THE UNITED STATES COAST AND GEODETIC SURVEY: ITS WORK AND PRODUCTS

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The United States Coast and Geodetic Survey, an agency devoted to the public service of the United States, has just completed the 50th year in its second century of progress. The activities of the Survey in the fields of engineering, science, and higher mathematics provide facts needed in the planning and execution of many of the activities of the nation; our end-products are indispensable to the day-to-day operations of many lines of business and commerce. Thus this highly technical bureau directly aids the United States Department of Commerce in carrying out the mandate of Congress to promote, foster, and develop the industry and commerce of the United States.

Through its field operations the Survey gathers certain raw materials in the form of engineering and scientific data. These data are converted into products essential to water and air navigation, mapping the country and the development of our natural resources. Survey data and publications serve certain strategic purposes vital in national defence. Field surveying parties make observations and measurements, obtain depth soundings and conduct aerial surveys which are forwarded to the Washington office where they are checked, reviewed and compiled into final products suitable for public use.

The production of nautical and aeronautical charts is a major function of the Survey. Sailing directions, tide tables, current tables and tidal current charts are published as supplements to the nautical charts. These and other important products of the Survey have many collateral uses — engineering, industrial and scientific.

One of the basic responsibilities of the Survey is the execution of geodetic control surveys to provide control for maps, charts, intermediate and local surveys and various engineering projects, both public and private. Large-scale topographic and planimetric maps along the coasts of the United States are produced as by-products of the compilation of nautical charts. Aerial photographs are taken to ensure an adequate amount of reliable topographic detail on the nautical charts but other important uses are made of the basic surveys. Tidal surveys are conducted for the purpose of reducing to a common level or datum plane soundings taken at different stages of the tide during hydrographic surveys. Magnetic surveys are conducted as essential operations in the preparation of nautical and aeronautical charts and other purposes. Seismological studies and investigations are carried on for the purpose of mapping earthquake areas and to evaluate earthquake risks through the operation of seismographs and systematic collection of earthquake data.

The demands upon the Survey have grown with the national progress of the United States, whose shoreline is now over 100,000 miles in length — more than four times the distance around the world. Added responsibilities came with the addition of Florida and Texas, the Louisiana Purchase, the discovery of gold in California, the purchase of Alaska, and the addition of Puerto Rico, the Canal Zone, Guam, the Hawaiian and Philippine Islands, and the Virgin Islands of the United States.

EARLY HISTORY

The Coast and Geodetic Survey is one of the oldest scientific and technical bureaus of the United States. In February, 1807, the Coast Survey had its beginning when President Thomas Jefferson obtained authority from the Congress for a trigonometrical survey of the coast and harbours of the United States, together with adjacent shoals and off-lying islands. At this time Florida was still a Spanish possession and the coast of the new republic extended only from Maine to Georgia.

Commerce and industry of that day were concentrated along the Atlantic coast with waterborne traffic the principal means of transportation. This resulted in a pressing need for accurate knowledge of the coast and adjacent waters to promote safety in navigation and to expedite waterborne commerce between the several States and with foreign countries. Through the years the wisdom of this undertaking has become increasingly evident from the benefits that have accrued to industry, science, and engineering and in providing for the national defence of the country.

Plans for the survey of the coast were requested by the Government of known men of science of that period, among whom was Ferdinand R. Hassler, a Swiss engineer, who had arrived in the United States in October, 1805. Hassler, then professor of mathematics and natural philosophy at Union College, Schenectady, New York, submitted a plan for the proposed survey that included « a complete triangulation survey of the whole coast including the determination of latitude, longitude, and azimuths of the principal places, and bases measured with the greatest possible accuracy ». This plan was accepted and Hassler spent several years in England and France either purchasing or supervising the design and construction of the precise instruments required for the survey.

Due to the necessity of obtaining instruments and other equipment required for the work, and the intervention of the War of 1812, field work did not get under way until 1816. Since that time the functions of the Survey have been carried on without interruption except for the period 1818-32. The initial operations of the new survey were the measuring of two base lines : one in English Neighbourhood, New Jersey, and the other at Gravesend Beach, Long Island. This work was followed by a reconnaissance survey through Long Island and Connecticut. The standards set by Hassler for triangulation closure in primary triangulation have held good to this day and triangulation executed by him more than 130 years ago is included in the present-day first-order nets of the United States.

PERIOD OF EXPANSION

During the period of 1818-32, the work of surveying the coasts of the United States came to a standstill due to the lack of funds. Following the renewal of the work in 1832 by an Act of Congress which made effective the prior act of 1807, field operations progressed on a much greater scale. President James Madison took personal interest and lent encouragement to the undertaking. Hassler continued direction of the work with the main objective being « to obtain the greatest certainty of accuracy in the results ». The survey of the coast of Florida was authorized by the Act of 1832 which recognized that the survey of the coast should provide data required in establishing the coastal defences of the country in addition to that required for navigation.

In 1833 James Ferguson, who had assisted in the survey of the boundary between the United States and Canada, was appointed first assistant in the Coast Survey. As chief of a survey party he conducted surveys along the north shore of Long Island while Edmund Blunt, the other principal assistant to Hassler, headed a party on Long Island. Four maps were published in 1834 at the scale of 1 : 100,000 showing the triangulation scheme in the vicinity of New York, Long Island, and the Connecticut shore, but hydrographic details of the off-shore areas were not included.

The first hydrographic survey was conducted in 1835 by the schooner *Experiment* in command of Lieutenant Gedney in Great South Bay and along the south shore of Long Island. The first Coast Survey vessel to be used extensively in oceanography was the brig *Washington*, which was constructed in 1837 for use as a revenue cutter, but served only during the winters of 1837, 1838 and 1839 in that capacity. During the summers of these years the vessel was loaned for temporary assignment to Coast Survey duty; in April, 1840, she was formally transferred to the Survey.

Topographic surveys based upon the control established in former years were conducted during 1836-38 on Long Island and along the coast of New York, Connecticut and New Jersey. Copperplate engraving was added to the activities of the Coast Survey and in 1842 the first copperplate printing press was obtained. During that year an engraving was completed of the first chart of New York Bay and Harbour.

Professor Alexander D. Bache became the second superintendent of the Coast Survey in 1844. At that time surveys had been extended into nine States with plans for extending the work into four additional States. During the summer of 1846, under the direction of Professor Bache, the first orderly scientific investigation of the Gulf Stream was undertaken. The attention of the scientific world was first directed to the existence of the Gulf Stream by Benjamin Franklin, who was a direct ancestor of Professor Bache.

Reconnaissance preliminary to the survey of the coast of the Gulf of Mexico was started in 1845 and the coast between New Orleans and Mobile was thoroughly examined. Upon acquisition from Mexico in 1846 of political control of the California territory, surveying the Pacific coast of the United States became an added responsibility of the Coast Survey. The first survey of the Pacific Coast was initiated in 1848. Rapid strides were made in copper engraving of charts for various coastal areas and harbours. Many of the copperplate engravings executed one hundred years ago reflect the finest techniques in past methods of chart reproduction.

Anticipating the acquisition of Alaska from Russia, the Coast Survey made extensive plans for surveying the waters and coastal regions of the new territory. When formal transfer of Alaska to the United States was made in October, 1867, George Davidson, an assistant in the Survey, was already in Alaskan waters with the cutter *Lincoln* and a surveying party. During the summer of 1867, the Davidson party made numerous observations and as a result of the season's work charts were published of Sitka and St. Paul Harbours and Kodiak Island. The first Coast Pilot of Alaska was published in 1869, based on the investigations by Davidson. Between 1867 and 1882 the Coast Survey compiled and published numerous charts of Alaskan waters.

Continuous operations were started in 1882 when the ship *Hassler* was sent north and the steamer *Patterson* was assigned to Alaskan waters. During this period triangulation, topographic, and magnetic surveys were conducted, in addition to hydrographic investigations. Upon discovery of gold in Alaska, the rush to the Klondike region in 1897 was served by a survey of the beach at Nome which had been made by Coast Survey ships. The gold rush created new interest in the territory and the Survey was given increased appropriations with which to carry on and expand its Alaskan work.

At the close of the Spanish American War, the Coast and Geodetic Survey was ready to proceed with the important work of surveying and charting the waters of the Philippine Islands. From 1900 to 1940 much of the original work in surveying the Philippines areas was accomplished.

Under normal conditions the work of the Coast and Geodetic Survey is carried on chiefly in the interest of commerce and industry, but with the advent of war it became necessary to rechannel all activities in order to concentrate on projects essential for war purposes. Adjustments were made in the volume of work during war periods to enable the Survey to meet the strategic needs for its products and services. All activities carried on during World War II were planned for maximum contribution to the war effort. Six of the Survey's nine major ships were transferred to the United States Navy. More than half of its commissioned officers were transferred to the Army, Navy, and Marine Corps. A large number of civilian employees joined the military forces.

Many special programmes were carried out by the office force as the Survey's contribution to the war effort. Aeronautical charts of various types and at different scales to meet specific requirements were produced for a large part of the world. An extensive war project of major importance was the production of target charts for aerial bombing. Over 1,800 different target charts were prepared including charts covering such important objectives as the Ploesti oilfields in Roumania, and the atom-bombed cities of Hiroshima and Nagasaki.

ORGANIZATION AND FUNCTIONS

The organization of the Coast and Geodetic Survey is comprised of two forces — office and field. The Director as the administrative head of the Survey is responsible for all phases of the work including standards of performance, efficiency of operations, fidelity of work, and the expenditure of appropriations. The office organization is comprised of the offices of the Director and Assistant Director and ten divisions. The six technical divisions are as follows: Coastal Surveys, Tides and Currents, Geophysics, Geodesy, Photogrammetry, and Charts. The other four are designated as Administrative Services, Personnel, Finance and Special Services, and Instruments, and perform administrative and service functions as their names indicate. This organization is shown in Fig. 1.

Division of Coastal Surveys. — This Division is responsible for the operation of the surveying fleet including construction, maintenance and repair of vessels. All hydrographic and topographic surveys by ship-based parties are executed under direction of the Division. In addition to the gathering of field data, this Division is responsible for plotting and smooth drafting of field surveys, preparation of descriptive and special reports and the installation and maintenance of special equipment. The nine district offices of the Bureau located in the principal coastal cities of the United States, and at Honolulu, T.H., are administered by the Division.

Division of Tides and Currents. — This Division operates field parties engaged in tide and current work along the coasts and inland tidal waters of the United States, its Territories and Possessions. Office personnel of the Division process and publish the resulting data in various forms required for use by the Survey, other governmental agencies, the courts of the United States, engineers, scientists and the public. Tide tables covering the world are prepared and published by the Division. In addition, special investigations and studies concerning tides and ocean currents are carried out in the interest of national defence. Research is conducted on tides, currents and related phenomena.

Division of Geophysics. — The magnetic observatories and seismological stations are administered by this Division ; also, field parties making magnetic and seismological surveys operate under the Division. Field work pursuant to magnetic operation includes the determination of the value of the earth's magnetic elements, the establishing of magnetic stations, airborne magnetic surveys, the standardization of instruments, and the maintenance of international magnetic standards. Magnetic data of the entire world are collected and compiled into world magnetic charts.

Seismologic work includes the gathering of earthquake information, surveys of important shocks, vibration observations on engineering structures, measurement of ground vibrations, and the operation of a seismic sea wave warning system in the Pacific Ocean. Office activities include the processing and publication of data obtained from field surveys, the location of earthquakes and analysis of destructive earthquake motions, and the development of plans and specifications for instruments and equipment. Basic magnetic and seismic research is carried on in the Division.

Division of Geodesy. — The Division is responsible for the operation and administration of geodetic field parties which establish all first and second-order triangulation, traverse, and levelling in the United States and its Possessions. Other geodetic activities include base line measurement, astronomic observations of latitude, longitude, and azimuth, and gravity determinations as required for surveying, engineering and research work. Two variation-of-latitude observatories in the United States are operated by this Division.

Office work includes the processing and publication of data resulting from field surveys. Research is carried on involving the mathematical development of map projections, plane coordinate grids, the variation of latitude, figure of the earth, and improvements in instruments and methods.

Division of Photogrammetry. — The operation of field parties engaged in topographic and planimetric surveys, processing of the resulting data, and the compilation of topographic maps from these data are planned and administered by this Division. Field work includes photographic missions and airport surveys. Large-scale topographic and planimetric maps along the coasts of the United States are compiled from aerial photographs by graphic or stereo-photogrammetric methods as by-products of the compilation of nautical charts. The Division conducts research for new and improved photogrammetric methods including the design and construction of photogrammetric equipment.

Division of Charts. — Hydrographic survey sheets are reviewed, verified and completed by this division; new nautical and aeronautical charts are compiled; Coast Pilots are revised from the results of field work and other sources; existing charts are maintained by the addition of new data; and charts are reproduced and distributed. Studies are made for improvement of survey methods and new methods of compiling and reproducing nautical and aeronautical charts are developed through intensive research and development. This Division supervises chart maintenance and distribution at field offices, field examination of Coast Pilots and the compilation and drafting of aeronautical charts in field offices. Aeronautical charts are being continually improved through a programme of flight-checking carried on under direction of the Division.

Division of Administrative Services. — This Division supervises the purchase of materials and services, maintains and operates the library, handles Bureau mail, messenger service, and general housekeeping activities.

Division of Personnel. — Plans and procedures are developed by this Division to provide for unified administration of the Bureau's personnel programme and uniform application of all personnel policies and practices within the agency. The specific functions are the recruitment and placement of personnel, classification of positions, maintenance of records and files, and the coordination of efficiency ratings throughout the Bureau.

Division of Finance and Special Services. — This Division has charge of the disbursements and accounts of the Survey including the preparation of the annual budget. In addition to auditing of accounts and approving expenditures the Division is responsible for the analysis of organizational methods and procedures and maintenance of appropriation, allotment, and obligations records. Under this Division the International Technical Corporation Programme is administered which includes the training of foreign nationals in office and field operations of the Bureau.

Instrument Division. — This Division is responsible for the invention, design. development, maintenance, construction, storage, and issue of instruments used in hydrographic, topographic and geodetic surveying, earthquake recording, study of terrestrial magnetism, and tides and currents surveys. Special instruments and machines are developed for chart reproduction.

PERSONNEL

Personnel of the Coast and Geodetic Survey consist of two major groups — commissioned officers and civilian personnel. Employment is in the Washington office and in the field service throughout the forty-eight States of the United States, its Territories and Possessions.

Commissioned personnel include the Director of the Bureau, who is a Rear Admiral (upper half) and the Assistant Director, who is a Rear Admiral (lower half); other officers range in rank from Captain down through Ensign. These officers, who are all engineers with additional technical training in the specialized work of the Bureau, hold administrative and key positions both in the Washington office and in the field service.

Civilian personnel are comprised of four types : (1) professional employees including mathematicians, geophysicists, and technical experts highly trained in various fields of engineering such as cartography, photogrammetry, geodesy, hydrography, and electronics ; (2) semi-professional personnel comprised of cartographic aids, survey aids, draughtsmen, scientific aids, instrument makers, cabinet makers, lithographic artists, and other employees specially trained in reproduction methods; (3) administrative, clerical, and custodial employees including personnel officer, budget officer, placement officer, administrative officers, accountants, secretaries, stenographers, clerks and messengers; and (4) crew members attached to the 16 vessels of the Survey now in active service.

On January 1st. 1951, there were 171 commissioned officers and 1,925 civilian employees in the Coast and Geodetic Survey. Of these, 914 were on duty in the Washington office, 242 were assigned to permanent field installations, 900 were engaged on field work attached to vessels and mobile field parties and 40 were employed on a part-time basis as tide observers and seismograph tenders.

Recruitment of Officer Personnel. — Initial appointment in the Bureau of officer personnel is to the position of deck officer. Candidates must be citizens of the United States, between the ages of 20 and 26 years. A prerequisite for consideration for eligibility is that applicants must be graduates, preferably in civil engineering, from a college or university of recognized standing. Deck officers are assigned to ship or shore parties engaged in any of the numerous surveying operations of the Survey. Deck officers serve for six months before being eligible for commission as Ensign — the lowest rank in the commissioned corps.

The mental and physical examinations for appointment and promotion of commissioned officers are conducted by a board appointed by the Secretary of Commerce, consisting of not less than five senior commissioned officers of the Survey.

Selection of Civilian Personnel. — The majority of the civilian employees of the Survey are selected through examinations given by the United States Civil Service Commission. This group includes the top-level employees who serve as administrative heads of technical and administrative branches and sections of the Survey; world-renowned experts in the fields of oceanography, hydrography, geodesy, geophysics, and seismology; professional employees in the Washington office; and a great majority of the semi-professional field employees.

Those semi-professional field employees who are not recruited through the Civil Service system are employed for short periods of time by chiefs of mobile field parties who recruit locally in the area in which the field party is in operation. Recruitment of crew members is conducted by the commanding officers of the various vessels at their home ports without recourse to civil service registers.

Personnel Training. — In selecting personnel for employment in the Survey, great care is exercised to obtain the candidate with the best possible qualifications for each position. But due to the specialized nature of the work, it is not always possible to obtain personnel who can, without additional training, assume the full responsibilities of many of the positions. Therefore, on-the-job training is an important aspect of every employee's duties. In the commissioned corps this on-the-job training begins upon initial appointment, and is supplemented by specialized training programmes conducted by experienced officers in specific fields. Also, rotation of field assignments gives both commissioned and civilian personnel an opportunity to obtain experience and training and for wider application of their engineering background.

SURVEYING VESSELS AND EQUIPMENT

For well over a century, vessels of the Coast and Geodetic Survey have carried on extensive surveying operations in the coastal waters of the United States, Alaska, Puerto Rico, the Virgin Islands, Panama, the Hawaiian and Philippine Islands, Midway and other islands of the Pacific.

Before the turn of the century sailing vessels were used extensively in conducting hydrographic surveys. The change from sail to steam and from wood to iron resulted in an immense difference in the efficiency and capabilities of the surveying ship. Gradually steam-driven vessels came into general use until sail completely disappeared during the early part of this century. For the past fifty years the surveying fleet has been almost entirely dependent on steam. Great were the handicaps under which the early surveys were executed and it is astonishing that so much accurate and detailed information was obtained and charted.

The historical record of the Survey notes many instances of great hardship encountered in surveying our coastal waters. An outstanding experience when great courage and endurance were displayed under extremely hazardous conditions was during the near-loss of the brig *Washington* in 1846. The *Washington,* after her successful cruise in the Gulf Stream during the summer of 1846, was caught in a hurricane during her return to port. The brig was severely damaged and would have been lost except for the superb seamanship of both officers and crew. After floundering for more than a week, the vessel reached port but not before the commanding officer and ten members of her crew were lost.

Among the last of the sailing vessels used in Coast Survey work was the schooner *Matchless,* which was regarded as the most handsome of the sailing fleet. She was a two-masted centre-board vessel, measuring 97 1/2 feet in length with 24 1/4 foot beam and 8-foot depth of hold. The vessel was elaborately furnished throughout with roomy quarters for officers and crew. The chart-room was large and bright. For many years this vessel was used as a training ship.

As early as 1847 the Coast Survey used the first steam-driven vessel in hydrographic surveying. The first vessel of this type was the *Bibb,* of wood construction, which was used along the east coast of the United States. The *Jefferson,* the first steam vessel of iron construction, was obtained by the Coast Survey in about 1849.

At the beginning of the present century the Coast and Geodetic Survey had in service a number of specially-built steam-driven surveying vessels. In addition to the coastal waters of the United States these vessels were used extensively in Alaska and the Philippine Islands. Much of the original work in surveying the coasts and adjacent waters of the Philippines was accomplished by our fleet of surveying vessels.

At the outbreak of World War I selected vessels of the Coast and Geodetic Survey were transferred to naval duty. The *Surveyor* was one of the vessels taken over by the Navy and was especially active on extensive escort and convoy duty in the Atlantic Ocean and Mediterranean Sea. Manned by officers of the Survey, the ship participated in several submarine engagements, including an attack in May, 1918, by two German submarines on a convoy to which she was attached as an escort. One of the submarines, the *U*-39, which had previously sunk the *Lusitania,* fired a torpedo at the convoy which grazed the bow of the *Surveyor.* The wake of the submarine was picked up by the *Surveyor* and she was able to deliver an effective depth-charge. The vessel could not leave the convoy to finish off the submarine but the U-boat was disabled to the extent that it was compelled to enter the port of Cartagena, Spain, there to be interned.

Our surveying fleet is comprised of 19 ships, 16 of which were in active service during 1951. Six of the ships are major sea-going vessels and the remainder are smaller types, 136 feet or less in length. The minor vessels are used for surveying in bays or inshore areas. The sister ships, the *Pathfinder* and *Explorer,* are outstanding examples of our modern specially-built surveying vessels which are among the major units of the fleet. These ships were designed and constructed for the Survey. The *Pathfinder* is 229 feet in length, draught 15 1/2 feet and has a displacement of 2,000 tons. The *Explorer* is essentially the same in design, except that the *Pathfinder* is about 10 feet longer. Launch and small-boat equipment normally carried by these ships includes four diesel-powered launches, four whaleboats, two dinghies, six skiffs and dories, and two rafts.

Both vessels carry the latest types of instruments and equipment developed for use in hydrographic surveying. Echo-sounding equipment includes both the NMC-2 and NMC instruments having maximum range of 4,000 fathoms; one NJ-3 instrument for sounding in depths under 400 fathoms; and six portable recording echo-sounding instruments for use in the survey launches. One low-frequency and two intermediate-frequency transmitters and a number of portable units for ship-launch and ship-shore voice communication are included in the radio equipment of the vessels.

The modern surveying vessels now in use, fully equipped with the latest types of surveying instruments, make possible the more critical surveys necessary to produce adequate nautical charts to meet present-day maritime demands. Progressive developments through pioneer work in improving the means and methods of conducting surveys together with improved charting techniques, have given the nautical chart its present high standard in precision and scientific status.

To facilitate off-shore surveys along bold and rugged coasts, with large and abrupt irregularities in depth, and many pinnacle-like rock masses, the Survey has developed the equipment known as the Wire Drag. This method of determining depth has been of inestimable value in surveying in the Long Island Sound region, where huge boulders were deposited by the ice of the glacial period. In the Florida Keys large coral heads rise well above the surrounding bottom. Parts of Alaska and the northern half of our New England coast are even more rugged with great seamounts rising to within a few feet of the surface.

The wire drag consists of a horizontal wire maintained at any desired depth below the surface by an arrangement of weights and adjustable upright cables which extend up to small buoys on the surface. The apparatus is towed by two vessels, one at each end. The horizontal wire will catch as the drag passes through the water and thus will indicate the location of any obstruction which extends above a plane at the depth determined by the setting of the horizontal wire. The exact location of the obstruction having been thus found, the least depth on it can then be determined by fathometer or by leadline.

Many improvments have been made in the wire drag since it was first introduced in 1904. The length of the wire drag in use today can be adjusted as necessary to cover a sweep up to twelve to fifteen thousand feet. As a result of successive improvements, the drag is now used to determine whether or not apparently clear water areas are free from obstructions; to discover and locate all obstructions in a shoal area; and to determine the maximum safe depth of a channel. The effectiveness of the improved wire drag is indicated by the fact that in the tens of thousands of square miles of water area dragged by the Survey more than 5,000 uncharted obstructions have been discovered.

HYDROGRAPHIC SURVEYING

Hydrographic surveys which determine the depths of water and the character of the sea bottom were formerly obtained with the handlead, deep-sea lead, or the pressure tube, and dangers were searched for with wire drag. During the past two or three decades considerable improvements have been made in hydrographic surveying methods with the development of echo-sounding equipment and improved methods of control. Accurate profiles are now obtained of the ocean floor which provide the cartographer with a wealth of information for detailed charting of submarine relief often characterized by intricate and distinctive patterns.

The hydrographic survey starts with the high-water line and control points as they appear on the topographic survey. In general, hydrographic surveys are extended inshore across the low-water line in areas where this is practicable and can be done without danger to personnel or equipment. The low-water line, one of the most important depth curves in a survey, is fully developed in our hydrographic surveys wherever tidal conditions permit.

Experience has shown that the most effective method of surveying an inshore area where the bottom slopes gradually is by means of a system of sounding lines parallel to the beach. Such lines can be run close to shore since the surveying launch is traversing a course parallel to the danger line rather than toward or away from it. Periods of high tide and calm weather afford the best conditions for inshore sounding and our operations are planned to take advantage of these.

The hydrographer endeavours to obtain depths which will develop the area and delineate submarine relief in a thorough and economic manner by the methodical system of evenly-spaced sounding lines. The first line of soundings is run as close to the high-water line as practicable. The lines of soundings nearest to shore are closely spaced with the two inshore lines spaced not more than 50 metres apart. The spacing of the system of lines is increased gradually until a maximum

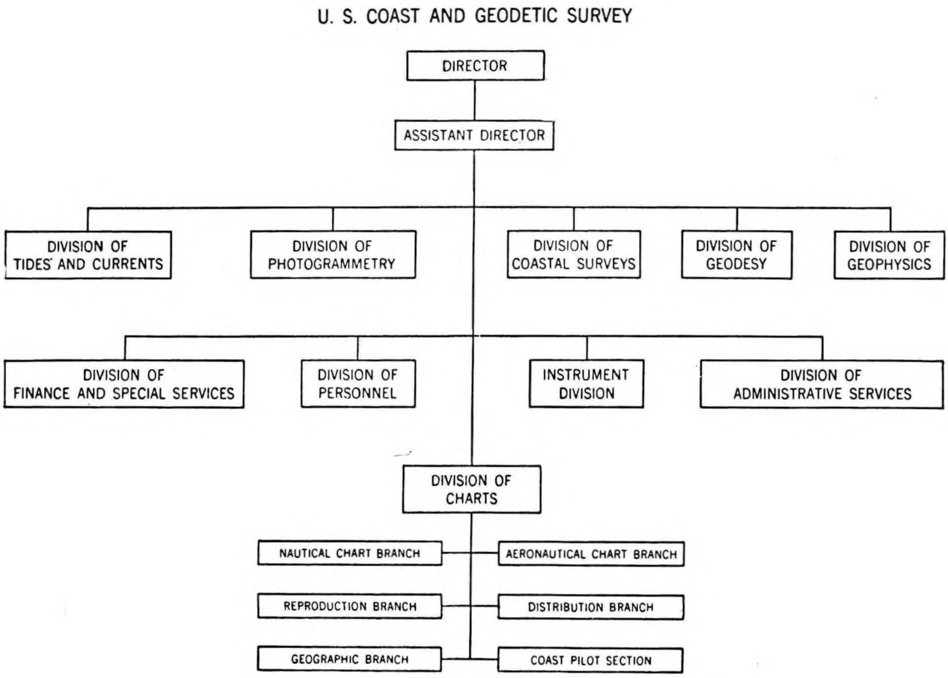

Fig. 1. — U.S. Coast and Geodetic Survey Organisation

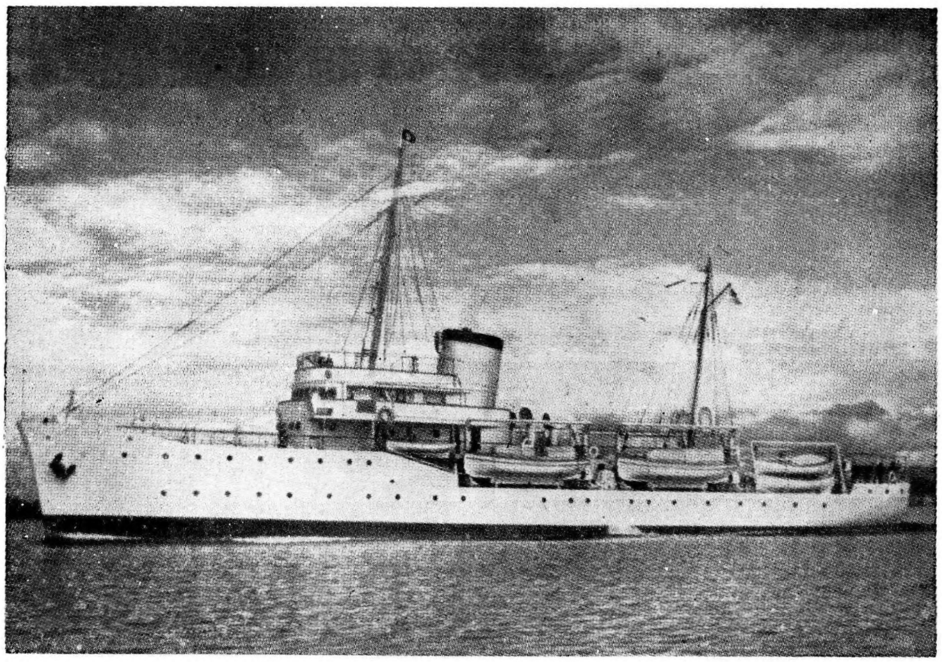

Fig. 2. — Coast and Geodetic Survey Ship *Explorer*. — Equipped with the latest electronic devices, the *Explorer* is one of the main units of the C. & G. Survey fleet.

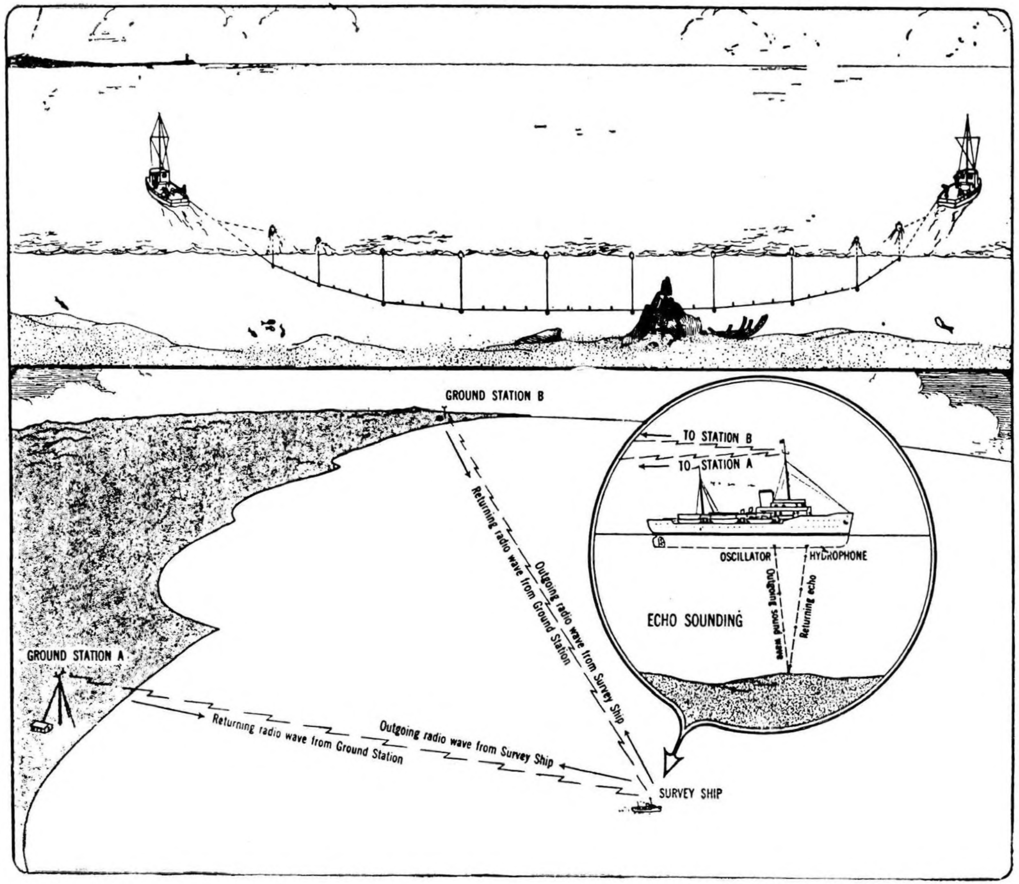

Fig. 3. — Two methods of Hydrographic Survey. — The top diagram illustrates the use of the wire drag for locating sunken roks and other obstructions. The lower diagram illustrates the use of electronic devices for determining position and depth.

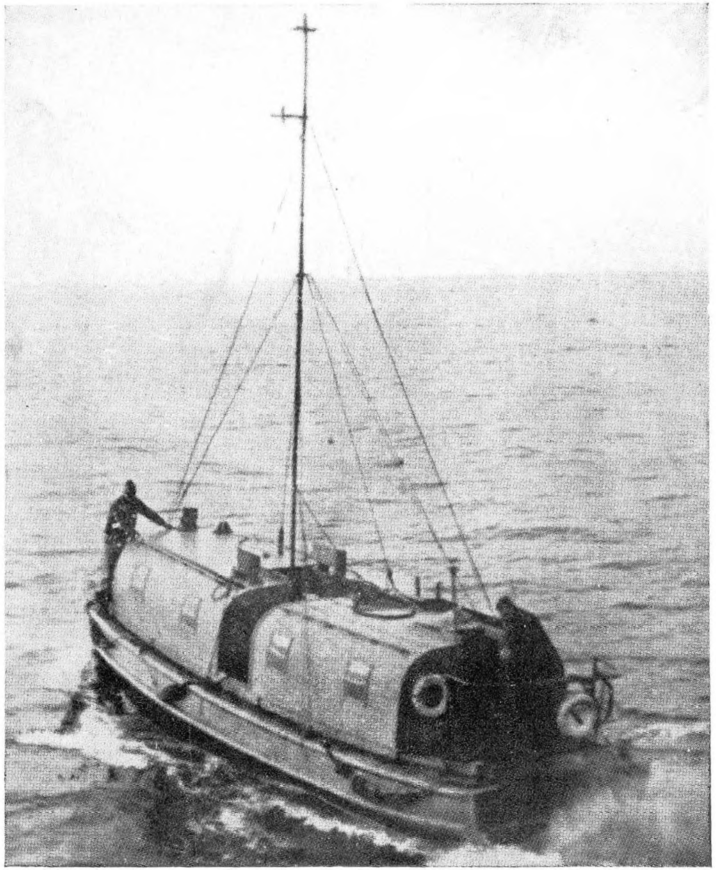

Fig. 4. — 36-ft. Launch with special shoran mast

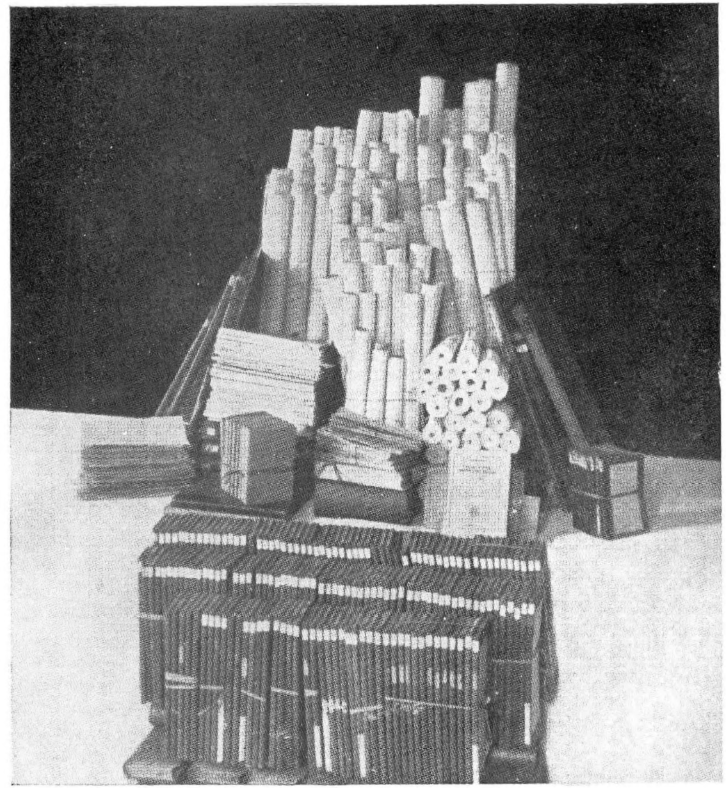

Fig. 5. — Material required in the making of one nautical chart. — To show all available information necessary for safe marine navigation, charts prepared by the Coast and Geodetic Survey are published in relatively small editions based on extremely detailed data, and must be constantly revised to keep up with the man-made and natural changes in coastal waters.

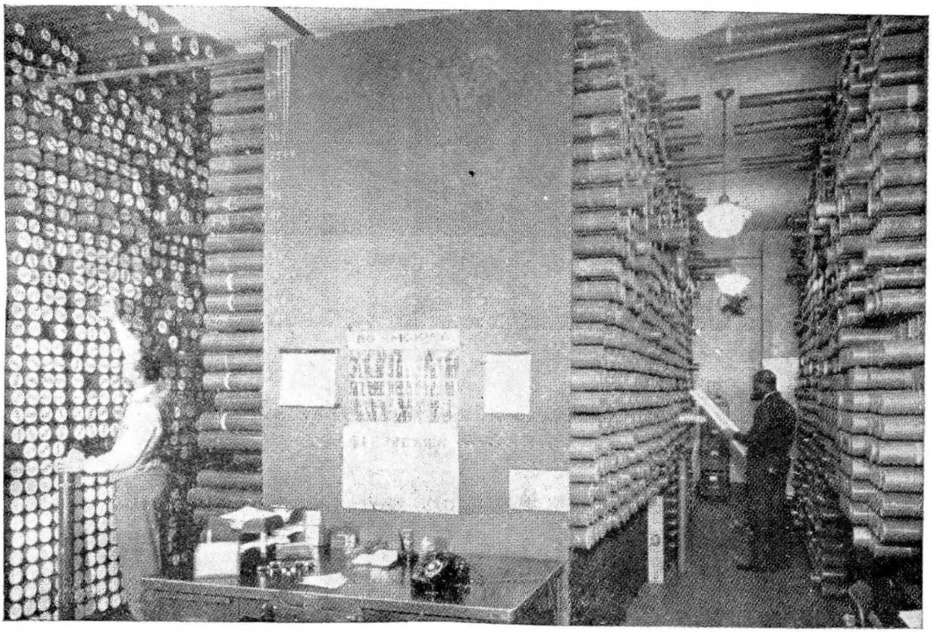

Fig. 6. — Hydrographic and topographic surveys. —These metal tubes contain century-old history of American coastline evolution.

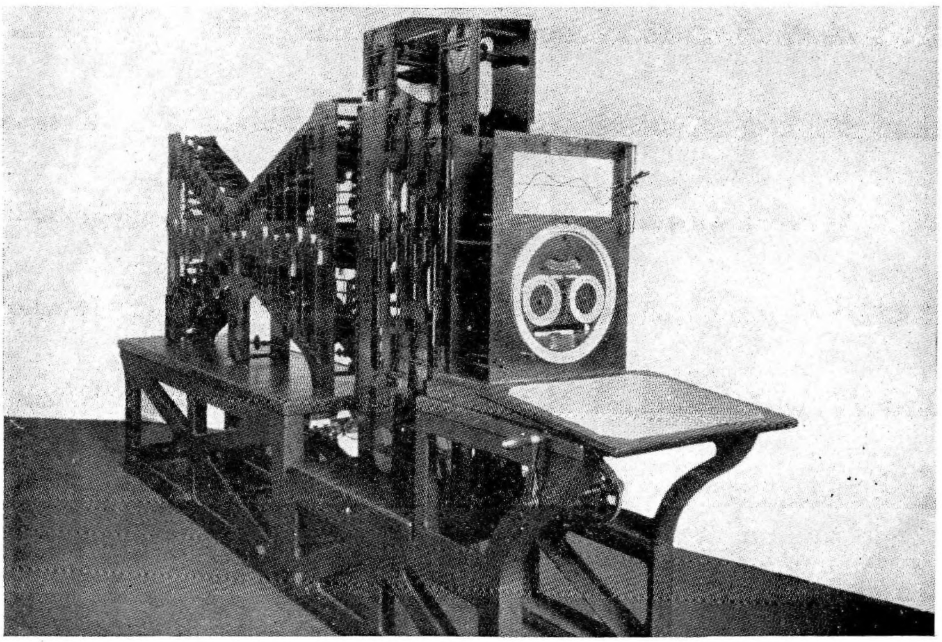

Fig. 7. — U.S. Coast and Geodetic Survey Tide-predicting machine. — When set to certain predetermined constants this machine automatically gives the times and heights of the tide for any port in the world and for any year.

is reached between the two outermost lines. Under many conditions a system of sounding lines parallel to the beach is impracticable. It is then necessary to use a system of evenly-spaced sounding lines approximately normal or at an angle of 45 degrees to the depth curves.

Soundings, the basic element of the hydrographic survey, are recorded on a work sheet by the hydrographer as the work progresses. The *boat sheet,* the designation given the work sheet, is used principally for plotting each position of the sounding vessel as the observations are made. In addition to the soundings, the boat sheet includes the locations and names of all control stations with descriptive notes added where necessary to identify a specific station. The boat sheet for an inshore hydrographic survey also contains the high-water line, the low-water line, the approximate limits of shoal areas, rocks, aids to navigation and suspected dangers. Sextant cuts to locate a rock, breaker, hydrographic signal, or other features are carefully plotted on the boat sheet.

The *smooth sheet* (fair sheet) is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey but contains other data necessary for a proper interpretation of the survey, such as depth curves, bottom characteristics, names of geographic features, and control stations. The smooth sheet is plotted with the utmost care and after being registered, verified, and reviewed in our Washington office, it becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original sounding records is rarely necessary.

The polyconic projection is used to plot the result of our surveys. This projection devised by Ferdinand Hassler (first Superintendent of the Coast Survey), is especially adaptable for surveys of comparatively small areas such as those covered by our hydrographic and topographic surveys, because it effects a satisfactory compromise with all the most desirable properties of map projections, because of its ease of construction, and because a general table for its use has been calculated for the entire spheroid (C. & G.S. Special Publication No. 5, *Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels*).

Echo Sounding. — One of the oldest electronic surveying equipments is that employing echo sounding to determine the depth of water under the vessel. This method is now used almost exclusively in the hydrographic work of the Coast and Geodetic Survey. With this equipment, soundings can be obtained in a second or two in depths of as much as a mile. Thousands of soundings are now being obtained in areas where formerly only a few scattered ones were economically feasible. The original equipment depended upon audio and visual methods, whereas, practically all equipments now in use are of the recording type. The recorders connected with the sonic sounding devices provide a continuous profile of the ocean floor, showing the ridges and depressions on a permanent visual graph. The dial-type echo-sounder, known as the *Dorsey* Fathometer, is a precision instrument designed by the Coast and Geodetic Survey.

The principle of echo sounding is the sending out of a sound impulse from the transceiver in the hull of the ship. which on reflection from the ocean floor is picked up by this same unit and amplified so that it will make a permanent mark on a graphic record. The effect of many consecutive soundings is to produce a profile of the ocean floor on the graph. Depths of water are measured accurately by measuring the small intervals of time required for the sound to make the round trip to the ocean bottom. Although round trip times are measured, only half of the measured values are recorded.

Echo-sounding equipments may be divided into two classes, those for relatively shallow water, such as obtained within a few miles of the shore, and those which will record depths in very deep water. Most of the smaller of shoal-water equipments are portable and may be used in launches as small as 25 feet in length. Portable echo-sounders are used in the surveying of harbours, bays, rivers and inshore areas along our coasts. This type of equipment is also installed in larger survey vessels for work in waters which are relatively shoal yet extending many miles offshore, as in the case of the Gulf of Mexico where depths of only 100 fathoms exist 100 miles offshore. Fathograms recorded by these equipments can be read to 0.1 foot if desired.

Deep water echo-sounders are, of course, used only in the larger ships and many are equipped with them for navigational uses. Most types of these equipments will record the profile of the bottom in depths ranging from a few fathoms to those exceeding 4,000 fathoms (or 4 1/2 miles). These recordings are made with a reading error of less than 10 fathoms in maximum depths and ranging to about 2 feet in the shoal areas. The larger ships are equipped with both a shoal and a deep-water echo-sounder so that all conditions of depth may be examined.

Many submerged features of interest have been found by using echo sounding methods. Mountain peaks rising to heights of 10,000 feet or more have been found in ocean depths of 2,000 or 3,000 fathoms. Great trenches have been found along the continental shelf which drop to depths of more than 4,000 fathoms from a surrounding general level bottom not much deeper than 2,000 fathoms. By means of echo-sounding equipments intensive surveys have been made of vast areas along the coasts of the United States and Alaska.

Hydrography accomplished annually averages more than 75,000 miles of sounding lines over areas totalling 25,000 to 30,000 square miles. In addition, about 200 square miles of water areas are wire dragged each year.

Control of Hydrographic Surveys. — The methods usually used to control hydrographic surveys depend on the distance from land and the depth of water. Where the survey vessel is close to shore its position or the position of the soundings is obtained from control stations on shore. The usual method of fixing hydrographic surveys within sight of land is by sextant three-point fix which is almost universally followed for position-fixing.

Beyond the limits of shore objects and where the use of buoys or three-point fix control is impraticable or unwarranted, a number of methods of control have been used in the past. Radio Acoustic Ranging, or RAR, including the radio-sono buoy, was a method developed by the Survey after World War I for offshore hydrographic surveying. By this method the position of the survey ship was determined from two or more previously located control stations by exploding a small bomb in the water near the ship and measuring the interval of time required for the sound to travel to each station. The explosion of the bomb and the radio signals that were transmitted automatically from the control stations were recorded on a chronograph carried aboard ship. The distances from the survey ship to the control stations were determined by measuring the time for the transmission of the under-water sound impulse and the ship's position was thus determined.

The application of these scientific principles resulted in the extension of hydrographic surveying to considerable distances offshore with increased accuracy. This method was hailed as a great achievement and an enormous area was surveyed using the system. There were, however, several disadvantages inherent in RAR, none of which was completely overcome. World War II brought forth several new navigational methods which have made possible great improvements in our system of controlling surveys. As a result of these developments Radio Acoustic Ranging has been replaced in the hydrographic operations of the Survey.

The Coast and Geodetic Survey was the first agency in the United States to use Shoran for control of hydrographic surveys. The very great accuracy of the Shoran fix has made it an essential control method for hydrographic surveys. The system was first tested in 1945 aboard the Coast and Geodetic Survey Ship *Explorer* in the Aleutian Islands, Alaska, to determine its application in precisely locating a survey ship while traversing back and forth on depth-finding operations. The tests proved successful and Shoran is now used on all the Alaskan survey vessels as the standard method for ship control. Vessels controlled by Shoran are able to take soundings day and night, in fog and clear weather, continuously knowing the location of the vessel within an area of uncertainty of about 20 feet.

Shoran equipment is a special type of Radar system designed and built by the Radio Corporation of America for the particular purpose of controlling the position of an aircraft during a bombing mission. The fact that the equipment was designed to be used in and transported by aircraft is reflected in the general design of all components, including the power sources. The variation of our equipment from the original design is in the modification of the standard airborne equipment to serve as the beacon at the fixed control stations ashore.

Shoran being a line-of-sight method is limited to distances of 50 to 70 miles. While very accurate in its determination of a position, the system provides a relatively small service area, especially when equipments are installed at low elevations. An improved method for control was offered by the Loran system, which utilizes low frequency radio impulses for transmission. Therefore an adaptation of Loran is not limited by the line-of-sight range, as is the case with the high frequency pulses of Shoran. By combining the frequency and modulation of Loran with the distance measuring features of Shoran, the Survey built the *Electronic Position Indicator.* The principle of position fixing with the E.P.I. is essentially the same as Shoran with a greatly increased service area.

Field tests made during the summer of 1945 were sufficiently gratifying to warrant further research and development in the system. The following months were spent in further design and engineering and the equipment now known as the Mark III, Model 2, has been developed. Field tests on this equipment have produced results fulfilling all expectations. Accurate control is now being obtained at distances ranging up to 400 miles. Recent tests have indicated a maximum usable range of about 540 statute miles without appreciable reduction in signal strength. Three of the major ships operating in Alaskan waters have been equipped with this system of control for use during the 1951 season.

TIDE AND CURRENT SURVEYS

Tidal investigations are carried out by the Coast and Geodetic Survey to provide basic data for the surveying activities of the Bureau, for the prediction of tides and currents as an aid to waterborne commerce, and for the industrial development of our coastal harbours.

In hydrographic surveys soundings must be corrected for the height of the tide at the time so that the nautical chart will show all depths referred to a uniform datum. Similarly, in photogrammetric surveys of coastal areas the aerial photographs which are taken at various stages of the tide have to be adjusted so that the shoreline depicts conditions at high water. Furthermore, in geodetic control surveys, the datum of mean sea level, used in levelling operations, is determined from tide observations at various places along our coasts.

Tide and current predictions which supply advance information on the rise and fall of the tide and the ebb and flow of the current are prerequisites to safe navigation. Such information is made available to the mariner through annual tide and current tables, and tidal current charts. During 1950 about 60,000 copies of tide tables were issued of world-wide areas. More than 21,000 copies of current tables were issued during the year.

The daily predictions published in the tide and current tables are calculated by a tide-predicting machine which was designed and constructed by the Coast and Geodetic Survey. It is about 11 feet long, 2 feet wide, and 6 feet high, and weighs a little over a ton. This machine not only traces a continuous curve showing the hourly variation of the tide or current but also indicates on dials the time and height of each high and low tide, or the time of each slack water and the time and velocity of each strength of current that will occur during the year.

Engineering and construction projects associated with the industrial development of coastal harbours require data on the elevation of tidal datum planes and the circulation of the tidal waters. Structures, for example, have to be located so that they will not be flooded by high waters and intake pipes for plants must be so placed that they will have an ample supply of water at all stages of the tide. Observational data on the ebb and flow of the current are essential in the solution of problems of sewage and water pollution.

Supplementing these principal uses, there is an increasing demand for tide and current data for collateral uses, such as fisheries, determination of boundaries of tidelands, offshore oil production projects, sports and recreational activities, and for investigations of slow changes taking place in the relation of land to sea.

The tidal programme of the Bureau includes the operation of tide stations distributed along the coasts of the United States and Alaska, and on Pacific Islands. Tidal investigations in Central and South America also are being carried out by the Coast and Geodetic Survey through participation in the programme of the Inter-American Geodetic Survey. The basic data from these tide stations are supplemented by short period observations from stations occupied during hydrographic surveys. A system of tidal bench marks is established by the Survey at each tide station to provide permanent reference points for the observed heights of the tide and the tidal datum planes determined therefrom.

Observations of the temperature and density of sea water are taken at most of the tide stations maintained by the Bureau as well as at a number of its cooperative tide stations in foreign countries. The data derived from these observations supply useful information to the shipping and fishing industries, to industrial plants using salt water, and to various scientific organizations.

Comprehensive current surveys are carried out by the Bureau to provide detailed information on the circulation of the tidal waters in our important harbours and waterways. The prosecution of these surveys, particularly those covering large areas, has been greatly facilitated by use of radio current meters designed by an officer of the Survey.

GEODETIC SURVEYING

As the name of the Coast and Geodetic Survey indicates, it is the agency of the United States Government which is responsible for geodetic control surveys. Originally our geodetic surveys were made for control of surveys of the coast and to provide a proper base for the nautical charts of the coastal waters. By Congressional action in 1871 these activities were expanded to furnish basic control for the interior of the country, including geodetic connections between the Atlantic, Gulf, and Pacific coasts of the United States.

The geodetic work of the Coast and Geodetic Survey consists of the field surveys and office processing necessary for the determination of points in the basic national networks of horizontal control and vertical control, and also includes gravity and geodetic-astronomic determinations. These geodetic surveys take into account the ellipsoidal figure of the earth, and are of the highest type of surveying. In addition to providing basic control for the mapping and charting programme of the United States, they are used both in the planning and construction phases of large engineering projects.

The horizontal control surveys determine the latitude and longitude of marked points and prominent natural and cultural objects as well as azimuths and lengths of the observed lines. The field operations for horizontal control include reconnaissance, measurements of base lines, astronomic determinations (particularly Laplace azimuths), triangulation, and traverse. Triangulation operations comprise the greater portion of the field work. Networks of arcs of triangulation extend over the United States. The arcs are formed by chains of triangles arranged in quadrilaterals and central point figures. The areas between the arcs are being filled in with a continuous net composed mostly of connected single triangles. For basic control, it is planned to have at least one station established in each 7 1/2-minute geographic quadrangle and to have permanent points at 4- to 5-mile intervals in the vicinity of main highways.

The main arcs comprise first-order triangulation, the criterion for which is that the discrepancy between a computed length and the measured length of a base or the adjusted length of a check line shall not exceed 1 part in 25,000 after the angle and side equations have been satisfied. The average discrepancy of this type is about 1 part in 75,000. Also, the allowable closure of a first-order triangle does not exceed 3 seconds, nor the average closure exceed 1 second. Modified second-order triangulation, which is used to fill in the areas between arcs, is observed with first-order instruments and slightly modified procedures with a maximum allowable triangle closure of 5 seconds and an average closure of about 1.5 seconds.

Triangulation observations are made with high-grade first-order direction theodolites, usually at night on signal lamp targets. In many areas of the country, triangulation surveys have been greatly expedited by using Bilby steel towers.

This is a double tower formed by two demountable portable steel tripods. The inner tripod supports the instrument independently, and the outer tripod supports the observing party, tent, signal lamps and other gear. These towers can be built in a few hours to heights of from 37 to 116 feet, and can be taken apart in even less time, hauled by truck to the next site, and re-erected many times.

Base lines and Laplace azimuths are included in arcs of triangulation at intervals, in order to maintain strength in length and orientation. First-order bases are measured with probable errors not exceeding 1 : 1,000,000, using standardized invar tapes under standard tensions and methods of support. Corrections applied include those for temperature and inclination. Laplace azimuths are observed with methods to ensure that the probable error will not exceed 0.3 second.

All points in the continental geodetic network of horizontal control are referred to the same datum (the North American 1927 Datum) and are therefore correctly related in position with respect to each other, regardless of their distance apart. The Clarke Spheroid of 1866 is the basis of computation.

Descriptions of stations and geographic positions are published for public use. The plane coordinate positions on the adopted state plane coordinate system are also published for all adjusted positions. The geographic positions have been determined for approximately 150,000 stations in the United States and Alaska, consisting of marked or monumented points and prominent objects. Stations are marked by bronze discs set in concrete monuments, bed-rock, structures, etc. The present standard complete marking of a triangulation station consists of a station (centre) mark, an underground mark, 3 feet or more below the centre where practicable, two or more reference marks, and an azimuth mark visible from the ground and usually about one-quarter mile distant. During an average year's work about 100,000 square miles of triangulation are completed, and about 10,000 geographic positions are established. About 25 base lines, average length about 6 miles, are measured each year.

The vertical control surveys determine elevations of the network of bench marks which extend over the United States. The elevations of 280,000 bench marks have been determined by approximately 143·000 miles of first-order levelling and 232,000 miles of second-order levelling. Most of the lines follow the routes of highway and railroad systems for economic reasons. At present, bench marks are set at intervals of one mile or less along the lines. The standard bronze disc marks are set in concrete monuments, bed-rock and permanent structures. The datum used by the Coast and Geodetic Survey is the mean sea level (sea level datum of 1929). The elevations of over 8,000 bench marks are determined annually and about 7,500 miles of first-and second-order levelling are run.

Gravity stations are well distributed over the United States. Pendulum gravity determinations are being supplemented by gravity meter observations.

Variation-of-latitude observatories are in continuous operation at Ukiah, California, and Gaithersburg, Maryland. These are two of five observatories, spaced around the earth on the same parallel of latitude, which take part in an international programme of observations to detect the movements of the axis of rotation of the earth. In addition to astronomic azimuth and longitude observations which are made at the numerous Laplace stations of the triangulation scheme, latitude observations are usually made at the same time for use in figure-of-the-earth studies.

TOPOGRAPHIC SURVEYING

Large-scale surveys of the topography of the coastline and the immediately adjacent land areas are essential to the production and maintenance of nautical charts ; consequently, since its inception, the Coast and Geodetic Survey has been engaged in mapping the coastline. For the most part, the topography executed by the Survey is limited to terrain features adjacent to the shoreline and other land features that are essential for control for hydrographic surveys and which are also necessarily shown on nautical charts as aids in alongshore navigation. With the advent of radar navigation, landforms are becoming increasingly important to the navigator.

The mapped areas with few exceptions consist of a strip only a few miles in width along the coastline, but extending along the entire seacoast, around bays, and up rivers to the head of navigation. In special cases, however, the scope of this work has been extended inland to meet specific requirements. In general, topographic surveys are made at the scales of 1 : 10,000 or 1 : 20,000 and occasionally at the scale of 1 : 5,000 or larger for special reasons.

The types of maps produced by the Survey are : (1) Topographic maps, including contours, of the lands adjacent to the navigable coastal waters of the United States. These maps provide complete topographic data for the compilation of nautical charts. After the manuscripts have been completed by the Coast and Geodetic Survey, including field-edit and review, they are turned over to the United States Geological Survey for publication as basic components of the standard topographic series of the United States. Maps thus produced are contributions toward eventual complete topographic coverage of the United States. (2) Planimetric maps which are complete for all shore and inshore details within their limits, except for contours. (3) Shoreline surveys which are produced where a revision of the shoreline is required but where existing planimetric or topographic maps are adequate for interior details. Shoreline surveys are registered in our permanent topographic surveys file but are not reproduced for general distribution. (4) Airport obstruction plans are special-purpose charts showing the runway pattern and other essential airport information and are produced specifically to show the positions and elevations of all obstructions within three miles of the ends of all runways. The obstructions are located by field survey usually with the aid of aerial photographs ; elevations are determined by ground survey methods.

Until the advent of aerial photography, ground plane table surveying was used exclusively by the Coast and Geodetic Survey as the method of making topographic surveys. Ground topographic methods have given way to the more economical and more expeditious method of photogrammetry which was first used in surveys made in connection with the Alaska-Canada boundary in the 1890's. At that time photographs were taken from the ground at points of known position and were used in lieu of planetable observations to determine the positions of minor points of detail. Although the method (terrestrial photogrammetry) was used with considerable success, it was not generally adopted and photogrammetry was not used again until 1918 when some aerial photographs became available for experimental surveys. This new method, more complete in coverage and less tedious in application, soon demonstrated its superiority over ground planetable surveying, and since 1928 has developed rapidly to the point where it is now used for nearly all our original topographic surveying work.

The development of aviation has made it simple and easy to produce aerial photographs of any region. But to produce maps from single-lens photographs requires considerable expensive ground control to combine a large number of these photographs into an accurate plot. To overcome these difficulties, personnel of the Coast and Geodetic Survey designed a nine-lens aerial camera and associated equipment which are now used in the topographic mapping programme of the Survey.

The camera has nine lenses of 8 1/4-inch focal length which produce at each exposure nine separate images on one piece of film. The images are transformed and combined in a special optical printer into a composite photograph approximately 35 inches square. These transformed prints afford excellent, detailed views of the ground. Each photograph covers an angle of 135° and provides coverage of an area of 32 square miles when taken at an altitude of 7,000 feet. This coverage increases to over 300 square miles at an altitude of 22,000 feet. The large area covered by a single exposure with this camera reduces the ground control necessary for aerial photographic surveys and reduces the cost of surveying with photographs, especially in areas where transportation is difficult and costly.

Stereoscopic plotting instruments have been designed especially for use with the large nine-lens prints. Stereoscopic pairs of rectified aluminium-mounted photographs are used on these plotting machines which are known as Reading plotters, after their designer, Captain O.S. Reading, U.S. Coast and Geodetic Survey. A visual relief model is obtained by the simultaneous examination of an overlapping pair of photographs and, by means of automatic parallax-analysing mechanisms and scale correctors, heights and contours are accurately measured and traced by this equipment.

Planimetric and shoreline surveys of areas of low relief are mapped from nine-lens photographs by radial plotting and graphic compilation methods. The control ordinarily consists of existing first-and second-order triangulation; at 1 : 20,000 scale each photograph covers an area 11 miles square.

Topographic maps, usually at 1 : 20,000 scale, are being compiled with the Reading plotters. Maps of standard accuracy have been made where the contour interval was 20 feet and the flying height 14,000 feet ; a contour interval of 100 feet is usually employed for maps of Alaskan areas. Ground control consists of identified stations of the existing first-and second-order geodetic triangulation network, plus vertical control stations spaced at intervals of one to three miles on the inland side of coastal flight strips. Graphic triangulation, or radial plotting, with the transformed but unrectified nine-lens photographs furnishes an abundance of image positions for use in a special rectification procedure prior to compilation with the plotters.

The Survey also uses a considerable amount of single-lens photography. The Fairchild cartographic camera, equipped with a 6-inch metrogon lens is the principal aerial camera in use. Topographic maps are compiled from single-lens photographs by means of a Zeiss stereoplanigraph, three Bausch and Lomb multiplex units and two Kelsh plotters ; and planimetric maps are compiled by graphic methods from the enlarged prints. A camera of 12-inch focal length having a 9×9 inch format is also used for planimetric mapping from single-lens photographs.

The stereoplanigraph is used for horizontal and vertical bridging or aerial triangulation between ground control stations with single-lens photographs. This work can be performed more accurately with the stereoplanigraph than with any of the other instruments of the Coast and Geodetic Survey. Moreover, the instrument is extremely flexible with regard to scale of compilation. In some applications data obtained with the stereoplanigraph are used as control for adjusting the multiplex and the Kelsh plotters, with which the final detailing and contouring are done.

Three multiplex units of seven projectors each are being used in the Baltimore field office to compile topographic maps. The publication scale of these maps is usually 1 : 25,000 with a contour interval of 20 feet, the flying height of the aerial photography being 12,000 feet. Five to seven models ordinarily are bridged to fit horizontal control and a vertical ground control station is established in each of the four corners of each model. The Kelsh plotter is used much as the multiplex with the exception that no bridging can be done with it yet. Ten-foot contours have been compiled accurately where the flying height was 12,000 feet.

Aerial photographs are taken from a B-17 aircraft, which is equipped with a plexiglass nose for the navigator. This sturdy long-range aeroplane is particularly suitable for the photography of the Survey inasmuch as it has a long range for use in the sparsely settled Alaskan areas, and also a relatively high ceiling. The aeroplane is equipped with two camera mounts, one for the nine-lens camera and one for single-lens camera. The aeroplane is owned and operated by the United States Coast Guard, but the navigator and photographer are employees of the Survey. During actual photography the navigator operates the plane.

Graphic compilation of planimetric maps and shoreline surveys from single-lens enlargements and nine-lens photographs comprises a relatively large proportion of the work of our Division of Photogrammetry. Radial line plots are very carefully made with transparent vinylite templets which are corrected graphically for paper shrinkage during their preparation. These surveys are usually made either at a scale of 1 : 10,000 or 1 : 20,000. The bulk of this compilation is performed in the field offices at Baltimore, Tampa, and Portland (Oregon).

Our average annual map production is 50 large-scale topographic maps (1,800 square miles), 45 planimetric maps (1,500 square miles), and 35 shoreline survey sheets covering 400 linear miles.

MAGNETIC AND SEISMOLOGICAL WORK

Observations made in the fields of geomagnetism and seismology are basic to several vital functions of modern life. An effective programme to meet these and related needs calls for long-range coordination of work over a vast area, and hence for the functioning of a technically qualified staff devoted to these activities. For the United States and its dependencies, responsibility for geomagnetic work is among those historically assigned to the Coast and Geodetic Survey in connection with its basic task of providing the navigator and airman with the charted data essential to navigation. Data of great scientific value are obtained in these studies. The safety of navigation depends to a very great extent upon the compass and the navigators' knowledge of its behaviour. Like the surveyor, the navigator must know the variation of the needle from true north, but in addition, the mariner must also know to what extent his compass is affected by the iron in his ship. The latter is a difficult problem and its solution requires a knowledge of the dip and intensity of the earth's magnetic field.

The seemingly diverse major activities of the Coast and Geodetic Survey are nevertheless closely coordinated to meet practical needs. Records obtained at magnetic observatories shortly after the turn of the century showed peculiar oscillations which were associated with distant earthquakes and seemingly indicated that the earthquakes gave rise to magnetic effects. Though it has since been concluded that the disturbances were wholly mechanical, it was necessary to install seismographs at the magnetic observatories before this question could be settled. The seismograms obtained were, of course, made available to seismologists, and ultimately the experience so gained led to the centralization of seismological work in the Coast and Geodetic Survey, in partnership with the magnetic work. Thus, a very practical service resulted in the collection of data which later proved to have scientific and engineering value, warranting the establishment of the activity on a permanent basis.

Magnetic Surveys. — Prior to 1850 Professor Bache (the second superintendent of the Coast Survey) personally engaged in and directed the initial geomagnetic work of the Survey, including observations for magnetic declination, dip and intensity. This work was pursuant to the original Hassler plan which prescribed that « magnetic bearings should be regularly observed at each principal station ». The comprehensive magnetic survey of today which had its beginning more than 100 years ago provides data essential to safe navigation by water and air ; it also supplies information useful in solving problems incident to radio communication, explorations, geophysics, and magnetic defence of harbours and supply — problems of vital importance in wartime and highly important in peace time.

Magnetic observations have been made at many thousands of stations including nearly every county seat in the more than 3,000 counties in the United States. Changes in the earth's magnetism have been determined by repeat observations made at about 150 selected stations distributed over the country, and from the continuous photographic records of the magnetic elements registered at magnetic observatories. Information concerning the gradual change in direction of the compass needle, essential in working with old surveys, is not confined to the period during which the Survey has been making observations, but has been derived from the most diverse sources including obscure reports of very early observations made in the older parts of the country.

The first observations made by the Survey were confined to the coastal regions since they were intended to provide magnetic data for nautical charts. Later the work was extended to the interior of the country, and was greatly expanded and intensified at about the turn of the century. There are now more than 8,500 stations at which observations of one or more magnetic elements have been taken. In many regions they bring out clearly the wide-spread irregularities that affect the magnetic lines.

The Coast and Geodetic Survey regularly issues magnetic charts that provide a basis for estimating magnetic elements in any given locality. Publications are available giving general information about the earth's magnetic field, the effects of daily variation and other transient fluctuations, and various other aspects of geomagnetism. In addition, an energetic programme is promoted in the Survey for

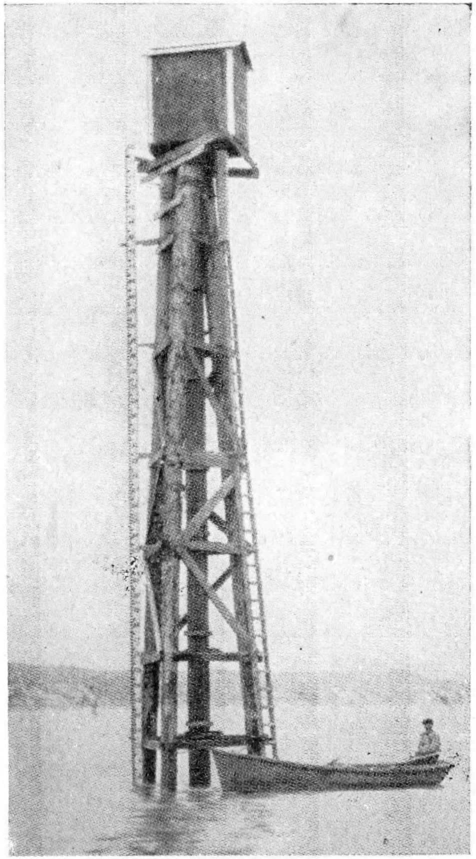

Fig. 8. — Tide gauge at Anchorage, Alaska (Low tide).

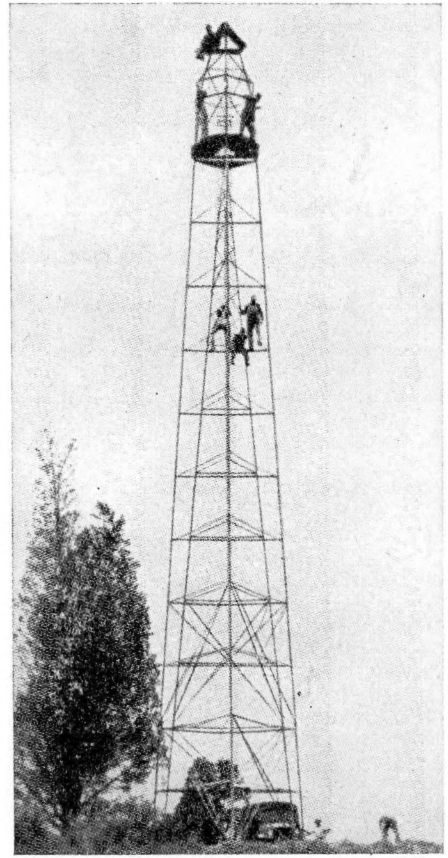

Fig. 9. — Bilby triangulation Tower. — Portable steel triangulation tower designed and built for the Coast and Geodetic Survey.

Fig. 10. — Landing a weasel at Buldir Island

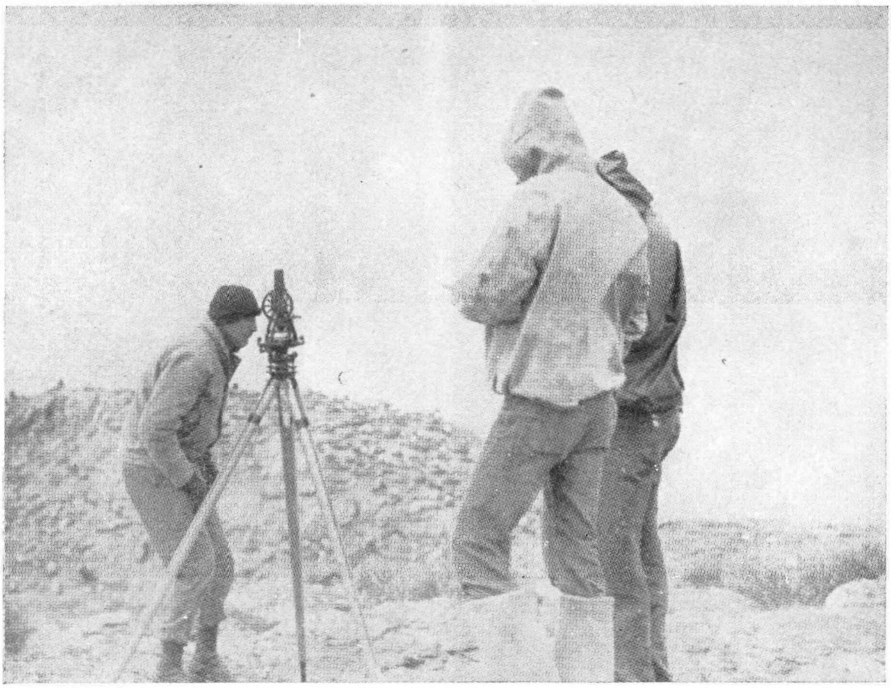

Fig. 11. — Making magnetic obervations with a transit magnetometer

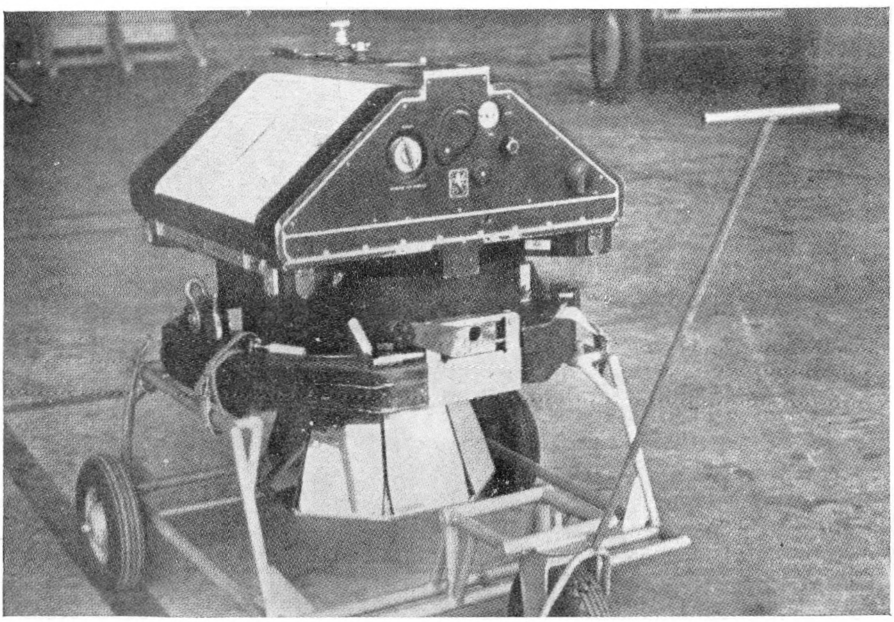

Fig. 12. — Nine-lens Aerial Camera. — Designed and used by the Coast and Geodetic Survey for obtaining topographic data. The camera takes nine photographs simultaneously, of adjoining areas, on a single piece of film 23 inches square. The centre photograph is taken vertically downward, while the other eight are oblique views.

Fig. 13. — One of the drafting rooms where aeronautical charts are drafted, reviewed and proof-read prior to reproduction.

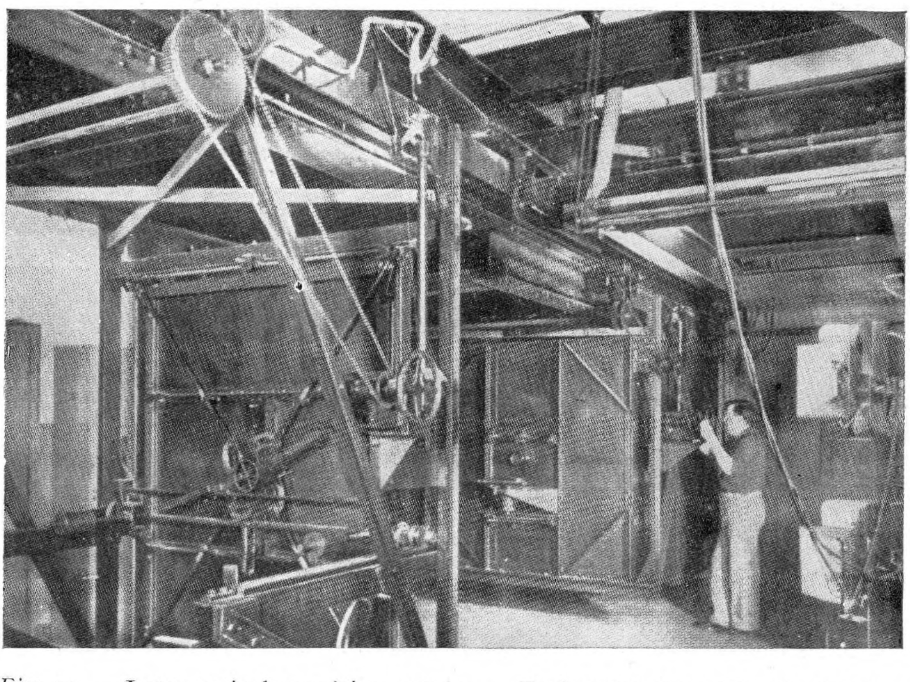

Fig. 14. — Large 50-inch precision camera. — Designed and used by the Coast and Geodetic Survey for the reproduction of nautical and aeronautical charts. Weighing 14 1/2 tons, this large wet-plate camera is housed in the Department of Commerce Building, Washington.

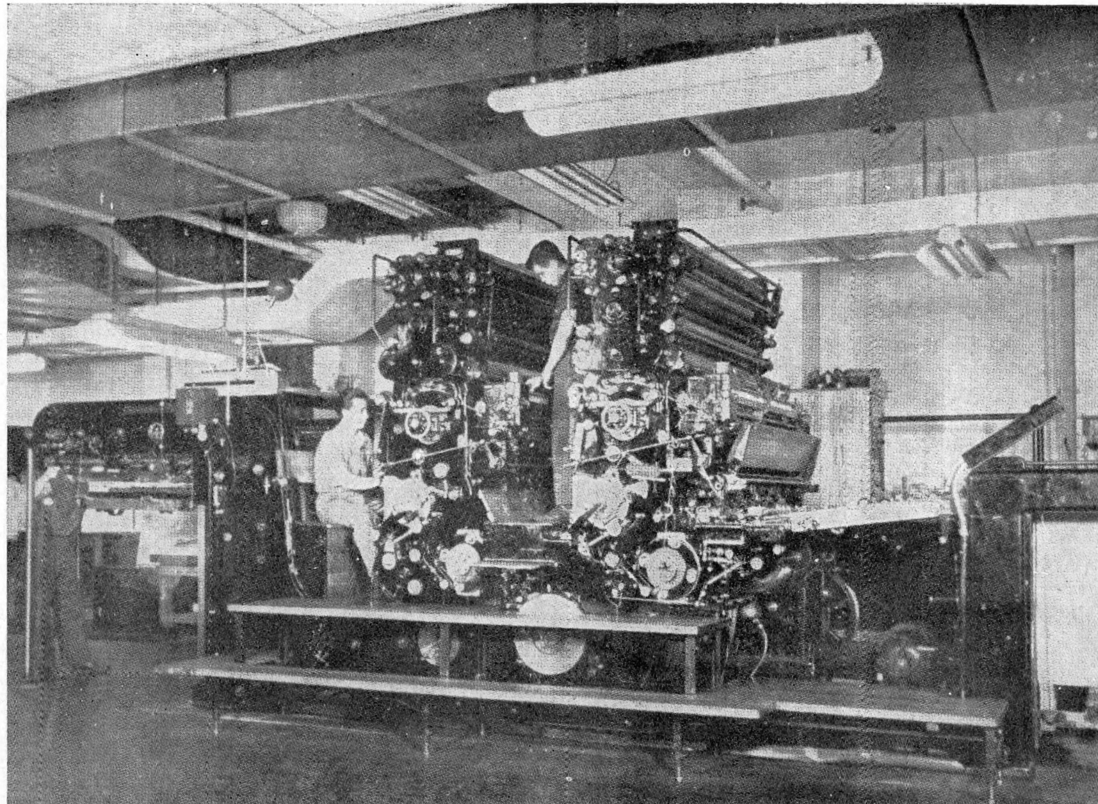

Fig. 15. — Two-colour offset press. — Two-colour offset press on which aeronautical and nautical charts are printed. This press has output of 4,000 impressions per hour.

working out new techniques and developing new instruments for making the highly refined measurements that provide the basis of an all-out programme of magnetic work.

Seismological Surveys. — In 1925 the Coast and Geodetic Survey was designated by law to make reports and investigations in seismology, the science of earthquakes. Prior to this time seismographs were in operation for a number of years at the magnetic observatories of the Survey. The Coast and Geodetic Survey now obtains earthquake data not only from its own observatories but from a number of cooperating organizations in the United States and abroad. Scientific study of data thus obtained yields information on the true nature and distribution of earthquake phenomena, the nature of seismic wave propagation and the physical structure of the earth. Seismic waves serve as a kind of X-ray to reveal complexities in the earth's structure which otherwise might never be known. When strong earthquakes occur the shaken areas are canvassed for information on damage and other effects. The results of all these operations are published in periodical reports.

Seismological studies provide structural engineers with basic ground-motion data on destructive earthquakes for use in designing structures in earthquake areas. Fifty-two seismographs of special design are operated in earthquake areas to obtain information on destructive ground-motions. Because of technical difficulties involved in applying this information to building design, the programme is considered to be in the research stage.

COMBINED SURVEYING OPERATIONS

Surveying our Alaskan waters and adjacent coastal areas has been a pioneer undertaking by the Coast and Geodetic Survey. Surveying in Alaska is at best slow and difficult due to rugged terrain, bad weather and foul inshore areas. Ice conditions and low temperatures add to the difficulties. To pursue this work successfully special planning and coordination of surveying operations have been necessary. In surveying isolated regions under adverse conditions the method of combined surveys has been developed by which each ship operates as an expedition.

The modern surveying ships in use today carry equipment and trained personnel for accomplishing all operations incidental to completing surveys in areas far-removed from home ports. Ship-based parties with personnel trained in hydrographic, topographic, geodetic and related surveys have been especially effective in conducting surveys in Alaska. In recent years extensive operations have been carried on along the bleak and barren chain of Aleutian Islands which extend more than 900 miles in a south-westerly direction from the Alaska mainland. In addition to the execution of hydrographic surveys, members of the surveying ship are required to establish geodetic control, conduct topographic surveys for the location of signals for hydrographic control and the delineation of shoreline by planetable, make magnetic observations and obtain tidal information through tide and current surveys. Also, aerial photographs are field-inspected and necessary control points are identified and described. Thus combined surveying operations with ship-based parties have come into general use as the medium for conducting our Alaskan surveys.

NAUTICAL AND AERONAUTICAL CHARTS

For more than one hundred years the Coast and Geodetic Survey has published nautical charts of the United States, its Territories and Possessions. The first chart published was an engraving on stone of Newark Harbour but the early charts were produced mainly as copperplate engravings. The early engravings were characterized by elaborate titles and notes and engraved views of headlands, lighthouses, and harbour approaches. Lithographic methods were employed in reproducing our charts as early as 1897 and since 1916 copperplate engraving has been gradually discontinued until now all our charts are produced entirely by modern photo-lithographic methods.

Rapidly expanding maritime and air commerce and developments in navigational aids and methods have increased the demand for new types of charts and modernization of existing charts. Chart production and distribution have increased in importance and magnitude in proportion to these increased demands. Moreover, in the interest of national security, extension of coverage and increased production have been necessary to meet military requirements.

Nautical and aeronautical charts are printed in our modern humidity-controlled pressroom. The line of presses includes 7 Harris single-colour and 2 two-colour presses taking printing plates of 38 1/2 by 50 inches, and 2 small presses taking plates 24 1/2 by 30 inches. The printing area of the plates is slightly smaller than the press size. The large presses operating at normal speed produce about 4,000 impressions hourly on each cylinder, whereas the small presses operate at about 3,000 impressions hourly. To meet increased demands our presses are being operated on a daily 16-hour basis and some presses operate 24 hours a day. Under this expanded printing programme about 7,000,000 impressions are being printed monthly.

Nautical Chart Production. — Nautical charts are compiled principally from our basic field surveys and include information necessary for safe navigation. To meet the different navigational needs nautical charts are published in different series, classified as *Sailing, General, Coast* and *Harbour.* Chart scales range from 1 : 2,500, the largest-scale harbour chart, to 1 : 5,000,000, the smallest-scale sailing chart. Nautical charts, with few exceptions, are constructed on the Mercator projection.

Of the 911 nautical charts on issue during 1950, a total of about 900,000 copies were distributed. New charts produced each year total about 15. Our annual nautical chart production also includes about 35 new editions and 400 new prints or reprints.

During the past 15 years the nautical chart published by the Coast and Geodetic Survey has undergone more radical changes in appearance and usefulness than in any similar period of the history of the Bureau. Four basic factors are responsible for the numerous innovations and significant changes in the modern chart. These are : rapid strides in surveying techniques with the resulting augmented knowledge of the ocean floor ; modernization by improved techniques and simplified symbolization ; improved reproduction methods and increased use of colours ; and new navigational methods.

Because of improvements in navigational and surveying techniques, the nautical chart now utilizes to the fullest extent the wealth of submarine detail contained in modern hydrographic surveys. Today, the navigator can not only determine his position from the fathometer record of these charted submarine features that he passes over, but he can also lay and plot the courses in advance to pass over those most prominent.

New navigational methods that also have had their effect upon the appearance of the modern chart include navigation with the aid of the fathometer, radar, and loran. Radar has had little effect upon the nautical chart with the exception of the charting of radar reflector buoys and, in some cases, the addition of contours and gradient tints on the land areas. The accurate delineation of the shoreline is sufficient for the navigator making use of radar.

One of the most striking changes in the appearance of the nautical chart today is the substitution of depth curves and blue tints for sanding. The shading of water areas brings out the gradation of depths to emphasize dangers to navigation and to make channels and other safe waters apparent at a glance. Detailed hydrographic surveys made with echo-sounding equipment have made possible more accurate depth curves on Coast and Geodetic Survey charts to bring out bottom characteristics and a truer portrayal of the actual shape of the ocean floor. This treatment permits the use of a minimum of soundings and has resulted in a chart which is not only extremely legible but invaluable for navigation with echo-sounding equipment.

On the modern nautical chart all basic information is printed in black including topographic contours and soundings ; various other colours are used to emphasize certain features. All land areas are overprinted in buff ; blue is used to emphasize water areas between the low water line and designated depth curves ; green, produced by overprinting in both blue and buff, is used to define marshlands and tidal flats ; and red is used to indicate cable areas, anchorages, and red buoys. Advances in lithography have made possible increased use of colours without an undue increase in cost.

A new type of nautical chart has been developed and published by the Coast and Geodetic Survey on which loran curves and all other basic information, including all required depth curves, are shown, but with soundings outside of the 10-fathom curve deleted. Charts of this series are printed on the reverse side of the standard editions.

The policy of the Coast and Geodetic Survey is to design the nautical chart so as to develop the greatest usefulness of our coastal waters and to promote safety in marine navigation through constant revisions from surveys by the Bureau and other reliable sources.

The Survey publishes a series of Coast Pilots which are primarily for navigational use. They provide descriptive data required by the navigator which cannot be shown conveniently on nautical charts. Each Coast Pilot covers a selected section of the coast and contains detailed data relative to the coastline and harbours, port information, sailing directions for coasting and entering harbours, and general information as to weather conditions, radio service, etc. Ten volumes are published at the present time for which new editions are issued at about seven-year intervals. Supplements containing changes and new information are published annually. Coast Pilots issued during 1950 totalled about 20,000.

Aeronautical Chart Production. — The aeronautical charting programme of the Coast and Geodetic Survey was initiated more than two decades ago to provide necessary charts for aviation with the same standard of accuracy and proficiency found in the nautical chart. Included in these activities are the compilation and printing of aeronautical charts of the United States, its Territories and Possessions, as required for civil aviation and for military use where these requirements are parallel. In addition, such aeronautical charts covering international airways as are required primarily by United States civil aviation are compiled and printed by the Survey.

Aeronautical charts on issue during 1950 totalled 914 including 271 standard and auxiliary charts, 555 instrument approach and landing charts, and 88 radio facility charts. About 7,000,000 copies of the standard aeronautical charts of the United States were distributed during the year. In addition, over 17,000,000 of the page-size airport and radio facility charts were issued.

Survey data resulting from field surveys by the Bureau supplemented by the best topographic information available from other sources are used in compiling the aeronautical charts. These charts are issued in several different types and scales. Charts now in use for the United States include 87 sectional charts at the scale of 1 : 500,000; 43 world aeronautical charts at the scale of 1 : 1,000,000; route charts at the scale of 1 : 2,000,000, and direction finding, local, instrument approach and landing, radio facility, and aircraft position charts at varying scales.

Before final publication a flight check is made with a preliminary copy of the chart. The charted area is flown over by an experienced observer and details of the chart are compared with the ground below. The necessary corrections are indicated and prominent landmarks are noted for addition to the chart. In the event of extensive changes the observer is sometimes able to obtain local source maps showing the necessary information but more often the changes are drawn in at the time of observation. Some of the most important information appearing on the aeronautical chart is obtained from the flight check.

An important aspect of the aeronautical charting programme of the Bureau is the constant attention given to research and development for better charting methods and presentation of detail. Constant improvement is made to the charts through this research and new types of charts are being developed as a result of experience gained by Bureau personnel. Progressive improvement of aeronautical charts through research and development is essential to our rapidly expanding air commerce.

RESEARCH AND DEVELOPMENT

Because of its highly specialized activities, the Coast and Geodetic Survey has from its inception recognized the importance of developing new and improved instruments, equipment, and techniques in order that better results might be obtained at reduced cost. Progressive research with the application of new scientific findings to our operations has been of paramount importance in developing our present-day methods and equipment. In recent years our research work has been intensified through maintenance of a Radio-Sonic Laboratory where improvements and adjustments are made of equipment used in the application of electronics to our surveying operations. Aerial photographic mapping is being continually improved through intensive research carried on in our Photogrammetric Laboratory by a technical group of experts assigned to this type of work. Improvements are being made in the quality, accuracy and speed of stereoscopic contouring with the Reading plotter. The Survey also maintains a modern repair shop for servicing all instruments and equipment used in its field and office work.

Many important improvements in operating equipment and methods used in hydrographic surveying have resulted in extensive modernization in the field of hydrography. Work now in progress includes the design and development of a new hydrographic launch and a landing craft to handle cargoes of up to three tons. To meet the special needs of the Survey, an aluminium shoal-water hydrographic launch has been designed and is now undergoing field tests. Improvements have been made in our tide and current instruments, including modification of the NK-7 portable depth recorder for use as a tide gauge.

New and advanced echo-sounding instruments, deep-water anchoring equipment for current meters and tide gauges, suitable equipment for positive calibration of sonic depth records, improved depth records, and improved logs for measuring the speed of vessels through water are among the objectives of our present research and development programme.

New and improved electronic equipment has been designed for seismological work at Coast and Geodetic Survey observatories. Improved visible remote seismograph recorders have been installed at several stations in connection with the seismic sea wave warning service. An improved method was introduced recently for calibrating the galvanometric seismographs by imposing a wide range of frequencies on the seismometer pendulum.

Laboratory tests simulating tide and seiche action at detector stations have facilitated the installation of sea wave detectors. Standard types of magnetic instruments for field and observatory use have been designed and manufactured in accordance with Survey specifications, including earth inductors, magnetometers and magnetic variometers. Special photographic recorders for use in Arctic regions, and visible recorders for observatory use, have been developed.

A new induction-type magnetometer, developed with the cooperation of the Naval Ordnance Laboratory, and its successful adaptation to aircraft use by the Coast and Geodetic Survey, has for the first time opened the way to immediate future airborne magnetic surveying of ocean areas and other regions inaccessible by ordinary methods.

Precision level rods are being constructed by an improved photographic process developed by the Survey. This process permits more uniform coating of rods with photo-emulsion and provides a more accurate printing mask. Facilities for handling rods are better and through continual experimentation better paints and lacquers are being obtained. These improvements have resulted in a better finished rod which is produced more quickly and at less expense.

In 1948 the Coast and Geodetic Survey installed a group of international business machines to be used primarily for computing by the punch-card method. These machines are standard equipment such as used in large business firms. Geodetic, magnetic, tidal analysis, and cartographic computations are being made on the machines. Many of the extensive geodetic problems being solved by this method include large sets of simultaneous equations involved in triangulation adjustments. Such problems comprising more than 2,000 simultaneous equations are being completed in three or four months. Using desk calculators, the services of five men would be required for one year to solve the same problem.

Plans are now being developed for expanding geodetic control into northern Alaska by means of Shoran tri-lateration. This method offers a rapid means of locating stations for which more accurate determinations can be made at a later date by conventional triangulation.

Our extensive operations in Alaska require the development of suitable instrumental equipment and methods appropriate to the unique and rigorous environmental conditions encountered in the Arctic and Sub-Arctic. All types of precise instruments require special modification to withstand the intense cold and humid conditions of Alaska. Through experimentation employing temperature chamber equipment the best metals and oils for instruments and equipment are being determined. Tests are now being conducted to determine the best material for cross lines in telescope reticules.

Improved procedures are in prospect for determining elevations through the development of techniques for use of photo-theodolites and precision altimeters. Experimentation is being made with new types of vehicles for surveys in inaccessible places such as alaskan tundra and bog areas. Techniques have been developed for landing amphibious vehicles over boulder beaches and through rough surf. Surveying operations are being expedited through the use of helicopters for placing personnel and equipment in areas not otherwise accessible.

PRESENT OPERATIONS AND PLANS FOR THE FUTURE

In view of the present strategic importance of Alaska major emphasis is being placed on the extension of our hydrographic surveys in the area. Seven of our 19 survey vessels operated during the summer of 1950 in southeast Alaska, in Prince William Sound, along the south coast of the Alaskan Peninsula, in the Aleutian Islands, in Bristol Bay and along the Arctic coast. Other hydrographic surveys were carried on in various regions along the Atlantic, Gulf and Pacific coasts of the United States as a part of the present programme of modernizing our nautical charts. Wire drag surveys for locating sunken wrecks and dangers to navigation were conducted in the vicinity of the entrance to New-York Harbour and along the coasts of Maryland and Delaware.

Aerial photographs are being taken with the nine-lens camera of areas along the Atlantic and Gulf coasts and in Alaska. Photographs are also being taken of many airports in the United States; surveys were completed during the past year for over 100 airports for use in compiling aeronautical charts for making instrument approaches and landings and for airport obstruction plans. Photogrammetric field surveys will be continued along the coasts of the United States and Alaska during the coming season.

The basic networks of horizontal and vertical control are being extended in the United States and in the interior of Alaska. In 1950 major field activities were carried on in the Missouri River Basin for flood control and reclamation studies. Special geodetic field projects are in progress to provide data for studies of horizontal earth movement in earthquake regions, deflection of the vertical from gravimetric observations, and settlement in the Long Beach, California, area. Progress is being made in adjusting the triangulation of the United States and Alaska and of the western European net.

Our present programme of tidal observations is carried on at the principal seaports in the United States and possessions and in foreign areas to provide data for prediction of tides and studies of mean sea level. A comprehensive tidal current survey of Tampa Bay, Florida, was completed in 1950 and tidal current charts have been compiled of the area. The collection of temperatures and densities of sea water at tide stations is a continuing operation and a number of new stations are added to the network each year.

Data were provided for further mapping of seismic areas and for the development of safe building-construction methods by the chain of seismograph stations maintained by the Survey. Data thus obtained were supplemented with information furnished by universities and private institutions. In 1950 the Survey received 8,500 earthquake messages through national and international cooperating agencies and announced the locations of 570 earthquakes.

Many of our present practices and techniques used in both office and field were first presented informally in publications issued more or less periodically since 1930. These publications provide a medium for exchanging ideas between our scientifically trained officers and employees on widely separated assignments in engineering work. Through these informal technical discussions officers keep in touch with and receive the maximum benefit from the efforts and experiences of one another. New methods and new developments are thus exposed to discussion and modification and made available to our field parties for trial or application. No regular schedule is maintained but the material is printed as it accumulates and at such intervals as to be of maximum use to operating units. In addition to being of great value to the Survey, the publications render indirectly a valuable public service.

The work of the Coast and Geodetic Survey is a pioneering effort which has expanded progressively in scope and importance with the increased demands for our products. The development and extension of our technical services and their importance in contributing to the general welfare of the nation are apparent. Each successive decade has seen a broadening of our operations with improved techniques and methods. Future operations are being planned to keep pace with modern developments in commerce and business and to meet the increased demands made upon us in preparing for National Defence. Our labours must continue with unabated vigilance so long as the sea washes our coasts, rivers flow and deposit their silt, earthquakes occur, and other changes are made by man and nature. The necessary services performed by the Coast and Geodetic Survey reveal their value in the inestimable wealth of added security to life and property on land and sea.