DEPARTMENT OF COMMERCE

LIGHTHOUSE SERVICE

THE UNITED STATES LIGHTHOUSE SERVICE

EDITION OF

1923

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

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Compiled by

JOHN S. CONWAY
DEPUTY COMMMISSIONER OF LIGHTHOUSES

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INTRODUCTION.

The coasts and inland navigable waters of the United States, and of its outlying territory excepting the Philippines and Panama, are all lighted and marked by the Lighthouse Service, which is consequently the largest organization of its kind in the world. Owing to the dependence on water transportation at the time of the formation of the Federal Government, this was the earliest public work of the United States, being provided for in 1789, at the first session of Congress. Long ere this, however, the remarkable maritime traffic developed by the colonies had led them to build lighthouses, and these colonial stations are all still in commission, so that the lighthouse work considerably antedates the Federal Government. Boston Light, the first station, has now been in continuous operation for 207 years, excepting for war interruptions. The establishment has grown with increase of territory and commerce, and in its operations the developments of science and engineering are continually applied, particularly in the fields of physics, optics, acoustics, and electricity, and of civil, mechanical, electrical, and marine engineering and naval architecture. The most rapid advances have been made in recent years, including, for example, the introduction of quick-revolving lenses throwing powerful light beams, oil-vapor lights, automatic acetylene lights, lighted buoys, more powerful sound signals, radio fog signals, automatic gas fog signals, submarine signals, improved light vessels and tenders equipped with radio, and concrete construction. A complete reorganization of this service, provided by law in 1910, permitted great simplification of its work and large economies. Contrary to the general governmental tendency, a decentralized system has been successfully applied, the work of the service being largely conducted from its district offices, and as a result it has the smallest proportion of personnel in Washington, only 40 persons in all being stationed there out of the 6,000 in the Lighthouse Service. The success of the plan is indicated by the satisfaction expressed by navigators, by the record of the service as to appropriations, and by the fact that 16,373 aids to navigation are now maintained by practically the same number of employees and of vessels as were required in 1910 for the 11,661 aids then maintained. On the human side marked advances have been made in providing for the well-being of the personnel, through provision for retirement, compensation for

injury, medical attention, longevity pay, improved living conditions on vessels, and in other ways. The men and women of the service have a worthy record not only of devotion to duty under difficult and oftentimes hazardous conditions, but of personal sacrifice and risks voluntarily taken to succor those in distress.

The Department of Commerce is charged with a number of functions having to do with the protection and regulation of shipping, and the Lighthouse Service, under the supervision of this department, performs a very necessary duty in this respect; all important maritime nations maintain organizations for this purpose.

This publication is a revision of that issued in 1915, which has been found useful in furnishing information and answering numerous inquiries as to the organization and operation of the United States Lighthouse Service. It has been prepared, as was the previous edition, by Mr. Conway, with the helpful assistance of others in the service.

GEORGE R. PUTNAM,
Commissioner of Lighthouses.

WASHINGTON, *March 1, 1923.*

Kilauea Point Light Station, Kauai, Hawaii.

THE UNITED STATES LIGHTHOUSE SERVICE, 1923.

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1. DUTIES AND ORGANIZATION.

The United States Lighthouse Service is charged with the establishment and maintenance of aids to navigation, and with all equipment and work incident thereto, on the coasts of the United States. The term "aids to navigation" comprises all land and sea marks established or adapted for the purpose of aiding the navigation of vessels, and includes light stations, light vessels, fog signals, buoys of all kinds, minor lights, and day beacons.

The executive office of the service is in Washington, under the Commissioner of Lighthouses and the Deputy Commissioner. There are in this office an engineering construction division, under the chief constructing engineer; a naval construction division, under the superintendent of naval construction; a hydrographic division,

under an assistant engineer; and the general office force, under the chief clerk.

The service outside of Washington is divided into 19 lighthouse districts, each of which is under the charge of a superintendent of lighthouses. In each district there is a central office at a location selected on account of either its maritime importance, or its geographical position. Attached to each district office is a technical force for the construction and upkeep of both land structures and floating equipment, and also a clerical force, with a chief clerk and assistants, for the work of the district. The principal technical assistant to the superintendent is the first assistant superintendent, and there are assistant superintendents, aids, and draftsmen as required by the size of the district. In the field are construction and repair parties under foremen, and in a number of districts there are mechanicians who attend to special repairs and installations of apparatus. All of this force is composed of civilians, except that in the three river districts, officers of the Corps of Engineers, who are in charge of river improvements, act also as superintendents of lighthouses.

One or more lighthouse depots are conveniently located in each district for carrying on the work of the district in the matter of storing and distributing supplies and apparatus. In addition to the various district depots, there is in the third lighthouse district, on Staten Island, New York Harbor, a general lighthouse depot, where many of the supplies for the whole service are purchased and stored and sent out for distribution, and where much of the special apparatus of the service is manufactured or repaired, and where also there is carried on various technical work in the way of testing apparatus and supplies and designing or improving apparatus.

Each district is provided with one or more lighthouse tenders for the purpose of distributing supplies to the various stations and light vessels and for transportation of materials for construction or repair, for the placing and care of the buoyage system in the district, and for transporting the superintendent and other officers of the service on official inspections of stations and vessels and on other official duty.

2. JURISDICTION.

The jurisdiction of the Lighthouse Service extends over the Atlantic, Gulf, Great Lakes, and Pacific coasts, the principal interior rivers, Alaska, Porto Rico, and Hawaii, and all other territory under the jurisdiction of the United States, including various banks and islands in the Caribbean Sea, with the exception of the Philippine Islands and Panama. In the Philippine Islands the lighthouse service is maintained by the insular government and supported entirely out of the revenues of the islands. At Panama the canal

government has charge of the lighting of the canal and approaches under the general appropriations for the canal.

All the work of establishing and maintaining the aids to navigation under the jurisdiction of the Lighthouse Service is performed directly by the service through district organizations, with the exception of a few minor aids, which are maintained by contract, and the exception of the American Samoan Islands, the island of Guam, and Guantanamo, Cuba, where the aids are maintained under the supervision of the naval commandants under allotments made from the appropriations for the Lighthouse Service. The Lighthouse Service also has supervision over the establishment and maintenance of private aids to navigation and the lighting of bridges over navigable waters of the United States.

At the present time the United States assists in the maintenance of but one lighthouse outside of its territory, this being at Cape Spartel, Morocco. This light is maintained in accordance with the convention between Morocco and the United States, Austria, Belgium, Spain, France, Great Britain, Italy, Netherlands, Portugal, and Sweden, in force since March 12, 1867. The lighthouse was constructed at the expense of Morocco, but it is maintained by the other contracting powers. The annual appropriation by the United States for this purpose is $325, and it is not under the control of the Lighthouse Service.

The jurisdiction of the Lighthouse Service over rivers not included in tidewater navigation is restricted to such as are specifically named in the various acts of Congress. These now include practically all the important navigable rivers and lakes of the country.

The following table shows the total length of coast line under the jurisdiction of the Lighthouse Service, that designated "general coast line" being measured by steps of 30 statute miles, and that designated "detailed coast line" by steps of 3 statute miles. There are also given the lengths of the coastal and interior rivers and tributaries so far as they are authorized to be lighted.

	General coast line.	Detailed coast or channel. line.
	Statute miles.	*Statute miles.*
Atlantic and Gulf coasts of the United States	3,500	10,000
Porto Rico, Virgin Islands, Guantanamo, and other United States possessions in the West Indies	370	450
Pacific coast of the United States	1,400	2,900
Alaska	6,600	15,000
Hawaiian and Midway Islands, Guam, and American Samoa	950	1,200
Great Lakes and connecting waters, United States portion	2,500	3,200
Coastal rivers (Atlantic and Gulf coasts, 1,470 miles; Pacific coast, 240 miles)	.....	1,710
Interior rivers (Mississippi River, 1,940 miles; Ohio River, 970 miles; Missouri River, 390 miles; Yukon River and tributaries, 1,700 miles; other rivers, 1,120 miles)	.....	6,120
Total	15,320	40,580

3. COOPERATION.

In performing its duties the Lighthouse Service cooperates actively with all other branches of the Government engaged in related work. Notices to mariners are issued jointly with the Coast and Geodetic Survey, and information affecting charts is supplied to that office for publication. Similar information is furnished the Lake Survey and other offices publishing charts. Cooperation is had with the Corps of Engineers, War Department, in connection with river and harbor improvements, as to special aids to navigation maintained for such works, information of improvements that will affect aids to navigation, the marking of river channels, lighting of wrecks, etc. Information as to deficiencies in aids is received from the Hydrographic Office and from naval vessels and from other maritime services of the Government. Telephone connection with many light stations is maintained, with the cooperation of the Coast Guard. The Public Health Service aids in matters of sanitation affecting lighthouse vessels and stations, the Bureau of Standards in the design of radio apparatus and in special tests, the Bureau of Mines in analysis of coal, the Forest Service in the growing and management of timber on lighthouse reservations, the Department of Agriculture in the protection of migratory birds on lighthouse reservations, the Steamboat Inspection Service in the inspection of steam plants of vessels. The Navy Department permits the Lighthouse Service to purchase from navy yards and naval stations provisions and clothing for crews of vessels, also fuel and miscellaneous supplies when the same may be spared. Similar privileges are afforded certain stations by the War Department. The Lighthouse Service supplies information respecting aids to navigation to all branches of the Government having need for such data and cooperates in the placing of buoys for special purposes.

Meteorological observations for the Weather Bureau are made at selected light vessels and stations, and information respecting ocean currents is obtained for the Coast and Geodetic Survey and the Hydrographic Office. Licensed officers on lighthouse vessels assist the Steamboat Inspection Service in the examination of applicants for certificates as lifeboat men under the seaman's act of 1915.

Special effort is made to consult the needs of merchant shipping as to aids to navigation. Applications from maritime interests for establishing or improving aids are carefully considered, and all matters involving extensive changes are taken up with such interests before action is decided upon.

Mariners and others interested are invited to give prompt information to the district superintendents of lighthouses, or by direct communication to the Commissioner of Lighthouses, of all cases of injury

to or unsatisfactory condition or incorrect position of any aid to navigation, or of the necessity for additional aids, or of any existing aid not needed, and of all cases where the lights are not exhibited punctually at sunset and extinguished at sunrise.

4. NATIONAL DEFENSE ACTIVITIES OF THE LIGHTHOUSE SERVICE.

The Lighthouse Service has cooperated in all wars and national emergencies with the military and naval forces of the United States. In the Revolutionary War Boston Lighthouse was repeatedly attacked and finally destroyed, and Sandy Hook Lighthouse also suffered damage; the strategy of a lightkeeper's family saved from destruction ships lying in the harbor of Scituate. During the War of 1812 the keeper of the lighthouse at Havre de Grace, Md., is reported to have defended that town from an attack by the enemy. In this war some of the lights, including Boston, were extinguished. In the Seminole War in 1836 the lighthouse at Cape Florida was attacked by the Indians, and the interior burned, and the assistant keeper and his assistant, who took refuge on the gallery, were shot. In 1837 the captain of the lightship at Carysfort Reef, Fla., and one of his crew were killed by the Indians. In 1856 the construction of the early lighthouses on the Pacific coast was delayed by the unfriendliness of the Indians, and it was necessary to build a blockhouse and provide arms before commencing the lighthouse at Cape Flattery, Wash. The first lighthouse tender on the Pacific coast, the *Shubrick*, carried several guns in order to protect light keepers and citizens from Indian attacks.

In the Civil War the Lighthouse Service was much involved, as was to be expected from the fact that a long coast line was exposed to attack from the sea. Nearly all the lighthouses on the southern coasts were seized, and as a result one-third of all the lights previously maintained by the United States were discontinued. Nearly all the light vessels in Chesapeake Bay and to the southward were taken, and a number of them were sunk for the purpose of obstructing channels. In July, 1863, the tender *Martha*, while engaged in lighthouse work in Chandeleur Sound, was captured and burned and her crew taken prisoners; the master subsequently escaped and reached New Orleans. The lighthouse tenders at Charleston and Mobile were seized; at Galveston the general supply schooner *Guthrie* and her master and crew were detained for many weeks, but later were allowed to leave port. A few of the lighthouses on the Florida coast were maintained continously, and the lights and light vessels were replaced from time to time during the war as the operations permitted. The Lighthouse Board cooperated with the Army and Navy in many ways. Illuminating apparatus and supplies deemed

necessary for temporary purposes were furnished to the Navy. Additional supplies of buoys and apparatus were purchased and kept available for prompt replacements and for special use. A number of light vessels were built for use as needed. Special buoys, lights, and lightships were placed in many instances to facilitate military operations, as, for example, at the entrances to York River, to Chesapeake Bay, and to Charleston, and on the James and St. Johns Rivers. Much of the apparatus was later recovered, and some of the vessels were raised and repaired. As early as practicable after the war the Lighthouse Service on the southern coasts was fully restored.

During the Spanish-American War of 1898 arrangements were promptly put into effect for providing efficient means of communication to the important light stations, vessels, and depots. A number of lighthouse tenders were transferred to the Navy Department for war purposes, and of these the tenders *Mayflower, Maple, Mangrove,* and *Armeria* rendered actual service, the latter as an ammunition supply vessel during the operations in the West Indies, and the others as dispatch boats and on miscellaneous duties. The services rendered by the *Mayflower* (*Suwanee*) and the *Mangrove* in action and in capturing enemy vessels brought these tenders into prominent public notice. The tenders also rendered valuable assistance in several important harbors in planting and protecting the submarine mine defenses.

Prior to the World War arrangements were in effect with the War Department for the assignment of lighthouse tenders from time to time for mine planting practice, and the service kept prepared in the event of necessity to turn over to the Navy Department, with the approval of the President, such vessels as might be required in naval operations.

The naval appropriation act of August 29, 1916, authorized the President, whenever in his judgment a sufficient national emergency exists, to transfer to the service and jurisdiction of the Navy Department, or of the War Department, such vessels, equipment, stations, and personnel of the Lighthouse Service as he might deem to the best interests of the country. On April 11, 1917, the President issued an Executive order transferring 30 lighthouse tenders to the War Department, and 15 lighthouse tenders, 4 light vessels, and 21 light stations to the Navy Department, including a total of 1,120 persons employed thereon. The tenders transferred to the War Department were subsequently transferred to the Navy Department. These vessels and stations after that time performed various duties under these departments, and also continued the maintenance of the aids to navigation and other duties necessary for the Lighthouse Service. On January 31, 1918, another lighthouse tender was transferred, making

1,132 persons and 50 vessels transferred. In addition to this number of persons 152 employees of the service joined the Army or Navy, making with those transferred a grand total of 1,284 employees who entered the military services, or approximately 22 per cent of the normal force of the Lighthouse Service. These persons were all awarded victory medals by the Navy Department. In July, 1919, all vessels and personnel were retransferred to the Department of Commerce.

The superintendents, assistant superintendents, and chief clerks of the various lighthouse districts (46 persons) also reported to the Navy and Army authorities, for service in coordinating the military and lighthouse duties of the transferred portions of the Lighthouse Service. Officers of the service served on joint committees, with representatives of the military departments, for arranging and improving the coordination of the work of the Lighthouse Service units. Also the officers of the Lighthouse Service throughout the war were in direct communication with the various bureaus of the Navy Department for this purpose.

The vessels of the Lighthouse Service did practically all of the work on the defensive entrance nets, they did mine laying, they placed floating practice targets, buoys, and marks for military uses; they were employed as patrols, and on much special duty. The light vessels and lighthouses acted as lookouts and reporting stations. Diamond Shoal Light Vessel, off Cape Hatteras, was sunk on August 6, 1918, by a German submarine, after reporting by radio the presence of the submarine, thus warning and saving many vessels. The larger lighthouse tenders were almost continuously in the danger zone, and were sent to buoy the wrecks of torpedoed vessels. During the raid of October, 1916, by the German submarine *U-53*, in the vicinity of Nantucket Island, the crews of three torpedoed vessels were given refuge aboard Nantucket Shoals Light Vessel. At one time there were 115 shipwrecked men on board the lightship, and 19 small boats cared for. By the evening of October 8, 1916, these men were all safely transferred to vessels of the United States Navy in response to radio messages from the lightship. Had it not been for the light vessel, it is probable that few of these shipwrecked men would have been saved, as on the next two days heavy shifting gales and a very rough sea were experienced in that locality.

The naval representatives on an interdepartmental board stated: "The service being performed by these tenders in the various naval districts is extremely valuable. In some cases they are the main reliance of the district commandants for seagoing vessels; in some instances the work being performed by these tenders is of a nature for which the Navy has no suitable vessels, as, for example, the laying of the defensive submarine nets."

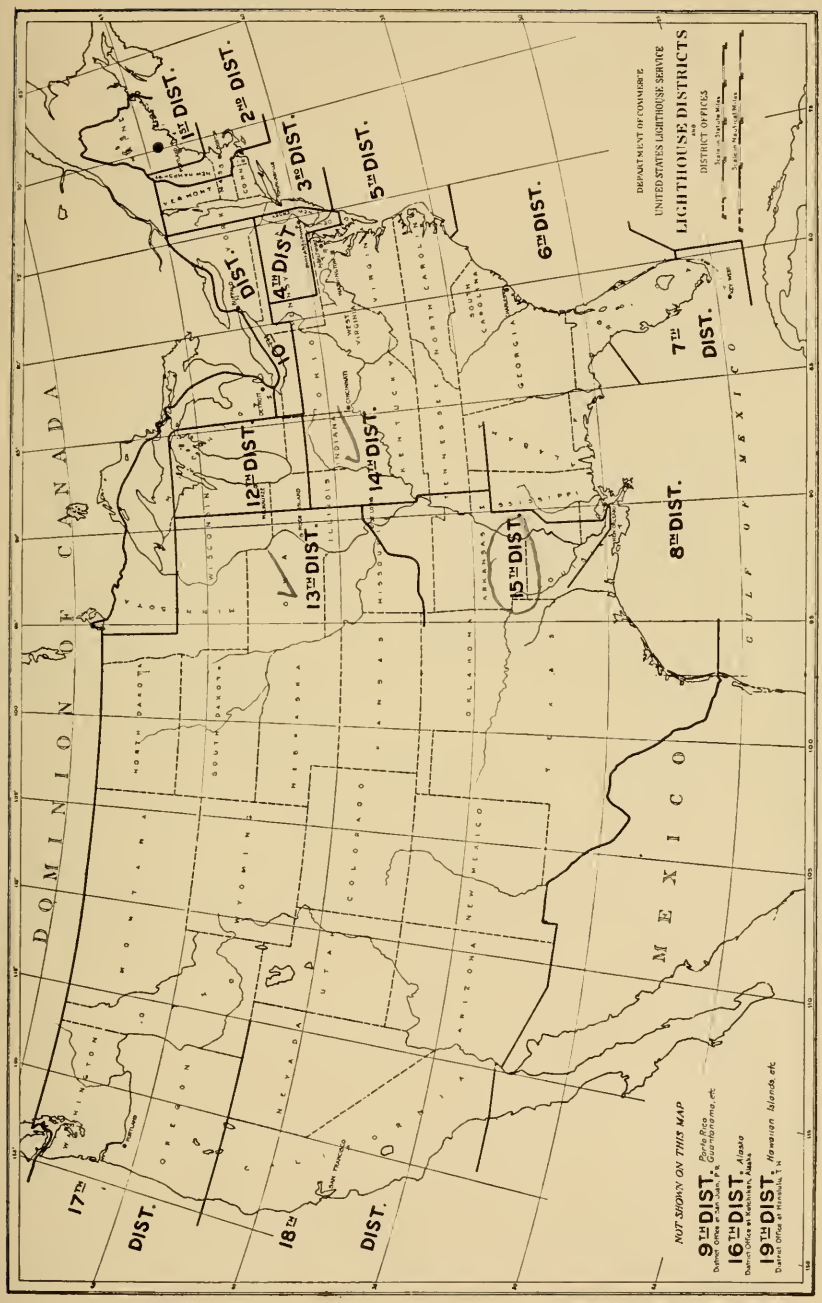
The commandant of a naval district wrote: "The district commandant wishes to use this opportunity to express his high appreciation of the cordial cooperation of the Lighthouse Service in the solution of many problems arising during the period when they were under Navy control. The Lighthouse Service has responded quickly and efficiently to every demand made upon them by the naval district. The services of the lighthouse vessels were of immense value in the laying of submarine-defense nets and, after the armistice, in removing these nets. This was a task which would hardly be possible of accomplishment without the assistance of the lighthouse vessels."

In addition to the work done by the tenders and other units transferred, directly under the orders of military officers, the Lighthouse Service cooperated in a number of other ways. At the General Lighthouse Depot, Staten Island, N. Y., facilities were provided for the establishment of a naval base, including large dock frontage for berthing vessels and a large amount of building space for barracks, storage, and offices. Repairs were made at this depot to naval and quartermaster vessels, and buoys and other supplies were issued. Repairs were made and supplies furnished at other depots. Numerous buoys and other aids were placed, changed, or discontinued, to meet special needs, and buoys and moorings were purchased for the War and Navy Departments. Keepers of important coast lighthouses and masters of light vessels were instructed to keep a lookout for submarine and other enemy activities, special publications were furnished them, and reports were promptly forwarded. There was also cooperation with the Navy and Treasury Departments in the improvement of coast communication facilities by telephone and radio, and a large number of lighthouses, light vessels, and tenders were provided with such facilities, under various appropriations.

Protective works were built around Navy radio stations, and coast patrol boats were supplied and repaired. The tenders assisted harbor fortifications in moving heavy articles.

At various times light vessels were taken off station, and a number of primary seacoast lights were extinguished at the request of the Navy Department, and all light stations, depots, etc., were closed to visitors under special orders from the Department of Commerce.

Various investigations were made at the request of the Department of Justice and the military and naval information services. Officers of the Lighthouse Service assisted the Shipping Board in various matters respecting the design and sea trials of various types of vessels. Other cooperative duty included the work of the chain section, War Industries Board, having to do with the standardization and allocation of iron and steel chain for the different activities of the Government; and the Wage Adjustment Board for the study of wage scales and other disputed questions on tugboat and other craft in New York Harbor.



General map of light house districts.

5. DISTRICT LIMITS AND OFFICES.

The limits of the lighthouse districts and the location of each district office, which is also the address of the superintendent in charge, are given in the following table:

District.	Limits of district.	Address of superintendent.
1st	Waters of Maine and New Hampshire	Press Building, Monument Square, Portland, Me.
2d	Waters of Massachusetts	Customhouse, Boston, Mass.
3d	Waters of Rhode Island, Connecticut, New York, and New Jersey northward of Cape May, including aids off Delaware entrance, Hudson River, Lakes Champlain and Memphremagog, but not Lake Erie.	Lighthouse Depot, Staten Island, N. Y.
4th	Waters of Delaware seacoast and Delaware Bay and River, including Cape May, N. J.	Post Office Building, Philadelphia, Pa.
5th	Waters of Maryland, Virginia, and North Carolina to and including New River Inlet, N. C.	New Customhouse, Baltimore, Md.
6th	Waters of North Carolina, South Carolina, Georgia, and Florida from New River Inlet, N. C., to and including Hillsboro Inlet, Fla.	Old Post Office Building, Charleston, S. C.
7th	Waters of Florida from Hillsboro Inlet to and including Cedar Keys.	Federal Building, Key West, Fla.
8th	Waters of Gulf coast from Cedar Keys, Fla., to mouth of Rio Grande, Tex., and Mississippi River below New Orleans.	Customhouse, New Orleans, La.
9th	Waters of Porto Rico and adjacent United States islands, and Caribbean Sea.	Insular Buildings, San Juan, P. R.
10th	United States waters of St. Lawrence River and Lakes Ontario and Erie.	Federal Building, Buffalo, N. Y.
11th	United States waters of Lakes St. Clair, Huron, and Superior, and Detroit River.	Post Office Building, Detroit, Mich.
12th	Waters of Lake Michigan and Green Bay	Federal Building, Milwaukee, Wis.
13th	Mississippi River above the mouth of the Missouri River, Minnesota, Illinois, Osage, Gasconade, and Missouri Rivers, St. Croix River and Lake.	Federal Building, Rock Island, Ill.
14th	Ohio, Tennessee, Kanawha, and Monongahela Rivers	Customhouse, Cincinnati, Ohio.
15th	Mississippi River below the Missouri River to New Orleans, La., and Red River.	Old Customhouse, Third and Olive Streets, St. Louis, Mo.
16th	Waters of Alaska	Commercial Building, Ketchikan, Alaska.
17th	Waters of Washington and Oregon	Customhouse, Portland, Oreg.
18th	Waters of California	Customhouse, San Francisco, Calif.
19th	Waters of Hawaiian, Midway, Guam, and American Samoan Islands.	New Federal Building, Honolulu, Hawaii.

6. AIDS TO NAVIGATION.

The statement following gives a summary of the 16,373 aids to navigation, under each principal class, in commission on June 30, 1922:

Lighted aids:	
Lights (other than minor lights)	1,879
Minor lights	3,055
Light-vessel stations	49
Gas buoys	638
Float lights	178
Total	5,799
Unlighted aids:	
Fog signals	544
Radio fog signals	4
Submarine signals	49
Whistling buoys, unlighted	74
Bell buoys, unlighted	246
Other buoys	7,204
Day beacons	2,453
Total	10,574
Grand total	16,373

Grouped according to the fixed or floating character of the aids the following tabulation may be made:

Lighted fixed aids	4,934
Unlighted fixed aids	3,001
Total fixed aids	7,935
Lighted floating aids	865
Unlighted floating aids	7,573
Total floating aids	8,438
Grand total	16,373

The class described as "Lights (other than minor)" includes major lights classified under the Fresnel system of orders, which will be described more fully in another place, range lenses, reflectors, and lens lanterns. (See p. 29.) There are 704 stations with resident keepers, provided with dwellings, and in many cases these keepers have charge not only of the principal light but also such other lights in the vicinity as may be conveniently cared for from the same station.

The number of keepers varies from one to five, according to circumstances, and the number of stations having more than one keeper is shown in the following statement:

Five-keeper stations	4
Four-keeper stations	28
Three-keeper stations	177
Two-keeper stations	220
Total stations with more than one keeper	429

The term "minor light" includes post lights and small lights generally not attended as a rule by resident keepers. These lights are usually cared for by persons living in the vicinity, who are not obliged to devote their entire time to the work and who sometimes have several lights, if conveniently located, in their charge. This type of light is frequently used on inland rivers and particularly on the Mississippi River and its tributaries.

Light vessels are used as a rule to mark offshore dangers, or the approaches to harbors or channels, where lighthouses would not be feasible or economical. They are more fully described on page 63.

Gas buoys are used to mark important channels or shoals or as general guides for navigation. Many improvements have been made in this type of aid, and they are considered among the most valuable of recent developments in modern coast lighting.

Float lights are usually small lights borne on a float or raft. They are employed for less important places where more convenient or economical than lighted buoys and where the expense of providing a foundation for a fixed structure would not be warranted.

Fog signals include various types of aerial and submarine sound-producing apparatus and radio signals for warning in foggy or thick

weather. The sound signals embrace various types of whistles, sirens, or horns, actuated by steam, compressed air, or electricity, and bells, operated by machinery of various types or by hand.

Radio fog signals, or radio beacons, are low-powered radio stations, sending definite automatic signals from lighthouses or lightships, which may be received by the radio compass or direction finder, enabling navigators to obtain bearings as though the sending station were visible. This system is a recent development and is more fully described on pages 46 to 51.

Submarine signals are auxiliary fog signals consisting of bells operated under water. They are more often a feature of light-vessel equipment, but are employed also at some light stations or attached to buoys.

Whistling and bell buoys are fitted with sound-producing apparatus operated by the motion of the buoy in the sea. Further information in regard to both types appears on pages 54–55.

Other buoys include those known as cans, nuns, and spars of various types, and are the most extensively used of all aids. They are more frequently employed in channels and inside waters generally, and are described more fully on pages 53–54.

Day beacons include minor fixed structures not bearing a light. They are of various types, the most common being a post or spindle bearing a target or some other object of a distinctive shape and color.

The number of light stations, light vessels, and fog signals of the world, as given in the British Admiralty List of Lights for 1922, is approximately as given in the table below. The statistics do not include the Great Lakes of North America nor rivers above the limit of seagoing navigation, and the lights are given in greater completeness for some countries than for others.

Continents.	Light stations.	Light vessels.	Fog signals.
Europe	7,428	167	806
North America	3,085	47	696
Asia	1,532	38	122
Australia and Oceania	755	3	23
Africa	622	1	13
South America	398	7	17
Total	13,820	263	1,677

It is of interest to compare similar statistics of light stations for about 1888 (The Modern Lighthouse Service, Johnson).

Continents.	Light stations.	Continents.	Light stations.
Europe	3,309	Africa	219
North America	1,435	South America	167
Asia	476		
Oceania	319	Total	5,925

The lists for 1922 show that the United States Lighthouse Service has under its charge materially more lights and fog signals than any other organization, and this would be numerically increased if there were included the lights on the lakes and rivers and if all aids to navigation were counted, including buoys and unlighted beacons.

7. HISTORY AND GROWTH OF THE LIGHTHOUSE SERVICE.

The history of lighthouses in the United States dates back to 1715–16, when the first lighthouse on this continent was built at the entrance to Boston Harbor by the Province of Massachusetts. This light was supported by light dues on all incoming and outgoing vessels, except coasters. On September 25, 1916, the two hundredth anniversary of its establishment was celebrated in Boston by the unveiling of a small commemorative bronze tablet at the lighthouse. Several other lighthouses were built by the colonies. Congress, by the act of August 7, 1789, authorized the maintenance of lighthouses and other aids to navigation at the expense of the United States. There were at that date 12 lights in operation maintained by the colonies. These, together with others completed later, 16 in all, were ceded to the General Government by the States. The Lighthouse Service of the United States is supported entirely by appropriations out of the general revenues of the Government. In a proper sense light dues, or tonnage taxes on vessels for the maintenance of the Lighthouse Service, have not been levied by this Government. There is, however, a tonnage tax collected on vessels arriving in ports of the United States which formerly was applied directly to the maintenance of the Marine Hospital Service but now is turned into the Treasury as a part of the general receipts.

The maintenance of lighthouses, buoys, etc., was placed under the Treasury Department and up to 1820 was directed personally by the Secretary of the Treasury, except for two intervals when supervision was assigned by him to the Commissioner of the Revenue. In 1820 the superintendence of the lights devolved upon the Fifth Auditor of the Treasury, who was popularly known as the general superintendent of lights and who continued in charge thereof until 1852, when the United States Lighthouse Board, consisting of officers of the Navy and Army and civilians, was organized, with the Secretary of the Treasury as ex officio president of the board. The board selected from its own number a member to act as chairman.

The Lighthouse Service was transferred to the Department of Commerce on July 1, 1903. On July 1, 1910, the Lighthouse Board was terminated and the present Bureau of Lighthouses established.

The 12 colonial lights in the order of their establishment were:

Boston, on Little Brewster Island, Mass.	1716
Brant Point, Nantucket Harbor, Mass.	1746
Beavertail, on Conanicut Island, Narragansett Bay	1749
New London Harbor, Conn.	1760
Sandy Hook, N. J., entrance to New York Bay	1764
Cape Henlopen, Del., entrance to Delaware Bay	1765
Charleston, on Morris Island, S. C.	1767
Plymouth Light, on Gurnet Point, Mass.	1769
Portsmouth, N. H., entrance to harbor	1771
Cape Ann Lights, Thachers Island, Mass.	1773
Great Point, Nantucket Island, Mass.	1784
Newburyport Harbor Lights, Mass.	1788

Four other lighthouses were undertaken by the colonies, but were not in operation at the organization of the Federal Government, these being Portland Head, Me. (completed in 1891); Tybee, entrance to Savannah River, Ga. (1791); Cape Henry, Va., for which only the materials had been collected (1792); and Bald Head, entrance to Cape Fear River, N. C. (1796).

All of these stations are still in operation, but the original structures at most of them have been added to or replaced; at Sandy Hook and Cape Henlopen, however, the old masonry towers are still in use.

The gradual increase in the number of aids to navigation from 1790 to 1920, by 10-year periods, and for 1922, is shown in the following table:

Year.	Lighted aids.						Unlighted aids.							Grand total.
	Lights.	Minor lights.	Light vessels.	Lighted buoys.	Float lights.	Total lighted aids.	Fog signals.	Submarine bells.	Whistling buoys.	Bell buoys.	Other buoys.	Beacons.	Total unlighted aids.	
1790...	12	.....	.....	.....	.....	12	(1)	.....	.....	.....	(1)	(1)	(1)	(1)
1800...	23	.....	.....	.....	.....	23	2	.....	.....	.....	77	5	84	107
1810...	42	.....	.....	.....	.....	42	2	.....	.....	.....	117	22	141	183
1820...	59	.....	1	.....	.....	60	3	.....	.....	.....	156	30	189	249
1830...	137	.....	16	.....	.....	153	12	.....	.....	.....	350	60	422	575
1840...	234	.....	30	.....	.....	264	26	.....	.....	.....	800	90	916	1,180
1850...	297	.....	35	.....	.....	332	49	.....	.....	.....	1,034	121	1,204	1,536
1860...	425	.....	47	.....	.....	472	111	.....	.....	9	1,738	220	2,078	2,550
1870...	528	.....	32	.....	.....	560	117	.....	.....	9	2,446	324	2,896	3,456
1880...	661	819	31	.....	12	1,523	194	.....	25	9	3,115	355	3,698	5,221
1890...	833	1,550	26	7	34	2,450	254	.....	60	75	4,143	372	4,904	7,354
1900...	1,243	1,745	44	93	38	3,163	393	.....	70	120	4,749	496	5,828	8,991
1910...	1,397	2,256	54	225	60	3,992	457	42	89	178	5,783	1,120	7,669	11,661
1920...	1,836	3,118	49	582	169	5,754	536	48	78	243	7,195	2,470	10,570	16,324
1922...	1,879	3,055	49	638	178	5,799	548	49	74	246	7,204	2,453	10,574	16,373

[1] No definite information on record.

NOTES.—The information prior to 1850 should be considered approximate only, and the figures given may be regarded generally as somewhat less than the actual numbers.

Minor lights and float lights originally covered only post lights on the Mississippi River and tributaries, first reported in 1875 (280 minor, 21 float).

Lighted buoys first reported in 1884 (4 buoys).

Early records of fog signals compiled from light lists and other sources and are somewhat indefinite. Whistles not regularly reported prior to 1872 (33 whistles); bells not prior to 1882 (115 bells).

Submarine bells first reported in 1906 (5 bells).

Whistling buoys first reported in 1876 (4 buoys).

Bell buoys first reported regularly in 1881 (11 buoys). Bell buoys were introduced about 1855 (9 buoys). Bell boats, filling practically same purpose, were used at an earlier date, although no definite records appear.

Buoy boats, consisting of a decked scow about 20 feet long by 7 feet beam, carrying a light mast or perch, were also in use in the early days.

The following diagram shows the number of aids to navigation and amount of appropriations for maintenance, yearly from 1901; also employees and lighthouse tenders from 1910:

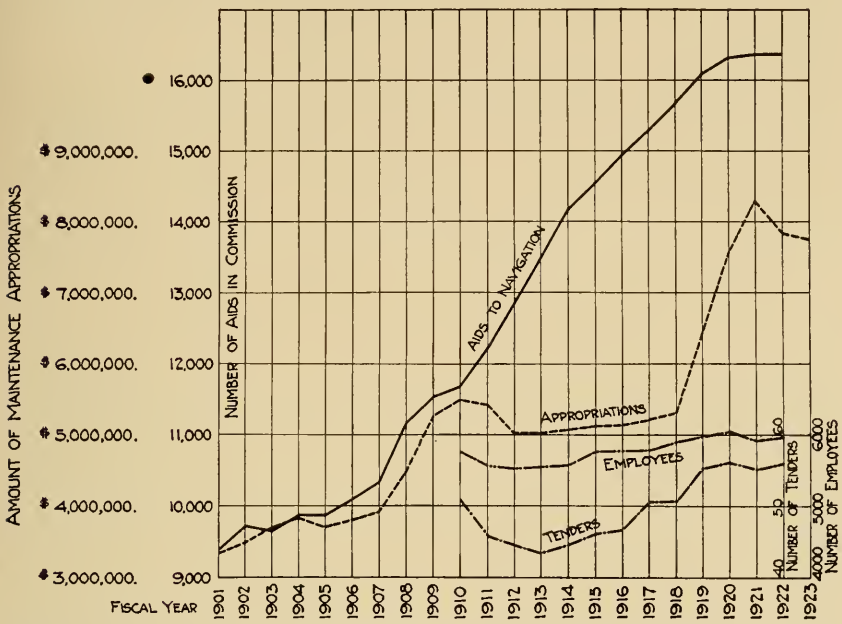


Diagram showing number of aids to navigation maintained, and amount of appropriations for maintenance, yearly from 1901, and employees and vessels from 1910. The number of aids to navigation increased from 1910 to 1922 by 4,711, or 40 per cent.

8. DEVELOPMENT OF LIGHTHOUSE WORK IN ALASKA.

The first aids to navigation of the Lighthouse Service in Alaska were established in the spring of 1884 (14 iron buoys) and the first light in June, 1895. The following table gives the total number of aids to navigation at the end of the fiscal years named (June 30 in each case), illustrating the progress of the service in the Territory:

Aids.	1890	1900	1910	1920	1922
Lights	0	1	37	196	210
Gas buoys	0	0	0	10	14
Fog signals	0	0	9	11	11
Buoys	27	57	84	224	225
Daymarks	15	25	30	94	124
Total	42	83	160	535	584

The 224 lighted aids are of the following classes: 10 lighthouses with resident keepers, 143 unattended flashing acetylene lights, 57 minor lights, 3 gas and whistling buoys, 6 gas and bell buoys, 5 gas buoys, and 6 float lights, the use of the latter named being confined to narrow channels or harbors where a small light answers all requirements of navigation.

Special attention has been given to increasing and improving the lighted aids and buoys in Alaska, as shown by the table above, which indicates an increase of over 500 per cent in the number of lighted aids and 265 per cent in the total number of aids during the past 12 years.

There has been a considerable increase of shipping to this Territory with the rapid development there of the mining and other industries. The coast line, however, is of great extent in proportion to the amount of shipping. It is a difficult coast to navigate because of a number of causes in addition to the incompleteness of the system of aids to navigation. All the southern and more frequented portions of the Alaskan coast are subject, even in the summer months, to fog, rain, and storms; the coast is precipitous and rocky and hidden dangers are numerous; there is a great rise and fall of tide, resulting in strong tidal currents; the traffic is new and mainly restricted to only a part of the year, so that it is difficult for navigators to become thoroughly familiar with the region and conditions; much of the coast has not been completely surveyed and thorough surveys are rendered difficult by the nature of the bottom, and the coast is so abrupt and the depths so great that convenient and safe anchorages are not always available. On the other hand, southeastern Alaska has a remarkable network of well-protected inside channels in large part sufficiently wide and deep for any class of vessels, and has numerous small harbors. During the summer season, when traffic is heaviest, there is either daylight throughout the 24 hours or the time of darkness is short, thus materially aiding navigation, but the reverse condition exists in winter, because of the northern latitude. The immense coast line in proportion to the population and the amount of shipping, and the uncertainty as to the permanency in routes of traffic, would not warrant the Government at this stage of development of the Territory in making the expenditures necessary to mark its coasts as elaborately as similar coasts in older and more settled portions of the United States.

The justice of the demands for additional aids to navigation in Alaska is, however, fully recognized. To meet these real needs, Alaska, which has formerly been under the charge of the district office at Portland, Oreg., was on August 1, 1910, made a separate lighthouse district, permitting the superintendent in charge to give his entire attention to this important Territory. A district office and depot were established at Ketchikan and lighthouse work in Alaska has since been directed from those headquarters.

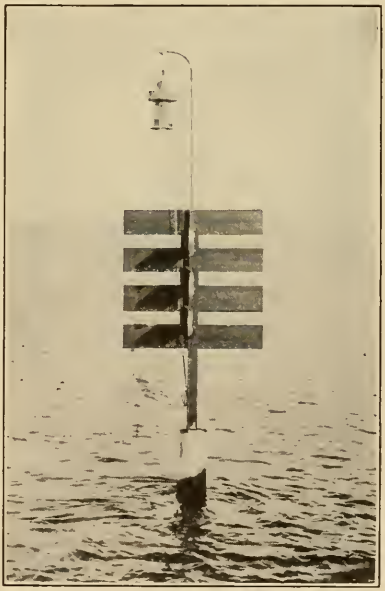
The largest tender now in the service, the *Cedar*, has been assigned to duty in Alaska, having been especially built for that purpose. The tender *Fern* has also been constructed especially for work in the inside waters of southeastern Alaska.

Appropriations for special works in Alaska made in recent years include five appropriations, aggregating $380,000, made by the acts of March 4, 1911, August 1, 1924, June 12, 1917, June 19, 1919, and March 28, 1922, for aids to navigation in Alaska; $25,000 for rebuilding and improving Lincoln Rock Light and Fog Signal (act March 4, 1911); $115,000 for establishing Cape St. Elias Light and Fog Signal (act October 22, 1913); $250,000 for the tender *Cedar* (act January 25, 1915); $62,000 for the tender *Fern* (act July 27, 1912); and $102,000 for the Ketchikan depot (acts July 1, 1918, and March 6, 1920), amounting in all to $934,000. In addition to these special works, the average expenditures from general appropriations for the support of the service in ordinary maintenance and betterments have averaged about $300,000 annually for the past four years.

9. TYPES OF CONSTRUCTION OF LIGHTHOUSES.

The type of construction adopted in each case for lighthouse structures depends largely on the importance of the light and the foundation conditions. Brief descriptions of some of the various types employed are as follows:

Post lights are generally a single-timber post, with a shelf or bracket for the lantern. In some cases ladders are attached, and to assist in identifying the aid by day wooden wing boards for daymark purposes are frequently added. For similar construction in water, single piles, either timber or concrete, are used. (See p. 17.) A small service box for the lantern and supplies is often added.



Sand Shoal Inlet Light, Va.

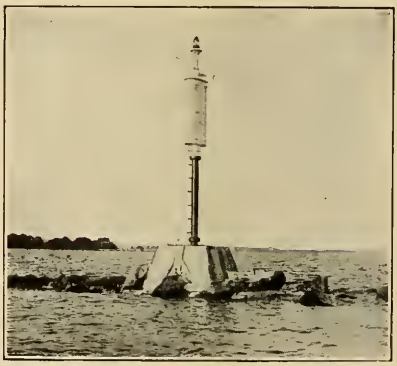
Where the light is of more importance, framed-timber towers have been used, generally built with four posts on proper foundations, battered and provided with the necessary framing and bracing, with a ladder and service box. Similar structures in water are generally of three or more piles, driven on a batter and forming a cluster at the top.

Recent improvements along this line include structural steel skeleton towers, also similar towers of iron pipe. Standard plans have been prepared for each of these types, both of which are useful when quickness of construction is desired. (See p. 18.) Each type is square in plan and strongly braced, with due provision allowed for

corrosion in proportioning the sizes of the members. (See p. 19.) For similar structures in water, concrete, or wooden-pile foundation structures consisting of four, seven, or nine piles, inclosed in cast-iron sleeves with suitable struts and ties, have been developed and standard plans prepared for each type.

In addition to the foregoing types, which are principally adopted for nonattended lights, mention should be made of unlighted beacons, or daymarks. Some of these may be merely a pile or stake, occasionally with a pointer indicating the channel; others are timber structures of various designs, carrying a target or some other characteristic feature to attract attention; others are iron or steel spindles with a barrel or some form of cage work at the top (see p. 21), and some older types are monuments of stone. A type recently developed is that of well-braced reinforced-concrete tripods, to replace old wooden tripods destroyed by the sea. (See p. 21.) In some localities, particularly on rivers in California, where fog is prevalent part of the year, echo boards are used. These are rather long, wall-like structures, with projecting wings, to permit steamers obtaining an echo from their whistles in passing. These sometimes carry a post light on top of the board.

Petaluma Creek Light, Calif.

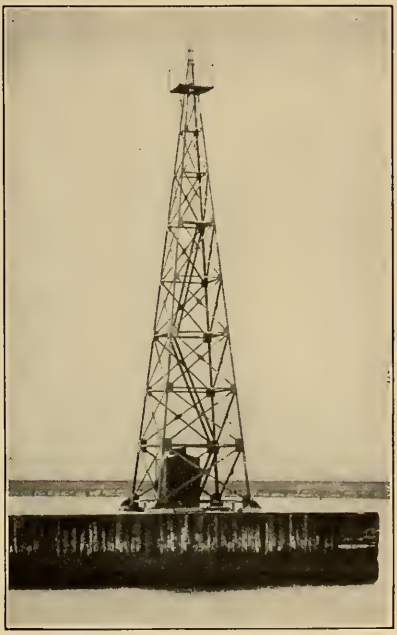


Larchmont Breakwater Light, N. Y.

In case of attended lights where resident keepers are employed, which may be considered as lighthouses proper, there are also many types. A form frequently used for harbor or lake lights is a combined tower and dwelling of timber or brick construction. (See p. 20.) Sometimes the tower only is of masonry, while the dwelling is frame. For the more important lights, the tower is detached from the dwellings and as a rule is of fireproof construction. Most of the older towers of this type are built of brick or stone masonry, with stairways, lantern, and other appurtenances of cast iron. Others of a more recent type have a structural open framework of wrought iron

or steel, usually with an inclosed stair well in the center. In still more recent years reinforced-concrete towers have been used and will probably be more extensively adopted in the future.

A completely equipped light station on a land site usually consists of the light tower, oil house, fog-signal building, keepers' dwellings, workshop, water supply and drainage systems, landing wharf, boathouse and ways, barn, and the usual outbuildings, roads, walks, and fences; although, owing to the restricted area of some sites, several of these purposes may be served by a single building. On submarine sites the whole station is frequently confined to one structure.



Fairport West Pier Light, Ohio.

Where not built on rock, the foundation for towers on land sites is usually a single block of concrete resting upon the foundation soil, which has been previously excavated to the proper depth. Occasionally these blocks are placed upon a timber grillage supported by piles for sites upon low or marshy land, and in all cases the block is extended so as to bring the unit pressures within the bearing power of the foundation material.

Many lighthouses at the entrances to harbors are built on the ends of breakwaters or pierheads, utilizing, as a rule, such structures as the foundation. In such cases the problem is not essentially different from ordinary shore construction, although the weight of the superstructure must be considered carefully to avoid undue settlement of the foundation, but at the same time a large margin of reserve strength must be provided to resist the impact of the waves and the vibrations caused thereby. Also, in such cases the necessary restrictions of available space require that the lighthouse be as compact as possible.

In the case of lighthouses on submerged sites the engineering features are important and often present great difficulties both in design and construction. Where the bottom is rocky or hard, the lighthouse is either built directly on the rock or on a pier. When placed on a ledge of rock, the latter is usually leveled or stepped as far as practicable and the structure heavily rag bolted to the rock. Two important lighthouses on the Great Lakes were built by con-

structing cofferdams, pumping out the water and leveling off the bedrock on which the lighthouse was built of cut stone, securely fastened. In other types, particularly on the Great Lakes, cribs filled with stone are placed on the bottom and capped with concrete or other masonry.

Buffalo Light Station, N. Y.

Important wave-swept lighthouses, most of which are masonry structures founded on rocky ledges or hard bottom, include the following 20 stations (see p. 21):

First district:
- Saddleback Ledge, Me.
- Halfway Rock, Me.
- Ram Island Ledge, Me.
- Whaleback, Me.

Second district:
- The Graves, Mass.
- Minots Ledge, Mass.
- Bishop and Clerks, Mass.

Third district:
- Race Rock, N. Y.
- New London Ledge, Conn.
- Stratford Shoal, N. Y.

Tenth district: Toledo Harbor, Ohio.

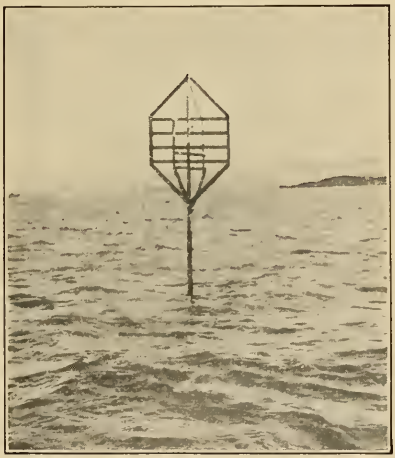
Eleventh district:
- Port Austin Reef, Mich.
- Spectacle Reef, Mich.
- Stannard Rock, Mich.
- Rock of Ages, Mich.

Twelfth district:
- White Shoal, Mich.
- Racine Reef, Wis.

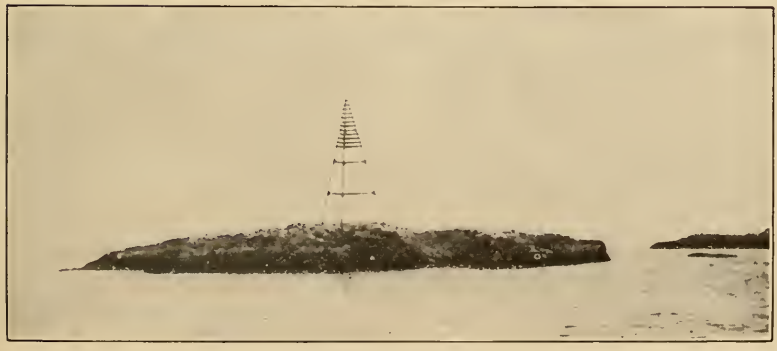
Seventeenth district: Tillamook Rock, Oreg.

Eighteenth district:
- St. George Reef, Calif.
- Mile Rocks, Calif.

Minots Ledge Light Station, Mass.

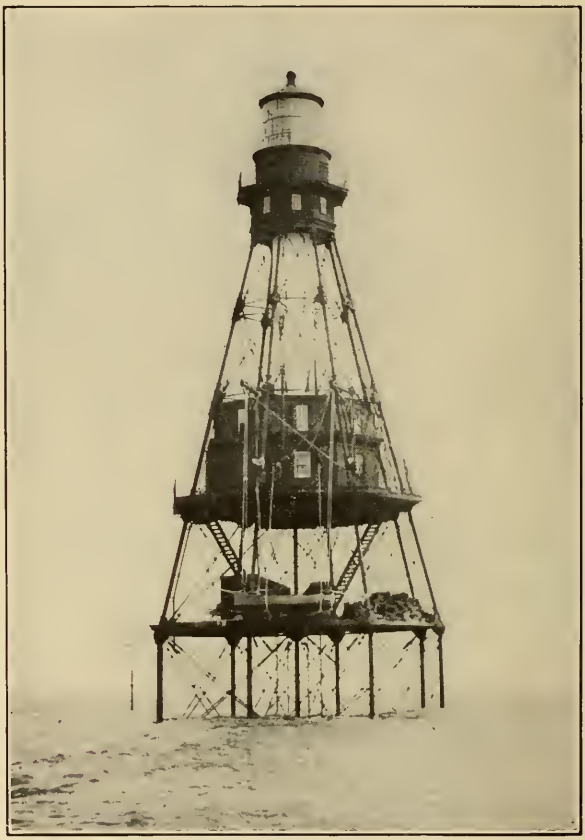


Berkeley Reef Beacon, Calif.



Duck Rocks Tripod, Me

Other severely exposed stations which are not given in the foregoing list include, in the seventh district, Fowey Rocks, Carysfort Reef, Alligator Reef, Sombrero Key, American Shoal, and Rebecca Shoal, Fla.; and, in the eighth district, Ship Shoal, Southwest Reef, Sabine Bank, La., and Galveston Jetty, Tex. These stations appear in other lists on pages 24 and 25.



American Shoal Light Station, Fla.

Other stations not named in any of these lists, but which are noteworthy because of their unusual remoteness or isolation, include, in part, the following 38 locations:

First district:
- Libby Islands, Me.
- Petit Manan, Me.
- Great Duck Island, Me.
- Mount Desert Rock, Me.
- Matinicus Rock, Me.
- Boon Island, Me.
- Isles of Shoals, N. H.

Third district: Falkner Island, Conn.

Fifth district:
- Bodie Island, N. C.
- Cape Hatteras, N. C.
- Ocracoke, N. C.
- Cape Lookout, N. C.

Sixth district:
- Cape Romain, S. C.
- Hunting Island, S. C.
- Cape Canaveral, Fla.

Seventh district: Dry Tortugas, Fla.
Eighth district:
Cape San Blas, Fla.
Sand Island, Ala.
Timbalier, La.
Matagorda, Tex.
Ninth district:
Navassa Island, West Indies.
Mona Island, P. R.
Culebrita Island, P. R.
Muertos Island, P. R.
Sixteenth district:
Cape Sarichef, Alaska.
Scotch Cap, Alaska.
Cape St. Elias, Alaska.
Sixteenth district—Continued
Cape Hinchinbrook, Alaska.
Lincoln Rock, Alaska.
Seventeenth district:
Cape Flattery, Wash.
Destruction Island, Wash.
Cape Blanco, Oreg.
Eighteenth district:
Punta Gorda, Calif.
Farallon, Calif.
Point Sur, Calif.
Nineteenth district:
Makapuu Point, Hawaii.
Molokai, Hawaii.
Kilauea Point, Hawaii.

For submarine sites, where the bottom is sand, either a pile or caisson foundation is employed. The screw pile, which was frequently employed some years ago, consists of a pile with a broad helicoidal flange on the foot, which is bored like an auger into the bottom, thereby greatly increasing the bearing power of the pile as well as anchoring it firmly. (See p. 25.) Another type of pile, used in locations such as the Florida Reefs, where the bottom is often soft coral rock, is fitted with a bearing disk resting on the bottom, to give a greater distribution of the load. The caisson type usually consists of a cylinder from 21 to 35 feet in diameter, built up of cast-iron plates, and sunk by dredging or by the pneumatic process into the shoal until a firm bearing is attained, after which the interior is solidly filled with concrete. (See p. 26.) A few caissons have been placed on rocks or ledges. Both of these types are comparatively modern, the first screw-pile structure in the United States being at Brandywine Shoal, Delaware Bay, lighted in 1850, and the first pneumatic-caisson structure being at Fourteen-Foot Bank, Delaware Bay, completed in 1887. There are at the present time 88 attended lighthouses on piles, most of which are in Chesapeake Bay and the Carolina Sounds, and 48 on caisson foundations, principally on the north and middle Atlantic coasts. The names and locations of such lighthouses are as follows:

ATTENDED LIGHTHOUSES ON PILES.

Second district: *Narrows, Mass.
Third district:
*Long Beach Bar, N. Y.
*Bridgeport Harbor, Conn.
Fourth district: Mahon River, Del.
Fifth district:
*Killick Shoal, Va.
*Craney Island, Va.
Lambert Point, Va.
Nansemond River, Va.
*White Shoal, Va.
*Point of Shoals, Va.
Fifth district—Continued.
*York Spit, Va.
*Deep Water Shoals, Va.
*Tue Marshes, Va.
*Upper Cedar Point, Md.
*Maryland Point, Md.
*Holland Island Bar, Md.
*Great Shoals, Md.
*Sharkfin Shoal, Md.
*Hooper Strait, Md.
*Drum Point, Md.
*Choptank River, Md.

* Indicates screw-pile structures (58).

Fifth district—Continued.
*Thomas Point Shoal, Md.
*Greenbury Point Shoal, Md.
*Love Point, Md.
*Seven Foot Knoll, Md.
Brewerton Channel Range Front, Md.
Wade Point, N. C.
*Laurel Point, N. C.
Roanoke River, N. C.
Pages Rock, Va.
*Bells Rock, Va.
*Old Plantation Flats, Va.
*Stingray Point, Va.
*Windmill Point, Va.
*Tangier Sound, Va.
*Janes Island, Md.
Somers Cove, Md.
*Great Wicomico River, Va.
*Ragged Point, Md.
*Cobb Point Bar, Md.
*Lower Cedar Point, Md.
*Mathias Point Shoal, Md.
Croatan, N. C.
Roanoke Marshes, N. C.
*Long Shoal, N. C.
*Hatteras Inlet, N. C.
*Gull Shoal, N. C.
*Bluff Shoal, N. C.
*Southwest Point Royal Shoal, N. C.
*Harbor Island Bar, N. C.
*Brant Island Shoal, N. C.
*Pamlico Point, N. C.
*Neuse River, N. C.
Sixth district: *Fort Ripley Shoal, S. C.
Seventh district:
Fowey Rocks, Fla.
Carysfort Reef, Fla.
Seventh district—Continued.
Alligator Reef, Fla.
Sombrero Key, Fla.
American Shoal, Fla.
*Sand Key, Fla.
Rebecca Shoal, Fla.
*Charlotte Harbor, Fla.
Eighth district:
Horn Island, Miss.
*Cat Island, Miss.
*Merrill Shell Bank, Miss.
*Lake Borgne, Miss.
*New Canal, La.
Amite River, La.
South Pass East Jetty, La.
South Pass West Jetty Range Front, La.
South Pass Range Rear, La.
Southwest Pass, La.
Timbalier, La.
*Ship Shoal, La.
Oyster Bayou, La.
Point au Fer Reef, La.
*Calcasieu Range Rear, La.
Galveston Jetty, Tex.
*Galveston Harbor, Tex.
*Red Fish Bar Cut, Tex.
*Half Moon Reef, Tex.
*Brazos Santiago, Tex.
Seventeenth district:
Desdemona Sands, Oreg.
Willamette River Range Front, Oreg.
Eighteenth district:
Oakland Harbor, Calif.
Southampton Shoal, Calif.
Carquinez Straits, Calif.
Roe Island, Calif.

ATTENDED LIGHTHOUSES ON CAISSONS.

First district:
Lubec Channel, Me.
Crabtree Ledge, Me.
Goose Rocks, Me.
Spring Point Ledge, Me.
Second district:
Deer Island, Mass.
Duxbury Pier, Mass.
Butler Flats, Mass.
Third district:
Sakonnet, R. I.
Hog Island Shoal, R. I.
Borden Flats, Mass.
Third district—Continued.
Whale Rock, R. I.
†Plum Beach, R. I.
Conimicut, R. I.
Latimer Reef, N. Y.
Orient Point, N. Y.
Saybrook Breakwater, Conn.
Southwest Ledge, Conn.
New Haven, Conn.
Pecks Ledge, Conn.
Greens Ledge, Conn.
Cold Spring Harbor, N. Y.

* Indicates screw-pile structures (58). † Indicates caissons sunk by pneumatic process (11).

Third district—Continued.
- Stamford Harbor, Conn.
- West Bank, N. Y.
- Old Orchard Shoal, N. Y.
- Romer Shoal, N. Y.
- Great Beds, N. J.
- Tarrytown, N. Y.
- Rockland Lake, N. Y.

Fourth district:
- Delaware Breakwater, Del.
- Harbor of Refuge, Del.
- Brandywine Shoal, Del.
- †Fourteen Foot Bank, Del.
- Miah Maull Shoal, N. J.
- †Elbow of Cross Ledge, N. J.
- Ship John Shoal, N. J.

Fifth district:
- †Thimble Shoal, Va.
- Newport News Middle Ground, Va.
- †Wolf Trap, Va.
- †Smith Point, Va.
- †Solomons Lump, Md.
- †Point No Point, Md.
- †Hooper Island, Md.
- Sharps Island, Md.
- Bloody Point Bar, Md.
- Sandy Point, Md.
- †Baltimore, Md.
- Craighill Channel Front, Md.

Eighth district: †Sabine Bank, La. (now unwatched).

† Indicates caissons sunk by pneumatic process (11).

In designing lighthouse structures, particularly towers, it is customary to assume the wind, wave, current, ice, and other external

Croatan Light Station, N. C.

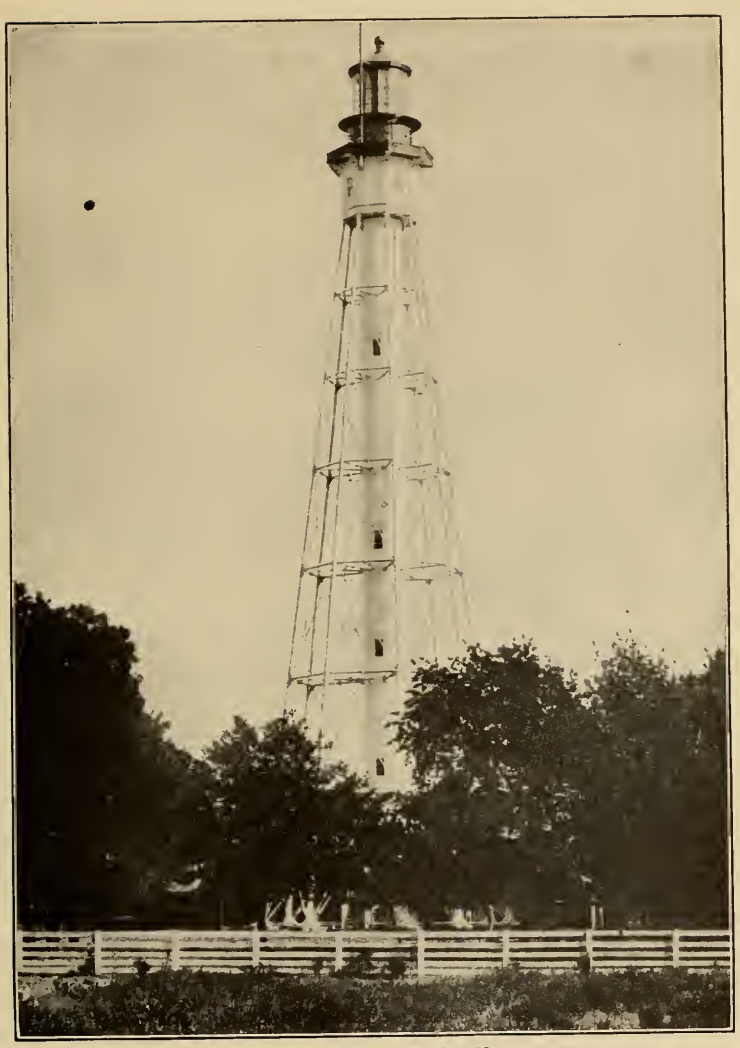
pressures at the maximum in each instance, as lighthouses are necessarily exposed to severe action from the elements. The usual procedure in determining the stability of a tower is to locate the common center of effort of all forces acting upon the structure to

overturn it, and to proportion the weights (with due regard for the buoyancy of the water in the case of submarine work) so that the resultant of the active forces and the net weight falls well within the outer edge of the base. In seeking this result the lateral resistance of the soil is considered, when the structure penetrates it for some distance, for the reason that it is often heavily compressed by a large deposit of riprap and offers good support. The superstructures are calculated in the manner generally employed for chimneys and viaduct bents, with the exception that great stiffness and rigidity must be provided, as excessive vibrations are detrimental to the proper operation of the lamps and clocks of the illuminating apparatus.

Hog Island Shoal Light Station, R. I.

Practically all the usual materials of construction are used in building lighthouses, as indicated in the foregoing paragraphs, such as stone masonry, brickwork, concrete (plain and reinforced), framed timber, and structural cast iron, wrought iron, and steel in various forms.

The heights of towers vary according to the character of the shore and the importance of the light. On the Atlantic coast, where the beach as a rule is low and presents little relief, comparatively tall towers are required for the principal coast lights, while on the Pacific coast, which is generally bold and high, a low tower erected on a prominent headland is generally sufficient. (See p. 29.) The tallest tower in the service is in the fifth district, at Cape Hatteras, N. C., and is 193 feet high. (See p. 28.) The names and locations of 20



Cape Charles Light Station, Va.

towers with heights of 150 feet and over, all located on the Atlantic coast, are as follows, in the order of height.

District.	Station.	Height, top of lantern above base.	District.	Station.	Height, top of lantern above base.
		Feet.			*Feet.*
5	Cape Hatteras, N. C.	193	5	Currituck Beach, N. C.	163
5	Hog Island, Va.	191	5	Bodie Island, N. C.	163
5	Cape Charles, Va.	191	9	Navassa Island, West Indies	162
8	Pensacola, Fla.	171	3	Shinnecock Bay, N. Y.	161
3	Absecon, N. J.	170	3	Barnegat, N. J.	161
4	Cape May, N. J.	170	6	Cape Fear, N. C.	161
5	Cape Lookout, N. C.	169	6	Cape Romain, S. C.	161
6	Mosquito Inlet, Fla.	168	6	Charleston, S. C.	161
3	Fire Island, N. Y.	167	6	St. Augustine, Fla.	161
5	Cape Henry, Va.	165	7	Dry Tortugas, Fla.	157

Cape Hatteras Light Station, N. C.

10. LIGHTING APPARATUS AND ILLUMINANTS.

The earliest type of lighting apparatus consisted of an open coal or wood fire, with other inflammable materials, such as pitch, burned in a brazier, on top of the tower. When Boston Light was established, in 1716, the customary oil burner of the period was used, inclosed in a lantern consisting of a cylinder of heavy wooden frames,

Point Reyes Light Station, Calif.

holding small, thick panes of glass. The illuminant was fish or whale oil, burned in spider lamps with solid wicks and suspended by iron chains from the top of the lantern. Sperm oil was in general use about 1812, and was burned in a lamp constructed on the Argand principle, with a rough reflector and a so-called lens or magnifier. This apparatus was inclosed in a heavy wrought-iron lantern glazed with panes about 12 inches square. Improvements were gradually

made in this apparatus, and by the year 1840 the useless bull's-eye "magnifiers" had been entirely removed, and the reflectors were made on correct optical principles, approaching the paraboloid in form, heavily silvered and properly placed. The lanterns were also improved by making the frames lighter, the panes larger, and by providing more adequate ventilation. To provide illumination all around the horizon, sets of from 8 to 20 lamps were used, placed side by side around the circumference of a circle. This arrangement, in its most complete form, is designated as the catoptric, or reflector system, and its relative merit as compared with the lenticular system originally devised by the French physicist, Augustin Fresnel, about

Pigeon Point Light Station, Calif.

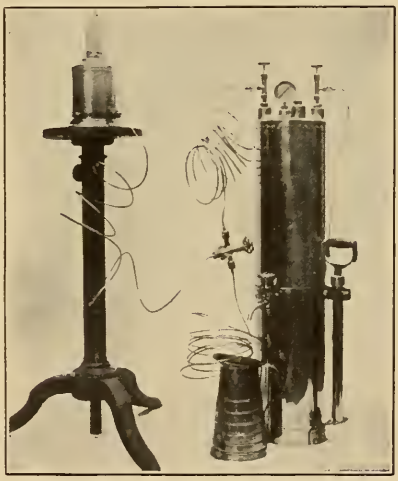
1822, was the source of much controversy in the years preceding the establishment of the Lighthouse Board in 1852. The first lens in the United States was installed at Navesink Light, N. J., in 1841, and is still preserved by the service. (See p. 108.)

The Fresnel apparatus consists of a polyzonal lens inclosing the lamp, which is placed at the central focus. The lens is built up of glass prisms in panels, the central portions of which are dioptric or refracting only, and the upper and lower portions are both reflecting and refracting, described as "catadioptric." The advantages of this system lie in the greater brilliancy, owing to the fact that a large proportion of the light given out by the source is concentrated by the prisms into beams useful to the mariner and the consequent economy

in the consumption of oil or other illuminant employed. The principal sizes of Fresnel lenses are classified according to their order, this depending upon the inside radius or focal distance of the lens—that is, the distance from the center of the light to the inner surface of the lens—as given in the following table:

Order.	Millimeters.	Inches.
First	920	36.2
Second	700	27.6
Third	500	19.7
Three-and-a-half	375	14.7
Fourth	250	9.8
Fifth	187.5	7.4
Sixth	150	5.9

One of the first steps taken by the Lighthouse Board in 1852 was to install lenses generally throughout the service in place of reflectors, and this change was carried out as rapidly as possible, being practically completed in 1859. Lenses are in use at the present time at all important stations, with many subsequent improvements, however, in the design and arrangement of the panels. Improvements were also made from time to time in the lantern inclosing the lens, and the standard type now in use is of cast iron and bronze with helical bars bent to the curvature of the lantern supporting lozenge-shaped panes of curved plate glass. These bars, crossing the beams of light diagonally, offer the least possible obscuration to the beams toward any point of the horizon. (See p. IV.) Suitable ventilators and flues to furnish the requisite draft and to carry off the products of combustion are also provided, and the entire lantern is constructed in a number of sizes corresponding to the order of the lens which it accommodates.

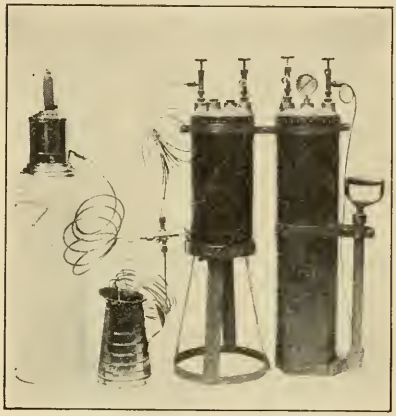


Incandescent oil vapor lamp, 55-millimeter mantle, with single tank.

The largest lens in use in the Lighthouse Service at present is that at Makapuu Point, Oahu, Hawaii, the landfall light for vessels bound from the States to the Hawaiian Islands. This is of the hyperradiant order, a larger size than those regularly listed, and has a focal distance of 1,330 millimeters, or 52.4 inches; the inside diameter of the lens is therefore nearly 9 feet, and it is inclosed in a specially designed lantern of 16 feet inside diameter. It is the only one of its type in the service. The number of other lenses, from the

first to the sixth orders, inclusive, in commission on June 30, 1922, is as follows: 57 first order; 26 second order; 65 third order; 25 three-and-a-half order; 350 fourth order; 129 fifth order; and 65 sixth order; total, 717.

Reflectors are also in use, particularly for range lights, which are frequently employed to mark the axis or center line of a channel. For ranges two lights are necessary, and are placed a proper distance apart, usually with the rear light higher than the front, so that both lights show in line in the same vertical plane when the observer is in the center of the channel. Such reflectors are either silvered surfaces of metal in the form of a paraboloid, similar to head lights for locomotives or automobiles, or in improved forms of glass lenses with prismatic glass reflectors back of the light source. The latter are known as range lenses. On June 30, 1922, there were 148 reflectors and 53 range lenses in use in the Lighthouse Service.



Incandescent oil vapor lamp, 35-millimeter. mantle, with double tanks.

During the transition period of lighthouse apparatus from reflectors to lenses sperm oil remained as the leading illuminant, but with the yearly diminution of the whale catch it gradually increased in price until its use became prohibitive. Colza or rapeseed oil was used in small quantities about 1862 and succeeding years, but during the period 1864–1867 lard oil was adopted as the standard illuminant, and was generally employed to 1877, when kerosene came into use. Its use was gradually extended, and by 1885 kerosene became the principal illuminant and so remains at the present time. The lamps used were also improved, passing through various styles to a special form of concentric wick, using five wicks for the largest sizes. The incandescent oil-vapor lamp, which is now generally employed for important lights, burns vaporized kerosene under an incandesent mantle, giving a much more powerful light with little or no increase in oil consumption. The kerosene is stored in a suitable tank and is forced by compressed air, produced by operating a hand pump attached to either the oil tank or a separate air tank, into the vaporizer of the lamp. The air pressure varies from about 40 to 60 pounds per square inch and decreases so slowly during the operation of the light that a few strokes of the pump once or twice a night serve to maintain the required pressure. The kerosene is converted into vapor by a preheating torch when starting the lamp and subsequently

by the heat of the mantle itself. The vapor issues from a minute nozzle, mixes with a proper supply of air, and ignites as a blue flame in a Bunsen burner under the mantle, which is thereby brought to a brilliant incandescence. Increased efficiency is given by the use of an automatic thermostat alarm, a device which summons the attendant by ringing an electric bell when the light is not burning properly, either too high or too low.

Various other illuminants are now in use; acetylene and oil gas are used for lighted buoys, unattended lighted beacons, etc. Some of these unattended lights have given excellent service; one located in Molokini Island, Hawaii, which is the remnant of the ruin of an ancient volanic crater, has burned continuously night and day without extinguishment since its installation in 1911. It is, of course, visited at intervals for inspection, painting, and replenishment of gas. Electric arc and incandescent lights are also used. Experimental installations have been made of primary electric batteries operating flashers and small incandescent lamps, with the object of developing a reliable and economical minor light with a flashing characteristic as a substitute for oil lamps, thereby reducing the cost of attendance and supplies, and increasing the efficiency of the aids. Electric lights with distant control are employed in a number of cases where a reliable source of current may be obtained. Such lights may be on pierheads or structures built in the water, and can be easily operated by a switch on shore connected to the light by cable. A flashing characteristic may be arranged by means of an automatic make and break apparatus consisting of a small motor driving a clockwork and wheel with cams. To prevent interruption of service by the burning out of a lamp filament, an automatic lamp substituting device has been developed, consisting of three lamps mounted radially on a spring-actuated shaft, controlled in rotation by a latch which is actuated by electromagneto when the lamp in service burns out. The principal details as to illuminants used in the service on June 30, 1922, are given in the following table:

	Lights.
Incandescent oil vapor	317
Kerosene wick	2,007
Acetylene	1,021
Oil gas	232
Electric incandescent	181

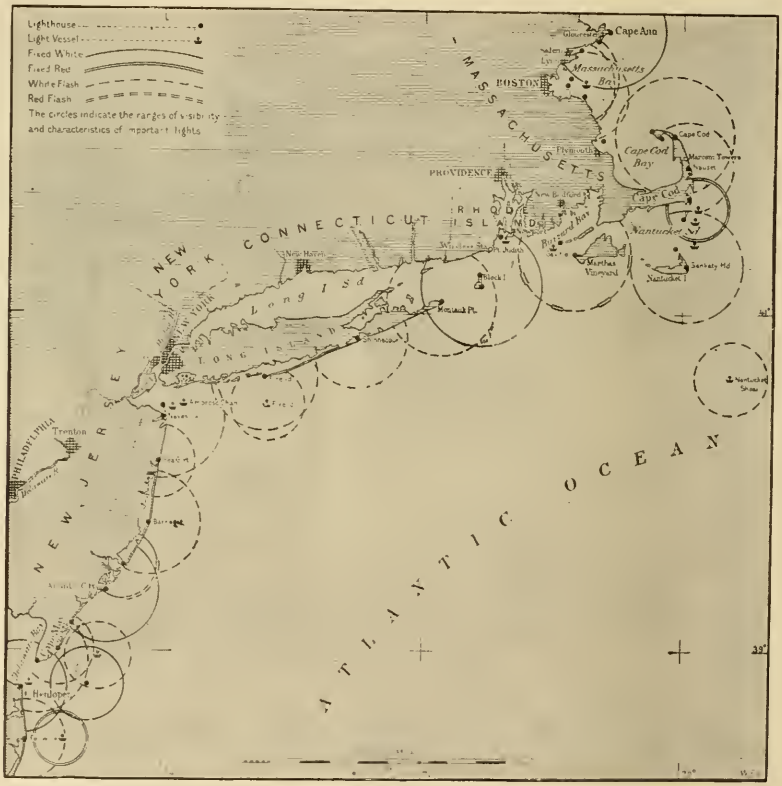
This table includes lighted buoys, but does not include the minor and float lights in the three river districts, of which there are 1,849 kerosene wick lanterns, 8 flashing acetylene lights, and 1 electric light.

All lights on the seacoast, with a few exceptions, are exhibited throughout the year, between sunset and sunrise. On the northern lakes and rivers lights are exhibited from sunset to sunrise at all

seasons when vessels can enter the ports or are navigating in their vicinity. Some of these lights, notably on Lake Michigan, are maintained throughout the year. The closed time varies with the seasons, generally embracing a part of December, January, February, and a part or all of March. Gas buoys and light vessels in these localities are replaced by unlighted buoys in the fall when endangered by ice conditions, and again placed on their stations as early as practicable in the spring.

11. DISTINCTIVENESS AND CHARACTERISTICS OF LIGHTS.

Lights on a well-marked coast should be sufficiently close that a vessel approaching land may always be in sight of at least one light. The illustration on page 34 shows that this condition is met in this country on our North Atlantic seaboard.



General lighting of Atlantic coast at entrances to Boston, New York, and Philadelphia.

In order to avoid the likelihood of confusion between lights, endeavor is made to give the lights distinct characteristics. As much of the coast was lighted before the introduction of modern lighthouse apparatus, the original lights were as a rule fixed, but at the more

important of these stations apparatus has now been installed to make the lights flashing or occulting. This effect is produced in the case of flashing lights by revolving all or a part of the lens, which is specially constructed with panels of prisms for concentrating the rays into beams; and in the case of occulting lights by some form of traveling screen or shutter which obscures the light at intervals. In either case the motion is regulated by a clockwork generally actuated by weights suspended by a cord wound over a drum and provided with the necessary governing mechanism so that the light and dark periods may occur in accurate sequence and produce the proper characteristic. The usual phases so attained are as follows: Fixed, showing a continuous steady light; flashing, showing a single flash at regular intervals; fixed and flashing, showing a fixed light varied at regular intervals by a single flash of greater brilliancy; group flashing, showing at regular intervals groups of flashes; occulting, showing a steady light suddenly and totally eclipsed at regular intervals; and group occulting, showing a steady light suddenly and totally eclipsed by a group of two or more eclipses at regular intervals. The foregoing refers only to lights which do not change color, white lights being the rule, but further diversification is obtained by the use of red screens, changing the color from white to red in various combinations, such lights being known as alternating. In the case of gas or electric lights the supply of gas or current is cut off at intervals by specially designed mechanisms whereby the characteristic may be adjusted as desired.

The terms "flashing" and "occulting" refer to the relative durations of light and darkness, a flash being an interval shorter than the duration of an eclipse, and an occultation being shorter than, or equal to, the duration of light. In approaching a light of varying intensity, such as fixed varied by flashes, or alternating red and white, due allowance must be made for the inferior brightness of the less powerful part of the light, which at a distance may show flashes only or white only, in the respective instances cited. Flashing lights may show a faint continuous light, due to reflection from the lantern, in clear weather and at short distances. White lights may have a reddish hue in some conditions of the atmosphere, and where lights change from white to red, by sectors or otherwise, there is a small amount of uncertain color on each side of the line of demarcation. Red sectors are produced by screens of colored glass; they are often employed to mark outlying dangers near the light, or the limits of channels, and are usually arranged so that the light shows white while a passing vessel is clear of such dangers, changing to red as the shoal or other obstruction is approached. Also, at the edge of a sector of visibility, the light is not cut off sharply, but gradually fades away.

Where necessary to give distinctiveness by means of color, red chimneys or shades and plates of red glass are provided, and in a few special cases green lights are used.

To assist identification in daylight, towers are frequently distinguished by characteristic painting, in addition to peculiarities of form or outline. The effect of several colors, when combined in bold patterns of spirals, bands, or blocks, is quite striking in a number of important lighthouses. (See p. 28.)

The principal details of characteristics of lights in commission on June 30, 1922, are given in the following table:

	Lights.
Fixed white	1,385
Fixed red	906
Fixed green	3
Flashing or occulting	1,490
Fixed and flashing	65

The above table includes lighted buoys, but does not include the 49 light vessels nor the 1,858 post and float lights on the Mississippi River and its tributaries, all of which are fixed, excepting 8. Of the light vessels, 15 have fixed white lights, 3 fixed white and red, and 31 flashing or occulting.

12. VISIBILITY AND CANDLEPOWER OF LIGHTS.

Under normal atmospheric conditions the visibility of a light depends upon its height and intensity; the distance due to the former being known as the geographic range, and to the latter as the luminous range. As a rule, for the principal lights the luminous range is greater than the geographic, and the distance from which the principal lights are visible is limited by the horizon only, and under some conditions of atmospheric refraction, the glare or loom of the light and occasionally the light itself may be visible far beyond the computed geographic range of the light. On the other hand, and unfortunately more frequently the case, these distances may be greatly lessened by unfavorable weather conditions due to fog, rain, snow, haze, or smoke. Weak and colored lights are more easily obscured by such conditions. The distances of visibility in nautical miles for objects of various elevations in feet above sea level are given in the following table, which is employed in calculating the geographic range:

Height, in feet.	Distance, in nautical miles.	Height, in feet.	Distance, in nautical miles.	Height, in feet.	Distance, in nautical miles.
5	2.55	60	8.85	130	13.03
10	3.61	65	9.21	140	13.52
15	4.43	70	9.56	150	14.00
20	5.11	75	9.90	200	16.16
25	5.71	80	10.22	250	18.07
30	6.26	85	10.54	300	19.80
35	6.76	90	10.84	350	21.38
40	7.23	95	11.14	400	22.86
45	7.67	100	11.43	450	24.24
50	8.08	110	11.99	500	25.56
55	8.48	120	12.52		

Distances corresponding to heights not included in the above table may be found approximately by the formula $D = \frac{8}{7}\sqrt{H}$, in which H = the elevation, or height, in feet, of the object above sea level, and D = the corresponding distance of visibility, in nautical miles. The formula is based on the mean curvature of the earth and is corrected for ordinary atmospheric refraction, and should be used only for moderate distances and elevations.

To make use of the above table in a practical way it is necessary to add the distance corresponding to the height of the observer's eye above sea level, as illustrated in the following example:

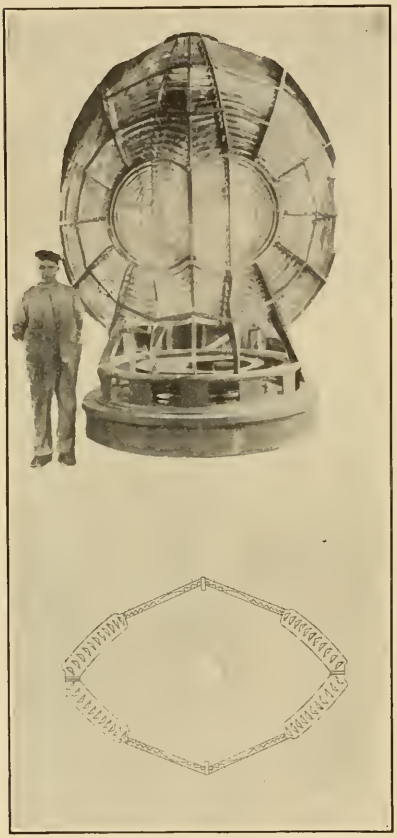
A light 130 feet high is seen just at the horizon; what, under ordinary atmospheric conditions, is its distance from the observer?

	Nautical miles.
From table, distance corresponding to 130 feet height	13.03
Add distance corresponding to height of eye above sea level, say 15 feet	4.43
Distance of light	17.46

The highest light in the service is at Cape Mendocino, Calif., the focal plane (or center of the light) of which is 422 feet above mean high water, thus giving it a geographic range of about 28 miles, under normal atmospheric conditions and with the observer's eye at a height of 15 feet. The following list gives the names and locations of 33 lights with focal plane heights of 200 feet and over, arranged in the order of height:

District.	Station.	Height of focal plane above mean high water.	District.	Station.	Height of focal plane above mean high water.
		Feet.			*Feet.*
18	Cape Mendocino, Calif	422	17	Cape Blanco, Oreg	245
19	Makapuu Point, Hawaii	420	19	Orote Point, Guam	240
9	Navassa Island, West Indies	395	16	Cape Hinchinbrook, Alaska	235
9	Hams Bluff, Virgin Islands	394	17	Columbia River Main Channel Range Rear, Wash	234
18	Farallon, Calif	358	9	Mona Island, P. R	231
16	East Chugach, Alaska	325	3	Staten Island, N. Y	231
9	Culebrita Island, P. R	305	3	Chapel Hill, N. J	221
9	Judge Bergs Range Rear, Virgin Islands	302	17	Cape Disappointment, Wash	220
9	Muertos Island, P. R	297	17	Cape Meares, Oreg	217
16	East Forelands, Alaska	296	19	Kilauea Point, Hawaii	216
18	Point Reyes, Calif	294	18	Alcatraz, Calif	214
9	Point Borinquen, P. R	292	19	Molokai, Hawaii	213
16	Seal Rocks, Alaska	285	11	Grand Island, Mich	205
18	Point Sur, Calif	270	17	Heceta Head, Oreg	205
9	Cape San Juan, P. R	260	3	Block Island Southeast, R. I	201
19	Aunuu Island, Samoa	250	16	Cape Stephens, Alaska	200
3	Navesink, N. J	246			

The intensities of lights were formerly indicated merely by the order of the optical apparatus. So long as the lenses were similar in arrangement and the same type of lamp was used this gave a convenient basis of comparison, but with the introduction of more modern apparatus, with flash panels of great power and illuminating apparatus of increased intensity, such distinctions became uncertain so far as indicating the relative brightness of lights. The statement of orders has now been generally superseded by a statement of the approximate candlepower in English candles. The actual determination of such candlepowers for large lenses is difficult, and it is in most cases estimated on the basis of accurate photometric measurements of small lights, proportioning the results so obtained to suit the elements of the lens under study, taking into account the intrinsic power of the light source, the horizontal and vertical angles of the various panels, the divergence of the rays at the source, the absorption or reflection of a percentage of the light by the prisms themselves, and such other factors as enter into consideration. Although only approximate, the final figures are, however, reasonably consistent, and from them the observer may judge of the relative brilliancy and power of the various lights.



Lens and diagram of prisms, Kilauea Point.
(See p. IV.)

The brightest light in the service is at Navesink, N. J., on the highlands at the entrance to New York Bay, the candlepower of which is estimated at 710,000. The geographic range of this light is 22 miles, but its glare has been seen at a greater distance under unusual conditions of the atmosphere. This great intensity is produced by a group of three incandescent oil vapor burners inclosed in a modern lens of high magnification. The names and locations of 52 lights in the service having candlepowers of 100,000 or greater are given in the following list in the order of brightness:

District.	Station.	Intensity of brightest part of light, in approximate English candles.	District.	Station.	Intensity of brightest part of light, in approximate English candles.
3	Navesink, N. J	710,000	6	Jupiter Inlet, Fla	170,000
19	Molokai, Hawaii	620,000	17	Heceta Head, Oreg	170,000
2	Cape Cod, Mass	580,000	10	Buffalo, N. Y	162,000
18	Santa Barbara, Calif	580,000	8	Ship Shoal, La	160,000
4	Liston Range Rear, Del	420,000	10	South Buffalo South Side, N. Y.	150,000
18	Point Arena, Calif	390,000	1	Monhegan Island, Me	150,000
2	The Graves, Mass	380,000	3	Montauk Point, N. Y	130,000
6	Hillsboro Inlet, Fla	370,000	4	Cape May, N. J	130,000
7	Dry Tortugas, Fla	370,000	5	Cape Charles, Va	130,000
12	White Shoal, Mich	360,000	7	Carysfort Reef, Fla	130,000
3	Shinnecock Bay, N. Y	350,000	18	Point Conception, Calif	130,000
3	Staten Island, N. Y	300,000	18	Piedras Blancas, Calif	130,000
16	Cape St. Elias, Alaska	300,000	4	Horseshoe Lower Range, Pa. (2 lights)	120,000
18	Farallon, Calif	280,000	8	Matagorda, Tex	120,000
5	Hog Island, Va	280,000	9	Point Tuna, P. R	120,000
8	Pensacola, Fla	280,000	1	Moose Peak, Me	110,000
11	Whitefish Point, Mich	270,000	1	Cape Elizabeth, Me	110,000
19	Kilauea Point, Hawaii	240,000	6	St. Augustine, Fla	110,000
11	Two Harbors, Minn	220,000	8	Cape San Blas, Fla	110,000
11	Split Rock, Minn	220,000	11	Stannard Rock, Mich	110,000
17	Grays Harbor, Wash	220,000	11	Outer Island, Wis	110,000
11	Rock of Ages, Mich	200,000	16	Cape Hinchinbrook, Alaska	110,000
1	Petit Manan, Me	180,000	18	Point Cabrillo, Calif	110,000
3	Fire Island, N. Y	170,000	2	Boston, Mass	100,000
6	Cape Romain, S. C	170,000	11	Manitou, Mich	100,000
6	Cape Canaveral, Fla	170,000			

13. FOG SIGNALS.

The first fog signal in the United States was a cannon, installed at Boston Light in 1719, which was fired when necessary to answer the signals of ships in thick weather. Guns of various types were used at other lighthouses, but have now been generally abandoned.

Bells were introduced at a comparatively early date, and at first were usually small, and rung by hand to answer vessels. Larger bells were developed and striking machinery, governed by clockwork, devised for ringing a regular code or characteristic. An automatic striking mechanism operated by compressed carbon dioxide has recently been devised and is operating successfully on a few buoys and stations where a moderate range is sufficient, thus dispensing with the necessity for attendance, which heretofore has been an expensive feature with fog signals. Such a device rings continually, and a hygroscopic controlling device has therefore been developed, which automatically starts the bell during fog and wet weather, and this is being given service tests. Many bells are now in use, ranging from small hand bells up to 4,000 pounds in weight, and are of value for inside waters, harbors, etc., but are not sufficiently powerful for use on the seacoast.

Trumpets were the next improvement, and were installed experimentally in 1851. The original device consisted of a steel reed or tongue inclosed in a box with a large trumpet or resonator; the ap-

paratus was sounded by means of compressed air produced by a horse operating suitable machinery for the purpose. Although the sound was more penetrating than that of a bell, the expense and inconvenience of the maintenance of a horse prevented its extended use. A modification was made, using an Ericsson hot-air engine as the motive power, and trumpets so equipped were established at a number of stations. A somewhat similar device, known now as a reed horn, is in use at a number of inside stations and is generally operated by compressed air, the compressors being driven by internal-combustion kerosene or gasoline engines. The sound is of moderate volume only and is not sufficiently loud for the majority of outside stations.

Detroit River Light Station, Mich., showing fog signal.

Steam whistles were investigated first in 1855, and an installation of a 5-inch whistle was made at Beavertail, R. I., in the fall of 1857, which was subsequently replaced about 1866 by a reed horn operated by a hot-air engine. The first stations regularly equipped were West Quoddy Head and Cape Elizabeth, Me., where the installations were placed in commission in 1869, consisting of a boiler and fittings with an 8 or 10 inch locomotive-type whistle, giving an 8-second blast every minute. This was the most powerful apparatus devised up to that time, and in point of volume and carrying power of the sound is still considered a very efficient aid. The rapid deterioration of the boilers, the expense of providing fresh water and fuel, the possibility of confusion with the whistle of a passing vessel, and, above all, the

time required to place the signal in operation in the event of sudden fog, are factors which have tended toward the nonuse or abandonment of this type of signal in practically all foreign lighthouse services, though it is still extensively employed in this country with whistles up to 12 inches in diameter. However, every precaution is taken to get these signals into operation as quickly as possible by use of banked fires, hot-water heaters, etc.

Experiments with sirens were first made in 1867, and the first service installation was at Sandy Hook East Beacon in the spring of of 1868. Originally this instrument consisted of a large cast-iron trumpet, to the mouthpiece of which there was attached a chamber containing a slotted disk or plate revolving upon a fixed disk or seat

Fog signal at Cape Henry Light Station, Va.

also slotted. The back of the seat was provided with a slotted disk valve for producing the characteristic, and the chamber itself was attached directly to the steam dome of the boiler. The revolving slotted disk and the slotted valve were both operated by a small steam engine. Steam at about 70 pounds pressure was driven through the apparatus, and the escape and interruption of the jets through the openings in the disk and rotating plate produced the note. The apparatus has been modified and improved, and in its present form the revolving plate has been superseded by a cylinder with peripheral slots, known as the rotor, which is inclosed in a casing also with slots, called the stator, leading to a horn or trumpet. The rotor is in some types driven by a separate auxiliary mechanism and in others automatically by the main supply of steam or air, this latter type being known as the automatic siren. Compressed air is gen-

erally employed as the sounding medium, though steam is used at a few places. The compressors are driven by internal-combustion engines. The principal advantages of the compressed-air siren are distinctiveness of note, which is entirely unlike the ordinary whistle, and quickness of starting, rarely over 10 minutes being required in any case, while some of the more recent installations may be sounded almost instantaneously.

A number of other signals have also been introduced, such as air whistles, in which the same type of plant as for an air siren is employed, except in regard to the sound-producing apparatus; also electrically operated bells and gongs, which do not differ essentially from those operated by clockwork.

Distant control is often used for electric fog signals, particularly when placed on the ends of jetties or breakwaters and other inaccessible places. The striking mechanism is usually driven by a motor incased in a storm-proof box or casing, with all gears running in a bath of oil. A generally heavy and safe construction is adopted, and the striker is connected by submarine cable, if necessary, to the starting box, located on shore, where it is necessary only to throw a switch to start the apparatus.

Other types are the "sireno," an electrically driven blower siren, and the "diaphone," a powerful instrument operated by compressed air and differing from the siren in having a reciprocating piston instead of a rotor. The diaphone was originally used in the Canadian lighthouse service and about 35 installations have been made in this country. The sound produced by this apparatus is somewhat similar to that of a siren, but with an abrupt roar at the end of the note which adds to its distinctiveness. It is manufactured in several sizes for varying types of service, and the larger instruments have been heard 25 miles from seaward.

Tests have been made with various shapes of resonators or trumpets for the most efficient propagation of the sound waves. A vertical mushroom trumpet has been found to give good results where an even distribution of the sound is desired at all points of the compass, as, for instance, in the case of light vessels. In other cases, particularly light stations marking important places, horizontal double-mouth horns have been found to give satisfactory results by effecting a wider and more even distribution of the sound.

Practically all fog signals as now installed are provided with a governing device for timing the strokes or blasts; this usually consists of a clockwork whereby the cycle is repeated every minute in order to facilitate identification.

There is sometimes an unfortunate conflict of interest between the need of a loud and distinctive sound to aid the mariner in a fog and the quiet and comfort of residents in the vicinity of the signal.

Aerial fog signals, though of the greatest value to the mariner, are subject to a number of aberrations, so that they can not be relied upon implicitly. Every endeavor is made to start fog signals as soon as signs of fog have been observed at the station, but such signals should be regarded by mariners as auxiliary aids only and soundings should be taken in all conditions of doubt. A fog often creeps imperceptibly toward the land and a vessel may have been in it some time before it is observed at the signal. Sound is conveyed irregularly through the atmosphere and mariners can not place dependence on judging their distance from the fog signal by the power of the sound. Under certain conditions of the atmosphere the sound may be lost a short distance from the signal, as there may be silent areas or zones; or the sound may carry much farther in one direction than in another, and these conditions may vary in the same locality within short intervals of time.

It is often observed that in any given direction from a fog signal, and near its limit of audibility, the sound may become extremely faint, and at a greater distance it may again become quite distinct. It should never, therefore, be assumed that fog signals are not in operation because the sound is not heard, even when in close proximity. When observed from vessels at sea, noises in the ship may interfere with the hearing from the deck or bridge, especially with the engines running. In such cases it is well to stop the ship and listen in a quiet position. Whistling and bell buoys are sounded only by the action of the sea; therefore in calm weather they are less effective or may not sound.

However, by due caution in navigation and the prudent use of the lead, sufficient warning of danger is generally obtained. In order to guard against the possibility of breakdowns, all modern fog-signal installations are in duplicate, so the second signal may be started at once in event of accident to the first. Care is taken to give each unit an equal amount of use, as far as practicable. These precautions are taken owing to the difficulty of making quick repairs at the station.

Submarine signals, which have been introduced in recent years, have as a rule a more effective and constant range of audibility than signals sounded in air. Such a signal consists essentially of a specially designed bell, submerged sufficiently to avoid wave disturbance with some form of striking mechanism. On light vessels the bell is usually swung over the ship's side on a chain attached to a davit, and the striking device is operated pneumatically to ring a certain set of blows at prescribed intervals. At light stations the bell is usually supported on a tripod, placed on the sea bottom, a short distance away from the light, and the striking mechanism operated electrically through a cable, with characteristic number of strokes at

regular intervals. When attached to buoys a swinging vane is provided, which is forced up and down as the buoy surges in the sea. The motion of the vane causes a spring to stretch, which is released at a sufficient tension, striking a blow on the bell. The blows are of equal intensity, being due to the elongation of the spring, although the interval between them varies with the condition of the sea, and no regular code of strokes is therefore practicable. Experiments have also been made with the oscillator, an instrument operated under water in much the same manner as a bell, the sound being produced by a vibrating diaphragm actuated by electric power, similar to the principle of many automobile horns.

In order to obtain the best results with submarine bells, a receiving apparatus, somewhat similar to a telephone, has been devised for attachment to a vessel. This is apparently more effective in vessels of deep draft, and a ship so equipped may determine the approximate bearing of the signal. The sound may be heard also on vessels not equipped with receiving apparatus, by observers below the water line, and particularly in iron or steel ships, but the bearing of the signal can not then be readily determined.

The numbers and types of the 597 fog signals in use on June 30, 1922 (not including sounding buoys), are shown in the following statement:

Radio (4)	4
Steam (95):	
Whistle	92
Siren	3
Air (183):	
Whistle	9
Siren	81
Diaphone	35
Sireno (electric)	10
Reed horn	48
Bell (264):	
Clockwork	225
Electric	20
Engine	1
Operated by gas	3
Hand	15
Horn (2): Hand	2
Submarine bells (49):	
On light vessels, operated by compressed air	38
On bottom, operated by electricity	2
On buoys, operated by the sea	9
Total	597

Since 1885 systematic records have been kept of the number of hours of fog or thick weather observed per year at each fog-signal station. These figures present interesting statistics and are of some value in approximating the prevalence of fog at various localities when proposed new signals are under consideration. A summary of the principal results is given in the subjoined table.

District.[1]	Number of stations.	Mean hours per year for district.	Maximum observed.			Highest annual average.		
			Station.	Hours.	Year.	Station.	Hours.	Years.
1	56	924	Seguin	2,734	1907	Moose Peak	1,644	8
2	36	714	Pollock Rip Slue Light Vessel.	1,737	1916	Pollock Rip Slue Light Vessel.	1,243	19
3	101	471	New London Harbor	1,809	1885	Block Island, SE	870	37
4	12	369	Delaware Breakwater	912	1887	Delaware Breakwater	497	36
5	77	227	Cape Henry	902	1904	Craighill Channel Range Front.	415	16
6	7	143	Charleston Light Vessel.	397	1920	Brunswick Light Vessel	183	13
7	1	94	Egmont Key	128	1913	Egmont Key	84	9
8	18	305	Cubits Gap	1,031	1917	Heald Bank Light Vessel.	638	16
10	16	236	Cleveland West Breakwater.	1,224	1915	Cleveland West Breakwater.	682	30
11	48	321	Thunder Bay Island	1,085	1909	Passage Island	517	37
12	56	341	Calumet Harbor	2,269	1913	Calumet Harbor	1,174	15
16	11	390	Cape Hinchinbrook	1,521	1920	Cape Hinchinbrook	869	10
17	31	464	Swiftsure Bank Light Vessel.	1,770	1912	Swiftsure Bank Light Vessel.	1,272	13
18	40	619	San Francisco Light Vessel.	2,221	1916	Point Reyes	1,384	37

[1] No fog-signal stations in the ninth, thirteenth, fourteenth, fifteenth, and nineteenth districts.

The absolute maximum record is that at Seguin, Me., 2,734 hours in 1907, equivalent to about 30 per cent of the entire year, 8,760 hours. The maximum observed on the Great Lakes was at Calumet Harbor, near Chicago, Ill., where 2,269 hours of fog occurred in 1913, amounting to about 26 per cent of the year. This and other stations near large cities are affected somewhat by smoke in the vicinity. The highest Pacific coast record was observed in 1916 on San Francisco Light Vessel, Calif., being 2,221 hours, or about 25 per cent of the year.

Fog is more generally prevalent throughout the first district than any other, as shown by the following table, from which it will be seen that out of 35 stations in the entire service averaging over 1,000 hours of fog per year, 19, or over one-half, are in that locality.

District.	Station.	Average hours of fog per year.	Years of record.	Percentage of fog based on entire period.
1	Moose Peak, Me	1,644	8	19
1	Petit Manan, Me	1,607	37	18
1	Libby Islands, Me	1,574	37	18
1	Whitehead, Me	1,511	37	17
1	Mount Desert, Me	1,418	28	16
1	Egg Rock, Me	1,404	17	16
1	Great Duck Island, Me	1,393	30	16
18	Point Reyes, Calif	1,384	37	16
16	Scotch Cap, Alaska	1,378	5	16
1	West Quoddy Head, Me	1,374	37	16
1	Matinicus Rock, Me	1,361	37	16
1	Little River, Me	1,300	16	15
1	The Cuckolds, Me	1,297	27	15
1	Seguin, Me	1,278	37	15
17	Swiftsure Bank Light Vessel, Wash	1,272	13	15
2	Pollock Rip Slue Light Vessel, Mass	1,243	19	14
12	Calumet Harbor, Ill	1,174	15	13
18	Blunts Reef Light Vessel, Calif	1,166	16	13
1	Nash Island, Me	1,162	16	13
18	San Francisco Light Vessel, Calif	1,148	23	13
16	Cape Hinchinbrook, Alaska	1,134	5	13
18	Bonita Point, Calif	1,122	37	13
1	Manana Island, Me	1,109	37	13
18	Point Cabrillo, Calif	1,087	12	12
18	Humboldt Bay, Calif	1,086	12	12
2	Great Round Shoal Light Vessel, Mass	1,086	28	12
2	Pollock Rip Light Vessel, Mass	1,084	37	12
1	Bass Harbor Head, Me	1,084	16	12
1	Isle au Haut, Me	1,083	13	12
18	Point Arena, Calif	1,059	37	12
1	Two Bush Island, Me	1,048	16	12
1	Pemaquid Point, Me	1,039	16	12
1	Tenants Harbor, Me	1,017	13	12
2	Nantucket Shoal Light Vessel, Mass	1,016	29	12
18	San Luis Obispo, Calif	1,010	30	11

14. RADIO FOG SIGNALS.

This system is based on the equipment of selected important lighthouses and light vessels along the coast with apparatus for sending radio signals of simple and definite characteristics during the continuation of fog or thick weather, by means of which the navigator of any vessel provided with a radio compass may take definite bearings to guide or to locate his ship, although no object is visible. The most valuable use of the radio fog signal will probably be as a leading mark, as, for example, to enable a vessel to make a lightship anchored in the approach to a harbor or to pass outside of a lightship anchored to guard against dangers off the coast. The navigator will also be able, as in navigation using visible objects, to locate his ship by cross bearings on two or more radio stations or by repeated bearings on the same station with the distance logged between bearings, or by a single bearing and dead reckoning, etc. This system, for the first time in navigation, affords a practicable means by which the navigator can take reasonably accurate bearings on fixed beacons which are not visible. Its prospective importance is due to the fact that one of the greatest needs for increasing safety of navigation is improved means to enable a mariner to guide and to locate his vessel in thick weather when he can see no lights or landmarks. Another

very important use will be to enable vessels to locate each other when meeting, approaching, or needing assistance in fog. Many striking illustrations of the importance of radio bearings in locating vessels at sea have been reported.

Radio fog signals are now in commission at the following places: Ambrose Channel Light Vessel, Fire Island Light Vessel, Sea Girt (N. J.) Light Station, Diamond Shoal Light Vessel, N. C., and San Francisco Light Vessel, Calif. The three stations in the vicinity of New York were selected so as to enable vessels approaching or leaving that port to locate themselves conveniently by cross bearings and to furnish convenient leading marks to approach the harbor. The stations are identified by the characteristics of the signals, thus Ambrose Channel sends one dash, Fire Island a group of two dashes, and Sea Girt a group of three dashes, with brief intervals between the groups. The particular station on which a radio bearing is being taken in a fog is by this means just as definitely known as is the light on which a sight bearing is taken by the navigator of a ship identified by its order of flashes or color. The signals are operated continuously during thick or foggy weather, and also at the present time they are sent each day from 9 to 9.30 a. m., and from 3 to 3.30 p. m., so as to permit any vessel equipped with radio compass to try out the method and apparatus in clear weather. To avoid continuous interference between the signals themselves they are sent on different time schedules as follows: Ambrose sends for 20 seconds, silent 20 seconds; Fire Island sends for 25 seconds, silent 25 seconds; Sea Girt sends for 60 seconds, silent 6 minutes. The signals are repeated rapidly, Sea Girt, for example, sending over 40 groups of dashes a minute.

The transmitting apparatus now in use is a commercial panel-type transmitting set of simple and rugged construction of about 1-kilowatt power. In addition to this set a special automatic motor-driven timing switch for producing the desired signal at regular intervals is provided. The antennas at the transmitting stations are the same as used for ordinary radio communication. The wave length used at present is 1,000 meters, the present international standard for such signals, and the range of usefulness varies from 30 to 100 miles, depending upon the sensitiveness of the receiving apparatus.

The method of radio direction finding, or radio fog signals, which has been developed by the Bureau of Standards and the Lighthouse Service, is based on the peculiar properties of the so-called coil aerial when used for the reception of radio signals. This coil consists of about 10 turns of insulated copper wire upon a rotatable wooden frame approximately 4 feet square. When the plane of the coil is parallel to the direction from which a radio signal emanates, the intensity of the signal received will be a maximum. As the coil

is revolved, the intensity of the signal diminishes until a minimum is reached when the plane of the coil comes to a position at right angles to the line of direction from the signal. This minimum, which is well defined, may be determined with sufficient accuracy for navigational purposes and is used in taking radio bearings.

The coil aerial mounted upon a vertical spindle provided with a pointer, and a graduated circle below the pointer for determining the position of the coil with respect to a known direction, constitutes what is known as the radio compass or radio direction finder. This apparatus, and the necessary radio receiving device, are installed on the vessel, preferably in a position easily accessible to the navigator.

In the installations which have been made on lighthouse tenders, the coil is mounted on the roof of the pilot house. The spindle extends through the roof and is provided with a handwheel for rotating the coil. The lower end of the spindle terminates directly above the center of a standard ship's binnacle and carries a pointer so arranged that the position of the coil may be read directly upon the compass card, thus giving the magnetic bearing of the radio signal station at a glance when the minimum point is reached.

In another form, which has been extensively installed on large foreign vessels, there are two large loop aerials mounted in a fixed position above the upper deck, one lying in the plane of the axis of the ship, and the other perpendicular to it. The lead wires are carried to the receiving panel, where each loop is connected to a fixed coil. Two small coils are so placed as to rotate within the fixed coils, and radio bearings are taken by rotating these, until a minimum signal is heard, and reading the direction on a fixed scale and at the same time reading the ship's head by the magnetic compass. There is a special receiving apparatus with a number of stages of amplification. There are two positions of the coil, 180° apart, which will give minimum signals, and means are provided in each of these systems to determine from which side of the coil the signal is coming, called the "sense" of direction.

After the radio direction finder has been installed on the vessel, a careful calibration is necessary to eliminate errors caused by distortion of the radio signal by the vessel itself. Simultaneous radio bearings and sight shots with an azimuth circle are taken on a convenient radio signal station at intervals of approximately 5° while the vessel is swung several times in a complete circle. The deviation of the radio bearing from the true bearing is thus obtained for all positions of the coil with respect to the ship's axis. In the installations made on lighthouse tenders, these corrections are then recorded on a circular frame of metal attached to the top of the binnacle and surrounding the magnetic compass, and applied to all subsequent readings of the radio direction finder.

In order to obtain satisfactory results from radio-compass navigation it is essential that the compass be properly constructed, installed, and calibrated, and that only receivers and amplifiers of the special type required be used in connection therewith.

Precaution must be taken by the navigator in applying bearings taken at any considerable distance to ordinary navigation charts on the Mercator projection, as the line of bearing on such a chart is not a straight line excepting in the meridian, and suitable corrections must be made.

The following is a brief summary of some of the advantageous features of this system of radio direction finding:

(*a*) The navigator can obtain bearings himself, he can do this promptly and as needed, and is not dependent upon others for the accuracy of the results.

(*b*) Any number of vessels may obtain bearings simultaneously and as frequently as may be desired.

(*c*) No knowledge of radiotelegraphy is necessary on the part of the navigator.

(*d*) Use of the radio signal as a leading mark for which to steer directly, or to keep outside of.

(*e*) The direction finder may be used for locating other vessels at sea, for preventing collisions in fog, or for seeking vessels in distress.

(*f*) The transmitting stations, being automatic, may be operated by employees of existing lighthouses or light vessels, thus avoiding the necessity of additional personnel.

The important possibilities of utilizing the directive element of radio signals for the location of vessels in fog were early recognized. This subject was mentioned in the Lighthouse Service Bulletin in 1912 and in its annual report for 1913 following experimental installations in France. The service application of the principle was dependent, however, on the improvement of the radio compass, and its successful use in this country has been rendered possible by extensive investigation of the subject by the Bureau of Standards, resulting in the development by that bureau of a simple and efficient radio compass suitable for use on shipboard.

Faraday's discovery in 1831 of electromagnetic induction was a basic step leading to the present development. The use of a coil for determining the direction of radio waves was developed by Hertz in 1888, and numbers of experimenters have worked on the problem since that time.

In 1915 and 1916 a more effective radio compass was developed at the Bureau of Standards, and in January, 1917, the Lighthouse Service and Bureau of Standards carried out tests of a radio-sending station installed at Navesink Lighthouse, N. J., and a radio compass installed on a lighthouse tender, with promising results. Further

development for the purpose of the Lighthouse Service was deferred during the war, but was again taken up in 1919, when these two services installed three experimental radio fog-signal sending stations at three lighthouses in Chesapeake Bay, and an improved radio compass on a tender, and a number of tests were made with satisfactory results. During the following year the apparatus was improved, and equipment was installed at the three stations in the vicinity of New York Harbor described herein. Tests of these stations were made for several months and they were placed in regular operation May 1, 1921.

During the World War considerable use was made abroad of radio-compass stations located on shore for obtaining bearings of ships and furnishing this information for use in navigation, especially of naval vessels. After the war the Navy Department established such stations on the coast of the United States, to be operated in conjunction with the naval communication stations already existing. A number of such stations are now in active operation on both the Atlantic and Pacific coasts, and are furnishing many bearings to ships asking for them. These stations are usually arranged in groups. The system is the reverse of that employed by the Lighthouse Service at its stations in which the navigator determines the position of the ship himself.

The Lighthouse Service proposes, as means are available and needs are developed, to install similar groups or single radio fog-signal stations in the vicinity of important entrances on the Atlantic and Pacific coasts of the country and on the Great Lakes, as well as on some of the principal intermediate capes and light vessels. Equipment has been purchased for the following seven stations: Boston Light Vessel, Mass.; Nantucket Shoals Light Vessel, Mass.; Cape Charles Light Vessel, Va.; Cape Henry Light Station, Va.; Swiftsure Bank Light Vessel, Wash.; Columbia River Light Vessel, Oreg.; and Blunts Reef Light Vessel, Calif. For the successful utilization of the system it is, of course, indispensable that the more valuable vessels at least be equipped with radio compasses, and it is believed that the additional safeguards resulting from such equipment will bring this about, particularly in view of the growing familiarity with the value of radio apparatus to shipping. As a result of further investigation still in progress by the services mentioned and others, and of actual test and experience, it is expected there will be improvements in this system and further applications of radio signaling for the safeguarding of navigation. It is not probable, however, that as a result of anything now in sight the extensive system of sound fog signals, such as sirens, whistles, horns, and bells, can be dispensed with, as these are of great value to vessels and boats of every size and description, many of which are not likely to be

equipped for receiving radio signals; and furthermore, these furnish warning signals the use of which is not dependent on the operation of any instrument other than the human ear.

It may be desirable to develop this system for the location of vessels in clear weather, at distances beyond the visibility of lights or other objects on land, and this may readily be done if sufficiently useful.

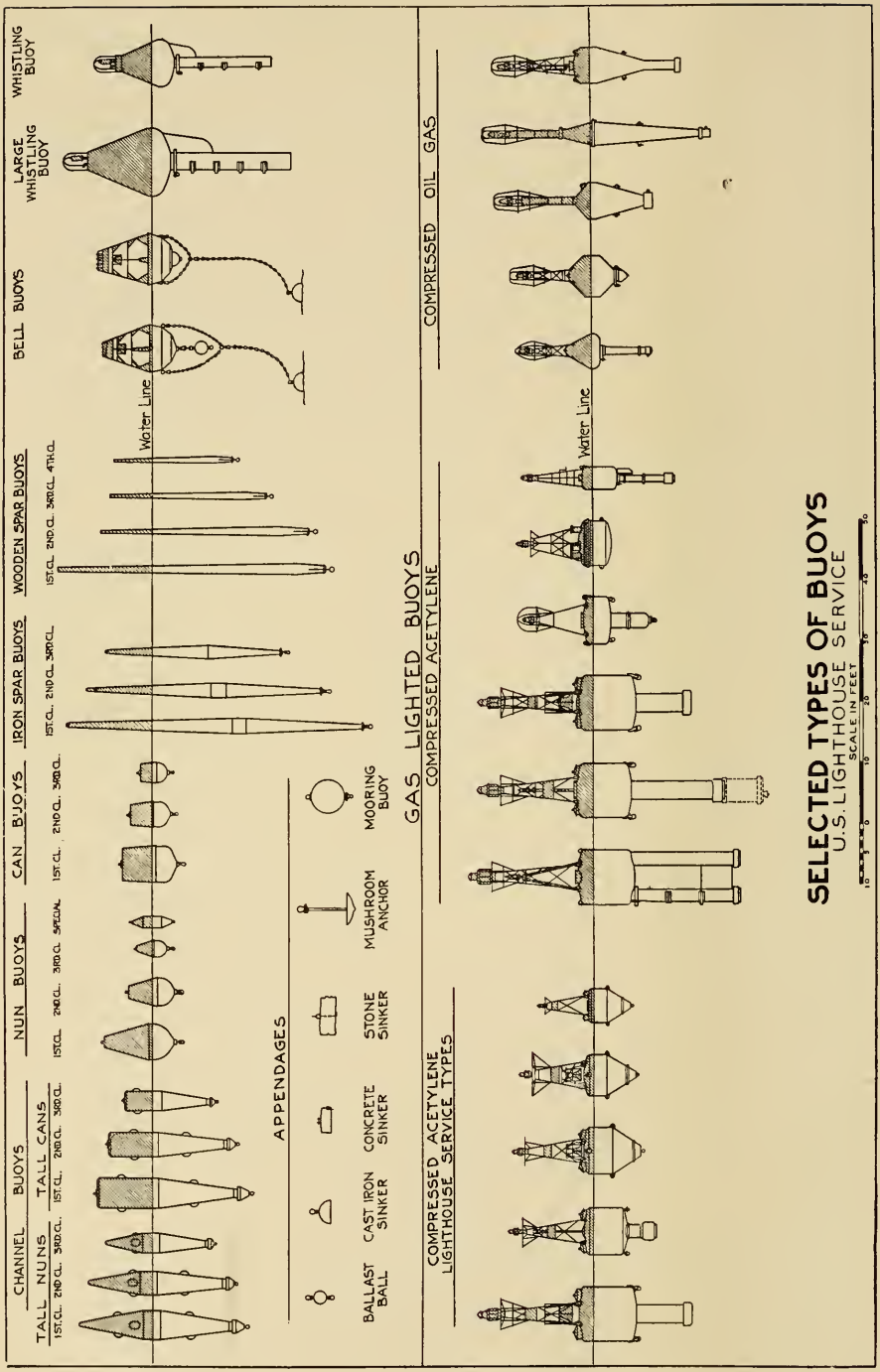
15. BUOYS.

Buoys are, as a rule, employed to mark shoals or other obstructions, to indicate the approaches to and limits of channels or the fairway passage through a channel, and in some cases to define anchorage grounds. There were some buoys in service at the time of the transfer of the lighthouses to the Federal Government in 1789. Buoys originally were either solid wooden spars or built up in various shapes of wooden staves, like barrels. Wooden spars are still extensively used, particularly in inside waters; but built-up buoys are now constructed of iron or steel plates.

In order to give the proper distinctiveness, buoys are given certain characteristic colors and numbers; and following the uniform practice of maritime nations generally, Congress by the act of September 28, 1850, prescribed that all buoys along the coast or in bays, harbors, sounds, or channels shall be colored and numbered, so that passing up the coast or sound or entering the bay, harbor, or channel, red buoys with even numbers shall be passed on the starboard or right hand; black buoys with odd numbers on the port or left hand; buoys with red and black horizontal stripes without numbers shall be passed on either hand, and indicate rocks, shoals, or other obstructions, with channels on either side of them; and buoys in channel ways shall be colored with black and white perpendicular stripes, without numbers, and may be passed close-to, indicating mid-channels. Buoys to mark abrupt turning points in channels or obstructions requiring unusual prominence, are fitted with perches or staves surmounted by balls, cages, or other distinctive marks.

Buoys marking light-vessel stations are placed in close proximity to the light vessel, are colored in a similar manner, and bear the letters LV with the initials of the station they mark. Buoys defining anchorage grounds are painted white, except those used for such purposes at a quarantine station, in which case they are painted yellow.

To assist further in distinguishing buoys, the ordinary unlighted types are made in two principal shapes in the portion showing above the water line—nun buoys, having conical tops, and can buoys, with cylindrical tops. When placed on the sides of channels, nun buoys, colored red and numbered in black, are placed on the starboard or right-hand side going in from sea, and can buoys, painted black


CHANNEL BUOYS
TALL NUNS
1ST CL. 2ND CL. 3RD CL.
TALL CANS
1ST CL. 2ND CL. 3RD CL.
NUN BUOYS
1ST CL. 2ND CL. 3RD CL. SPECIAL
CAN BUOYS
1ST CL. 2ND CL. 3RD CL.
IRON SPAR BUOYS
1ST CL. 2ND CL. 3RD CL.
WOODEN SPAR BUOYS
1ST CL. 2ND CL. 3RD CL. 4TH CL.
BELL BUOYS
LARGE WHISTLING BUOY
WHISTLING BUOY
Water Line
APPENDAGES
BALLAST BALL
CAST IRON SINKER
CONCRETE SINKER
STONE SINKER
MUSHROOM ANCHOR
MOORING BUOY
GAS LIGHTED BUOYS
COMPRESSED ACETYLENE
COMPRESSED OIL GAS
COMPRESSED ACETYLENE LIGHTHOUSE SERVICE TYPES
Water Line
SELECTED TYPES OF BUOYS
U.S. LIGHTHOUSE SERVICE
SCALE IN FEET
10 5 0 10 20 30 40 50

with white numbers on the port or left-hand side. The numbers and letters placed on all buoys are formed by standard stencils, to insure uniformity, and the largest size practicable is used, so that these may show as prominently as possible.

Buoys are anchored in their positions by various types of moorings, depending on the character of the bottom and the size and importance of the buoy. They are placed in position and cared for by the lighthouse tenders, which are provided with specially designed derricks and lifting gear for handling them. It is customary to relieve all buoys at least once a year for overhauling, repairing, cleaning, and painting, and oftener when circumstances render it necessary. Although among the most useful of aids to navigation, buoys are liable to be carried away, dragged, capsized, or sunk, as a result of ice or storm action, collision, and other accidents, and therefore may not be regarded as absolutely reliable at all times. Great effort is made, however, by the service to maintain them on station in an efficient condition, which frequently requires strenuous and hazardous exertions on the part of the vessels charged with this duty. It is necessary to keep an ample supply of spare or relief buoys, with the necessary appendages, always on hand to provide for emergencies, and the systematic relieving of buoys on station.

Buoys may be divided broadly into two general classes, lighted and unlighted, of which the latter are in the great majority, Unlighted buoys comprise spars, both wooden and iron, can, nun, bell, and whistling buoys, with a few other types for special purposes. Lighted buoys are provided with some form of gas apparatus and a lantern; frequently a bell or whistle is also attached, in which case they are known as combination buoys. A brief description of each kind follows.

Wooden spar buoys are usually cedar, juniper, or spruce logs, trimmed, shaped, and provided with an iron strap and band at the lower end for attaching the mooring, which is as a rule a heavy stone or concrete block,or iron sinker, sometimes shackled directly to the buoy, or to a short piece of chain, as required by the depth. Such buoys are among the most economical and generally used of all aids, and are particularly employed in rivers and harbors. They are, however, easily damaged by ice or collision, and in some waters suffer greatly from the attacks of the teredo and other marine borers, although this may be reduced by special paints or other protective treatment when not unduly expensive. Four sizes or classes are in use, varying in length from 50 to 20 feet over all, to conform properly to the depth of water at the position of the buoy. The weights of such buoys vary from 1,500 to 350 pounds each.

A special type of buoy, built up of light steel plates welded together by the electric-arc process, has recently been developed as

a substitute for wooden spars, thus obviating costly maintenance expense, especially in congested waterways, where the spars are frequently broken by passing vessels. In addition to the greater visibility obtained by means of their increased diameter, it is also practicable to build these buoys with either can or nun tops, thus improving their distinctiveness and usefulness to mariners.

Iron spar buoys are built up of iron or steel plates in the form of wooden spars, and are particularly valuable where severe ice conditions exist, or where the teredo is unusually active. They are naturally more expensive and heavier to handle, thus restricting their use to special localities. They are made in three classes, in lengths of from 50 to 30 feet over all, weighing from 4,000 to 2,000 pounds, respectively.

Cans and nuns, as already noted, are built of iron or steel plates, the former showing a cylindrical and the latter a conical top, and are the most extensively used of metal buoys. The interior of the buoy is divided into two or more compartments, by bulkheads or diaphragms, to prevent sinking when damaged. Each kind is built in three classes or sizes, and in addition two general types are in use, the ordinary type and the tall type, or channel buoys; the latter being a modern development of a larger and more prominent buoy for use in deeper water. These buoys weigh from 8,300 to 700 pounds each, according to size, and are generally moored by means of a stone or concrete block, or a specially designed hemispherical cast-iron sinker, shackled on a length of chain about two or three times the depth of water in which the buoy is placed. The ordinary type buoys require a cast-iron ballast ball attached directly below the buoy, the mooring chain being shackled in turn to the lower end of the ballast ball; this is necessary to assist the buoy in maintaining an upright position, regardless of tidal or other currents. The ballast ball is not needed with the tall type buoy, which has more stability, due to its greater draft and to a fixed counterweight of cast iron bolted on its lower end. To prevent kinking or twisting of the chain, a swivel is occasionally placed in the mooring chain for all types of larger buoys.

Bell buoys have a hemispherical-shaped hull, built of steel plates, with flat deck, and carry a structural-steel superstructure which supports a bronze bell and usually four iron clappers. The motion of the buoy in the sea causes these clappers to strike the bell, so that the action is entirely automatic. Although the buoy is quite sensitive and responds to even a very slight motion of the waves, the sound may be faint or absent in unusual calms. This type of buoys is especially efficient in harbors or inside waters for marking points where a sound signal is desired. Bell buoys weigh about 6,900 pounds each, complete, and are moored by means of a bridle of chain attached to lugs

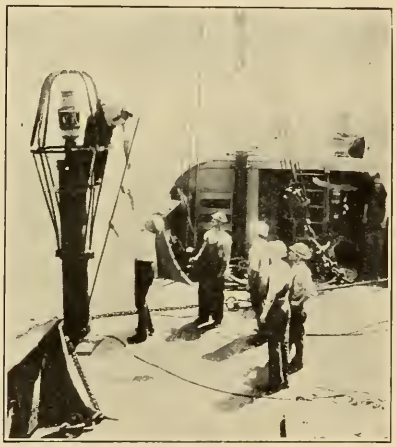
on the opposite sides of the hull near the water line, the main mooring being shackled to the middle and lowermost part of the bridle and extending in the customary scope of chain with a swivel to a heavy cast-iron sinker on the bottom. A large-sized ballast ball is shackled to a mooring eye at the bottom of the buoy, and the whole effect of this arrangement is to assist in the pendular motion necessary for ringing the bell.

When subjected to heavy ice or unusual gales, it has been found occasionally that the ballast ball strikes the under side of the buoy body so violently as to start the riveted seams, thus causing the buoy to fill with water and sink. A recent improvement designed to overcome this condition consists in the attachment of a fixed hollow counterweight of cast iron poured with lead, bolted fast to the lower end of the buoy. This has proved so satisfactory that all new bell buoys have been constructed accordingly and the ballast-ball type will be gradually superseded. Another valuable improvement for use in distinguishing bell buoys by sound, where several are located in the same vicinity, is the chime buoy. In this type the single bell is replaced by four bronze gongs of varying sizes, mounted in order of diameters one above the other on the same spindle, with the smallest gong on top and with four clappers of different lengths, so that each gong is struck by but one clapper. As the sea rocks the buoy, the clappers, striking against their respective gongs, ring out four distinct notes of different pitch. There is, of course, no particular sequence or rhythm to the sounds, but the effect is quite distinctive and somewhat pleasing.

Whistling buoys are built of steel plates, and consist of a pear-shaped body with the smaller end uppermost, with a long open tube on the lower end. This tube extends throughout the length of the buoy, and is closed at the upper end by a headplate on which is mounted a check valve and a whistle on the superstructure of the buoy. The sound is produced by the air in the upper portion of the tube being compressed by the falling of the buoy in the waves, its means of escape being through the whistle. A fresh supply of air is drawn through the check valve as the buoy rises again. Like the bell buoy, the sound is automatic, depending solely on the motion of the waves, and therefore the whistle may be silent when the sea is very smooth. The whistling buoy is most efficient in rough outside waters, where a ground swell exists, and is employed for important points where a sound signal is considered desirable. It is generally moored with a single chain of the proper scope and a heavy iron sinker. The weight of the buoy is about 6,500 pounds. For great depths, where the necessary quantity of chain impedes the flotation of the ordinary size of this buoy, a special and larger size is in use similar to the regular size in design and operation but weighing about 11,000

pounds. Occasionally an additional buoy is shackled to a bight of the mooring chain when the water is unusually deep.

Lighted buoys are a modern invention, having come into use within about the last 40 years, and are considered by mariners generally as among the most valuable of recent developments in coast lighting. The first buoy of this kind was a gas buoy established experimentally by its manufacturers in 1881 near Scotland Lightship, entrance to New York Bay; it was officially taken over by the Lighthouse Service in April, 1884. Electric buoys, operated by a cable from shore, were established in Gedney Channel, New York Bay, in November, 1888, and were discontinued in 1903, after many mishaps, due chiefly to breaking of the cable. The operating expense was high, and in the final year of service these buoys were extinguished through accidents on 120 nights.



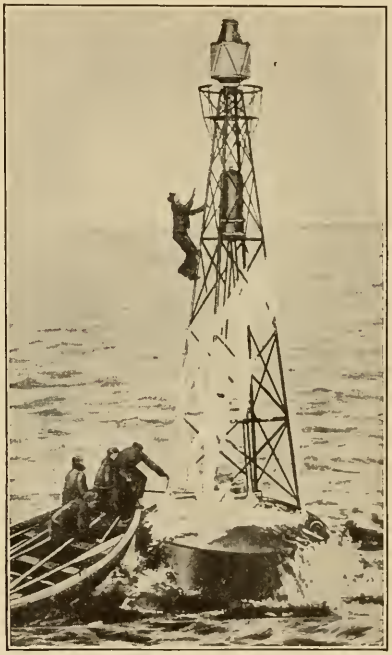
Testing pressure in gas buoy, New York Bay.

All of the lighted buoys now in service use compressed gas, either oil gas or acetylene. Various types of self-generating acetylene buoys have been in use, operating on the carbide-to-water and water-to-carbide principles, but have been abandoned on account of uncertainty of length of run, difficulty of cleaning, and danger of explosion.

In the types now in use the gas, at a pressure of about 12 atmospheres, is contained either directly in the body of the buoy or in tanks fitted into compartments of the body, and is piped to the lantern at the top of the superstructure. If the light is flashing, as is usually the case, a small pilot light burns continuously and ignites the main burner as gas is admitted from the flashing chamber, which is a regulating compartment in the base of the lantern provided with a flexible diaphragm and valves for cutting off and opening the flow of gas at intervals, the operation being due to the pressure of the gas in the reservoirs. The length of the light and dark periods may be adjusted to produce the desired characteristic, such as five seconds light, five seconds dark, etc. Some types burn the gas as an ordinary flat flame, while others make use of an incandescent mantle, which is, however, not wholly satisfactory in rough water on account of breakage.

Gas buoys are usually moored with a bridle attached to a proper scope of chain, including a swivel. The chain is shackled to a concrete or iron sinker or to a mushroom anchor for the larger types on

rough outside stations. They are made in a number of different sizes, weighing from 2,800 to 34,500 pounds each, depending on the importance of the location, and burn continuously by night and day for intervals of a month to a year without recharging. The apparatus is patented by the various makers and has been brought by them to a considerable degree of perfection, so that considering the rough usage to which such buoys are subjected by the elements, gas buoys are generally satisfactory within the limits of reliability to be expected from such aids. They should not, however, be relied upon implicitly, as they may become extinguished or dragged from their proper positions, or the apparatus may be out of order and some time may elapse before the buoy can be reached to repair or relight it. Gas buoys furnish valuable marks for approaching entrances, defining channels, and marking dangers, and at times may obviate the necessity for light vessels or lighthouses on submerged sites, either of which would be many times more expensive. There is a constant demand among mariners for more gas buoys and for buoys with more brilliant lights.



Gas and whistling buoy, entrance to New York Bay.

Many gas buoys are provided with some automatic form of sound-producing device, such as a bell or whistle, and in a few cases have both a whistle and a submarine bell. Such buoys are known as combination buoys, and the fog signals on each operate in the manner heretofore described (see pp. 44 and 54), and are of especial value in fog or thick weather, or in case of accidental extinguishment of the light. In a few cases, gas buoys equipped with a bell struck by means of mechanism operated by compressed carbon dioxide, in the manner described on page 39, have replaced light vessels with great economy and possible application to other stations as improvements are made. The numbers and types of the 8,162 buoys in the Lighthouse Service in commission on June 30, 1922, were as follows:

Unlighted buoys (7,524):	
Wooden spars	5,061
Iron spars, cans, and nuns	2,143
Bell buoys	246
Whistling buoys	74

Lighted buoys (638):	
Gas buoys	417
Gas and bell buoys	145
Gas and whistling buoys	67
Gas, whistling, and submarine bell buoys	9
Total	8,162

16. RIVER LIGHTING.

The lighting of nontidal rivers is limited to those which have been specifically authorized by law; these, however, now embrace nearly all the important streams of the country. In the Lighthouse Service three districts, the thirteenth, fourteenth, and fifteenth, are engaged entirely in the lighting of the Mississippi River and its principal tributaries. The lighting of these streams began in 1874 and has since been continued. The problem presented by these districts differs considerably from that found in the coast and lake districts. As noted in a previous chapter (p. 2), the superintendents in charge of these districts are officers of the Corps of Engineers, United States Army, and are usually those in charge at the same time of the river improvement work of the War Department proceeding in the vicinity.

The lights used are simple in character and are generally known as post lights. In some cases these consist of an ordinary 14-inch hand lantern, inclosed in a square or triangular tin case with plain glazed sides; and in other types a specially designed post lantern, with a 1-inch flat wick and pressed glass lens about 8 inches in diameter, is used inside a small triangular case, with glass on two or three sides as the location requires. A wire screen is fitted to the top of the lantern to prevent the entrance of insects. These lights burn kerosene and, as a rule, are fixed white in character, although some are fitted with red globes or shades.

The channel of these rivers generally follows the concave banks, with crossings where the concavity shifts from one side of the river to the other, and the lights are located so as to show the general shapes of the bends and the positions of the crossings. The lights are usually placed on the banks of the river and the crossings marked by two range lights, one ahead, the other astern. Where the crossing is crooked it is sometimes necessary to have a series of range lights, and during low water some of the lights are placed on sand bars or on small floats or rafts, these latter being known as float lights.

The most complete type of structure on which post lights are placed consists of a post with braces and steps, with the lantern on top. Wings are attached to make a better daymark, and are set in oblique positions with a view to catching the sunlight in various directions and thus assist the pilots in locating it. The wings are perforated to diminish wind action, and the stations are further

designated by numbers placed conspicuously above them. It is necessary to shift the position of many of these lights from time to time, on account of changes in the channel, caving banks, and other reasons. For this reason many of these structures are of a more temporary character than the type just described; in some localities, notably on portions of the Ohio River and its tributaries, with comparatively high and stable banks, the light may even be attached to a tree.

Where the channel is narrow or crooked, or the ends of wing dams are to be marked, buoys have been found desirable, and a special type has been developed. It has been found that the buoy best adapted to fulfill the conditions peculiar to these waters is one having

Mississippi River post light.

but a slight reserve buoyancy, in order that drift and other floating objects coming in contact with it will pass over the buoy, submerging but not displacing it. One type in use is a built-up spar consisting of a central barrel-shaped section fitted with galvanized sheet-iron cones or hoods at each end. A slide for a hand lantern is provided at the upper end, and the buoy is moored by a light wire cable attached to the lower end, with an iron weight for a sinker. Another type is composed of two galvanized sheet-iron cones placed base to base; the upper portion is a right cone, but the lower is oblique in order that the buoy may not spin in the current and untwist the light wire anchor cable.

The river lights are attended by persons living in the vicinity, known as lamplighters, and in some cases a group of several lights may be in charge of the same person when they may be conveniently

cared for in that manner. These lamplighters are not required to devote their entire time to the service, as in the case of regularly appointed keepers. The supplies for the lights are delivered by the lighthouse tender or Engineer Department vessels, and such vessels also patrol the river and make the changes in location as required. Captains and pilots of river steamers are supplied with franked postal cards on which they are requested to report to the superintendent's office whenever a light is found not burning properly.

Of the 3,233 aids in commission on June 30, 1922, classed as minor lights and float lights, 1,858, or about 58 per cent, were in the three river districts. In the remaining districts the systems of river lighting are naturally not so extensive, although the aggregate number of these lights in such rivers as the Connecticut, Hudson, Delaware, and St. Johns on the Atlantic coast, and the Columbia and Willamette on the Pacific coast, together with many other shorter streams, constitute no small part of the activities of many districts. A specially designed post lantern is manufactured by the Lighthouse Service for this work in the coast districts. It is constructed of brass, with an outside protecting cage, and contains a pressed glass lens of 200 millimeters (approximately 8 inches) diameter, with a 1-inch flat wick burner, using kerosene. Great pains were taken to make the lantern wind proof, and at the same time to provide proper ventilation and a reasonably bright light. The type now in use has been found satisfactory, even in gales of considerable violence. The lights are carried on various types of simple structures ranging from single posts on shore to pile clusters for use in the water. They are attended by light attendants, as in the case of the river districts, or sometimes by the keepers of some adjacent light station.

17. LIGHTHOUSE DEPOTS.

An important feature of lighthouse work consists of the lighthouse depot, which is used as a base of supplies and repairs and a base station for vessels. There are 40 such depots in the various districts, as given in the following list. The principal depot of the district is indicated by the larger type.

First district:
- Bear Island, Me.
- LITTLE DIAMOND ISLAND, ME.

Second district:
- CHELSEA, BOSTON, MASS.
- Woods Hole, Mass.

Third district:
- Juniper Island, Vt.
- Goat Island, R. I.
- New London, Conn.

Third district—Continued.
- STATEN ISLAND, N. Y.
- Atlantic City, N. J.
- Tucker Beach, N. J.

Fourth district:
- EDGEMOOR, DEL.
- Lewes, Del.

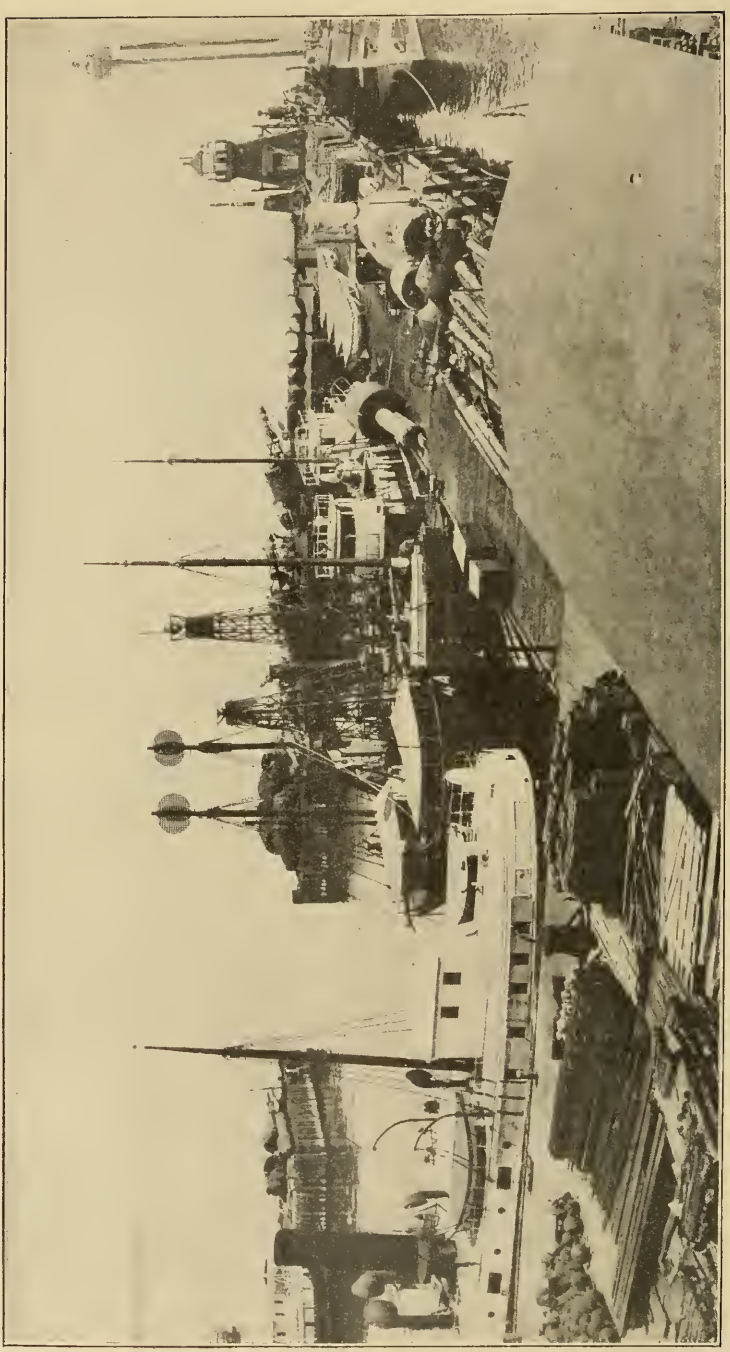
Fifth district:
- Annapolis, Md.
- Lazaretto Point, Md.

Fifth district—Continued.
Point Lookout, Md.
PORTSMOUTH, VA.
Washington Wharf, D. C.
Washington, North Carolina.
Sixth district:
CHARLESTON, S. C.
Seventh district:
Egmont Key, Fla.
KEY WEST, FLA.
Eighth district:
Fort San Jacinto, Galveston, Tex.
Mobile, Ala.
PORT EADS, LA.
Ninth district:
SAN JUAN, P. R.
Tenth district:
BUFFALO, N. Y.
Erie, Pa.
Maumee Bay, Ohio.
Tenth district—Continued.
Rock Island, N. Y.
Sandusky Bay (Cedar Point), Ohio.
Eleventh district:
DETROIT, MICH.
Minnesota Point, Minn.
St. Marys River, Mich.
Twelfth district:
Charlevoix, Mich.
MILWAUKEE, WIS.
Sixteenth district:
KETCHIKAN, ALASKA.
Seventeenth district:
Ediz Hook, Wash.
TONGUE POINT, OREG.
Eighteenth district:
GOAT ISLAND, CALIF.
Nineteenth district:
HONOLULU, HAWAII.

To be of the greatest efficiency, depots should be central in location with reference to the district, adjacent to important mercantile centers for facilitating purchases, and easily accessible by truck, rail, and water. Many of the depots in the service were originally intended only for the storage of relief or spare buoys and were often located on islands or other remote places, hence not fulfilling the ideal conditions just outlined. Constant effort is made, however, to improve such conditions as available funds permit; and, as an instance, the case of the second and sixth districts may be cited, in which new depots on the mainland have been provided in place of the old depots on islands in the harbors.

The principal features of a depot are a dock and a storehouse. To these, other structures, such as isolated oil houses for inflammable articles, lamp, machine, carpenter and blacksmith shops, cement houses, buoy, lumber, and coal sheds, offices, keepers' dwellings, derricks and other lifting gear, tramways, and similar appurtenances, are added as may be required by the extent and character of the work in the respective districts.

The principal work at a lighthouse depot consists in caring for the articles in stock and the filling of approved requisitions for the use of such articles in the work of the service; also in the cleaning, painting, and overhauling of the buoys and appendages, as well as in the manufacture and trial of illuminating and fog-signal apparatus, building of launches and small boats, framing of structures preparatory to transfer to sites, etc. Tools and equipment for working parties on stations and vessels are also stored at the depots when not in active use. Damaged and worn-out articles are brought to the depot



Wharves at General Lighthouse Depot, Staten Island, N. Y.

from the vessels and stations for repair or survey and condemnation, as their condition warrants. The depots are headquarters for the vessels of the Lighthouse Service, both for the routine work of the tenders and for examination and sometimes repair of tenders and light vessels.

The general depot at Staten Island, N. Y., which is much larger than the customary district depot, has already been mentioned on page 2. This depot fills the double purpose of being headquarters for the third district, as well as a central supply station, repair shop, and purchasing agency for the entire service. Proposals for annual supplies are issued from this depot for articles to be delivered on contract. These are then issued to other districts on the basis of requisitions made by the superintendents. The various shops at this depot are employed chiefly in the manufacture and repair of special apparatus used by the service, much of which can not be obtained from regular dealers at an economical price, and a considerable amount of repair work to vessels is also performed. A small laboratory is also maintained for the analysis and testing of articles used in the service, and a large amount of experimental work is done on various light and sound producing devices, either submitted by the makers for test or designed by the technical force of the service. About 200 persons are engaged at this depot, this number including also those who are directly concerned in the work of the third district.

18. LIGHT VESSELS.

The Lighthouse Service maintains light vessels on 49 stations and has for this purpose 61 light vessels, of which 12 are relief vessels, all figures being those of June 30, 1922. They are generally employed for marking dangers at sea, approaches or entrances to harbors, or important points in the courses of vessels, where a lighthouse would not be feasible or economical, and are of particular value in providing both a light and a fog signal which may be approached close-to, thus enabling mariners to fix their position at sea with reasonable certainty. In this respect light vessels are superior to lighthouses, as in the case of the latter, in the majority of instances, due allowance must be made for a safe distance in passing. A valuable secondary advantage is the fact that light vessels may be shifted to meet varying conditions of traffic, such as changes in shoals or channels, use of deeper draft vessels, and similar contingencies.

The first light vessel established in this service was in 1820 off Craney Island, Elizabeth River, Chesapeake Bay, Va. The first outside vessel was placed 7 miles off Sandy Hook, N. J., in 1823. The idea of lightboats, as they were then called, became popular, and by 1839 there were 30 in service, most of them being small craft in inside waters. The largest vessel was that on the Sandy Hook station, which had a tonnage of 230.

By the year 1852, when the Lighthouse Board was established, there were 38 light vessels in service, of which number 26 were in bays or sounds. The maximum number of men employed on each was 10 for the most exposed stations, varying down to 4 for those least exposed. The type of vessel used at that time was evidently not wholly suitable for the purpose, as there were often complaints that the vessels were frequently blown from their moorings, and that the expense of maintenance and repair was excessive, considering also the comparative feebleness of the lights.

The early activities of the board were directed toward the replacement of many inside light vessels by lighthouses, screw-pile foundations being used extensively for the latter; and more careful attention was given to the design of vessels suitable for exposed outside stations.

Diamond Shoal Light Vessel, *No. 105*, N. C.

Wooden construction was the rule up to the year 1882, when the first iron light vessel, *No. 44*, was built, for station on the seacoast of New Jersey. About the same time several vessels of the composite type, with steel frames and wooden sheathing, were constructed; but the modern tendency has been toward all-steel construction. Another practical feature of design which has greatly increased the efficiency of light vessels is the use of propelling machinery, thus enabling them to proceed to and from their stations under their own power and to assist them in maintaining their positions in heavy weather. The first light vessels in this service so equipped were *No. 55*, *No. 56*, and *No. 57*, built in 1891 for service on the Great Lakes.

The question of the proper form of the hull of a light vessel presents many interesting and complex problems in naval architecture. Steadiness and ease of motion are the chief requirements for the

general efficiency of the light, as well as for the comfort of those on board. In order to obtain this desired result recent practice is to design the hull so that the wedges of immersion and emersion in tranverse rolling are approximately equal, thus avoiding the usual impulse of excess buoyancy, while the metacentric height has been reduced to a minimum of 12 inches. The lines are quite full fore and aft, thus increasing the displacement rapidly as the vessel pitches into a sea, while bilge keels and ballast are both employed when necessary to insure steadiness; the whole idea being to make use of all elements tending to control both rolling and pitching. The scantling throughout is much heavier than ordinarily required in vessels of similar size, for the double purpose of providing great excess strength as well as guarding against the injurious effects of corrosion. The most recent vessels are constructed almost entirely of steel throughout; water-tight bulkheads are provided below the main deck in ample numbers, to increase the stiffness and safety of the vessels, and especial care is taken in the design of the mooring gear, which consists essentially of a large central hawse pipe, protected by a water-tight breakwater, with chain compressors, springs, and a powerful double windlass, usually operated by steam. The main mooring chain is, as a rule, composed of links made of the best double-refined wrought iron, $1\frac{5}{8}$ inches in diameter, with cast-iron studs, in accordance with rigid specifications, and tested to a proof strain of over 80,000 pounds. The chain is carefully inspected during all stages of manufacture, and is made up into cables of suitable lengths, with the necessary shackles and swivels. Such chain weighs approximately 160 pounds per fathom (6 feet), so that the entire weight of a standard 120 fathoms cable is about 9 tons. Specially designed cast-steel mushroom anchors, in weights up to 7,500 pounds, are used for mooring to the bottom, and in the case of vessels in severely exposed positions in deep water a spherical mooring buoy designed to resist collapsing pressures is shackled into the submerged portion of the chain, tending to carry a portion of the weight and forming a double catenary which is of value in avoiding severe strains on the vessel as it surges in rough weather.

The standard type of propelling machinery now in use consists of one vertical, inverted, direct-acting, surface-condensing, fore-and-aft compound engine of a size suitable to the dimensions and duty of the vessel, driving a cast-iron propeller and supplied with steam from two Scotch boilers; the engine and boiler space being located amidships. Some of the more recent vessels are provided with internal-combustion kerosene engines of the semi-Diesel type, which are more economical than steam, particularly in avoiding the expense and difficulty due to keeping light vessels supplied with coal and fresh water, as well as avoiding the deterioration of boilers. Engines

of the full Diesel type are to be installed on some of the new light vessels now under construction.

Much progress has been made in the interior arrangements of light vessels, particularly in the way of accommodations for the crew. The early lightships were single-deck vessels, with the quarters generally below the water line. A forecastle head was then added, which was gradually extended in height and length, until an entire spar deck had been developed. The latest vessels are flush-decked throughout, with all quarters on the main deck well above the water line, thereby also conducing greatly to the stability and safety of the vessel when seas are shipped in heavy weather. The details of the interior of the present types of light vessels are also worked out

Nantucket Shoal Light Vessel, *No. 85*, Mass.

with care; comfortable staterooms and berths are provided, the vessels are steam heated throughout, sanitary plumbing systems with baths, toilets and drainage attachments are fitted, and in some cases electric lights are also installed.

The complement of a first-class light vessel is generally 4 or 5 officers and 10 or 11 men, which is varied in the case of smaller and less exposed vessels as conditions justify, down to a minimum of 4 men all told, for the smallest size of inside lightships. Liberal provision is made for shore liberty, as will be taken up in greater detail in another chapter. (See p. 91.)

The illuminating and fog-signal apparatus on board light vessels has undergone many improvements. Ordinary ship's lanterns served for lights on the early vessels, while the fog signal was a hand

bell or horn. When reflector lights were introduced, each light was composed of eight lamps with reflectors 12 inches in diameter, each hung in gimbals secured to a ring which encircled the mast, the whole apparatus being inclosed in a lantern with large panes of glass to protect the light from the wind. When not in use the lanterns were lowered and kept in a small house with a hinged roof at the base of the mast, and were lighted and hoisted to the masthead at night. This arrangement is still in use on some of the older vessels. Sometimes such lights are shown on two masts. White lights are commonly employed, red being used occasionally when necessary to give distinctiveness.

The next development was the substitution of a group of three lens lanterns instead of the reflectors, placed in gimbals on a ring around the mast and operated similarly to the reflector lanterns. In recent years steel masts have been installed. Each mast is surmounted by a gallery and rail with a lens lantern secured on top of the masthead. The illuminant may be acetylene or electricity, with a definite flashing characteristic. In the case of vessels with two masts, both are equipped with lanterns, one being used regularly and the other kept as a stand-by in case of accident to the first.

Corresponding improvements have also been made in fog signals on board light vessels, but these installations are essentially the same as have already been described. (See p. 39.) The 12-inch steam whistle is still used on many light vessels as the main signal, and a pneumatically operated submarine bell is frequently added as an auxiliary. The radio fog signal, described on page 46, has been added in some cases. These installations have been found of considerable value, and it is expected that the number will be increased. Experiments with a new type of submarine electrically operated oscillator are now in progress on one vessel.

All the important outside light vessels on the Atlantic, Gulf, and Pacific coasts, 20 in all, and also 10 relief ships, are equipped with radio, operated by the Lighthouse Service.

Light vessels are distinguishable in the daytime by their unusual shape and rig, including generally some form of gallery at the mastheads, and by their characteristic painting and lettering. The hull is often painted red or straw color, although many other colors or combinations of color are employed to make adjacent vessels as different as possible, and a short station name is painted on the sides of the vessel in the largest-size letters practicable. From 1867 to 1913 light vessels also exhibited a number, painted at first on the stern and afterwards on each bow and quarter. The numbers are still retained as part of the official designation of the vessel for service purposes, but are no longer prominently displayed. Light vessels on seacoast stations are also assigned international code-signal letter

flags, identifying the geographical locality, which they display to passing vessels when it is necessary to warn them. Radio call letters are also assigned to light vessels provided with such apparatus.

Light vessels are brought in from station at regular intervals for docking, overhauling, and repair, and during the interim a relief light vessel is placed on the station. Care is taken when practicable to have the relief ships so equipped that they can show the identical light of the station ship at night, and during fog the identical fog signal; also sounding the same code number on the submarine bell, and displaying the international signal flags described above of the vessel relieved. Relief vessels are painted red, with the middle third of the hull white, bearing thereon the word "Relief" in large black

Relief Light Vessel, *No. 103*, Great Lakes.

letters. In special cases where the relief vessel occupies several near-by stations in rotation, the station name is painted on the sides when a change is made.

To avoid confusion when light vessels are off their stations while proceeding to or from port, or during stress of weather, they fly under such circumstances the signal letters QE, a square yellow flag over a triangular flag with vertical bands of red, white, and blue, meaning in the international code "Lightship is not at anchor on her station."

The average life of a light vessel is estimated at 30 years, and in order to maintain the present number of light vessels it is necessary to build on an average two new light vessels annually.

The principal facts relating to light vessels in commission during the fiscal year 1922 are shown in the table on the following page. The vessels are arranged geographically, and the outside more exposed stations are separated from those in more protected localities.

LIGHT VESSELS IN COMMISSION DURING THE FISCAL YEAR 1922.

Number.	Station.	District.	Tonnage or displacement.	When built.	Material of hull.	Dimensions. Length over all.	Dimensions. Breadth.	Dimensions. Depth.	Indicated horsepower (self-propelling).	Regular complement. Officers.	Regular complement. Crew.	International code signal letters of station.	Radio call letters.	Light.	Fog signal.
	OUTSIDE COAST STATIONS.					*Ft. in.*	*Ft. in.*	*Ft. in.*							
74	Portland, Me	1	[1] 495	1902	Wood.	129 9	28 6	13 0	380	4	8	BALV	NAMS	Acetylene, occulting white	Steam chime whistle, submarine bell.
54	Boston, Mass	2	[1] 375	1892	Steel	118 10	26 0	14 0	150	4	7	BAGY	NADX	Acetylene, flashing white	Air siren, submarine bell.
73	Pollock Rip Slue, Mass	2	[1] 693	1901	...do...	123 9	28 6	14 9	400	4	8	BAEK	NAFT	Oil, fixed white and fixed red	Steam chime whistle, submarine bell.
66	Great Round Shoal, Mass	2	[1] 590	1896	...do...	123 0	28 6	13 0	350	4	8	BAFK	NABG	Acetylene, occulting white	Do.
85	Nantucket Shoals, Mass. ⊙	2	[1] 683	1907	...do...	135 5	29 0	14 9	380	5	10	BAFE	NLA	Electric incandescent, white.	Do.
68	Fire Island, N. Y. ⊙	3	[1] 590	1897	Comp.	122 10	28 6	14 6	350	5	10	AZMS	NLS	Acetylene, white	Steam chime whistle, submarine bell, radio.
87	Ambrose Channel, N. Y. ⊙	3	[1] 683	1907	Steel	135 5	29 0	14 9	325	5	10	AZMY	NALS	Electric incandescent, white.	Do.
11	Scotland, N. J	3	320	1853	Wood.	[2] 104 0	24 8	11 6	Sail.	2	5	AZNB	NARV	Acetylene, occulting white and fixed red.	Bell, single stroke.
44	Northeast End, N. J. ⊙	3	197	1882	Iron	115 6	25 0	10 6	Sail.	4	7	AZHQ	NARS	Acetylene, occulting white	Steam siren, submarine bell.
79	Five-Fathom Bank, N. J. ⊙	3	[1] 668	1904	Steel	129 0	28 6	14 9	325	4	8	AZHP	NADV	....do	Steam chime whistle, submarine bell.
69	Overfalls, Del	3	[1] 590	1897	Comp.	122 10	29 6	14 6	350	4	10	AZHT	NAKT	....do	Do.
52	Fenwick Island Shoal, Del. ⊙	5	[1] 375	1892	Iron	118 10	26 6	14 4	180	4	9	AZHJ	NAJS	Acetylene, triple flashing white.	Air siren, submarine bell.
91	Winter-Quarter Shoal, Va. ⊙	5	[1] 685	1908	Steel	135 5	29 0	14 9	400	4	10	AZHD	NADT	Acetylene, double flashing white.	Steam chime whistle, submarine bell.
101	Cape Charles, Va. ⊙	5	[1] 360	1916	...do...	101 10	25 0	13 2	200	4	7	AZGP	NAJV	Acetylene, occulting white	Air siren, submarine bell.
105	Diamond Shoals, N. C. ⊙	5	[1] 825	1922	...do...	146 3	30 0	14 9	475	5	10	AYTB	NITQ	....do	Steam chime whistle, submarine bell, radio.
80	Cape Lookout Shoals, N. C.	5	[1] 668	1904	...do...	129 0	28 6	14 9	350	4	10	AYQT	NABV	Acetylene, triple flashing white.	Do.
94	Frying-Pan Shoals, N. C. ⊙	6	[1] 670	1911	...do...	135 6	29 0	14 9	363	5	10	AYQR	NLC	Acetylene, group flashing white.	Do.
34	Charleston, S. C	6	[1] 218	1864	Wood.	101 10	23 0	10 0	Sail.	2	7	AYOQ	NAZJ	Acetylene, double flashing white.	Air diaphone.
1	Savannah, Ga	6	[1] 228	1855	...do...	[2] 103 0	21 0	13 0	Sail.	2	8	AYNL	NART	Oil, fixed white and fixed red	Air siren, submarine bell.
84	Brunswick, Ga. ⊙	6	[1] 683	1907	Steel	135 5	29 0	14 9	325	5	10	AYKV	NABX	Acetylene, triple flashing white.	Steam whistle, submarine bell.

⊙ = Equipped for radio communication.

[1] Displacement.

[2] Length between perpendiculars.

LIGHT VESSELS IN COMMISSION DURING THE FISCAL YEAR 1922—Continued.

Number.	Station.	District.	Tonnage or displacement.	When built.	Material of hull.	Dimensions. Length over all.	Dimensions. Breadth.	Dimensions. Depth.	Indicated horsepower (self-propelling).	Regular complement. Officers.	Regular complement. Crew.	International code signal letters of station.	Radio call letters.	Light.	Fog signal.
	OUTSIDE COAST STATIONS—Continued.					*Ft. in.*	*Ft. in.*	*Ft. in.*							
102	South Pass, Fla	8	[1] 360	1916	Steel	101 10	25 0	13 2	200	4	7	AWYQ	NAGT	I. O. V. double flashing white.	Air siren, submarine bell.
81	Heald Bank, Tex. ⊙	8	[1] 668	1904	...do...	129 0	28 6	14 9	325	4	8	AWVH	NLP	Oil, 2 fixed white	Steam whistle, submarine bell.
93	Swiftsure Bank, Wash. ⊙	17	[1] 685	1908	...do...	135 5	29 0	14 9	400	5	11	ATXJ	NABT	Oil, fixed white and fixed red	Do.
67	Umatilla Reef, Wash. ⊙	17	450	1897	Comp.	122 7	28 6	13 0	200	4	11	AUCK	NACV	Oil, 2 fixed white	Do.
88	Columbia River, Oreg. ⊙	17	[1] 683	1907	Steel	135 5	29 0	14 9	325	5	11	AUCY	NAJT	....do	Do.
83	Blunts Reef, Calif. ⊙	18	[1] 668	1904	...do...	129 0	28 6	14 9	380	4	11	AUFL	NACT	....do	Do.
70	San Francisco, Calif. ⊙	18	[1] 590	1897	Comp.	122 10	28 6	14 6	349	4	11	AUGE	NAKS	Electric, incandescent, flashing white	Steam whistle, submarine bell, radio.
	Relief vessels.														
86	Relief	2	[1] 683	1907	Steel	135 5	29 0	14 9	380	4	6	.....	NAJJ	Oil	Steam-chime whistle, submarine bell.
90	....do ⊙	2	[1] 685	1908	...do...	135 5	29 6	14 9	380	4	9	.....	N1TS	Oil and electric, incandescent	Do.
78	....do. ⊙	3	[1] 668	1904	...do...	129 0	28 6	14 9	325	5	8	.....	N1TR	Acetylene	Steam whistle, steam siren, aerial bell, submarine bell, radio.
49	....do	5	[1] 470	1890	Comp.	120 10	27 0	14 0	Sail.	4	6	.....	NESC	....do	Air siren, submarine bell.
72	....do ⊙	5	[1] 693	1900	Steel	123 6	28 6	14 0	350	5	10	.....	.....	Electric, incandescent	Steam chime whistle, submarine bell.
53	....do ⊙	6	[1] 375	1892	Iron	119 0	26 6	14 0	135	5	9	.....	NAJC	Acetylene	Steam whistle, submarine bell.
92	....do ⊙	17	[1] 685	1908	Steel	135 5	29 0	14 9	400	3	5	.....	NADB	Oil	Do.
76	....do ⊙	18	[1] 578	1904	...do...	129 6	28 8	14 4	380	2	5	.....	NACD	....do	Do.
	SOUND AND BAY STATIONS.														
5	Stone Horse Shoal, Mass.	2	104	1865	Wood.	81 6	21 6	9 0	Sail.	2	7	BAEP	NANT	Acetylene, occulting white	Air whistle.
3	Handkerchief, Mass.	2	140	1852	...do...	69 4	23 0	10 0	Sail.	2	5	BAEM	NAQS	Acetylene, flashing white	Bell.
20	Cross Rip, Mass.	2	165	1867	...do...	81 6	21 6	10 0	Sail.	2	5	BAES	NAQB	....do	Do.
9	Hedge Fence, Mass.	2	104	1857	...do...	81 2	28 2	9 6	Sail.	2	7	BAET	.....	Oil, 2 fixed white	Air whistle, submarine bell.
41	Vineyard Sound, Mass.	2	387	1876	...do...	120 6	26 9	11 0	Sail.	3	6	BACI	NACX	Acetylene, flashing white	Air siren, submarine bell.
42	Hen and Chickens, Mass.	2	410	1877	...do...	121 7	26 6	10 6	Sail.	3	7	AZXT	NAPP	Oil, fixed white	Air whistle.

39	Brenton Reef, R. I	3	387	1875	...do...	119 6	26 9	13 0	Sail.	4	6	AZNK	NASB	Acetylene, occulting white	Air whistle, submarine bell.
23	Ram Island Reef, Conn	3	186	1857	...do...	94 2	24 0	9 0	Sail.	2	5	AZUB		...do	Bell.
13	Bartlett Reef, Conn	3	155	1854	...do...	79 8	21 8	10 4	Sail.	4	6	AZTP		...do	Air whistle.
48	Cornfield Point, Conn. ⊙	3	[1] 470	1891	Comp.	120 10	27 8	12 0	Sail.	4	6	AZTO	NASC	Acetylene, occulting white, and oil, fixed red.	Air siren, submarine bell.
	Relief vessels.														
4	Relief	2	104	1855	Wood.	77 0	20 0	10 0	Sail.	1	0		NAZV	Oil	Bell or horn.
16	...do	3	250	1854	...do...	103 6	22 6	11 0	Sail.	2	3		NASK	Acetylene	Air siren or whistle, submarine bell.
	GREAT LAKES STATIONS.														
75	Lake St. Clair, Mich	11	160	1902	Steel.	83 9	24 0	9 6	Sail.	2	2			Acetylene, flashing white	Bell, single stroke.
96	Lake Huron, Mich	11	[1] 170	1914	...do...	101 0	23 6	11 5	None.	3	4			Electric incandescent, double flashing white.	Air siren, submarine bell.
99	Poe Reef, Mich	11	[1] 215	1920	...do...	91 8	22 0	10 7	125	4	3			Acetylene, double flashing white.	Steam whistle.
89	Martin Reef, Mich	11	[1] 205	1968	...do...	88 3	21 0	10 0	90	4	3			Oil, fixed white	Steam whistle, submarine bell.
98	Lansing Shoal, Mich	12	[1] 195	1915	...do...	101 0	23 6	11 5	100	4	2			Electric incandescent, flashing white.	Air siren, submarine bell.
57	Grays Reef, Mich	12	130	1891	Wood.	102 8	20 0	12 6	100	4	2			Oil, fixed white	Steam whistle, submarine bell.
56	North Manitou Shoal, Mich.	12	130	1891	...do...	102 8	20 0	12 6	100	4	2			...do	Do.
95	Milwaukee, Wis	12	[1] 368	1912	Steel.	108 5	23 0	11 6	200	4	5			Electric incandescent, quadruple occulting white.	Steam chime whistle.
60	Eleven-Foot Shoal, Mich	12	[1] 160	1893	Wood.	87 2	21 6	10 0	Sail.	3	3			Oil, fixed white	Steam whistle, submarine bell.
77	Peshtigo Reef, Wis	12	[1] 155	1906	Steel.	75 0	21 6	9 3	Sail.	2	3			...do	Air chime whistle.
	Relief vessels.														
82	Relief	11	[1] 209	1912	...do...	95 2	21 0	10 0	90	4	3			Acetylene	Steam whistle, submarine bell.
103	...do	12	[1] 310	1920	...do...	96 5	24 0	11 9	175	4	5			...do	Do.

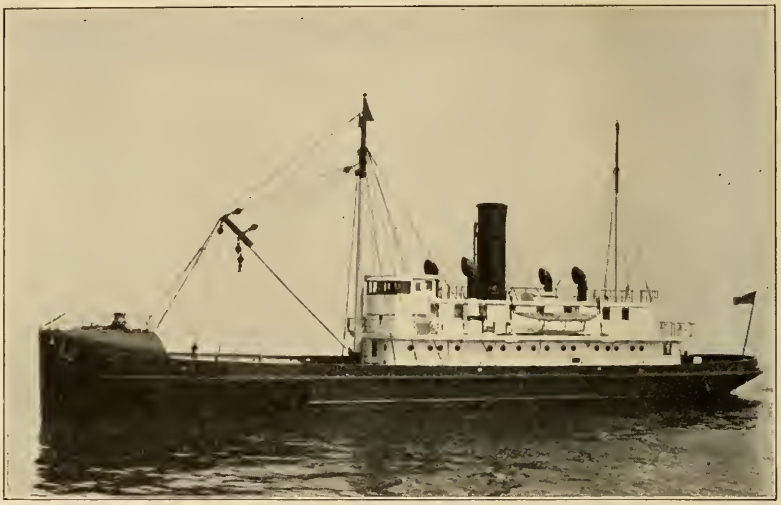
⊙=Equipped for radio communication.

[1] Displacement.

19. LIGHTHOUSE TENDERS.

The work of these vessels is to attend to the buoyage, to supply the light vessels and isolated light stations both with the ordinary articles for maintenance and materials for construction or repair, and also for inspection purposes when necessary. The 56 vessels which were in commission during the year ended June 30, 1922, steamed a total of about 481,000 nautical miles in the performance of their duties.

The original tenders were sailing vessels and the first in use was the former revenue cutter *Rush*, transferred to the Lighthouse Service in May, 1840, and thereafter used in New York Bay and vicinity; prior to that time and for a considerable period thereafter much of the buoy work and other duty now devolving on tenders



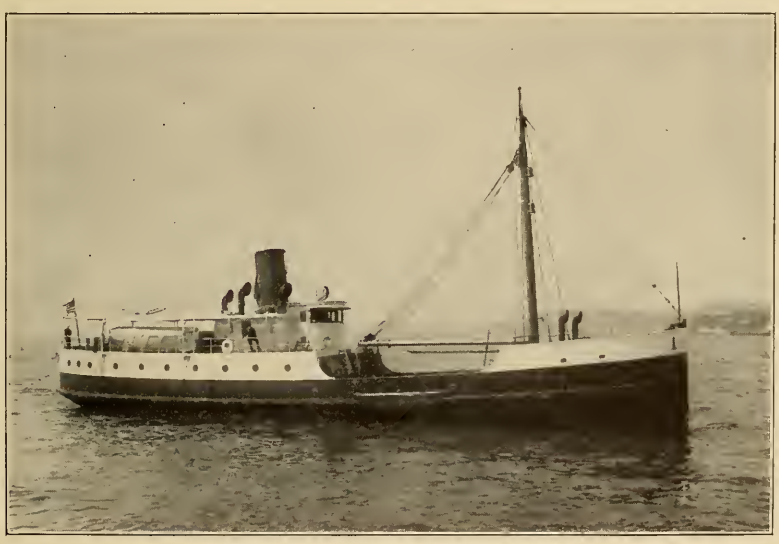
Lighthouse tender *Spruce*, third district.

was performed by contract. Beginning about 1852, a number of sailing tenders were purchased or built. The first steam tender was the *Shubrick*, built at the Philadelphia navy yard in 1857 and first used on the Pacific coast in 1858. In 1865 six small steamers, used in the Civil War, were transferred to the Lighthouse Service from the Navy Department for service on the Atlantic coast, and these replaced a number of the sailing vessels. The early steam tenders were side-wheelers, and frequently carried sail as well.

The first screw-propelled tender was the former *Iris*, purchased in 1865. With the exception of the stern-wheel tenders in the river districts, and one side-wheel vessel, all of the tenders now in service are screw vessels. The old sailing tenders were disposed of, and by 1882 only two remained, the *Pharos* and the *Mignonette*, both schooners. The latter was lost in a hurricane off the Texas coast in

1887, while the *Pharos* was in service as late as 1908, when she was condemned and sold.

The essential features of a lighthouse tender, in which it differs from the ordinary vessel of similar size, are the low forward deck and the buoy-handling gear, whereby the foremast is rigged as a derrick, with a boom and falls for reaching over the side. The construction of the hull, the framing of the deck and all parts of the superstructure, also all mechanical appliances, are designed with a large reserve of strength, and are made as simple and sturdy as possible. As these vessels are frequently required to take and keep the sea even in the face of the most violent storms, a high degree of seaworthiness is essential; and as the nature of their duty requires them to be handled



Lighthouse tender *Rose*, seventeenth district.

around shoals, rocks, and other obstructions in the placing and relief of buoys, their economic maximum draft is proportionally limited, and unusually strong hulls are required to prevent damage from accidental grounding which such work frequently entails.

It is the policy of the service in the design of lighthouse tenders to plan working boats as effective as possible for placing and tending buoys and for other lighthouse duties, and to provide suitable and sanitary quarters for the officers and crews of the vessels. As opportunity offers in connection with the overhaul of older vessels improvements along these lines are effected.

As the average life of a lighthouse tender is estimated at 25 years, it is necessary on an average to build from one to two new tenders a year in order to maintain the present number of vessels in service.

To provide for frequent overhaul, cleaning, and painting of the underwater body, it is customary to dock tenders in exclusively salt-water districts every six months; in districts having a reasonable amount of or all fresh water, once a year is deemed sufficient. A standard style of painting is prescribed, using red lead and approved antifouling paints for the underwater body, black for the exposed outside of the hull and funnel, and white for the topsides and deck houses. White is also given the preference for the larger portion of the interior painting, while the lower deck is painted metallic brown and the upper deck light lead.

Since 1867 it has been the custom to give botanical names to tenders, generally of some plant, flower, or tree indigenous to the district when they are assigned. The name appears on the stern; brass miniature lighthouses are also fitted on each side of the bow.

The typical arrangements of a number of tenders are along the following general lines, although in many instances variations have been made. The anchor windlass is forward on the main deck; this is often protected by a forecastle head. Below this the chain lockers, tanks, and crew's quarters are located. The open portion of the main deck is devoted to space for carrying and handling buoys; a large hatch gives access to the fore hold, which is the principal freight-carrying space. The foremast is fitted with a boom, falls, and lifting gear as a derrick for handling buoys and heavy articles. The hoisting engine for the derrick is sometimes on the main deck, just aft of the foremast, or in the hold directly below, and operated from the deck by levers. The officers' quarters, wardroom, galley, and entrances to the upper engine room and drum room are usually on the main deck, the gangways of which are as a rule inclosed. There is generally an open space aft with towing bitts and a hawser rack. The amidships portion of the hold is given over to the engine, boiler, and bunker space, while the after space contains petty officers' quarters, ship's stores, and tanks.

The upper or spar deck generally extends from just abaft the foremast to the stern; here may be found the wheelhouse and master's quarters, the small boats, generally three in number, a launch, a whaleboat or cutter, and a dinghy, and quarters for the superintendent or other official passengers. The mainmast is used for the display of the customary range light, flags, and for the support of the antenna yard when the vessel is fitted with radio. At the present time nearly all tenders engaged in outside work are so equipped, and these installations have been found valuable in increasing the efficiency of the work and preventing unnecessary straining for orders and other information.

In addition to the national ensign, which is displayed at the flagstaff while under way in daylight, tenders may fly the Lighthouse

Service flag at the foremast head. This flag was first used in 1869, and is triangular in shape, with a red border, and bears a blue lighthouse on a white field. While working on buoys in channels or other frequented waters, tenders may display a red flag and a black ball at the foremast head, as a warning to other vessels to slow down in passing.

The largest tender of the service is the *Cedar*, stationed in Alaskan waters. This vessel is 200 feet over all, 36 feet molded beam, and of approximately 1,800 tons displacement at 13 feet draft. The smallest regular tender is the *Poinsettia*, a gasoline-propelled vessel

Lighthouse tender *Cedar*, sixteenth district.

about 50 feet long, 16 feet beam, and 2 feet 9 inches draft. In addition to these vessels, a fleet of approximately 1,730 small boats is also maintained by the service, attached to vessels, stations, and depots, of which about 375 are provided with motors. These boats are all designated by numbers, except a few larger launches which are given botanical names to conform to the general practice of the service.

General information concerning tenders in commission during the fiscal year 1922 will be found in the table on the following page. The vessels are arranged geographically, and their usual duty is also indicated, although this may be changed as required by emergencies.

TENDERS OF LIGHTHOUSE SERVICE IN COMMISSION DURING THE FISCAL YEAR 1922.

Name.	District.	Displacement. Light.	Displacement. Loaded.	When built.	Description.	Material of hull.	Dimensions. Length over all.	Dimensions. Breadth.	Dimensions. Depth.	Mean draft. Light.	Mean draft. Loaded.	Indicated horse-power.	Regular complement. Officers.	Regular complement. Crew.	Signal letters.	Radio call letters.	Home port.
SEAGOING.		Tons.	Tons.				Feet.	Feet.	Feet.	Ft. in.	Ft. in.						
Hibiscus	1	818	1,081	1908	Steamer, twin screw	Steel	190	30	16	11 0	13 3	1,000	7	27	GVRF	NAKN	Portland, Me.
Anemone	2	818	1,053	1908	do	do	190	30	16	11 0	13 0	1,000	7	26	GVRH	NABP	Woods Hole, Mass.
Tulip	3	774	1,142	1908	do	do	190	30	16	10 7	13 9	1,000	7	27	GVRC	NXX	Staten Island, N. Y.
Spruce	3	930	1,070	1919	do	do	172	32	17	9 9	10 9	1,040	4	24	GVLS	NIXD	Do.
Orchid	5	818	1,081	1908	do	do	190	30	16	11 0	13 3	1,000	7	28	GVRM	NLT	Portsmouth, Va.
Columbine	5	429	643	1892	Steamer, single screw	do	155	27	15	9 6	12 3	800	7	24	GVNM	NLL	Do.
Cypress	6	790	1,080	1908	Steamer, twin screw	do	190	30	16	11 0	12 0	1,000	7	28	GVRD	NLM	Charleston, S. C.
Ivy	7	736	916	1904	do	do	173	30	13	8 5	9 6	700	7	22	GVTR	NAKV	Key West, Fla.
Sunflower	8	806	1,246	1907	do	do	174	31	15	9 8	12 2	900	7	27	GVRB	NUFM	Galveston, Tex.
Lilac	9	542	582	1892	Steamer, single screw	do	155	27	15	11 0	11 6	800	6	26	GVNP	NUCF	San Juan, P. R.
Cedar	16	1,245	1,970	1917	do	do	201	36	18	9 6	14 0	1,150	8	25	GVLM	NLW	Ketchikan, Alaska.
Heather	17	631	831	1903	do	do	179	28	15	9 6	11 6	685	7	20	GVPL	NAKL	Seattle, Wash.
Manzanita	17	774	1,000	1908	Steamer, twin screw	do	190	30	16	10 7	12 7	1,000	7	24	GVRJ	NLU	Astoria, Oreg.
Madrono	18	654	806	1885	Steamer, single screw	Iron	180	27	15	9 9	11 6	750	7	21	GVNF	NAMV	San Francisco, Calif.
Sequoia	18	809	1,100	1908	Steamer, twin screw	Steel	190	30	16	10 11	13 5	1,000	7	24	GVRK	NLV	Do.
Kukui	19	838	935	1908	do	do	190	30	16	10 11	13 6	1,000	6	24	GVRL	NLF	Honolulu, Hawaii.
SEAGOING, LAKE OR BAY WORK.																	
Zizania	1	575	643	1888	Steamer, twin screw	Iron	161	27	12	9 1	10 9	650	6	22	GVNK	NZZ	Portland, Me.
Azalea	2	330	516	1891	Steamer, single screw	Steel	154	25	12	6 6	9 0	400	6	22	GVNQ	NXY	Woods Hole, Mass.
Mayflower	2	630	668	1897	Steamer, twin screw	do	164	30	12	7 9	8 1	650	6	24	GVNW	NZQ	Boston, Mass.
Hawthorn	3	800	950	1921	Steamer, single screw	do	160	30	14	6 6	9 0	700	4	23	GVLP		New London, Coun.
Larkspur	3	738	888	1903	Steamer, twin screw	do	169	30	14	9 1	10 6	750	7	25	GVPM	NAMB	Staten Island, N. Y.
Oak	3	800	950	1921	Steamer, single screw	do	160	30	14	6 6	9 0	700	4	23	GVLN		Do.
Pansy	3	431	454	1878	Steamer, twin screw	Iron	152	25	11	7 7	7 11	250	4	18	GVMW		Newport, R. I.
Iris	4	519	606	1897	Steamer, single screw	Steel	153	30	10	8 7	9 10	800	5	20	GVPH		Philadelphia, Pa.
Arbutus	5	398	545	1879	Steamer, twin screw	Wood	153	25	11	7 1	9 0	360	7	23	GVMT	NAGM	Portsmouth, Va.
Holly	5	431	499	1881	Steamer, side wheel	Comp.	176	24	10	7 0	8 6	400	5	18	GVPJ		Do.
Laurel	5	218	299	1915	Steamer, single screw	Wood	105	22	9	6 1	6 10	160	4	12	GVRP		Baltimore, Md.
Maple	5	567	799	1893	Steamer, twin screw	Steel	164	30	12	7 3	9 5	650	7	24	GVNS	NAPV	Do.
Mangrove	6	606	821	1897	do	do	164	30	12	7 2	8 6	550	7	24	GVNT	NANV	Charleston, S. C.
Camellia	8	276	377	1911	do	do	117	24	10	5 10	7 7	280	4	17	GVRN		New Orleans, La.
Magnolia	8	685	877	1904	do	do	173	30	13	7 6	9 2	700	7	25	GVPT	NAPS	Mobile, Ala.

Crocus	10	681	1,035	1904	do	do	165	29	14	9 6	12 3	700	5	23	GVPN		Buffalo, N. Y.
Amaranth ⊙	11	597	975	1892	Steamer, single screw	do	166	28	14	8 6	12 6	672	6	20	GVNR	NAPC	Detroit, Mich.
Aspen	11	353	415	1906	do	do	126	25	12	7 3	8 3	440	4	10	GVMD		Do.
Marigold ⊙	11	477	696	1890	do	Iron	160	27	12	8 5	11 0	550	6	20	GVPC	NAQV	Do.
Hyacinth ⊙	12	493	914	1903	do	Steel	165	28	14	7 0	11 6	768	6	20	GVPQ	NAGV	Milwaukee, Wis.
Sumac ⊙	12	600	887	1903	Steamer, twin screw	do	169	30	13	8 10	11 9	700	6	23	GVPW	NASG	Do.
Fern ⊙	16	245	317	1915	Steamer, single screw	Wood	112	22	10	7 1	8 6	360	5	11	GVRQ	NAFV	Ketchikan, Alaska.
Rose ⊙	17	395	567	1916	Steamer, twin screw	Steel	127	24	11	7 0	9 4	330	5	16	GVRS	NASD	Astoria, Oreg.
INSIDE WATERS AND ENTRANCES.																	
Shrub	2	362	435	1912	Steamer, single screw	Wood	106	29	13	6 5	6 9	300	2	13	GVLC		Boston, Mass.
Daisy	3	61	84	1892	do	do	80	14	5	4 0	5 0	60	2	5	GVPF		Staten Island, N. Y.
Elm	3	259	318	1918	Oil, single screw	do	101	30	9	5 6	6 9	150	2	8	GVLJ		Do.
Pine	3	55	56	1918	Gasoline, single screw	do	61	15	6	4 3	4 4	50	2	3	GVLK		Atlantic City, N. J.
Woodbine	4	85	107	1913	do	do	95	16	7	5 2	5 11	125	2	5	GVRT		Edgemoor, Del.
Juniper	5	125	146	1903	Steamer, twin screw	Steel	95	18	8	4 6	5 0	290	4	8	GVPS		Portsmouth, Va.
Palmetto	6	156	170	1917	Gasoline, twin screw	do	90	22	8	3 9	4 0	150	4	8	GVLD		Charleston, S. C.
Water Lily	6	29	39	1895	do	Wood	64	11	5	3 3	3 8	50	2	3	GVPK		Do.
Poinsettia	7	27	31	1915	Gasoline, single screw	do	50	16	6	2 5	2 9	50	2	3	GVLB		Key West, Fla.
Sundew	7	580	710	1919	Steamer, single screw	do	98	24	13	9 3	11 0	325	2	8	GVLQ		Do.
Cosmos	8	57	61	1909	Gasoline, twin screw	do	75	15	6	3 9	4 0	100	2	3	GVLF		New Orleans, La.
Aster	8	64	109	1921	do	do	75	21	7	3 8	5 7	70	2	5	GVLR		Mobile, Ala.
Clover	11	163	205	1899	Steamer, single screw	do	93	22	7	5 4	6 4	140	4	8	GVPD		Sault Ste. Marie, Mich.
MISSISSIPPI RIVER AND TRIBUTARIES.																	
Dandelion	13	232	302	1893	Steamer, stern wheel	Wood	140	31	5	2 6	3 3	500	4	15	GVLH		Rock Island, Ill.
Goldenrod	14	194	283	1888	do	Steel	169	27	4	2 10	3 6	304	2	12	GVNH		Cincinnati, Ohio.
Oleander	15	463	548	1903	do	do	189	31	7	3 6	4 6	600	4	17	GVND		St. Louis, Mo.

⊙=Equipped for radio communication.

20. RECENTLY BUILT LIGHTHOUSES AND VESSELS.

During the past 12 years about 60 important new lighthouse structures and 22 new vessels have been completed. Detailed technical descriptions of these have been published in the annual report of each year, and the following descriptions of a few typical

White Shoal Light Station, Mich.

structures have been condensed from the more complete statements in the current reports.

White Shoal Light Station, Mich., is located in the northeasterly end of Lake Michigan, and stands in 23 feet of water, replacing a lightship formerly moored near by. It is a very important station, as it marks the western entrance to the Straits of Mackinac. The foundation consists of a timber crib 72 feet square, supporting a

reinforced concrete pier which extends 20 feet above lake level. A structural steel tower, backed with brick and faced with terra cotta, rises from the pier, and in its nine stories contains the keepers' quarters and other rooms of the station. The illuminating apparatus consists of a second-order two-panel flashing lens rotating in a mercury float, giving a white flash of 1,200,000 candlepower every 8 seconds. This light is 125 feet above the lake surface and is visible 20 miles in clear weather. The fog-signal equipment consists of a 6-inch aerial whistle blown by compressed air and a submarine bell mounted on a tripod in 60 feet of water three-fourths mile distant from the station and operated by an electric cable from the station. The total cost of the work was nearly $227,000 and the light went into commission in 1910.

Livingstone Channel Light, Detroit River, Mich.

Livingstone Channel Lights, Detroit River, Mich.—This series of lights marks the Livingstone Channel in the Detroit River, an important link in Great Lakes traffic between Lake St. Clair and Lake Erie. The use of the channel is restricted to southbound

Livingstone Channel Light foundations under construction in cofferdam.

traffic and was opened in 1912. The beacons consist of concrete piers 35 feet long and 22 feet wide, pointed upstream, with ice breakers protected by steel plating. A square concrete base is built on each pier supporting a steel tank house and lamp-post, each carrying a lens lantern equipped with automatic acetylene

apparatus. Six of these piers were built in place before water was admitted inside the cofferdam for excavating the rock bottom of the river, and four other piers, intended for the lower portion of the river, were built as concrete caissons within the cofferdam, subsequently floated out and sunk at their proper locations and filled solidly with concrete. The approximate cost of the work was $160,000.

Los Angeles Harbor Light Station, Calif.

Los Angeles Harbor Light and Fog Signal, Calif.—This structure is the principal guide for Los Angeles Harbor and is located on a monolithic concrete block 40 feet square at the outer end of San Pedro Breakwater, 2 miles from the mainland, in about 50 feet depth of water. The lighthouse has a structural steel framework, with the first two stories covered with steel plates and the upper stories with cement plaster walls on reinforcing metal. The illuminating apparatus consists of a fourth-order bivalve lens, showing a white flash of 69,000 candlepower every 15 seconds. The fog signal is a 6-inch automatic siren blown by compressed air. Quar-

ters for keepers are provided in the tower, which was completed in 1913 at a cost of about $35,500.

Kilauea Point Light Station, Hawaii.—This station is the principal landfall light for vessels bound to the Hawaiian Islands from the Orient and is located on the north coast of Kauai, the largest of the western islands of the group. The site is on a cliff 180 feet above high water on hard volcanic rock. The tower is of reinforced concrete and is relatively short because of the good elevation afforded by the site. It carries a powerful second-order, two-panel, double-flashing lens, with incandescent oil vapor apparatus, giving a double white flash of 250,000 candlepower every 10 seconds. Fog is rare in this vicinity and hence no fog signal is required. Three

Brandywine Shoal Light Station, Del.

keepers' dwellings, constructed of rubble stone, are provided adjacent to the tower, along with other necessary outbuildings. The station cost about $78,000 and was completed in 1913. (See p. IV.)

Brandywine Shoal Light Station, Del.—This station, located on a dangerous shoal almost in the middle of Delaware Bay, is remarkable as the first reinforced concrete caisson lighthouse in this country. It was built in 1914, at a cost of $75,000, to replace a former structure built on a screw-pile foundation. The foundation consists of a reinforced concrete pier 35 feet in diameter, constructed on shore, launched, towed to the site, and there sunk in position on a pile foundation consisting of 74 wooden and 12 reinforced concrete piles. It supports a three-story reinforced concrete dwelling, circular in plan, which carries the lantern. The illuminating apparatus is a third-order incandescent oil vapor light, with 3-second

occultations every 30 seconds. The intensity of the light is 12,000 candles and it is visible 13 miles in clear weather. The fog signal is a reed horn with three trumpets pointing in different directions. Quarters for three keepers are provided in the tower.

Cape Sarichef Light Station, Unimak Pass, Alaska.

Cape St. Elias Light and Fog Signal, Alaska.—This station, located on the southerly end of Kayak, is an important mark for vessels bound for Prince William Sound, and was established in 1916 at a cost of about $115,000. The structure is a compact reenforced concrete building, combining the tower, fog signal, storage house, dwelling, and hoist house. The light is incandescent oil vapor, exhibited in a double flashing lens rotated in a mercury float, with an intensity of 300,000 candles, visible 15 nautical miles in clear weather, although within a few weeks after its establishment it was sighted by a passing vessel at a distance of 37 miles, on a cloudy night with heavy rain squalls and a rough sea. The fog signal consists of duplicate 6-inch automatic sirens, operated by compressed air, giving a double blast every 60 seconds. The off-lying dangerous reefs in the vicinity of the station are marked by a gas, whistling, and submarine bell buoy, moored in 126 feet of water 2 miles off shore.

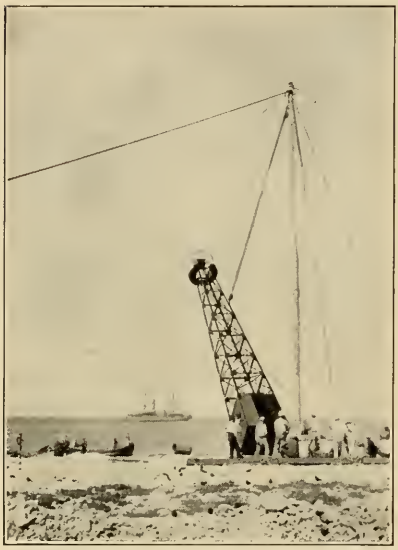
Unattended light, Prince William Sound, Alaska.

Navassa Island Light Station, West Indies.—The necessity for this station was brought about by the opening of the Panama Canal, the island being in the track of vessels plying between the United States Atlantic ports and the Canal Zone. It is located in the Windward Passage, 30 miles west of Haiti, and 90 miles south of Guantanamo

Navassa Island Light Station, West Indies.

Bay, Cuba. The island is about 2 miles long and 1 mile wide, of limestone formation, with steep sides and a nearly flat top approximately 240 feet above the sea. The tower is of reenforced concrete, 150 feet high, with its foundation resting on solid rock, and the illuminating apparatus consists of two fourth-order flashing lenses

mounted side by side, so that the beams from each coalesce at a short distance from the lantern, forming a single flash. The characteristic is a double white flash every 30 seconds visible 27 nautical miles in clear weather. The quarters consist of a reenforced concrete building 58 feet square, built in the Spanish style, with a high single story and a patio in the center. The station is one of the most remote and isolated of those maintained by the service, and requires a voyage of 600 miles from the nearest district headquarters at San Juan, P. R. The approximate cost was $121,000 and the light was first exhibited October 21, 1917.



Constructing Caribbean Sea lights.

Caribbean Sea Lights.—There are a number of reefs in the Caribbean Sea lying in the track of vessels between the Yucatan Passage and the Panama Canal, the usual route of ships bound to and from the Gulf ports of the United States. In June, 1919, lights were placed on Serrana Bank, Quito Sueno Bank, and Roncador Cay, three of the most prominent of these dangers. Each light consists of a 375-millimeter lantern on a 40-foot steel tower, with flashing acetylene apparatus, including a sun valve for automatically cutting off the gas supply during daylight. Sufficient acetylene gas, compressed in tanks, is provided to last each station 12 months without replenishing. Arrangements have been made with the Governor of the Panama Canal for cooperative attendance of these lights by a steamer sent out from the Canal Zone. The cost of establishment was about $30,000.

Point Borinquen Light Station, P. R.—This new structure, located on the northwest cape of the island of Porto Rico, replaces a former station built during the Spanish days, deteriorated by age, erosion, and earthquake. The tower is of reenforced concrete, of simple and heavy design, to offer maximum resistance to earthquake shocks. It is 46 feet high, and carries a lantern with a third-order 12-panel flashing lens in a mercury float, with incandescent oil vapor as the illuminant. The light shows a group of four white flashes of 32,000 candlepower each, every 30 seconds, and is visible 24 nautical miles in clear weather. The dwelling is a single story reenforced concrete structure, with quarters for two keepers. The work was completed in September, 1920, at an approximate cost of $70,000.

Thimble Shoal Light Station, Va.—This site is located in the water, on the shoalest point of Horseshoe Bar, at the entrance to Hampton Roads, Chesapeake Bay, about 3½ miles northeast of Old Point Comfort, Va. This vicinity has been prominently marked for over 100 years, first by Willoughby Spit Light Vessel, and since 1872 by a lighthouse. The present structure, which went into commission December 1, 1914, replaced a former screw-pile lighthouse destroyed by collision and fire. It consists of a cast-iron caisson foundation, 42 feet in diameter at the bottom, reducing to 30 feet diameter, and curving outward again at the deck to 38 feet diameter, sunk by the pneumatic process 13 feet into the bottom of the bay. The water is 11 feet deep at low tide, and the deck is nearly 19 feet above high water with a normal range of 3 feet, the total height of the

Point Borinquen Light Station, near Aguadilla, P. R.

pier being 46 feet. The pier is filled solidly with concrete up to the basement, except for cistern spaces near the top and is protected on the outside by riprap stone. It supports a 3-story conical cast-iron tower, containing quarters for 3 keepers, on top of which is a fourth-order cylindrical helical-bar lantern with a focal plane 55 feet above high water. It exhibits an occulting white incandescent oil vapor light of 7,200 candlepower, visible 13 miles in clear weather, showing light 1 second, eclipse 1 second. The fog signal is an air diaphone sounding a 2-second blast every 10 seconds.

The construction of this station, which cost complete about $100,000, presented a number of difficult engineering problems, the most important being the erection of the caisson foundation, weighing over 260 tons, which was assembled on shore at Berkley, Va., launched from a marine railway, towed 15 miles to the site, sunk in position, fitted up with working chamber, air locks, compressors and the

necessary piping and appurtenances, and excavated the proper depth into the bottom, all of which was successfully accomplished.

Molasses and Pacific Reefs, Fla.—These two automatic acetylene lights were placed in commission in 1922 to assist in outlining the great chain of coral reefs and keys lying off the southeastern coast of

Thimble Shoal Light Station, Va.

Florida in the general vicinity of Miami. The reefs have been marked for many years by a group of six primary light stations from Fowey Rocks to Sand Key at intervals of 25 to 30 miles apart. Pacific Reef is located, roughly, midway between Fowey Rocks and Carysfort Reef, and Molasses Reef approximately splits the distance between Carysfort and Alligator Reefs.

The structures are similar, consisting of pyramidal skeleton towers made up of wrought-iron columns, tie-rods and struts, and cast-iron sockets resting on nine solid wrought-iron piles, each 8 inches in diameter, driven through cast-iron disks resting on the reefs, the water being about 8 feet deep at each site. A timber working platform was built at each place to receive the building materials brought alongside in a barge. There were many times when the sea was too rough to land on the platform, and the construction work was attended by many difficulties.

Each tower supports a special form of fourth-order helical bar lantern and gallery inclosing a lens with a cluster of three acetylene burners giving a 1,700-candlepower flashing white light at a focal plane elevation of 45 feet above high water, visible 12 miles in clear weather. Pacific Reef tower is painted white and its light flashes every 3 seconds, while Molasses Reef is painted brown and flashes every 5 seconds. Each structure is provided with sufficient compressed acetylene gas in tanks to last about 6 months without replenishing, and the lights require no attendance beyond occasional visits of inspection. The total cost of the work complete was about $75,000.

Tender "Cedar."—This is the largest vessel at present in the service and was built at Long Beach, Calif., for seagoing duty in Alaska. The tender is about 200 feet long, 36 feet beam, and has a displacement of about 1,800 tons at a draft of 13 feet in salt water. It is constructed of steel throughout, with seven water-tight bulkheads, and a double bottom. The propelling machinery consists of a triple-expansion engine supplied with steam from two Scotch boilers, using oil as fuel. Ample bunker tanks give the vessel a steaming radius of approximately 3,800 nautical miles at cruising speed. The vessel is fitted throughout with all modern appliances, including sanitary plumbing and fixtures, drainage system, fire main, steam-smothering fire system, hot and cold fresh-water system, oil-burning galley range, electric lights throughout, and radio-communication apparatus. The vessel cost about $248,000, went into commission in 1917, and has proven stanch and seaworthy on a number of long voyages to the western portion of Alaska, 1,500 miles from district headquarters at Ketchikan. (See p. 75.)

Light vessel "No. 103."—This lightship was built in New York for relief duty on the Great Lakes. It has a length of about 96 feet, beam of 24 feet, and a displacement of 310 tons at 9 feet draft in fresh water. The entire vessel is constructed of steel and carries a steel tubular lantern mast surmounted by a rail and gallery with a lens lantern secured on top of masthead. The illuminating apparatus is a flashing device using compressed acetylene piped from tanks carried in a tank room on the upper deck. The fog signal apparatus is a 10-inch steam whistle controlled by a clockwork mechanism.

The vessel is propelled by steam and is fitted throughout with all modern safety and sanitary equipment. It was completed in 1920 at a cost of about $161,000, and has since given good service on Lake Michigan. (See p. 68.)

Light vessel "No. 105."—This vessel was built in New York for the important station off Diamond Shoal, near Cape Hatteras, N. C., the former station ship having been sunk by a German submarine during the war. It is 146 feet long, 30 feet beam, with a salt-water displacement of 825 tons. The vessel is constructed entirely of steel, with a flush spar deck above a complete main deck, and two steel tubular lantern masts each fitted with gallery, rail, and lantern. The illuminating apparatus is flashing acetylene and the fog signal apparatus is of three types—a 10-inch steam whistle, a submarine bell, and a radio fog signal—all giving definite characteristics of the station. The last named is particularly valuable to vessels equipped with a radio compass, or direction finder, by means of which their positions may be located very accurately. The vessel is propelled by steam, using oil for fuel, with large bunker tanks containing 12 months' supply for ordinary duty on station. It is fitted completely with modern appliances, including a steam boat hoist, electric lights, mechanical refrigeration, radio communication apparatus, hot and cold water system, sanitary plumbing and drainage systems, and fixtures. The hull is painted red, with "Diamond" in large white letters on each side. The cost was about $440,000, due in part to war conditions. The vessel went on station in August, 1922. (See p. 64.)

Tenders "Oak" and "Hawthorn."—These vessels are alike in all respects, being 160 feet long, 30 feet beam, and displace about 875 tons when at a mean draft of 9½ feet in salt water. They were built in New York for general buoy work in that vicinity, replacing old and obsolete vessels in that duty. They are constructed of steel with ample deck space and a powerful derrick for handling buoys and other heavy articles. These vessels are propelled by single-screw triple-expansion engines, with steam furnished by Scotch boilers using coal as fuel. They are fitted throughout with all modern appliances and equipment and cost about $378,000 each, and were delivered to the Government in December, 1921.

Tender "Spruce."—This vessel is about 172 feet in length over all, 32 feet beam, with a maximum draft of 11 feet. It was built for mine-planting purposes by the War Department during the war and was transferred to the Lighthouse Service, along with five other similar vessels, all of which are intended to replace older tenders worn out in service. The *Spruce*, formerly the *Col. Garland N. Whistler*, is the first of this fleet to be reconditioned for lighthouse purposes, and has been converted at the general depot into a very satisfactory

tender for deep-sea work. Oil is used for fuel, burned under Scotch boilers, which, with a pressure of 160 pounds per square inch, drive the twin-screw triple-expansion engines at 145 revolutions per minute, giving a speed of about 11 knots. The general arrangements of the vessel conform to the requirements of the service, including powerful buoy-lifting gear and all modern equipment and appliances. The *Spruce* went into commission as a lighthouse tender in November, 1922, and has been assigned to the third district, with headquarters at Staten Island, replacing the *Myrtle*, a vessel 50 years old, which has since been sold. The *Spruce* has been reconditioned for lighthouse work at a cost of about one-eighth of the expense of building a new tender. (See p. 72.)

Lighthouse tender *Hawthorn*, third district.

21. PERSONNEL AND CIVIL-SERVICE SYSTEMS.

All positions in the Lighthouse Service are governed by the civil-service rules, which were extended to this service by President Cleveland May 6, 1896, and all appointments and promotions are made on a strictly merit basis. This is of great importance in maintaining a good organization and rigid discipline in a purely technical service, on the efficient conduct of which is directly dependent the safety of lives and property. The service is justly proud of its long and honorable record in fulfilling an important public duty, and it is only by close adherence to those worthy traditions that its ideals may be perpetuated.

The technical and clerical positions in the Lighthouse Service, such as superintendents, assistant superintendents, draftsmen, aids, radio operators, and clerks of all grades are in the educational class of classified competitive positions; all original appointments are there-

fore made from rosters of eligibles established as a result of educational examinations conducted by the Civil Service Commission. Registers of eligibles for all noneducational positions peculiar to the Lighthouse Service, such as officers of vessels, keepers of lights, etc., are established and maintained by the district civil service boards. Applicants for such positions are rated by these boards from answers made in their application forms, and if an eligible rating is obtained their names are entered on the register and they are given due consideration for appointment from time to time as vacancies occur, in accordance with civil-service rules. Original appointment is usually in the lowest grade, the more responsible positions being filled whenever practicable by transfer and promotion of employees in less important positions who have earned such consideration by reason of efficiency and length of service. Positions of additional keepers are authorized in the larger districts to provide for preliminary training and assignment to duty in cases of emergency.

In the case of officers on lighthouse vessels, licenses by the Steamboat Inspection Service are required similar to the licenses required for officers on commercial vessels.

The general rule adopted by the Steamboat Inspection Service is that experience obtained on propelled lighthouse vessels shall be considered as equivalent to that obtained on merchant vessels subject to inspection by that service.

The duties of all positions of keepers require that the lights be given the necessary care and attention in cleaning, filling, and lighting, and often that the incumbents possess ability to handle a boat; in many cases knowledge of operating machinery is required, in view of the fog-signal and revolving-light mechanisms at a number of stations. The same requirements apply in a less degree to the positions of lamplighters and light attendants in charge of minor lights. The term "light attendant" indicates a type of position in which the employee is engaged full time of eight hours per day, while the designation "lamplighter" applies to positions in which the incumbents work but a portion of their time each day. Selection for these positions is made with sole reference to the ability and fitness of the applicants, the proximity of the applicant's home to the lights, and facilities possessed by them, such as the ownership of a suitable boat when needed, etc.

Trades and skilled positions, such as machinists, carpenters, blacksmiths, etc., are also in the classified competitive civil service, and employment in such positions is made by selection from registers based on the physical ability, training, experience, and fitness of the applicants for the employment desired.

The compensation of all positions in the service not fixed by law is based, so far as practicable, on similar requirements in the com-

mercial world; thus the entrance salary for draftsmen and other technical employees is, as a rule, from $115 to $150 per month, for clerks $90 per month, for junior officers of vessels from $115 to $130 per month, for radio operators $75 per month, for assistant keepers of lighthouses $50 to $55 per month, the latter three grades receiving also a subsistence allowance while on duty. It should be observed that these are the average base rates only and that the compensation varies according to the character and location of the work. In addition to the above rates of pay, keepers of lighthouses after five years' continuous service are granted an increase in pay of $5 per month. Officers on lighthouse vessels receive longevity pay at the rate of $5 per month after five years' continuous service in the Lighthouse Service, or two years' continuous service in grade, and $10 per month after 10 years' continuous service in the Lighthouse Service, or 5 years' continuous service in grade. The pay of lamplighters and attendants in charge of minor lights is based upon the number of lights cared for, distance necessary to be traveled, and conditions met, averaging roughly about $8.50 per month for each light in the river districts. The pay of trades and skilled positions is generally governed by the prevailing rates in the locality.

All appointed employees in offices, at depots, on tenders, and in the field force at monthly rates of pay, who have been in the service for a considerable period of time, may be granted leave when properly approved, not exceeding 30 days each of annual and sick leave in any one calendar year. Per diem employees and nonappointed members of crews on vessels are also entitled to leave under rules covering such positions.

Special rules are in effect regarding leave and shore liberty on light vessels and at isolated light stations. These rules provide for a rotative system, so that all may have an equitable amount, without interfering with the proper conduct of work on the station or vessel, and fix a maximum of 120 days per year in the case of light vessels and 96 days per year at isolated light stations where families do not reside or where the location is unusually remote or unhealthful. In the case of more favorably located stations, the ordinary rules apply to leaves of absence.

Careful attention is paid to the welfare of employees in all cases in which remedial measures are authorized by law. All persons in the service are entitled to the benefits of the Federal compensation act of September 7, 1916, providing for compensation for injury or death sustained in the line of duty. In addition, expenses of medical or surgical attendance, or of burial, are allowed under certain conditions. Medical and hospital treatment by the Public Health Service is extended to various classes of employees, those on vessels and keepers, and assistant keepers under certain limitations being

cared for without charge, while other employees may receive care and treatment at the same rates as fixed for the Army and Navy. The Public Health Service also gives information and advice, when called upon, in regard to medical questions and matters of sanitation affecting the Lighthouse Service, and provides for the free vaccination of certain classes of employees against smallpox and typhoid fever. That service has also cooperated in the preparation of a medical handbook for the use of lighthouse vessels and stations on the prevention of disease and care of the sick and injured, with special reference to first aid to the injured. Medicine chests, containing such articles as may be needed for isolated vessels or stations in emergency cases, with directions for use, are also furnished by the Lighthouse Service.

Libraries are furnished all light vessels and inaccessible offshore light stations, with proper arrangements for their exchange at intervals, and revision as the books become obsolete in accordance with suggestions obtained from library authorities. These libraries were first introduced in the service in 1876, and are carefully selected from books of a good standard appropriate to the persons who will use them; while largely fiction, other classes of literature are included in reasonable proportions, including technical books when specially requested. In the matter of educational facilities at stations not accessible to schools and where there are children of school age, inquiry is made from time to time into the education of the children, and any course which will lead to their suitable education is encouraged; and, other things being equal, preference is given to employees having children between the ages of 5 and 16 years in filling vacancies by transfer at stations convenient to schools. The law permits the payment of travel and subsistence expenses of teachers instructing the children of lighthouse keepers. Consultation is had with State and local educational authorities, and in some localities, notably in the State of Maine, good results have been achieved through traveling teachers provided by the State, who are transported when practicable by lighthouse tenders in making their visits.

One of the most beneficial items of legislation enacted during recent years is the lighthouse retirement act of June 20, 1918, which provides for optional retirement at the age of 65 years after 30 years of active service and general retirement at the age of 70 years of all officers and employees engaged in the field service or on vessels of the Lighthouse Service, except persons continuously employed in district offices and shops. The maximum retirement pay under this system is three-fourths the average annual pay for the last five years of service. Additional legislation is very desirable to cover cases where an employee is found to be disabled for useful service,

through no fault of his own, before reaching the age fixed in the present act. Persons excepted from the special lighthouse retirement act receive the benefits of the general civil service retirement law of May 22, 1920.

The officers and crews on vessels, keepers and assistant keepers at light stations and depots, and watchmen at the general lighthouse depot are required, when on duty, to wear uniforms as prescribed for their respective grades. Keepers and assistant keepers are also authorized to wear sleeve insignia as prescribed to indicate length of service. Lamplighters and attendants in charge of minor lights are not required to wear uniforms. These uniforms must conform to the regulations issued on the subject, which cover all details for each class or rank. Such regulations were first issued in 1883. The standard material for the clothing is dark navy-blue cloth or serge, except in hot weather, when white duck is allowed. The standard cap bears in the middle of the front a gold-embroidered wreath inclosing a silver-embroidered lighthouse. Officers of tenders wear a single-breasted coat shaped to the figure with a fly front and standing collar, trimmed with braid. Other employees wear a double-breasted sack coat with gilt buttons embossed with a lighthouse. Deck officers of vessels wear an anchor on the collar; engineer officers wear a propeller. The relative rank of such officers is indicated by sleeve stripes of braid near the cuff of the coat. Keepers of lighthouses wear within a loop on the collar the letters K, 1, 2, etc., as the case may be, indicating, respectively, keeper, first assistant, second assistant, etc., and do not wear sleeve ornaments. Petty officers of tenders wear ornaments on the sleeve only, midway between the shoulder and elbow; three gilt zigzag lines for radio operators, a gilt quill for clerk, a white steering wheel for quartermasters, a red propeller for machinists, and two white anchors crossed for boatswains.

In order to insure uniformity in the practical operations of the service, one of the first acts of the Lighthouse Board was to issue a set of rules and regulations for the government of employees, with detailed instructions concerning the routine of their duties. Such regulations were first issued October 22, 1852, and have been since revised and amended from time to time. These regulations are authorized by the law governing the Lighthouse Service, and the latest edition went into effect June 13, 1918, comprising a volume of about 200 pages, with chapters appropriate to the various activities of the service. The regulations are supplemented by Instructions to Employees, the latest edition of which took effect July 15, 1915. This is a book of about 100 pages, with chapters dealing with the duties of different grades of employees, such as keepers of lighthouses,

officers of tenders, etc., with general chapters on disciplinary and professional matters applicable to all.

All employees are required to familiarize themselves with the instructions and to be governed thereby. The lighthouse is and should be a common synonym for absolute reliability. Strict rules for the government of the service must be made and observed, and this has been the policy from its earliest days. President Thomas Jefferson, in approving the dismissal of a keeper in a case referred to him for decision, made the following remarks in his own handwriting, dated December 31, 1806: "I think the keepers of lighthouses should be dismissed for small degrees of remissness, because of the calamities which even these produce."

On the other hand, devotion to duty is always praised and rewarded. Keepers in charge of stations who attain a high efficiency, as shown by inspections made during the year, are entitled to wear the superintendent's efficiency star, and those who win this star for three successive years are entitled to wear in lieu thereof the commissioner's star. Whenever employees render service to endangered persons or property, or otherwise perform their duty under hazardous or trying conditions, including any special act of unselfish or unusual service of any kind, either in the office or the field, in a manner to merit commendation, a special report is made and a commendatory letter, signed by the Secretary of Commerce, is addressed to such person and the fact noted on the official records of the service. Also, the light station in each district attaining the highest general efficiency during the year is entitled to fly the "efficiency flag," being the regulation service flag, for the succeeding year.

As a means of attaining the ends sought by the regulations and instructions, systematic inspections are made of all branches of the service by its officers. Each light station and depot is inspected at least twice a year; each tender and light vessel at least three times a year, at such times as will secure the most efficient service, and not at regular intervals that may be anticipated. Inspection of non-attended lights, buoys, and unlighted beacons is made at least once a year. Additional inspections are made whenever rendered necessary by unusual conditions. Such inspections are made by the district officers, who fill out a form provided for the purpose at the time of making the inspection, and in case it appears that a bad state of repair or other unsatisfactory condition exists, the commissioner is promptly notified.

Such inspections are supplemented by traveling officers of the service; a superintendent on general duty, who attends particularly to the technical features, such as the condition of vessels and stations from the engineering standpoint; and an examiner, whose activities are more particularly addressed to business methods and fiscal mat-

ters, such as accounts, reports, etc. The officers of the bureau also make inspections from time to time as opportunity permits in order to obtain information at first hand regarding the operations of the service.

On June 30, 1922, there were 5,985 authorized positions in the Lighthouse Service, divided into the following principal classes:

Executive and technical employees	90
Clerical employees	155
Depot keepers and assistants	118
Light keepers and assistants	1,445
Light attendants and lamplighters	1,616
Custodians of reservations	14
Officers and crews of vessels	1,901
Construction and repair force	646
Total	5,985

22. LIGHT KEEPERS' QUARTERS.

On account of the comparative isolation of many lighthouses and to insure immediate attention at all times, it is the practice of the service to furnish quarters for keepers at all attended lights. Dwellings for keepers and their families are provided for nearly all important lights located on shore, while in the case of offshore stations, where women and children are not permitted to reside on account of the hazard in making a landing and the restricted space, quarters for the keepers only are allowed.

There is no standard type or design of keepers' dwellings, by reason of many different local conditions which have to be met, embracing all kinds of climate from the exposed coasts of Maine, Alaska, and the Great Lakes to the semitropical conditions of Porto Rico and Hawaii. Attempt is made to have such buildings conform to the prevailing local styles and customs, and at the same time to harmonize them architecturally so far as practicable with the light station and its surroundings. Consideration must also be given to the kind of materials most available in the vicinity, for economical reasons, as the limit of cost for such dwellings is fixed by law at not to exceed $6,500 at one station, exclusive of the site. While this was formerly ample under ordinary conditions, it is no longer so, and the great difficulties of transportation frequently make the costs much higher than would prevail in localities close to markets for materials and sources of skilled labor. Unnecessary or elaborate ornamentation is avoided, and care is taken to use simple and substantial designs appropriate to the purpose. In recent years preference has been given to fireproof construction, when funds permit, and the use of perishable materials has been eliminated when feasible to avoid or lessen future repairs. In all new dwellings hot-water or

steam heat is provided in climates requiring it, as well as sanitary plumbing with water-supply and sewerage systems; these features are also being added to older dwellings not so equipped, as circumstances allow.

In some cases double or triple dwellings have been built at stations with more than one keeper, but recent practice favors detached

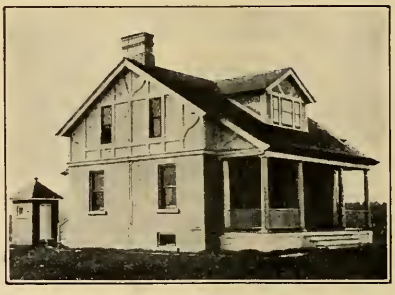
Fort Pickering, Mass.

Cape Hatteras, N. C.

Point Conception, Calif.

Barbers Point, Hawaii.

Fort Point, Calif.



Pointe aux Barques, Mich.

Dwellings for light keepers.

houses, as insuring greater privacy, and giving better opportunity for individual gardens or yards. Many reservations have areas of tillable soil, on which keepers are permitted and encouraged to grow vegetables, etc., for household consumption.

Where quarters are furnished by the Government, a fuel allowance is made for heating and cooking, and each station to which a Government power boat is assigned is also granted an allowance of gaso-

line or other fuel, based on the reasonable official requirements of the station.

In order to avoid any possible interference with the work, persons outside the service are not permitted to occupy any premises belonging to the Lighthouse Service; no traffic or trade is allowed to be carried on within any lighthouse reservation, nor may articles be exposed for sale on the premises. Visitors must be received with courtesy and may be admitted in limited numbers to lighthouses at prescribed hours not conflicting with the regular duties of the keepers. A placard entitled "Rules for visitors" is posted in convenient places where it may be seen by such persons. Probably more visitors are received at Absecon Light Station, Atlantic City, N. J., than any other in the United States, about 10,000 persons visiting this lighthouse in July, August, and September of each year.

23. SAVING OF LIFE AND PROPERTY.

While the work of the service is primarily concerned with the maintenance of aids to navigation, it frequently happens that opportunity presents itself to give assistance to persons or vessels in distress, and in such cases it is the duty of light keepers and their assistants, and of officers and crews of lighthouse vessels, to give or summon aid to vessels in distress, whether public or private, and to assist in saving life and property from perils of the sea whenever it is practicable to do so. The records of the service are replete with many heroic incidents of this character, and it is customary to include a brief statement of this work in the commissioner's annual report, giving the name of the vessel or employee rendering this service, the object or person aided, and the nature of the assistance performed. Commendatory letters signed by the Secretary of Commerce are addressed to such employees, and in specially meritorious cases involving great personal danger recommendation may be made to the Secretary of the Treasury for the award of life-saving medals.

In the annual report for 1921 mention is made of 125 occasions on which services in saving life or property were rendered by employees of the Lighthouse Service, and the report of 1922 includes 128 similar incidents. These latter may be grouped into the following general classes:

	Cases.
Assisting disabled small boats	60
Assisting disabled larger vessels	34
Furnishing food, clothing, and shelter	5
Rescuing persons overboard	12
Recovering property	2
Assisting at fires	8
Recovering bodies	1
Miscellaneous	6
Total	128

24. LIGHTING OF BRIDGES.

One of the duties of the Lighthouse Service incidental to its general work is the supervision of the lighting of bridges over navigable waters of the United States; also of lights on sheer booms, piers, dams, and similar obstructions to navigation. All parties owning, occupying, or operating bridges over any navigable river are required by the act of August 7, 1882, to maintain at their own expense, from sunset to sunrise, throughout the year, such lights on their bridges as may be required by the Commissioner of Lighthouses; failure to do so may subject the offender to a fine of not exceeding $100 for each offense, and each day during which such violation continues is considered as a new offense.

Special regulations are issued on the subject, the latest edition being dated July 15, 1920, intended for the guidance of shipmasters, pilots, and bridge owners. They prescribe standard methods for marking the piers and waterways of bridges with various combinations of red and green lights for different classes of bridges, illustrated by diagrams or plates showing the proper arrangements. The red lights indicate danger, while the fairway is marked by green lights. In the case of draw or swing bridges, mechanism must be provided for changing the color from red to green, and vice versa, as the draw is opened or closed. All lights are required to be securely attached and of sufficient intensity to be visible on a dark night with a clear atmosphere not less than 1 nautical mile. Provision is made for exempting bridges infrequently used from the more detailed requirements of these regulations, so long as such lights as are necessary for the security of navigation are maintained in each case.

On June 30, 1922, there were 1,674 bridges lighted in accordance with the regulations. The bridges are inspected at intervals and any deficiency in lights is called to the attention of the owners.

25. PRIVATE AIDS TO NAVIGATION.

It is unlawful for anyone to establish or maintain any light or other aid to navigation similar to those maintained by the Lighthouse Service without first obtaining permission to do so from the Commissioner of Lighthouses in accordance with regulations established by the Secretary of Commerce; violation of these provisions may subject the offender to a fine of not exceeding $100 per day.

In accordance with the law, those desiring to establish a private aid may apply for authority, on a blank provided for the purpose, to the commissioner through the proper superintendent of lighthouses. This application must contain the material facts relating to the proposed aid, such as whether a light, fog signal, buoy, with its exact location, color, and other descriptive items, in order that it may be

properly ascertained that no conflict will exist between this and any neighboring Government aid. Private aids authorized under the rules cover a useful purpose in marking privately dredged channels or localities where special service is rendered. Such aids are usually under the control of municipalities, corporations, yacht clubs, or other organizations. Light and fog signals on ferry slips and on piers, used only by certain vessels, and stakes, bushes, and barrel buoys marking shallow and little-used channels, are not affected by these regulations. Information regarding lawfully maintained private aids is printed in the customary publications of the service, the same as for Government aids, and they are also entitled to the same protection of law as is afforded aids maintained by the Lighthouse Service. On June 30, 1922, there were 886 authorized private aids in commission, comprising 230 lights, 13 lighted buoys, 523 unlighted buoys, 83 other unlighted aids, and 37 fog signals.

26. LAWS FOR PROTECTION OF AIDS.

Heavy penalties are prescribed by law for obstruction to or interference with any aid to navigation. Exhibiting a false light, or extinguishing a true light, with intent to bring any vessel into danger, is a felony punishable by imprisonment of not less than 10 years, or for life. Any person who obstructs or interferes with any aid to navigation maintained by the Lighthouse Service, or who anchors a vessel so as to obstruct range lights, may be subject to a fine of $500 for each offense, and each day during which the violation continues may be considered as a separate offense. These provisions apply also to any lawfully maintained private aid, as noted in the previous chapter.

In addition to the Federal statutes on the subject, various States and Porto Rico have passed laws providing penalties to be imposed on persons interfering in any manner with aids to navigation maintained by the Lighthouse Service, as follows: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Florida, Alabama, Texas, Porto Rico, Ohio, Michigan, Minnesota, Wisconsin, Washington, Oregon, and California.

The Lighthouse Service takes the position, inasmuch as the aids to navigation are established and maintained at heavy expense for the sole purpose of safeguarding maritime interests and the lives and property intrusted to their care, that it is therefore the obvious duty of masters and pilots, in their own interests, as well as those of the public welfare, to exercise special care to avoid collisions with these aids to navigation. Failure to do so renders persons in charge and the owners of offending vessels liable for the full amount of damages

to aids and subjects them to the penalties prescribed by law. It is a part of the duty of the Lighthouse Service to prosecute all such offenders vigorously.

Making fast any vessel or boat to a buoy or beacon is an interference with an aid to navigation of a serious nature, and any person committing this offense is liable to prosecution.

Masters of towboats should exercise special care to avoid barges in tow striking and injuring buoys, beacons, or light vessels.

27. PUBLICATIONS.

The principal publications of the Lighthouse Service are light lists, buoy lists, and notices to mariners, the first two of which are sold at a nominal price to shipmasters or pilots for their information and guidance. There are three important light lists, each revised annually, containing information regarding lighthouses, lighted beacons, light vessels, lighted buoys, and fog signals, giving in tabular form and in geographical sequence the name of each aid, the character and period of the light, the location of the structure, with the latitude and longitude of more important aids, the height in feet of the light above high water, the distance in miles at which the light may be seen in clear weather, and the approximate candlepower. Other columns give a brief description of the structure, vessel, or buoy, with the height of towers in feet, the characteristic blasts or strokes of the fog signal, if any, and such additional explanatory remarks as may be necessary in any case. The three lists mentioned are devoted respectively to the Atlantic and Gulf coasts, the Great Lakes, and the Pacific coast, in separate octavo volumes, with the following number of pages each for the 1922 editions: Atlantic List, 424 pages; Lake List, 231 pages; and Pacific List, 200 pages. These light lists aim to give all the important information as to lights and fog signals in a convenient manner for the purpose of mariners engaged in coastwise or transoceanic navigation. Effort is made to publish the Atlantic and Pacific Lists on January 1, or as soon after the first of the calendar year as possible, and the Lake List on April 1, immediately prior to the opening of the season of navigation.

In addition, the service publishes annually and separately for each lighthouse district, except those on the Great Lakes, a buoy list, which gives a list of all the buoys in the district, both lighted and unlighted, as well as all the other aids. The lists for the three lake districts are consolidated in one volume. The buoy lists are issued rather for the use of local authorities and pilots and for the Lighthouse Service. As far as the location of buoys is concerned, the larger scale charts published by the United States Coast and Geodetic Survey and the United States Lake Survey are preferable sources

of information, as such charts show at a glance the location and character of all buoys and aids with reference to their surroundings, and are, moreover, corrected to the date of issue; while the lists can only be brought up to date when a new edition is published. The present series of buoy lists forms a set of 14 octavo volumes, ranging from about 150 to 20 pages each, depending on the size of the district.

Announcement of all changes in aids to navigation, information of dangers, changes in shoals and channels, facts of interest affecting charts and coast pilots, corrections to published lists, and similar items affecting navigable waters under the jurisdiction of the United States, are published weekly in a Notice to Mariners, prepared jointly by the Coast and Geodetic Survey and the Lighthouse Service. This publication is distributed gratuitously to maritime organizations and others interested. For important changes in seacoast lights and lightships used by vessels in foreign trade, a supplementary poster notice is also issued for prominent display to mariners. A Notice to Mariners covering all navigable waters of the world is published weekly by the Hydrographic Office, Navy Department.

Light lists are also issued for each of the three river districts, comprising the Mississippi River and its tributaries, covering broadly the upper Mississippi, the Ohio, and the lower Mississippi, respectively. These are small volumes published annually in vest-pocket size and contain simply the number and name of the aid, the distance from some starting point, the side of the channel, and the color of the aid.

A special publication of the service is a small quarto pamphlet of about 20 pages, including diagrams, containing the Regulations for Lighting Bridges, to which reference has already been made on page 98. This publication is issued only when a new edition is necessary.

The service publication of chief interest to the general public is the Annual Report of the Commissioner of Lighthouses to the Secretary of Commerce, which is available for distribution after the convening of Congress in regular session in December of each year, and covers the work of the service for the fiscal year ended on the preceding June 30, as required by law. In its present form this is an octavo volume of about 90 pages, and gives a general description of the operations and cost of the service during the year, with recommendations for new legislation and estimates for appropriations for the second next following year, supplemented by detailed statistics of various classes of aids to navigation and fuller details of many subjects mentioned in the report proper, along with brief technical descriptions of important works of construction or repair completed during the year.

Other publications of the service are of a routine character, printed in limited editions, and intended more particularly for its internal

government and administration. A number of these have been referred to in the preceding pages. They embrace the Regulations, the Instructions to Employees, the Medical Handbook, the Lighthouse Service Bulletin (a monthly leaflet, commenced in January, 1912, containing items of interest to the service), the Regulations for Uniforms, the Civil Service Regulations, and the various forms. blanks, record books, etc., needed in the work of the service.

A few special publications have also been issued, such as formulas for whitewash, etc., a description of Boston Lighthouse on its two hundredth anniversary, and a first edition of this pamphlet containing general information regarding the Lighthouse Service.

Mention should also be made of the various printed specifications and proposal forms issued by the service from time to time covering new vessels, lighthouses, annual supplies, and other large purchases for which contract with bond is required. These are distributed to prospective bidders in response to their inquiries as a result of public advertisements in newspapers and other periodicals.

28. ENGINEERING AND FISCAL MATTERS.

Careful supervision is exercised over all technical and administrative work of the service, the desire being to attain a high professional standard in modern methods of design and construction, with due regard to the economical expenditure of funds.

Surveys are made with especial care, with bearings given from the true meridian, and the distances well checked, to insure great accuracy. Each corner where practicable is permanently marked by a substantial monument and at the conclusion of the survey maps are prepared showing the information obtained. A standard form of map and instructions are prescribed for surveys of lighthouse reservations. All notebooks and other records are preserved, and in connection with each important new structure a complete record is kept of the engineering elements, such as computations, stress analyses, weights, and estimated cost. These principles apply to the design of vessels as well as shore structures, full details of the form characteristics of vessels being worked out by curves of displacements, centers of buoyancy, and gravity coefficients and metacenters, all with varying conditions of load, etc., in order that complete stability and seaworthiness may be assured.

Plans and specifications are prepared for all important works. Standard sizes of drawings are prescribed, being based on multiples of the dimensions of customary letter-size sheets 8 by 10½ inches in size. Each drawing bears a standard title giving information regarding the subject, the scale, date, and the persons responsible for its preparation. A standard form of advertisement, proposal, instructions to bidders, general conditions, and contract is used throughout

the service, and a number of standard plans and specifications covering materials, articles, and structures, including small boats assigned to stations, have been prepared for service use as a guide to designing wherever practicable and economical.

All works of construction and repair are supervised closely in order to make certain that the plans and specifications are followed, and persons charged with such duty are required to keep proper construction records and to make regular reports of progress. In the case of work performed by the field forces of the service, written work orders are issued showing the work to be done and the authorized amount of expenditure. When the inspection of supplies or material under purchase can be more conveniently handled by a district office near the location of the contractor's shop or plant, superintendents cooperate with each other by forwarding the plans, specifications, and other necessary information to the office assigned this additional duty.

Progress photographs are also taken from time to time to show the development of work under way, and record photographs are kept of all light stations and vessels, with descriptions of the construction, equipment, and similar information. About 9,500 photographs of various lighthouse objects are on file in the commissioner's office, covering practically every phase of the activities of the service. There is also a small collection of lantern slides, some of which are colored, and various motion picture films illustrating the activities of the service, all of which are useful in explaining lighthouse work to scientific or maritime organizations.

The administration of fiscal matters pertaining to the Lighthouse Service forms one of its most interesting problems. A rigid economy is enforced in this direction, and no expenditure is authorized or permitted which is not necessary to render the aids to navigation efficient.

The appropriations made by Congress for the Lighthouse Service may be divided into two broad classes, general and special. General appropriations are those providing for the payment of salaries and the other ordinary expenses of maintenance, operation, and betterment, including supplies, materials, and wages, and are limited to the fiscal year for which appropriated, while special appropriations are those designated for some specific purpose—usually new construction or extensive rebuilding, such as new lighthouses, vessels, etc., and are available until the works are completed. The total amount of special appropriations varies from time to time with the needs of the service and the action of Congress. The estimates for such appropriations formerly aggregated about $1,000,000 annually, but for the fiscal years 1915 to 1923 the average annual appropriations for special works were $803,000, approximately.

The general appropriations for the maintenance of the service for the fiscal year 1923 were $7,748,290, subdivided as follows:

Salaries, Bureau of Lighthouses	$68,290
Salaries, lighthouse keepers	1,300,000
Salaries, lighthouse vessels	1,700,000
Salaries, Lighthouse Service	400,000
General expenses, Lighthouse Service	4,200,000
Retired pay, Lighthouse Service	80,000
Total	7,748,290

The names of the first three and the last one of these appropriations indicate their respective objects; the appropriation "Salaries, Lighthouse Service," is for the compensation of technical and clerical employees in the field service, while the appropriation "General expenses" covers all items of supplies, repairs, maintenance, and incidental expenses required in the Lighthouse Service, including the wages of laborers attending post lights and pay of mechanics and laborers in the field force and at depots. The law requires that these appropriations shall be so apportioned by allotments as to prevent expenditures which may necessitate deficiency or additional appropriations to complete the service of the year. Careful accounts are therefore kept and periodical reports made by each district, showing under each appropriation the total allotments, vouchers paid, obligations, available balances, etc. On account of the casualties to which the property and equipment of the service is frequently subjected by reason of storm damage and other accidents, a close scrutiny of available funds is a highly necessary feature in the management of the service finances. Allotments under the various general appropriations are made to the lighthouse superintendents in charge of districts at the beginning of each fiscal year for operation of their district during that year. All requisitions for supplies made by each district, or other expenses incurred by them, are charged against this allotment. This has been found advantageous in placing definite responsibility for the judicious expenditure of funds and increasing economy and efficiency. It is necessary when making allotments to keep a small reserve to provide for storm damage or other emergencies.

All purchases, except in cases of unusual emergency, or where the amount involved is nominal, are required to be procured by public contracts after public advertisement for proposals with the lowest and best bidder therefor. Every effort is made to obtain the widest possible competition in all cases. Vouchers and pay rolls are required to be carefully checked, and signed certificates of performance are required on all bills, covering the receipt of the articles and the correctness of the quantity and quality. Payments on approved

vouchers are generally made by checks issued by duly bonded special disbursing agents; cash payments for salaries or wages are made to employees at the general depot.

Property records are kept of all property in offices, depots, stations, and vessels. These records are verified and audited from time to time by superintendents or by traveling representatives of the commissioner, and an annual inventory of stock at depots and property at light stations and on vessels is taken. When changes are made in the personnel having custody of property at stations and on vessels an additional inventory is required. Spare property lists are prepared annually, showing property available for transfer to other lighthouse districts, and circularized to the various offices. Property is divided into seven general classes, as follows:

Class 1. Issuable materials or supplies.
Class 2. Working equipment, fixtures, and fittings.
Class 3. Working tools for construction and repair.
Class 4. Buoys and appendages.
Class 5. Condemned articles.
Class 6. Shipments in transit.
Class 7. Office furniture and equipment.

A stock and stores account is kept of all issuable materials and supplies, and issue is made only on approved requisitions. An invoice accompanies each shipment, a copy of which must be receipted and returned to the issuing office or depot. A cost-keeping system has been in operation in this service since 1912, and reports from the various districts, showing the results, are received and summarized annually for the benefit of the service. The system was designed to show in a clear manner and with a minimum of labor and expense classified information as to the purpose for which all funds are applied. It shows the cost of maintaining each tender and light vessel of the service, and each office, depot, and principal light station; minor light stations and other aids to navigation are grouped into classes for cost-keeping purposes and the cost of each group ascertained. In all cases the costs of these units or groups are further subdivided into main headings, such as salaries, subsistence, general supplies, etc. The cost for repairs are subdivided to show hired labor, materials, and contract work separately. The results thus obtained are of value in preparing estimates, in planning work, and in comparing the efficiency of different districts, vessels, apparatus, methods, etc. A generalized summary of costs for the fiscal year ended June 30, 1922, as derived from this cost-keeping system appears on pages 106 and 107.

Summary of Costs, Lighthouse Service, Fiscal Year Ended June 30, 1922.

TOTAL COSTS OF PRINCIPAL FEATURES.

Feature.	Maintenance expenses.					Betterment expenses.					Grand total.	Per cent.
						Repairs and improvements.						
	Salaries.	Subsistence.	General supplies.	Incidental expenses.	Total.	Hired labor.	Materials.	Contract work.	New works.	Total.		
Administration [1]	$439,835	[2] $38,575	$22,448	$8,578	$509,436	.....	.....	.....	.....	.....	$509,436	5.2
Distributive charges [3]	1,682,563	338,830	955,911	42,653	3,019,860	$140,816	$126,872	$155,803	$463,539	$887,030	3,906,890	39.6
Aids to navigation [4]	2,667,124	371,656	904,549	25,165	3,968,494	245,293	303,628	94,892	842,350	1,487,163	5,455,657	55.2
Total	4,789,522	749,061	1,882,908	76,299	7,497,790	387,109	430,500	250,695	1,305,889	2,374,193	9,871,983	100.0

TOTAL COSTS OF DETAILED FEATURES.

Offices	$439,835	$38,575	$44,743	$8,578	$531,731	.....	.....	.....	.....	.....	$531,731	5.4
Depots	265,927	.....	249,097	15,461	530,485	$50,474	$46,058	$12,301	$16,307	$125,140	655,625	6.6
Tenders:												
Large	381,374	94,362	216,023	7,558	699,317	9,534	18,560	49,704	.....	77,798	777,115	7.9
Medium	905,489	215,708	419,662	17,144	1,558,003	73,566	51,669	77,327	413,578	616,140	2,174,143	22.0
Small	129,773	28,760	48,834	2,393	209,760	7,242	10,585	16,471	33,654	67,952	277,713	2.8
Total	1,416,636	338,830	684,519	27,095	2,467,080	90,342	80,814	143,502	447,232	761,890	3,228,971	32.7
Light vessels:												
Exposed	319,291	58,749	96,008	720	474,768	12,307	28,509	25,122	352,192	418,130	892,898	9.0
Moderately exposed	207,340	37,482	34,143	146	279,111	1,665	8,768	4,863	103,620	118,916	398,027	4.0
Relief	102,527	20,420	29,778	189	152,914	3,717	6,697	17,857	.....	28,271	181,185	2.0
Lakes	88,921	18,517	15,285	648	123,371	3,835	2,743	4,213	.....	10,791	134,162	1.3
Total	718,079	135,168	175,214	1,703	1,030,164	21,524	46,717	52,055	455,812	576,108	1,606,272	16.3

Light stations:												
Primary seacoast and lake lights	463,632	73,397	126,719	4,230	667,978	40,808	43,730	13,968	29,856	128,362	796,340	8.1
All other lights (except post lights)	1,180,368	163,069	277,018	13,601	1,634,056	138,082	163,269	15,924	298,128	615,403	2,249,459	22.8
Post lights	266,172	22	41,894	819	308,907	7,136	17,238	3,437	.....	27,811	336,718	3.4
Daymarks and spindles	9	.....	122	.....	131	1,375	3,453	816	.....	5,644	5,775	.....
Total	1,910,181	236,488	445,753	18,650	2,611,072	187,401	227,690	34,145	327,984	777,220	3,388,292	34.3
Buoys	38,863	.....	283,582	4,812	327,257	37,369	29,221	8,691	58,554	133,835	461,092	4.6
Grand total	4,789,522	749,061	1,882,908	76,299	7,497,790	387,109	430,500	250,695	1,305,889	2,374,193	9,871,983	100.0

AVERAGE COST OF SELECTED FEATURES.

Average cost of—	Salaries.	Subsistence.	General supplies.	Incidental expenses.	Total maintenance.	Repairs and improvements.	Total cost.
District office, exclusive of third	$16,557	$461	$352	$400	$17,770	.....	$17,770
District depot, exclusive of general depot	4,093	.....	1,696	234	6,023	$2,460	8,483
Large tender, Pacific	37,339	9,823	22,595	569	70,326	3,922	74,248
Large tender, Atlantic	38,670	9,178	20,941	881	69,670	10,352	80,022
Medium tender	27,149	6,432	12,691	474	46,462	4,738	51,200
Exposed light vessel	15,964	2,937	4,800	36	23,738	17,610	41,348
Moderately exposed light vessel	10,913	1,973	1,797	8	14,690	806	15,496
Lake light vessel	7,367	1,543	1,290	54	10,238	899	11,137
Primary seacoast light station	3,091	489	845	28	4,453	657	5,110
Other light station (except post lights)	558	77	131	6	772	150	923
Post light, river district	102	.....	8	.....	110	1	111
Post light, other district	90	.....	30	1	121	26	147

[1] Includes offices, except expenses of publications.
[2] Includes transportation and other traveling expenses.
[3] Includes depots and tenders; also item excepted above, charged to supplies.
[4] Includes light vessels, light stations, minor fixed aids, and buoys.

With reference to the cost of establishing new aids, so much depends upon the local conditions that little definite information can be given. The following approximate statements, however, furnish some idea of the prevailing range. Minor lights cost from about $50 to $15,000 each; lighthouses with quarters, and fog signal where necessary, from $40,000 to $200,000 and over per station. The light and fog signal at St. George Reef, Calif., the most expensive lighthouse thus far constructed in this country, cost over $700,000; it is on Northwest Seal Rock, 6½ miles off the northern coast of California, in the Pacific Ocean; construction was commenced in 1883, and the light first exhibited in October, 1892. Lighthouse tenders cost from $130,000 to $400,000 each, depending on their size and duty, the average medium-sized tender will cost now about $300,000. A first-class self-propelling light vessel will cost about $250,000; smaller and less powerful light vessels may be built for down to about $150,000. Lighted buoys cost from about $1,000 to $7,500 each, the larger and more expensive sizes being needed for outside stations. Whistling buoys cost about $600 each, and bell buoys about $700 each; cans and nuns, including also iron spars, range from about $85 to $300 each, depending on size, while first-class wooden spars are about $20 each, with corresponding reductions for smaller classes. The cost of moorings for buoys is not included in any type mentioned, this will vary from a few dollars to $500 and over per buoy, depending on the location and depth of water.

29. EXHIBITS OF THE LIGHTHOUSE SERVICE.

It has been the custom of the Lighthouse Service for many years to participate in various national expositions and similar occasions, by a display of various articles and equipment used in its work, illustrating some of the progress made, the apparatus or methods employed, and the results so obtained. A typical exhibit was shown at the Panama-Pacific International Exhibition, held in San Francisco during 1915.

The historic features included a collection of water colors, painted in 1859, of early light stations on the Pacific, the old 10-pounder cannon used from 1855 to 1857 at Bonita Point, Calif., being the first fog signal on the Pacific coast, the first Fresnel lens imported into this country in 1841 for use at Navesink, N. J., as well as the first lens used on the Pacific coast at Alcatraz, Calif., in 1854; also a collection of old lamps used for burning sperm oil, lard oil, and early plunger and air-pressure lamps for kerosene.

From a practical standpoint, the exhibit included photographs and models of important light stations and vessels. A modern flashing lens and lantern, with incandescent oil-vapor apparatus, also improved forms of other illuminating devices, fog-bell strikers and a

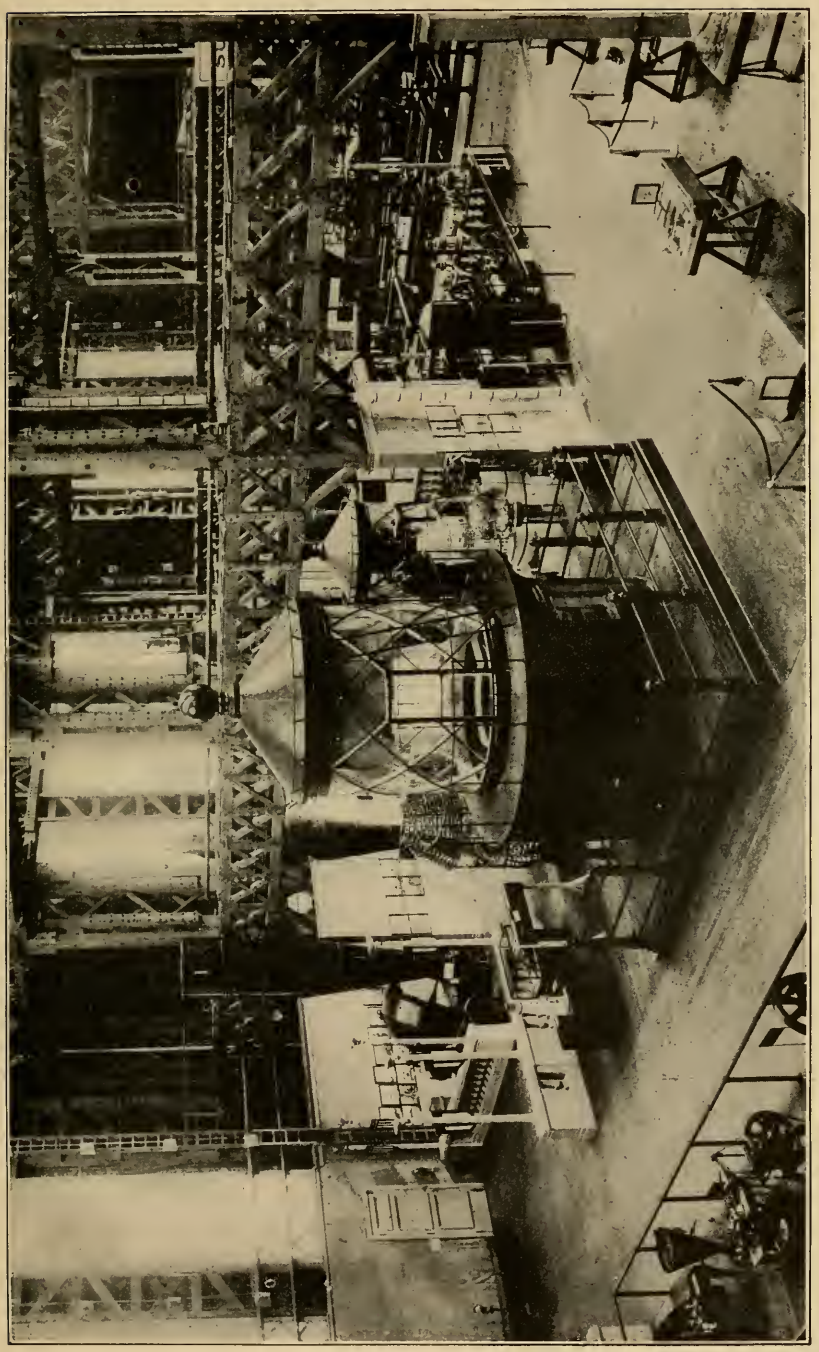


Exhibit of Lighthouse Service at San Francisco, 1915.

recent type of compressed-air fog signal, using a 6-inch siren were shown, as well as typical sizes and types of buoys, such as whistling, bell, cans, and nuns, with ballast balls, sinkers, and anchors. A special feature was the complete parapet deck, watch room, and helical bar lantern, a massive metal structure standing 29 feet high above the floor level and weighing approximately 44,000 pounds, subsequently installed at Cape St. Elias, Alaska.

A medal of honor was awarded the exhibit by the exposition authorities. Similar awards and tokens have been granted to previous exhibits made by the Lighthouse Service in past years at other expositions, among which may be mentioned the International Exposition at Vienna in 1873, the Centennial Exhibition at Philadelphia in 1876, the Third International Geographic Congress at Venice in 1881, the International Fisheries Exhibition at London in 1883, the Industrial Exhibition at Cincinnati in 1884, the World's Columbian Exhibition at Chicago in 1893, the Trans-Mississippi Exposition at Omaha in 1898, the Pan-American Exposition at Buffalo in 1901, and the Louisiana Purchase Exposition at St. Louis in 1904. Smaller exhibits have been frequently shown at various local expositions of a maritime character, and a small permanent exhibit of a few selected pieces of typical apparatus is maintained in the Washington office.

30. PAST AND PRESENT OFFICERS OF THE SERVICE.

The names of officers in direct charge of the operations of the Lighthouse Service, from the time of the establishment of the Federal Government to the present, with their respective dates of service, are given in the table below. In colonial days the management of the lights was in the hands of the local authorities of the various colonies and provinces. It should be observed that up to 1820 many matters, involving even routine business, were approved personally by the President.

Name.	From—	To—
PRIOR TO THE LIGHTHOUSE BOARD.		
Alexander Hamilton, Secretary of the Treasury	Aug. 7, 1789	May 8, 1792
Tench Coxe, Commissioner of the Revenue	May 9, 1792	Jan. 21, 1798
William Miller, jr., Commissioner of the Revenue	Jan. 22, 1798	Apr. 6, 1802
Albert Gallatin, Secretary of the Treasury	Apr. 7, 1802	July 24, 1813
Samuel H. Smith, Commissioner of the Revenue	July 31, 1813	Dec. 31, 1819
Stephen Pleasonton, Fifth Auditor of the Treasury	Jan. 7, 1820	Oct. 8, 1852
CHAIRMEN OF LIGHTHOUSE BOARD.		
William B. Shubrick, captain, U. S. Navy	Oct. 9, 1852	Feb. 7, 1859
Lawrence Kearney, captain, U. S. Navy	Feb. 7, 1859	June 6, 1859
William B. Shubrick, rear admiral, U. S. Navy	June 6, 1859	Oct. 30, 1871
Prof. Joseph Henry, LL. D. (Secretary of the Smithsonian Institution)	Oct. 30, 1871	May 13, 1878
John Rodgers, rear admiral, U. S. Navy	June 23, 1878	May 5, 1882
Robert H. Wyman, rear admiral, U. S. Navy	June 5, 1882	Dec. 2, 1882
Stephen C. Rowan, vice admiral, U. S. Navy	Jan. 18, 1883	Feb. 26, 1889
David P. Harmony, rear admiral, U. S. Navy	Feb. 27, 1889	May 29, 1891

Name.	From—	To—
CHAIRMEN OF LIGHTHOUSE BOARD—continued.		
James M. Greer, rear admiral, U. S. Navy	June 1, 1891	Dec. 1, 1894
John G. Walker, rear admiral, U. S. Navy	Dec. 4, 1894	Mar. 23, 1897
Winfield S. Schley, commodore, U. S. Navy	Apr. 5, 1897	Mar. 25, 1898
F. V. McNair, rear admiral, U. S. Navy	Apr. 4, 1898	July 5, 1898
Rush R. Wallace, commodore, U. S. Navy	July 11, 1898	Oct. 3, 1898
Francis J. Higginson, commodore, U. S. Navy	Oct. 3, 1898	Apr. 22, 1901
Norman H. Farquhar, rear admiral, U. S. Navy	May 2, 1901	May 6, 1902
George C. Remey, rear admiral, U. S. Navy	May 6, 1902	Aug. 8, 1903
John J. Read, rear admiral, U. S. Navy	Aug. 8, 1903	June 17, 1904
Robley D. Evans, rear admiral, U. S. Navy	June 20, 1904	Jan. 5, 1905
Benjamin P. Lamberton, rear admiral, U. S. Navy	Jan. 6, 1905	Feb. 25, 1906
George C. Reiter, rear admiral, U. S. Navy	Feb. 25, 1906	Dec. 31, 1907
A. Marix, rear admiral, U. S. Navy	Jan. 6, 1908	June 30, 1910
COMMISSIONER OF LIGHTHOUSES.		
George R. Putnam	July 1, 1910	.....

At the present time the law requires that many important matters affecting the service must receive the approval of the Secretary of Commerce.

The work of the service is performed under the supervision of the Secretary of Commerce, Herbert Hoover, Mem. Am. Inst. M. E., Mem. Am. Soc. C. E.

The present principal officers of the service are George R. Putnam, Mem. Am. Soc. C. E., Commissioner of Lighthouses; John S. Conway, Mem. Am. Soc. M. E., Mem. Am. Soc. C. E., Deputy Commissioner; H. B. Bowerman, Mem. Am. Soc. C. E., chief constructing engineer; and Edward C. Gillette, Mem. Soc. N. A. and M. E., superintendent of naval construction.

The superintendents of lighthouses, with the duty or district assigned to each, were as follows on March 1, 1923:

District.	Superintendent.	District.	Superintendent.
General duty	Everett M. Trott.	Thirteenth	Maj. B. C. Dunn, Corps of Engineers, U. S. Army, Assoc. Mem Am. Soc. C. E.
First	Carl E. Sherman.	Fourteenth	Lieut. Col. E. N. Johnston, Corps of Engineers, U. S. Army, Mem. Am. Soc. C. E.
Second	George E. Eaton.	Fifteenth	Col. C. L. Potter, Corps of Engineers, U. S. Army, Mem. Am. Soc. C. E.
Third	Joseph T. Yates, Mem. Soc. N. A. and M. E.	Sixteenth	Walter C. Dibrell.
Fourth	Benj. B. Dorry.	Seventeenth	Robert Warrack.
Fifth	Harold D. King.	Eighteenth	Harry W. Rhodes, Mem. Am. Soc. C. E.
Sixth	Henry L. Beck.	Nineteenth	Ralph R. Tinkham, Assoc. Mem. Am. Soc. C. E.
Seventh	Wm. W. Demeritt.		
Eighth	Edward S. Lanphier, Assoc. Mem. Am. Soc. C. E.		
Ninth	Fred P. Dillon.		
Tenth	Roscoe House.		
Eleventh	Edward L. Woodruff, Mem. Am. Soc. C. E.		
Twelfth	Charles H. Hubbard.		

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