempt has been made to make all EPI antenna systems uniform.

The measurements extended over a period of several days to afford an opportunity to study and develop the line-measurement techniques.

MONOMOY POINT--CAPE MAY MEASUREMENTS

The EPI ship equipment was trucked from Washington to Chatham, Mass. There it was transferred to a Navy duck for a trip across an inlet and along 5 miles of beach to the Navy EPI station at the south end of Monomoy Point. The equipment was then set alongside the Navy EPI equipment, and connected to their EPI antenna and power supply.

The ground-station EPI equipment was transported by truck from Washington to Cape May, N. J., and unloaded at the Navy EPI station at the Hereford Inlet Coast Guard Station in North Wildwood, N. J. This equipment was placed alongside the Navy EPI equipment, and connected to their EPI antenna and power supply.

The EPI and communication equipment was set up in a little less than an hour. It is not to be inferred that a system can be put into operation this quickly, since the setting up of the antenna tower is by far the most time-consuming part of the job. It will take even longer, if shelters have to be constructed.

Measurements started about 11:00 a. m. on February 1, 1956, and continued until 4:00 p. m. In the beginning, a distance measurement was made every 10 minutes, alternating between teams 1 and 2. Later, measurements were also made by team 3, composed of an Army Map Service man at each station. This was the first time these men had operated EPI equipment. Team 3 was introduced to study the training needed to develop experienced operators and to measure the divergence in readings between experienced and inexperienced operators.

Spaced throughout the observations, noise measurements were taken at both stations, and zero-check readings were taken at the ship station. The latter is a measurement to relate the timing and sweep circuits of the ship-transmitted signal to the sweep circuits used to present the ground-station signals on the scope.

On February 2d, measurements were started at 9:00 a. m. and continued through 2:00 p. m. They were then discontinued because the Navy needed the EPI stations the following morning for an indefinite period.

Following these measurements, the equipment was returned to the Cheltenham-Fredericksburg test stations and the calibration rechecked. Since then, tests have continued and system improvements made to correct some of the uncertainties, which should make it more adaptable to direct-line measurements.

SUMMARY OF RESULTS

The results are presented in tabular form. Both the line measurements and the calibration measurements are summarized.

Correction to the EPI distance was arrived at as follows: The average of the EPI distances between Cheltenham and Fredericksburg was found to be 4.5 microseconds longer than the known distance. This average is for a period of 3 days of measurement. Two days of calibrations were prior to the line measurement between Monomoy Point and Cape May, and 1 day of calibration measurement followed the test. A total of 62 calibration measurements were made by teams 1 and 2. The average of each day's results was the same. At Monomoy Point an additional correction was required as the equipment was a considerable distance from the EPI antenna, necessitating the addition of an extra 225 feet of coaxial cable, over the length for which the system was calibrated. After allowing for the velocity of the signal in this cable, an additional correction of 0.7 microsecond was necessary. This was added to the 4.5 microseconds to make a total correction of minus 5.2 microseconds.

Based on a geodetic distance of 495,252 meters and a velocity of the radio waves of 299,692 km./sec., the true distance between the EPI antennas at Monomoy Point and Cape May is taken as 3,305.1 microseconds.

By carefully weighing the results of the line measurement and applying the 5.2 microseconds correction, the true distance between Monomoy Point and Cape May and the EPI measured distance agree within 0.5 microsecond or 75 yards, the EPI distance being short by this amount.

Table 1.—*Calibration measurements, Cheltenham to Fredericksburg*

(True distance = 500.9 microseconds)

Date	Conditions	Teams	Number of observations	Average EPI distance measured	EPI minus true (correction)	Spread of readings
1956				*Microseconds*	*Microseconds*	*Microseconds*
Jan. 24	(1)	1 and 2	14	505.4	-4.5	1.4
Jan. 26	....	1 and 2	17	505.4	-4.5	0.8
Feb. 6	(2)	1 and 2	8	504.0	-3.1	0.4
Feb. 14	....	1	10	505.4	-4.5	1.0

(1) All values between noon and 2:30 p.m.
(2) Ground saturated at both stations due to prolonged rain (rejected).

Table 2.—*Line measurement, Monomoy Point to Cape May*

(True distance = 3,305.1 microseconds or 495,252 meters)

Date	Conditions	Teams	Number of observations	Average EPI distance measured	Corrected EPI distance	Spread of readings	Error in distance measured	
1956				*Microseconds*	*Microseconds*	*Microseconds*	*Microseconds*	*Meters*
Feb. 1	(1)	1 and 2	21	3,309.3	3,304.1	1.5	-1.0	-150.0
Feb. 1	(2)	1 and 2	8	3,309.8	3,304.6	1.0	-0.5	-75.0
Feb. 1	(1)	3	4	3,308.8	3,303.6	3.0	-1.5	-225.0
Feb. 2	(1)	1 and 2	20	3,311.7	3,306.5	3.0	+1.4	+210.0

(1) Average of day's readings.
(2) Best group of day's readings-taken between 2:00 p.m. and 4:00 p.m.

DISCUSSION OF RESULTS

The best group of the Monomoy Point to Cape May measurements was that between 2:00 p.m. and 4:00 p.m. on February 1st. Measurements prior to that time were made when the ground-station transmitter was off frequency and also when a faulty grounding condition existed at the ground station. Measurements made on February 2nd cannot be considered of much value because of the considerable variation in the readings. The reason for this variation is believed to have been caused by changes of ground conductivity at the ground station, since these measurements were taken during heavy rain. Conductivity effects have also been observed at the calibration stations. The measurements on February 6th during the Cheltenham-Fredericksburg calibration is an example of ground-conductivity changes due to heavy rain. All during the measurements, a strong interfering signal was present at Monomoy Point, caused by excessive harmonic radiation from a broadcast station on Cape Cod. This signal made matching signals difficult, but by careful observation it is believed that a fair measurement was possible.

Value of method of calibration.—In review, a longer series of measurements between Monomoy Point and Cape May is indicated, however, it is thought that the final answer would not be greatly altered. Measurements made while the system was in adjustment and with the correction applied, gave an EPI distance which agreed within 0.5 microsecond (75 meters) of the true distance. The towers used for the EPI antennas at both stations were quite different from those used for calibration. It is significant that although the equipment was trucked nearly 1,000 miles, transshipped several times, and returned to the original testing site, it maintained calibration. Success in using this method of calibration seems to be in duplicating the antenna and ground systems at the calibration and line-measuring sites.

Stability of the system.—Both the calibration and the line measurements indicate that the system is somewhat lacking in stability. Two factors which cannot be entirely separated, contribute to instability. These are (1) the transmitter frequency, and (2) the changes in earth conduction in the area around the antenna system. Evidence of both of these factors appears in the line measurements of February 2nd and the calibration measurements of February 6th. From measurements on the Cheltenham-Fredericksburg line, it has been proven that when the earth returns to its normal dry condition, the distance readings return to the normal value. While setting the transmitter frequency requires careful adjustment, once set it maintains this frequency quite well.

Changes in the antenna system seem to be the one important factor influencing frequency. When the equipment is cold, it requires several hours before terminal frequency stability is reached.

Operator's error.—During this series of measurements, teams 1 and 2 made 101 distance measurements. In averaging the measurements of the two teams, their readings agreed within 0.25 microsecond. Most of this difference is between ground-station operators. A series of ship operator comparison measurements were made at the ship instrument. Two operators measured the distance, one immediately following the other, while the same operator was attending the ground-station equipment during both measurements. The operators at the ship equipment seldom disagreed as much as 0.1 microsecond. There was no important difference in the spread of readings between the two teams throughout the series. The important point is that the ground-station operator establishes habits in adjusting the instrument which is capable of producing a difference of 0.25 microsecond even between experienced operators.

Comparing the inexperienced team's operation to that of the experienced team, a difference of 0.5 microsecond was observed. Also, inexperienced teams spread of readings was greater than that of an experienced team.

FURTHER CONSIDERATION OF EPI FOR LINE MEASUREMENTS

As emphasized earlier, the EPI system was not designed for line measurements, but with some modifications it could be better adapted for this purpose. While no basic changes are contemplated, the following minor alterations should result in improved operation for line measurements:

1. Improve the antenna system by a more elaborate ground plane. The present ground-plane system is made up of thirty-two 100-foot radials centering at the base of the antenna. From information available on the design of ground systems, in order to make the antenna system more nearly independent of changes in ground conductivity, one hundred and twenty 200-foot radials would be necessary. When the land is clear around the antenna, placing the ground plane is one of the simpler operations in establishing an EPI station.

2. Work is now being conducted to minimize the range-frequency (transmitter) dependence of the system. Improvement here is important whether the system is used for line measurements or surveying.

3. By measuring and stabilizing the factors which account for time delays in the system, it should be possible to eliminate a correction making the observed distances equal to the true distance. Work done to solve this problem is of value for both line measurement and hydrographic surveying.

4. Establish a uniform method of adjusting the ground-station equipment, so that by following the same pattern of adjustment more consistent results will be obtained between operators.

As a speculation, if the proposed program is developed, the present EPI system, properly modified, should be capable of consistently measuring distances within 0.5 microsecond (75 meters). By proper selection of sites, and, if the measurements are made at times of low noise level, line distances of between 450 and 500 statute miles are possible. The error figure would remain nearly the same for all distances measured.

Representatives of the Army Map Service, the Engineer Research and Development Laboratory, and of the Aeronautical Chart and Information Center witnessed the tests at the measuring end of the line (Monomoy Point). An Army Map Service representative witnessed the operation at the ground end of the line at Cape May.

* * *

Journal No. 6 Awards

An Awards Committee, under the auspices of the Association of Field Engineers of the Coast and Geodetic Survey, made the following selections as the prize-winning articles in Journal No. 6:

First Prize ($25.00)—"On Duty With the Inter-American Geodetic Survey," by Comdr. E. B. Brown.
Second Prize ($15.00)—"Mapping the Earth," by Rear Admiral Robert W. Knox.
Third Prize ($10.00)—"Radio Wave Propagation as Applied to Shoran," by T. J. Hickley.

The paper, "Movement of Triangulation Marks Set in Permafrost," by Comdr. J. T. Jarmin, received ***Honorable Mention.*** Selections were made on the basis of content, timeliness, clearness of presentation, interest, originality, and future value to the Bureau. The Awards Committee consisted of Capt. Charles Pierce, chairman, and Messrs. A. L. Shalowitz and G. C. Tewinkel.

Modifications in Second-Order Astronomic Position Determinations

CURTIS W. THORSON, Geodetic Engineer
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THE EXTENSIVE USE of second-order astronomic positions for the determination of geoid heights, and the related problem of the figure of the earth, has led the author to consider modifications which simplify the observing program and tend to increase the accuracy of the computed position. A troublesome problem, in the type of observation considered, is the choice of suitable stars, their subsequent identification, and the computation of apparent position. A procedure is established for preparing an observing list from a star catalogue of apparent places so that the chosen stars satisfy the observing conditions. Of major importance in such observations is the determination of the "personal equation" of the observing team (observer and timekeeper). The paper presents a method for eliminating the effect of the "personal equation" of the timekeeper.

The astronomic positions depend upon altitude and time observations. Latitudes are based upon observations on Polaris at any hour-angle and upon a circummeridian south star before and after transit of approximately the same altitude as Polaris. For longitude determinations, stars within 5° of the prime vertical--one in the east and one in the west--are chosen in pairs where the altitudes do not differ by more than 1°.

OBSERVING LISTS

Latitudes and longitudes may be observed without resort to previously prepared observing lists, stars being selected at the station site. This procedure, though initially simpler, places undue strain upon an observer who must select suitable pairs under the pressure of observing and may involve difficulties with regard to star identification and the computation of the apparent places of the stars. A better approach is the prior preparation of observing lists, as this leaves the observer free for observing and insures that the pairs used comply with required conditions.

Latitude List.—Observing lists for latitude are easily prepared. As Polaris may be observed at any hour-angle, the observing list will include only south stars. These stars will transit when the local sidereal time is equal to the right ascension of the star. Hence, from an approximate longitude the range of local sidereal time for the period of observations may be determined and a suitable number of stars in this range may be selected from the *Apparent Places of Fundamental Stars* (Her Majesty's Stationery Office, London). The only restriction in regard to altitude is that the south star be within 5° of the altitude of Polaris at the time of observation. If possible, a fairly bright star should be chosen to facilitate its location, thereby reducing the possibility of using a wrong star.

Longitude List.-- The observing list for longitude is more difficult to achieve. Several restrictions are involved that limit the observations to a small area of the sky in both the east and the west. The stars must be within 5° of the prime vertical and the altitudes of east-west stars of a pair must agree within 1°. In addition, the altitude should be greater than 30° to reduce the effect of anomalous refraction and should not be much greater than 40°, in order to avoid excessive strain on the observer. The construction of most instruments is such that without the use of a prismatic eyepiece, stars much over 40° in altitude are very difficult to observe with consistent accuracy. Under these conditions, the azimuth range for observations is 85° to 95° from north, both east and west, and the altitude range is from 30° to 40°.

Considering the established limits and an approximate latitude (ϕ), a table is then prepared which gives the hour angle (t) and the declination (δ) as functions of the altitude (h) and the azimuth (A). This table may be computed for each degree of altitude, azimuth, and latitude from the formulas:

$$\text{Sin } \delta = \text{Sin } \phi \ \text{ Sin } h + \text{Cos } \phi \text{ Cos } h \text{ Cos } A \qquad (1)$$

$$\text{Sin } t = \text{Cos } h \text{ Sin } A \text{ Sec } \delta \qquad (2)$$

The values for intermediate latitudes are determined by interpolation.

The construction of this table consumes considerable time if all the values are entered. However, if one can visualize this table as representing a section of the sky in either the east or the west, and that all stars, within the range of declinations shown, will enter and leave this area at some specific time, altitude, and azimuth, the problem can be simplified.

In the east, stars are increasing in altitude and azimuth from north while decreasing in hour-angle; therefore they will enter the table in either the top row or the left-hand column and will exit from either the bottom row or the right-hand column. West stars will move in an opposite manner as they are decreasing in altitude and azimuth from north while increasing in hour-angle. Thus, for preselection of star pairs, the only portions of this table necessary are the border values of hour-angle and declination. These quantities will establish the end points of the star's apparent path through the area. These values were determined for Table 1 by equations (1) and (2). However, with suitable accuracy, the same values may be interpolated from the star identification tables in Hydrographic Office Publication No. 214, *Tables of Computed Altitude and Azimuth* (Government Printing Office, Washington), using the hour-angles and declinations at altitudes 28° and 40° and at azimuths 84° and 96°, all for the desired latitude.

The observing method used requires that a star be in the area at least 8 minutes, and preferably longer, so it is obvious that stars with declinations near the extremes shown on the chart are not usable. By comparing the hour-angles associated with a star of 14° 05' declination, it will be seen that the star will be in the area for about 10 minutes. On the high declination side it is apparent by the same check that stars above 24°10' will not be usable. Therefore, stars within this range are usable and will be listed and plotted to determine if they can be paired, east and west.

Prior to listing the stars, the approximate local sidereal time for a desired date, longitude, and starting time must be computed. As an example,

Table 1.-- *Star preselection tables*
(Latitude = 35°)

Altitude

Azimuth	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°
85°	04^h28^m 20°24'	04^h24^m 20°54'	04^h21^m 21°23'	04^h17^m 21°51'	04^h13^m 22°20'	04^h09^m 22°48'	04^h05^m 23°16'	04^h01^m 23°43'	03^h57^m 24°10'	03^h54^m 24°37'	03^h50^m 25°03'
86°	04^h26^m 19°39'										03^h48^m 24°22'
87°	04^h24^m 18°54'										03^h47^m 23°40'
88°	04^h22^m 18°09'										03^h45^m 22°59'
89°	04^h21^m 17°24'										03^h44^m 22°19'
90°	04^h19^m 16°40'										03^h42^m 21°38'
91°	04^h17^m 15°56'										03^h40^m 20°58'
92°	04^h15^m 15°11'										03^h39^m 20°17'
93°	04^h13^m 14°27'										03^h37^m 19°37'
94°	04^h11^m 13°44'										03^h36^m 18°58'
95°	04^h09^m 13°00'	04^h06^m 13°33'	04^h02^m 14°05'	03^h59^m 14°38'	03^h55^m 15°10'	03^h52^m 15°42'	03^h48^m 16°13'	03^h45^m 16°45'	03^h41^m 17°16'	03^h38^m 17°47'	03^h34^m 18°18'

Hour-angle

Declination

The declination remaining constant, the hour-angles and azimuths for entrance and departure from the usable area are obtained from the suitable rows and columns as a function of the declination.

East stars: enter left-hand column or top row and exit at bottom row or right-hand column.

West stars: enter bottom row or right-hand column and exit at left-hand column or top row.

Table 2.—*List of available stars at station Lookout, Tenn., (January 8, 1957, GCT)*

Star Number	Page No.	Mag.	R.A.	Dec.	H.A.	L.S.T.	Azi.	Alt.	H.A.	L.S.T.	Azi.	Alt.
West stars					Out				In			
1188	147	5.3	07^h11^m	$16^\circ14'$	04^h18^m	11^h29^m	$90^\circ37'$	$30^\circ00'$	03^h48^m	10^h59^m	$95^\circ00'$	$36^\circ01$
277	148	3.6	07 16	16 37	04 19	11 35	90 04	30 00	03 46	11 02	95 00	36 45
279	149	3.5	07 18	22 04	04 15	11 33	85 00	33 27	03 43	11 01	89 22	40 00
1200	155	5.0	07 44	18 37	04 23	12 07	87 24	30 00	03 35	11 19	94 33	40 00
1208	158	6.0	07 55	15 54	04 17	12 12	91 02	30 00	03 50	11 45	95 00	35 23
1220	165	5.9	08 21	18 28	04 23	12 44	87 35	30 00	03 35	11 56	94 45	40 00
321	167	5.5	08 30	20 35	04 26	12 56	85 00	30 22	03 39	12 09	91 34	40 00
1228	169	4.7	08 41	21 37	04 18	12 59	85 00	32 30	03 42	12 23	90 00	40 00
East stars					In				Out			
1400	269	5.7	15^h16^m	$20^\circ44'$	04^h25^m	10^h51^m	$85^\circ00'$	$30^\circ40'$	03^h40^m	11^h36^m	$91^\circ20'$	$40^\circ00'$
570	271	5.5	15 24	15 35	04 16	11 08	91 28	30 00	03 53	11 31	95 00	34 47
583	276	3.7	15 44	15 33	04 16	11 28	91 30	30 00	03 53	11 51	95 00	34 44
584	277	4.3	15 47	18 16	04 22	11 25	87 50	30 00	03 34	12 13	95 00	39 57
591	279	3.9	15 54	15 48	04 17	11 37	91 11	30 00	03 51	12 03	95 00	35 11
1421	282	5.3	16 06	17 10	04 20	11 46	89 20	30 00	03 42	12 24	95 00	37 48
609	286	3.8	16 20	19 15	04 25	11 55	86 32	30 00	03 36	12 44	93 34	40 00
618	289	2.8	16 28	21 35	04 19	12 09	85 00	32 26	03 42	12 46	90 06	40 00

corresponding to 1900 EST, January 7, 1957, the GCT is 0000, January 8, 1957. At station *Lookout*, the local sidereal time at 1900 EST is approximately equal to the sidereal time of 0^h GCT, January 8, 1957 ($07^h\ 09^m$) plus the GCT ($00^h\ 00^m$) corresponding to the EST ($19^h\ 00^m$), minus the estimated longitude of the station ($05^h\ 41^m$). Adding an hour-angle of 4^h (approximate hour-angle for all stars in the prime vertical) to the local sidereal time of $01^h\ 28^m$, a right ascension is obtained for the first east star of about $05^h\ 28^m$. By subtracting an hour-angle of 4^h from the local sidereal time, an approximate right ascension is obtained for the first west star of $21^h\ 28^m$. With this information available stars are chosen from the *Apparent Places of Fundamental Stars.* The list should contain all stars within the desired range of declination for about 2 hours subsequent to the starting time. Included in this list are the star numbers, page numbers, magnitudes, and declinations and right ascensions to the nearest minute. It is advisable to omit stars dimmer than magnitude 6.0 (Table 2).

Referring again to the preselection table and using the declination as argument, the altitude, azimuth, and hour-angle of each star is determined at the time of each star's entry into the usable area and also its later exit (Table 2). For example, an east star of declination $16^\circ\ 40'$ will enter at altitude 30° and azimuth 90° and will exit at altitude $36^\circ\ 50'$ and azimuth 95° with hour angles $04^h\ 19^m$ and $03^h\ 46^m$, respectively. Thus the position of each star is known at two points on its apparent path and by plotting this path its position can be determined at any instant during the time the star is in the area.

In order to plot the paths of the stars a chart is set up with altitude and local sidereal time as the coordinates. Local sidereal time is computed for each star from the right ascension and hour-angle (both entry and exit) by subtracting hour-angle from right ascension for east stars and adding the two for west stars. From this information the apparent path of each star is plotted (fig. 1). At points of intersection, east and west stars reach the same altitude at the same time, which is the ideal situation for the selection of pairs. In some cases pairs may have to be chosen from stars whose paths do not intersect. In this situation the lack of intersection means a time delay which is sometimes unavoidable during the periods that available stars are scarce.

In selecting the pairs, it must be remembered that a time interval of at least 8 minutes and preferably 10 minutes must be available to give sufficient time for all the 8 pointings that constitute an observation. Hence, approximately 10 minutes prior to the time of intersection of a star pair the first star is observed followed by observations on the second star. This insures that the pair has been observed over the same altitude range. Sometimes a star can be observed upon twice in succession and at other times an intervening star in the opposite direction may be taken before returning to the first star. Figure 1 with selected pairs demonstrates some of the possibilities.

No mention has heretofore been made of the azimuth of the stars, which is an essential coordinate. In order to locate any of the stars this factor must be known, as well as time and altitude. Therefore, as the azimuth is known at the two end points of the apparent path of each star, it is a simple matter to determine it at any desired point through the use of proportional parts.

In figure 1, a typical selection of pairs has been indicated (heavy black lines). Star No. 1400 is the east star and star No. 1188 is the west star of the

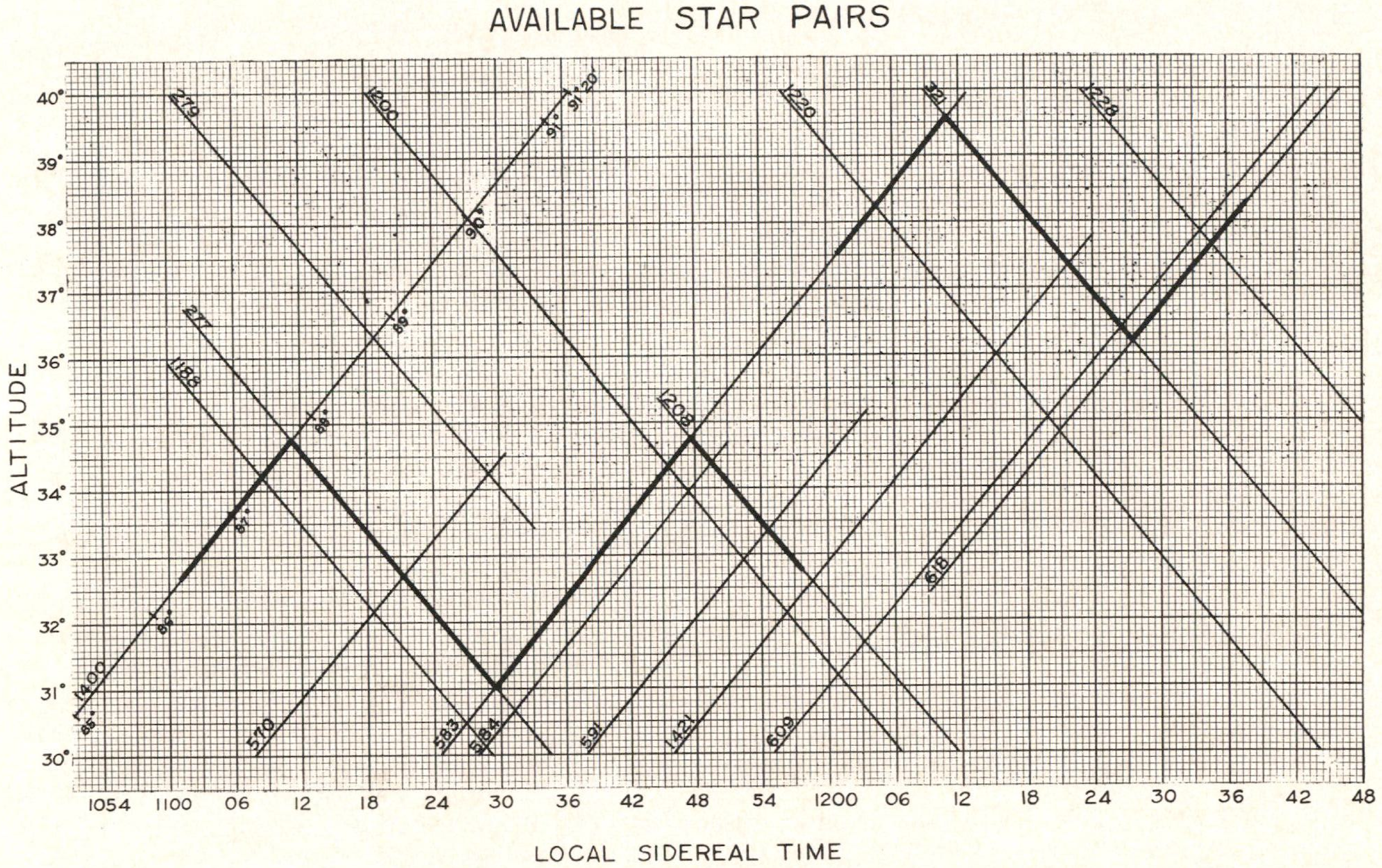


FIG. 1.—Star Pairs for Station *Lookout*, Tenn., January 8, 1957 (GCT).

first pair. The azimuths at time of entrance and departure from the observable field are obtained from the List of Available Stars (Table 2) and are indicated at the beginning and end of the line for that star. The azimuths of whole degrees are then interpolated (by calculation or spacing dividers) and also recorded (this has been indicated for star No. 1400 only). In actual practice the azimuths for all stars will be noted on this graph.

On the graph, 5 selected pairs are shown. If it is planned to use a star twice in succession, the observer will keep the star in the telescope at the end of one set of observations and begin a new set when the recorder indicates it is time to start on the new pair.

The construction of an observing list for longitude insures that observations are made which satisfy the initial conditions. With a little practice one man can do the work for a single station in a few hours. The end result will be easier and more accurate field work and more rapid computations.

OBSERVING PROCEDURE—MENTAL INTERPOLATION METHOD

Time control is of paramount importance in longitude observations and less important for latitude determinations. The mental interpolation method, utilizing directly the National Bureau of Standards time signal broadcast by WWV eliminates the need for a chronometer except as a device for keeping the approximate local sidereal time. A portable radio is tuned to WWV and kept on during the observing period. This, of course, causes the observer and recorder to speak a little louder than normal but careful tuning of the radio will keep the annoyance to a minimum. In eliminating the chronometer, the time lag occasioned by the timekeeper is done away with as well as the loss of time used in making chronometer checks.

The observing program begins with a horizontal pointing on Polaris. In order to facilitate its location, the star's altitude can be computed from the latitude of the station and values in Table I of *The American Ephemeris and Nautical Almanac* (Government Printing Office, Washington). Once located, its azimuth can be determined from Table IV of the same volume and the horizontal plate set accordingly. Thus the theodolite is oriented to north and no further reference need be made to Polaris during the longitude observations.

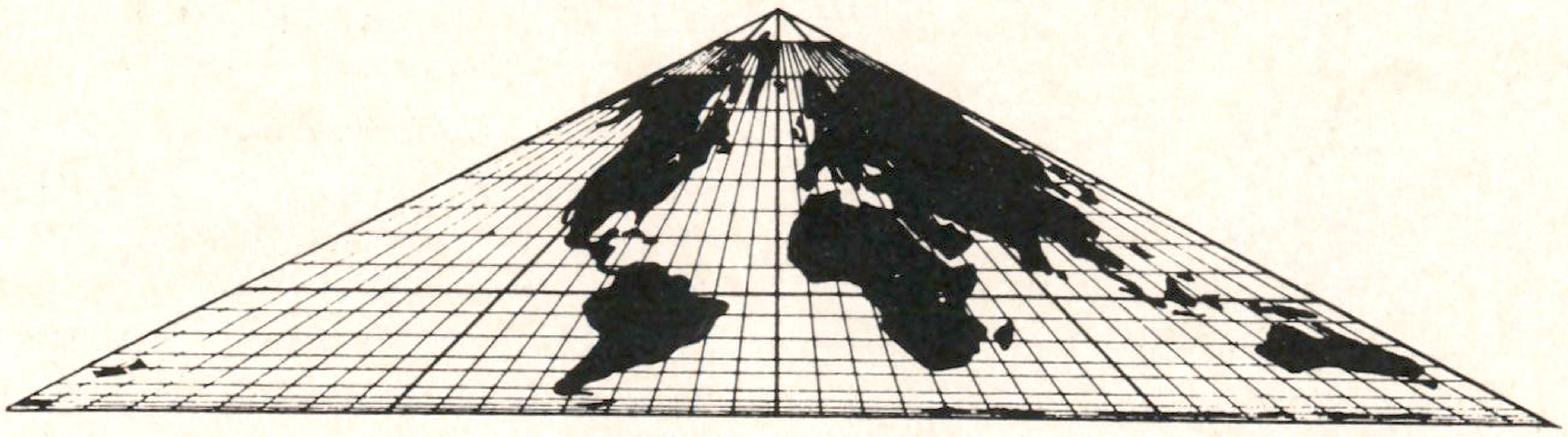
After the instrument orientation is accomplished, the recorder checks the observing list and gives the observer the proper horizontal and vertical plate settings for the first longitude star plus the number of minutes before the star is due in the center of the telescope. The observer makes the proper settings and waits for further warning which will come about 1 minute before the star is due. Upon receiving this warning, the observer looks for the star and notifies the recorder when he sees it, calling out the approximate magnitude as a check. The recorder then checks with a mean time watch, which has been set to coincide with the National Bureau of Standards (WWV) time signal, and gives a 10-second warning of the next approaching zero second of the time signal. The observer makes certain that the star is on the incoming side of the horizontal crosshair and at the zero second, which comes after a silent 59th second for WWV, begins to count with the radio time signal watching the star as it nears and crosses the hair. He continues to count through the next second after the coincidence of star and crosshair, and then mentally estimates the fractional part of a second to add to the whole number he has counted prior to the coincidence of star and crosshair, thus determining the estimated instant of the star's passage. The resulting figure is usually between 2 beats of the time signal, the one just prior to the coincidence of star and crosshair and the one immediately after--such as 02.4, although the instant of passage might be on an even second. The recorder notes down this figure along with the hour and minute of the time signal as obtained from his mean time watch and then records the circle readings. The process then repeats for each pointing at approximately 1-minute intervals.

Obviously, it is impossible to estimate the coincidence of a rapidly moving star and a fixed crosshair consistently to the nearest 0.1 second of time. Realistically, the range of an experienced observer's estimates will be around 0.4 second of time. The important thing is to make the estimates without bias or second thought. For latitude observations, the procedure is modified to the extent that all pointings are made on the even second of the time signal. The observer picks up the star about 10 or 12 minutes prior to transit in order to insure sufficient time for all pointings. He receives the same 10-second warning of the approaching zero second but, instead of waiting for the star to coincide with the crosshair, he brings the star into the crosshair on an even second. This modification is possible because time must be known to only the nearest 0.5 second and is particularly adaptable to stars whose altitudes are changing slowly, as is the case with Polaris and south stars near the meridian.

This method involves eye-ear coordination on the part of the observer in making his estimates of time, and concentration is of utmost importance. The recorder must be alert and with practice can eliminate some of the annoyance of the constant beat of the radio signal by turning down the volume between positions. However, this is not a recommended practice unless the recorder is fast and quick-minded; as time passes rapidly he can become very busy with his multiple duties.

The chief advantage of this method is that the observer is the only person involved in a "personal equation," thus eliminating the need of an observer-recorder team. A secondary advantage is that an experienced observer can work alone in an emergency, with no change in the accuracy of the results. The writer has experimented with this and has found it possible but not a recommended practice.

(The basic idea for the method of preparing observing lists described in this paper was contained in a report by Comdr. Raymond H. Tryon, Jr. The mental interpolation method was suggested by Donald A. Rice.--Ed.)



Safety Devices for Leveling Parties

LT. COMDR. EMERSON E. JONES
U. S. Coast and Geodetic Survey

FIG. 1.—Level crew set up

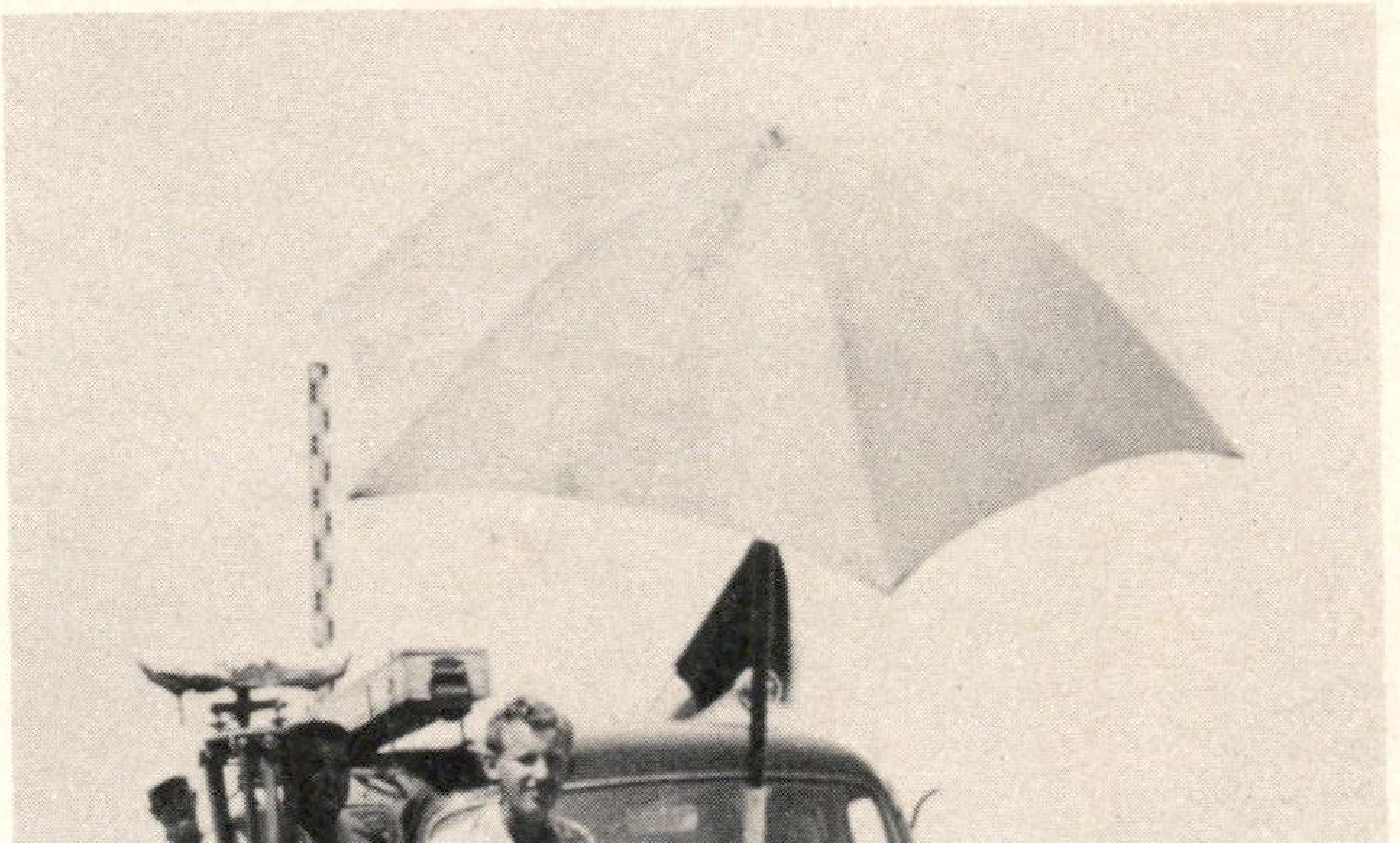


FIG. 2.—Crew moving up

SINCE THE MAJORITY of our lines of leveling are now established along heavily traveled highways, it is well for each member of a leveling unit to be alert in matters concerning safety. We want to avoid having any of our personnel included in the annual statistics such as we had for 1954 when accidents on our highways killed 36,500 and injured 1,250,000. Also, being alert to matters pertaining to safety is in line with the safety program of Secretary of Commerce Weeks, as outlined in his memorandum of November 30, 1954, which states:

> The President has called on all departments and agencies of Government to take immediate steps which will reduce the rate of accidents to federal employees.
>
> It is essential to the best interests of our department and the well-being of all personnel, that positive action be taken to eliminate causes of injuries, fires, and occupational health hazards. This is fundamental to efficient and economical operations.
>
> I am glad to announce that, consistent with this objective of the Administration, the Department of Commerce is inaugurating a new employee safety program which I am sure will reduce substantially the present rate and cost of accidents.
>
> I hope every employee will cooperate fully in this program to reduce accidents. Safety is a responsibility we must all share. I know that working together we can get the job done.
>
> Sinclair Weeks

Noting the increase, during recent years, of traffic speeds and the decrease in running-board area, particularly on trucks with large rounded bodies, it was incumbent upon the chief of party to develop additional safety features for the level crews riding their trucks during surveying operations. The devices accumulated by this party and described in this article have added to the convenience and efficiency of the crews as well as to their safety. Also, they are in further compliance with the California Vehicle Code Summary which states, "It is unlawful for anyone to ride on any part of your vehicle that is not intended for the use of passengers."

Pictured in figures 1 and 2 is a level crew at work along a highway. The crew is shown at a setup and then moving up on one of the new trucks which has been fitted out with the various safety features that are described.

Observer's platform.--To improve the platform, the running board was widened 6 inches and

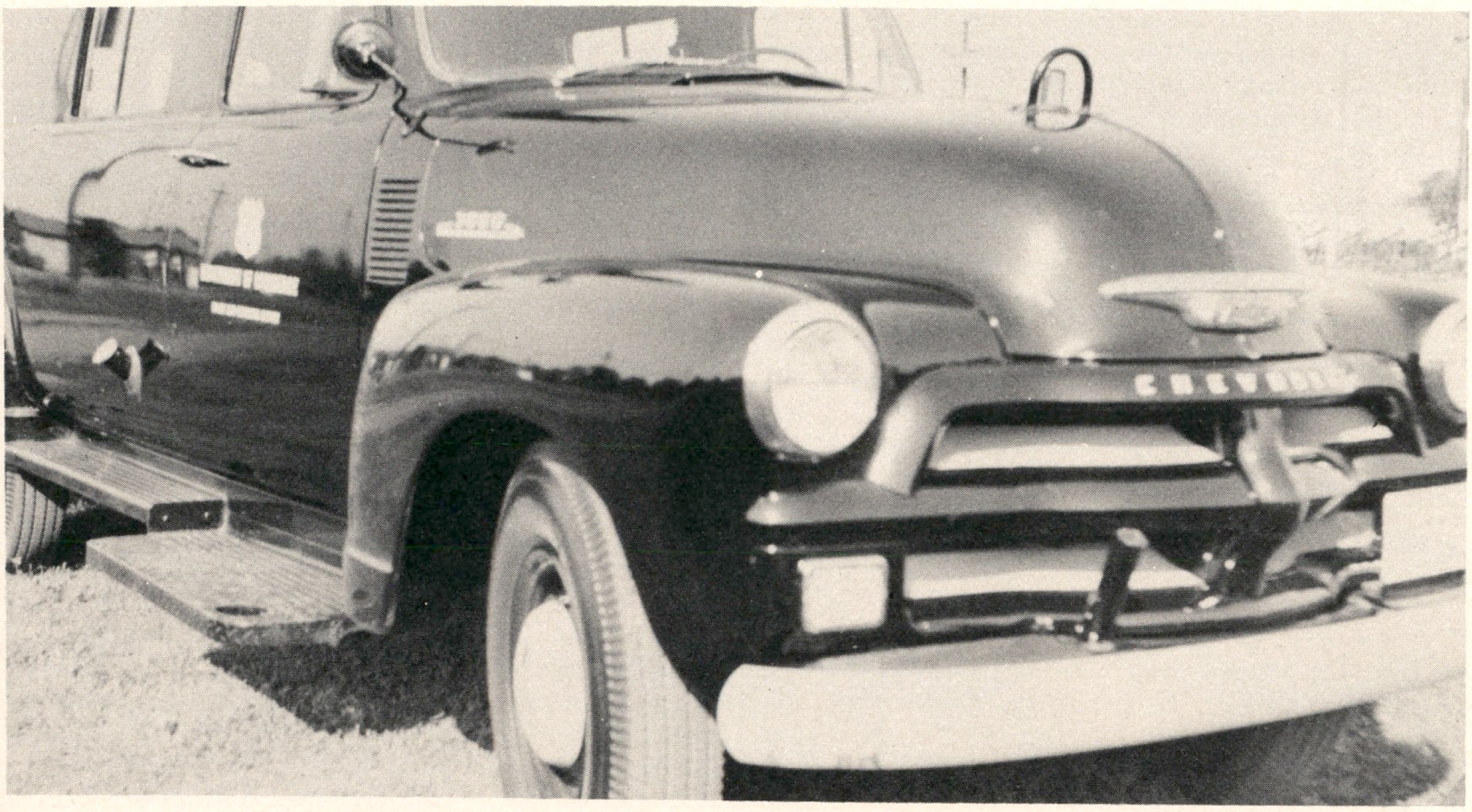


FIG. 3.--Front detail of level truck

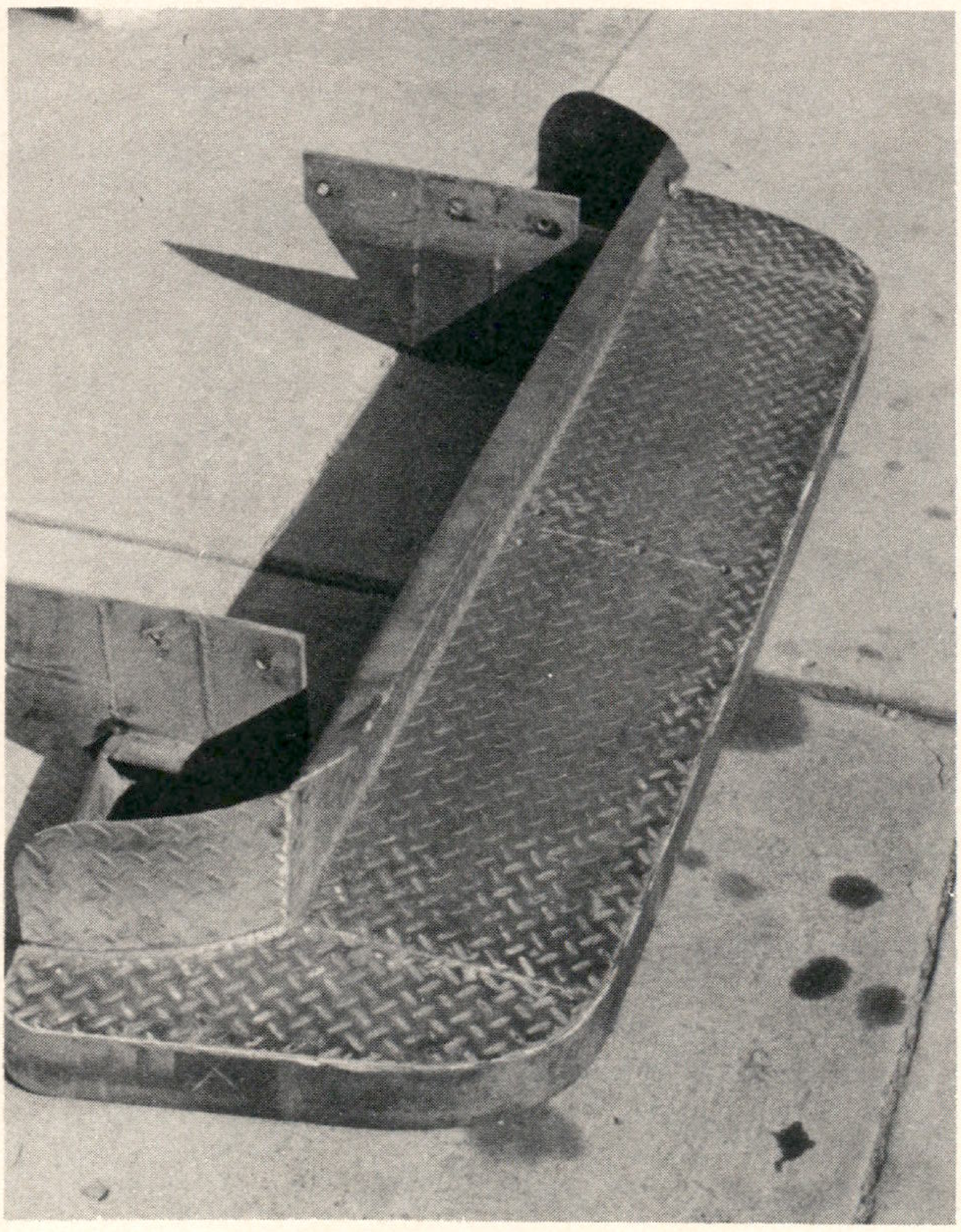


FIG. 4.--Top of rear step assembly

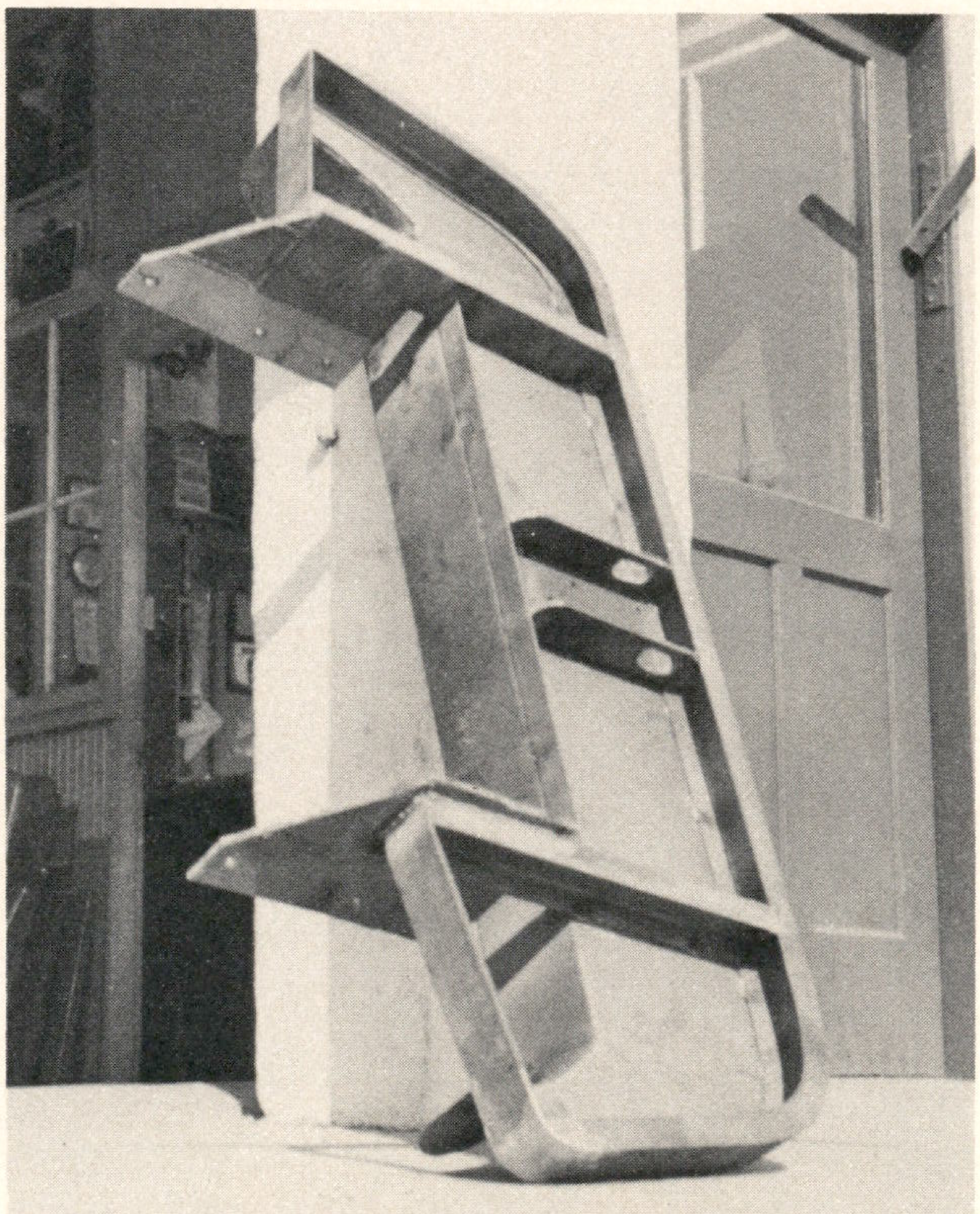


FIG. 5.–Bottom of rear step assembly

lowered 3 inches as shown in figure 3. It was reinforced with three braces underneath and bolted to the main frame. A 4-inch cup was made from pipe and recessed in the front right corner to serve as a holder for the tripod shoes. Large drain holes were cut in the side of the cup to avoid the accumulation of dirt. A grab bar fabricated from 3/4-inch pipe, reinforced inside the truck, was bolted over the door to complete the observer's position.

Umbrellaman's position.--For the umbrella a 1-3/4-inch tube was inserted at a 30° slope to the plate behind the bumper and welded to it and the bumper bracket, upon which it was seated. A nonskid tread, of the type used in school buses, was cemented on the plate behind the bumper and to right of the umbrella holder. A grab bar, shaped from pipe and welded to a plate, was bolted near the front of the hood.

Rodmen's rear step.--The rear bumper assembly and spare tire were removed and replaced by bolting to the truck frame the fabricated assembly shown in figures 4 and 5. The step plate was installed about 6 inches below the bottom of the body in order to be the proper height for the ball of a trailer hitch. Note the holes cut in the reinforcement underneath for safety chains. The assembly was bolted to the frame in order that it could be moved to another truck if desired, or to a new truck upon the sale of an old one. To complete the rodmen's position, a pipe grab rail was fabricated and bolted in place as shown in figure 6. The exhaust tail pipe was bent outward and run through the step riser in order to decrease the hazard of grass fires. The spare tire was mounted inside the truck with a bolt and reinforced stud for convenience, although it could have been left in its original position without interference.

Warning lights, flags, etc.--Warning blinker lights were installed—an amber sealed-beam fog light forward and a red 50-candlepower sealed-beam spot light rear, with a switch at the dashboard. Short 3/4-inch pipe sockets with wingnut set screws for flags were fabricated and braced on a small plate which was bolted to the top, reinforced, as shown in figure 7. The flags were hemmed and slid over 3/4-inch doweling stock, then stapled or thumbtacked in order not to slide in the wind. A three-arm, truck, extension mirror was installed to improve the recorder's vision.

Windows.--To increase the driver's vision and ventilation for the personnel, sliding windows were installed on each side. The driver's ability to maneuver the truck safely was greatly improved, the "blindness" to the rear largely being removed.

FIG. 6.--Rear step installed

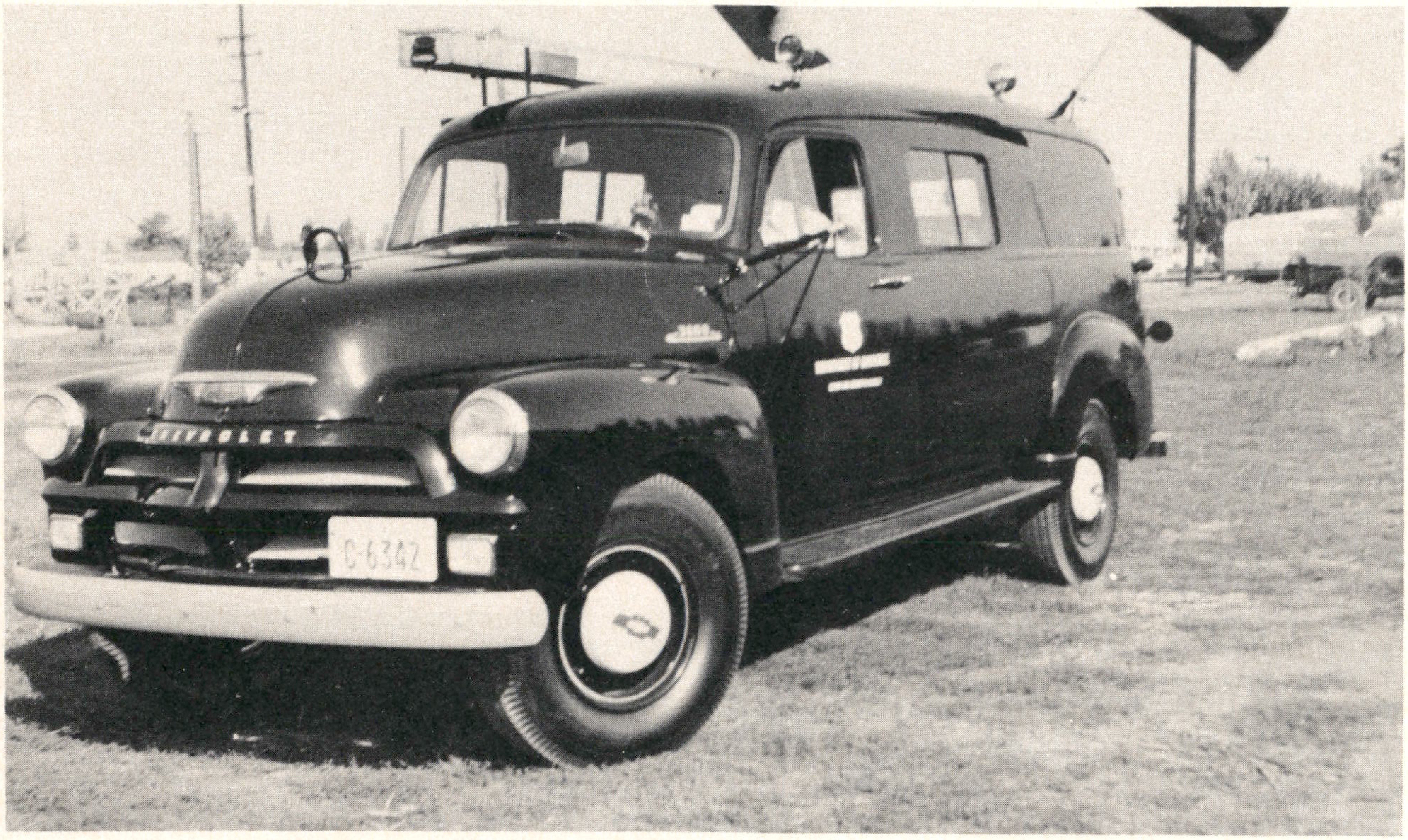


FIG. 7.--Lights, flags, and mirror

Seats.--A used long automobile seat, rebuilt and reupholstered, was installed in the rear to carry personnel. A small upholstered "box" seat was made to fit between the front 2 seats to carry the 6th man. A shorter rear seat may be preferred for ease of installation and to leave room for long material on 1 side. Regardless of extra length, only 3 men can usually be comfortable in the rear seat, the extra man preferring the "box" seat.

Rod flags.--High-speed traffic often does not see the truck warnings in time to slow down, until they are upon the rodmen. Therefore an attempt is being made to flag the rodmen. To encourage the practice of carrying a flag--along with hammer, foot pin, and rod--a flag holder which clamps onto the rod is being tried. Such a flag needs to be almost "automatic," as indicated in figure 8.

Additional precautions.--In addition to changes in the equipment, the following safety precautions should be taken:

(1) Whenever operating along highways, the rodmen should display red flags. The special flag holders made to clamp to the rods will expedite this precaution. Traffic is usually almost on top of the rodman before it sees the truck and its warning signals. If the wind on the flags compromises accuracy, the rodmen should carry or wear red flags as a wide sash.

(2) Whenever working along highways, display

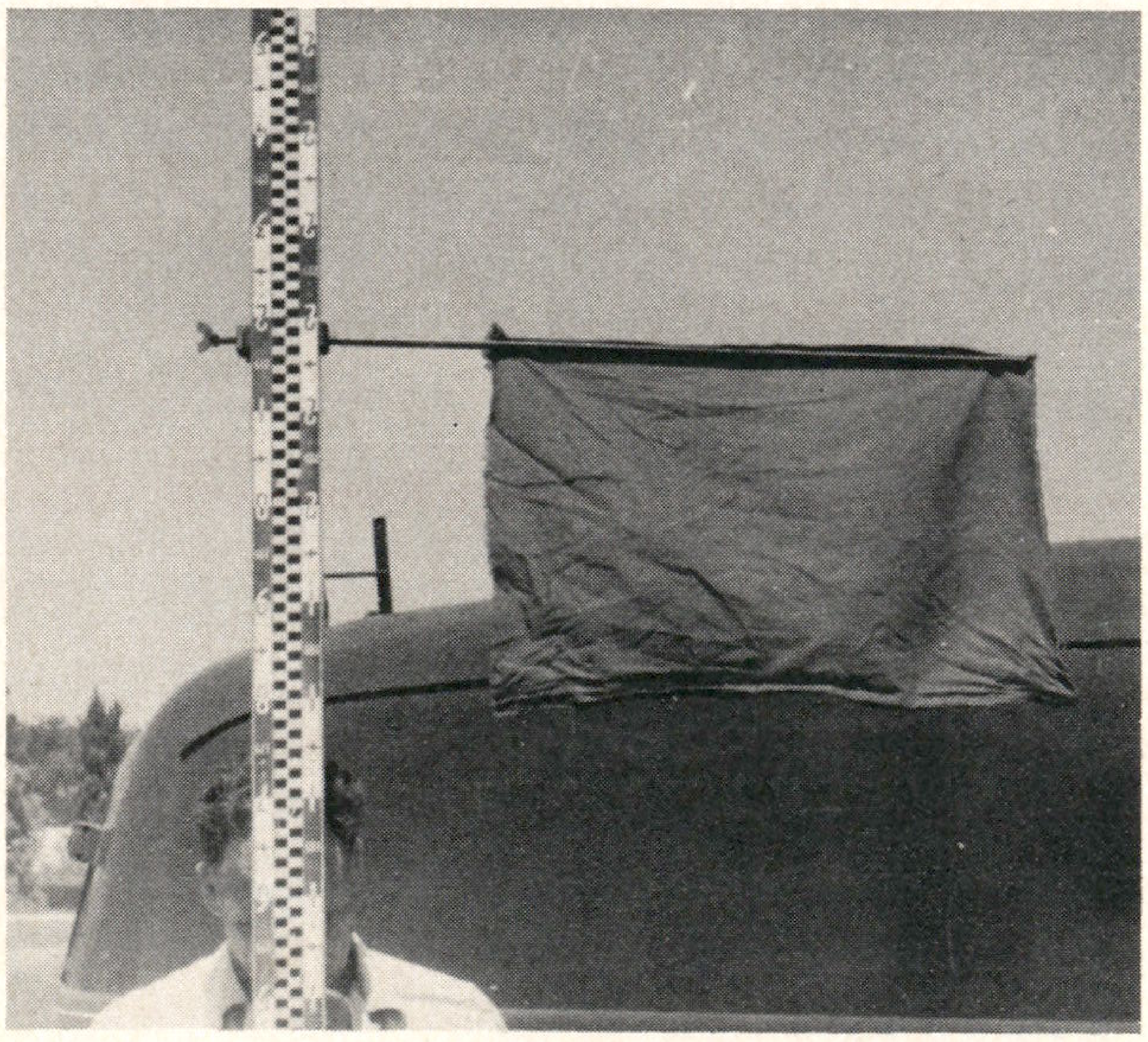


FIG. 8.--Closeup of rod flag

the red flags provided and operate the blinker caution lights.

(3) Ride only on the parts of the trucks designed for the purpose as required by state law.

(4) Observe all traffic rules. Do not walk on the highway side of the truck.

(5) The trucks should not be used where their operation will create an unusual hazard.

(6) The unit chiefs and each member of their parties should bear in mind that it is their duty to prevent accidents. The unit chief should frequently discuss safety with his assembled unit.

Drum Buggy

CAPTAIN SAMUEL B. GRENELL

U. S. Coast and Geodetic Survey

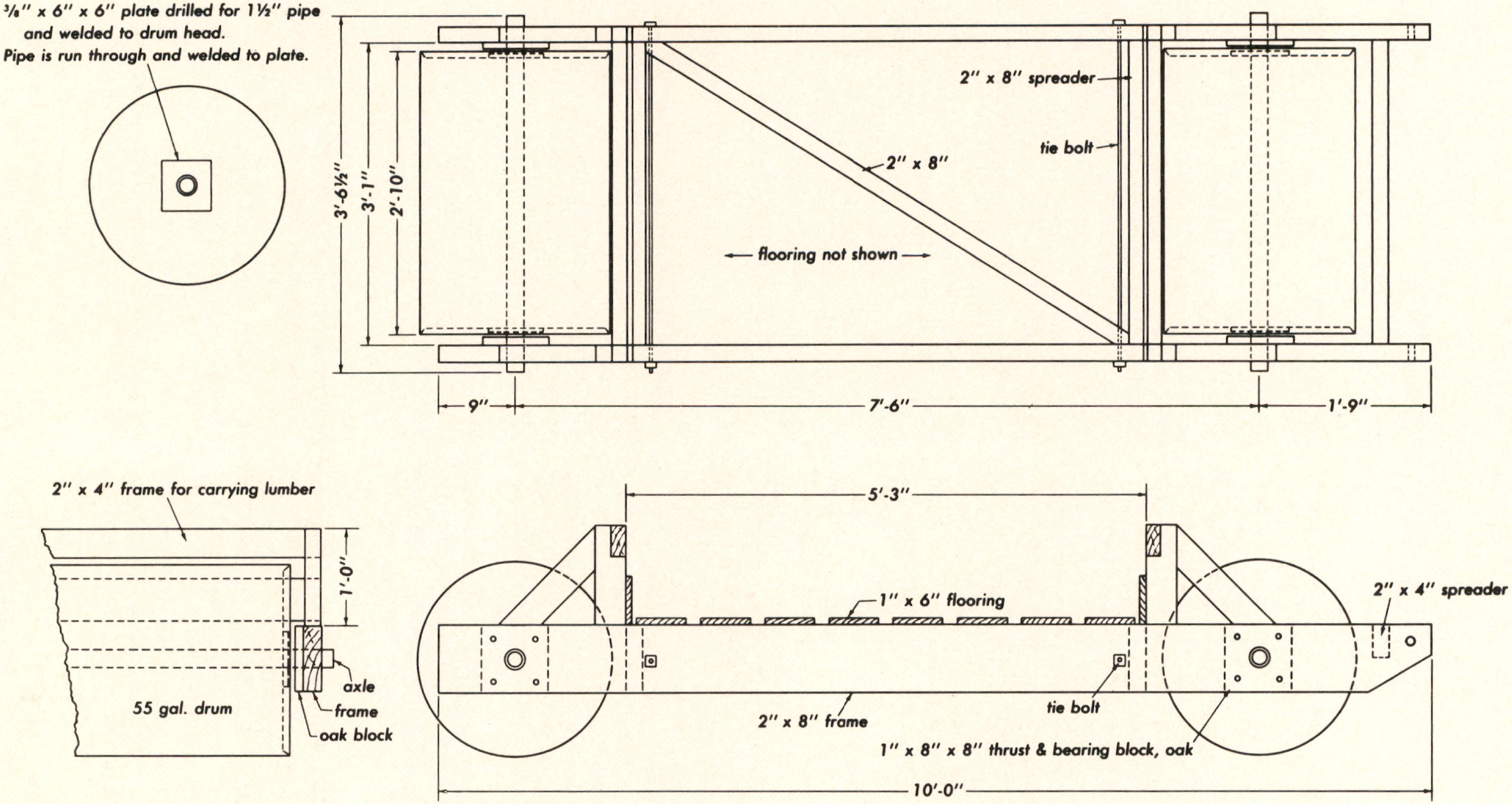
DURING THE *Explorer's* 1955 field season, the only feasible site for one of the Shoran stations was on the highest point of an island, well inland from the shoreline. A 600-foot "high-line" was built from the base of the hill to the top. The problem was to transport building material, fuel, and heavy gear from the beachline bluff to the base of the high-line across about 300 yards of boggy tundra. A standard 2-wheeled trailer could not operate on this type of ground, nor could a weasel be landed at any place along the shore.

The plan on the opposite page is of a vehicle which was constructed in one day by the ship's force from materials at hand. For lack of a better name, it was called a "drum buggy." The buggy is very light and can be easily transported ashore in a whaleboat, or floated. It was hauled across the soft ground by the high-line winch, a gasoline driven drum-type winch weighing about 300 pounds, located at the base of the high-line. The buggy could also be towed by a weasel or small tractor. Locke L. Cranford, Chief Engineer of the *Explorer*, is responsible for the basic idea of using 55-gallon drums as rollers. He worked out the details of assembling and securing the axles and supervised the actual construction.

Heavy loads were transported across the soft ground with ease. The low platform was well adapted for hauling drums of fuel and construction lumber, items which are a problem to transport on a weasel or wheeled trailer. After operation at this one station, the buggy was in excellent condition and should be good for several seasons use.

While no actual dollar value can be placed on the time and labor saved by the buggy, the value was considerable in an operation where working time is limited by weather conditions. This vehicle can be constructed by any of our field units and will doubtless be used many times in years to come.

(Similar conveyances have been used by other parties. It has been reported that the ship ***Pathfinder*** had occasion to use one in Nushagak Bay. The 16-foot range of tide made it necessary for the shore party to use it to haul the dory across a wide, difficult, mud and gravel beach.—Editor.)



DRUM BUGGY
Used by U.S.C. & G.S. Ship *Explorer*
1955

Scribing Map Details on Plastic

JOSEF J. STREIFLER, Cartographer
U. S. Coast and Geodetic Survey

ENGRAVING on emulsion-coated glass as a chart reproduction technique has been practiced successfully in the Coast and Geodetic Survey for nearly 40 years. The experience gained through engraving on glass became the foundation upon which the techniques of scribing on plastics have been developed. Inasmuch as the two methods are similar, especially with regard to the tools and uses of the products, a careful distinction is made between the words "engraving" and "scribing" to avoid any possible confusion of the terms and to avoid any detraction from the well-deserved, highly developed reputation of the glass engraver.

Until a few years ago practically all maps and charts were prepared for reproduction in the form of drawings made with black ink on metal-mounted paper, to which was added supplementary "stick-up" for names and vegetation patterns. The process of printing the blueline-base guide copy on the metal-mounted paper from the manuscript required the paper to be submerged in water for developing; this damaged the surface texture of the paper so that ink could neither be applied evenly nor neatly. Various methods of burnishing or coating the paper were used in an effort to restore or produce a suitable inking surface. The inking operation itself then became a highly developed skill among topographic draftsmen. The preparation of the paper surface, the sharpening and care of pens and pen points, the consistency of the ink, line-weight specifications, atmospheric humidity, and the size of the ink supply on the pen point were items of significance. In spite of the care taken to keep the drawing clean and maintain line uniformity, a lithographer was required for painting and retouching the negative of the inked drawing.

The actual date of beginning plastic scribing, in common with similar developments, is difficult to determine. The apparent advantages of engraving on glass as compared to inking, and the availability of new, stable, transparent plastics, undoubtedly contributed to the development. By 1950, several of the Government agencies had experimented with various types of plastics, plastic coatings, and tools in order to find a workable combination of materials and devices. The idea sought was a scribed negative from which the detail could be transferred onto the press plate by means of a single direct photographic process. Parts of maps had been scribed as a routine procedure by the Bureau as early as 1946. Possibly the first positive step toward the general introduction of plastic scribing for topographic mapping in the Bureau took place in 1952 in the form of a demonstration before representatives of all the divisions. The engraving tools developed for use on glass were found to be also well suited for scribing on plastics.

Tests were immediately begun to apply the new technique to topographic drafting as it seemed to be an answer to the difficulties of inking. Material, equipment, and instruments were procured to start a small training program. It was found that experienced ink draftsmen required no more than 2 days of practice with the new system before they could do productive work. The training period for inexperienced draftsmen was much shorter than for ink drafting. In addition, the scribed maps were far superior for reproduction than the inked sheets, as the lines had clear sharp edges and uniform width.

COATED PLASTIC SHEETS

Plastic sheets, 0.005-, 0.0075-, and 0.010-inch thick, polished on both sides, have been used successfully. The sheets are coated on one side with an opaque paint by means of a whirler, roller, or sprayer. The paint must have characteristics that will allow it to be removed by a scribing tool--in the form of a clear, clean line--and will include some degree of translucence. Either white or yellow coatings are used, depending on how the copy is to be employed. A small amount of the paint is also supplied to the draftsman in order to obliterate any possible imperfections in the coating, to delete errors, to make corrections or revisions. A grease pencil can also be used to obliterate a scribed line. To remove the cut-away paint (shavings), a squirrel or beaver hair brush should be used inasmuch as a coarse brush may damage the edges of lines.

In the earlier stages of development of the method, it was found necessary to also use a plastic spray on coatings that had become too hard and brittle for successful scribing. Only the portion of a sheet that could be scribed in 1 day was sprayed at one time because the sprayed coating became too hard by the next day and required respraying. The spray dries sufficiently for use in 10 to 15 minutes.

SPECIAL DRAFTING TABLES

A special drafting table having a glass top and and a light beneath is required for the scribing method inasmuch as the draftsman, working on an opaque, coated plastic, needs to see lines against an illuminated background. The top of the table in use at present is 42" by 60" overall, the glass portion is 30" by 48", and the height is adjustable from 30" to 36". Illumination, supplied by four 40-watt, 48-inch fluorescent tubes, is controlled by two switches each of which controls two alternate lamps. The tubes are mounted in a concave ventilated chamber painted white.

A separate tool cabinet on casters is also needed by the draftsman as he must work in any position about the table. The cabinet in use is 30" high with four drawers, and has a 12" by 16" top.

SCRIBING TOOLS AND SHARPENERS

Three cutting tools are used to scribe nearly all the map details on any sheet. The accompanying illustration shows the scribing tools, the kind of work they are used for, and the types of jigs used for sharpening the cutting edges.

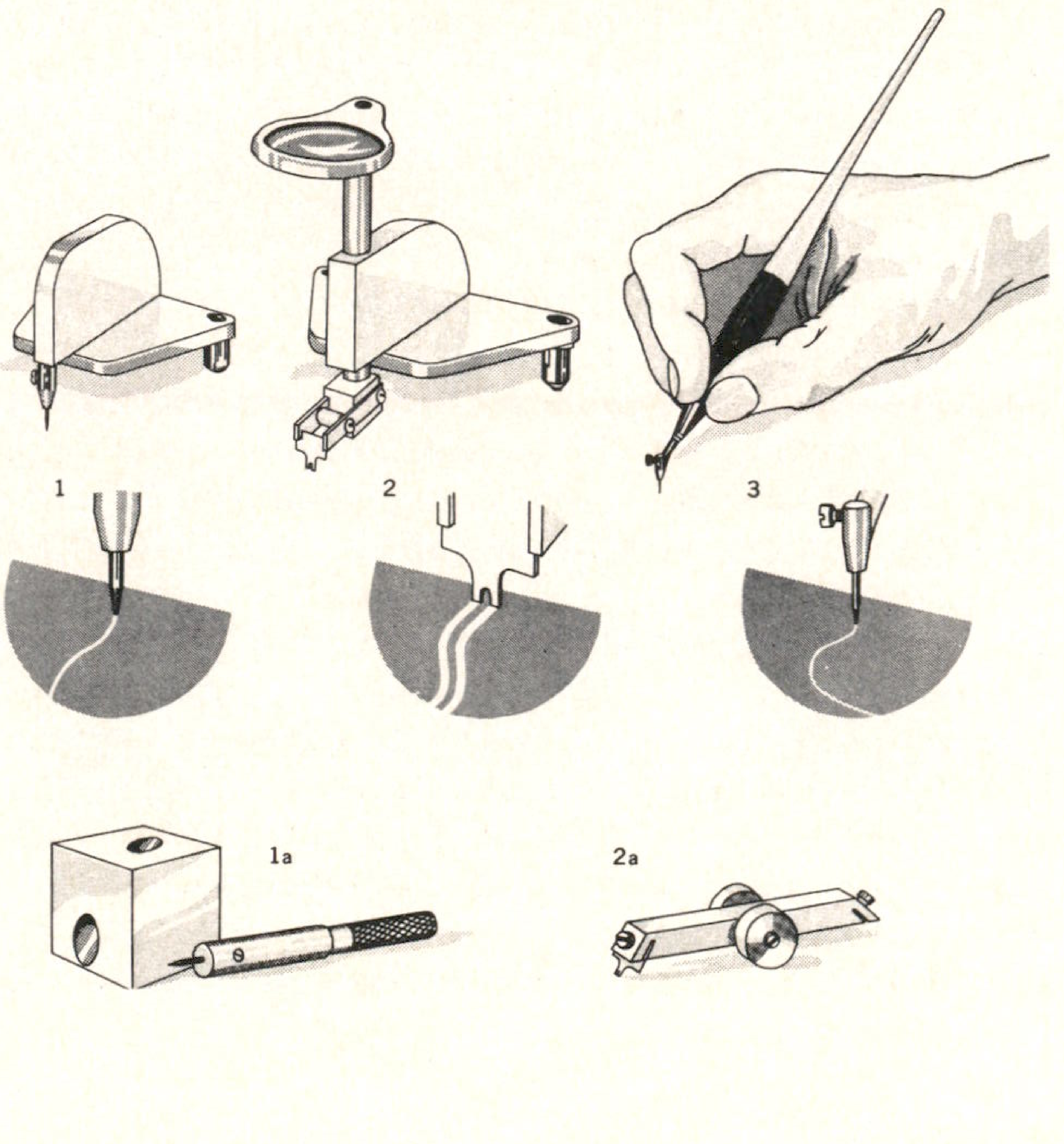
The rigid scriber (1) is most widely used. It is about 2 inches long, 1-3/4 inches wide, 1-1/2 inches high, and is made entirely of metal. The base plate is 1/8 inch thick; the back and sides are about 1-1/2 inches long, with the sides tapering so that the front is about 1 inch long. The two rear corners of the base plate rest on ball-bearing feet 1/2 inch long. The upright web serves as a handle or grip, and extends about 1/2 inch over the front edge of the base plate. A small chuck is fixed to the lower edge of the overhanging portion of the web. The chuck grips a needle about 5/8 inch long, such as an ordinary phonograph needle.

The needle point requires special sharpening to get a cleanly scribed line of desired weight. The needle is placed in a special chuck (1a) that fits in a metal jig having a hole whose axis forms an angle of 51^0 with the horizontal. The chuck is rotated as the jig moves across an Arkansas oilstone, honing a conical-shaped point on the needle. The needle is then placed in the rigid scriber and honed on the oilstone until the conical point is truncated to the diameter of the line to be scribed. This type of scriber and needle are used for line weights up to 0.012 inch. Ordinarily, the usual steel phonograph needle requires frequent sharpening, which is objectionable. However, a special type of needle with an offset point has been used with much less sharpening for line weights up to 0.006 inch. Although this needle cannot be inserted in the special jig for the first sharpening phase, the second phase has nevertheless proved to be adequate.

The swivel scriber (2) resembles the rigid scriber except that the cutting blade is on a swivel or caster arrangement like an ordinary contour pen. It is equipped with a magnifier which rotates with the swivel. This tool is used for either single wide lines or double lines, such as roads, which can be drawn best with this "tractor" type of action. The cutting edge consists of a spring steel blade set in a slot in a carriage which is offset from the axis of the swivel. The blades are normally shaped to the desired specifications by the instrument makers, but they require a small amount of additional retouching by the draftsman. A special jig (2a) is used for retouching and sharpening. The jig holds the blade so that when it is used vertically in the scriber, the leading and trailing edges of the cutter form angles of 51^0 and 5^0, respectively, with the horizontal. A close adherence to these angles assures uniformly good scribing results. The preparation of this cutting blade is more time consuming than that required for the rigid scriber needle, but a careful job is rewarded by faultless scribing quality and longer useful life without further sharpening.

The pen-type scriber (3) is very much like an ordinary penholder and is provided with a small chuck to hold the scribing tool. The chuck is fixed at an angle so that the tool, such as a phonograph needle, is vertical. This scribing tool is mostly used where contours are close together or where a drainage pattern is close and intricate. The needle itself is sharpened in the same manner as that for the rigid scriber.

These scribing tools enable the draftsman to remove the plastic coating by a cutting operation for the delineation of all details formerly executed in ink. Thus, careful attention to sharpening the needles and blades is of primary



importance in the successful application of the method. Smoothness of cutting is the criterion of the proper sharpened point. The amount of pressure the draftsman needs to apply depends on the hardness and thickness of the coating as well as the weight of the line being cut. He can conveniently test a tool in the margin of the sheet. If a tool is properly sharpened, it can be used to cut the coating for its designed line weight or symbol, producing with ease a sharply defined line uniform in all directions without "digging in."

Other types of scribing tools and templets have been developed for specialized use. The dotting device is an example. Operating on the principle of a ratchet screwdriver, the chisel-type bit spins in one spot by pressing the device vertically downward, thus removing the coating in a small, sharp, round dot. Templets are used to produce repeated shapes such as circles, triangles, and squares. They consist of "cutouts" in thin transparent or translucent material. A lineosçope is used to check the weight and quality of a line or symbol.

APPLICATION OF PLASTIC SCRIBING

The object in making a scribed sheet is to obtain a medium from which the press plate can be made by means of a direct contact printing process. This requires that the scribed sheet be in negative form. Inasmuch as the reversed image of the original manuscript can be printed on the scribe coating as easily as the positive image, no problem is involved. Due to the restriction for some standard maps of printing all detail in only one color, the addition of type, halftone screens, and vegetation patterns requires that only one final sheet be prepared for reproduction.

The procedure through which the scribing method is used is somewhat different from that of inked sheets. The coated plastic sheet, upon which has been printed an image of the manuscript, is first scribed. The scribed data include all details such as projection lines, roads, drainage, contour lines, and buildings, but do not include "stickup." The scribed sheet is then processed to furnish a new positive black-line print on a clear plastic sheet. All the stickup which had been omitted from the first sheet, including lettering, symbols, vegetation patterns, and halftone shading, is placed on this new medium. A third sheet is then made, resulting in a single, negative copy containing all the map data. This constitutes the final file negative from which copies can be reproduced by contact printing. The procedure avoids the use of an overlay sheet with its difficulties with regard to register, storage, damage, or loss; it also eliminates the possibility of losing portions of stickup through repeated handling or aging.

In the preparation of standard topographic quadrangles, color separation scribing is being accomplished successfully. The requirement of several different color press plates for the printing of multicolored topographic quadrangles demands a separate final negative of each color. These negatives may be scribed; produced from partial positive stickup of type, vegetation patterns, or screening; by selective removal of solid areas for tints; or by a combination of any of these. Usually as many blueline images on scribe-coated sheets are obtained as are needed in scribing the required details and symbolization on different color bases. The background of the completed scribed sheet is sufficiently translucent to permit an acceptable comparison on a light-table of any two basic colors for good agreement. This is also a marked improvement over the former inking method, where a comparison for good agreement between colors was much more laborious and difficult.

White coated sheets are not being used extensively in the Bureau, but they are sometimes advantageous. The scribing can be done without a light-table by laying a piece of black matte paper beneath the sheet. All the stickup information can be placed on the opposite side of the same sheet. The method of reproduction includes the use of a copy camera to produce a film negative of the composite sheet by photographing the sheet against a black background with front illumination. Here the scribed lines are photographed as though they were inked lines rather than being treated as a negative. Of course, the scribed information can be processed onto other material by contact printing in the same manner as the yellow coated sheet.

PLASTIC SCRIBING IN OPERATION

Plastic scribing is used to a distinct advantage in the field offices of the Bureau, three of which are equipped for contact printing with vacuum printing frames, arc lamps, and developing tanks. A photographic emulsion called Watercote is applied to a scribe-coated plastic sheet with a sponge, cloth, or brush in subdued light. After the drying period of a few minutes, the sheet is then placed in contact with a manuscript or a negative of a manuscript in the printing frame, exposed to the arc lamp, developed by swabbing with an ammonia solution, rinsed with water, and dried. Thus, it is possible for a field office to reproduce a provisional copy from any transparent or translucent drawing with a relatively small amount of equipment. A somewhat poorer copy can be made without the special printing frame and arc lamp by simply placing a heavy cover glass over the sheets in contact and exposing a longer time to a single bright light. Examples of the work done in the field offices are: preparing a guide copy from a manuscript in preparation for scribing; adding edge information from an adjoining sheet onto a guide image for scribing, to facilitate accurate joining of sheets; producing a file copy for use while the original is sent to another office; and producing a duplicate copy from which further copies can be made after sending the original to another office. These applications of plastic scribing have served to avoid the delays formerly experienced by having all work for provisional and operational uses sent to the Washington office for reproduction.

Plastic scribing has yielded results even greater than was initially anticipated. During the first year, when scribing was applied about 8 months in the Washington office to topographic mapping, the total number of maps produced by the drafting unit increased nearly 30 percent over the previous year's production, even though the number of draftsmen in the unit had decreased 10 percent. A given job performed by scribing in the Baltimore office required only about 60 percent of the time that had been estimated for inking. Two years later, production again increased more than 40 percent over the previous year. Moreover, the quality of the scribing was entirely satisfactory for reproduction and filing without major retouching, which was not so with ink drafting. It is believed that the peak of production is being approached, as the development of materials, techniques, and training appears to be fairly well stabilized.

* * *

How Fast Does Sound Travel in Sea Water?

Vital Navy operations depend on prompt and highly reliable knowledge on the speed of sound in the sea. It is not enough to know that the speed is in the range of 4,600 to 5,140 feet per second in large natural bodies of water, and that factors such as salinity tend to vary the velocity of sound from one part of the sea to another. In a Navy operation, responsible officers want to know on the spot, and instantaneously, what the velocity is, and they want to know it for a wide range of depths which may change constantly during the time an operation is coming to a climax. Any conning officer who has sweated out the detection of a submarine--in an exercise or as the real thing--can appreciate the importance of a reliable reading on the speed of sound in the water he is traveling through at the moment.

The velocimeter has been developed and tested as an automatic instrument that almost instantaneously gives the velocity of sound in sea water. This highly reliable instrument has been designed and constructed at the National Bureau of Standards, and more recently tested at the U. S. Navy Underwater Sound Laboratory, in New London, Conn. The work of developing this instrument was sponsored by the Office of Naval Research. The NBS-ONR velocimeter will provide answers promptly on the speed of sound to depths as great as 300 feet. Readings come in values that are immediately useful--the speed as a function of depth or the speed as a function of time.

It has long been known that variations in sound velocity occur with changes in temperature and, to a lesser extent, with changes in the salinity of water. Sound velocity also increases about one foot per second for each 55 feet of increase in depth. Several other factors, not all of which are well understood, influence the velocity of sound in the sea. The velocity gradients resulting from these variables produce curvatures in the rays of sound being propagated in the sea. In some instances, reflections are produced if, as is often the case, the thermal or salinity gradients are abrupt. Instruments generally employed by the Navy to give information on sound velocities depend upon a measured temperature and an assumed salinity. The NBS-ONR velocimeter, on the other hand, is independent of these variables in that it affords an almost instantaneous meter reading of the actual sound velocity.

Essentially, the new instrument consists of transmitting and receiving transducers which are located side by side. The pair of piezoelectric transducers are polarized barium-calcium-lead titanate crystals. The acoustic path is from one crystal to a reflector, then back to the other crystal. In all, the path is about 10 cm. The signal applied to the transmitting transducer is a negative spike with a rise time of about 0.05 microseconds and a duration of about 0.1 microseconds.

The received pulse, which is distorted because of a transducer response and absorption by the liquid, is reshaped by an amplifier and used to lock-in the blocking oscillator. Then the scale is expanded by beating against a crystal-controlled local oscillator so that the final frequency range is from 0 to 1 kilocycle.

The depth transducer is a strain-gage type pressure element. The unbalanced d. c. voltage from the bridge circuit drives the X-axis of the recorder so that the chart presents a plot in terms of speed of sound versus depth.

It is necessary to exercise care in making sure the velocimeter is properly calibrated. Since the attenuation characteristics of sea water are almost independent of salinity, the instrument may be calibrated in pure water for which the speed of sound is accurately known as a function of temperature.--From *Research Reviews*, Office of Naval Research, August 1956.

Federal Liability for Failure of Navigational Aids

A. L. SHALOWITZ, LL.M.
U. S. Coast and Geodetic Survey

A DECISION of considerable significance to maritime commerce, and of possible far-reaching implication to Federal service agencies, was recently rendered by the Supreme Court of the United States in the case of ***Indian Towing Co., Inc., et al. v. United States***, 350 U. S. 61. The case relates to the grounding of the tug *Navajo* on Chandeleur Island, Louisiana, and the severe damage to its cargo. Suit was brought against the United States under the Federal Tort Claims Act alleging that the grounding was caused by the failure of the light on the island, and that this failure was attributable to negligent acts and omissions on the part of Coast Guard personnel whose duty it was to check the light.

The district court dismissed the action on the ground that the United States had not consented to be sued in the manner in which the suit was brought, and the court of appeals affirmed the dismissal. On appeal to the Supreme Court, a hearing was granted because the case presented an important aspect of the still undetermined extent of the Government's liability under the Federal Tort Claims Act. By an equally divided Court (4 to 4), the judgment of the court of appeals was affirmed. On petition for rehearing, the earlier judgment was vacated and the case reargued before the full Bench. By a 5 to 4 decision, the judgment of the court of appeals was reversed and the case remanded to the district court for further proceedings.

Present interest in the case lies not so much in its ultimate outcome, but in the interpretive rules which the Court enunciates with respect to certain provisions of the Tort Claims Act, and in the possibilities the case poses. To better understand the significance of the decision, it should be read in the light of the origin and purpose of the Act and in the interpretations that have heretofore been placed on it.

THE FEDERAL TORT CLAIMS ACT

The Federal Tort Claims Act (28 U. S. C. (1952) secs. 1346(b) and 2671-2680) was passed by Congress in 1946 as Title IV of the omnibus Legislative Reorganization Act. Essentially, it was a waiver-of-immunity statute and marked the culmination of nearly 30 years of effort to mitigate unjust consequences of sovereign immunity from suit. The English political theory that the King could do no wrong was repudiated in America at quite an early date, but in its place there grew up a legal doctrine that the Crown is immune from suits to which it had not consented. After the American Revolution, this doctrine of consent was invoked on behalf of the Republic and was vigorously applied by our courts. As the activities of the central Government broadened, the number of remediless wrongs multiplied--wrongs which would have been actionable if inflicted by an individual or a corporation, but remediless because committed by an agency of Government.

This shedding of the sovereign armor of Federal immunity, under the Tort Claims Act, was not the first to find its way on our statute books. The Tucker Act of 1887, the Patent Infringement Act of 1910, the Suits in Admiralty Act of 1920, the Public Vessels Act of 1925, and the Oyster Bed Damage Act of 1935--predecessors of the Tort Claims Act--were all piecemeal surrenders of immunity.[1]

Prior to the passage of the Tort Claims Act, the only remedy that an aggrieved plaintiff had for damages resulting from the negligent act of a Federal employee, while acting within the scope of his employment, was to have a private bill passed by Congress compensating him for the loss. The alleviation of this costly and burdensome procedure of private relief bills was the other facet of the Tort Claims Act.

The Act waives sovereign immunity of the United States from suits in tort and permits claims for injury ". . . caused by the negligence or wrongful act or omission of an employee of the Government while acting within the scope of his office or employment, under circumstances where the United States, if a private person, would be liable . . ." (28 U. S. C. sec. 1346(b)).

Mr. Shalowitz is a Special Assistant to the Director and a member of the District of Columbia and Maryland bars.

The views expressed are those of the author and do not necessarily represent the views of the Coast and Geodetic Survey.

[1] Even as early as 1861, the principle of recognizing Federal tort liability was approved. President Lincoln, in his annual message to Congress, stated: "It is as much the duty of the Government to render prompt justice against itself in favor of citizens as it is to administer the same between private individuals."

LIMITATION OF LIABILITY

The Act does not apply to all cases of negligence. The waiver of immunity is circumscribed by 13 exceptions, the most important being the so-called "discretionary function" clause, which provides that the Act shall not apply to "any claim based upon . . .the exercise or performance or the failure to exercise or perform a discretionary function or duty on the part of a Federal agency or an employee of the Government whether or not the discretion involved be abused" (28 U. S. C. sec. 2680(a)). It is around this exception that many of the cases revolve, and is the one which the Supreme Court passed on in the *Indian Towing* case.

It has been the general policy of courts not to allow recovery where damage results from the exercise of a discretionary function; and to that extent, the same result would have been reached by judicial construction even if the exception had not been included in the Act. The Act makes this specific, but it furnishes no yardstick for ascertaining what a discretionary function is. Courts have struggled with this exception ever since the first case arose under the Act. In the absence of clear legislative guidelines, and lacking Supreme Court interpretation, the lower Federal courts in the early cases had applied the exception in the light of the circumstances involved and in an effort to balance the general purpose of the Act against the practical necessity of leaving the Government free from crippling interferences. It was natural that such judicial construction would not be uniform, and no satisfactory answer was produced for determining exactly where the delicate line of immunity from liability is to be drawn in the complex scale of governmental operations.

In a number of cases, the rule was adopted that even if the decision is discretionary, once made, the Government must thereafter proceed with due care *(Hernandez v. United States,* 112 F. Supp. 369 (1953), where it was held that while the decision to block a road was discretionary, the failure to set out warning signals was not). In other cases, the courts have examined the statute, regulation, or order under which the agency or employee was operating at the time, and if words expressly providing for the use of discretion, such as "may" were found they were made the basis for the decision *(Kline v. United States,* 113 F. Supp. 298 (1953)). And contra, where the statutory language leaves the agency or employee with no choice but to perform an act, courts have held the act to be non-discretionary and must be performed with due care *(Somerset Seafood Co. v. United States,* 193 F. 2d 631 (1951)).

The early cases to come before the United States Supreme Court, under the Federal Tort Claims Act, dealt primarily with the Act's coverage and did not involve the discretionary function exception. Generally, a liberal interpretation was followed, as exemplified by the holding in *Brooks v. United States,* 337 U. S. 49 (1949), that members of the armed forces could recover for injuries *not* incident to their service; and the holding in *United States v. Yellow Cab Co.,* 340 U. S. 543 (1951), that the Act also covered claims for contribution from the Government as a joint tort feasor in a case where the passengers of a taxicab were injured as a result of a collision with a United States mail truck.[2]

THE DISCRETIONARY FUNCTION EXCEPTION IN THE SUPREME COURT

Notwithstanding this liberal trend in favor of claimants, the Supreme Court sharply divided on the application of the discretionary function clause in the first case to come before it *(Dalehite v. United States,* 346 U. S. 15 (1953)). This case was one of imposing magnitude resulting from the Texas City disaster in 1947, in which 560 persons died and 3,000 were injured. Out of the holocaust arose 273 claims for wrongful death, personal injuries, and property damage, aggregating some $200,000,000. The disaster resulted from the spontaneous combustion of ammonium nitrate fertilizer which was being loaded onto ships, under Government auspices, as part of a foreign aid program. The negligence alleged was in the manufacture, packaging, and transportation of the explosive material without warning of the possibility of explosion, and the negligence of the Coast Guard in failing to supervise its storage and in fighting the fire after it started. Faced with a complex fact situation, reflected by an enormous record, the Court--resting on the legislative history of the Act, which assured protection for the Government against liability for errors in administration or in the exercise of discretionary functions--held in a 4 to 3 decision that the acts or omissions complained of fell within the discretionary function exception on the basis that the exception includes not only determinations by executives and administrators in establishing plans, specifications, or schedules of operations, but also *the acts of subordinates in accordance with official directions.* "Where there is room for policy judgment and decision," the Court said, "there is discretion." (The Court also noted the traditional immunity of public bodies for injuries due to fire fighting.)

While the Court made no attempt to define the scope of the exception, but rather chose to apply

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[2] Here, the Court said: "Recognizing such a clearly defined breadth of purpose of the bill as a whole, and the general trend toward increasing the scope of waiver by the United States of its sovereign immunity from suit, it is inconsistent to whittle it down by refinements." *Id.* at 550.

it in an *ad hoc* manner to the facts in hand, the effect of the decision was to extend the area of discretionary function further down the scale toward the operational level. Nevertheless, the Court did not close the door to recovery for all subsequent actions arising from a discretionary function. Without defining precisely where discretion ends, there is clear implication in the majority opinion that a distinction exists between injuries flowing from decisions made at a planning level and those arising on the operational level.

THE RECENT SUPREME COURT DECISION--FAILURE OF A NAVIGATIONAL AID

In the *Indian Towing* case, *supra*, the Supreme Court came to closer grips, although obliquely, with the application of the discretionary function clause, and appears to have provided a more definitive yardstick for determining where in the scale of governmental operations the operational level begins, at which the Government could be held liable for the negligent acts of its employees.

It was contended by the Government that section 2674 of the Act which imposes liability "in the same manner and to the same extent as a private individual under like circumstances" must be read as excluding liability in the performance of activities which private persons do not perform.[3] But the Court denied that immunity attached to uniquely governmental activities, since all governmental activity is inescapably "uniquely governmental" in that it is performed by the Government. It said that the statute imposing liability on the United States "as a private individual under like circumstances" does not depend upon the presence or absence of identical private activity, and that "it is hornbook tort law that one who undertakes to warn the public of danger and thereby induces reliance must perform his 'good Samaritan' task in a careful manner."

On the matter of the discretionary function exception, the crux of the opinion is contained in the following significant passage:

> "The Coast Guard need not undertake the lighthouse service. But once it exercised its discretion to operate a light on Chandeleur Island and engendered reliance on the guidance afforded by the light, it was obligated to use due care to make certain that the light was kept in good working order; and, if the light did become extinguished, then the Coast Guard was further obligated to use due care to discover this fact and to repair the light *or give warning that it was not functioning.*" (Emphasis added.) *Id.* at 69.

The Court thus follows the discretionary-operational distinction. Had the Court found for the Government, then governmental liability for torts of United States agents would have been greatly restricted.

The Court's interpretation of "like circumstances" in the statute as not meaning "identical circumstances" also broadens the scope of the Act and opens the door to many situations that would otherwise be barred under previous rulings of the Court (for example, the *Feres* and *Dalehite* cases, note 3 *supra*).[4] This seems sound statutory construction, otherwise any activity that is uniquely governmental, whether involving an exercise of discretion or not, would be barred. This would hardly be in keeping with the statutory exception which makes "discretion"the criterion rather "governmental." To hold otherwise, would narrow governmental liability, as was said in the dissenting opinion in the *Dalehite* case, to "the misconduct of file clerks and truck drivers"—a result hardly commensurate with the 30 years the statute was in the making.

OTHER MARITIME TORT CASES

Several cases in the so-called "maritime tort" class have been decided in the lower Federal courts, but all were prior to the Supreme Court decision in the *Indian Towing* case, and therefore exhibit conflicting results. For example, in the *Somerset Seafood* case, *supra*, the Government was held liable for the negligent marking of a wreck on the basis that under the Wrecks Act the duty to mark and remove the wreck was mandatory. But the court went even further and stated, by way of dicta, that even if the decision to mark or remove the wreck be regarded as discretionary,. there is liability for negligence in marking after the discretion has been exercised and the decision to mark has been made. Said the court: "There is certainly no discretion to mark a wreck in such a way as to constitute a trap for the ignorant or unwary . . ." (The dictum is in keeping with the Supreme Court's holding in the *Indian Towing* case.)

In the *Kline* case, *supra*, the court refused to go along with the dicta in *Somerset Seafood*, and held the Government not liable for failure to rebuild

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[3] The Government's contention followed the holding in *Feres v. United States*, 340 U. S. 135 (1950), which denied liability for injury sustained by a member of the armed forces, *while on active duty*, through the negligence of others in the armed forces, on the ground that no private individual has power to conscript or mobilize a private army. The *Dalehite* case, *supra*, followed the same reasoning with respect to fire fighting.

[4] See also ***Sigmon v. United States***, 110 F. Supp. 906 (1953), which barred recovery for injuries to Federal prisoners, and *National Mfg. Co. v. United States*, 210 F. 2d 263 (1954), which barred recovery for injuries arising from an erroneous flood forecast, on the ground that private persons do not operate prisons or disseminate flood information.

a range light because the Coast Guard had discretion under the statute as to whether, when, and how lights should be restored. (This case would seem to be in direct conflict with the *Indian Towing* case, except for the court's finding that the record fails to show that the Coast Guard did not take adequate steps to warn the seafaring public that the range light was not in operation. The court also distinguished the *Somerset* case on the basis of the mandatory provision of the Wrecks Act.)

In *Bray v. United States*, 1954 AMC 308 (1953), the complaint charged that the failure of a lighted buoy, maintained by the Coast Guard, to be lighted, or properly lighted, was the cause of damage. In denying recovery, the district court did not rely on the permissive wording of the statute under which the Coast Guard was authorized to establish and maintain aids to navigation, but rather on the ground that it is a provision for fostering shipping and does not declare a duty actionable at law, in equity, or in admiralty. Under the doctrine of the *Dalehite* case, the court held that the discretionary function exception of the Tort Claims Act precluded jurisdiction of the case because the Coast Guard was performing a governmental function.

Thompson v. United States, 111 F. Supp. 719 (1953), involved damage to a yacht in striking an overhead electrical cable. The cable and height were properly shown on the Government charts, but no information was given that it was a high-voltage wire. The court found for the United States on the ground that the plaintiff had knowledge that it was an electrical power cable, and hence the omission of such information from the chart would have no causal connection to the accident. Although the court intimated that the proper place for a warning as to the high-voltage nature of the cable would have been on the nautical chart, it did not pass on the question whether failure to include such information would or would not fall within the purview of the discretionary function exception of the Tort Claims Act.

IMPLICATIONS FOR FEDERAL CHARTING AGENCIES

While the decisions in the lower and higher Federal courts point up the great difficulty of drawing the line where Federal immunity ends and liability begins under the Tort Claims Act (witness, for example, the closely divided Supreme Court in the *Dalehite* and *Indian Towing* cases), there is evidence of a trend toward a liberal construction (in favor of claimants) of the Act generally and the discretionary function exception specifically.

The *Indian Towing* decision has now been buttressed by *United States v. Union Trust Co.*, 350 U. S. 907 (1955), in which the Supreme Court, upon authority of the *Indian Towing* case, affirmed, in a *per curiam* opinion, the holding of the two lower courts that the United States was liable for the negligence of its control tower operators in regulating air traffic at a public airport. This narrows Federal immunity from suit to those claims for negligence that arise from decisions made on a policymaking or planning level. But it still leaves open the question as to where the operational level begins at which Government liability attaches. In *Dalehite*, the Court carries Federal immunity further down the scale of governmental operations towards the operational level, while *Indian Towing* limits immunity to the initial decision of the Federal agency under its statute of authorization.

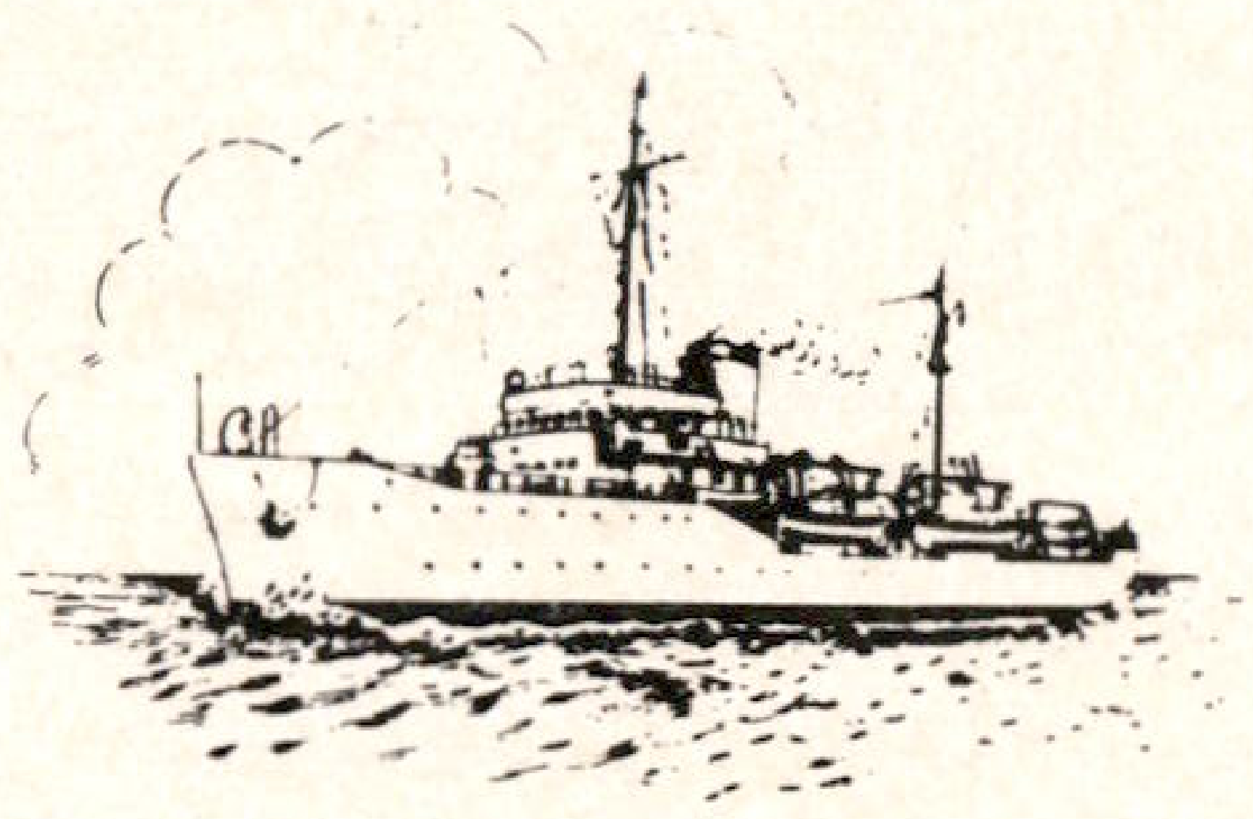
Apart from the Court's interpretation of the discretionary function exception, the recent cases make two other significant contributions toward clarification of the Tort Claims Act: One is the holding that "under like circumstances" in the Act does not mean "identical circumstances" and therefore governmental liability can attach to the negligent performance of operations that have no counterpart on the private level *(Indian Towing* case); the other is the holding that discretion exercised on the operational level is not the discretion contemplated by the Act *(Union Trust* case).

These recent Supreme Court cases hold important implications for all service agencies of Government, particularly those that deal with the safeguard and control of marine and air commerce. The present temper of the Court appears to be to hold these agencies to a stricter accountability for acts of negligence that result in injury to the public, and therefore pose new responsibilities for them, both in the matter of an exercise of greater care on the operational level and in the matter of duly warning the public of potential dangers. But neither is the navigator absolved from taking all necessary precautions to avoid disaster, for, in the final analysis, monetary recovery will depend upon the causal connection between the alleged negligence of the Government and the accident, and such matters as the plaintiff's failure to use the latest nautical charts, Coast Pilots, and Notices to Mariners, or his failure to listen to daily broadcasts concerning aids and dangers to navigation, will directly affect the outcome. *(See*, for example, the *Kline* case, *supra*, where, in denying Government liability, these criteria of prudent care were raised by the trial judge.)

For the Federal charting agencies, the decisions raise some interesting questions. In the gamut of operations involved in the publication of nautical charts and related data--from the inception of the field survey to the final printing--there are many levels of responsibility, below the overall policy or planning level, where matters of judgment and discretion arise. It is doubtful whether the doctrine of the *Indian Towing* case, limiting Federal immunity to the exercise of the initial discretion, would be applicable in such situations. Since *Indian Towing* has not overruled *Dalehite* with respect to the level at which liability attaches, perhaps the true interpretation of the Act lies in the direction of both doctrines, and in considering each case on an *ad hoc* basis--in the light of the particular facts involved--keeping in mind the overall purpose of the Act as expressed by the Supreme Court in the *Indian Towing* case, namely: "The broad and just purpose which the statute was designed to effect was to compensate the victims of negligence in the conduct of governmental activities in circumstances like unto those in which a private person would be liable and not to leave just treatment to the caprice and legislative burden of individual private laws. Of course, when dealing with a statute subjecting the Government to liability for potentially great sums of money, this Court must not promote profligacy by careless construction. Neither should it as a self-constituted guardian of the Treasury import immunity back into a statute designed to limit it."

ADDENDUM

Since preparing this paper, the Supreme Court, in a far-reaching decision *(Rayonier Inc. v. United States*, 352 U. S. 315 (Jan. 28, 1957)), passed on the question of Federal immunity from liability for the negligence of the Forest Service in fighting a forest fire. By a decided majority (7 to 2), the Court vacated the judgments of both lower courts who had dismissed the complaint on authority of the *Dalehite* case. (This was prior to the *Indian Towing* decision.) In holding that fire fighting is not immune and that liability can attach to "uniquely governmental" activities, the Supreme Court to this extent overrules the *Dalehite* case. The broadest base is now given to the purpose and scope of the Tort Claims Act by the Court's holding that "the very purpose of the Tort Claims Act was to waive the Government's traditional all-encompassing immunity from tort actions and to establish *novel and unprecedented* governmental liability." (Emphasis added.) (The Court's statement in *Feres v. United States*, note 3 *supra*, that the purpose of the Act "was not to visit the Government with novel and unprecedented liabilities," must, in the light of this most recent pronouncement, be taken as limited exclusively to members of the armed forces on active duty.) The liberal trend in favor of claimants, evidenced in *Indian Towing* by a narrow margin, has now been given positive and unmistakable direction.



EXTRACTS FROM FIELD REPORTS

Bridge Alignment, Greater New Orleans Expressway

(From 1955 Special Report of Lt. Comdr. Norman E. Taylor)

The work on this project consisted of furnishing centerline alignment for a proposed bridge. It was required that alignment be marked on platforms to be built at specified intervals along the proposed bridge. Centerline at each end of the proposed 24-mile bridge was marked by stations located by a private concern.

Our work consisted of preliminary location of platform sites and after completion of platforms we placed alignment points on the platforms.

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Several conferences were held with the project engineer and it was agreed to first set buoys on approximate line and location to simplify final location of platforms.

A 90-foot Bilby tower was erected over the north alignment station and a 103-foot Bilby tower was erected over the south alignment station. Two, 1:20,000 scale boat sheets were prepared and used throughout the project to plot sextant fixes for location of buoys and to plot sextant fixes for distances along the centerline for location of platforms.

Line-of-sight between the two control towers was first established using heliotropes and back-sight points set so that poor visibility would not delay operations.

Piling for platforms Nos. 1 and 2 were driven from location by sextant fixes and alignment from the north tower using the back-sight point. Piling at No. 3 was driven from location by sextant fix and alignment from both towers using heliotropes for line-of-sight. Piling at Nos. 4 and 5 was driven from location by sextant fixes and alignment from south control tower with line-of-sight obtained from heliotropes from north control tower. The buoys previously established were used only to place pile-driving barge on general location. Radios were placed on each tower and on the pile-driving barge and the leads of the pile driver were "talked" onto line by personnel on control towers.

Bridge company personnel completed all platforms. On one clear night final alignment was marked on each platform by using standard triangulation lights and first-order instruments.

The project engineer requested the towers be moved on line about 100 feet back from the control points and this was done using the back sights previously established.

It is believed that the accuracy required by the instructions could not be obtained except by occupying the platforms, and they proved to be much too unstable for this. The project engineer agreed that a single pointing would provide sufficient accuracy so the following method was used to provide final alignment.

At night, observers from both control towers obtained line from lights on the towers. A signal light was placed on each platform in turn and aligned by the closest control tower observer. This point on the platform was marked. The signal light was then moved across the platform in 2-inch intervals and alighment rechecked. Each point that appeared to be on line was marked. When both left and right extremes were found, the final alignment was set midway between these extremes. The center platform (No. 3) was set from both the north and south control towers and the point selected by the method of extremes varied only 1 inch. The extremes on the center platform were 29 inches apart and about 10 miles from the control points. On platforms closer to the observer the extremes were much less and alignment well within the 6 inches requested.

Poor visibility was the main difficulty encountered since alignment depended upon intervisibility of north and south control points which were over 24 miles apart. The north and south control points were selected and located by bridge company personnel and the tower footings were on muddy ground which caused some of the widespread on center platform alignment. The present location of the steel towers is on stable ground and any work done from them should cause little difficulty. Alignment was not rechecked after moving the towers.

Triangulation, Stevens Village to Umiat and Colville River to Admiralty Bay, Alaska

(From 1955 Season's Report of Comdr. Edmund L. Jones)

STEVENS VILLAGE-UMIAT ARC

The area covered by this arc can be divided into three distinct regions. The southern part, between Stevens Village to a few miles northwest of Bettle Field, long lines were necessary to take advantage of the few really prominent station sites atop ridges of from 1,500 to 3,600 feet in elevation. The middle section of the arc followed the John River and thence the Anaktuvuk River through Anaktuvuk Pass where there were many rugged and jagged peaks extending up to 6,000 feet in elevation. The northern part, on the Arctic slope, consisted of rolling hills which gradually lessened until at the north end of the project in the vicinity of Umiat, 16-foot light supports had to be used to prevent grazing lines.

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This 290-mile arc of first-order modified triangulation, which included two base lines, was completed in 55 days. The reconnaissance was the best that this party has ever encountered, the advanced planning and the supply support was equally as good, and the weather was favorable. These factors and the untiring effort of the men on the party made this progress possible.

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An attempt was made to obtain near-simultaneous, reciprocal, vertical-angle observations on all stations. Only where this would entail serious delay to the progress was this omitted. About 98 percent of the reciprocal vertical observations were near-simultaneous (within 30 minutes).

The taking of near-simultaneous, reciprocal, vertical observations presented no particular problem between observing parties since they were equipped with excellent, Army-type PRC-10 portable radios. It did require, however, that not all of the observers could be moved forward after completing a schedule. Generally, one observer remained on an occupied station to carry the simultaneous observations forward on the next schedule. An attempt was made to have one line of vertical observations simultaneous through the entire scheme.

Throughout the scheme, there were found more than the usual number of even 2- or 4-minute errors in reading the vertical angles, despite numerous caution warnings to the observers concerning this matter. Corrections were made in the original record in colored pencil, so that it would be obvious that these were office corrections. Loop closures were run, giving assurance that the corrections made represented true value.

The accuracy of the reciprocal vertical observations was checked by the criterion that the sum of the reciprocal values exceeds 180 degrees by the value 0.46 times the length of the line in kilometers.

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156th MERIDIAN ARC

This arc, all on the Arctic slope, extended from the Kigalik River at latitude 69° 20', northward along the 156th meridian to Admiralty Bay on the Arctic coast. The southern part of this arc afforded considerable relief, consisting of rolling hills and small ridges with shallow valleys. Progressing northward there was a gradual lessening of relief with occasional small mesas or buttes. The terrain on the northern half of this 90-mile arc was very flat and wet, and literally studded with thousands of small shallow lakes.

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Refraction, which was a big worry during the early stages of the work, turned out to be a nuisance rather than a serious problem. Although there was a great amount of reobserving, repeat schedules were necessary in only a few figures. By standing order, observations were scheduled on short notice at any time of day or night that the refraction conditions would permit. The observing units were very good about promptly reporting these periods so that observations could be almost immediately started.

About 90 percent of the stations were built by a separate building party. This enabled the subparties to have more frequent observing schedules, and, also, to use the one McCulloch power earth drill on each subparty to set the pipe marks.

Setting of pipe marks came in for special attention. A 1-1/2-inch hole was drilled with the McCulloch power drill to a depth of about 24 inches. Two quarts of cement were then placed in the bottom of the hole. The bottom part of a 30-inch long copper pipe with a disc brazed to the top, was ribboned with a hack saw, and the ribbons bent slightly outward so that the pipe would just slip down in the drilled hole. The pipe was then driven with a few healthy blows so that the ribboned ends were forced out into the walls of the hole. Tundra was then packed around the exposed top of the pipe, which extended 4 to 5 inches above the ground.

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PHOTOGRAMMETRY

Photogrammetric work was given equal priority with the other phases of field work on the project. At times there was a scarcity of helicopter transportation, since this party was not assigned helicopters in the same proportion as the other parties. This required a more efficient scheduling of operations so that the photogrammetric work could be combined with other work requiring the same transporation. By necessity this party had to make full and complete use of every helicopter trip and every back haul utilized.

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Marked stations were all paneled with white signal cloth and K-20 near vertical photographs were taken from about 3,000 feet above the station. Difficulty was experienced at some of the 6,000-foot peak stations in the Anaktuvuk Pass area.

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ACCIDENTS AND SAFETY

Despite a special attempt to make the party safety-conscious, there were four major accidents during the season. Pilots were repeatedly cautioned against overloading aircraft, landing on mountain tops without first using smoke grenades to determine wind direction, and attempting to fly in adverse weather. As a result of two of the accidents, the following special safety regulations were issued and enforced to the best of our ability: No employee was to *carry* a loaded gun on the project, and no passengers were to be carried on an aircraft with a cargo of gasoline, blazo, or kerosene.

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A daily flight card was devised by this party to keep a pilot record of each flight. They were turned in daily. Not only did these cards provide a great help in planning operations, since the flight time to various parts of the project could be readily obtained, but they gave a valuable means of checking the accuracy of the pilot's reported time. Checks were run on various pilots during the season without their knowledge. The method used was simply to occasionally check the actual time of takeoff and arrival and then compare it with the reported time as furnished by the pilot on the flight cards. It is possible that the pilots knew that an occasional check was being run on their reported flight time since no trouble was experienced in this respect during the season.

The card, also, furnished information on the type of flight, passenger, cargo, or deadhead. Many outlying gasoline caches were established in the project area to gas the helicopters in the immediate area of their work. The card provided space so that an accurate record could be kept of the gasoline available in these caches.

SPECIAL EQUIPMENT

Several special equipment items, not ordinarily used in the past on Alaska geodetic parties, were designed or furnished by the Alaska liaison office and are worthy of special comment.

Portable light tripod.— The design of this new type light tripod is excellent and no desirable changes are needed. The tripod is both sturdy and light, and fills a long felt need experienced by observers on sharp mountain peak stations.

Metal baseline taping stands.—These tripods were made in Seattle at the direction of the liaison office. They were usable but not entirely satisfactory. They could be greatly improved for use on tundra in Alaska if they were lengthened about 10 inches and had an additional spread at the base of the same amount.

Power earth drill.—Two McCulloch gasoline powered chain saws with 1-1/2-in earth drilling attachments were furnished this party. These drills were used in setting pipe marks in permafrost and their continued use is highly recommended. The chain saws were equally useful.

Aluminum foil.— This was furnished, since in past years there had been requests for foil to target intersection stations. Fluorescent cloth, which is much superior and lighter than foil, has now replaced its use for this purpose.

Wet cell storage batteries.—These batteries were used with signal lamps in the same manner that truck batteries are used for this purpose on steel tower parties in the States. This party was forced into the use of this type of battery because of the high rate of consumption of the standard dry cell batteries. A spare wet cell was kept on charge at the subparty camp for each observer. The use of these batteries proved highly satisfactory.

Throw away signal lamps.—This party was provided with inexpensive, flashlight-type lanterns designed for use with telephone dry cell batteries. These lamps were difficult to center and the reflectors were of poor quality. An attempt to use them on peak stations in the Anaktuvuk Pass area resulted in two uncompleted schedules and delayed the observing until the conventional 5-inch grid signal lamp was placed on the stations involved. Their use is not recommended except on short lines under ideal conditions.

Radio equipment.—The radio communication, within the party was, in the main, satisfactory. Supply camp units were equipped with TCS transceivers, and/or Viking transmitters. After considerable difficulty during the first part of the season they finally functioned well the rest of the season. The first 0-units were equipped with radios of the 1095-type, and, in general, they did not function satisfactorily, particularly on Baker subparty. At first, it was thought that we were operating beyond the range of these radios, but after noting the success of other parties using transceivers in the same class but of different make it was then believed that these radios were either defective or not of the same high quality. Each observing unit was equipped with an Army Signal Corps radio, the PRC-10, which gave very fine field results.

Floors for living tents.—The over-abundance of water on the Arctic slope forced the party to devise portable floors for the living tents of observing units on the 156th Meridian arc. These floors consisted of one-half inch plywood panels on 2- by 2-inch frames. The panels were 2 feet wide and could be transported, rather awkwardly, by helicopter. These floors added greatly to the morale of the field units.

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Leveling in Nevada and California

(From 1955 Season's Report of Lt. Comdr. E. E. Jones)

This leveling was done for the purpose of studying earth movement, principally as the result of an earthquake in December 1954. Apparent movement in the level net was found in some of the separated vicinities as pin-pointed by the supplemental instructions and tie data. Old lines were recovered and the spacing brought up to modern requirements. New vertical control was provided for the Nevada Department of Highways, the U. S. Geological Survey, and the Army Map Service, which are preparing new maps in the area.

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The party's liaison and cooperation with other organizations continued throughout the project. Upon our arrival in the project area, the San Francisco district officer advised us of the interest of Prof. David B. Slemmons of the University of Nevada in the investigation of the earth movement. Several office visits and field trips were made together. Dr. Slemmons had a summer geology class encamped in the fault area, and he pointed out details of the earth movement. In turn, the party assisted Dr. Slemmons briefly in the field, and kept him informed of our field results.

The Geological Survey is mapping several quadrangles in the area near Austin, Nev., and the general locations of marks were furnished in order that they may be mapped. Preliminary field elevations were also furnished. The Army Map Service is also doing some small-scale mapping in the project area. Preliminary elevations and differences were furnished the Nevada Department of Highways for construction surveys. The releveling along U. S. Highway 50, line 15, also furnished control for the leveling of the highway grades across the movement area. A number of Geological Survey level marks of 1908 were recovered with some difficulty and new descriptions written, if not included in our lines.

A great deal of local interest was expressed in our findings on the movement in the area, but no information was generally released pending study and adjustment by the Washington office and interpretation by geologists. Most people wanted to know whether the valleys were sinking or the mountains growing.

A massive vertical movement was indicated by the releveling in the earthquake area. Line 15 (Nev.) along U. S. Highway 50 forms a cross section to the fault area near the epicenter of the quake. East of the break, the alluvial valley seemed to have sunk and tilted. Benchmark S 46, about 0.6 mile east from the broken area, appeared to have dropped about 4.2 feet, and R 46,

Scarp east of Fairview Peak where a vertical height of 23 feet was measured.

about 2 miles east, dropped about 2 feet. Benchmark Q 46, in different structure, about 4 miles to the east dropped about 0.4 foot, some effect extending about 10 miles east of the fault zone. Just to the west of the most faulted area, benchmark T 46 has possibly raised on the order of 0.2 foot as though its hill-structure had been relieved of some load of the valley to the east and had rebounded. The highway across the fault was built as a tangent about 18,000 feet long. When observed through a transit, backsighting along the eastern centerline, the western end of the tangent appears to have been shifted 6 feet relatively to the north. At this point the faulted area is about a mile wide through which most of the displacement appears to have accumulated.

To the north in Dixie Valley, even more tilt appeared to have occurred. B.M. 4023 (USGS), 300 feet east of the major fault at the mouth of IXL Canyon, has dropped 7 feet. At the north end of the fault zone, the movement appeared more vertical, while at the south it was more horizontal. This is understood to have been shown by the seismograms.

The displacement at the faults was complex in a plane not readily determined. Dr. Slemmons explained that a curved slip fault may have created a crack and void in which slumpage occurred to increase the scarp heights.

A horizontal movement on a hillside can result in an apparent vertical scarp. This probably accounted for measurements at the fault amounting to as much as 23 feet. Where there were several large cracks and adjacent distortion, the displacement was complex and cumulative and could only be measured accurately by extensive control surveys before and after the quake.

It was noted that the high side of cracks was on the east for cracks north of West Gate in the southern end of the Clan Alpine Mountains. This is the reverse direction of the scarps on the west side of Dixie Valley and south of Chalk Mountain near Fairview Peak. However, the movement was complex and further study would be required before it could be confidently stated whether there is a sunken block in the valley east of Chalk Mountain.

Small earthquake aftershocks occurred during this project, but no evidence of active movement was found. These were too numerous and too small to log accurately without instruments.

Leveling over fault at mouth of IXL Canyon, west of Dixie Valley.

First-Order Baseline, Levels, and Precise Alignment

(From 1956 Season's Report of Walter R. Helm, Geodetic Engineer)

The Holloman Air Development Center of the U. S. Air Force had need of a straight section of railroad track 35,000 feet long to be used as a traffic way for vehicles traveling at high rates of speed, i.e., subsonic, sonic, and supersonic. These vehicles are used for various aerodynamic tests, etc.

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The entire track is to be constructed with sufficient accuracy so that no portion of the rails will depart from a straight line, either vertically or horizontally, by more than the arc of a circle with radius of 1,000,000 feet. In order to obtain such accuracy it is planned to excavate the ground and build the roadbed first. Thence in the top of the concrete bed, near one of the rails, a series of bronze disks, 100 feet apart, are to be set. A precise survey is then to be run over these marks, obtaining elevations, distances, and alignment. The rails are then to be set on the bed with the alignment marks on the disks and the elevations as a guide. The positions of the marks on these disks are to be accurate within 0.03 inch in relation to their neighboring disks.

In order that the above-mentioned bronze disks can be set with sufficient accuracy so that the final distance and alignment marks will fall on them, it was necessary to establish an original line of reference before construction started. This line of reference consists of a series of monuments roughly 1/2-mile apart and 200 feet west of the proposed track, with a bronze disk in the top of each. Monuments BL 29 through BL 41 were set by the Corps of Engineers for this purpose.

The Coast and Geodetic Survey was requested to make the surveys necessary for construction of the track. The initial phase, that is, the survey of the offset monuments to be used as a line of reference for construction, is the substance of this report. The final phase will be accomplished when the Corps of Engineers gives notice that the basic construction has been completed and the 100-foot disks set.

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The line follows along the east side of a sand dune plateau which is 20 to 25 feet high. It enters the sand dune area about half way between monuments 40 and 41 and a finger of the dunes extends across the line at monument 36 but ends 200 to 300 feet east of the monument.

To the east of the sand dunes, where most of the line runs, the land is flat and sandy and is covered with a low growth of cactus and bunch grass. One shallow arroyo crosses the line between monuments 36 and 37. However, it is so wide and shallow that only the higher and thicker vegetation distinguishes it from the rest of the desert.

There is a large, partially buried blockhouse near the south end of the existing track and a small observation building about a quarter mile west of monument 32. No other structures were near the line, but a number of test structures can be seen to the east and southeast.

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The weather is typical of all desert country. The air is clear, dry, and bright except for frequent sandstorms. The latter occur once or twice a week and last all day. They start about midmorning and reach their height about 4 to 5 o'clock in the afternoon. At such times, survey operations must be curtailed or suspended.

A number of agencies, both governmental and private, use the Air Development Center as a testing ground. As a consequence, there is considerable activity on the test track, the desert area north of the track, and the air above the entire test area, much of which presents a danger to working personnel. As evidence, the stretch of desert along the proposed track was liberally strewn with spent artillery shells, bombs, rockets, jato units, and even 50 caliber bullets from planes practicing strafing. The Air Force usually set up road blocks to prevent entry of personnel while dangerous tests were being conducted. These precautions, although vitally necessary, held up survey operations for hours at a time. More important, and worse, these tests were usually timed to take advantage of the best weather, thus blocking off the working grounds at the most inconvenient times. Many of the best working hours were lost in this manner.

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Distances were measured in accordance with standard and accepted methods and procedures for first-order base measurement as outlined in Special Publication No. 247, *Manual of Geo-*

detic Triangulation. As an added refinement, two steel tapes were used--one for all of the forward measurements of fractional lengths and the other for the backward.

Elevations were obtained by the standard and accepted methods and procedures for first-order leveling as outlined in Special Publication No. 239, *Manual of Geodetic Leveling.*

Marks were aligned by the method of measuring small deflection angles on either side of the line and thence computing the distance off line. A mean of ten measures of each angle was used and only one setting of the instrument circle employed, in order to minimize the instrumental error. The line was broken down into successive half, quarter, eighth, etc. sections.

All traverse measurements fell well within the specifications for first-order base measurement.

All level sections fell well within the limits of the specifications for first-order leveling except the connection between the line at BL 41 and Benchmark R239, which fell well within the limits of the second-order level line connection.

Alignment procedures and methods were developed as the work progressed, not only to produce the straightest line possible, but to ascertain the limits which should be imposed in aligning the 100-foot interval monuments in the second phase of the project, 6 months hence. Since the railroad is to be 6 1/2 miles long, observations of deflection angles are subject to the same atmospheric errors as triangulation observations. The horizontal refraction is probably accentuated by the proximity of all lines of sight to the ground. For this reason, probable errors based on dispersion of individual observations give a rosier picture of the accuracy than experience teaches one to believe. However, these refraction anomalies diminish in proportion to the distance to previously aligned points and should have no effect when aligning points of 100-foot intervals.

As to the longer sections, as a test, monument BL 36 was aligned once from a setup 18 feet north and then again from a setup 18 feet south, using BL 29 and BL 41 as fixed points. These two alignment marks were 1.58 cm. apart (0.05 foot), approximately what would be expected from an analysis of the probable error computed from observations taken over this distance. The halfway point between the two lines was used as the final alignment mark.

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Pacific Ocean Offshore Survey

(From 1955 Season's Report of Capt. Charles Pierce)

The exclusive sounding equipment used on the project consisted of an EDO echo sounder which was modified by Buships design of a Lamont Geological Laboratory precision depth recorder including a time-facsimile chart recorder. Since this is new equipment found on only a few survey ships of the U. S. Navy, a brief description follows:

The modified equipment consists of a tuning fork power supply, a synchronous drive rotating a recording drum, electronic circuits for supplying voltage to a stylus which prints by spark discharge on standard facsimile paper, and a stylus translation mechanism driven by a separate motor.

The rotating drum closes the keying contacts of the echo-sounder transmitter through a keying gate every second. The gate is set manually for a recurrence rate appropriate to the depth and allows a group of five pulses to be sent at 1-second intervals. The first of the series of transmitted pulses operates a recording gate, which short circuits the input to the facsimile recorder for a preset interval. Thus, the fast recorder prints only a small part of the transmitted pulse, none of the reverberation, and only for the gated interval set by the operator to include the time of the bottom reflected pulses. The operator of the recorder monitors the recorder input both aurally and visually so that he may set the gates for a minimum of unwanted recording. To check the constancy of rotational speed of the drum, the 1000 c.p.s. pulse, which is transmitted every second by National Bureau of Standards' WWV, may be recorded.

The advantages of the modification to the Standard EDO deep sea sounder are:

1. Use of the time-facsimile recorder for both recording and keying has eliminated the problem of timing caused by uncertain scale values in earlier instruments.
2. Use of a single stylus to record both the outgoing signal and the echo has eliminated uncertainty of the zero point.
3. Measurement of depth is good to better than 1 fathom in 3,000 fathoms, excluding uncertainties of speed of sound in sea water.
4. Transmitting and receiving circuits of the EDO

echo sounder are used but recording of the transmitted and reflected pulses is done on the time-facsimile receiver.

5. The instrument has reduced all other sources of error to the extent that the uncertainty in the speed of sound in sea water and the slope of the bottom are the principal sources of error in absolute depth measurement.

The modified EDO equipment was used during some very rough weather. Transducers were available for use on either side of the keel, and generally selection of the lee transducer improved recording of reflected pulses. Use of the gating arrangement was found obligatory in normal sea conditions and only infrequent use was made of the PDR setting, which continuously recorded the echoes from the 1-second pulses.

Some modification to the time-facsimile recorder was found necessary. The 1-millisecond pulse lacked the intensity to record in depths over 1,000 fathoms. This pulse duration was lengthened to about 30-40 milliseconds and an electronic keyer was designed to lengthen the pulse and provide constancy of duration of pulse.

Most trouble was encountered in the 1 RPS wheel contacts; adjustment and cleaning after each cruise was standard practice. Several stylus carrying belts broke and were replaced during the season. The 1 RPS wheel was renewed and the old wheel returned to the manufacturer to be built up.

The time-facsimile recorder is 19 inches wide and records in bands of 400 fathoms; as the bottom record runs off either end of the paper it automatically returns on the opposite end. The phase in multiples of 400 fathoms can be identified by following through from a known depth, or by comparison with another type recorder, such as the NMC-2, or by aurally listening and counting seconds with the headphones provided on the modified equipment. Frequent check on the timing of the time-facsimile recorder was obtained by direct recording of WWV 1-second pulses. No attempt was made to adjust for zero initial setting. Scaling of the initial pulse from the record is a simple operation and accurate to one-half fathom.

The establishment of four EPI shore stations was required for control of the hydrography during the field season. This operation is costly requiring the use of the ship and personnel exclusively. Twenty-eight days were required for installation of the four shore stations.

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Because of the expense of establishing EPI shore stations and the importance of these stations to EPI-controlled surveys, the following recommendations are made:

1. The sites should be selected with great care preferably by an electronic scientist with EPI experience.
2. For maximum range, the site should be close to the ocean to prevent loss of strength of the transmitted ground signal.
3. Erection of the mast should be done with great care. Insure that all anchors are solid, that guy wires are either new or that old guys have been overhauled and oiled. Experience has proved that a properly erected EPI mast will withstand winds over 100 miles per hour.
4. Provide adequate living quarters for the personnel and furnish them with proper radio equipment for communications. The success of 24-hour operation at sea is dependent upon 24-hour operation at the shore station. Any morale-building factors that can be provided personnel at these isolated stations will be reflected in better performance.
5. Do not try to rush the installation of an EPI shore station. Take the time necessary to build it correctly, and provide the personnel with necessary equipment and supplies.
6. If possible, assign radio operators to EPI shore stations under a technician, since seamen rarely have either the aptitude or the interest in this class of work.

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Buships authorized the *Pioneer* to permit Naval Electronics Laboratory personnel or their prime contractor to undertake towed magnetometer observations aboard the *Pioneer*. . . . A gallows frame was erected at the stern to facilitate the launching and retrieving of the 200 lb. torpedo housing the magnetic instruments and associated circuits. The equipment is identical with the airborne-type magnetometer and was towed behind the ship on a 500-foot length of electrical cable. Recording and electronic equipment for continuous recording of the earth's total magnetic intensity was housed in an after cabin, starboard side, main deck. In effect, towing of the magnetometer increased the length of the *Pioneer* to 810 feet.

Towed magnetometer observations were continued by representatives of Scripps Institution of Oceanography for the balance of the field season. The only data furnished to Scripps as corollary to their observations were the half-hourly positions of the ship and the sounding at half-hour positions.

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Wire Dragging for Wrecks
North Carolina Coast South of Cape Hatteras

(From 1955 Season's Report of Comdr. John C. Mathisson)

The purpose of this project as directed in principal instructions was for the wire drag of wrecks off the Atlantic coast from the vicinity of Oregon Inlet, N. C., southwestward to the vicinity of the entrance to Charleston Harbor, S. C., including hydrographic surveys of Diamond Shoals off Cape Hatteras, and Cape Lookout Shoals, N. C.

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All of the hydrographic surveys and most of the wire-drag operations accomplished on this project were controlled by shoran. A few of the drag strips close inshore (off Atlantic Beach and the skiff investigations) were controlled using visual fixes. Shoran control or some other type of electronic control was, of course, necessary because the distance of most of the wrecks offshore made it impossible to use sextant fixes.

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The height of towers at shoran shore stations were limited to 100 feet and the ground elevations at most station sites were so low that little extra height was obtained. The distance at which reliable shoran returns were received under average conditions was about 33 or 34 statute miles, but under abnormal conditions reception was obtained at greater distances. Generally, better reception was noted in the morning before 1000 and in the afternoon after 1500 with the period in between very difficult to receive signals much farther than 28 statute miles. Contrary to previous experience on this type of work when last performed in 1950, the best reception was obtained after the passage of a barometric high-pressure area when the barometer started to fall. Some of the wrecks were too far offshore for shoran control, and on several of them it became necessary to use the tender as a station ship anchored offshore in order to provide the necessary control. This was not done unless absolutely necessary when control could not be obtained by any other method.

All three vessels were equipped for shoran reception and it is believed that this is the first time the tender has been so provided on this type of offshore wire-drag operation. This was found most advantageous. In addition to providing assistance in accomplishing the hydrographic surveys required, it made possible the assignment of sonar search to this vessel while the dragging vessels were setting out and taking in the drag and at other times. The repair of the sonar on the tender by the replacement of a bearing outside of the hull, which required docking during the early part of the season, proved most valuable as this vessel was able to obtain sonar contacts on a number of wrecks while the dragging vessels were occupied in handling the drag.

Shoran stations were placed at eight different sites during the season. Two of these were occupied twice. One house trailer was available for use as a station and another was purchased second-hand at nominal cost before the field season began. The use of these trailers proved considerably less expensive in time and money than building a shack at each station site. Also, in having these mobile units it was possible to move the equipment with little difficulty during the three hurricanes that passed over the project area.

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Wire-drag equipment used was the heavier equipment requiring 45-pound weights on the intermediate buoys and 185-pound weights on the end buoys. The ground wire was made up in units of 100 feet using the special *fiege* wire-drag fittings. Buoys were equipped with 70 feet of upright wire and an additional 50-foot extension was provided so that the maximum depth of drag was limited to 120 feet.

During periods of moderately rough sea, wire-drag operations were confined to long sweeps in which a 9,000-foot drag was used with 600-foot sections. This length of drag provided the necessary coverage when two parallel sweeps were made over a wreck location. To provide more coverage on several occasions, a 10,200-foot drag was used. It was found that sweeps could be made in moderate seas (with winds up to force 3+), but testing the lift became difficult and sometimes impossible when the sea was too rough. Relatively favorable weather with not too rough sea conditions was required for clearing wrecks after they were found. In the vicinity of Cape Hatteras, where currents are strong and erratic, it was found that with a drag length of less than 4,000 feet, a wreck location could be missed and not covered by the strip so, for clearing wrecks, a drag of this length with 500-foot sections was used during most of the season.

Standard dual-control methods were used on all wire-drag operations. Both towing vessels were provided with field sheets on which to plot positions and this is considered very desirable.

Before starting to wire drag over a wreck location certain preliminary investigations were found desirable and necessary. It would be impossible to overemphasize the desirability of making a thorough sonar search of the area surrounding the reported position of a wreck. Excellent results were obtained with the sonar during this season, and in areas of relatively flat bottom a sonar contact was always obtained. The search was made on a system of lines spaced at about 1/2-mile intervals for a distance of 2 to 3 miles in all directions. If there is any reason to believe the reported position to be approximate, the area search should be increased to approximately 4 miles in all directions.

After a wreck,has been located approximately by sonar, sufficient time should be spent to obtain a reliable and verified echo sounding on the shoalest part of the wreck. This will, of course, save considerable time in wire dragging if the minimum sounding can be obtained by echo sounder. An attempt was always made to verify a minimum sounding. Concentrated schools of fish frequent the area immediately in the vicinity and over a wreck location and it is sometimes difficult to determine whether a shoal sounding is from fish or the wreck. On one wreck a shoal sounding was obtained and verified 4 days later, when reduced, at a slightly different position, which proved to be a school of fish that apparently frequented the area at the same depth. With experience, it is possible to differentiate between soundings on a wreck and those from schools of fish.

In conducting dragging operations in areas where there are no modern surveys, it was found necessary to make a hydrographic survey in an area surrounding the reported position or sonar contact. Sometimes depths were obtained while making the sonar search but more often a survey was made and recorded for smooth plotting on the wire-drag sheets. This survey was found necessary in order to set the uprights at shoal enough depth so that the wire would not ground on shoals, which were found frequently uncharted, especially off Cape Hatteras and to the northward.

The current direction is, of course, important to know before deciding the direction of a drag strip. During periods of slight to light winds the direction of the surface current was obtained by plotting successive shoran fixes and determining the direction from them. With more wind a current tester, devised by the ship *Stirni*, was used to test the direction of the current. This consisted of two poles, approximately 14 feet long, weighted on ends and with cork floats attached at the center, which were separated by 18 feet of line. One pole was fitted with a flag and anchored. When the two poles came up into the current, the direction could be determined by observing the azimuth by gyro between the two, and the strength could be determined by observing the time required for a piece of paper or other drifting object to pass from the first pole down current to the second pole.

Contrary currents were found in the area off Cape Hatteras. Often the current as observed on the surface would not be the same as at the depth of the drag, and dragging in the area and maintaining a reasonable lift proved difficult. In other areas, especially southwest of Cape Lookout, practically no current was apparent and drag strips were always laid out with the direction of the wind.

Before starting a drag strip, the following information was passed by radio from the guide vessel to the end vessel:

1. Starting coordinates of end vessel's guideline.
2. The azimuth of the strip.
3. The total length of the drag, excluding towline.
4. Length of sections.
5. The length of uprights.
6. The length of towline.
7. Number of buoys to be set out by the end vessel.
8. The side of the drag strip assigned to end vessel.

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In setting out the drag a departure from usual practice was used in order to attempt to speed up the end vessel's operations. The guide vessel dropped the end of the ground wire with double toggles in the approximate center and just off the layout line a sufficient distance so that the layout line would be reached when a predetermined number of lengths of ground wire had been laid out (usually three). The guide vessel would then be on the guideline where the first intermediate buoy would be put out. The guide vessel would then "spin" right on the azimuth of the layout line. This method made it possible for the end vessel to pick up the end of the ground wire on the approximate azimuth of the layout line and save time in coming up on the azimuth of the layout line. In picking up the end of the ground wire it is necessary for the end vessel to be positioned on the starboard quarter and a little distance off the guide vessel in order to be in position to pick up the double toggles.

At times when strong currents were present no attempt was made to hold the vessel to a layout line, and the drag was laid out sufficiently in advance of the layout line so that the approximate position, where it was desired to start the drag strip, would have been reached by the time the drag was all out and the vessels were ready to go ahead on the drag strip. Currents in excess of 2 knots were experienced in this project and it became necessary to lay out the drag in excess of 3/4-mile up current from the layout line.

In dragging, the positions of the two towing vessels were maintained on an azimuth at right angles to the azimuth of the guideline and abeam of each other. This was accomplished by adjusting the towing speeds of the two vessels.

In order to clear obstructions within the limits required in the instructions, it was necessary to estimate the probable lift so that the proper depth of drag could be set. At times, it became difficult to maintain the estimated lift. It was found that if towed too slow the toggles would tend to raise the ground wire and excessive lifts would be recorded. If towed too fast, the same would result. In clearing strips, the layout line should be laid out sufficiently in advance of the obstruction so that the lift can be tested and adjusted before the obstruction is reached.

In plotting, the Odessey protractor, with a compass rose around the perimeter for use in laying off the direction to the end buoy, was used. In drag strips at excessive distances from the shoran stations, it was sometimes found that the vessel closer inshore could receive the two stations while the one on the offshore side could only receive one station. In these cases, the position of the fixed vessel would be passed to the other where it would be used to determine the position by plotting on the bearing to the vessel and one shoran arc.

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During this season the search for wrecks by sonar proved very efficient. Not one wreck was found by dragging after a thorough sonar search. In some cases, a wreck was found by sonar outside the required drag limits that would have been missed, had not a sonar search been made. It is believed that in future work of this type a sonar search should be made in an area of at least 3 miles in all directions from the reported position, and that this especially should be done when the reported position seems unreliable.

When currents are contrary, causing the control of the drag to be difficult, the clearing of demolished wrecks within 2 feet of the shoalest sounding or hang proved difficult, and sometimes time consuming. In future instructions it is recommended that, in depths not dangerous to navigation, this allowance between the shoalest depth or hang and the clearance be increased, and the following specified for all wrecks:

Depths to 40 feet	2 feet
Depths to 50 feet	3 feet
Depths above 50 feet	4 feet

There may be a reason to specify a closer clearance for demolished wrecks than for others, but that reason is not readily apparent.

EPI Calibrations

(From 1956 Special Report of Capt. W. F. Malnate)

During the execution of the Pacific Ocean offshore survey from March to October 1956 a total of six EPI (Electronic Position Indicator) stations were used to control hydrography. They were located at intervals of 215 to 250 miles along the coast. Due to the extent of the work, conditions for calibration of the stations varied. The method of calibration for any one station was also varied from time to time to meet conditions and avoid waste of time spent on unproductive running.

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Three methods of calibration were used, with variations, that is, shoran, three-point visual fix, and circling a buoy previously located by three-point visual fix. In all methods, the ship was underway at reduced speed, and a series of 20 comparisons taken at regular intervals. The usual interval was 1 minute.

To use the shoran method, shoran equipment was installed at the EPI station at the time of establishment. A short traverse was necessary to locate the shoran mast with respect to the EPI mast. For calibration of the EPI, the ship was navigated on an extension of the line between the shoran and EPI masts or on the perpendicular bisector at a distance of between 15 to 25 miles from the station site.

For a distant EPI station, sometimes a shoran distance and gyro bearing were taken to give a location of the ship. This method is not perfect but does give a reasonable result if care is taken in observing and plotting the bearings. In some cases it is best to compute the position of the ship from the shoran distance and the gyro bearing. An inverse is computed to get the actual distance from the ship to the EPI station mast.

In the three-point fix method, EPI readings were taken every minute, with sextant angles every 2 minutes. The results of the fixes were plotted accurately on a large-scale chart. A convenient point in the vicinity of the series of fixes was selected, and an inverse computation made to get the distance from the EPI station to be calibrated. The azimuth to the EPI station was then laid down on the sheet and small intercepts along the azimuth line determined by constructing perpendiculars from the fix points to the azimuth line. These small intercepts were added or subtracted, as necessary, from the inverse computed distance to obtain the true distance from the fix point to the EPI station.

The buoy method consisted of maneuvering the ship around a buoy, maintaining a constant distance from it. A complete circle is made, taking EPI readings every minute. The results are meaned to give EPI distance of buoy from EPI station.

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From a study of the results of the various calibration periods undertaken during the 1956 season, the following facts stand out:

1. Shoran calibration at distances of 15 to 30 miles is expected to give a correction which is from 1 to 2 microseconds less than obtained over a distance of 150 to 250 miles.
2. That passage of the EPI signal over a large mass of land will so weaken the signal to a point where a normal calibration does not hold. Thus, it is evident that the strength of the received EPI signal plays a part in the calibration.
3. Calibrations should be made in an area which has conditions similar to the working area.
4. Where the working area covers a vast territory, the best values for the corrections are probably a mean of both the short and long distance calibrations.
5. To insure maximum accuracy from EPI, the various gain controls must be set properly both ashore and afloat.
6. In areas of poor visibility, calibration by means of shoran or circling a previously located buoy will save considerable time.
7. EPI stations should be located as near the water as possible, and no large land masses should be between the EPI and its service area.

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Calibration of Shoran Sets Used in Launches

(From 1956 Special Report of Capt. Walter J. Chovan)

Shore stations were located at Sand Key Lighthouse, Key West, and Stock Island, Fla. The station at Key West was built directly on the site of triangulation station *EPI-G*, 1954. The station at Sand Key was placed on the side of the skeleton tower in such a position that the antenna reflectors could be trained to cover the project area without interference from the light structure. The antenna was located by a measured distance and direction from the light center (*Sand Key Lighthouse*, 1853). The station at Stock Island was located adjacent to the Ferry Terminal Building. The tower site was located with third-order accuracy.

The antenna reflector at station *EPI-G* was at a height of 106 feet above MHW; that at Sand Key, 40 feet above MHW; and that at Stock Island, 55 feet above MHW. Mobile stations were mounted in ship launches Nos. *114* and *117*, with the antennas mounted on 15-foot aluminum masts. Power for the launch sets and the Sand Key installation was furnished by Onan gasoline generators model OTC 59R-2 with an output of 115 v., a.c., 1500 watts. Stations *EPI-G* and Stock Island (*Sit*) were connected to a 110-220 v., a.c., shore supply. Onan generators were on these stations for use in emergencies.

The shore antennas were at all times trained upon the areas in which launches were working.

Distances from the antenna positions of *Key*, *EPI-G*, and *Sit* were determined by inverse position computation to a number of lights and daybeacons.

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Prior to calibration, the shoran sets in the launches were given an arbitrary zero set. Observations at each light were made as follows:

1. A zero check was taken.
2. Two or more range readings were taken at each of the three sides of the light structure or other aid being used for calibration, care being taken to ensure the placing of the launch antenna mast in the same relative position each time. Two observers made alternate range readings to reduce the human error.
3. At the conclusion of a set of readings another zero check was made.

Zero set determination was as follows:
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1. The range readings at each light or marker were meaned to obtain a reduction to the light center.
2. The mean rate *(Key)* or *(Sit)* and drift *(EPI-G)* values thus obtained were compared to the computed distances and corrections determined.
3. A mean of corrections for both the rate and drift stations was thus determined.
4. The preliminary zero set was then increased (or reduced) by the amount of the correction obtained.
5. The values thus determined, to the nearest hundredth, were then placed in each set by adjusting the goniometers.

Range readings were made crossing the baseline (*Key-EPI-G*) and the minimum sum of the rate and drift stations noted. These were compared with the actual baseline distance. It is significant to note that when the algebraic sum of the correctors were applied to the observed baseline crossings, a close determination of the actual value is obtained.

Launch	Observed	Corrected	True
117	7.686	7.709	7.713
114	7.732	7.713	7.713

At periodic intervals during the field season, reobservations were made at the various calibration points. The range readings were then reduced to the zero setting, and the value compared with the true distance to determine the amount of correction. Several sextant fixes were observed simultaneously with shoran distances when the launches were locating navigational buoys.

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Correctors for both stations were plotted against distance and labeled with the dates each were determined. Correction curves were then drawn. Correctors were scaled from those curves whose dates corresponded or approached days worked in the field. Since the plotted values to determine these curves were first reduced to the zero set, corrections applied in the sounding volumes must include both the scaled correctors and any deviation of the zero check from the zero set.

Observations With the Model II Roberts Current Meter

(From 1955 Special Report of Capt. S. B. Grenell)

Two of the modified, double-contact version of the Model II Roberts Current Meter, Nos. 86 and 94, were used exclusively for the current observations of the *Explorer* during the 1955 field season.

The principle of the separate directional and velocity contacts within the meter transmitting their pulses over independent circuits finds its greatest advantage when coupled with the newly developed Current Meter Recorder. It was found during the field season that apart from these advantages, the modified meter is also an improvement over the former in respect to maintenance and reliability on station.

A defect was discovered while using Meter No. 94 concerning the decomposition of the transmitting contacts by the presumed electrolytic action of dissimilar metals. This apparent source of trouble, although a common detail of construction in the meters, could be easily removed, and in no way detract from the feasibility of the double contact system.

Special white plastic bearings for the impeller shaft, furnished by the Washington office, were used for a brief period of operation. This type of bearing, it was found, did not have the wearing qualities of the standard lignum vitae wood bearings, so only the wood bearings were utilized for the remainder of the season.

Current Meter Recorder No. T-10 was used in conjunction with the modified Roberts Current Meters on all current stations during the 1955 field season. The recorder was placed inside the 120-inch current buoy and recorded directly from the current meter while a radio transmitter receiving pulses through a relay box on the recorder transmitted the same signals to be monitored by the ship. The radio linkage was employed on each of the current stations for the reason that no determination could be made as to whether the Current Meter Recorder was functioning on station, and, in two instances when the recorder failed to operate adequately, the radio monitored record was the record finally used for the remainder of the observation.

In practically all instances when the current meter functioned properly, the recorder faithfully registered the velocity and directional signals. The velocity stylus worked intermittently only on one station and on this occasion it was necessary to compute velocity from the directional marks, however, causing direction to be indeterminate. This failure of the velocity stylus was a result of its coil having worked loose in its mounting and separated the coil from its contact arm. Merely securing the mounting remedied this condition and prevented recurrences.

The most persistent source of malfunctioning occurred with the time registering mechanism. The time stylus discontinued after about 3 days' operation on the first station and discontinued after less than 1 day's operation on the second station. It was found that the pawl controlling the time-marking relay tended toward sticking, and it required a slight adjustment of the count wheel to assure smooth operation.

One modification was made on the Current Meter Recorder to facilitate handling and to meet field exigencies for space and compactness. This modification concerns the insertion of the 4.5-v. d.c., supply into the common (return) lead from the current meter. It was found under field conditions that the addition of a small two-pronged plug inserted into the relay box assembly and connected so as to break the "C," or common line of the Model I plug, permitted the entire bank of batteries to be grouped in one container. By using one cable from this container and picking off the various voltages required, and terminating each with its respective plug, a more compact installation was effected. The appearance of the whole assembly also was enhanced by eliminating loose wires threaded throughout the components. With the modification, it is possible to change the three-wire cable from meter to recorder without making or breaking the common lead outside the relay box for the 4.5-v. supply.

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Current Meter Recorder tapes were transferred from the formica reels to cardboard reels of similar shape for storing and scaling. Scaling was accomplished on a specially built stand, supporting two 1/4-inch dowell spindles about 2 feet apart, and a raised 3- by 16-inch platen between for writing and scaling. The cardboard receiving reels contained a section of cylindrical cardboard at the center, like that on which new tapes are mounted, and a wooden plug was inserted into this core with a hold drilled to fit the wooden spindles. Thus, a reel could be mounted many times and turned rapidly without damaging its lightweight construction.

A large saving in time and labor resulted from the use of one Current Meter Recorder tape in lieu of many chronograph tapes requiring handling and folding. By use of the device for rapidly transferring the tape from one reel to another, the tape was expeditiously scanned for continuity of time, later scaled for the current readings, and finally rewound to place the beginning of the record at the outside.

Echo-Sounder Corrections

(From 1956 Special Report of Comdr. G. C. Mast)

Three Model 808 echo-sounding instruments, all calibrated for 800 fms./sec., were used interchangeably on the ship *Lester Jones* and launch *176*.

Three echo-sounder corrections were applied: *Echo*, *Index*, and *Phase*. Echo corrections were obtained from curves. Where a variation in paper speed was encountered during scanning, it was not always possible to determine whether the cause was an excessively tight coil spring or an actual change in motor speed. Appropriate notations were made in the sounding volumes and the necessity of speed corrections can only be determined by a study of the completed smooth sheet.

No bar checks were taken on the ship. Depending on weather and sea conditions, bar checks were taken twice daily on the launch.

During the months of April through June, bar checks were made by lowering a transmitting oscillator into the water by means of a hand sounding machine.

Beginning with July, following a break in the hand sounding machine, the standard (reflecting bar) bar check method was used.

On the launch, the initial was held at zero and any deviation therefrom was considered as an *index* correction. On the ship the initial was held at 1.0 fathom.

Phase comparisons were made on all instruments and the results recorded in the sounding volumes.

* * * * *

Inasmuch as the bar check did not encompass the entire range of depths, monthly serial temperatures were taken to supplement the bar check data. A correction curve was drawn for each month and the first part of the curve was based on bar check values (D-M), of which draft was an integral part. The portion of the curve extending beyond the limits of the bar check was obtained from monthly temperature-salinity corrections computed for 5-fathom intervals.

After the curves had been drawn for each month, it was found possible to combine the months of May and June, and July through September, using a criterion of one-half of one percent. To have attempted to combine the October and November results with previous data would have delayed the processing of field records until the end of the season. Thus, a separate curve was drawn for the October-November period.

The draft of the ship was 7.8 feet (1.3 fms.) and the initial held at 1.0 fathom. The corrections for the ship soundings were obtained by adding +0.3 fathom to the monthly correction curves based on temperature-salinity data. As with the launch corrections, a mean curve was drawn for the periods of April, May and June; July through September; and October-November.

* * *

Echo-Sounder Corrections

(From 1956 Special Report of Comdr. H. G. Conerly)

Two echo-sounders were used for all the work. One was an 808 Type, No. 152 SPX, with the fish units mounted in the keel of the launch at a depth of 3 feet. The other was an EDO Model 255, No. 203, with the transducer mounted on the side of the launch and kept at the same position at a depth of 1 foot throughout the season.

For correction to the 808 instrument, all the good pole comparisons, leadline comparisons, and bar checks for the entire season were used to determine a mean. Those that were wild because of weather or currents were not considered. Due to the soft bottom, the leadline comparisons were not very reliable. Some of the pole comparisons taken in areas of soft bottom were rejected and those on hard bottom only were used.

Comparisons made at different times during the season did not indicate a change in velocity. The only apparent change was the usual differences obtained on different days.

To draw the curve of corrections, the echo-sounder readings were plotted as abscissas and the differences between that and the standard plotted as ordinates. The pole and leadline comparisons were grouped with four to six in a group and the bar comparisons were all meaned and only one point plotted at each depth.

From the curve the corrections were scaled. There were very few soundings on the B scale and attempts to get a good comparison between the A and B scales were not successful due to the very limited number of times that the launch was near deep enough water to get the comparisons. Very good comparisons were obtained during the 1955 season, and since the B scale had been used very little and there was very little chance of the correction changing, the same corrections were used.

To compute corrections for the EDO, a direct comparison with the standard could not be used due to the variable speeds. The vibrapac did not remain constant, resulting in a rather complicated correction computation.

When sounding, the cycles were recorded at the head of each page of the sounding volume. The speed was constant enough to use that speed for the very few minutes that it would take to fill the page. During comparison with the standard, the cyles were recorded at each comparison.

In order that a curve could be drawn, each comparison was corrected to what it would have been had the cycles been 60.0. A mean could then be taken and the curve drawn to obtain the correction for the speed at 60.0 cycles. These were scaled from the curve and recorded. The corrections were then determined for every 1/4 cycle, from 60.75 to 59.00 cycles, by direct computation.

When the corrections were entered in the volume the cycles for that page were noted and the corrections entered accordingly. This causes very few pages to have the same corrections.

* * *

Two-Man Observing Party Gear

(From Letter of Comdr. William N. Martin)

The combination of an electrical haul up winch and 12-volt lighting arrangement using truck batteries with a switch box makes a 2-man observing party feasible under all conditions except where it is necessary to pack to the station. Using this equipment, such a party can observe heavy stations night after night from high towers without being overworked. These ideas were obtained from Commander Deane's party and have been used on this party about 1 year. In addition to the efficiency of using 2 instead of 3 men on an observing party, the saving in dry cell batteries has been tremendous.

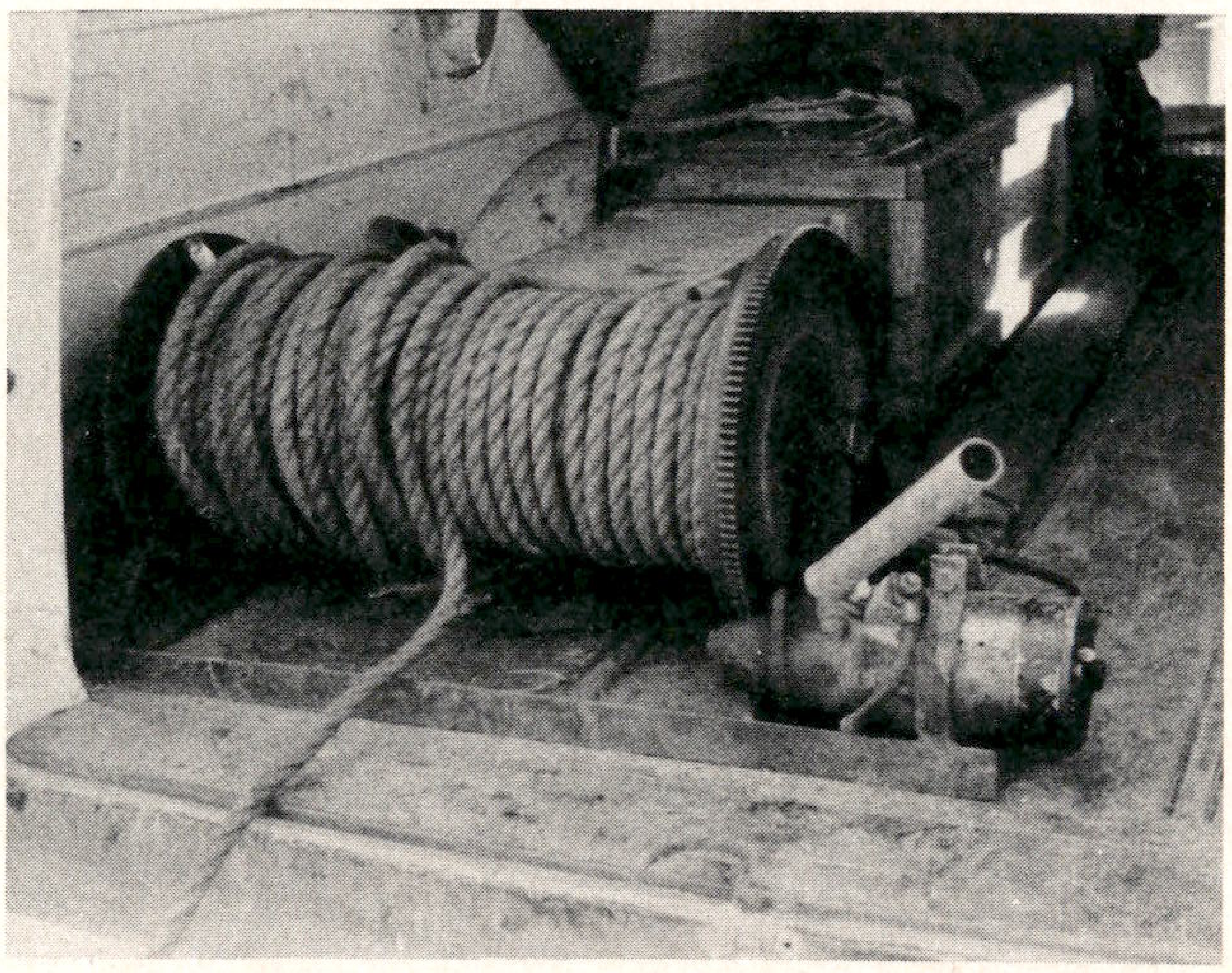


FIG. 1.--Haul up winch mounted in truck. Pipe welded to motor serves as control handle. Extra batteries are in box behind the winch.

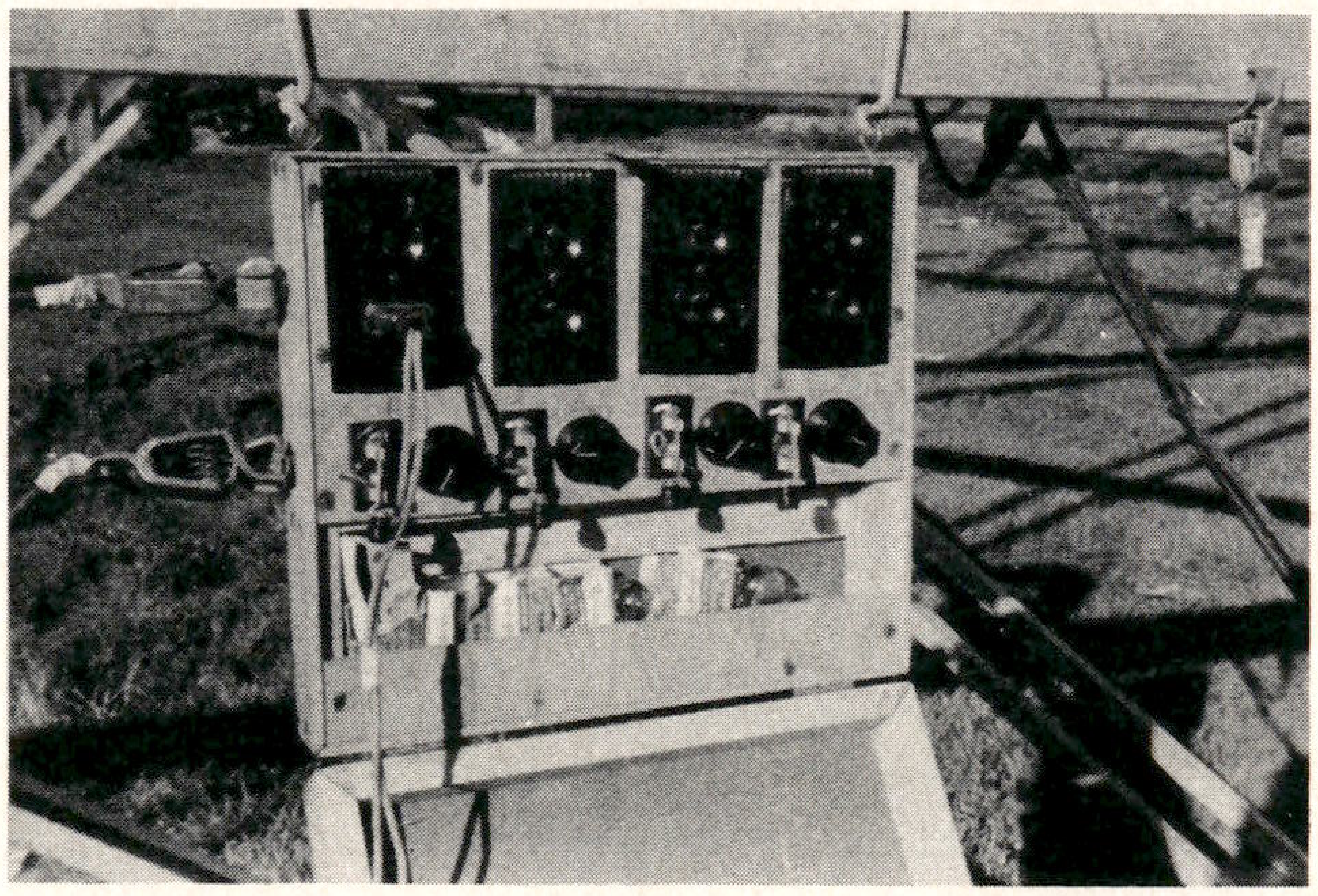


FIG. 2.--Switch panel for show and call lights.

The haul up winch is shown in figure 1. In this particular instance, the truck uses a 12-volt system and the starter motor is 6 volts. Two 6-volt booster batteries are placed in series-parallel with the truck battery when supplying electricity to the tower for lights and when the truck is in operation. By changing leads, power for the winch is taken from one of the 6-volt batteries. A better arrangement, when the truck uses a 12-volt system, is to obtain a 12-volt starter, then the one additional 12-volt battery is placed in parallel and the leads do not have to be shifted. On our 6-volt trucks, one additional 6-volt booster battery is used in parallel when hauling up and driving; it is placed in series when furnishing electricity to the tower lights. Usually the gear is divided into 2 loads. Both the winch man and man at the top keep their hands on the rope at all times while hauling up.

The truck batteries are charged in going to and from work under normal driving conditions. When the work is very close to the base camp, or the weather is very cold, additional charging of the batteries is necessary. An inexpensive rectifier-type charger is used at the base camp for about 30 minutes in the mornings.

Electrical connections are made to the inner and outer towers from the 12-volt truck hookup by alligator clips. The switch panel, shown in figure 2, is tied to the rail at the observing platform. The lead-ins to the panel are connected to the inner and outer towers, and the show and call lights are plugged into the wall-type receptacles. The current to each light is controlled by a rheostat, and signaling is accomplished to the other observing parties by the knife switches. Six-volt bulbs are used in the show and call lights. The only dry cell batteries needed on the tower are for use on the observing instrument.

The lone lightkeepers also use 12-volt systems for showing lights from the towers. Their switch boxes are much lighter, dispensing with the wall receptacles and using screw posts and alligator clips for the leads to the show lights.

NEW PROCEDURES

This Department is for the purpose of recording significant changes in field and office procedures that have been made the subject of *Planning Board Letters* or other office memoranda or circulars. A selected number of such items will be published in future issues of *The Journal* based upon their relative importance and general interest.--Editor.

Planning Board Letters

Nautical Chart Tide Note

(Planning Board Letter Approved July 21, 1955)

It is recommended that the sample Tide Note "A" be adopted for nautical charts in place of the present Note "B."

The recommendation is made in the interest of standardization of symbols and format with the Hydrographic Office. (See H. O. Tide Note "C.")

The number (755) is the month and year the note was brought up to date. This information is needed in the Nautical Chart Branch for ready reference, as it is the policy to check the tide note every three years.

It is understood that the Hydrographic Office plans to revise their tide note to conform with Note "A" insofar as it is practicable on foreign charts.

Tidal Information

Place	Height referred to datum of soundings (MLW)			
	Mean High Water	Mean Tide Level	Mean Low Water	Extreme Low Water
	feet	feet	feet	feet
West Point......	2.8	2.0	0	- 3.0
Yorktown........	1.4	1.0	0	- 3.5

(755)

Proposed Tide Note (A)

TIDES (referred to mean low water):	Millstone Point
Mean high water	2.7 ft.
Mean sea level	1.4 ft.
Lowest tide to be expected	- 2.5 ft.

Aug. 1950

Present Tide Note (B)

Tidal Information

Place	Height above datum of soundings		
	Mean H.W.	Mean Sea Level	Lowest Tide to be expected
	feet	feet	feet
Puerto Mulas...	3/4	1/2	-1
Puerto Ferro...	1/2	1/4	-1

Hydrographic Office Tide Note (C)

Folded Alaska Radio Facility Chart

(Planning Board Letter Approved April 3, 1956)

It is recommended that the fourteen loose-leaf Alaska Radio Facility Charts (8" by 10 1/2") be combined in a single folded chart at the same scale (1:3,000,000). The chart would be in two sections printed back to back and would be reproduced under the same specifications as the folded charts of the United States. The chart would provide better continuity and eliminate the need for the following separate supplemental charts and sheets now published:

(1) Alaska Civil Airways and Mileage Chart.
(2) Alaska Coastal ADIZ Chart.
(3) Location Index.
(4) Chart Index.
(5) Dates of Latest Prints (the single chart to be included in the U. S. Dates of Latest Prints).
(6) RF Legend Sheet. (Use same legend sheet as published for the U. S. series.)

Alaska DF Charts

(Planning Board Letter Approved Feb. 23, 1956)

It is recommended that Alaskan Direction Finding Charts Nos. 1, 2, and 3 (scale 1:3,000,000) be cancelled, effective June 30, 1956.

The DF series of the United States was discontinued June 30, 1954, as the charts had outgrown their usefulness and were replaced by the Jet Navigation Chart series. The Alaskan DF series was retained at that time, as there was no other coverage at an intermediate scale. However, the Jet Navigation Chart series (scale 1:2,000,000) now covers all of Alaska and satisfies civil requirements for this type of chart.

In addition, Aircraft Position Chart 3094, Seattle to Tokyo (scale 1:5,000,000), has recently been published by this Bureau for long-range navigation.

Production of Jet Navigation Chart, Central United States

(Planning Board Letter Approved March 6, 1956)

It is recommended that a Jet Navigation Chart covering the central United States (scale 1:-2,000,000) be published. This chart would be centered near the overlap of the corners of the four existing jet navigation charts now covering the entire United States. There is a military requirement for such a chart for operations in the central United States to avoid shifting charts several times. The same requirement exists also for operators of civil aircraft in the area.

Change in Coast Pilot Format

(Planning Board Letter Approved May 3, 1956)

It is proposed to adopt a format for Coast Pilots which will have two 18-pica columns with 1-1/2-pica gutter to be the same as H. O. Sailing Directions.

Adopt a 7-7/8" by 10-1/4" trim size for our bound books as compared with the present 7" by 10" trim size. Proposed size is the same as used in H. O. Sailing Directions, Coast Guard Light Lists, and Great Lakes Pilot. We will continue to publish bound volumes for our distribution, and the Hydrographic Office can use prints from our plates for loose-leaf publications.

Discontinuance of Stamping Elevations on Bench Marks

Change in Design of Bench Mark Disks

(Planning Board Letter Approved Nov. 5, 1956)

(a) It is proposed to discontinue the practice of stamping elevations on bench marks, with the exception of those in Kentucky where the stamping of elevations is well advanced at the request of State officials. This decision not to stamp elevations has been reached after considerable deliberation of the following factors:

(1) Earth movements of various magnitude change the elevations of bench marks.
(2) Readjustments shift adopted elevations.
(3) Bench marks are sometimes moved without our knowledge.
(4) The difficulty of changing the stamping on bench marks.
(5) Interested parties may request elevations as they do positions of horizontal control.
(6) The inconvenience to local surveyors of writing Washington for elevations is offset by the above factors.

(b) So that our bench marks may conform to this plan, it is proposed to adopt a disk that does not provide for stamping elevations. After the present supply of geodetic marks is exhausted, it is proposed to use the disk now used by Tides and Currents without the circle in the center of the disk. This disk will then be used by both the Geodesy Division and the Tides and Currents Division.

Preparation of Flood Zone Maps

(Planning Board Letter Approved Jan. 22, 1957)

It is proposed that the Photogrammetry and Tides and Currents Divisions prepare flood zone maps of five to six Atlantic coast cities for the Federal Flood Indemnity Administration of the Housing and Home Finance Agency during the remainder of this fiscal year. This work is to be done on a reimbursable basis, project No. 20,000-807. A tentative selection of the cities to be covered (1 to 3 maps of each place) includes Charleston, Norfolk, Baltimore, Atlantic City, Providence, and Boston.

The existing Bureau planimetric maps of these areas will provide base map data. Each map will show zones indicating the frequencies of high water; for example, 5-year, 25-year, 50-year, and 100-year frequencies. These zones will be bounded by contours that will be sketched largely from elevations obtained from city engineers.

Revision of Radio Facility Chart Series of the United States

(Planning Board Letter Approved Dec. 21, 1956)

1. DISCUSSION

Radio Facility Charts are designed for the pilotage of aircraft along designated airways under instrument flight rules and operating under air traffic control. Only such information needed to satisfy these conditions is portrayed. It is desirable to produce the charts at the smallest scale that will accommodate the amount of data to be shown to keep the number of charts to a minimum and avoid excessive overlaps. Accordingly, the charts have been produced at varying scales, depending upon the density of the data.

At present ten charts cover the United States with an eleventh interim chart of the high density area between Washington, D. C., and Boston, Mass.

The increasing number of en route radio aids together with the airways predicated upon these aids have congested certain charts to an extent that they are nearly illegible. Further expansion of the airways system is scheduled over the next five years. In order to remedy this condition, it will be necessary to enlarge the scale of the charts or simplify the presentation or a combination of both.

2. RECOMMENDATIONS

(a) A new layout of U. S. Radio Facility Charts be adopted consisting of 17 charts at varying scales.
(b) The presentation be modified for greater clarity.
(c) The price of 25 cents per chart be continued.
(d) The subscription price be reviewed upon conversion to a new format and the price be revised as necessary.

Change in Numbering of Bureau Publications

(Recommendation of Publications Committee Approved November 6, 1956)

The numbering of Bureau publications has been given considerable attention through discussions on various occasions during the past several years. The Publications Committee has been aware of the necessity of formulating a long-range policy to provide for the orderly numerical designation of all future Bureau technical manuals and other book publications. Based on the various ideas put forth, the following policy is recommended for adoption by the Subcommittee on Numbering authorized by the Publications Committee at its last meeting:

1. The practice of designating serial publications will be discontinued. The serials have comprised published papers intended to serve for a brief period before revision becomes necessary. In the future, all serials having any lasting value will be converted to numbered publications if reprinting becomes necessary. The Annual Report, Coast Pilots, Tide Tables, Current Tables, publications listing earthquakes, etc., will be published without any numerical designation. This class follows in the category of yearly publications and the date will, therefore, serve as sufficient identification. The Journal, administrative, and processed publications will be considered in this category and will also be omitted from numbered publications.

2. On all future new publications it is proposed to drop the designation "Special" and use only the word "Publication." A numbered prefix should be designated before a hyphen to identify the class of subject matter. The hyphenated prefix should be followed by the number of the publication.

No special publication now in existence will be changed until such time as the publication undergoes a general revision. No publication number will be changed for reprinting alone. The new numbering system with classifications is designated as follows:

10-1, 10-2, etc.--General publications of Bureau-wide scope.
20-1, 20-2, etc.--Hydrography.
30-1, 30-2, etc.--Tides and Currents.
31-1, 31-2, etc.--Oceanography.
40-1, 40-2, etc.--Geomagnetism.
41-1, 41-2, etc.--Seismology.

60-1, 60-2, etc.--Geodesy (General).
61-1, 61-2, etc.--Leveling.
62-1, 62-2, etc.--Triangulation.
63-1, 63-2, etc.--Gravity.
64-1, 64-2, etc.--Geodetic Astronomy.
70-1, 70-2, etc.--Topography and Photogrammetry.
80-1, 80-2, etc.--Cartography and Reproduction.

Instrument publications will be placed under the subject category of the instrument.

This new system of designating publication numbers is suggested for adoption at the beginning of calendar year 1957.

Establishment of Operations Coordination Board

(Office Memorandum Approved April 15, 1957)

By this order there is constituted an Operations Coordination Board whose duties shall be to insure that all operations are thoroughly integrated for maximum efficiency and economy in the execution of the over-all Bureau plans as approved by the Director.

The Operations Coordination Board will be composed of the Chiefs of the Operating Divisions, or in their absence the Assistant Chiefs, the Assistant Director for Administration, and the Assistant Director, who will be Chairman. The Chiefs of the Administrative Divisions will also be members of the Board and will actively participate in the work of the Board to the extent necessary to insure the proper and full utilization and coordination of the administrative areas.

The full Board shall physically meet at least once every four weeks, with an additional meeting of the Chiefs of the Operating Divisions midway between full board meetings. Such additional meetings shall be called as the Chairman may deem necessary or upon request of four division chiefs.

(The Operations Coordination Board supersedes the Planning Board.--Ed.)

Hydrographic Smooth-Sheet Details

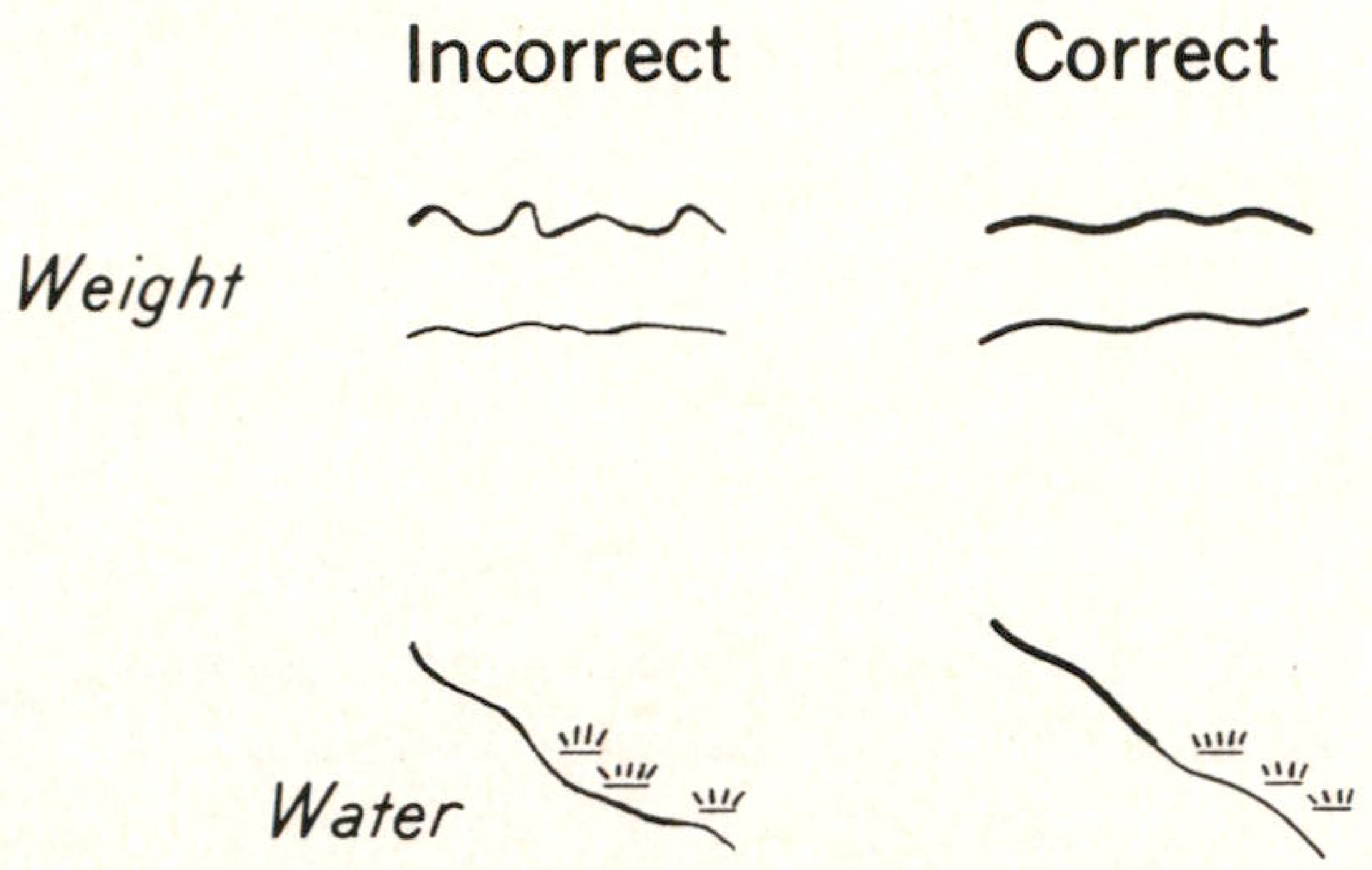
(Hydrographic Instruction 11, Effective Dec. 19, 1956)

Section 1. *Purpose*. The smooth sheet, shoreline, and alongshore details transferred, or plotted, by inexperienced personnel frequently fail to conform to cartographic standards. In consequence, an unnecessary amount of revision is required during verification. It is the purpose of this instruction to point out some of the more common mistakes, and to indicate methods for correction in order that less time will be required to verify the smooth sheets. Reviewing officers in the field can obtain substantial savings in time by insisting upon adherence to cartographic standards as set forth in Chapter 7 of the *Hydrographic Manual*. Six plates are attached which illustrate the details most frequently required in revisions and the practice followed during verification and inking of the smooth sheet.

Sec. 2. *Legibility*. .01 In chart compilation, film copies of smooth sheets are frequently reduced to one-half scale. Small figures, congested details, and illegible symbols on the smooth sheet become indistinct in the one-half reproduction. It has, therefore, been the practice of the Verification Unit to clarify and enlarge the small symbols and figures, and to eliminate congestion on the smooth sheet sufficiently for details to reproduce more distinctly at the reduced scale. (See Plates IV and V, and Paragraph 721 of the *Hydrographic Manual*.)

.02 Where shoal areas are intensely developed, the smooth plotter will find it impossible to plot all soundings. In such cases a careful selection of soundings should be made, being sure that the soundings selected are adequate to permit proper delineation of the depth curves and making certain that the least depth is clearly shown. Attention is invited to the use of subplans described in Paragraph 7751 of the *Hydrographic Manual*, and the use of overlay tracings described

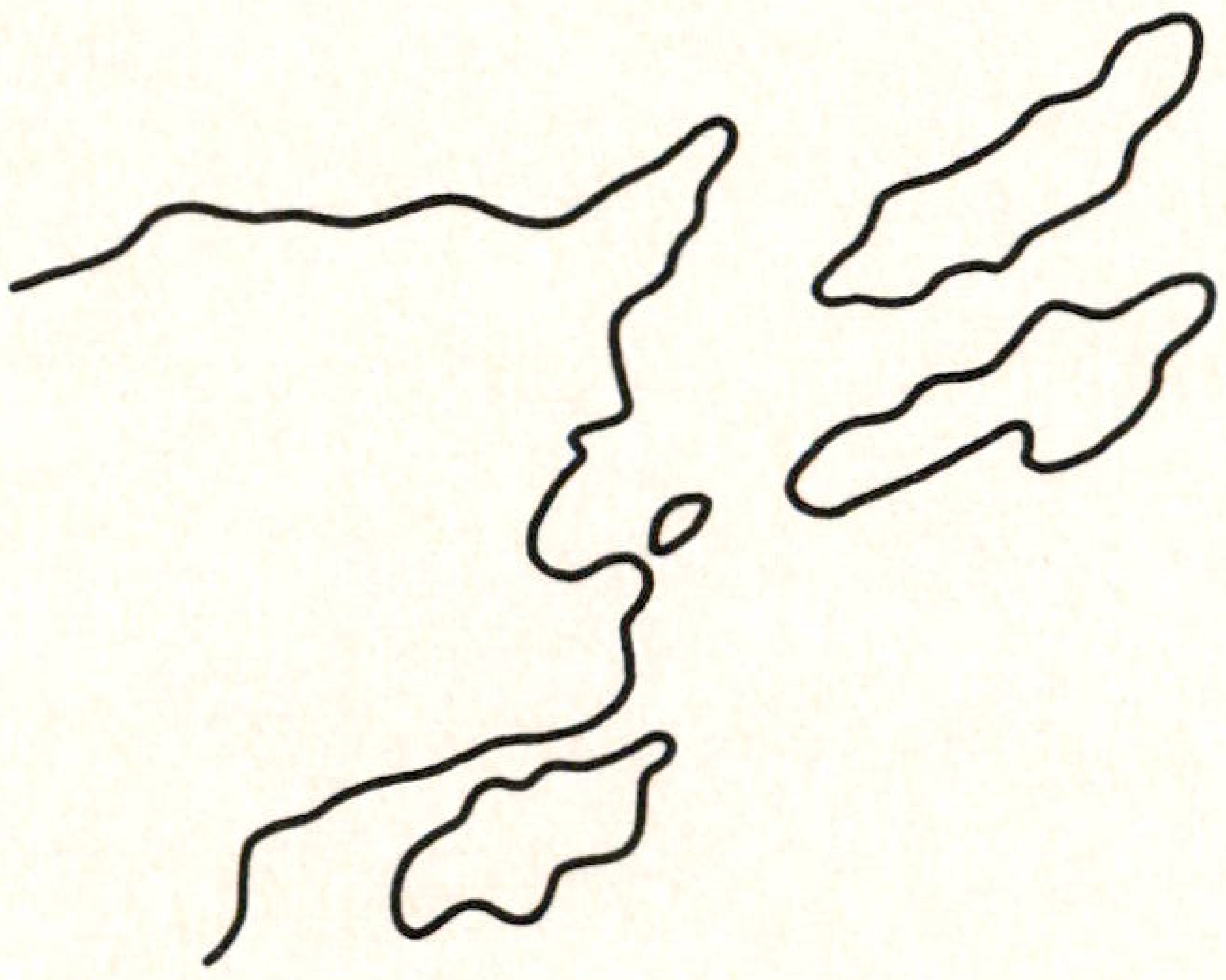
SHORELINE



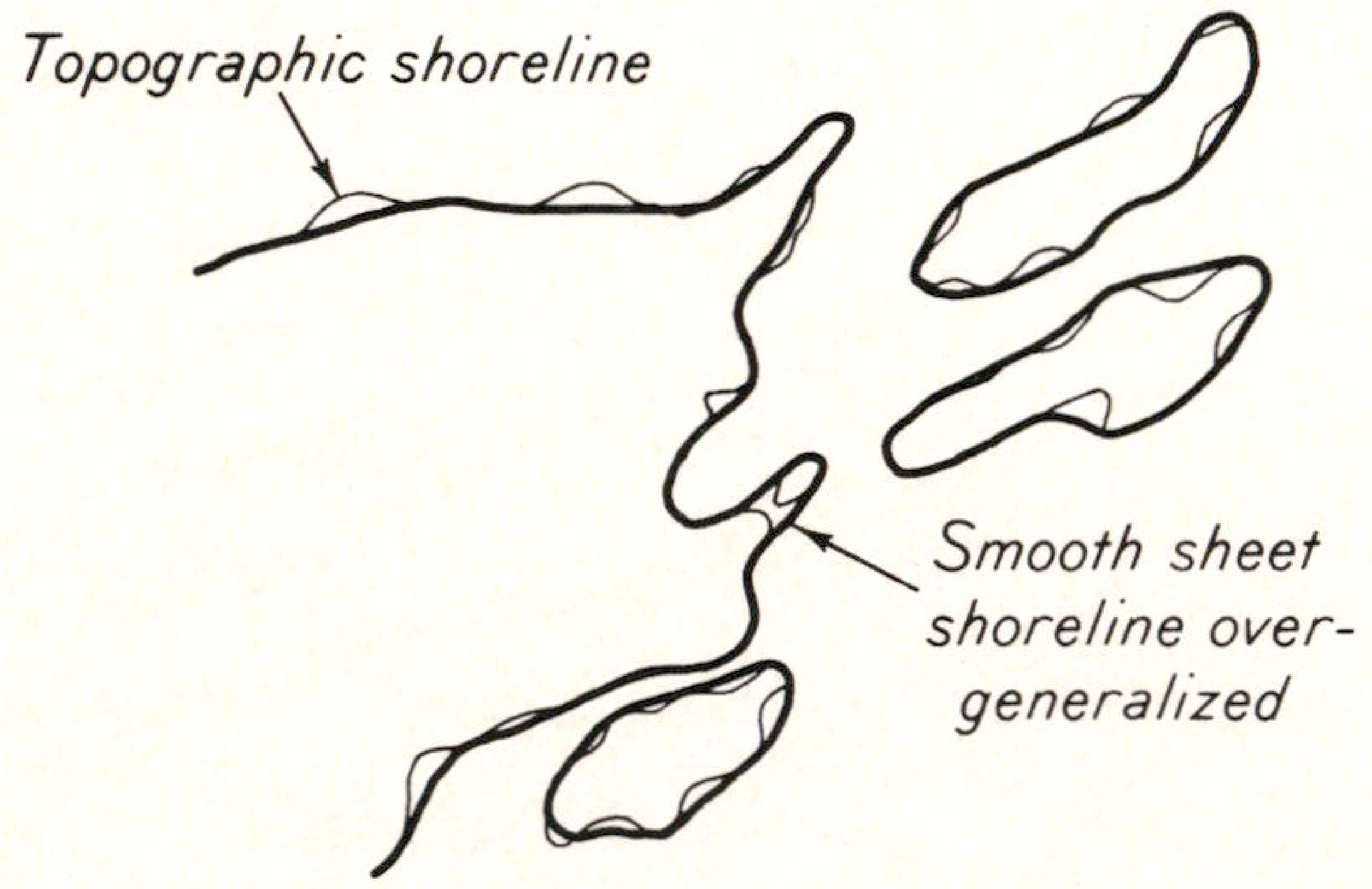
The mean high-water line on fast, solid land should be a firm continuous solid, black line, about 0.4 mm. thick. A shoreline of intricate detail should be about 0.3 mm. thick.

The shoreline of marsh, swamp, and mangrove areas should be shown by a fine solid black line about 0.2 mm. thick.

Shoreline on topographic manuscript



Shoreline on smooth sheet over-generalized



Shoreline on smooth sheet transferred out of position

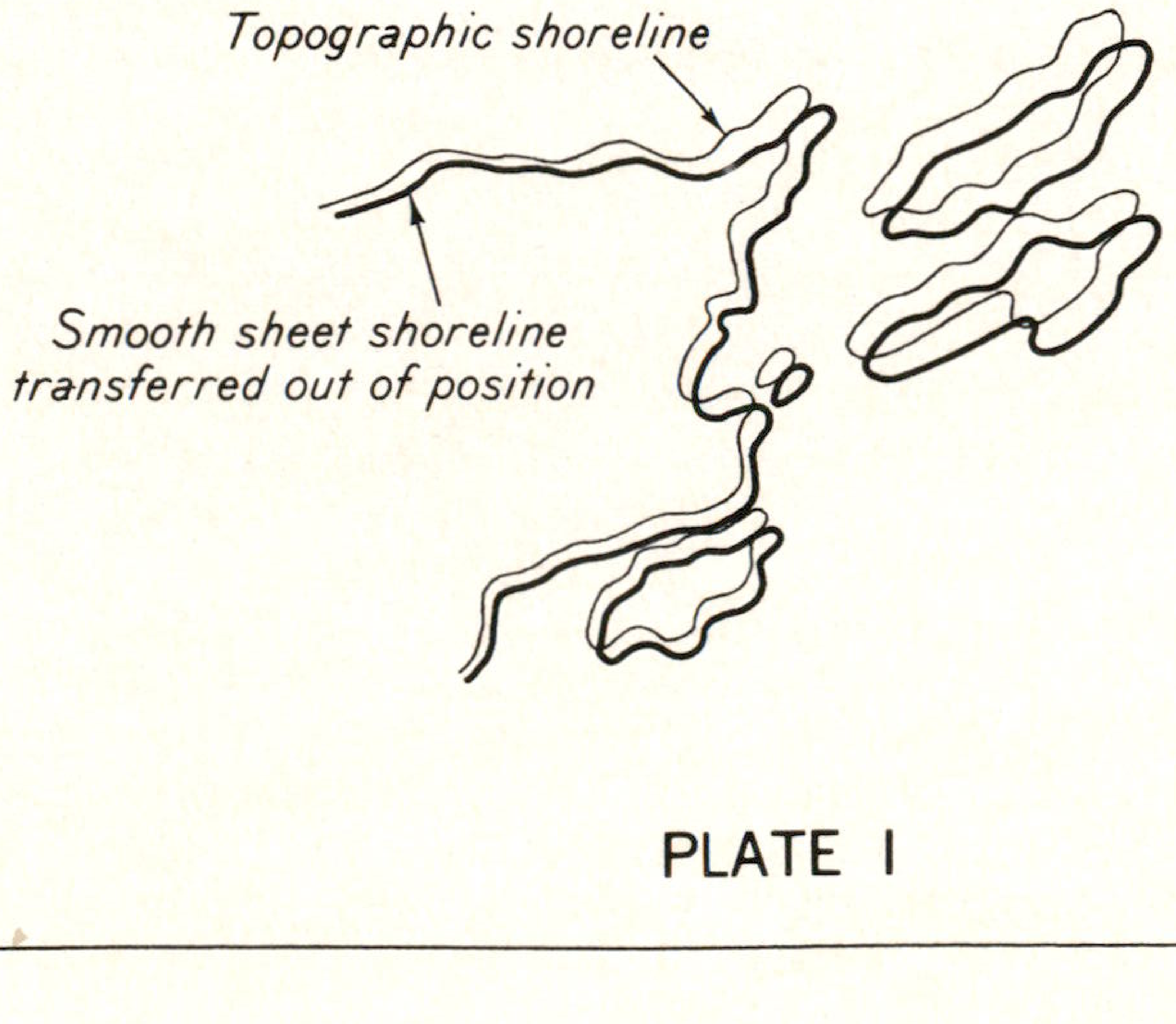
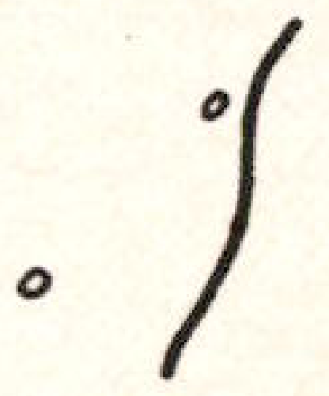
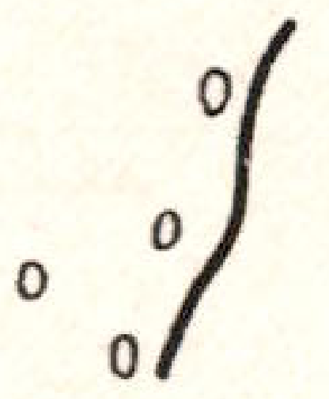
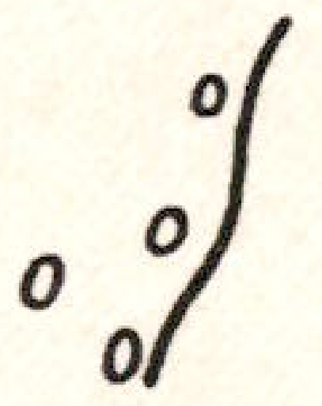
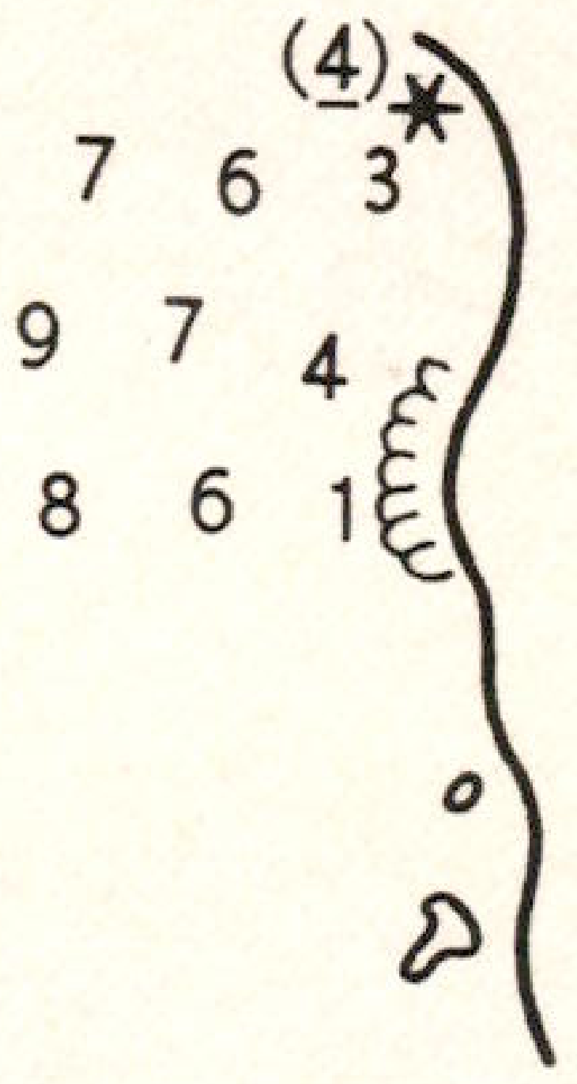


PLATE I

BARE ROCK SYMBOLS

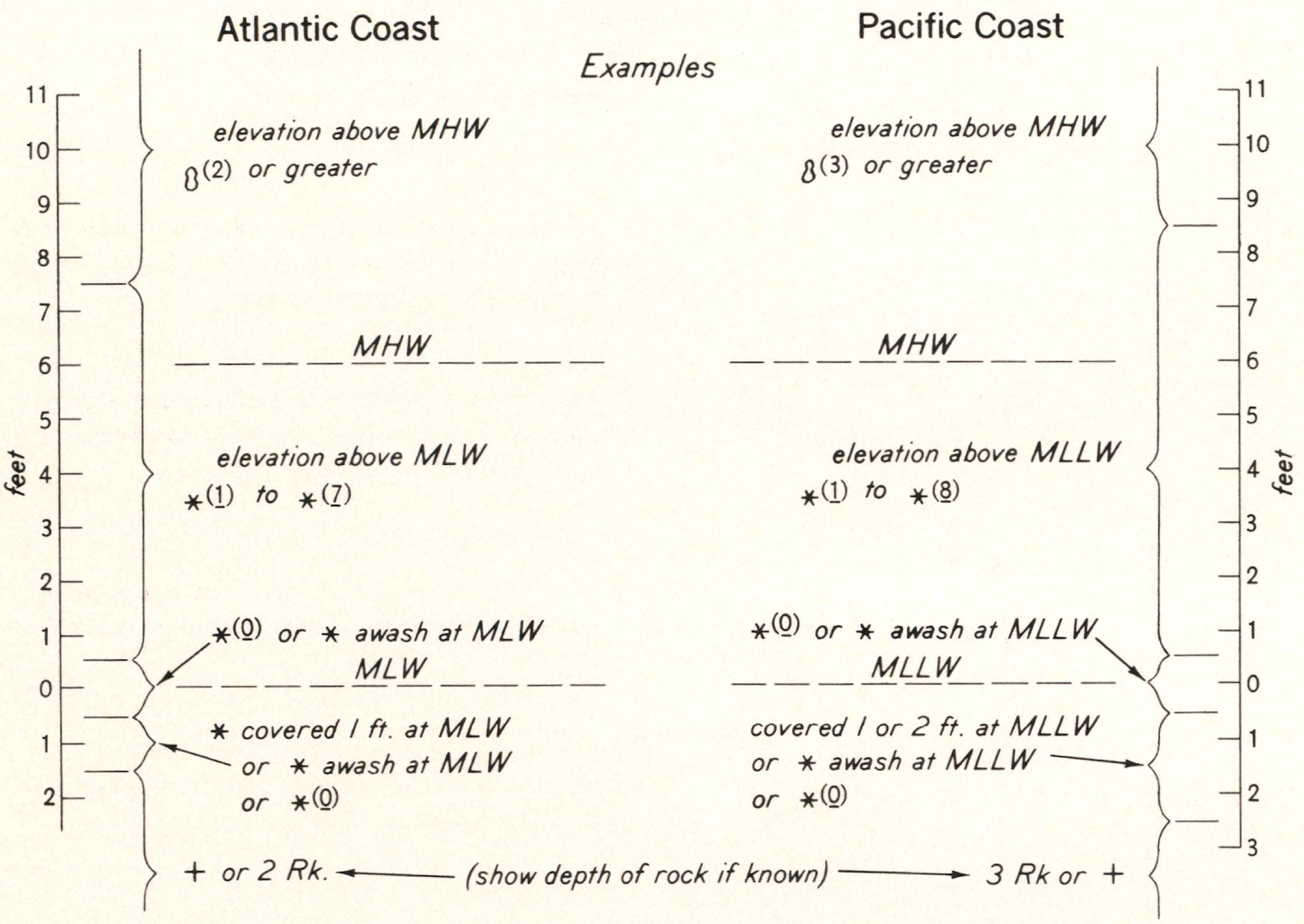
Incorrect	Correct	
		*Omit some lesser rocks to clearly show the more prominent rocks.*
		In general all information on topographic sheets should be shown on the smooth sheet; however, in the case of a large-scale topographic sheet and a small-scale hydrographic sheet some generalization is acceptable.
		*Accentuate single rocks. Shape is preferred.*
		*Do not use fine lines for bare rocks.*
Color	*Black ink*	*Topographic origin.*
	Pencil	*Hydrographic origin (inked red during verification).*

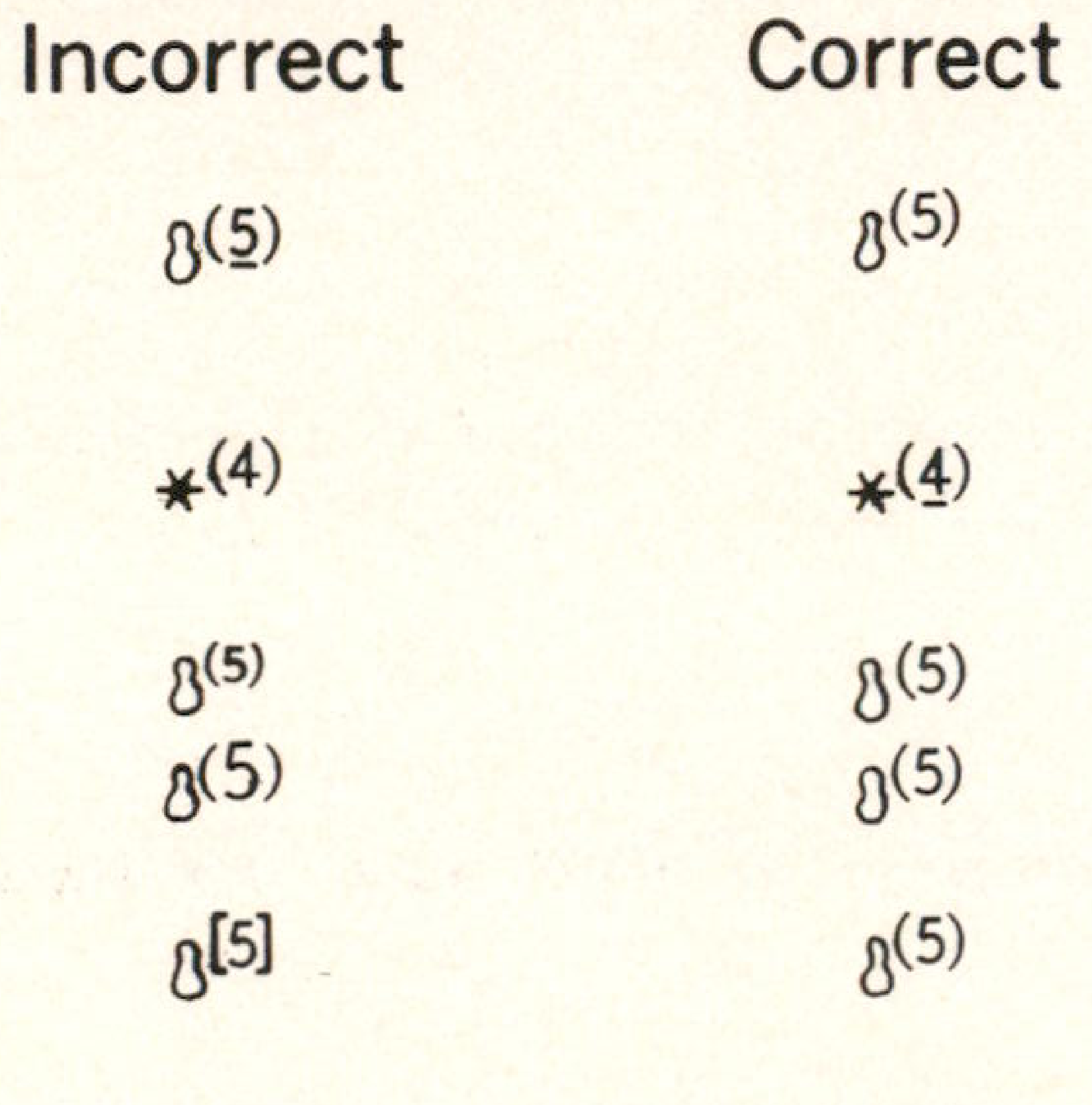


In areas adjacent to the survey outside the area of hydrography, only the shoreline and bare rocks should be transferred to the smooth sheet. Rocks awash, sunken rocks, and elevations originating with the topographic survey should be omitted.

PLATE II

ELEVATION FIGURES OF ROCKS FROM HYDROGRAPHIC DATA





Rock elevations referenced to MHW are not underlined.

Rock elevations referenced to MLW or MLLW are underlined.

Elevation figures should be 2 mm. in height.

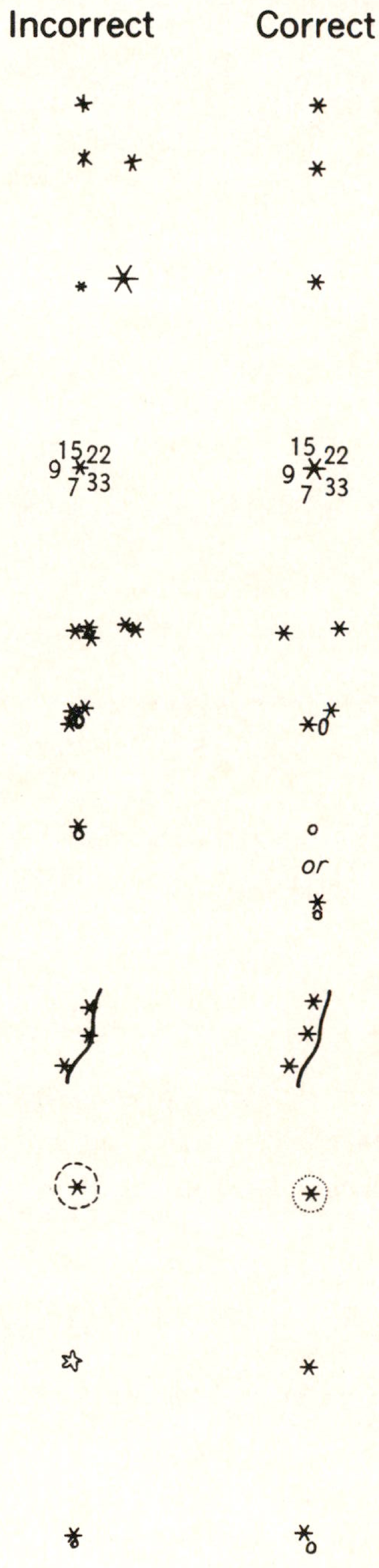
Use parentheses, not brackets.

Color of Elevation Figures

Bare Rocks	*Red ink*	*Topographic origin.*
	Pencil	*Hydrographic origin (inked black during verification).*
Rocks Awash	*Black ink*	*Topographic origin.*
	Pencil	*Hydrographic origin (inked black during verification).*

PLATE III

ROCK AWASH SYMBOLS

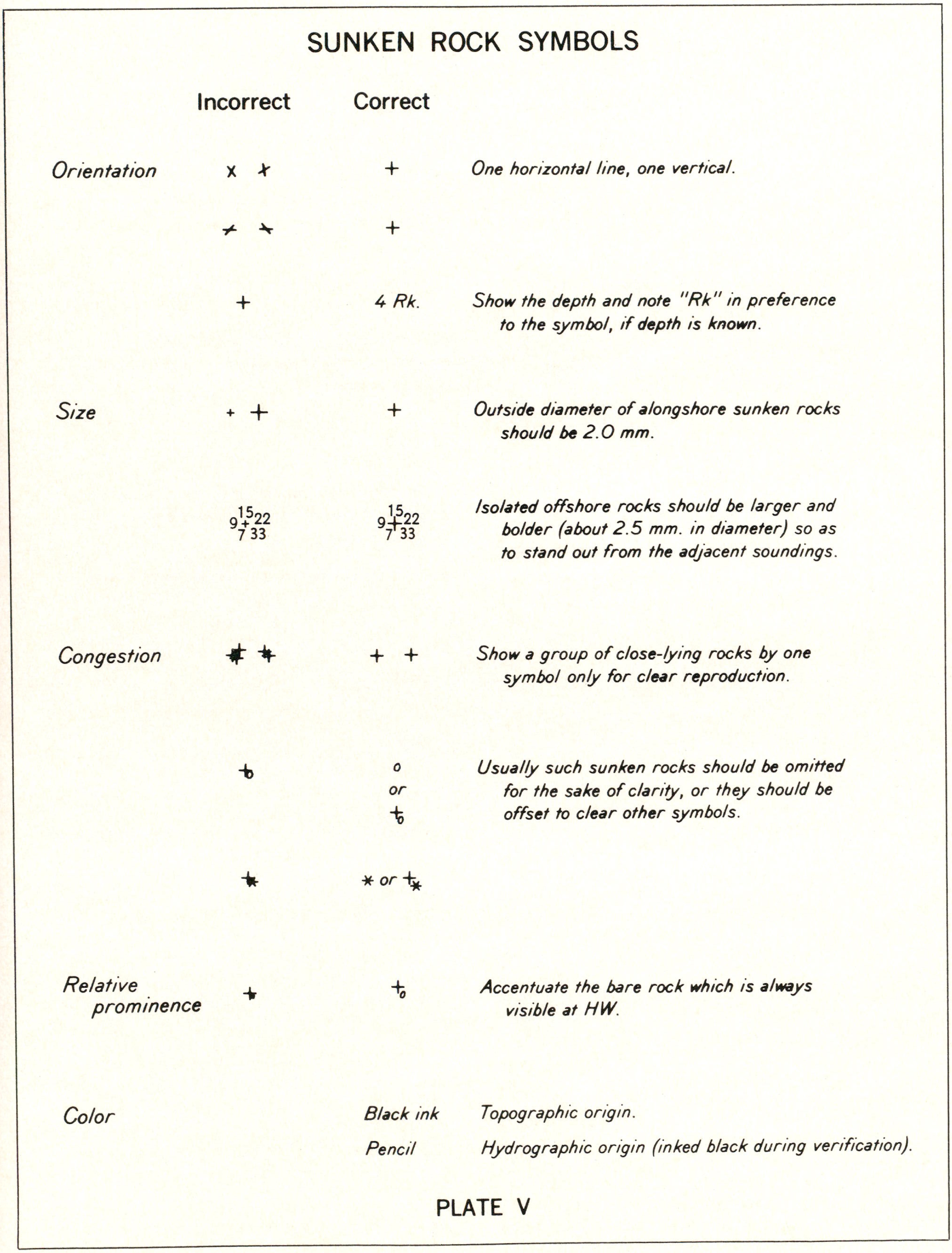


Orientation	*One line horizontal, others intersect at an angle of 60°.*
Size	*The outside diameter of alongshore rocks should be about 2.0 mm. A smaller symbol (about 1.5 mm.) is acceptable in congested areas.*
	Isolated offshore rock symbols should be larger (about 2.5 mm. in diameter) and bolder so as to stand out from adjacent soundings.
Congestion	*Show a group of close-lying rocks by one symbol where necessary for clarity and clear reproduction.*
	Usually such rocks awash should be omitted for the sake of clarity, or they should be offset for clear reproduction.
	Offset such rocks so as to clear shoreline.
	Rocks accurately located by planetable methods are enclosed in a circle of dots–not dashes.
	Show small ledge areas as a rock awash.
Relative prominence	*Accentuate the bare rock which is always visible.*

Color

Black ink	*Topographic origin.*
Pencil	*Hydrographic origin (inked black during verification).*

PLATE IV

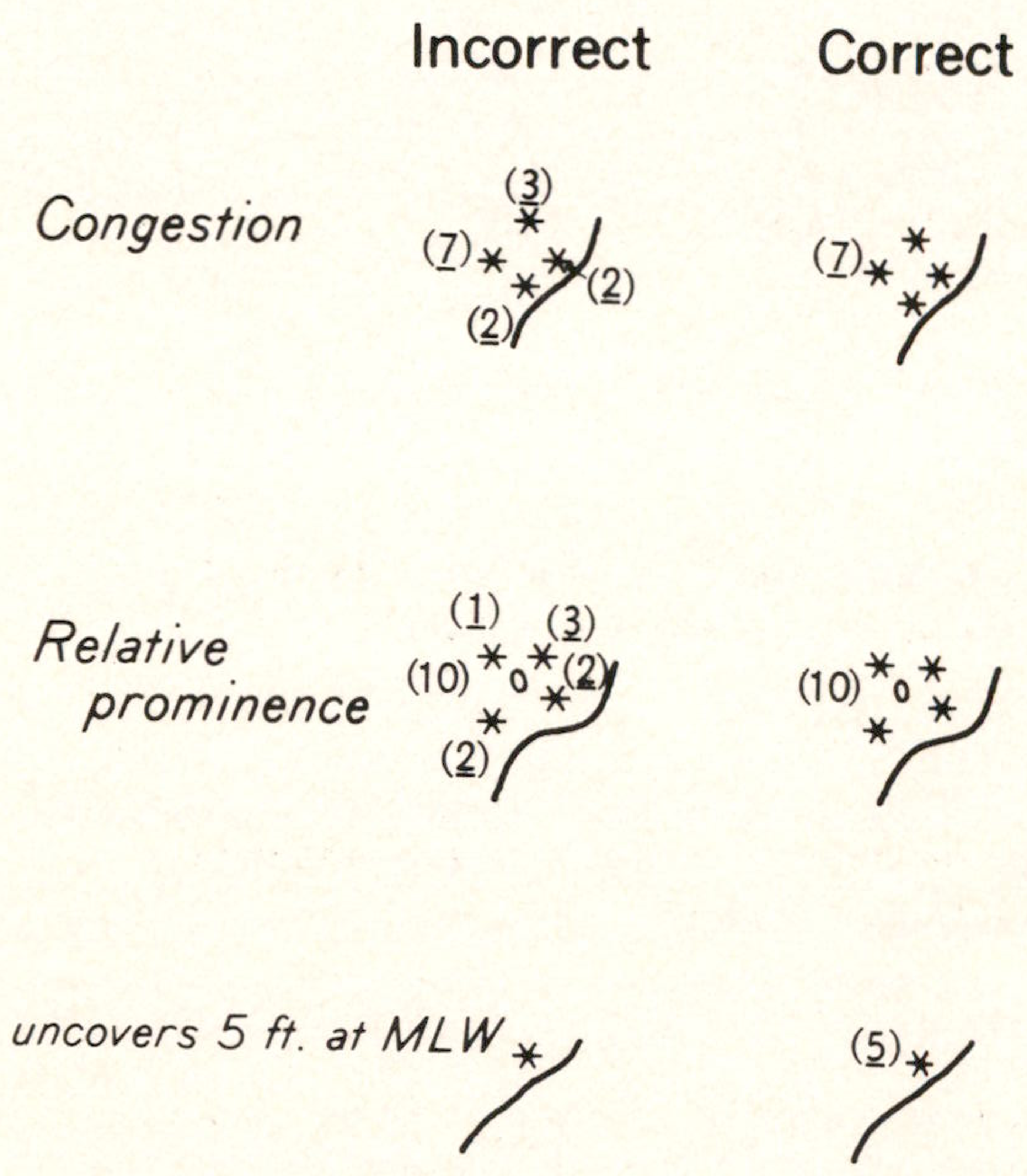


SUNKEN ROCK SYMBOLS

	Incorrect	Correct	
Orientation	x ✗	+	*One horizontal line, one vertical.*
	✗ ✗	+	
	+	*4 Rk.*	*Show the depth and note "Rk" in preference to the symbol, if depth is known.*
Size	+ +	+	*Outside diameter of alongshore sunken rocks should be 2.0 mm.*
	15 9+22 7 33	15 9+22 7 33	*Isolated offshore rocks should be larger and bolder (about 2.5 mm. in diameter) so as to stand out from the adjacent soundings.*
Congestion	✱ ✱	+ +	*Show a group of close-lying rocks by one symbol only for clear reproduction.*
	+o	o *or* +o	*Usually such sunken rocks should be omitted for the sake of clarity, or they should be offset to clear other symbols.*
	✱	✶ *or* +✶	
Relative prominence	+	+o	*Accentuate the bare rock which is always visible at HW.*
Color		*Black ink*	*Topographic origin.*
		Pencil	*Hydrographic origin (inked black during verification).*

PLATE V

SELECTION OF ELEVATION FIGURES



Show only the elevation of the highest rock of a rock group. This is applicable to both inshore and offshore areas.

The elevation of the highest rock of a rock group should be shown omitting the lesser elevations.

Use notes only to accentuate offlying or isolated rocks. Do not use notes in congested alongshore areas.

Use leaders only when necessary to clarify detail.

PLATE VI

in Paragraph 7752 of the Manual. If the overlay tracing contains a shoaler sounding than any shown on the smooth sheet, the shoaler sounding should be transferred to the smooth sheet.

Sec. 3. *Transfer of shoreline.* Although the shoreline on the smooth sheet is not the authority for topography, no appreciable inaccuracy in position or delineation should be made in the transfer of shoreline to the smooth sheet. (See Plate I, and Paragraph 752 of the *Hydrographic Manual.*) With the present use of transparencies, slight displacements of the shoreline are easily detectable and can be eliminated by adequate check methods. Shoreline transferred by inexperienced members of the party should be checked before and after inking. Any divergence in delineation should be rectified, and illegible symbols and figures clarified before transmittal of smooth sheets to the Washington Office. (Paragraph 757, *Hydrographic Manual.*)

Sec. 4. *Inkwork.* .01 Expertness as a draftsman is not a prerequisite for smooth-sheet work. A little practice plus patience and strict adherence to standard procedure will produce acceptable results. Aside from individual skill, good inkwork is dependent on several factors: (1) Color of ink, (2) the flow qualities of the ink, (3) the flow properties of the pen, (4) quality of the inking surface, (5) humidity, and (6) the drafting ability of the inker. The inkwork on smooth sheets may be improved, in part, provided attention is given to ink color and ink flow qualities. Waterproof drawing inks vary considerably in quality and some will not give satisfactory results under all conditions. Some inks deteriorate with age, lose their original bright color, lose their original flow qualities, and some coagulate. Green ink is particularly perishable. Fresh supplies should be requisitioned as needed.

.02 The most frequent complaint regarding black inkwork on smooth sheets is that the lines appear grey instead of jet black. This may be attributable to the failure of the inker to thoroughly shake the bottle of ink before use. Black ink and some of the colored inks contain pigment which settle to the bottom of the bottle and must be thoroughly agitated at frequent intervals to keep the pigment in suspension and to get full benefit of the color. The practice of cleaning inkwork on smooth sheets with art gum is undoubtedly a contributing factor and should be avoided.

.03 Another source of trouble is the lack of control over the flow qualities of the ink. Often, the colored inks, when new, are too thin for quality inkwork on smooth-sheet paper. Thin ink runs at the edges of lines and penetrates deeply into the paper. This can usually be remedied by evaporation. Pour the ink into a flat saucer and let it thicken. Test the density at frequent intervals and pour the ink back into the bottle when the desired results can be obtained. (Paragraph 726, *Hydrographic Manual.*)

Sec. 5. *Selection of penpoints.* Good drafting also depends on the proper selection of a drafting pen to fit the work at hand. The inexperienced draftsman should experiment with various points to determine which points are best suited to him. Many penpoints have very fine burs around the tip, which cause them to scratch. The points may be smoothed by lightly polishing with crocus cloth. There are many techniques used by draftsmen to alter penpoints to suit varying thicknesses of ink, and for other purposes. These are all based on individual preferences and each has developed his own measures. (Paragraph 725, *Hydrographic Manual.*)

Sec. 6. Plates I to VI. .01 See figure 189, *Hydrographic Manual,* Nautical Chart Symbols and Abbreviations.

.02 Plates I to VI show the mistakes most frequently made and the correct method of drafting. Each smooth plotter should examine these very carefully and compare his own work with the correct examples shown. These plates supplement, and in many cases repeat, the information contained in figure 189 of the *Hydrographic Manual.*

.03 Compliance with these and other instructions contained in the *Hydrographic Manual* will considerably reduce the heavy workload which now exists in the Verification Branch of the Washington Office.

Sec. 7. *Effective date.* The provisions of this Instruction are effective immediately.

(Signed) H. Arnold Karo
Director

Shoran Corrections

(Hydrographic Instruction 10 (Revised), Effective May 13, 1957)

Section 1. *Purpose.* This circular is intended to assure that an adequate number of properly determined shoran correction measurements are made in order to maintain a high standard of accuracy for all shoran-controlled hydrographic surveys. It is intended to show how this can be accomplished through a uniform procedure, by proper instrument adjustment, a studied selection of sites for correction measurements, and the proper application of an approved correction-measuring method.

Sec. 2. *Correction requirements.* .01 *Units to be calibrated.*—All ship and launch APN-3 (ship units) are to be calibrated for a correction value to every ground-station unit which these vessels use during a survey. It is not sufficient that a ship unit be calibrated on a ship and later transferred to a launch and the same calibration correction applied. When ground stations are moved to a new location, recalibration of all ship units used in that area must be made. The calibration values found during the first ground station location must not be related to the corrections for the new location. When spare receiver units are used in an equipment, they should be calibrated as well as the regularly used receiver.

.02 *Correction coverage.*--1. The correction is not a constant. It starts as a rather small value near the ground station and increases nearly linearly with distances up to about the refractive line-of-sight. After this, the correction increases nearly exponentially until the signal disappears. The linear portion of the correction curve is of greatest interest since most of the hydrographic operations are within that area. Beyond the line-of-sight, the correction value is likely to have a large time variation since signals in this region are sensitive to factors affecting propagation ("Radio Wave Propagation as Applied to Shoran," by Thomas J. Hickley, *The Journal,* No. 6, Aug. 1955).

2. The arrangement of calibration points and check points should be selected to assure that the hydrography will be accurately positioned relative to the abutting topographic features and to harmoniously position the hydrography of the various survey units. Care should be exercised in selecting calibration sites where the signal from any

ground station grazes along the shoreline. The operator should be alert to reflections from the shoreline or other objects such as large metal structures. Quite often such signals will appear as separate pulses but may also appear as a single composite pulse.

3. When the sea and land topographic features allow, and when the survey area is extensive, corrections to each ground station should be obtained at points near minimum and near maximum range. Also, when possible, intermediate distance-correction measurements should be obtained.

4. When the survey area is small and concentrated, a single distance-correction typical of the distances from the ground stations to this area may be sufficient.

.03 *Practicable considerations.*—It is realized that there are many survey areas where it is extremely difficult to derive corrections sufficient to cover the survey region. However, a reasonable effort should be made to develop a correction-distance curve from each ground station, even though the topographic configurations are unfavorable. When it is possible to develop this correction curve, it should be so done rather than a quicker job less accurately accomplished. When it is impractical to accomplish the distance-correction curve by actual observation, then the statistical method outlined in Sec. 4.05 may be used.

Sec. 3. *Frequency of corrections.* .01 *Purpose of frequent measurements.*— Frequent correction measurements are made to constantly monitor the instrumental stability of the shoran system. By so doing, many hours of inaccurate surveying may be avoided. Because of small instrumental and propagation changes, repeated measurements of corrections at the same test site are seldom in exact agreement. However, a variation of much more than 0.010 mile indicates that instrument instability might be developing. A close study should indicate the particular part of the system responsible for this instability. Frequent observations at the same test site will better establish the average.

.02 *Required corrections per trip.*--On a trip averaging 10 or more days, at *least* two calibrations on each ground station shall be made during the trip. A suggested interval between observations is one at the start and a second at the midpoint of the trip. It is desirable but not necessary that measurements be equally distributed between the test sites in the area. On trips of a week's duration (5 days), a single calibration on each ground station should be made. These are the minimum requirements. When possible, more frequent observations should be made. Whenever changes in equipment are made which may affect the characteristics of the equipment, new correction values should be determined.

.03 *Frequency of zero check.*—The zero check should be considered a part of the operation of establishing a correction value. A zero check should be made directly before correction determination. During normal survey operations a zero check should be made at the beginning of every change of watch, or at least once every 4 hours as an absolute minimum.

.04 *Frequency of calibration adjustment (cal. adjust) and WWV comparison.*—1. The calibration adjustment is the comparison and adjustment of the ship crystal oscillator frequency with the more standard frequency of the CPN-2 ground station crystal oscillators. When using the CPN-2 ground stations each day, all ship stations shall calibrate after about 1 hour of equipment warm-up. This calibration adjustment shall also be made prior to any correction-calibration.

2. At the beginning of a season and at least twice more during the season, a WWV or WWVH frequency comparison shall be made for all CPN-2 ground stations and for all ship units that use the AVQ ground stations. While it is not necessary, it is good precautionary practice to periodically check all ship and ground stations against WWV or WWVH.

Sec. 4. *Correction methods.* .01 *Accuracy requirements.*—Most correction determinations are a comparison of the distance as measured by shoran from the ship to the shore station to the distance found by a more accurate method. The methods of finding the true, or comparison, distance, discussed in the next two subsections, are considered as an order of accuracy higher than shoran distances.

.02 *Three-point-fix method.*—This is the most used method for correction determination. Since this method requires more than normal care to realize a strong position fix, the signals must be situated so as to give strong intersections and must be located by an accurate method, i.e., graphic plot, or triangulation, as opposed to preliminary photoplot. To prevent errors due to sheet distortion, this position should be plotted on a metal-backed sheet along with the shoran lines of position from the ground stations.

.03 *Range and angle method.*—This is one of the most precise methods, but may require setting up range markers and other signals in advance. With this method, the survey vessel steams along on a range until a predetermined sextant angle to shore signals closes. The position of the vessel for this angle and range and the distance to each ground station are computed in advance. The difference between the computed distances to the ground stations and the shoran distances to the ground stations is the correction value for shoran readings at that particular distance for a particular zero check reading. There are several variations of this method (reference: the unpublished "Final Report of Raydist Equipment Tests," by Roswell C. Bolstad, and the unpublished "Report on Shoran Test Project," July and August 1955, by Roswell C. Bolstad). It is sometimes possible to use the ground station shoran tower as one of the range markers. This arrangement has the advantage of a close measurement to one shore station and a distant measurement to the other.

.04 *Other methods.*—It is sometimes possible to bring small vessels alongside a pier, piling, or rock, the position of which has been accurately determined. Line crossings between shore stations, while not considered a calibration method, will serve as a check on system stability. For stable system conditions the baseline distance should remain constant. Another method that has been used to test the accuracy of shoran corrections is to end the sounding lines against the beach. The final shoran position should then agree with the beach topographic features, provided the topographic features are accurately located. Disagreements between topography and shoran positions should be investigated in the field to determine if shoran corrections determined for use in that area will resolve the differences.

.05 *Statistical method.*--1. An extensive study of shoran distance corrections has revealed three important facts:

(1) The shoran distance-correction curve is nearly linear except when close to or far from the ground station.

(2) The slope of the shoran distance-correction curve is nearly the same for all shoran instruments when antenna heights are equal or nearly so.

(3) For any ground station antenna height within the range normally used for hydrographic surveys, the slope of the distance-correction curve is most sensitive to the antenna height on the mobile unit.

2. The shoran distance-correction curves for various equipments operating under identical conditions seldom coincide; however, the curves will be nearly parallel. The curves will have a negative slope and will increase negatively with increasing distance from the ground station. The rate of increase is, in some respects, a function of ship antenna height. For purposes of deriving distance-correction curves, ship antenna height may be classified as LOW or HIGH according to the following definitions:

(1) LOW ship antennas are those under 40 feet and the slope of the distance-correction curve is 0.003 mile per mile (statute).

(2) HIGH ship antennas are those in excess of 40 feet and have a slope rate of 0.0018 mile per mile (statute).

3. To derive a correction curve, it is necessary to determine the correction at one or more distances by methods previously described. The correction curve of proper slope can then be used to correct shoran readings at all distances throughout the survey area. Frequency of correction checks, outlined in Sec. 3, and all other requirements must be adhered to as well as for all other methods.

4. The statistical method is not to be used when it is possible to develop the correction-distance curve by direct measurement. When there are regions where only one correction distance can be measured, the statistical method shall be used as it will be more accurate than applying the same correction at all distances.

5. To aid in applying the correction for the purpose of plotting, the correction curve may be translated into tabular form. Values in this table should be the distances from the ground station corresponding to a correction change of 0.01 mile and the corresponding correction will be the mid-value in this distance differential.

Sec. 5. *Zero check and zero set.* .01 *Function of the zero check.*--The zero check measures the time relation between the zero of the distance-measuring scales and the marker pulse. Since it is possible for a shift to occur in the distance-measuring scales, the zero check is used to detect any such shift. This is the method of observing the stability of the timing relationship within the ship equipment.

.02 *Function of the zero set.*—The zero set is accomplished by means of a screwdriver adjustment on the front panel of the ship indicator which functions to change the time position of the reference marker. When the reference marker is changed by the zero set, both rate and drift zero check values change, since the reference marker is a common marker for both. The zero set is thus used to make the zero checks some convenient value or to reduce the station corrections to a minimum.

.03 *How to use the zero check and zero set.*— 1. The value measured by the zero check should be used only as a reference value. When possible, this reference value should be maintained by means of the zero set adjustment provided the reference marker has changed. In theory, if the zero check value is maintained at approximately 99.820 miles, the delay set into the shore stations will be compensated to bring the correction near to zero. Actually it has been found that this does not necessarily hold, and the zero set should be shifted to give minimum station correction values.

2. It is desirable to avoid an arithmetical correction because of changes in zero check value. If the zero check value changed by more than 0.005 mile from the normal value either by a sudden jump or slow drift, the reading should be restored to the original value by means of the zero set when this is possible. If such a jump or drift is detected, a recalibration should be made at the earliest opportunity. The new zero check value should then be used as reference in keeping check on the ship equipment's stability.

Sec. 6. *Adjustment of equipment before correction measurements.* .01 *Need for equipment adjustment.*—Unless both ship and ground station equipments are properly adjusted, consistent repeatable correction values cannot be expected. While it is important that proper instrument adjustment be maintained all during surveys, it is even more important that careful instrument adjustment be made during correction calibration since the values derived are influential in the final value of many position measurements.

.02 *Ship-station equipment adjustment.*--Before a correction measurement, the following steps should be taken: 1. Adjust the line voltage to the proper value.

2. Take a zero check and record the value for reference.

3. Notify the ground stations that correction calibrations are to be made and tell them the direction to point their antennas if reflectors are used on the ground-station antenna.

4. Adjust the receiver gain to a value where additional gain does not produce a change in the shape or position of the ground-station signal.

.03 *Ground-station equipment adjustment.*—When notified that a correction calibration is about to take place, the ground-station operator should proceed as follows: 1. Point the antenna as directed by the ship.

2. Adjust the line voltage to the proper value.

3. Standardize the ground-station delay.

4. Adjust the receiver gain to the proper value consistent with the ship signal strength.

Sec. 7. *Use and recording of corrections.* .01 *Boat-sheet plotting.*—To simplify plotting, an average correction value can be used for plotting the boat sheet, except for large-scale surveys of close development work. For such cases and assuming a correction-distance curve has been developed, the areas can be divided into correction zones for large-scale surveys.

.02 *Plotting and recording corrections.*—When a number of correction measurements are made at the same site, a plot of the corrections against time should be made. This will show any trend in the correction value indicative of equipment degradation. When measurements over a wide distance range are possible, a plot should be made of the correction as a function of distance from each ground station. Such a plot should be made for each ship instrument operating with a pair of ground stations. All graphs and tabulated values of corrections should be submitted in the shoran correction report with the records.

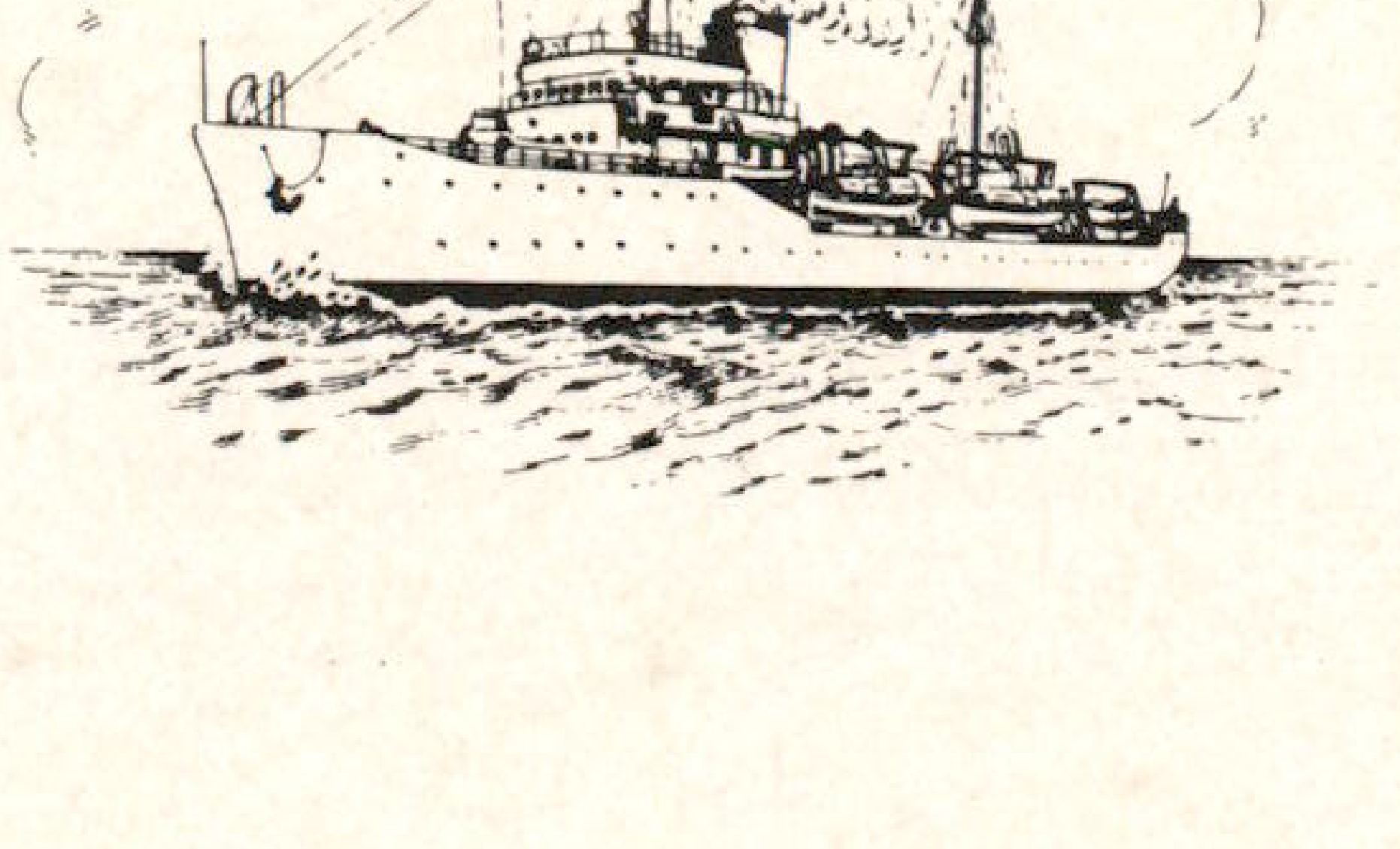
.03 *Recording equipment numbers.*—1. The number identifying each launch, ship, and ground-station set used shall be recorded in the sounding volume at the beginning of the day, and any change in sets during the day shall be shown in the sounding volume by appropriate notes. A record should be made of the heights of all ground stations, ship and launch antennas, and this should be made a part of the final shoran report.

2. The shoran report should contain a plot of the developed correction curves. The appropriate distance-correction curve derived by the statistical method should be superimposed upon these curves to aid in a study of the value of this method.

Sec. 8. *Effect on other issuances.* This Instruction supersedes Hydrographic Instruction 10, dated May 10, 1956.

Sec. 9. *Effective date.* The provisions of this Instruction are effective immediately.

(Signed) H. Arnold Karo
Director



Notes on International Scientific Meetings

International Congress of the Onomastic Sciences

THE FIFTH meeting of the International Congress of the Onomastic Sciences was held at the University of Salamanca, Spain, from April 12 to 15, 1955, with more than 200 delegates from some 26 countries in attendance. The United States delegation consisted of Mr. Lewis Heck of the Coast and Geodetic Survey and Dr. M. F. Burrill, executive secretary of the Board of Geographic Names.

Working sessions of the various sections were held on the first 3 days with a final plenary session in the morning of the fourth day. More than 80 papers on a wide variety of subjects were presented to the congress. Mr. Heck gave a paper on the disputed origin of the name California, and Dr. Burrill presented a paper on "Some Considerations in International Standardization of Geographic Names." Of noteworthy interest was the increased attention to the practical every day use of names on maps, exemplified by the spontaneous establishment of Section VI that was devoted to the consideration of the international standardization of geographic names. At the previous congress in Sweden, only one paper dealt with the use of names in cartography.

The next meeting of the congress is to be held at Munich, Germany, in 1958.

--LEWIS HECK

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Seventh Consultation on Cartography

THE COMMISSION on Cartography met at Mexico City, from July 26 to August 5, 1955, in conjunction with the Sixth General Assembly of its parent body, the Pan American Institute of Geography and History. Sessions were held at the University City campus of the National University of Mexico, on the outskirts of Mexico City.

The Cartographic Consultation consisted of plenary sessions for the transaction of formal business of the organization and of committee meetings in the several branches of cartography and geophysics. The outstanding visible evidence of the work accomplished was a series of resolutions expressing international agreement on procedural standards, methods of coordinating the work, and proposals for effective collaboration.

The Coast and Geodetic Survey was represented by Capt. A. J. Hoskinson (Ret.), Capt. E. B. Roberts, Comdr. H. F. Garber, and Messrs. L. P. Disney, M. Y. Poling, and F. J. Ortiz. Captain Hoskinson attended as a member of the Committee on Geodesy; Captain Roberts, the Committee on Gravimetry and Geomagnetism, and the Committee on Seismology; Mr. Disney, the Committee on Tides; and Mr. Poling as Chairman of the Committee on Urban Surveys. Other committee meetings were attended when possible by Bureau representatives.

It is evident from the satisfactory personal and official contacts achieved at such meetings that the Commission on Cartography fulfills a worthwhile function in pan-American relations. The Coast and Geodetic Survey takes an important part in the establishment of standards for field programs.

—E. B. ROBERTS

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British Commonwealth Survey Officers' Conference

THE CONFERENCE was held at Cambridge, England, August 15 to 24, 1955, and was attended by representatives from virtually all of the British Commonwealth and Colonies. These conferences are normally held at 4-year intervals, and embrace all phases of survey activity from reconnaissance to map reproduction. Survey organizations of the United States, France, Belgium, and the Netherlands were also invited to send observers. In addition to the Coast and Geodetic Suvery, other Federal agencies represented were the Geological Survey, Army Map Service, Aeronautical Chart and Information Center, and Joint Chiefs of Staff of the Department of Defense.

Lord Lloyd, Parliamentary Under Secretary for the Colonies, opened the conference. A total of

28 papers were presented at the technical sessions, which were held at Cambridge University. Through careful advance planning, it was possible to distribute copies of all papers so that a considerable amount of time was available for informal discussion.

A feature of the conference was the exhibition of the prototype model of the Thompson-Watts photogrammetric plotter by the designer, Prof. E. H. Thompson. This instrument incorporates several innovations in design. Other major topics on photogrammetry included: (a) modern methods as applied to mapping in Canada; (b) high-altitude multiplex mapping; and (c) large-scale (1/2,500 and 1/1,250) mapping in Great Britain, including photogrammetric control and the use of plotting machines to replace chaining and graphical methods on the ground. It was noted that the British make wide use of the Decca system for flight-line control.

Several papers were given on recent geodetic control activities, including an account of the 30th meridian triangulation arc in Africa, recently completed by the Army Map Service with the support of observing personnel furnished by the Coast and Geodetic Survey. Other major projects were primary triangulation in East and Central Africa and in Nigeria--examples of the role played by the Directorate of Colonial Surveys since 1946 in coordinating modern geodetic surveys over a whole geographic region. The British Ordnance Survey presented results of tests which compared tacheometric and chaining methods in producing 1/-1,250-scale plans of an urban area. New designs of the Small Tavistock and Geodetic Tavistock theodolites were exhibited; these new instruments are cleaner in outward appearance and both have been changed to the coincidence-reading principle.

Other discussions included the use of electronics in surveying applications, mainly centering on the geodimeter and the tellurometer. The latter instrument, recently developed in South Africa, was first publicly announced at the conference.

Delegates had an opportunity to visit the Royal Navy hydrographic survey ship *Shackleton* (245 feet, 1,200 tons). Fathometer and Decca operation was demonstrated in one of the ship's launches. The British still rely fundamentally on visual fixes, as they as yet have no mobile-transmitter electronic ranging system. However, Decca is used extensively, once the correction pattern has been determined for an operating area.

The British Ordnance Survey has installed a unit for IBM computation of survey data. The unit is built around a Type 626 IBM calculator, which is the British counterpart of the American 602A. The plan of the Ordnance Survey is to begin with a rather modest installation for a short-term experimental period and to decide later whether to make use of the more elaborate electronic machines. Current opinion is to avoid an elaborate layout, but this may prove practical if large computing blocks can be arranged.

—D. A. RICE

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International Astronomical Union

THE NINTH General Assembly of the International Astronomical Union was held at University College, Dublin, Ireland, during the period August 29 to September 3, 1955, under the presidency of Prof. Otto Struve of the United States. More than 600 delegates attended, including nearly 200 from United States universities, observatories, and governmental agencies. Other large delegations were from Great Britain (146), France (104), Germany (62), and the U.S.S.R. (21).

Scientific affairs of the Union are handled by 40 commissions, which encompass the entire field of astronomy, and are divided into 7 groups. One of these groups, Fundamental Astronomy, contains 3 commissions--geographical positions, latitude variation, and time--bearing on the work of the Coast and Geodetic Survey. These commissions are currently engaged in the International Geophysical Year program for measurement of latitude and longitude at selected points around the earth, as well as observations with the Markowitz moon camera. The Coast and Geodetic Survey will operate a station in Hawaii under both these programs during the IGY.

A summary of the International Latitude Service results for the period 1949-1955 was given by Professor Cecchini, Director of the Central Bureau. Proposals were made for a gradual conversion to more modern instruments for observation of latitude variation. These would include a group of at least three photographic zenith tubes at national observatories on approximately the same parallel, as well as a chain of the Danjon-type astrolabes with impersonal micrometers. Several years of overlapping observations will be required, however, before observations with the present zenith telescopes can be terminated.

Of particular interest to geodesists was an announcement concerning the revised and enlarged catalog of Apparent Places of Fundamental Stars (FK4), to be published by the University of Heidelberg beginning in 1960.

At its final session, the General Assembly adopted a definition of the fundamental unit of time, as had been previously requested by the International Committee on Weights and Measures. By this definition, one astronomical second is the fraction 1/31,556,925.975 of the tropical year for 1900. Recent development of the caesium atom resonator provides an independent time standard. Thus, there are two different kinds of uniform time--one based on the laws of motion and gravitation, and the other on electrical forces within the atom. Whether or not these time standards will agree over a long period of time is a matter of vital importance in physics.

The new president of the Union is Prof. André Danjon, Director of the Paris Observatory. He will serve until the next General Assembly, which will be held in Moscow in 1958, at the invitation of the National Academy of Sciences of the U.S.S.R. The United States National Committee extended an invitation to hold the 1961 meeting at Pasadena, California.

—D. A. RICE

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Special Committee for the International Geophysical Year

THE THIRD Meeting of the Special Committee for the International Geophysical Year (CSAGI) was held at the Palais des Academies, Brussels, from September 8 to 14, 1955, at the invitation of the Belgian Royal Academy of Sciences. Dr. Sydney Chapman (Great Britain), President of the Special Committee, presided. A United States delegation of about 24 persons, including Capt. E. B. Roberts--member of the U. S. National Committee for the IGY and Secretary of the Geomagnetism Technical Panel--was in attendance.

In some ways, this was the most important meeting held by the Special Committee, since the general tightening up of diverse programs originating in nearly 50 cooperating nations was achieved. This was accomplished through the medium of plenary sessions where general principles were discussed, and through the labors of working groups who examined worldwide programs and derived recommendations for overall coordination.

Dr. Joseph Kaplan, U. S. Chairman, and Dr. Lloyd Berkner (United States), Vice President of the Special Committee, were prominent in the affairs of the meeting. Members of the Russian delegation, of about 15 persons, participated in almost all working group sessions.

The first general public announcement of the detailed plans of the United States for the artificial satellite experiment was given in a lecture by Dr. Homer Newell of the Naval Research Laboratory. This was attended by numerous representatives of the international press associations as well as a large group of scientists, all of whom were deeply interested in this significant lecture.

--E. B. ROBERTS

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International Association of Geodesy

THE TRIANGULATION SECTION of the International Association of Geodesy held a symposium at Munich, Germany, from May 22 to 26, 1956. More than 40 delegates from 18 countries convened to discuss various problems in connection with the proposed second-phase adjustment of the European triangulation network, as well as to consider theoretical problems of fundamental geodesy relating to the adjustment of triangulation. The resolutions which were adopted at the final session indicated a greater spirit of cooperation between countries on geodetic problems than has ever existed in the past.

The work of the symposium was divided into three parts and assigned to three subcommissions. The first subcommission was under the chairmanship of Prof. A. Marussi of the University of Trieste. It considered the present status of the triangulation nets in each country and defined the general specifications under which these nets should be developed and extended, including the spacing of base lines and Laplace azimuths. The group also was responsible for making arrangements for neighboring countries to provide adequate boundary connections at common points.

A second subcommission, under the direction of Dr. W. Grossman of the Technische Hochschule at Hanover, Germany, considered the mathematical techniques to be used in adjusting these nets. Each country is to adjust its own network and at the same time provide for regular least-square connections to common points, so that the equations involving lines at these points can be solved at some central office. The variation of coordinates method would be used with each country determining whether it would compute on the ellipsoid or on a rectangular grid. The junction points should be on the ellipsoid. This group also gave consideration to the proper reduction of horizontal directions, Laplace azimuths, and base lines from the geoid to the ellipsoid. It was proposed that a group of neighboring countries submit data for test computations. Professor Baarda of the Netherlands offered the facilities of his organizations for studying and testing special computational techniques.

A third subcommission, under the direction of Brig. M. Hotine, Director of Colonial Surveys, Great Britain, considered problems which are highly theoretical and probably not required for the development and the adjustment of the European network, at least in this second phase. This group discussed some of the fundamental geodetic problems which are encountered in the extension of networks in any continent.

Mr. Floyd W. Hough of the Army Map Service, and Messrs. B. K. Meade and C. A. Whitten of the Coast and Geodetic Survey attended this symposium so it was possible for a United States representative to be present at each of the three subcommissions when they met separately. Mr. Whitten, who is President of the Triangulation Section, presided at the plenary sessions and assisted Prof. M. Kneissl, President of the International Commission on European Triangulation, in coordinating the work of the three subcommissions.

—C. A. WHITTEN

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Pan American Committee for the International Geophysical Year

AN AMERICAN hemisphere regional meeting of the countries of America participating in the International Geophysical Year was held July 16-20, 1956, at Rio de Janeiro, Brazil. This was under the joint auspices of the Special Committee for the IGY and the Pan American Committee for the IGY. The latter committee is sponsored by the Pan American Institute of Geography and History. Capt. E. B. Roberts attended this meeting in several capacities, including those of member of the Pan American Committee, member of the U. S. National Committee, and representative of the International Association of Geomagnetism and Aeronomy.

Dr. E. O. Hulburt, Western Hemisphere Adjunct Secretary of CSAGI, and Dr. M. Maldonado-Koerdell, Secretary of the Pan American Committee, were the principal officials of the conference, which was attended by several dignitaries, including Dr. Sydney Chapman, President of CSAGI.

Delegates of the majority of American Republics and of Canada were present to discuss and cooperate in the programs contributing to the IGY. As in the case of the general meetings of the Special Committee, the work was performed by temporary working groups, generally consisting of specialists in the several working disciplines. A gratifying amount of prospective activity was found to be on the program throughout most of the Latin American countries. Arrangements were made for the suitable distribution of stations and for some international collaboration.

The meetings were held through the courtesy of the Brazilian Government at the Army Technical School near Copacabana Beach.

—E. B. ROBERTS

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International Congress on Photogrammetry

THE EIGHTH International Congress on Photogrammetry was held in Stockholm from July 17 to 26, 1956. The conference was attended by more than 800 delegates from 41 nations, including 80 delegates from the various governmental and private mapping organizations of the United States. The Coast and Geodetic Survey was represented by Capt. O. S. Reading (Ret.), Comdr. L. W. Swanson, and Mr. G. C. Tewinkel. Captain Reading was re-elected to the governing Council of the International Society.

About 350 technical papers were presented on the general subjects of aerial photography, plotting instruments, aerial triangulation, topographic mapping, non-topographic applications, education, terminology, bibliography, and photo interpretation. Several papers were presented on the subject of the adjustment of aerotriangulation, some of which applied the least squares principle. Considerable interest centered around the results of an international test for accuracy and economy, in which the Coast and Geodetic Survey had participated by performing aerotriangulation and adjustment with photographs and control furnished by the French Government.

Concerning photogrammetric applications, reports were repeated indicating root mean square errors of less than 4 inches for cadastral purposes. Errors in former ground surveys became noticeable and troublesome in the photogrammetric operations. The ideas of convergent photography were favorably accepted.

An extensive exhibition included essentially all the photogrammetric instruments of the world.

—G. C. TEWINKEL

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Third Air Navigation Conference—ICAO

THE INTERNATIONAL Civil Aviation Organization (ICAO) held its Third Air Navigation Conference at Montreal, Canada, from September 18 through October 23, 1956. The meetings were conducted in the ICAO Conference and Council rooms in the International Aviation Building. The conference was attended by delegates from 27 contracting states and the main plenary meetings were held in the council chambers of ICAO.

Substantive work of the conference was conducted in committees and subcommittees and it was necessary to meet in plenary sessions only four times. A coordinating committee composed of the chairman and vice chairman of the conference and the chairmen of the committees and subcommittees, assisted, if necessary, by the secretariat, met daily to coordinate the work of the conference and to monitor its progress.

The delegation from the United States was headed by Mr. Oscar Bakke of the Civil Aeronautics Board. The alternate delegates were Messrs. R. W. Craig and W. E. Koneczny. Mr. John D. Kay was the representative from the Coast and Geodetic Survey.

Ten agenda items were considered during the work of the conference. Of particular interest to the Coast and Geodetic Survey was agenda item 10, "Revision of specifications for aerodrome obstruction plans and profile charts," as the preparation of these charts has been delegated to the Coast and Geodetic Survey by both the Civil Aeronautics Board and the Civil Aeronautics Administration. For 10 years the Bureau has conducted the field work and provided for the production of Obstruction Plan Charts that have now become world standards for charts of this type. A paper prepared in the Bureau on the procedures for conducting an aerodrome obstruction survey was reproduced in the three official languages of the conference and distributed to all member states.

The Conference recommended in its final report that Aerodrome Obstruction Plan and Profile Charts be prepared on two formats: (1), Type A, which would provide the minimum of information required for operational use, a simple plan and profile of each runway and takeoff flight path area; and (2), Type B, would be a comprehensive chart and include all the information shown on Type A chart, plus the additional information required for a detailed plan of a complete aerodrome.

—JOHN D. KAY

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Seventh International Hydrographic Conference

THE SEVENTH International Hydrographic Conference was held under the auspices of the International Hydrographic Bureau at Monte Carlo, Principality of Monaco, from May 7 to 18, 1957. Thirty of the 35 States Members were represented by some 80 delegates and technical advisers, and 11 international scientific organizations sent observers. The United States was represented by Rear Adm. H. C. Daniel and Messrs. G. Medina and W. Watt of the Hydrographic Office, Rear Adm. Robert W. Knox and Capt. S. B. Grenell of the Coast and Geodetic Survey, Mr. Wm. T. Laidly of the Lake Survey, and Mr. E. S. Brown of the State Department. Admiral Daniel was head of the delegation.

The Bureau was established in 1921 to coordinate and encourage standardization of the efforts of national hydrographic offices and to promote, on an international basis, the safety of navigation. Since all countries have a community of interest in the coasts of foreign waters, it is essential that basic information in the form of hydrographic surveys; accurate and up-to-date charts; comprehensive descriptions of coasts, ports, and navigational aids; improvements of hydrographic survey methods and instrumentation; and the development of navigational techniques be freely exchanged.

The work of the Conference was handled through committees. All committee reports were submitted to the plenary sessions where each proposal contained in the reports was voted on. In general, the technical proposals adopted were consistent with the established policies and procedures of the Hydrographic Office, the Coast and Geodetic Survey, and the Lake Survey.

Election of the Directing Committee for the period 1957-1962 was held at the closing session of the Conference and resulted in the selection of Rear Adm. Robert W. Knox (USA), Rear Adm. Alfredo Viglieri (Italy), and Vice Adm. Leon Damioni (France). A subsequent ballot for President of the Directing Committee resulted in the election of Rear Admiral Knox. This is the first time in the history of the Hydrographic Bureau that an official of the Coast and Geodetic Survey has been honored with such a post.

An interesting exhibit of hydrographic surveying equipment was displayed in the exhibition hall of the Bureau by manufacturers from various countries. In addition, the delegates were taken to sea on H. M. S. *Owens* for a demonstration of Decca positioning equipment.

--ROBERT W. KNOX

FEDERAL SURVEYING AND MAPPING AGENCIES

This is the fourth of a series of articles that will be published from time to time on the history, organization, and present activities of the major surveying and mapping agencies of the Federal Government.--Editor.

Aeronautical Chart and Information Center

(United States Air Force)

COLONEL RICHARD W. PHILBRICK and ROBERT D. DIXON, Cartographer

MANY CARTOGRAPHIC AGENCIES have been in existence for a long time mapping the land and charting the sea. However, it was not until the twentieth century that man conquered the air and thereby created a need for a new cartographic item--the aeronautical chart. The rapid advancement that has taken place in aviation during the past 15 years has caused development in the air charting field to go forward at an accelerated pace. Increases in speed, range, and altitude of new aircraft, the introduction of electronic aids to navigation, and the development of highly complex weapons systems have necessitated many new type graphics to support modern aviation. In order to fulfill its rapidly changing requirements in this field, the Air Force maintains the Aeronautical Chart and Information Center as its principal cartographic agency.

HISTORY

During the early years of aviation when most aeronautical activity was of a local nature, very little was required in the way of air charting materials and air navigational aids. The emergence of the airplane as a major weapon of war and a principal means of transportation made it apparent that special types of graphic aids would ultimately be required for air navigation.

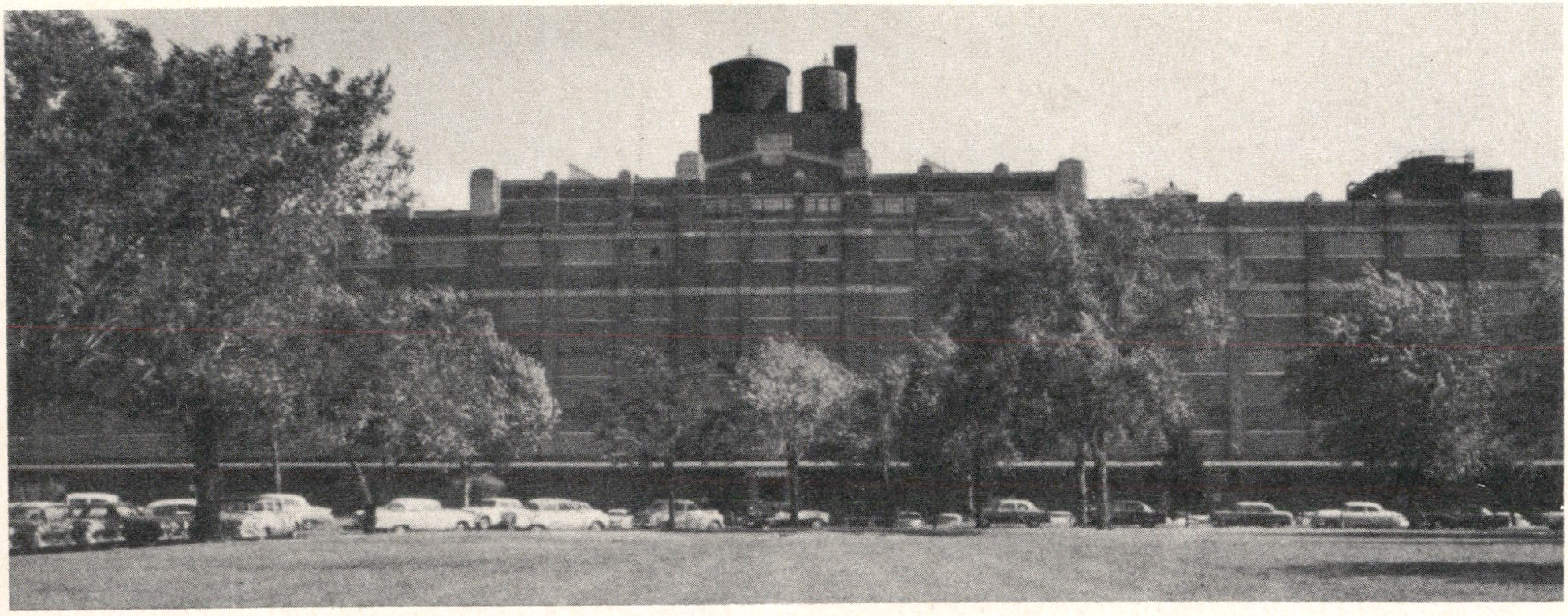
In 1920, the Information Division of the Army Air Service began the collection of miscellaneous maps and charts published by Government agencies and commercial firms and disseminated them for military air use. None of these maps and charts contained any aeronautical information.

On April 20, 1923, the newly formed Airways Section of the Army Air Service authorized the production of 9 Air Navigation Strip Maps, scale 1:500,000, covering the principal air routes of the United States. On December 15, 1928, a Map Unit was established under the Information Division of the Army Air Corps. The number of strip maps was increased to 52 and the Map Unit assumed responsibility for production and maintenance. During the next 11 years the Map Unit coordinated with the Coast and Geodetic Survey and other Government cartographic agencies in the production of aeronautical charts for military use.

With the increase in world tension during the late 1930's, the need for world coverage of air navigation charts was recognized. In 1941, the Map Section of the Information Division, Army Air Corps, began planning preparation of several basic series of aeronautical charts in various areas of the world. Arrangements were made with the Coast and Geodetic Survey to begin work on the World Planning Series, scale 1:5,000,000; and the Western Hemisphere Aeronautical Chart Series, scale 1:1,000,000; and with the Corps of Engineers for production of World Long Range Navigation charts, scale 1:3,000,000.

In January 1942, the Map Section became the Map Chart Division of Air Traffic Services, Army Air Forces, with responsibility for preparation, procurement, compilation, reproduction, and distribution of aeronautical charts. On September 2, 1942, the Secretary of War authorized the production of World Aeronautical charts (WAC), scale 1:1,000,000; Aeronautical Planning charts (AP), scale 1:5,000,000; and Long Range Air Navigation charts (LR), scale 1:3,000,000, on a worldwide basis. Also authorized was the production of Pilotage charts, scale 1:500,000;

Colonel Philbrick is the Commander of the Aeronautical Chart and Information Center.



THE HOME OF AERONAUTICAL CHART AND INFORMATION CENTER

Approach charts, scale 1:250,000; and Target charts as required for military purposes.

In February 1943, the Army Air Forces Aeronautical Chart Plant was established at St. Louis, Mo., to assume part of the load in production of the various chart series and to distribute charts to Air Force units. Although the Plant operated throughout the remainder of World War II with a personnel of approximately 500, it was necessary for the Air Forces to rely heavily on the other Government cartographic agencies for compilation and printing. During this period, the first world coverage by the WAC's, AP's, and LR's was completed. Also, many of these charts of China, North Africa, Canada, South America, and the Middle East were recompiled from trimetrogon photography. The Geological Survey gave major help to the Air Forces in developing and compiling trimetrogon photography.

The Map Chart Division was redesignated as Aeronautical Chart Service (ACS) on April 26, 1944, and was assigned to Reconnaissance Division, Headquarters, Army Air Forces. After the close of World War II, the Aeronautical Chart Service continued to operate on a limited basis and with reduced personnel. Activities consisted primarily of maintenance of the major series of charts and completing compilation from trimetrogon photography accomplished during the war. In April 1946, the ACS was transferred to the Air Transport Command; and on May 26, 1947 it was transferred to Strategic Air Command.

By 1948, the interest in military preparedness had revived. The Air Force had become a separate arm of national defense. The rapid technological advancement in aviation and electronics, and the special attention given strategic air offense, brought about a great expansion in the program for producing air target graphics, and created a need for development of new types of charts for air navigation. The Aeronautical Chart Service was expanded and personnel increased to approximately 2,000.

On March 1, 1950, ACS was transferred to Air Materiel Command. The Korean War stimulated chart development and production permitting the testing of new charts for use with new military weapons, especially jet aircraft, under combat conditions. In 1951, because of added aeronautical information responsibilities, the name of the organization was changed to the Aeronautical Chart and Information Service (ACIS).

ACIS was transferred, May 10, 1952, to Air Photographic and Charting Service, Military Air Transport Service. On August 12, 1952, the name of the organization was changed to Aeronautical Chart and Information Center (ACIC) and its headquarters moved from Washington, D. C., to St. Louis, Mo. Due to increases in Air Force requirements for new air navigation charts, air target graphics, and aeronautical information, another expansion took place in 1954 of production facilities which brought the total personnel to approximately 100 military and 3,500 civilians.

MISSION

The Aeronautical Chart and Information Center is charged with the responsibility for providing the Air Force with aeronautical charts, graphic air target materials, aeronautical information publications, maps, terrain models, evaluated intelligence on air facilities, and related cartographic services. This responsibility includes developing Air Force cartographic requirements, planning production programs, collecting and evaluating source material, compiling, reproducing, and distributing the various cartographic items; collection, storage, and distribution of foreign and domestic charts or maps produced by other agencies; maintenance of adequate files of worldwide aeronautical information for dissemination through the media of aeronautical information publications as well as aeronautical charts; establishment and maintenance of offices in overseas commands; maintenance of a library of all Air Force aerial and still photography and an operational print file for common use by Department of Defense and other agencies; and providing photographic laboratory services to Department of Defense agencies in the Pentagon.

LOCATION AND PRESENT FACILITIES

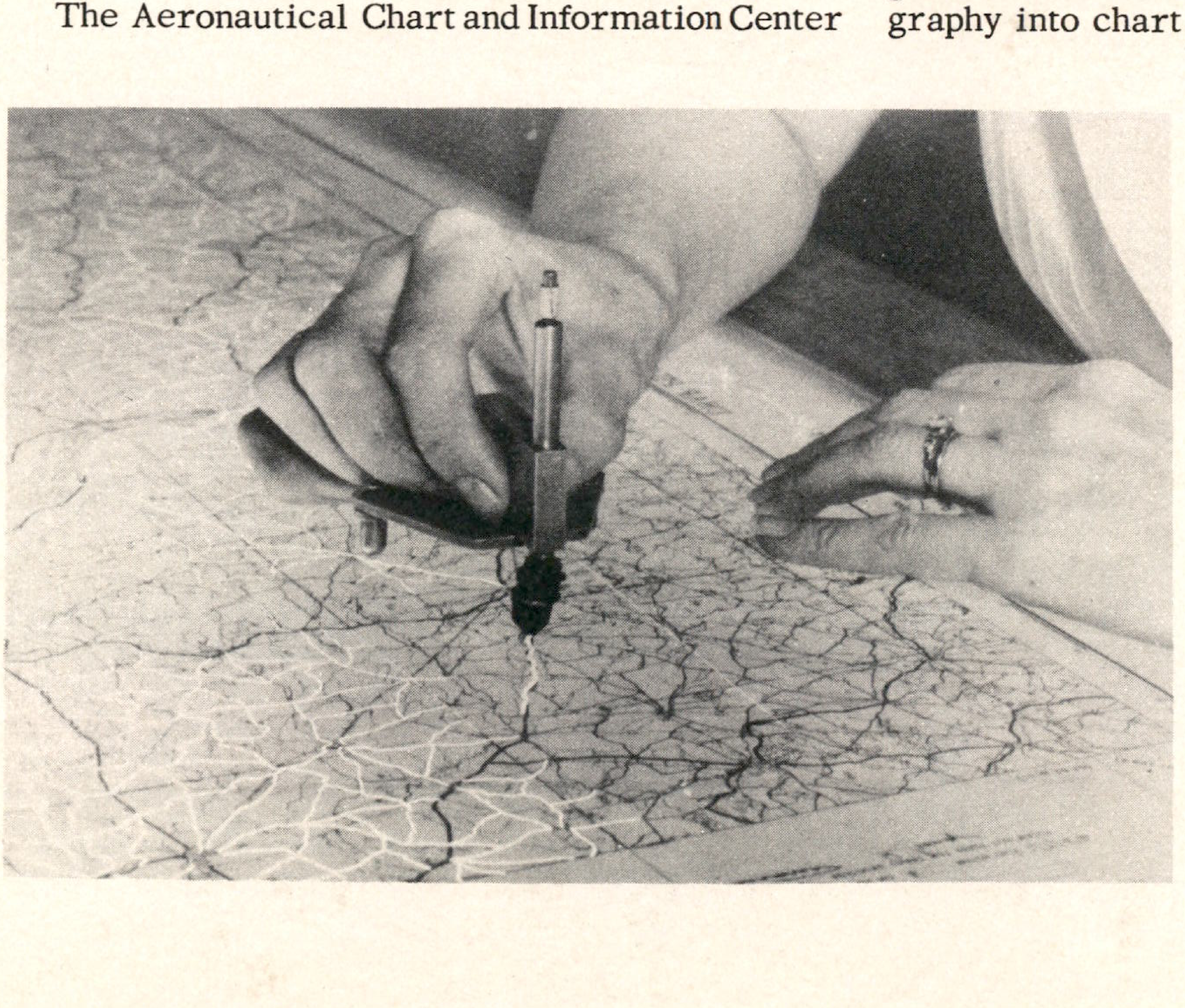
The command activities and principal production facilities of ACIC are located on a government reservation of 24 acres in St. Louis. This installation consists of 20 buildings with over 500,000 square feet of floor space. In it are located the operational staff and other supporting staff offices as well as the Production and Distribution Plant. The South Annex with 361,000 square feet of floor space, which houses the storage and distribution activities, is approximately 6 miles to the south at the St. Louis city limits. The Washington office is located in the Langston Hall area and in the Pentagon. Overseas Squadrons or Detachments are located in Germany, England, Japan, Hawaii, Guam, Alaska, and the Canal Zone.

ORGANIZATION

The Aeronautical Chart and Information Center is organizationally a component of the Air Photographic and Charting Service located at Orlando, Fla. Other components of the Air Photographic and Charting Service are responsible for the accomplishment of aerial photography, airborne electronic surveying for the procurement of geodetic control data, and of Air Force motion pictures. The Air Photographic and Charting Service is one of the service organizations assigned to the Military Air Transport Service, a principal command of the Air Force.

The Commander, an Air Force officer, is responsible for the operation and activities of the Aeronautical Chart and Information Center. He maintains administrative staff directorates or offices to carry out support functions relating to personnel, materiel, security, manpower and organization, information services, and comptroller activity. He exercises control over the primary mission activities through the Directorate of Operations. This directorate performs many staff functions such as investigating technical requirements to be fulfilled for air weapons systems; developing cartographic requirements for supporting weapons systems and Air Force activity in general; and planning and implementing approved cartographic programs.

The Production and Distribution Plant is the central production activity. It is headed by a civilian chief who maintains staffs or support offices for production engineering, production control, specification and techniques, and chart quantity analysis, as well as a cartographic and a technical library. The principal production elements of the Plant are: Photogrammetry Division, which employs many different photogrammetric methods in converting aerial photography into chart manuscript bases, mosaics, and



Color separation by negative engraving.

technical data; the Aeronautical Information Division, which compiles aeronautical data for charts and aeronautical information publications utilizing an up-to-date file of aeronautical information for all areas; the Cartography Division, which finalizes all new cartographic compilation, revises and maintains existing charts, and performs the necessary drafting or engraving on all charts prior to reproduction; the Reproduction Division, which accomplishes the printing of charts and all reproduction work required to support the printing activity; and the Distribution Division, which is responsible for the storage, packaging, and shipping of charts and publications to points throughout the world.

The Washington office is operated as a detachment of the St. Louis Headquarters. It is responsible for carrying on the required staff and production liaison activity in the Washington area and for the collection and evaluation of the vast amount of source information required for the preparation of charts and publications. The Photographic Records and Services Division is a part of the Washington office and includes the Air Force Central Film Library, an Operational Print File, and photographic laboratory facilities required for servicing Air Force Headquarters and Department of Defense offices in the Pentagon.

Overseas Aeronautical Chart and Information Squadrons are located in Germany (with a detachment in England), and in Japan with detachments in Hawaii and Guam. ACIC offices are located in Alaska, and the Canal Zone. These overseas units distribute charts and aeronautical information publications to Air Force using elements; produce Radio Facility charts, Approach and Landing charts, and other aeronautical aids for their respective areas; collect and disseminate aeronautical information; and coordinate ACIC matters of interest with Air Force organizations and other chart and publication users in their respective theaters.

ITEMS CURRENTLY PRODUCED AND MAINTAINED

The Aeronautical Chart and Information Center produces and maintains several series of standard and special aeronautical charts, ranging in scale from 1:250,000 to 1:5,000,000, for use in all types of operations, as well as for planning and flight training. The more important series are as follows:

1. World Aeronautical charts (WAC), scale 1:1,000,000. This series, consisting of 938 charts, sheet size 22 by 29 inches, provides world coverage of land areas. They have a variety of uses as general purpose charts for planning, operations, etc. They depict in appropriate colors as many pertinent topographic, hydrographic, and cultural features as are practicable to show at this scale. These charts also contain aeronautical information that is not subject to frequent change. The Coast and Geodetic Survey produces this series for the United States and Alaska.

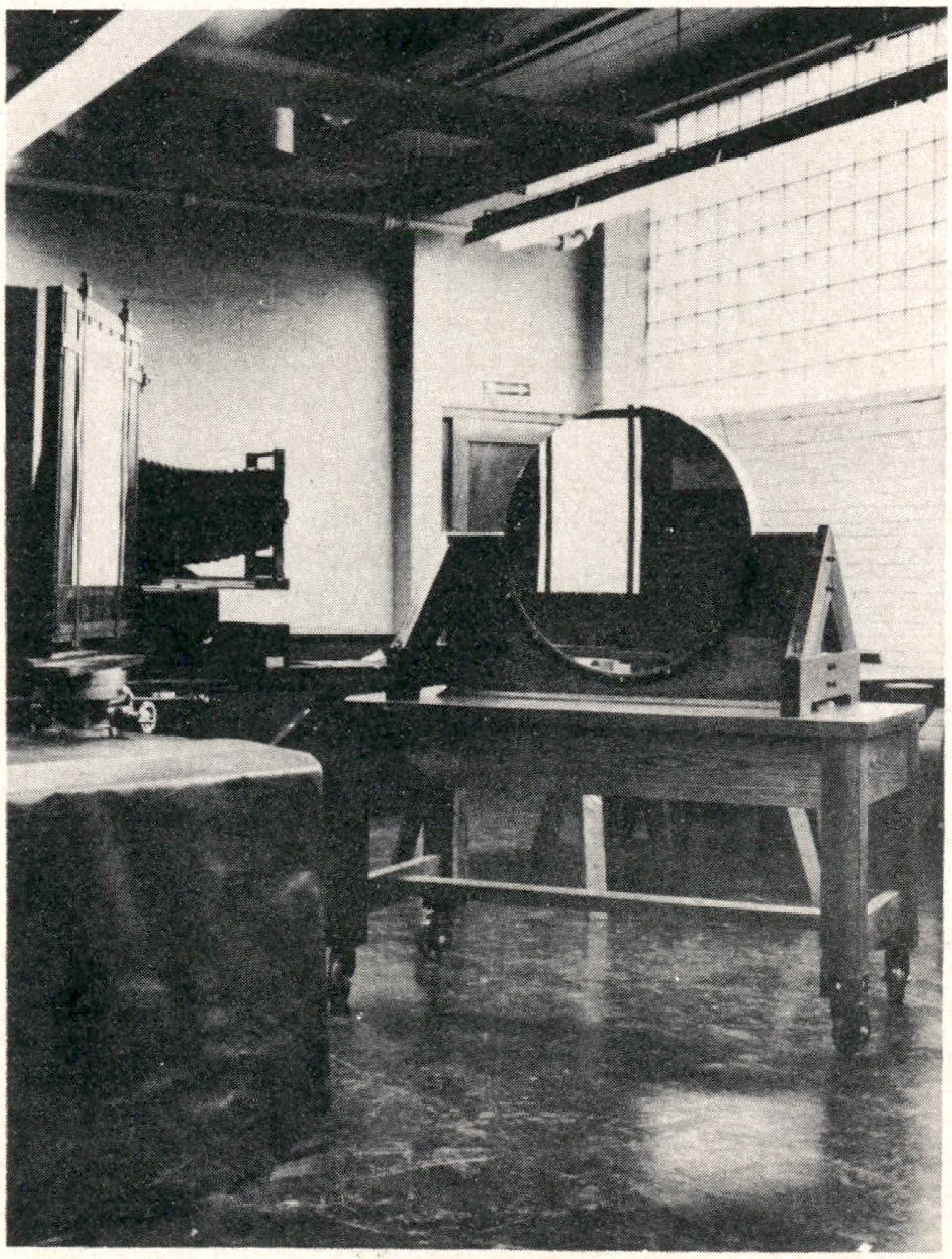
2. Pilotage charts (PC), scale 1:500,000. These are produced as a coordinate series, cover selected areas of the world, and generally are used for tactical and certain strategic operations. They are on the same sheet size and show ground features and relief in the same manner as the WAC's, with increase in density commensurate with the larger scale. Recent


Preparation of shaded relief.

investigative and development work has resulted in modification of this series for low-altitude, high-speed operations. Conversion of the series to new specifications is now underway.

3. Aeronautical Approach charts (AC), scale 1:250,000. This basic coordinated series covers selected areas of the world where intense military activity may develop and where current air operations are of a nature as to require charts showing more detailed ground information. They are used in strategic operations for radar navigation and target approach, and in tactical operations for short-range bombing, interdiction, and ground air support. They also are used for intelligence and planning purposes.

4. Jet Navigation charts (JN), scale 1:2,000,000. This is a new chart series designed to fulfill current and future requirements of high-speed, long-range, and high-altitude flying, and at the same time provide for radar, celestial, dead reckoning, and pilotage navigation. One hundred of these charts, providing coverage of the land areas of the world, are being published on sheet size 42 by 58-1/2 inches on Lambert conformal conic projections (except in polar areas where the inverse Mercator projection is used), and include topographic features, names, aeronautical aids, and other information required for jet aircraft navigation. They are so designed that strips of minimum width of 12 inches may be cut from them and used independently where operational space is limited in jet aircraft. JN charts for the Northern Hemisphere have been published. Production of those for the Southern Hemisphere is planned. The Coast and Geodetic Survey publishes the four JN charts covering the United States.



Variable perspective camera.

5. Aeronautical Planning charts, scale 1:5,000,000. This series consisting of 43 sheets, was designed to provide world coverage at a scale suitable for staff and operational planning of activities over air routes and in overseas theaters. They show only the topographic, hydrographic, and cultural features and certain aeronautical information necessary to flight planning. Plans are underway to modify this series to render it suitable for joint service use and to replace four other planning chart series now being maintained.

6. Other series. These are published to fulfill requirements for charts for specific purposes and include Gnomonic Tracking charts, scale 1:4,000,000; and Strategic Planning, Weather Plotting and Weather Recording, Radar Tracking, Loran and Consol, Evasion, and geography charts, at various scales.

While some of the charts described above are used as air target materials, a number of series of charts, mosaics, and data sheets are published specifically to fulfill air target requirements. City centered charts for target purposes, produced in the past at scales 1:500,000 and 1:250,000, are being replaced by the coordinated standard series at these scales. City centered target charts, scale 1:100,000, are produced to provide coverage of an area surrounding a target at a scale permitting detailed study of the area. They show identification and analysis information for targets including city layout, street and railroad patterns, drainage, landmarks, contours, and spot elevations.

Target mosaics and Target charts, scale 1:25,000, are prepared for potential targets; the former when photography is available, and the latter when it is not. They are used for intelligence analysis of strategic and tactical factors concerning selected targets, for planning bombing operations, for pre-strike briefings, special studies, and bomb damage assessment.

Several other items of air target materials are produced, such as the Geodetic Data Sheets which provide the best possible position and elevation, together with certain other technical information concerning points of military interest.

To provide military aviation with all of the necessary "aids to navigation" data, in an accurate and up-to-date manner, ACIC produces several aeronautical information publications. The most important ones are:

USAF-USN Pilot's Handbooks contain approved instrument procedures, to facilitate approach of land-based aircraft to airfields under controlled instrument flight conditions, and landing charts showing features that are in the immediate vicinity of an airfield. Revised editions of charts in the Handbooks are produced and distributed as often as the aeronautical information becomes obsolete. Thirteen Pilot's Handbooks for low-altitude operations and six Pilot's Handbooks for jet operations are produced, covering various areas of the world. The Coast and Geodetic Survey produces a large part of the approach and landing charts and other data for Pilot's Handbooks covering the United States. The contents of the Pilot's Handbooks have recently been redesigned on a reduced size format and conversion to the new specifications is underway.

USAF-USN Radio Facility charts (RFC) and In-Flight Data booklets are produced in bound volumes on a bi-weekly, monthly, or bi-monthly basis for 9 major areas of Air Force operation. These publications contain tabulations of radio navigational and communications facilities, airways, danger areas, airport directories, and miscellaneous navigational data. They contain information and procedures to be used during in-flight operations for accomplishing radio communications and navigation. To supplement the bound volume RFC in high speed aircraft operations, a series of Special (sheet type) Radio Facility charts, consisting of 11 sheets covering the United States, is published once each month on the same scale and projection as the Jet Navigation charts. An investigation is underway to determine if such a sheet type RFC, together with an in-flight data booklet, could replace the current standard RFC's used for all types of military aircraft operation in different areas of the world.

Other aeronautical information publications include Foreign Clearance Guide, Supplementary Flight Information Documents, and Air Field and Seaplane Stations of the World.

MISCELLANEOUS SERVICES

The Photographic Records and Services Division of the Washington office maintains a central film file of all Air Force aerial and still photography, and an operational print file of selected aerial photographs for common use by Department of Defense and other agencies. All Air Force photography is being indexed by 1^{o} square areas, at scale 1:250,000, on transparent overlays keyed to the best large-scale maps or charts of the area. Separate transparencies for each mission show complete identifying information.

Liaison is maintained with Air Force field units engaged in cartographic or photogrammetric work. Most of this kind of activity in the field is accomplished by Reconnaissance Technical Squadrons. The Center supports them by providing source material for use in compilation, providing the units with up-to-date procedures, reviewing and editing the work they perform, and maintaining a school for advanced training of officers and airmen in cartography and photogrammetry.

ACIC occasionally provides personnel to support Air Force or joint service field survey programs, such as eclipse observations and special control programs for astronomic observation.

Special studies are conducted for the Air Force on technical matters which critically affect the accuracy and utility of cartographic materials and data. These studies include such matters as accuracy of geodetic datums and positions, suitability of cartographic products for use in Air Force weapons systems, and optimum type of photograph for production of charts.

PROPORTIONATE AMOUNT OF EFFORT TO EACH ITEM OR SERVICE

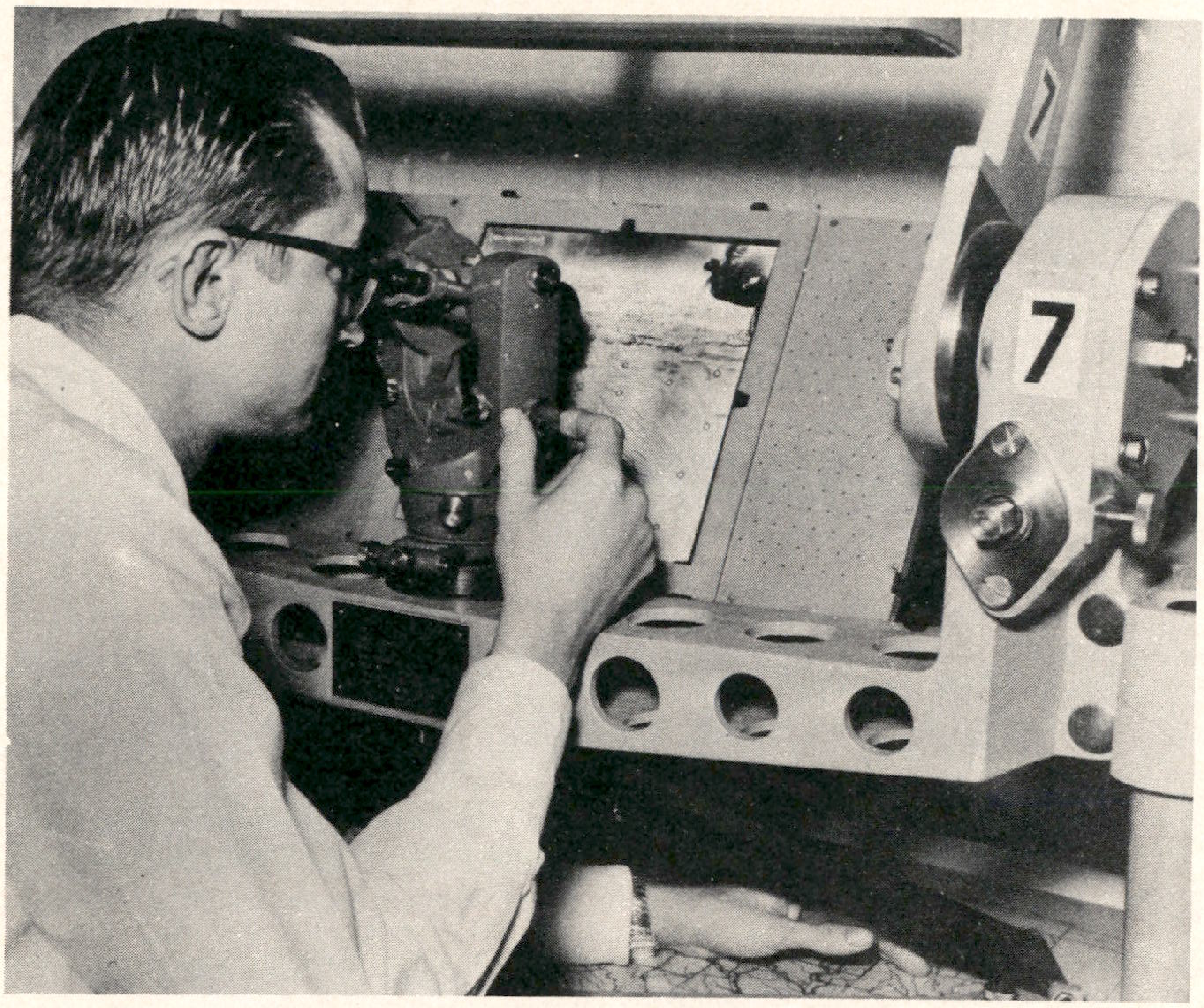
While most products of ACIC have distinctive characteristics, which make it possible to consider them in particular categories, there are some which have dual purpose and use and cannot be specifically categorized. Generally, the proportionate amount of effort devoted to each category is approximately as follows: standard series air navigation charts, 38 percent; air target materials, 34 percent; aeronautical information publications and services, 12 percent; photographic and miscellaneous services, 16 percent.

CHART DESIGN AND DEVELOPMENT

In order to determine, as far in advance as possible, the new cartographic items and services which the Air Force will require, ACIC conducts a continuing program to investigate and analyze information on new weapons systems and potential changes in operational procedures.

In these investigations, the technical data that form the bases for new weapons systems which require cartographic or geodetic support are isolated and reflected in Technical Planning Briefs. Prior to and after new weapons systems become operational, all pertinent data are collected and analyzed for use in initiating detailed requirement surveys.

Graphic requirements may originate at any



Photoalidade measures elevations from oblique aerial photographs.

level of the Air Force. When information on a new requirement is received, a preliminary analysis is made to determine its general nature. Also, a determination is made as to whether the requirement relates to existing development projects, whether cartographic materials exist that may satisfy the requirement, or whether a complete research and development project is warranted.

When the pertinent facts concerning a requirement are sufficiently firm, a Requirements Guide is prepared which provides criteria for the production of prototype models and serves as a basis for reexamination of user requirements as conditions or circumstances change. After prototype models are produced and field tested, the results of the test and evaluation are carefully analyzed and the necessary refinements and modifications are made. Upon approval and acceptance the graphics are programmed and scheduled for production.

The Center carries on extensive development activity in connection with cartographic, photogrammetric, and reproduction techniques. Refinements have been achieved in preparing drawings by engraving (scribing) on resin coated vinyl sheets. Through this process the old hand drafting method has been virtually eliminated. Such developments as the quick etch, the photomechanical vignetting, the Dystrip and the variable density contour processes, have been described in ACIC Technical Reports and in technical journals. Development work is continuing on techniques for producing certain kinds of terrain relief models. Investigations are being conducted to produce reduced graphics which can be projected on a screen in an aircraft cockpit. Other examples of research and development are a number of experimental graphics for use with missile guidance systems.

Considerable research is being conducted under the Family of Charts (AC, RC, WAC and JN--interrelated series of aeronautical charts) concept to bring about improvement in portrayal of chart detail, colors, portrayal techniques, symbolization, pictorial relief, etc. The purpose of this study is to bring the major chart series in line with changing requirements. Field testing is now being accomplished on several experimental charts to determine optimum content and portrayal for each chart series.

PRODUCTION AND DISTRIBUTION

Production activities are centralized in the Production and Distribution Plant where in a single operational unit all work assignments are processed through the various production and distribution phases. The major phases involved are: chart research (collection and evaluation of source data), base chart and mosaic compilation, chart maintenance, editing and engraving, processing and application of aeronautical information, preparation of reproduction copy, printing, storage, and distribution.

While the Plant performs the major portion

Radial line plotter makes a single paper template from three simultaneous trimetrogon exposures.

of the production work of ACIC, it has been found expedient and advantageous to accomplish certain kinds of work through commercial contracts or through arrangement with other Government cartographic agencies. Such contract work includes photogrammetric and cartographic compilation, preparation of color separation drawings or engravings, and lithographic printing. The Plant is responsible for monitoring and supervising this work.

Although the collection and evaluation of source data for use in chart production are accomplished by the Washington office, the Plant coordinates those activities of the Chart Research Division which affect the operations of the Plant.

Normally, in assignments for new or recompiled charts, the Washington office carries out an organized search and collection of all available materials covering the areas involved, such as maps, geodetic control, intelligence data, and aerial photography. These materials are analyzed and evaluated and decisions are made as to which portions are considered most suitable for use as compilation source material. Research reports for compilation use are prepared in detail, specifying what source materials should be utilized in the compilation process and the degree of reliability which can be placed on each item. These reports also describe geodetic control data and aerial photography available in the area of the compilation.

While the major compilation effort of the Plant has been devoted to production of new products requiring complete compilation, a large portion of the effort is devoted to the maintenance of existing chart series. In the production and maintenance of charts of scale 1:500,000 and smaller, the normal compilation procedure is as follows: Selection-tracings of source maps are assigned as "base"; photographic film reductions of these tracings are panelled to a copy of the graticule to form the "map adjustment base," upon which the source information is assembled, adjusted, and correlated; and additional detail is added from supplementary sources, such as aerial photography and intelligence data. A final compilation is usually traced from the map adjustment base. Contours, vegetation, and names are prepared on separate sheets keyed to the base compilation, resulting in a compilation consisting of several interrelated sheets.

The Cartography and Aeronautical Information Divisions maintain a file of "standards" consisting of copies of ACIC-produced charts on which hand annotations of latest information are added as received. Criteria for determining when a given chart should be revised or recompiled are based largely on the nature and extent of the annotations and the degree to which the existing chart may be considered hazardous. Since reproduction material is retained, minor revisions may be applied directly to photographic or scribed negatives and a chart reprinted in a short time. Major changes or availability of greatly improved source material necessitate recompilation.

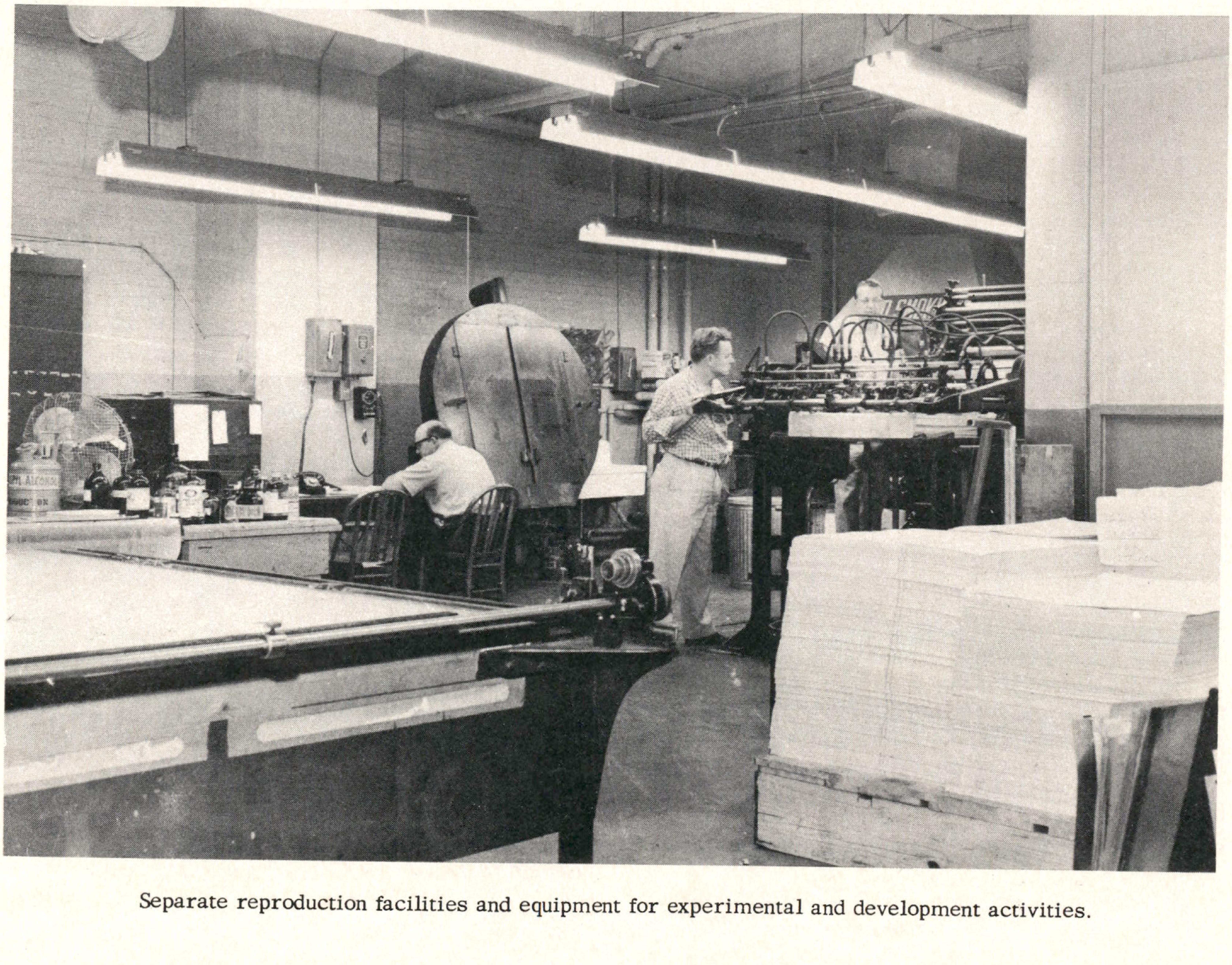
Where aerial photography is available, the basic compilations are performed by the Photogrammetry Division. The method employed depends upon the characteristics of the photography, quality of source material and geodetic control, and the scale and intended use of the end product. Photogrammetric compilation of large-scale charts, particularly that for the 1:100,000 scale air target charts, is accomplished by means of the Kelsh, Mahan, or multiplex stereoplotting equipment, where the photography is adequate. In the absence of photography suitable for stereoplotting, such charts are usually compiled by preparation of a blue-line base from best source material and correction of this base by photo-revision methods.

The Zeiss C-8 Stereoplanigraph and the Wild A-7 Autograph are used to compile critical areas for target materials, for extension of control, and for determining precise positions and elevations of selected points.

Small-scale photogrammetric compilation is performed principally for production of 1:250,000 scale Aeronautical Approach charts, which are, in turn, used as primary source material for cartographic compilation of charts of smaller scales. Normally, compilation for small-scale charts is accomplished from trimetrogon photography, where such photography exists.

Maintenance of charts, produced from photogrammetric compilation, is accomplished when additional geodetic data or aerial photography indicate that a significantly improved product could be produced by photo-recompilation or photo-revision.

Aerial photograph mosaics are normally compiled and published at a scale of 1:25,000. The mosaics are controlled either by a network of photogrammetric control points or by the best available map, depending on the adequacy of the photography and the control for photogrammetric control extension. Most rectification is accomplished on Bausch and Lomb Autofocus Rectifiers from computed settings. Template plots are used only in areas of very poor geodetic control or for extremely high tilts. Frequently, photographs are furnished with tilts exceeding the general limits of the



Separate reproduction facilities and equipment for experimental and development activities.

Bausch and Lomb Rectifiers. Techniques have been developed whereby highly tilted, short-focal-length photographs can be rectified in the final step from copy negatives made of partially rectified prints appropriately enlarged. For highly tilted long-focal-length photographs, negatives are made on a variable perspective camera to provide the required affine transformation.

In order that aeronautical charts and publications may be published with as accurate and current aeronautical information as possible, the Aeronautical Information Division carries on a continuous data processing procedure whereby "raw" air intelligence, operational statistics, engineering plans, photography, and many other types of information pertaining to worldwide air routes and facilities are collected, evaluated, and maintained as permanent facility records. This Division maintains a complete file of worldwide air facilities and route information.

Pertinent aeronautical information of relatively stable nature is selected for incorporation into the aeronautical information overprints which are applied to most of the standard navigation chart series. The information is maintained on a day-to-day basis on working copies of Radio Facility charts and certain other publications which are issued on a bi-weekly, monthly, or bi-monthly basis. For the domestic RFC's, both the typesetting and printing are accomplished by commercial contract. In foreign areas, this is accomplished through field printing plants which service the theater headquarters. The information is also used in preparation of new Approach and Landing charts to be included in Pilot's Handbooks, as well as for editing or revising materials to be included in any of the other aeronautical information publications.

Aeronautical Video Plates (AVP), consisting of plastic discs 10 inches in diameter and 1/4 inch thick, on which has been reproduced certain cartographic and aeronautical information together with graticules, are prepared for use by air traffic controllers. When in operational use, the information on a plate is electronically superimposed on a Ground Position Indicator scope, making it possible to identify aircraft position with respect to ground detail. Compilation of the AVP's is accomplished by engraving on resin-coated plastic material.

Although a certain amount of editing is required in all compilation phases, the responsibility for final editing of all base charts is in the Cartography Division where a separate branch is assigned this function. The final compilations, as well as the color-separation drawings, are edited to insure conformance to specifications, that proper source data are utilized, and that general cartographic standards are met. All reproduction materials including press plates are edited.

In the final color separation, virtually all separation plates are prepared by engraving on resin-coated vinyl sheets. A coated sheet is superimposed on the transparency of the manuscript compilation and placed on a light-table. The chart detail is then engraved or etched in the resin coating on the vinyl sheet. Great savings in manpower and calendar time have been realized through these new processes which have eliminated the laborious tasks of hand drafting on metal-mounted sheets and hand drafting of color-separation plates. The quality of the line work on printed charts has also been greatly enhanced.

The Reproduction Division consists of a complete printing plant, containing offset lithographic presses, and a complete photographic laboratory which supports the printing plant and performs the miscellaneous reproduction work required throughout the chart-production processes.

In the normal reproduction of a chart, the engraved color-separation negatives are transformed into positives by the quick etch process. Color separations for gradient tint bands and open water area to be tinted are prepared by the Dystrip process. Registration checks and the necessary stripping and opaquing operations are then accomplished. From the color-separation negatives an Ansco color or Watercote proof is made for editing purposes. The photomechanical vignetting process is employed for water and wooded areas and registered to the separation sheets. Screen tints and vignetted areas are composited to the various color-press plates by multiexposure.

Printing is accomplished by the lithographic press most suitable to the particular chart. Size of chart and number of colors are factors. Charts are printed, trimmed, folded, and packaged. Printing quantities are determined on the basis of requirements for operational stocks, stockpiles, shelf stocks, requirements of other agencies, and reprinting or revision schedules.

In support of production operations, the Reproduction Division provides camera copy services, film and paper prints, blue-line prints, plastic deep-etch and Watercote prints, and Dystrips.

A separate unit containing lithographic and photographic laboratory facilities is maintained for purposes of research and development. In addition to the new reproduction techniques and processes already described, this unit has developed other new techniques, such as the ACIC Camera Back for precision mosaic framing, use of contact screens for making water area vignettes, and the open-face vacuum frame.

Printed materials are transported to the warehouses of the Distribution Division and are stored according to the major chart categories. Distribution is made direct to Air Force organizations in the Zone of Interior and Northeast Air Command. Bulk shipments are made to the ACIC squadrons and detachments overseas and to Navy depots for further distribution. Most aeronautical information publications are distributed on an automatic basis. While considerable automatic distribution is made of aeronautical charts, great quantities of these items are issued on basis of requisitions. Controlled automatic distribution is made of air target materials. Approximately 95 million copies of charts and related items are distributed annually.

CORRELATION WITH WORK OF OTHER CARTOGRAPHIC AGENCIES

When parallel civil and military requirements exist for an item of aeronautical charting material of the United States, its Territories, or possessions, production responsibility is assumed by the Coast and Geodetic Survey. However, when a cartographic requirement of a military nature is established and it has been determined that no requirement exists for civil use, production is undertaken by ACIC. The major portion of the aeronautical charts covering the United States, its Territories, and possessions are produced by the Coast Survey and the quantities required for Air Force use are obtained on a transfer of funds basis.

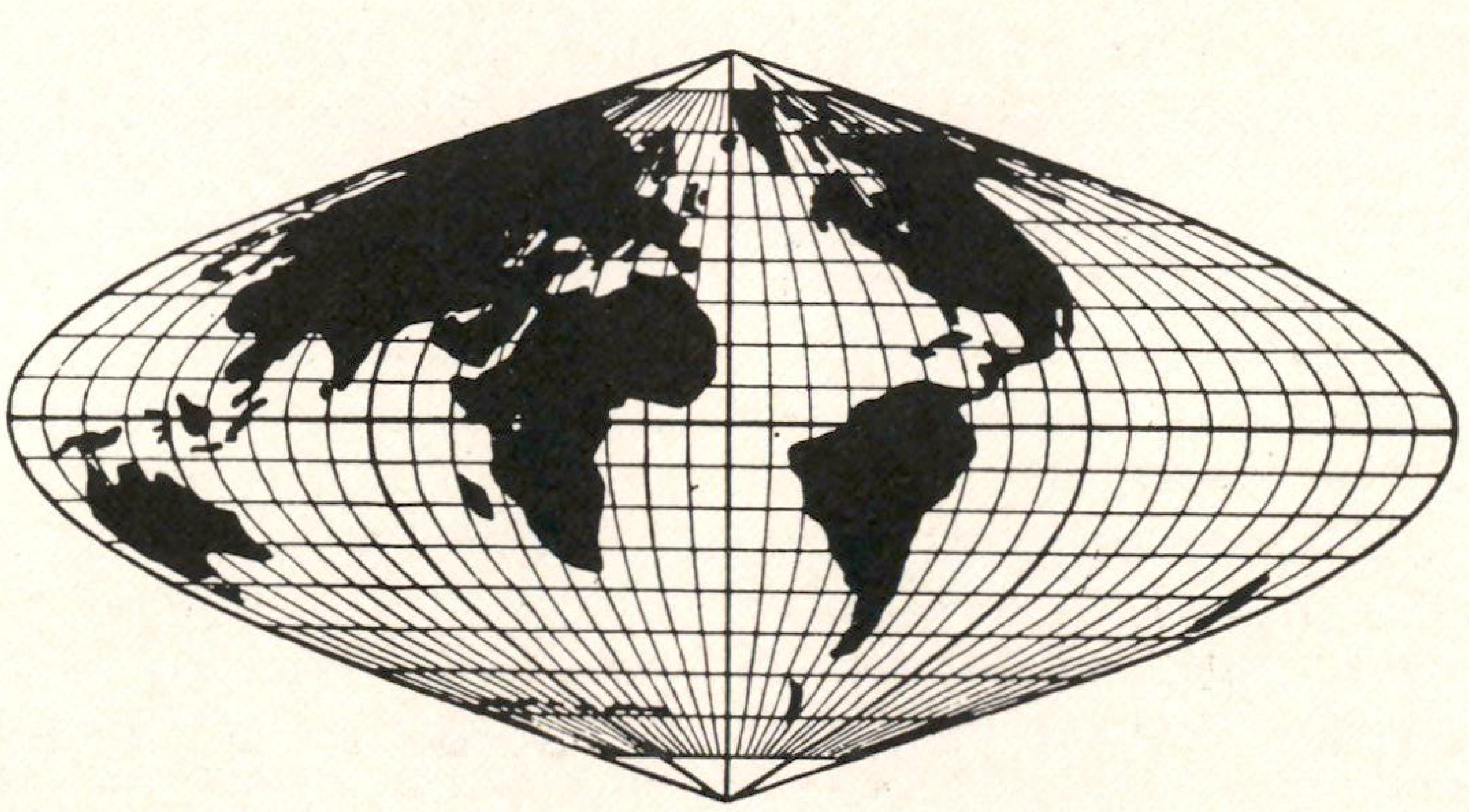
Liaison is regularly maintained with the Coast Survey on matters relating to revision schedules, conformance to specifications, suitability of products of Air Force use, new military cartographic requirements which may also become civil requirements, and availability and accuracy of geodetic data.

Coordination is effected with the Hydrographic Office relative to standardization of aeronautical charts and publications produced by either agency for use both by Air Force and Navy, quantities and delivery of printed charts and publications produced by each agency for joint use, and the procurement of hydrographic data concerning Navy airfields and navigational facilities.

The Army Map Service (AMS) maintains a library of cartographic materials and geodetic data for joint use by Department of Defense agencies. The services of this library are made available to ACIC for collection of source materials required for chart production. Coordination is effected with AMS on joint compilation programs such as the 1:250,000 scale base compilation program in which joint specifications are followed. Requirements of either ACIC or AMS for charts published by the other agency are fully coordinated.

Agreements concerning joint compilation programs by defense agencies are accomplished at meetings held under the auspices of the Photography and Survey Section, Joint Intelligence Group of the Joint Chiefs of Staff. Problems of joint interest to all United States agencies concerned with aeronautical charts and information are presented and resolved at meetings of subcommittees of the Air Coordinating Committee. Production of air target materials is coordinated by Headquarters USAF, Directorate of Intelligence, by assignment to the producing agencies for production of specific items.

Coordination with the Geological Survey of the Department of the Interior and the Soil Conservation Service of the Department of Agriculture, includes the procurement of topographic maps and aerial photography for Air Force use, as well as arrangements whereby these agencies perform certain photogrammetric and cartographic services for ACIC.



BOOKS PUBLICATIONS LITERATURE

Oceanography

THE CIRCULATION OVER THE CONTINENTAL SHELF SOUTH OF CAPE HATTERAS. Dean F. Bumpus, ***Transactions, American Geophysical Union,*** August 1955.

South of Cape Hatteras, a southerly-flowing coastal current, such as is common to the northward, is a transient affair. Such a current, when present, is restricted to a very narrow portion of the continental shelf. The dynamic pressure gradient resulting from the combined effect of the runoff and the cross-shelf thermal gradient together with the prevailing wind and the frictional drag of the Florida Current provides for a northeasterly drift over a broad part of the Carolina continental shelf.

SOME RECENT OCEANOGRAPHIC SURVEYS OF THE GULF OF MEXICO. George B. Austin, Jr., ***Transactions, American Geophysical Union,*** October 1955.

An apparently semi-permanent, large scale, anti-cyclonic eddy repeatedly observed on four earlier oceanographic surveys was investigated in greater detail during Cruise 54-10 of the *A. A. Jakkula,* August-September, 1954. Evidence from the five surveys made in the region of the eddy indicates that the eddy is an integral part of the Gulf Stream system in the Gulf of Mexico. From the single ship survey of Cruise 54-10 an attempt was made (1) to locate and define the eddy, and (2) to establish whether or not it was a temporary or permanent feature of the Gulf of Mexico and the Yucatan Current, or to determine whether or not it changed physically in space and time or both.

SEA TEMPERATURE VARIATIONS ASSOCIATED WITH TIDAL CURRENTS IN STRATIFIED SHALLOW WATER OVER AN IRREGULAR BOTTOM. Dale F. Leipper, ***Journal of Marine Research,*** November 30, 1955.

Unusual features of the large and nearly periodic variations in sea temperature, which are observed in shallow stratified water along the coast of southern California, may be caused by tidal stirring over an irregular bottom and by subsequent horizontal and vertical oscillating movements associated with tides.

INSTRUCTION MANUAL FOR OCEANOGRAPHIC OBSERVATIONS (Pub. No. 607, U. S. Hydrographic Office). Second edition. 1955. 210 pages.

This manual covers the taking and reporting of the various oceanographic observations made by naval and other research vessels in the course of their work. Among the chapters in Part I are: introduction to oceanographic observations, obtaining sea water samples and temperatures, obtaining bottom sediment samples, obtaining biological specimens, sea and swell observations, meteorological observations, water transparency and light absorption measurements, shipboard chemistry, and instructions for recording oceanographic observations, measurements, and samples on log sheets. Part II contains 17 oceanographic codes and tables.

THE FLOOR OF THE OCEAN. Sir Edward C. Bullard, ***Memoirs and Proceedings of the Manchester Literary and Philosophical Society,*** 1955-56.

The oceans are geologically the least known parts of the earth's surface. Continuously recording echo sounders have enabled detailed topographic maps to be made of the sea bottom. The continents are usually bordered by the continental shelves in the edges of which submarine canyons are cut. Many of these canyons are probably produced by turbidity currents. Samples of the bottom sediments can be obtained with coring tubes. The sediments are primarily calcareous in depths less than 2,500 fathoms and consist of red clay at greater depths. The study of long cores may throw light on past climates and on the chemical processes controlling deposition. The deeper structure of the ocean basins can best be studied by seismic methods. The continental shelf has been shown to be a pile of sediments. The unconsolidated sediments in the deep ocean are usually only about 300 m. thick. The Mohorovicic discontinuity (the base of the crust) is only 10 km. deep under the ocean compared with 35 km. under the continents. The nature of the material below the unconsolidated sediments is doubtful, much of it is probably basalt, but there may also be consolidated sediments.

CONFIGURATION OF THE ALEUTIAN RIDGE--RAT ISLANDS--SEMISOPOCHNOI I. TO WEST OF BULDIR I. William Gibson and Haven Nichols, *Bulletin of the Geological Society of America*, October 1953.

The configuration of a 150- by 200-mile section of the Aleutian Ridge, extending from the Aleutian Trench on the south to the floor of the Bering Sea on the north, is presented by means of depth curves at 50-fathom depth intervals. These accentuated the submarine topography and gave substance to many interesting configurations that were not evident on the published navigational chart. In addition to the Aleutian Trench, a submerged central-cone depression, four seavalleys, and many transverse canyons are shown.

Great distortion of the bottom occurs along the edges of the seavalleys and many implications relative to the formation of mountains, island arcs, and trenches can be seen in the configurations. The authors point out that vertical and horizontal movement may take place along inclined step faults. These and the canyonlike transverse faults may outline irregular crustal blocks where differential movement would occur. Most of the earthquake epicenters may be aligned along inferred step faults by allowing for probable uncertainties in their locations. Any definite correlation between earthquakes and submarine topography, it is believed, must wait for more accurate epicenter determinations along the Aleutian Ridge.

INTERPRETATION OF THE CONFIGURATION OF ALEUTIAN RIDGE. Olcott Gates and William Gibson, *Bulletin of the Geological Society of America*, February 1956.

Data from a contour map of the submarine topography surrounding the Near Islands, from the companion map of the Rat Islands by Gibson and Nichols (1953), and from the geology of the western Aleutian Islands suggest that the submarine topography reflects the structure of the western part of the Aleutian Ridge.

Four principle topographic provinces are recognized: (1) the Crest of the Aleutian Ridge contains the Aleutian Islands, the Insular Shelf at depth ranging from present shorelines to 70 fathoms, and the Ridge Shelf at a depth of 100 to 500 fathoms, all apparently the result of subaerial and marine erosion since the middle Tertiary and of glaciation in the late Pleistocene; (2) the Insular Slopes from the sides of the Aleutian Ridge--the North Insular Slope is a long, steep, linear scarp that probably marks a major fracture in the earth's crust; the South Insular Slope appears to be a broad, faulted and warped arch containing numerous steep-sided linear sea valleys and canyons; (3) the Aleutian Bench is a prominent step in the general slope from the islands to the Aleutian Trench, and its inside edge may be the trace of a thrust fault; and (4) the arcuate Aleutian Trench has a steep north side, a flat floor at a depth of about 4,000 fathoms, and a south side containing an en echelon topographic pattern.

A structural interpretation of the submarine topography suggests that the western part of the Aleutian Ridge is an arched and faulted asymmetrical wedge bounded by a northward-dipping normal fault on the north and by a northward-dipping zone of reverse faults on the south. Formation of this wedge probably began with major uplift and faulting of the western Aleutian area during the middle Tertiary, and the many earthquakes and active volcanoes in the Aleutian arc today indicate that deformation is still continuing.

AN ESTIMATE OF THE EFFECT OF TURBULENCE IN THE OCEAN ON THE PROPAGATION OF SOUND. John A. Knauss, *The Journal of the Acoustical Society of America*, May 1956.

A hydrophone monitoring a constant level sound source in the open ocean records a sound whose intensity fluctuates over short periods of time. Previously it has been demonstrated that much of this fluctuation can be accounted for by the temperature microstructure. It has been suggested that another cause of the observed fluctuation could be inhomogeneities in the velocity field (turbulence). This paper is an attempt to estimate the magnitude of turbulence in the ocean. The conclusion is reached that turbulence contributes very little to the fluctuation observed in the intensity of underwater sound signals.

ECHO-SOUNDER OBSERVATIONS OF MIDWATER NETS AND THEIR TOWING CABLES. Richard H. Backus and J. B. Hersey, *Deep-Sea Research*, September 1956.

By echo sounding from a following ship it has been possible to determine the shape of towing cables as well as the depth to a net with varying amounts of wire out. It was found that at 2.5 knots the depth to the Isaacs-Kidd midwater trawl can be closely approximated by computing it from the wire angle measured at the surface.

SUSPENDED ECHO-SOUNDER AND CAMERA STUDIES OF MIDWATER SOUND SCATTERERS.

Henry R. Johnson, Richard H. Backus, J. B. Hersey, and David M. Owen, ***Deep-Sea Research***, September 1956.

Twelve-kilocycle-per-second echo sounders have been lowered in the sea to observe sound scatterers at short range. Once, an echo sounder was lowered to a point midway between the surface and a deep scattering layer to record the latter during its evening ascent. Individual scatterers moved upward at a rate of about 15 feet per minute. It was estimated that there was about one scatterer for each 650 cubic meters of water at the time of the layer's passage by the transducer.

On another occasion a transducer was lowered at night by 35-fathom increments to a depth of about 400 fathoms. Counts of strong scatterers at the several levels were made except in the uppermost level where scattering was too intense. Water volume per scatterer varied from about 800 to 2,000 cubic meters, depending on the depth of the observation.

A camera has also been used with the echo sounder to obtain simultaneous acoustic and photographic records of scatterers. The most successful experiments show a correlation between pictures of fishes and strong echoes.

INTENSITY AND FREQUENCY OF SEVERE STORMS IN THE GULF OF ALASKA.

Edwin F. Danielsen, Wayne V. Burt, and Maurice Rattray, Jr., ***Transactions, American Geophysical Union***, February 1957.

A review of the circumstances surrounding the sinking of the S.S. *Pennsylvania* with all hands in the Gulf of Alaska during January 1952, necessitated an historical survey of severe storms in the Gulf of Alaska. The purpose of the investigation was (1) to determine from weather data the frequency and variability of occurrence of storms which would generate very high waves, and (2) to demonstrate the importance of factors other than measured wind speed such as duration, fetch, and air-sea temperature difference on development of very high wind waves. Criteria were developed for screening out the storms which probably generated high waves and sustained them for long durations. From the records for the winters of 1922-23 to 1951-52, excluding World War II years, 15 storms were selected and critically examined for their wave creating potential. The ***Pennsylvania*** storm of January 8-10, is compared with two other storms of higher wind speeds which did not generate higher waves. In addition, a longer-period storm survey of high January winds shows a large annual variability with January 1952 the extreme.

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Cartography

INVESTIGATION OF THE ACCURACY OF PLOTTING AND SCALING-OFF.

N. D. Haasbroek. ***Netherlands Geodetic Commission***, Delft. 1955. 176 pages.

In this publication, the author establishes the various factors which go to make up the accuracy of plotting and scaling-off with divider and plotting scale, or with tracing point and engineer scale. These factors, which have received scant notice in the literature on land surveying, are submitted to an accuracy test. By applying the law of propagation of errors, one is able to form an idea of the accuracy of plotting and the accuracy with which distances and areas can be scaled-off from the plot.

The factors and their standard mean error in microns, as found by the author and the 28 test persons who cooperated with him, are as follows: (1) plotting an abscissa or an ordinate with a coordinatograph--16; (2) the location of a calibration line on a plotting scale or an engineer scale--6; (3) a scale interval of 1 cm. of a plotting scale or an engineer scale--neglected; (4) plotting a distance with divider and plotting scale or with tracing point and engineer scale--33 to 50; (5) scaling-off a distance with divider and plotting scale or with engineer scale--24 to 43; (6) the perpendicular distance between a plotted point and the pencil line which can be drawn through that point along a triangle--42; (7) the perpendicular distance between an ink line which can be drawn with a ruling pen along a triangle through two plotted points and the theoretical straight line connecting these two points--45; (8) the perpendicular distance between a pencil line which can be drawn along a triangle through two plotted points and the theoretical straight line connecting these two points--40; (9) plotting a point upon a pencil line with a divider or tracing point when the scale is placed along that line--32; (10) the perpendicular position at the top of the "perpendicular" of 10 cm. erected on a base line with triangles--144; and (11) putting a needlepoint of a divider on an ink line from where distances must be scaled-off--estimated 15.

The author concludes his study by using a closed traverse to demonstrate how those factors which are applicable will affect the work and what should be done to reduce the systematic errors.

ERDL DEVELOPMENTS IN PLASTIC SCRIBING. Q. S. Johnson, *Surveying and Mapping*, January-March 1956.

The article discusses the development, design, testing, and evaluation of equipment and techniques used in color-separation drafting by the plastic-scribing process at the Engineer Research and Development Laboratories of the U. S. Army Corps of Engineers. Testing and evaluation procedures are described as are new tools, coated plastics, and such accessory items as permanent-type scribing points, swivel attachments, and lettering and symbolization templates.

MAPPING THE LAND. Arthur H. Robinson, *The Scientific Monthly*, June 1956.

This paper presents the modern methods of topographic mapping. World mapping coverage is briefly discussed. Attention is called to the fact that up to very recent times while the countries of Europe were individually well mapped there was a lack of coordination between the countries. The author describes the relationship between the topographic surface, the geoid, and the spheroid. In the making of a topographic map, attention is focused on photogrammetry including a description of the use of Multiplex projectors. Scribing on plastic and the use of shading in addition to contours are also discussed in connection with the preparation of the map for printing.

NAUTICAL CHART MANUAL (U. S. Coast and Geodetic Survey). H. R. Edmonston, Fourth edition. 1956. 138 pages.

This publication serves principally to give practical guidance to cartographers and draftsmen in the construction and revision of nautical charts. It presents not only the basic facts of chart construction, but also the details of current practice in the Bureau.

The manual is divided into the following parts: Classification of charts, nautical chart terms, rules and practices, topography, hydrography, aids to navigation, projections and grids, geographic names, and terminology. An appendix contains such items as weights of lines, sizes and styles of type, sample notes, conversion tables, scales and equivalents, and border layouts.

Chart No. 1, containing the standard symbols and abbreviation which have been approved for use on nautical charts published by the United States of America, is inserted in a pocket on the back cover. This pamphlet, also available separately, is arranged in accordance with a standard form approved by a Resolution of the Sixth International Hydrographic Conference in 1952.

HOW ACCURATE IS THAT MAP. Morris M. Thompson, ***Surveying and Mapping***, April-June 1956.

The paper discusses the importance of accuracy specifications in topographic mapping, methods of expressing map accuracy, and possible improvements in existing specifications. The following conclusions are reached: (1) existing accuracy requirements for topographic maps need to be clarified, but not tightened; (2) accuracy tolerances should be expressed in terms of standard deviation; (3) vertical accuracy tolerances should be a function of the ground slope; and (4) accuracy-checking procedures should be broadly standardized and made a part of accuracy specifications.

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Photogrammetry

AN ANALYTIC TREATMENT OF THE PROBLEM OF TRIANGULATION BY STEREOPHOTOGRAMMETRY. Hellmut H. Schmid (Ballistic Research Laboratories, Report No. 961), Aberdeen Proving Ground, Md., October 1955.

The report essentially comprises the culmination of a series of supporting reports on the same subject by Dr. Schmid and his associate, Mr. Duane Brown. The other report numbers are 784, 880, 915, 937, and 960. The purpose of the study is the determination of positions of objects whose images are shown on aerial photographs with all possible accuracy by measuring the rectangular coordinates of the images and computing the positions by means of electronic computers. The possible accuracy appears to be considerably better even for block or strip of photographs using random ground control than results obtained by means of first-order plotting instruments using fully controlled single models.

The report includes the mathematical derivations as well as the formulas for evaluating the coefficients of the observation equations. The derivation is geometrically rigorous, utilizing the least squares principle for adjusting the image coordinates for accidental observation errors. The solution calls for 6 unknowns per photograph; a block of 100 photographs gives rise to 600 normal equations.

Corrections for earth curvature, lens distortion, and film distortion are applied. The use of a stereocomparator having an accuracy of 2 microns is assumed for measuring the image coordinates. Premarking ground points are needed to obtain the maximum accuracy of the system. A photograph overlap of 67 to 70 percent in both directions is deemed advisable.

PHOTOGRAMMETRY APPLIED TO CADASTRAL SURVEYS. Herbert F. Trager, *Surveying and Mapping*, January-March 1956.

A recent reallotment project in Germany furnished accuracy data for an extensive photogrammetric application. Root-mean-square errors in the positions of marked boundary stones were limited to ±4.7 inches on 1:6,200 aerial photographs taken from 4,200 feet with lens of 8-1/4-inch focal length. The data were determined by Stereoplanigraph where each model was controlled by a point in each of the four corners and a check point in the center. This accuracy was derived from a consideration of 117 points. Other comparisons were made for two other flying heights and nearly 1,300 more ground control points. The mean difference of photogrammetric measurements and field distances for 183 points at 1:6,200 was only ±3.74 inches. A byproduct of the study was the indication that film shrinkage accounted for an error of about 5 microns at the negative scale.

PHOTOGRAMMETRIC SURVEYS FOR NAUTICAL CHARTS. Bennett G. Jones, *International Hydrographic Review*, November 1955.

The article describes in considerable detail the photogrammetric procedures used in the Coast and Geodetic Survey in connection with the construction and maintenance of nautical charts. Portions of charts are shown as examples of two different types of applications of the techniques. An explanation is given of the techniques and practice of furnishing shoreline compilation and the locations of hydrographic signal sites for the use of the hydrographic surveyor.

The procedures discussed include project and flight planning, aerial photography, the airplane, the cameras, photographic processing, field surveys including control surveys, radial and instrument plotting methods, aerotriangulation, compilation, editing, drafting, and revisions. A detailed description of the nine-lens system is included. The different kinds of map products of the organization are defined.

USE OF AERIAL PHOTOGRAPHS FOR REVISION OF LAND INFORMATION ON NAUTICAL CHARTS. H. R. Brooks, *International Hydrographic Review*, November 1955.

The revision of the land information on nautical charts is done by means of aerial photographs in the Coast and Geodetic Survey wherever applicable. The rapidity and completeness of this type of revision has proved to be an economical, simple, and effective way of showing changes in shoreline, locations of piers, and obstructions to navigation. Special low-altitude aerial photographs are obtained of areas being considered for revision or reprinting. The necessary photographic detail can usually be delineated on the photographs and transferred to a map copy to fit fixed reference details by means of a simple reflecting projector having a variable scale adjustment.

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Tides and Currents

SURFACE WATER TEMPERATURES AT TIDE STATIONS, ATLANTIC COAST, NORTH AND SOUTH AMERICA (Special Publication No. 278, U. S. Coast and Geodetic Survey). *Government Printing Office*, Washington. Fifth edition. 1955. 69 pages.

SURFACE WATER TEMPERATURES AT TIDE STATIONS, PACIFIC COAST, NORTH AND SOUTH AMERICA AND PACIFIC OCEAN ISLANDS (Special Publication No. 280, U. S. Coast and Geodetic Survey). *Government Printing Office*, Washington. Fifth edition. 1956. 74 pages.

These publications contain summaries of surface water temperatures observed daily at tide stations maintained by the Coast and Geodetic Survey and at stations maintained cooperatively with organizations in the United States and other countries. The data are useful to industrial users of harbor and coastal waters, to marine transportation companies, to the Navy and other Federal agencies, to engineers, to research workers in marine biology, meteorology and oceanography, and to the public in general.

The principal table contains monthly and yearly means and extremes, as well as a summary of monthly values for the series, including mean of the monthly means, the maximum and minimum observations, and mean of the monthly maxima and minima. Monthly mean temperature curves showing seasonal trends are included for many stations.

These publications are revised every fourth year.

TIDAL HYDRAULICS. George B. Pillsbury. *Corps of Engineers*, Vicksburg, Miss. Revised edition, May 1956. 247 pages.

This publication gives a development of tides and tidal currents which are of interest to engineers engaged in harbor and waterways improvement. Enough of the theory is presented for the engineers' use and references are made to Coast and Geodetic Survey publications for more details. A method is given for computing currents and tides in a tidal channel from the constants commonly applied to steady flow but with the acceleration and deceleration of a tidal current included. The tidal currents depend upon the acceleration head and the storage and release of water in the channel as well as upon frictional resistance. Examples of computations are included to bring out the methods.

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Sea Level and Coastal Changes

THE SEASONAL OSCILLATION IN SEA LEVEL. June Pattullo, Walter Munk, Roger Revelle, Elizabeth Strong. *Journal of Marine Research,* June 30, 1955.

On the basis of all available tide gauge records, bathythermograms, and Nansen bottle casts, a compilation, on a global scale, was made of monthly departures of *recorded* and *steric* sea levels from their annual means. The steric fluctuation is defined in terms of the seasonal fluctuation in specific volume. The results are given in the appendixes and in three charts, together with error estimates. In general, the departures are comfortably above the uncertainties introduced by year to year variations and by the effects of local topography.

Recorded and steric departures agree remarkably well in low and temperate latitudes (conditions are *isostatic*). In these regions the steric levels are associated largely with temperature fluctuations in the upper 100 m. In high latitudes conditions are indeterminate.

Pronounced semiannual fluctuations are found along the west coast of South Africa, in Indonesia, in corresponding regions of the Labrador and Oyashio Currents, and in the Gulf of Mexico and adjoining Gulf Stream stations. Elsewhere, the oscillations are largely annual in character, with low sea level in each hemisphere during its spring and with high level during the fall. Recorded amplitudes vary from a few centimeters in the tropics to a few decimeters at higher latitudes; they exceed one meter in the Bay of Bengal. Atmospheric pressure effects and long period astronomic tides account for only a small part of the recorded fluctuations.

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Navigation

NAVIGATION DICTIONARY (Publication No. 220, U. S. Navy Hydrographic Office). *Government Printing Office,* Washington. 1956. 253 pages.

A comprehensive dictionary of navigational terms. The purpose of the volume is to furnish the navigator of any type craft with definitions that represent present usage. The Preface states that while it is recognized that the selection of terms to be included is necessarily somewhat arbitrary, it is also realized that in some instances terms do not have universally or even generally accepted meanings, and also that different terms are used with the same meaning. This is particularly true with respect to abbreviations and symbols. In resolving such difficulties, consideration has been given to the authoritativeness of the source, the extent of usage, logic, and consistency. In some instances, synonyms are given.

The definitions are followed by a table of abbreviations, pertinent symbols, and a bibliography of principal sources used.

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Geodesy

THE HEIGHT OF MOUNT EVEREST, "A NEW DETERMINATION (1952-1954)." B. L. Gulatee. Technical Paper No. 8, *Survey of India,* Dehra Dun. 1954. 23 pages.

This pamphlet describes the geodetic work carried on by the Survey of India on the plains of Bihar and in the Himalayan foothills between 1946 and 1954, which was used in computing the new value of 29,028 feet for the height of Mount Everest. New triangulation placed stations at distances of 30 to 40 miles from the peak. This work was reinforced by 3 measured bases and 3 spirit-leveled connections. The peak was observed from 8 stations in this scheme ranging in height from 8,670 to 14,762 feet. A comprehensive program of plumb-line deflections and gravity observations were carried out to delineate the geoidal rise under Mount Everest. Better values for the coefficient of refraction were available due to the research that has been carried on since the beginning of the century. The author states that the weighted mean value worked out to be 29,028 feet with a probable error of

±0.8 foot, derived from internal evidence alone, and that the odds are 20 to 1 against this value being in error by more than 10 feet.

SURVEYING AND MAPPING FOR A HYDRO-ELECTRIC DEVELOPMENT. D. J. Fraser and A. D. Hartwell, Separate No. 731, *Proceedings of the American Society of Civil Engineers*, June 1955.

This paper describes the methods and procedures employed in obtaining accurate surveys and maps of a proposed hydro-electric development. The area involved is the watershed of the McCloud River in the north central part of California. This river, which has a large undeveloped power potential, rises on the slopes of Mt. Shasta and flows southwesterly through rugged mountainous country with deep canyons and heavy timber, finally emptying into the Shasta Reservoir.

The paper discusses reconnaissance, aerial photography, triangulation, and other features necessary for producing the surveys and maps for the proposed development.

PLANE COORDINATE INTERSECTION TABLES (2-1/2 MINUTE) (Special Publications Nos. 333 and 335 to 344, U. S. Coast and Geodetic Survey), *Government Printing Office*, Washington. 1955-1956.

These publications are a continuation of the series originally reported in the June 1953 issue of The Journal, which contained a description of the tables and their use. Additional numbers in the series were reported in the August 1955 issue.

The present publications contain the tables for the following states in the numerical order indicated above: New Jersey, Texas, Ohio, Nevada, Washington, Maine, New Hampshire, Kentucky, Rhode Island, Vermont, and New Mexico. The tables for Texas, Ohio, Washington, and Kentucky are based on the Lambert conformal projection; those for the other states employ the transverse Mercator projection.

GEODETIC LEVELING INSTRUMENTS (Special Publication No. 334, U. S. Coast and Geodetic Survey). D. L. Parkhurst, *Government Printing Office*, Washington. 1955. 19 pages.

The expansion of the geodetic leveling program of the Coast and Geodetic Survey, and leveling outside the United States by other organizations, which rely on the Survey for servicing their equipment, has necessitated redesign of the level and rod from the standpoint of production and maintenance. The purpose of this publication is to furnish a description of the latest design and methods of construction.

Changes in the design of the geodetic level include the mounting of the telescope on cylindrical pivots, replacing the conical type of the previous design. A plate of graphite-impregnated bakelite has been set into the under side of the telescope at the bearing point of the lifting cam to eliminate the wear on the telescope itself. Near the front end of the telescope housing a spring and plunger have been added to insure that the telescope rests on the point of the tilting screw during observations.

The rod has undergone a complete redesign with a view to longer life, elimination of objectionable color change, greater structural strength, and reduction of cost of reconditioning.

INTRODUCTION TO THE GEODIMETER. G. R. L. Rimington, *Cartography* (Australian Institute of Cartographers), March 1956.

The geodimeter combines optics and electronics into a unit of equipment which is used for measuring unknown distances in terms of an established velocity of light. The purpose of the paper is to produce, by taking minor liberties, "a down to earth description of the instrument that can be easily followed." The author describes the transmitter and receiver units of the instrument, and the method of measuring the time interval required for the beam of light to travel from the transmitter to the mirror and back to the receiver.

FIELD USE OF THE GEODIMETER. C. K. Waller, *Cartography* (Australian Institute of Cartographers), March 1956.

This article is a companion paper to the one noted above. The previous paper discusses the theoretical aspects of the instrument. This paper reports on experiences of the National Mapping Office of Australia with the geodimeter in the field. Extensive tests were made during all seasons and under varying atmospheric conditions. The instrument proved rugged enough to stand up during transportation even over severe road conditions. During the tests the Bergstrand velocity of light was used--299,793.1 km./sec. However, after analysis of the results of geodimeter measurements of geodetic base lines both in Australia and elsewhere, together with recent laboratory measurements, a decision was made tentatively to adopt a value of 299,792.5 km./sec.

THE ESTABLISHMENT OF AN INTERNATIONAL GRAVITY STANDARD. G. P. Woollard, J. C. Rose, and W. E. Bonini, *Transactions, American Geophysical Union,* April 1956.

A program of pendulum and gravimeter measurements for the establishment of a gravity standard between Mexico and Alaska is described. The problems involved in obtaining precise measurements with pendulums are discussed, and values for three independent sets of pendulum measurements and gravimeter measurements are compared.

TACHEOMETRIC SURVEYING--METHODS AND INSTRUMENTS. William Mussetter, *Surveying and Mapping,* April-June and Oct.-Dec. 1956.

Tacheometric instruments important to the surveyor may be subdivided into two groups: (1) Those which measure an intercept on a distant staff by means of a fixed parallactic angle; and (2) those which measure the angle subtended by a fixed base.

Part I covers the instruments in the first group and are those employing the familiar stadia-intercept principle, double-image tacheometers, and instruments involving the tangential principle (no longer manufactured). Relative merits of the instruments and sources of error in the measurements are discussed.

Part II covers the instruments in the second group. A discussion of the theory of subtense measurements is included and the author describes methods of short-base triangulation and traverse with short-base triangles. A survey of the latter type in Norway resulted in loop closures ranging from 1:7,500 to 1:10,000. An Army Map Service traverse of 34 courses over a length of 13.3 kilometers gave a closure between triangulation, using six-position angles, of 1:8,900.

SUBSIDENCE OF THE LAND SURFACE IN THE TULARE-WASCO (DELANO) AND LOS BANOS-KETTLEMAN CITY AREA, SAN JOAQUIN VALLEY, CALIFORNIA. J. F. Poland and G. H. Davis, *Transactions, American Geophysical Union,* June 1956.

Releveling of bench marks in 1953 and 1954 by the U. S. Coast and Geodetic Survey indicates that subsidence of the land surface has now exceeded 10 feet in two areas of the San Joaquin Valley. In the Tulare-Wasco (or Delano) area of Tulare County, subsidence which was as much as 5 feet in 1940 now has about doubled. The maximum rate of subsidence in recent years has been about 0.8 foot a year. In the Los Banos-Kettleman City area of western Fresno County, major subsidence extends from Ora Loma on the north to beyond Huron on the south, a distance of 70 miles or more. The maximum rate there approaches 1 foot a year. Plots of subsidence against decline in artesian pressure suggest that pressure decline is a major cause of the subsidence. Compaction of the soil after irrigation is known to have caused substantial local subsidence in the Los Banos-Kettleman City area, and tectonic adjustment and other causes also may have contributed to the subsidence.

CRUSTAL MOVEMENT IN CALIFORNIA AND NEVADA. C. A. Whitten, *Transactions, American Geophysical Union,* August 1956.

In 1951, about 20 years after the original surveys, resurveys were made of two small triangulation nets crossing the San Andreas Fault--one near Monterey, and the other in the vicinity of San Luis Obispo. The results confirm the northwestward movement of the oceanic block relative to the continental block. These linear displacements may be expressed in terms of angular distortion within the earth's crust. The change in azimuth is about one second of arc every 10 years.

Similar surveys were made in the Imperial Valley in California in 1941 and again in 1954. The results here show that points on the west side have moved about 6 feet relative to points on the east side.

In the vicinity of Dixie Valley, Nevada, a survey was made in the summer of 1954. A severe earthquake occurred in December 1954 and the survey was repeated in the summer of 1955. The results of these surveys show that points on the west side of the fault moved northward and those on the east side shifting, the maximum relative displacement being about 8 feet. Precise leveling in the Dixie Valley area show vertical movement in addition to the horizontal displacements. The floor of the valley has dropped 2 feet on the east side and 5 feet on the west side, showing a tilt.

A STATISTICAL ANALYSIS OF HIRAN MEASUREMENTS. Joseph L. Stearn and Ernest J. Parkin, *Transactions, American Geophysical Union,* December 1956.

A study of many sets of observations of electronic distances is discussed with the purpose of formulating a statistical testing procedure for making a decision to accept or reject a mission of one day's observations. Significance tests, making use of a difference between group means and standard deviation of groups, give a reasonable criterion for ascertaining whether group means show a significant difference and whether individual measurements appear to "belong to different populations."

A standard deviation of 0.0022 obtained from experience indicates that a mission with group means differing by 0.0025 can be accepted without much risk of being wrong, provided the individual measurements are sufficiently accurate. Arbitrary limits set upon difference of group means, and deviations of individual measurements from a group mean, can result in rejection of missions which by use of several significance testing techniques will indicate acceptance.

Where there is sufficient doubt whether to accept or reject, and a mission is rerun, an analysis of variance can be utilized in order to determine if all the data may be combined with a grand mean as the final adopted value.

SURVEYING FOR CIVIL ENGINEERS. Philip Kissam. ***McGraw-Hill Book Company, Inc.***, New York. 1956. 716 pages.

This textbook is a continuation of the author's book entitled "Surveying-Instruments and Methods for Surveys of Limited Extent," published by the same company in 1947. The author's stated purpose of the new book is "to cover surveying operations which, because of their size, permanence, importance, or the need for high accuracy, have special requirements for precise measurements, efficient procedures, or special operations."

The book is divided into five parts. Part I, which is entitled Instruments and Methods for Large Surveys, contains, besides the introduction, chapters dealing with the equipment and methods for precise leveling, precise taping, and triangulation. Other chapters in this part cover the compass, simple control surveys, and topographic surveys. Part II, Operations, deals with the special operations involved in celestial observations, and in boundaary, public land, city, mine, hydrographic, and bridge and tunnel surveys. Part III, Procedures for Precise Control, is devoted mainly to the computation and adjustment procedures for precise leveling triangulation, and traverse. Part IV is entitled Aerial Surveying, and Part V is the Appendix which contains chapters dealing with the theory of probability, least squares, and the State Plane Coordinate Systems.

The author's idea in dividing his book has been to provide a text for a course which could be terminated at any time after Part I. He recommends, however, that a minimum course should include Parts I and II and at least some sections of Part IV.

ONE HUNDRED AND FIFTY YEARS OF ACCURACY. H. Arnold Karo, ***Public Works***, January 1957.

This article deals with the geodetic aspect of the work of the Coast and Geodetic Survey and its practical application to mapping, particularly for public works engineers and surveyors. The broad scope of the geodetic work of the Bureau is covered, and the point stressed that products of the Survey are the results of a century and a half of accuracy. Geodetic survey methods are described, including the measurement of base lines, first- and second-order triangulation, and leveling. Description and spacing of geodetic markers are treated, and reference is made to the determination of horizontal positions in terms of State Plane Coordinates. Specific mention is made of the application of geodetic control to city, county, and state surveys. The demand for this control for various scientific and defense projects is pointed out, as well as for specific large public engineering projects. Special reference is made to the use of geodetic control in aerial mapping.

A NEW DETERMINATION OF THE FIGURE OF THE EARTH FROM ARCS. Bernard Chovitz and Irene Fischer, ***Transactions, American Geophysical Union***, October 1956.

As part of a broader study on the figure of the earth, a tentative size is derived, based on four arcs: a meridional arc extending from South Africa to Scandinavia, a meridional arc extending from Chile to Canada, a parallel traversing the United States, and a parallel extending from western Europe to Siberia. The first two arcs were completed within the past 3 years and are the longest of their kind ever available--about 100° in length. The information they supply on the earth's size is presented here for the first time.

The data were applied in two forms: astrogeodetic (free-air), and isostatically reduced deflections. The solutions assumed a flattening, $f = 1/(297 \pm 1)$. The following values were obtained for the semi-major axis a: free-air, 6,378,240 ± 100 m.; and isostatic, 6,378,285 ± 100 m. As a single value, 6,378,260 ± 100 m. can be taken. The uncertainty of a is due not only to the data, but also in large measure to the assumed uncertainty in f, and to an uncertainty due to the systematic undulations of the geoid as given by Jeffreys.

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Geomagnetism

LONG-PERIOD VARIATIONS IN GEOMAGNETIC ACTIVITY. Edwin J. Chernosky, *Transactions, American Geophysical Union,* August 1955.

The correlation shown by Bartels between annual means of the sunspot number and of the magnetic *u* figure is markedly improved when means of two longer periods are used. These are the fundamental solar periodicities—the 11-year sunspot-number and latitude cycle, and the 22-year sunspot magnetism cycle. A plot of 11-year running means shows a 22-year variation not too evident in Bartels' annual means, and 22-year running means show a secular low at about 1900, with generally rising activity since then in both the objective *u* and the subjective *C* measures. Differences in *u* and *C* are ascribed more to evaluations of different regions of the magnetic time-variation spectrum than to inconsistencies of *C*.

A PRELIMINARY REPORT ON MODEL STUDIES OF MAGNETIC ANOMALIES OF THREE-DIMENSIONAL BODIES. Isidore Zietz and Roland G. Henderson, *Geophysics,* July 1956.

Model experiments were made to devise a rapid method for calculating magnetic anomalies of three-dimensional structures. The magnetic fields of the models were determined using the equipment at the Naval Ordnance Laboratory, White Oaks, Md. An irregularly shaped mass was approximated by an array of prismatic rectangular slabs of constant thickness and varying horizontal dimensions. Contoured maps are being prepared for these magnetic models at different depths and for several magnetic inclinations. The fields of these three-dimensional structures are obtained by superimposing the appropriate contoured maps and adding numerically the effects at each point. The equipment and laboratory methods are described. Theoretical and practical examples are given.

ARCTIC ASPECTS OF GEOMAGNETISM (The Dynamic North, Book 1, Part 12). David G. Knapp. *Office of Chief of Naval Operations,* Washington. 1956. 70 pages.

Four centuries of accrued data on the distribution and fluctuations of geomagnetism in the Arctic are reviewed and discussed, with special emphasis on the more complete and accurate data obtained during protracted stays in the North. Coverage is comprehensive, with nearly 400 references, although no actual data are tabulated. The article also reviews the problems to be considered in planning and conducting observations in this field, the nature of the patterns to be expected in the vicinity of the magnetic poles, and the special conditions that attend the use of any type of magnetic compass in modern aircraft at high latitudes.

EARTH'S MAGNETISM. W. M. Elsasser, *Smithsonian Contributions to Astrophysics,* Vol. 1, No. 1, 1956.

The author presents a concise and cogent discourse on the prevalent ideas concerning the sources of the earth's magnetism and of its secular change, as ascribed to a fluid, metallic core. The reader is introduced to such new concepts and recent findings as toroidal fields, differential rotation between mantle and core, geomagnetic westward drift, shearing and twisting of lines of force to produce amplification of fields, and the important distinction between two-dimensional notions (which cannot give rise to dynamo action) and three-dimensional ones (which can).

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Seismology

MICROSEISMS AT BERMUDA. Dean S. Carder, *Transactions, American Geophysical Union,* October 1955.

From an examination of above-normal microseisms recorded on the Bermuda Milne-Shaw seismograph over several hurricane and winter seasons, it was found that in all cases, if the periods were 4 to 5 seconds or if the microseisms were strong, they could be attributed indirectly to local weather conditions. Occasionally weak 7- to 10-second microseisms could be traced to storm conditions from as far away as the coast of Alaska, but absorption of all microseisms across the northwest Atlantic is relatively high. Strong microseisms may be generated when local storm conditions are not apparent but when the wind is favorable for the production of opposing swells.

TRANSMISSION OF MICROSEISMS ACROSS NORTH AMERICA AND THE WESTERN NORTH ATLANTIC. Dean S. Carder, *Transactions, American Geophysical Union,* October 1955.

A comparison of microseisms recorded at Bermuda and North American stations indicates that the North Atlantic between the continent and Bermuda has a relatively high absorption rate for microseisms having periods of 10 seconds or less. If the source area is on the margin of the continent and the period on the continent is 6.5 to 9 seconds, energy absorption over a 1,000-km. oceanic path is probably at least an order greater than over an equal continental path, and absorption rates of the longer periods are relatively less. The oceanic passage is accompanied by a slight increase in period. All 4- to 5-second microseisms recognizable on the Bermuda Milne-Shaw records are believed to have local sources.

STRONG-MOTION RECORDS OF THE KERN COUNTY EARTHQUAKES. Frank Neumann and William K. Cloud, *Bulletin 171 of California State Division of Mines*, November 1955.

The Coast and Geodetic Survey program of earthquake investigation is outlined and some results from the July 21, 1952 Kern County earthquake are given. Distribution of intensity in the 160,000-square mile felt area of the shock is discussed and is summarized by an isoseismal map. Strong-motion seismograph results are indicated, and the relationship between acceleration, intensity, and distance examined. Damage due to permanent shifting of the ground is mentioned and possible causes suggested. The paper concludes with a comparison between the July 21 earthquake and the August 22 aftershock.

LABORATORY STUDIES OF GRAVITY WAVES GENERATED BY THE MOVEMENT OF A SUBMERGED BODY. R. L. Wiegel, *Transactions, American Geophysical Union,* October 1955.

In order to gain some insight into the phenomenon of gravity waves generated by underwater seismic disturbances (the tsunami), a laboratory study was made of the waves resulting from an idealized two-dimensional model of the movement of a submerged body. Bodies of several shapes, sizes, and weights were allowed to drop vertically or to slide down inclines of several angles, in waters of various depths, from several heights above the bottom, but always below the water surface. The surface time histories were recorded at a point close to the origin of the disturbance, and at a point or points some distance from the origin. In addition, motion pictures were taken of several of the tests. It was found that a crest always formed first, followed by a trough from one to three times the amplitude of the first crest (depending primarily upon the slope of the incline), followed by a crest with about the same amplitude as the trough. Because of the dispersive qualities of the waves, additional crests and troughs continued to form with increasing distance from the origin. The magnitude of the amplitudes depended primarily upon the submerged weight of the body, but also upon the depth of submergence, the water depth, and other characteristics of the generation. Within the limits of experimental conditions, it was found that the time intervals between the first and second crests remained constant, regardless of the water depth, the distance of fall, the weight of the body, or the time of the fall. It was, however, found to be related to the length of the body, with the period increasing with increasing length, and to the slope of the incline, with the smaller the incline the greater the period.

U. S. EARTHQUAKES 1953 (Serial Publication No. 785, U. S. Coast and Geodetic Survey). L. M. Murphy and W. C. Cloud. *Government Printing Office*, Washington. 1955. 51 pages.

U. S. EARTHQUAKES 1954 (Serial Publication No. 793, U. S. Coast and Geodetic Survey). L. M. Murphy and W. C. Cloud. *Government Printing Office*, Washington. 1956. 110 pages.

These publications are summaries of earthquake activity in the United States and regions under its jurisdiction. They are part of the earthquake series issued annually by the Survey, and contain descriptive data of all felt and damaging earthquakes, reports on well-water fluctuations caused by earthquakes in the United States, a list of worldwide earthquakes located by the Survey, and a report on the strong-motion instrumental results obtained during the year.

The 1954 issue contains details of a series of strong earthquakes in Nevada culminated by the Fairview Peak earthquake of December 16, 1954. A major feature of this shock was a series of spectacular surface ruptures extending for a distance of approximately 55 miles, with vertical displacements up to 10 or more feet.

THE FALLON-STILLWATER EARTHQUAKES OF JULY 6, 1954 AND AUGUST 23, 1954. Series of 5 papers by Perry Byerly; David B. Slemmons; Don Tocher; K. V. Steinbrugge and D. F. Moran; and William K. Cloud; *Bulletin of the Seismological Society of America*, January 1956.

West central Nevada's short earthquake history since 1860 includes a relatively large number of severe shocks. The Fallon-Stillwater earthquakes were the strongest on record in the area. The papers give the geologic setting for the earthquakes, details of movement along the Rainbow Mountain Fault, an analysis of the damage caused, and a study of intensity distribution and instrumental results. The papers include 11 maps, 29 photographs and a number of tables and drawings.

A COMPARISON OF EARTHQUAKE ACCELERATIONS WITH INTENSITY RATINGS. John Hershberger, *Bulletin of the Seismological Society of America,* October 1956.

The maximum accelerations recorded on 108 strong-motion records obtained in 60 earthquakes were compared with intensity ratings assigned to the places where the records had been obtained. The results seem to show that acceleration alone cannot be used as a measure of intensity.

THE SEISMOGRAPH AND THE SEISMOGRAPH STATION (Processed Publication, U. S. Coast and Geodetic Survey). Dean S. Carder. 1956. 24 pages.

A guide to institutions or persons who wish to install and operate a seismograph station, to those who may be persuaded to install and operate a seismograph, or to those who wish to improve existing stations. This brochure gives aids in the selection of sites for seismograph stations, and on the selection of instruments.

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Electronic Instruments

SOME ASPECTS OF ELECTRONIC SURVEYING IN OFFSHORE AREAS. G. A. Roussel, Paper No. 857, *Proceedings, American Society of Civil Engineers,* December 1955.

This paper describes some of the electronic systems used for radiolocation work, with special emphasis on their use by geophysical crews in petroleum exploration work in the Gulf of Mexico.

The circular methods, in which the position is defined by the intersection of two or more circular arcs centered on known fixed points, are first described. In this category, the author describes and evaluates Radar, Sonic, Shoran, and Electronic Position Indicator methods as follows: Radar, utilizing a conventional search unit, has a range from 12 to 25 miles on passive targets such as an oil derrick on an offshore platform, decreasing to 2 to 5 miles if a wire mesh corner reflector is located on a buoy. Representative figures given for accuracies obtainable, using an accurate ranging unit in conjunction with the search unit, are from ±200 to ±300 feet at a range of 2 to 3 miles to ±500 to ±600 feet at a range of 10 to 12 miles. This method is available to everyone. The sonic method involves buoys, generally called "sonobuoys," which have a hydrophone and a radio transmitter. The former picks up the sound vibrations from the water which triggers the latter. The range of this method as used in geophysical work is limited to 6 to 12 miles. The author states that the advantages of this method are that the time of detonation of the explosive charge and the time of the radio signal from the sonobuoy can be recorded on the seismograph record so that a permanent record can be made of each fix. Also, the radio frequencies necessary for this method are available without too much difficulty. Shoran and EPI are both discussed briefly. The paper brings out the fact that while these methods are both accurate and extremely useful, they require radio frequencies which are usually assigned to the military agencies. Therefore, these methods are not available for commercial operation.

The hyperbolic methods--Loran, Raydist, Lorac, and Decca--in which the position is defined by the intersection of two hyperbolic lines of position, are described. Loran is dismissed with the comment that it is a long-range radionavigation method without sufficient accuracy for surveying purposes. The author points out that fundamentally Raydist requires 3 radio transmitter locations and a relay station on shore. Using the Gulf coast Raydist networks accuracies of ±200 to ±300 feet are obtainable at ranges up to 125 to 150 miles offshore. At short ranges he states that the accuracy improves to a maximum of ±15 to ±25 feet in the center of the network. Lorac is based on the same principles as Raydist but it does not employ the separate relay station. It is pointed out that the range and accuracy of the Lorac method is comparable to that of Raydist when the two use almost identical frequencies and geometric configurations of the base stations. Decca, an English system, has a range somewhat greater than Raydist and Lorac but should have somewhat less accuracy. However, the frequencies required for Decca are not available in the United States.

INTERPRETATION OF HIGH-RESOLUTION ECHO-SOUNDING TECHNIQUES AND THEIR USE IN BATHYMETRY, MARINE GEOPHYSICS, AND BIOLOGY. S. T. Knott and J. B. Hersey, *Deep-Sea Research,* December 1956.

Experience in making observations with commercially available correlation recorders designed for sounding ocean depths has suggested design modifications which would combine the capabilities of both shallow- and deep-water sounders in one instrument as well as improve their general performance for research. The design and construction of such a recorder is described. Some examples are given of its application to the study of smaller-scale bottom features; to the echolocation of fish schools, individual fishes, and other aggregations of marine animals; and for locating instruments in depth and range.

Occasionally, echo-sounder pings penetrate the bottom to reflect from deeper horizons; the recorder then presents a continuous-structure section. By using a sound source having a broad spectrum instead of the usual single-frequency ping, and by extending the receiver designed to record in two or more filter bands, shallow structures have been observed which could not be recorded with the high frequency of the conventional echo sounder.

AN ELECTRONIC SEA-WAVE RECORDER. V. Narayana Rao, ***Transactions, American Geophysical Union,*** February 1957.

This article describes a surface type of sea-wave recorder which is based on the principle of the variation in the capacitance between the sea water and an insulated wire placed vertically in it with changes in the level of the sea water. This change in capacitance is used to modulate the frequency of an oscillator. An electronic unit is used for recovering from the frequency modulated signal an electrical voltage which is an exact replica of the sea wave. This electronic unit is described in detail. The type of recording suitable for various applications and also the performance characteristics of this instrument are also discussed.

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Miscellaneous

STEADY AS YOU GO. Robert F. A. Studds. *Dodd, Mead & Company,* New York. 1956. 306 pages.

"Steady As You Go" is of the career-type books, planned to tell the story of the Coast and Geodetic Survey, to the young engineer who may be contemplating joining its commissioned ranks. It is written in the language of the layman, yet contains an accurate account of the intricate operations of the Survey. The story is woven around the adventures of a young engineer during his first years in the commissioned service of the Survey. It carries the reader to a steel-tower triangulation party in Wisconsin, the Washington office of the Bureau, a mountain triangulation party in Arizona and New Mexico, a river leveling party in Utah, a ship in the Gulf of Mexico which is doing ship hydrography and coastal topography, a combined operations party working from a small vessel in southeastern Alaska, a major ship operating in Bristol Bay, Alaska, and an aerial-photographic party working in northern Alaska. The overall work of each party is explained to the young engineer as well as the specific part of the operations that will be his responsibility.

SCIENTIFIC WRITING. Meta R. Emberger and Marian R. Hall. ***Harcourt, Brace and Company,*** New York. 1955. 468 pages.

This text and reference book contains 15 chapters and 2 appendixes. The first 6 chapters emphasize the intellectual activity that must precede composition. Chapter 7 discusses the problem of directing the paper to the reader. Scientific style and techniques of exposition are covered in chapters 8 and 9. The research paper, the short report, and the long report are each presented in separate chapters. Special types of papers, such as the abstract, the case history, and the book review follow in a single chapter. The last two chapters cover the format and illustrations. One appendix contains selected readings and word lists, and the other a group of representative business letters.

WORLD MAPPING. H. Arnold Karo, *Surveying and Mapping* Oct.-Dec. 1956.

The article emphasizes governmental responsibility for basic mapping programs to provide the necessary details for proper development and administration in all categories. Reviews the extent of world mapping and concludes that not more than 25 percent of the land area of the world is covered with even reconnaissance type topographic maps at a scale of 1:250,000 or larger. The appraisal shows further that only about 5 percent of the land surface has large-scale maps based on adequate geodetic control, that 8 to 10 percent is covered with secondary large-scale maps, and about 5 percent has inferior large-scale coverage lacking in adequate control. Four world maps are included showing the present status of topographic mapping, nautical charting, aeronautical charting, and triangulation.

WATER--THE YEARBOOK OF AGRICULTURE, 1955 (U. S. Department of Agriculture). *Government Printing Office,* Washington. 751 pages.

This volume provides a means by which the technical specialist, scientist, and farm and civic leader, can obtain a comprehensive background for understanding the implications of present water problems. In the broadest sense, the book is centered about the problems of agriculture, but it reaches far beyond the farm to the factors involved in the making and prediction of weather, runoff, erosion, sedimentation, infiltration, and surface- and ground-water flow. It considers watershed, forest and range management, recreational, wildlife, domestic and irrigation needs, conservation, flood control, legal and legislative implications, and fundamental scientific research. The book contains many topics, each authored by a specialist in the field.

UNITED STATES COAST AND GEODETIC SURVEY (1807-1957). Gilbert T. Rude, *The Retired Officer*, Jan.-Feb. 1957.

This article deals largely with a comparison of methods used in the early work of the Coast and Geodetic Survey and those used today. Practically every phase of the Bureau's work is discussed and the vital uses of its products are shown. Comparison is made between early lead-line sounding and present-day echo sounding, pointing up the tremendous saving in time that results. The older methods of position fixing are contrasted with the modern electronic methods.

THE COAST AND GEODETIC SURVEY--150 YEARS OF HISTORY. A. Joseph Wraight and Elliott B. Roberts. *Government Printing Office*, Washington. 1957. 89 pages.

This publication was prepared in commemoration of the Sesquicentennial of the Coast and Geodetic Survey. It highlights the significant events in the 150 years of service to commerce, industry, and the national defense, and recalls the contributions of the many outstanding personalities that have been associated with its long history.

The events of the Survey are treated broadly in three chronological periods of approximately a half-century each. The first three chapters comprise the first period and carry the Survey from its early beginning through the Civil War. The next two chapters cover the period up to World War I--an era characterized by great areal expansion of the Nation and corresponding increase in the Bureau's responsibilities. The last three chapters take in the events from World War I to the present time--the period of acoustics, photogrammetry, and electronics.

The appendixes include a glossary of special terms, a list of source material, and a chronological list of the Bureau's superintendents and directors.

COAST AND GEODETIC SURVEY--HIGHLIGHTS OF 150 YEARS. Elliott B. Roberts, *United States Naval Institute Proceedings*, February 1957.

The article deals with the early history of the Survey, its development through the years, some of the outstanding personalities, and a brief coverage of what the Survey is today. Particular emphasis is given to naval figures who participated in the early work, as well as to events of naval interest including the war services of the Bureau.

SESQUICENTENNIAL OF COASTAL CHARTING. Albert A. Stanley, *The Military Engineer*, Jan.-Feb. 1957.

This article describes the origin and development of the Coast and Geodetic Survey, through its formative period under the leadership of Hassler and Bache, to the comprehensive organization it is today. Emphasis is placed on the high degree of support and cooperation between the various military organizations and the Coast and Geodetic Survey. It highlights the contributions the Survey has made to the national defense during the Civil War and during both World Wars.

WHERE ARE OUR SEAWARD BOUNDARIES? A. L. Shalowitz, ***United States Naval Institute Proceedings***, June 1957.

This paper points out the inadequacy of using general language in treaties, state papers, and legislative enactments, in so far as delimitation of the seaward boundaries of our country is concerned. Unless appropriate criteria for interpreting such language are available, the boundaries can neither be demarcated on the ground nor laid down on a chart with any degree of engineering certainty. Some of the problems and their solutions are presented in the context of historical precedents in the judicial and executive fields. The paper also discusses recent developments on the international scene in this field, particularly as reflected in the final report on the Law of the Sea, submitted to the United Nations in July 1956 by the International Law Commission, and examines its recommendations against the background of established American practice.

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SHIP ***EXPLORER,*** ONE OF THE PRESENT FLEET OF SURVEY VESSELS

Cumulative Index
The Journal of the Coast and Geodetic Survey
Numbers 5 to 7

Cumulative Index—Numbers 5 to 7

This Index is subdivided into Principal Articles and department sections as listed in the Contents of each issue. There is also included a subdivision on Miscellaneous Items under which all shorter items having reference value are indexed. The principal articles are indexed by author and title and other items by title only. However, all department material and miscellaneous items by Coast Survey personnel are indexed by author under Principal Articles and cross-referenced to the appropriate subdivision. There are also included in the Principal Articles subdivision a number of general classifications, such as Alaska, Electronics, Geodesy, Hydrography, etc., under which all articles dealing with those classifications are indexed by Journal number and page.

The following numbers of ***The Journal*** of the Coast and Geodetic Survey are included in this index:

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PRINCIPAL ARTICLES

FEDERAL SURVEYING AND MAPPING AGENCIES

NEW PROCEDURES

RECENT LEGISLATION

NOTES ON INTERNATIONAL SCIENTIFIC

Notes on the following meetings will be found in the issues indicated: Air Navigation Conference--ICAO, (1956) No. 7--137; Astronomical Union, (1952) No. 5--178, (1955) No. 7--134; British Commonwealth Survey Officers' Conference, (1955) No. 7--133; Committee on the Nomenclature of Ocean Bottom Features, (1954) No. 6--173; Congress of the Onomastic Sciences, (1955) No. 7--133; Congress on Photogrammetry, (1956) No. 7--136; Consultation on Cartography, (1952) No. 5--176, (1955) No. 7--133; Geographical Congress, (1952) No. 5--177; Gravity Commission, (1953) No. 6--173; Hydrographic Conference, (1952) No. 5--173, (1957) No. 7--137; Pan American Committee for the International Geophysical Year, (1956) No. 7--136; Special Committee for the International Geophysical Year, (1954) No. 6--172, (1955) No. 7--135; Union of Geodesy and Geophysics, (1951) No. 5--174, (1954) No. 6--170, (Association of Geodesy, 1956) No. 7--135.

BOOKS, PUBLICATIONS, LITERATURE

Items dealing with the following classifications will be found in the issues indicated: Cartography, No. 5--186, No. 6--178, No. 7--151; Coast Pilots, No. 5--188, No. 6--180; Electronic Instruments, No. 5--191, No. 7--160; Federal Tort Claims Act, No. 6--189; Geodesy, No. 5--189, No. 6--182, No. 7--154; Geomagnetism, No. 7--158; Geophysics, No. 5--190, No. 6--184; Miscellaneous, No. 5--181, No. 6--190, No. 7--161; Navigation, No. 6--189, No. 7--154; Oce-

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