The Modern Light-House Service

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Arnold Burges Johnson

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MODERN LIGHT-HOUSE SERVICE.

BY

ARNOLD BURGES JOHNSON,
CHIEF CLERK,
UNITED STATES LIGHT-HOUSE BOARD.

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LETTER OF TRANSMITTAL.

TREASURY DEPARTMENT,
OFFICE OF THE LIGHT-HOUSE BOARD,
Washington, September 14, 1889.

SIR: At the request of Hon. Warner P. Sutton, chief clerk of the International American Congress, made in his note of August 8, 1889, I have prepared, and inclose for the use of that Congress, a paper on The Modern Light-House Service. The short time allowed must serve as my apology for failing to give this subject the more thorough treatment it deserves.

I am, sir, with great respect, your obedient servant,

A. B. JOHNSON.

Hon. JAMES G. BLAINE,
Secretary of State, Washington, D. C.

PREFACE.

During the preparation of this work I consulted and drew more or less freely upon my previous professional papers, published in Appleton's Annual Cyclopedias, and in the Popular Science Monthly, for which due credit is given in the text. Findlay's Light-Houses of the World, the Admiralty Lists, and the Sailing Directions issued by the Navy Department furnished me with the statements as to light-houses of the various nationalities. The account of the light-dues charged by other countries than Great Britain and the United States is based upon the pages of Urquhart's Dues and Charges on Shipping in Foreign Parts and the book on Port Charges of the World, by Messrs. Hunter and Patten. The Hydrographer of the Navy and the naval officers under him have placed me under many obligations, as have the officers of the Department of State and the Bureau of Navigation of the Treasury Department, and I have availed myself of Heap's Ancient and Modern Light-Houses, Barnard on Light-Houses, and the published reports of the Light-House Board. But with all this help I should not have been able to finish this paper in the short time allowed me but for the intelligent assistance of Mr. E. S. How, of this office. The labor could only be performed at night, after the current work of the day had been accomplished, and there has been little opportunity for revision.

A. B. J.

WASHINGTON, D. C., *September* 14, 1889.

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CHAPTER I.

ITS RISE, GROWTH, AND NEEDS.

Science has made wonderful progress during the last quarter of a century, but in no way more than in pharology. The light-house engineer has marked the spread of commerce and civilization by the evidences of his skill. These are now so highly appreciated that the time must come when all the prominent points of the coasts of the world will be marked with beacons by day and with lights by night, thus transforming them from dangers to guardian monitors for the mariner.

It is impossible to say when, in the age of man, guiding lights first came into use. It is claimed by some that Homer refers to light-houses in these lines:*

Ὡς δ' ὅτ ἂν ἐκ πόντοιο σέλας ναύτῃσι φανήῃ
Καιομένοιο πυρός τὸ δὲ καίεται ὑψόθ' ὄρεσφιν,
Σταθμῷ ἐν οἰοπόλῳ τους δ' οὐκ εθέλοντας ἄελλαι
Πόντον ἐπ' ἰχθυόεντα φίλων ἀπάνευθε φέρουσιν.

Ἰλιάδος XIX: 375–379.

It is also claimed that Virgil had knowledge of light-houses, and that he stated that one was placed on a tower of the temple to Apollo, on Mount Leucas, "the light of which, visible far out at sea, warned and guided mariners," Others say that the Colossus of Rhodes, erected about 300 B. C., showed from his uplifted hand a signal light. But the famous Pharos of Alexandria, built about 285 B. C., is the first light of undoubted record. Other lights were shown from towers at Ostia, Ravenna, Apamea, and other places mentioned by Pliny, Suetonius, and Byzantinus. The light-house at Corunna, Spain, is believed to be the oldest existing light-tower. This was built in the reign of Trajan, and in 1634 it was reconstructed.

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* Pope translates these lines thus:

So to night-wandering sailors pale with fears
Wide o'er the watery waste a light appears,
Which on the far-seen mountain blazing high
Streams from lonely watch-tower to the sky.

—*Pope's Iliad*, xix: 405–9.

It is well for us, who owe so much to old Spain, to remember that not the least of the things for which we must be grateful is this example which she still retains for our encouragement. Let us aim to transmit the light she has brought down to us as far into the future as she has brought it from the past.

While Spain has the oldest existing light-house, England and France each have towers erected by their Roman conquerors, which were used as light-houses, and the ages from thence down to us have other towers to show that the art of building for the benefit of the fire-worshipers of commerce has lost nothing with the lapse of time.

Europe having at one time the commerce of the world, naturally provided so well for it that its light-house system, especially in its western part, leaves little to be desired. The New World has taken a lesson from the Old, and has welcomed all commerce by its beacon fires. Where much has been given much has been required, and light-houses have sprung up where they have been most needed. Commerce has been bold and has searched out the dark corners of the world, but it stays longest where it is most welcomed and best entertained. Where there are light-houses there comes ships; some may come where there are no lights, but with the welcome rays come the many and the richly laden.

The famous Cordouan Tower, at the mouth of the Gironde, in the Bay of Biscay, was the work of Louis de Foix. It was completed in 1611, in the reign of the great Henry IV, of France, and was twenty-six years in building. It is 197 feet high, and consists of successive galleries, enriched with pilasters and friezes. Round the base is a circular building, 134 feet in diameter, in which are the light-keeper's apartments, and which also forms a sort of outwork to break the force of the waves against the main building. The tower itself contains a chapel and numerous apartments, and is ascended by a spiral staircase. It has been modified and adapted to the modern system of lighting; and, after a lapse of more than two hundred and fifty years, it is still considered the finest light-house in the world.

The erection of the Eddystone Light-house off Plymouth, England, formed an era in the construction of light-houses. The masonry was 76 feet 6 inches, and the top of the lantern 93 feet above the foundation. It was completed in 1759. The various courses were so dovetailed into each other, and the whole fifty secured together, that the tower was almost as solid as if cut out of the solid block. Immense difficulties had to be overcome from the first landing on the rock on April 5, 1756, to the laying of the first stone, June 12, 1757, and the last, on August 24, 1759. But strong as it was, it became necessary to take it down and rebuild it on a neighboring rock, as that on which it was founded was weakened from the constant assaults of the sea. This was safely done within our own time.

The next English light-house of a similar nature is the equally famous Bell Rock Light-house. It was commenced in 1807, finished in 1810, and illuminated in February, 1811. The tower is 100 feet high, and cost £60,000.

A later, and the most noble, erection of this kind is that on the Skerryvore Rock, off the west coast of Scotland. This cost in its erection, with the harbor for the tender, and other necessaries, £87,000, and was first illuminated in 1844.

Another grand light-house of this nature, and also one of the most important in the British list, is that on the Bishop Rock, off Scilly, 145 feet high, built at an expense of £36,500.

The light-house at Carlingford, on the east coast of Ireland, the foundation of which is 12 feet below high water, is an analogous structure, 111 feet in height, though not in such an exposed situation, and was finished in 1830.

Another noble and ornamental light-house is on the west coast of France, on the Héhaux de Brehat. It is nearly as high as the Skerryvore, and is deserving of all admiration.

The Wolf Rock Light-house, off Land's End, Cornwall, Wales, is the latest great British work, and both in its structure and its illumination it combines all the refined improvements. A survey was made in 1861, and the foundation commenced in March, 1862. In the first season only eighty-three hours of work could be done, and between that and its completion, on July 19, 1869, there were in the eight working seasons two hundred and ninety-six landings on the rock, and the time occupied was equal to about one hundred and one working days of ten hours each. The cost was £62,726.

The great distinction between the later towers and their predecessors is that the stones of each course are dovetailed together laterally and vertically, so that the use of metal or wooden pins is needless. This method was first used at the Hanois Rock, Guernsey. On the upper face, and at one end of each block, is a dovetailed projection; and on the under face, and at the other end, is a dovetailed indentation. The upper and under dovetails are made just to fall into each other, and when the hydraulic cement is placed on the surface it so locks the dovetailing that the stones can not be separated without breaking. Thus, when this cement is set and hardened, the whole of the base is literally one solid mass of granite. The lower courses for the first 39 feet of the Wolf Rock Light-house have fillets on their outer edges, into which the upper course is stepped, and this prevents the action of the waves from penetrating the joint.

THE COMMERCE OF THE WORLD.

The commerce of the world is enormous, but it is unevenly distributed. The following table prepared by the Navigation Bureau of the Treasury Department, presents it by nations:

Tonnage of the world up to December 31, 1888.

[Vessels under 100 tons and yachts excluded, also the lake and river tonnage of the United States. Net tonnage sailing vessels, gross of steam-vessels.]

British	10,829,202	Mexican	7,416
American (United States)	1,918,1/5	Montenegrin	2,464
Argentine	36,913	Norwegian	1,456,264
Austro-Hungarian	276,294	Persian	838
Belgian	111,934	Peruvian	13,182
Bolivian	3,803	Portuguese	77,808
Brazilian	144,649	Roumanian	529
Chilian	91,253	Russian	417,653
Chinese	45,188	Sarawak	2,217
Colombian	986	Siamese	10,318
Costa Rican	816	Spanish	537,781
Danish	259,409	Swedish	462,392
Dutch	356,081	Turkish	217,068
French	984,946	Uruguayan	8,927
German	1,409,838	Venezuelan	3,758
Greek	291,120	Zanzibar	4,723
Hawaiian	22,544	Other countries	16,177
Haytian	4,390		
Italian	846,901	Total	21,048,704
Japanese	174,747		

The whole number of lights in the world is, in round numbers, about six thousand, of which some two hundred and fifty are shown from light-ships.

The following tables, made up from the British Admiralty Lists, will show their distribution. This statement only approximates exactness, but it is the best that is at present attainable. It is collated from statements which are from one to five years old, so it is quite likely that the difference between its sum and the number mentioned above may have been made up by this time.

Number of light stations in the different portions of the world.

Europe	3,309
North America	1,329
Asia	476
Oceanica	319
Africa	219
South America	167
West Indies	106
Total	5,925

These lights are distributed as follows:

Europe:		
Great Britain and Ireland		817
France:		
North coast	170	
West coast	171	
South coast	79	
Corsica	24	
		444

Sweden:		
West coast	53	
East coast	214	
The Sound	28	
		295
Italy:		
West and southwest coast	116	
East coast	58	
Sicily	50	
Sardinia	20	
		244
Norway		220
Spain:		
North and west coasts	63	
South coast	23	
South and east coasts	101	
		187
Germany:		
North Sea	78	
Baltic Sea	101	
		179
Turkey:		
West coast	50	
Archipelago	83	
Dardanelles	12	
Sea of Marmora	9	
Bosphorus	14	
		168
Netherlands:		
Coast	122	
Zuider Zee	44	
		166
Russia:		
Coast	130	
White Sea	13	
Azov Sea	11	
		154
Denmark:		
Coast	126	
Iceland	6	
		132
Black Sea (Russia and Turkey)		88
Portugal		29
Belgium		18
		3,309
North America:		
United States (exclusive of post lights)—		
Atlantic coast	467	
Gulf coast	79	
Pacific coast	38	
Northwestern Lakes	218	
		802
Dominion of Canada:		
Labrador	5	
Cape Breton	50	
Islands in the Gulf of St. Lawrence	12	
Prince Edward's Island	47	
Gulf and river St. Lawrence	183	
Nova Scotia	65	
Bay of Fundy, Nova Scotia	34	
Bay of Fundy, New Brunswick	32	
British Columbia	10	
		443
Newfoundland		51
Mexico		15
British Honduras		7
Costa Rica		3

North America—Continued.	
Honduras	3
San Salvador	3
Nicaragua	1
Guatemala	1
	1,329
Asia:	
China	81
Hindustan	78
Eastern Archipelago	75
Japan	67
Bay of Bengal	30
Straits of Malacca	29
Turkey in Asia, and Syria	28
Philippine Islands	26
Red Sea	15
Gulf of Tartary	14
Ceylon	10
Gulf of Aden	7
Gulf of Suez	7
Cochin China	6
Siam	2
Corea	1
	476
Oceanica:	
Australia	203
New Zealand	79
Tasmania	12
Sandwich Islands	8
Fiji Islands	8
Society Islands	3
Samoa and Friendly Islands	3
New Caledonia	2
Caroline Islands	1
	319
Africa:	
Algeria	48
West and south coasts	44
Egypt	26
East coast	25
Canary Islands	13
Cape Verde Islands	12
Tunis	12
Morocco	6
Tripoli	5
Réunion Islands	5
Azores Islands	4
Mauritius	4
Madagascar	4
Zanzibar	4
Cormora Islands	3
Madeira Islands	2
Seychelle Islands	2
	219
South America:	
Brazil	65
Chili	21
Uruguay	16
Argentine	12
United States of Colombia	10
Venezuela	10

South America—Continued.

Peru	10
Ecuador	9
British Guiana	6
French Guiana	5
Dutch Guiana	3
	167

West Indies:

Windward Islands	44
Cuba	21
Leeward Islands	18
Bahama Islands	15
Curaçao, Buen Ayre, and Oruba Islands	6
Bermuda	2
	106

Chapter II.

COST TO THE UNITED STATES.

The theory of coast lighting is that each coast shall be so set with towers that the rays from their lights shall meet and pass each other, so that a vessel on the coast shall never be out of sight of a light, and that there shall be no dark spaces between lights. This is the theory upon which the United States is proceeding, and it plants lights where they are most needed upon those lines. Hence from year to year the length of the dark spaces on its coasts is lessened or expunged entirely, and the day will come when all its coasts will be defined from end to end by a band of light by night and by well-marked beacons by day.

In the first century of its existence the Light-House Establishment of the United States will have cost about ninety-three and a quarter millions of dollars, as will appear from the following tabular statement, which is taken from the publications of the Treasury Department:

Amount expended by the United States in support of its Light-House Establishment each year from 1791 *to* 1890, *inclusive.*

1791	$22,591.94	1825	183,553.55	1859	1,257,619.20
1792	38,976.36	1826	188,941.33	1860	994,093.82
1793	12,061.68	1827	306,918.17	1861	894,302.63
1794	37,496.36	1828	253,727.94	1862	661,370.52
1795	29,861.30	1829	277,274.06	1863	873,230.52
1796	35,207.48	1830	233,112.81	1864	948,159.51
1797	48,174.47	1831	320,718.97	1865	1,215,917.07
1798	52,906.18	1832	256,642.39	1866	1,370,396.06
1799	69,509.15	1833	313,809.73	1867	2,176,632.36
1800	40,633.68	1834	296,792.25	1868	2,590,101.62
1801	81,429.95	1835	350,468.62	1869	1,910,674.12
1802	68,928.85	1836	343,560.95	1870	2,582,203.78
1803	75,787.95	1837	414,009.39	1871	2,675,322.63
1804	93,775.82	1838	476,920.12	1872	3,166,672.44
1805	122,029.74	1839	770,256.62	1873	2,910,961.64
1806	88,993.38	1840	594,627.69	1874	2,493,182.06
1807	86,582.63	1841	458,372.36	1875	2,925,353.77
1808	90,051.98	1842	397,658.99	1876	2,703,280.12
1809	83,140.74	1843	187,178.99	1877	2,367,220.70
1810	94,037.74	1844	287,089.30	1878	2,193,893.33
1811	114,970.79	1845	443,658.88	1879	2,343,638.64
1812	126,603.12	1846	403,126.81	1880	2,426,370.61
1813	128,144.38	1847	514,891.58	1881	2,642,668.99
1814	78,961.46	1848	652,340.04	1882	2,392,147.12
1815	48,816.78	1849	630,191.49	1883	2,224,432.30
1816	108,369.52	1850	909,133.44	1884	2,330,549.57
1817	122,187.29	1851	750,464.64	1885	2,284,868.97
1818	162,067.51	1852	710,754.07	1886	2,073,358.91
1819	115,350.79	1853	956,026.39	1887	2,143,719.22
1820	163,656.34	1854	1,310,978.42	1888	2,556,733.51
1821	149,440.22	1855	1,836,058.41	1889	2,597,400.00
1822	144,991.38	1856	1,754,808.09	1890	*3,503,994.12
1823	207,913.23	1857	2,001,474.70		
1824	153,419.96	1858	1,925,844.60	Total	93,238,925.80

*This is the amount appropriated for the fiscal year to end June 30, 1890, and it will doubtless be all expended.

APPROPRIATIONS.

The following list of the appropriations, amounting to more than $3,500,000, made by the second session of the Fiftieth Congress, and approved on March 2, 1889, will show the exact and minute care exercised by Congress over the United States Light-House Establishment:

DEFICIENCIES.

AN ACT making appropriations to supply deficiencies in the appropriations for the fiscal year ending June thirtieth, eighteen hundred and eighty-nine, and for prior years, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following sums be, and the same are hereby, appropriated, out of any money in the Treasury not otherwise appropriated, to supply deficiencies in the appropriations for the fiscal year eighteen hundred and eighty-nine; and for prior years, and for other objects hereinafter stated, namely

* * * * * * *

LIGHT-HOUSE ESTABLISHMENT.

Keepers of Light-Houses: To reimburse the appropriation for salaries of keepers of light-houses the amount paid and to be paid for salaries of the additional employees authorized in the office of the Light-House Board by the legislative, executive, and judicial appropriation act for the fiscal year eighteen hundred and eighty-nine, but not appropriated for therein, nineteen thousand seven hundred dollars.

Repairs of Light-Houses: For repairing, rebuilding, and improving light-houses and buildings, for improvements to grounds connected therewith; for establishing and repairing pier-head lights; for illuminating apparatus and machinery to replace that already in use, and for incidental expenses relating to these various objects, forty thousand dollars.

Point Sur Light-Station, California: For completing the light-house and fog-signal at Point Sur, California, including one thousand five hundred dollars for right of way and water privilege, ten thousand dollars.

Northwest Seal Rock Light-Station, California: For continuing the construction of a light-house on Northwest Seal Rock, off Point Saint George, California, two hundred thousand dollars.

Duluth Harbor, Minnesota: For establishing range-lights at Duluth Harbor, three thousand two hundred and eighty-four dollars and twelve cents.

* * * * * * *

CLAIMS ALLOWED BY THE FIRST AUDITOR AND COMMISSIONER OF CUSTOMS.

* * * * * * *

For repairs of light-houses, one dollar.

* * * * * * *

For Light-House Establishment, eighteen hundred and sixty one and eighteen hundred and sixty-two, two hundred and sixty-one dollars and ninety-six cents.

* * * * * * *

Approved, March 2, 1889.

LEGISLATIVE, EXECUTIVE, AND JUDICIAL.

AN ACT making appropriations for the legislative, executive, and judicial expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following sums be, and the same are hereby, appropriated, out of any money in the Treasury not otherwise appropriated, in full compensation for the service of the fiscal year ending June thirtieth, eighteen hundred and ninety, for the objects hereinafter expressed, namely:

* * * * * * *

Light-house Board: For chief clerk of the Light-House Board, two thousand four hundred dollars; two clerks of class four; two clerks of class three; one clerk of class two; three clerks of class one; one clerk, at nine hundred dollars; two assistant messengers; in all, sixteen thousand five hundred and forty dollars.

For the following additional employees in the Office of the Light-House Board, who shall be paid from the appropriations for the Light-House Establishment, namely: One clerk of class two, who shall be a stenographer; one clerk of class one; nine clerks at nine hundred dollars each; one laborer, six hundred dollars; one assistant civil engineer, two thousand four hundred dollars; one draughtsman, one thousand eight hundred dollars; one draughtsman, one thousand five hundred and sixty dollars; one draughtsman, one thousand four hundred and forty dollars; and one draughtsman, one thousand two hundred dollars; in all, nineteen thousand seven hundred dollars.

* * * * * * *

Approved, February 26, 1889.

SUNDRY CIVIL.

AN ACT making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following sums be, and the same are hereby, appropriated for the objects hereinafter expressed for the fiscal year ending June thirtieth, eighteen hundred and ninety, namely:

* * * * * * *

LIGHT-HOUSE ESTABLISHMENT.

Supplies of Light-Houses: For supplying light-houses, beacon-lights, and fog-signals with illuminating, cleansing, preservative, and such other materials as may be required for annual consumption, for books, boats, and furniture for stations, and other incidental expenses, three hundred and forty thousand dollars.

Repairs of Light-Houses: For repairing, rebuilding, and improving light-houses, and buildings, for improvements to grounds connected therewith; for establishing and repairing pier-head lights; for illuminating apparatus and machinery to replace that already in use, and for incidental expenses relating to these various objects, three hundred and thirty-five thousand dollars.

Salaries of Keepers of Light-Houses: For salaries, fuel, rations, rent of quarters where necessary and similar incidental expenses of not exceeding one thousand one hundred and fifty light-house and fog-signal keepers, six hundred and twenty-five th

Expenses of Light-Vessels: For seamen's wages, rations, repairs, salaries, supplies, and incidental expenses of light-ships, two hundred and fifteen thousand dollars.

Expenses of Buoyage: For expenses of establishing, replacing, and maintaining buoys, spindles, and day-beacons, and for incidental expenses relating thereto, three hundred and twenty-five thousand dollars.

Expenses of Fog-Signals: For establishing, replacing, duplicating, and improving fog-signals and buildings connected therewith, and for repairs and incidental expenses of the same, sixty thousand dollars.

Inspecting Lights: For mileage and traveling expenses of members of the Light-House Board, including rewards paid for information as to collisions, and for the apprehension of those who damage light-house property, three thousand dollars.

Lighting of Rivers: For establishing, supplying, and mantaining post-lights on the Hudson and East Rivers, New York; the Raritan River, New Jersey; the Delaware River, between Philadelphia and Bordentown, New Jersey; Connecticut River, Connecticut; the Elk River Maryland; Cape Fear River, North Carolina; Savannah River, Georgia; Saint John's and Indian Rivers, Florida; at the mouth of Red River, Louisiana; at Chicott Pass, and to mark navigable channel along Grand Lake, Louisiana; on the Mississippi, Missouri, Ohio, Tennessee, Illinois, and Great Kanawha Rivers; on the Columbia and Willamette Rivers, Oregon; Sacramento and San Joaquin Rivers, California: and on Puget Sound, Washington Sound, and adjacent waters, Washington Territory; the Light-House Board being hereby authorized to lease the necessary ground for all such lights and beacons as are for temporary use or are used to point out changeable channels, and which in consequence can not be made permanent, two hundred and fifty-four thousand dollars.

Survey of Light-House Sites: For preliminary examinations, surveys, and plans for determining the proper sites and cost of light-houses and structures for which estimates are made to Congress, one thousand dollars.

COAST AND GEODETIC SURVEY.

* * * * * * *

For traveling expenses of officers and men of the Navy on duty, and for any special surveys that may be required by the Light-House Board or other proper authority, and contingent expenses incident thereto, three thousand dollars.

* * * * * * *

LIGHT-HOUSES, BEACONS, AND FOG-SIGNALS.

Mount Desert Rock Fog-Signal, Maine: For establishing complete a fog-signal upon Mount Desert Rock, off the coast of Maine, four thousand five hundred dollars.

Bear Island Light-Station, Maine: For building a new keeper's dwelling at Bear Island Light-Station, Maine, three thousand seven hundred and fifty dollars.

Great Duck Island Light-Station, Maine: For establishing a light and fog-signal on Great Duck or Long Island, Maine, thirty thousand dollars.

Great Round Shoal Light-Ship, Massachusetts: For establishment of a light-ship with a fog-signal to mark the channel through Great Round Shoal, near Nantucket, Massachusetts, sixty thousand dollars.

Steam-tender for the second light-house district: For a new steam-tender for service in the second light-house district, eighty thousand dollars; said amount to be expended under the direction of the Secretary of the Treasury: *Provided*, That the construction of said tender shall be let to the lowest responsible bidder, after advertisement, and said tender shall be built in an American ship-yard.

Beaver Tail Fog-Signal, Rhode Island: For the purchase of land required for the Beaver Tail (Rhode Island) fog-signal station, and the payment of the necessary expenses incident to such purchase, three thousand five hundred dollars, or so much thereof as may be necessary.

Castle Hill Light-Station, Rhode Island: For the construction of the light-house at Castle Hill, Rhode Island, five thousand dollars, additional to the sum already appropriated.

Coney Island, New York: For establishing a light or lights, and a fog-signal on the western end of Coney Island, New York, twenty-five thousand dollars.

Sandy Hook Light-Ship, New Jersey: For the construction and establishment of a light-ship with a fog-signal, for the Sandy Hook station, entrance to New York Harbor, sixty thousand dollars.

Squan Inlet Light-station, New Jersey: For the establishment complete of a light about midway between Barnegat and Navesink, New Jersey, twenty thousand dollars.

Shark's Fin Shoal Light-Station, Maryland: For establishing a light on Shark's Fin Shoal, Maryland, to take the place of Clay Island Light, twenty-five thousand dollars.

Greenbury Point Shoal Light-Station, Maryland: For establishing a light on the shoal off Greenbury Point, Maryland, to replace the one on the point, twenty-five thousand dollars.

Bush's Bluff Light-Ship, Virginia: For establishing a light-ship and fog-signal at or near Bush's Bluff Shoal, Elizabeth River, near Norfolk, Virginia, in addition to the balance remaining of the appropriation made by the act approved March third, eighteen hundred and eighty-five, for a light-house and fog-bell on Bush's Bluff, which is hereby made available for the same purpose, forty thousand dollars.

Hog Island Wharf and Roadway, Virginia: For establishing complete a wharf and roadway to the light-house at Hog Island, Virginia, five thousand dollars.

Diamond Shoal Light-Station, North Carolina: For the establishment of a light-house on Outer Diamond Shoal, off Cape Hatteras, North Carolina, two hundred thousand dollars: *Provided*, That the contract for the construction of the same may be let, for the entire structure at a total cost of not exceeding five hundred thousand dollars, in the discretion of the Light-House Board, with the approval of the Secretary of the Treasury.

Pamlico Light-Station, North Carolina: For establishing complete a light off Pamlico Point, North Carolina, to replace the one on the point, twenty-five thousand dollars.

Gull Shoal Light-Station, North Carolina: For establishing complete a light and fog-signal on Gull Shoal, west side of Pamlico Sound, North Carolina, thirty thousand dollars.

Bull's Bay Beacon, South Carolina: For establishing a small beacon-light at Bull's Bay, South Carolina, sixty dollars.

Fernandina Harbor Range-Lights, Florida: For the establishment of one or more sets of range-lights to guide into the harbor of Fernandina, Fla., one thousand seven hundred and fifty dollars.

Pascagoula River Ranges, Mississippi: For establishing range-lights, to guide into the mouth of the Pascagoula River, Mississippi, one thousand dollars.

Pearl River Light-Station, Mississippi: For the establishment of a light on the east bank of Pearl River, opposite the draw in the railway bridge, two hundred and fifty dollars.

Point Isabel Light-Station, Texas: For reëstablishing the light on Point Isabel, and the purchase of land therefor, entrance to Brazos Santiago, Texas, eight thousand dollars.

Roe Island Light-Station, California: For establishing complete a light house and fog-signal on Roe Island, Suisun Bay, California, ten thousand dollars.

For the purchase of a site and the construction of a first-order coast light-house at or near Heceta Head, at or near the mouth of the Siuslaw River, Oregon, eighty thousand dollars.

For connecting the Tillamook Rock (Oregon) light-station by telegraph cable, and a land telegraph line, with Fort Stevens (Point Adams) Oregon, six thousand dollars.

Columbia River Light-Ship, Oregon: For establishing a light-ship with steam fog-signal to mark the bar at the mouth of the Columbia River, Oregon, sixty thousand dollars.

For establishing complete a light-house and fog-signal on the easterly end of the outer breakwater at Chicago, Lake Michigan, Illinois, without regard to the completion of said breakwater, thirty-six thousand dollars.

Twin River Point Fog-Signal, Wisconsin: For establishing complete a steam fog-signal upon Twin River Point, Lake Michigan, Wisconsin, five thousand five hundred dollars.

Point Peninsula Light-Station, Michigan: For crib-work protection for boat-house and landing at Point Peninsula Light-Station, Michigan, two thousand dollars.

Simmon's Reef Light-Station, Wisconsin: For establishing complete a light and fog-signal on Simmon's Reef, Michigan, sixty thousand dollars.

Beaver Island Fog-Signal, Michigan: For establishing complete a fog signal at Beaver Island, Lake Michigan, five thousand five hundred dollars.

Manistee Fog-Signal, Michigan: For establishing complete a steam fog-signal at Manistee light station, Lake Michigan, Michigan, five thousand five hundred dollars.

Cleveland Breakwater Fog-Signal, Ohio: For establishing complete a steam fog-signal on the breakwater at Cleveland, Ohio, five thousand two hundred dollars.

Grosse Isle Ranges, Michigan: For the establishment of range-lights on Grosse Isle, Detroit River, Michigan, seven thousand dollars.

Lake Saint Clair Ranges, Michigan: For establishing range and stake lights in Lake Saint Clair, from Grosse Point to the entrance of Detroit River, Michigan, three thousand dollars.

Saint Clair River Ranges, Michigan: For establishing range-lights to guide through Saint Clair River, Michigan, one thousand five hundred dollars.

Presque Isle Fog-Signal, Michigan: For establishing complete a steam fog-signal at Presque Isle, Lake Huron, Michigan, five thousand five hundred dollars.

Cheboygan Fog-Signal, Michigan: For establishing complete a steam fog-signal at Cheboygan, opposite Boise Blanc Island, Straits of Mackinac, Michigan, five thousand five hundred dollars.

Old Mackinac Point Light-Station, Michigan: For establishing complete a fog-signal at Old Mackinac Point, Michigan, five thousand five hundred dollars.

Point Iroquois Fog-Signal, Michigan: For establishing complete a steam fog-signal at Point Iroquois, Lake Superior, Michigan, five thousand five hundred dollars.

La Pointe Fog-Signal, Michigan: For establishing complete a steam fog-signal at La Pointe, (Point Chequamegon), entrance to Ashland Harbor, Lake Superior, Michigan, five thousand five hundred dollars.

Devil's Island Light-Station, Wisconsin: For establishing complete a light at Devil's Island, Apostle Group, Lake Superior, Wisconsin, fifteen thousand dollars.

Two Harbors Fog Signal, Minnesota: For establishing complete a steam fog-signal at Two Harbors, Lake Superior, Minnesota, five thousand five hundred dollars.

STEAM-TENDER FOR THE LAKES.

Steam-tender for the Great Lakes: For a steam-tender for service on the Northern Lakes, eighty-five thousand dollars; said amount to be expended under the direction of the Secretary of the Treasury: *Provided*, That the construction of said tender shall be let to the lowest responsible bidder after advertisement, and that said tender shall be built in an American ship yard.

Approved, March 2, 1889.

As it is evident that each of the nations represented in this Congress is doing what it can to light its coasts, and as each is concerned in ascertaining the best methods, it has been deemed that it would at least be interesting, and perhaps timely, to give some account of the process by which the United States has within her borders an eighth part of all the lights which encircle the globe, and more than a proportionate share of the other aids to navigation which come under the control of Light-House Establishments.

Chapter III.

THE LIGHT-HOUSE ESTABLISHMENT OF THE UNITED STATES.

The light-house system of this country commenced with its commerce There is little doubt but that the early colonists recognized the necessity for beacons with which to guide their home-returning shallops to a safe anchorage, and that they took effective means to show the English and Dutch ships which should make their landfall at night the safe way to their harbor. But the first authentic evidence of this being done at the public charge is the record of the proceedings of the general court of the Province of Massachusetts Bay, from which it appears that on March 9, 1673, a petition came from the citizens of Nantasket, Massachusetts (now Hull), for the lessening of their taxes, because of the material and labor they had expended, over and above their proportion, in building the beacon on Point Allerton, the most prominent headland near the entrance to Boston harbor. At that session also it appears that bills from Nantasket were paid for making and furnishing "fier-bales of pitch and ocum for the beacon at Allerton Point," which "fier-bales" were burned in an iron grate or basket on the top of a beacon, for the building of which Nantasket had furnished 400 boat-loads of stone.

The first light-house on this continent was built at the entrance to Boston Harbor, on Little Brewster Island, in 1715–'16, at a cost of £2,285 17*s.* 8½*d.* It was erected by the order and at the expense of the general court of the Province of Massachusetts Bay, and it was supported by light-dues of 1*d.* per ton on all incoming and outgoing vessels, except coasters, levied by the collector of imports at Boston.

The frontispiece is a photograph of an engraving of this light, and with it is shown one of the first light-house tenders, a pinnace of some tonnage.

The maritime colonies followed the example of Massachusetts, and when the United States, by the act of August 7, 1789, accepted the cession of the title to, and joint jurisdiction over, the light-houses on the coast, and agreed to maintain them thereafter, they were eight in number, and comprised the following lights, all of which are still in existence, though so greatly improved that they are the same only in purpose and in site:

Portsmouth Harbor Light, New Hampshire; Boston Light, on Little Brewster Island; the Gurnet Light, near Plymouth, Massachusetts; Brant Point Light, on Nantucket, Massachusetts; Beaver Tail Light, on Conanicut Island, Rhode Island, in Narragansett Bay; Sandy Hook Light, New Jersey, entrance to New York Harbor; Cape Henlopen, Delaware, at the entrance to Delaware Bay; Charleston Main Light, on Morris Island, entrance to the harbor of Charleston, South Carolina.

When the lights came into the possession of the Federal Government, they were placed under the direction of the Secretary of the Treasury, who seems to have given them his personal attention, but to have taken no important action without the direct approbation of the President.

As an instance of this, the following letter, the original of which hangs in the office of the Light-House Board, is here given:

MOUNT VERNON, *October* 12, 1790.

SIR: I have received your letter of the 5th instant. The public service requiring the arrangement which you have made relative to the light-houses of Newport and Portland, they are perfectly agreeable to me, and receive my approbation. I am, sir, your most obedient servant,

GEORGE WASHINGTON.

TO ALEXANDER HAMILTON, Esq.,
Secretary of the Treasury of the United States.

On May 8, 1792, the office of Commissioner of Revenue was established, and the superintendence and control of the lights were devolved upon him. On April 6, 1802, this office was abolished, when the then Secretary of the Treasury, Mr. Gallatin, resumed the control of the lights. Their management remained in the Secretary himself, who gave it much of his personal attention, until July 24, 1813, when, on the re-establishment of the office of Commissioner of the Revenue, the control of the lights became again a part of his work. That office was a second time abolished by the act of December 23, 1817, which went into operation on July 1, 1820, when all its duties, including those of superintending the lights, were devolved on the Fifth Auditor of the Treasury. During these thirty years that had elapsed since the lights had come under the control of the General Government, the number had been increased, under Congressional enactment, from 8 to 55; and each seems to have been built to meet immediate and pressing local want, and without reference to any general system.

The Fifth Auditor, Mr. Stephen Pleasanton, who was popularly known as the general superintendent of lights, accepted that duty in 1820, and continued in charge until 1852. During this time the establishment was increased from fifty-five light-houses and a few buoys to three hundred and twenty-five light-houses and light-ships with, numerous buoys, monuments, and other aids to navigation.

The general superintendent of lights was the officer who executed the orders of Congress, but to whom was delegated a certain discretionary power. Congress, in appropriating the funds for a light, usually fixed its location, its kind, and its order. He formulated the orders of Congress by advertising for proposals to build the kind of light-house desired, and signed the contract on the part of the Government. The collector of customs nearest to the location of the proposed light was usually made the local superintendent, and after he had selected the exact site was furnished with a plan of the building, and was authorized to employ a suitable mechanic as overseer, who was to make sure of the quality of the material and labor used. Payments were made only on the certificate of this overseer. The local superintendent was expected to visit each light-house in his district yearly, in June, if possible, and to report to the general superintendent in Washington the condition of each, and this was often done.

The light-houses were kept in repair by contract; and it appears from the reports of the general superintendent that the repairs were, in his opinion, promptly and effectually made. The methods of supplying the lights varied, apparently, with their increase in number. When Mr. Gallatin was Secretary of the Treasury, oil and money to purchase other supplies were furnished to a contractor, who made a yearly visit to each light, to keep the illuminating apparatus in repair, and, at the same time, supplied the illuminant, wicks, chimneys, and cleaning stores. This was not difficult when there were but some fifty lights; but Mr. Pleasanton found, as their number increased, a new method of supply was necessary. He accordingly advertised for proposals to furnish all the supplies needed for the whole Light-House Establishment, and to keep all the illuminating apparatus in complete repair for a given sum per lamp per year, and made a contract with the lowest bidder, to continue for five years, paying him $35.87 per lamp per year to supply everything necessary for keeping up the lights. The contractors were also to visit each light-house annually, and report on its condition, specifying the repairs needed to each structure, as well as to its illuminating apparatus; and they were also to report on the conduct and ability of the keepers. And the keepers were to report on the quality of the supplies furnished, and on the condition of the illuminating apparatus and buildings. This plan Mr. Pleasanton reported as working satisfactorily to the Government.

Meantime, complaints were made in various quarters as to the efficiency of the Light-House Establishment. The Messrs. E. & G. W. Blunt, of New York City, the publishers of Blunt's "Coast Pilot," were among the more prominent complainants, or, rather, they forwarded to Washington the complaints made to them by shipmasters, and thus they were brought into antagonism with the General Superintendent of Lights, who felt called upon to defend his administration. An account of this was laid before the Senate by the Secretary of the Treasury, on January 26, 1838, in response to its resolution of inquiry made the day previous.

Mr. Pleasanton had referred to the charge of the Messrs. Blunt, "that the Light-House Establishment was badly managed." The Blunts, on November 30, 1837, in a letter to the Secretary of the Treasury, undertook to show that the annual sums appropriated by Congress were not judiciously or energetically used. Among other things, they said that "the establishment has increased beyond the ability of any single individual at Washington to superintend it in its more important details, and the efficiency of the whole has become greatly lessened. The intelligent gentleman who for so many years has had the general superintendence of the lights has had but little assistance of the proper kind; he has been compelled to rely too much on contractors; and the representations of contractors will always be favorable. The duties of the office of Superintendent of Lights at Washington coming immediately under the direction of the present incumbent have been conducted, to the best of our knowledge, with skill and promptitude; but those duties have been, for many years, almost necessarily confined to the payment of salaries and contractors and other financial matters; and there can be no doubt this least important part of the whole system has been exceedingly well managed."

Meantime, Congress had been so profuse in its appropriations for light-houses that the propriety of erecting those for which funds had been more recently appropriated was questioned. So, on March 3, 1837, it was provided in the act making appropriation for building a large number of light-houses, light-boats, buoys, etc., that before any of these improvements should be commenced, the Board of Naval Commissioners should cause an examination to ascertain whether the safety of navigation required any additional facilities, and, if so, what was most suitable for each place, and to report their opinion in regard to all such places to the Secretary of the Treasury, who should proceed with the work so recommended; and that if the Board should advise that the improvements were not needed, they should not be made, and the commissioners' opinions, with the facts, should be reported to Congress.

The Navy Department detailed twenty-two officers on this duty, and, as the Treasury Department placed at their disposal its revenue cutters, they were enabled to carry out their orders, which were quite precise, and to make their report to the commissioners in time for them to report to Congress, by the end of the year, their recommendations, which in effect arrested the erection of thirty-one of the proposed light-houses, for which $168,700 had been appropriated. In concluding their report, the Navy Commissioners said:

When the importance of the light-house system is considered. in relation to the safety of human life and of the vast amounts of property, to the facilities and rapidity of communication which it gives between different parts of our extensive Atlantic and Lake coasts, and to the cost of establishing and supporting it, the Board would respectfully suggest whether some additional measures may not be desirable for obtaining the necessary information to secure the greatest public advantage for the expenditures which may hereafter be authorized for these purposes.

On March 22, 1838, the Senate

Resolved, That the Committee on Commerce be instructed to inquire into the expediency of importing one or more sets of the most approved apparatus, now employed on the coast of Europe in the light-houses; and

That the same committee be instructed to inquire whether a more efficient, safe, and useful system of locating, constructing, lighting, and managing the light-houses necessary for our coasts may not be adopted.

On May 10, 1838, the Committee on Commerce made report. Among other things it said:

The committee fully concur with the navy board, that legislation should proceed on more safe and satisfactory information. Hitherto Congress had before it, when proceeding to authorize the erection of new houses, little information beyond the loose, irresponsible statements of petitioners, most of whom were in many instances unknown, and there is too much reason for believing that those most active in getting up these petitions have been persons interested in their success, that some importance might be given to an unfrequented harbor where they had lands; that they might be made superintendents of lights, or make sale of the sites, or get a contract, or be benefited in some other way which had no connection with the public interest, beyond making it subserve their own. Legislation should proceed upon a more safe and satisfactory basis.

The result of the discussion which followed this report was the insertion in the current appropriation act for building light-houses, etc., approved July 7, 1838, clauses providing, among other things, that the Secretary of the Treasury import two sets of lenticular apparatus, and one set of the reflector apparatus—all of the most improved kinds—to have them set up, and their merits as compared with the apparatus in use tested by satisfactory experiments; and $15,000 were appropriated for that purpose; that Congress may be furnished with more exact information in regard to the light-house system, the President divide the Lake and Atlantic coasts into districts, and appoint a naval officer to examine each district, whose duty it shall be to inspect all the light-houses, etc., and to report upon their present condition and usefulness; also to report whether the public emergencies require any, and if any, what, further additional light-house works, and of what kind; and also to report whether any modification of the system of erecting, superintending, and managing the light-houses, etc., is required, and, if so, in what particulars; also that these officers were to examine and determine whether it was expedient to construct the specified light-houses.

Under this act the President divided the Atlantic coast into six, and the Lake coast into two, districts, and in August, 1838, an officer of the Navy was detailed to each; a revenue-cutter or a hired vessel was assigned to him, and he was instructed by General Superintendent Pleasanton, on August 4, 1838, to make his examinations and reports as soon as possible, that their result might be communicated to Congress.

These officers presented a detail of facts that deserved grave attention. Their reports showed much of poor management, and something of a lack of energy, while certain minor deficiencies were pointed out with fullness of statement. But while details were severely criticised, more fault was found with the system itself than with its administration. Lieutenant Bache's report is noticeable for its presentation of a plan for a new system, somewhat like that which is now actually in operation.

Mr. Pleasanton met the criticisms in these reports by confession and avoidance. If too many lights had been established, and if some were in wrong places, as charged, it was the fault of Congress. If they were not well built, it was the fault of contractors or collectors. But, in the light of the facts given in the reports, it would be possible to remedy the errors of detail, and he should do so as rapidly as the funds at his disposal would permit. He did not, however, admit that the system could be improved except in its administration.

On February 18, 1842, the House of Representatives

Resolved, That the Committee on Commerce inquire into the expenditures of the light-house establishment since the year 1816, including expenditures for building and repairing light-houses, light-ships, beacons, and every work embraced under this general head, and make their report of the result of their inquiries; and also to examine into the propriety of reorganizing this establishment; of changing the mode of its superintendency, and equalizing the compensation given to them and to the light-house keepers, and to the keepers of other lights, buoys, etc., and the propriety of suppressing some of the posts of this establishment, and of so modifying the laws and practices under them in reference to this establishment as to secure strict observation of the duties of superintendents and keepers of lights; and to report the result of their examinations to this House, with such plans as they may agree upon, tending to reduce the annual expenditures of this establishment, and to improve the facilities and safety to navigation.

Resolved, That the Committee on Commerce be instructed to inquire into the expediency of providing by law for a retrenchment of the expenditure and better regulation of the light-house department; and, also, whether the same ought not to be placed under the charge of the Topographical Bureau.

On May 25, 1842, the committee made a careful and apparently exhaustive report, tabulating the expenses of the establishment year by year, and taking a kindly view of its administration, as the following extracts will show:

From July, 1820, when the number of light-houses was 55, to the present year, when the number of light-houses is 256, of light-boats 30, of beacons about 35, and of buoys nearly 1,000, the establishment has been under the charge of the present general superintendent, the Fifth Auditor of the Treasury. It might well be expected that a twenty-two years' service would have given to the incumbent an experience and a practical knowledge of his business, which should not, for slight causes, be lost to the public. A transfer of his duties to other and inexperienced hands could not but be attended with derangements, and probably with an increased expenditure. It has now a good degree of method, system, and economy; and with some improvements, particularly in regard to inspection, it is believed that our establishment may, with no disadvantage, compare with that of any other nation. Every innovation is not an improvement. When an old and well-tried system works tolerably well, change and experiments should be avoided. More time and further experience will furnish correctives far better than any which may be anticipated from a change of system and a displacement of those who have thus far given that system a claim upon the confidence of the country. That complaints to some extent have been made is true, and that complaints would be made occasionally under any mode of administration is equally true; but, taking into account the magnitude of the establishment, the multiplicity of its details, and the large number of agents necessarily in the service, it seems to the committee that it merits no little commendation. In the opinion of the committee a transfer of the duties of the Treasury Department, imposed by law in regard to our light-house establishment, is not called for by the public good. * * *

The appointment of inspectors, whose duty it should be to devote their entire time, under the direction of the general superintendent, to frequent examinations of the light-houses, light-boats, buoys, etc., would be attended with no great increase of expense. The amount now paid to the collectors acting as superintendents is about $11,000. There is already attached to the establishment a small vessel. That, with the addition of another, and the salaries of two inspectors for the two districts on the Atlantic coast, bays, etc., if two should be deemed necessary, the increase of expense will be inconsiderable. The frequent reports of these inspectors to the general superintendent would enable him at all times to know the precise condition and order of the establishment, and to increase its efficiency, usefulness, and economy.

As Congress coincided with its committee, no further legislative action was then taken on the subject.

On the day that the Committee on Commerce reported to the House of Representatives, Mr. Forward, then Secretary of the Treasury, appointed Mr. I. W. P. Lewis, a civil engineer of high repute, as agent to visit certain light-houses, and to make an examination of their positions, and of the floating lights, beacons, and buoys, and to report generally, and in particular on specified points, which covered a large range, including mooted points, as to the management of the lights.

On January 31, 1843, Mr. Lewis made his report, which was submitted to Congress on February 25, 1843, by Secretary Forward, with recommendations. The agent had inspected seventy light-houses in Maine, New Hampshire, and Massachusetts, or one-third of all in the establishment. He reported as to the condition of each with such a reckless vigor that Mr. Pleasanton, in his reply, made after Mr. Spencer had succeeded Mr. Forward as Secretary of the Treasury, characterized Mr. Lewis's report as "these calumnies," and declared himself as "having been grossly misrepresented by him."

Relative to this controversy, a prominent Boston journal said:

The report that resulted from this partial survey was a severe blow to the defenders of the old system; and if the Government had possessed the proper energy and vigilance, such an array of facts could not have been passed over unnoticed. A most important benefit, however, resulted to the public from the detail of the defective condition of the light-houses, and particularly as to the illuminating apparatus contained in this report of Mr. I. W. P. Lewis; for it compelled the general superintendent of light-houses to bestir himself and get things a little more to rights. All the prominent coast lights received new lanterns and apparatus as fast as the contractor could supply them, and many of the minor lights were similarly renovated. The public mind was also directed to the subject in consequence of the attacks brought upon Mr. Lewis by his temerity in exposing the actual condition of things, and the subject has by slow degrees begun to assume that importance which so properly belongs to it.

But Secretary Forward, on February 24, 1843, in transmitting Mr. Lewis's report to Congress, accompanied it with recommendations indicating on his part, at least, a comprehension of the fact that the system in vogue was not equal to the requirements made upon it by the country's commerce. Among other things he suggested—

That no appropriation be made thereafter, for the erection of a new light-house, until the necessity for such a light shall have been ascertained by a competent engineer, who shall report on its necessity, on the site to be selected, and shall submit a suitable plan, estimate, and specification, for the required buildings; also detailing the magnitude of the light required, and its distinctive character, with a view to render it intelligible to seamen, if established—all of which shall be submitted to Congress, for such action as may be then deemed proper; that whenever the repairs of light-house buildings or floating lights called for exceed five hundred dollars, the nature and extent of such repairs, and their probable cost, shall be carefully estimated and reported before they shall be authorized; and that contracts shall be made where the expenditure for the construction or repairs of land and floating lights exceed five hundred dollars, which contracts shall be filed in the Treasury; that the system of illumination, and whatever is connected with the lighting apparatus, shall be placed under the supervision of the engineer, who shall report the alterations or improvements, if any, which may be required, such report to be approved before the work is authorized; that for the attainment of these purposes, the Secretary of the Treasury be empowered to appoint a competent scientific and practical engineer, with a salary of $3,000, whose whole time shall be devoted to the regulation of the details of the light-house system, and who shall annually report the condition of the Light-House Establishment, and its wants for the coming year, with detailed estimates, and such other information as comes within the scope of his duties, for the information of the Treasury and of Congress.

Congress adjourned before action was had, and the matter went over with many others to the next session.

On June 19, 1845, the then Secretary of the Treasury, Hon. R. J. Walker, had Lieuts. Thornton A. Jenkins and Richard Bache detailed for that purpose from the Navy, and sent abroad "to procure information which may tend to the improvement of the light-house system of the United States; and as it is alleged that important improvements have been made in the light-houses of Europe, especially in those of France and Great Britain, the Department wishes to understand fully what those improvements are, and if they are adapted to introduction into our country." They were especially directed to procure information as to the organization of light-house systems; the construction of light-houses; the lighting apparatus used abroad; attendance on lights and its expense and efficiency; and as to buoys and their appendages. They were also required to make full descriptive reports, with recommendations; and they were to visit some of our own light-houses to compare them with those they had seen while abroad. Lieutenants Jenkins and Bache spent the greater part of the next year in Great Britain and on the Continent, and, after a tour among the principal light-houses of this country, on June 22, 1846, made a report with recommendations for the "reorganization of the Light-House Establishment by the appointment of an engineer and optician, and a number of district superintendents to assist the general superintendent, under the direction of the Secretary of the Treasury."

Under this organization the duties of the general superintendent were to be slightly changed; the engineer was to make the plans, drawings, and specifications of works, assist in the selection of sites, superintend the construction and repairs of all towers and buildings, and inspect, at least once a year, the principal light-stations; the optician was to superintend the construction of and to test all illuminating apparatus, make experiments upon apparatus and illuminants, visit all the lights once a year, to direct repairs and adjustments of illuminating apparatus, which would take all the time of the engineer and optician.

The coasts were to be divided into ten districts, and each was to be placed in charge of an officer of the Navy as district superintendent, who was to inspect the light-houses, monthly at least, who was to establish positions of the aids to navigation by angles, bearings, etc., attend to buoys, etc., and make the regular reports to the central office. They also earnestly recommend the substitution of the French lenticular apparatus for the reflectors then in use. They argued in favor of the economy of the change, and detailed the manner in which it might be effected.

The Secretary of the Treasury, Mr. Walker, in transmitting the report to Congress, after stating that the suggestions for the improvement of the system met his hearty concurrence, said:

> The report of the inspecting officers detailed from the Navy to examine the lights on our coasts showed their absolute defects; the present report shows their deficiencies as compared with other countries. The trial made of one of the French lights at Sandy Hook (Highlands of Navesink), entrance to New York Harbor, has been very successful, but the use of this apparatus has not been extended.

The Secretary then discussed the propriety of the changes, and stated that the existing laws still required the use of the old-fashioned reflectors in the light-houses. He concluded with the following suggestions in the interest of reorganization:

> It is obvious that a very considerable range of practical and theoretical knowledge is required for the improvement of the system; more than can be looked for from one individual, however eminent in science. The proper organization of the system, and planning of its details, require the efficient head of a bureau familiar with the working of a general organization—a person capable of furnishing information in regard to the coasts and harbors from actual surveys; persons minutely acquainted with the wants of navigation, with the details of location and construction of the light-houses, and with the chemical and mechanical principles involved in lighting. While this knowledge cannot be obtained from one person, a board may be organized, without expense to the Government, by which the system may be considered in all its particulars, and an efficient plan of action recommended. Such a board might consist of the Fifth Auditor, the Superintendent of the Coast Survey, two naval officers, two engineer officers (one military, the other a topographical engineer), and a secretary, who might be a junior officer of the Navy. By their action a plan might be prepared which would secure approval, and provide for the necessary progress of our system of light-houses, and our other aids to navigation. I would, in conclusion, respectfully request from Congress the authority to organize such a board, and to execute the plans which they may suggest, as far as practicable under existing laws regulating this branch of the public service.

Congress received this report and these recommendations as it had those previously presented, and, as before, without immediate action. But on March 3, 1851, an act of Congress was approved, in which the Secretary of the Treasury was authorized to put the Fresnel illuminating apparatus into light-houses as rapidly as he thought best; to appoint a board of proper persons to inquire into the condition of the establishment, and make a detailed report and programme to guide legislation in extending and improving the system of construction, illumination, inspection, and superintendence; and to detail engineer officers from the Army to superintend the construction and renovation of future light-houses. On May 21, 1851, Mr. Corwin, the Secretary of the Treasury, constituted and instructed this Board. It consisted of Commodore W. B. Shubrick, U. S. Navy, as president, Commander S. F. Du Pont, U. S. Navy, General Jos. G. Totten, U. S. Engineers, Colonel James Kearney, U. S. Topographical Engineers, Prof. A. D. Bache, Superintendent U. S. Coast Survey, and Lieut. T. A. Jenkins, U. S. Navy, secretary.

On January 30, 1852, the Board made an elaborate report of seven hundred and sixty pages, illustrated by forty plates, and with numerous wood-cuts, embodying the scientific and practical information necessary to a clear understanding of the light-house system. The examinations extended into the construction of towers, dwellings, and illuminating apparatus, included a careful investigation of the manner in which keepers performed their duties; of the ability and fidelity of the inspectors; of the mode of supplying the establishment with oil and other stores, and of the method of making contracts and testing supplies. It contrasted our methods with the light-house administration of Great Britain and France. Every source of reliable information seems to have been explored to reach a true estimate of the merits and defects of our system. The Board recommended that the lights be classified, after the French method, into orders, to be followed by a system of designation. The orders running from one to six would indicate the magnitude or intensity of the light—the first order being the largest. The designation would define its characteristic, as fixed, flashing, revolving, red, white, or a combination of these qualities. Then it recommended the general adoption of the Fresnel lenticular system of illuminating apparatus in place of the old system of illumination by the Argand lamp and parabolic reflector. And it also recommended a more vigorous administration of the establishment, and to that end the erection of a board much after the French plan, which should combine in it all the scientific experience necessary to the highest success in illumination, construction, hydrography, engineering, knowledge of the needs of commerce, and especially of administration. It recognized the services of Mr. Pleasanton, who had administered the light-house service for over thirty years, bringing it up from twenty-five lights to three hundred, saying that "great credit is due to the zeal and faithfulness of the General Superintendent and to the spirit of economy which he has shown," which spirit, perhaps, accounted for the "lack of zeal exhibited for the adoption of modern improvements;" but they asserted the impossibility of any one man's ability to handle the system then, and the necessity for organization, for subdivision, and for a system comprehending the great and varied requirements necessary to a successful administration of the many separate and distinct interests constituting the establishment, and bringing all under the consideration and final direction of a central head, which they proposed should be, instead of one man, a board of experts, having, or capable of obtaining, the knowledge necessary to every detail of each branch of the great and still growing establishment.

This report was referred by the Senate to its Committee on Commerce on February 5, 1852, but was taken up for action in the House of Representatives, which embodied the plans it suggested in an appropriation bill, which passed both houses, and was approved on August 31, 1852, by the President. This organic act, constituting the Light-House Board as it now exists, is contained in the last nine sections of the act providing for the civil and diplomatic expenses of the Government for the year ending June 30, 1853. This act required the President, immediately after its passage, to appoint two officers of the Navy of high rank, two engineer officers of the Army, and two civilians of high scientific attainments, whose services might be at the disposal of the President, an officer of the Navy and an officer of the engineers of the Army as secretaries, who should constitute the United States Light-House Board; the Board to be attached to the office of the Secretary of the Treasury, and under his superintendence to discharge all the administrative duties relating to the construction, illumination, inspection, and superintendence of light-houses, light-vessels, beacons, buoys, sea-marks, and their appendages, and embracing the security of foundations of existing works, procuring illuminating and other apparatus, supplies, and materials of all kinds for building and rebuilding, and keeping in good repair buildings, vessels, and buoys of the United States. The Secretary of the Treasury was to be president, but the Board was to elect from its own number a member to act as chairman in the president's absence. The Board was to meet quarterly, and as much oftener as might be found necessary; and to it were to be transferred all the archives, books, documents, models, drawings, apparatus, returns, etc., belonging to the Light-House Establishment of the United States, together with the clerical force employed on light-house work.

The Board was required to arrange the Atlantic, Gulf, and Pacific coasts of the United States into twelve light-house districts, and an officer of the Army or Navy was to be assigned to each as light-house inspector under its orders.

The Board was to make and promulgate, with the approbation of the Secretary of the Treasury, rules and regulations necessary for securing an efficient, uniform, and economical system of administration. It was to have prepared, by its Engineer Secretary, or other engineer officers of the Army under its orders, all plans, drawings, specifications, and estimates of cost of all illuminating and other apparatus, of construction and repair of towers and buildings. It was to procure by public contract all material for the construction and repair of light-houses, light-vessels, beacons, buoys, etc., and all construction and repairs were to be made under the superintendence of its Engineer Secretary. It was to furnish estimates of all the expenses which the several branches of the Light-House Establishment might require, and to make a full annual report. The members of the Board were to receive no pay for their services other than that they received in the Army, Navy, or civil service, and they were prohibited from having any interest in any light-house contracts, as were all others in the light-house service. Each of those who had served on the Provisional Board were appointed on the Permanent Board, and its organization was completed by adding to it Prof. Joseph Henry, Secretary of the Smithsonian Institution, and Capt. E. L. F. Hardcastle, U. S. Army, the latter as its Engineer Secretary. The Board met on October 9, 1852, and elected Commodore Shubrick, U. S. Navy, as its chairman; and then it arranged to receive from the General Superintendent the property of the Light-House Establishment, and to make the necessary rules and regulations for its governance. Those who had made the programme which had guided legislation to the creation of this Board, and who had in mind all the details necessary for carrying out the plan, and who had the necessary industry, perseverance, and patience to put them into operation; those who knew all the defects of the service and all the excellences of the French service on which the new establishment was to be modeled; those who had so much at heart the interests of the plan, and who had staked their reputation on its success, were appointed on the Board. And their zeal was tempered by the addition to it of the calm wisdom of Prof. Joseph Henry, the Secretary of the Smithsonian Institution, whose habits of patient investigation, and impartial decision on the weight of ascertained authority, and whose already great reputation as a physicist, would go far to prevent any unnecessary changes or any hasty action.

The plans proposed by the Provisional Board to Congress, and formulated in the organic act, were put into operation by the Permanent Board as rapidly as existing law and the funds at the control of the Board would permit.

An Inspector, who was either an Army or Navy officer, and, as soon as needed, an engineer officer from the Army were assigned to each light-house district. The Inspectors, under the charge of the Naval Secretary, who also had charge, in the absence of the Chairman, of the office of the Board, were charged with the maintenance of the lights and light-houses and with the discipline of the light-keepers. The district Engineers, under the direction of the Engineer Secretary, were charged with building the light-houses, with keeping them in repair, and with the purchase, the setting up, and the repairs of the illuminating apparatus. Both Inspectors and Engineers made regular and special reports to the Board, acting always under its direction, and the Board made a full annual report to the Secretary of the Treasury, who, in turn, made a full annual report to Congress. The Board assigned its members first to an executive committee, and then divided them into committees on finance, engineering, light-vessels, lighting, and experiments, and placed that one of its members most expert in each particular branch at the head of the committee having charge of that branch. The committee on light-vessels was afterward charged with the care of buoys also, when it was called the "committee on floating aids to navigation." In after years, the committee on the location of light-houses was added to the number. The executive committee, consisting of the Chairman and the two Secretaries, were in perpetual session, carrying on the routine business of the establishment, while the other committees met frequently, and the full Board met monthly, or oftener though required by law to meet but once a quarter.

The Board finding, from the experience of the keepers of the lights at Highlands of Navesink, that the lenticular apparatus could be managed by the average light-keeper after instruction by an expert, and that its use was more economical in oil than was the reflector apparatus in use, pushed its substitution with vigor, and, as they had anticipated, with a diminution of the annual expenditure for oil.

It perfected the classification of lights, and so differentiated them by proper distinctions that mariners were enabled to identify and recognize each light. It substituted light-houses for light-ships, wherever practicable, as rapidly as desirable, thereby making large saving in expense for maintenance without diminution of the light produced. When sperm-oil became too expensive for economical use, the Board cast about for a substitute for it as a light-house illuminant, and after trying and discarding *colza*, a vegetable oil, it finally, after much experimentation, adopted lard-oil, at a large saving in cost and without diminution of light. And again, twenty years after, when it was evident that a further economy could be made, it substituted mineral-oil for lard-oil, after much tentative action, resulting in the invention and manufacture of lamps for its proper combustion. It has tested gas as a light-house illuminant without finding it adapted to the purpose, although it still has several stations lighted with gas from the neighboring cities, and one series of stations lighted with compressed gas made by its employés.

It has also tested electricity to a certain extent, but thus far it has found that for general purposes its use is of more hinderance than help to navigators, and hence has been forced to restrict its use as an illuminant within well-defined limitations. By a long series of investigations into the laws of sound, it ascertained the principles on which fog-signals, as aids to navigation, were to be constructed, and giving them to the public, stimulated the invention of proper machines, stimulated their manufacture, and then put them in operation without other expense to the Government than their purchase.

When the commerce on the Mississippi had induced Congress to authorize aids for river navigation, the Board devised and put into operation a system of lights which has revolutionized steam-boat navigation, making it so safe that the boats which tied up at night now run as by day, and that at a small cost, as compared with the expense of the lights on the ocean and even on the lake coasts.

The Board has organized and built up by degrees a corps of intelligent light-keepers, who, entering the service in its lowest rank, after examination are eligible to promotion in grade and pay according to merit, as vacancies occur, whose tenure of office is practically during good behavior, where transfers in location are made when the wishes of the keepers and the wants of the service coincide, and whose physical and mental welfare are carefully looked after by the Board, which aims to make its keepers contented in their responsible and isolated situations.

The Board has had the services of some of the brightest and most active minds in the American Navy. The Light-House service has, like the Coast Survey, come to be regarded as a training-school for young officers and as a field for the best efforts of those higher in rank. The roll of light-house Inspectors contains the names of the flower of the Navy; hence it is no source of wonder that a tour of light-house duty is sought by the more ambitious and studious of our naval officers, and that the service has its choice from among the best of them in times of peace.

The Army has also been well-represented in the light-house service. On the list of the light-house Engineers will be found many of the names which have given our military establishment reputation if not fame, and such have been their victories in solving the problems of sub-marine structures, of opposing successful resistance to the violent attacks of the elements under the most discouraging circumstances, that it is a question whether those names connected with the erection of certain light-houses will not live when history has let die the memory of their brilliant military achievements.

The civil service has been well represented on the Board itself, in connection with the Army and the Navy, by such men as Professors Bache, Peirce, Hilgard, Henry, and Morton, who have acted as the scientific advisers of the service, and whose names are identified with the solution of problems in physics which have been worked out under their direction in methods for guiding mariners by light at night, and by sound when light was unavailable. Something of the operations of the Light-House Board will be detailed in its proper place.

CHAPTER IV.

LIGHT-HOUSE CONSTRUCTION.

The light-houses on the New England coast were constructed previous to 1840 in two forms, namely: conical towers of rubble stone masonry, and wooden frame towers erected upon the roofs of the keepers' dwellings. The stone towers were built on the natural rock, from stone split from the adjacent ledges, or from pieces collected on the beach, sometimes even from fragments of the cliffs rounded by attrition in the surf. The walls were usually 3 feet thick at the base, tapering to 2 feet in thickness at the top, and the towers varied in height from 20 to 50 feet. At the top of the tower and within the walling of rubble, a dome of brick was turned, with a square opening near the springing-line on one side forming a scuttle entrance to the lantern. On this brick dome, a flat roof composed of slabs of stone 4 inches thick was laid, projecting over the walls of the tower from 6 to 12 inches. The lanterns were attached to the towers by imbedding the lower ends of their iron angle-posts into the masonry of the walls some 3 or 4 feet, and the entire construction of the towers was rude in kind.

The wooden towers erected on the keepers' dwellings were framed into the roof of the house. The angle-posts rested on the attic floor-beams unsupported by studding; consequently the framing of the house-roof was distorted by the swaying lateral motion of the tower in storms, and there was necessarily some leakage.

In 1847 the construction of six difficult light-house structures was devolved by Congress on the Topographical Engineers of the Army. They used the iron pile system, when applicable, and made numerous improvements in the combination of the framework, in making appropriate arrangement of elevated apartments for the keepers, in making disk pile foundations, for coral or incrusted bottoms, and in improved devices for the foundations. Capt. W. H. Swift, of this corps, rebuilt the Black Rock beacon in Long Island Sound, some 4½ miles from Bridgeport, Conn. Three successive stone beacons, costing, together, some $21,000, had, in the course of twelve years, been demolished. Captain Swift, at a cost of but $4,600, erected a pile beacon 34 feet above low water, 3 feet higher than any of its predecessors, which is still standing. An artificial foundation was made by placing six 12-ton stones partly in an excavation, and by bedding them in concrete, making a solid platform, and setting into it five wrought-iron periphery piles and one center pile, measuring from 3 to 5½ inches in diameter. They were sunk through holes drilled to receive them, rose in the form of a conic frustum, and were solidly joined together, and properly capped at the top.

OLD MINOT'S LEDGE LIGHT-HOUSE.

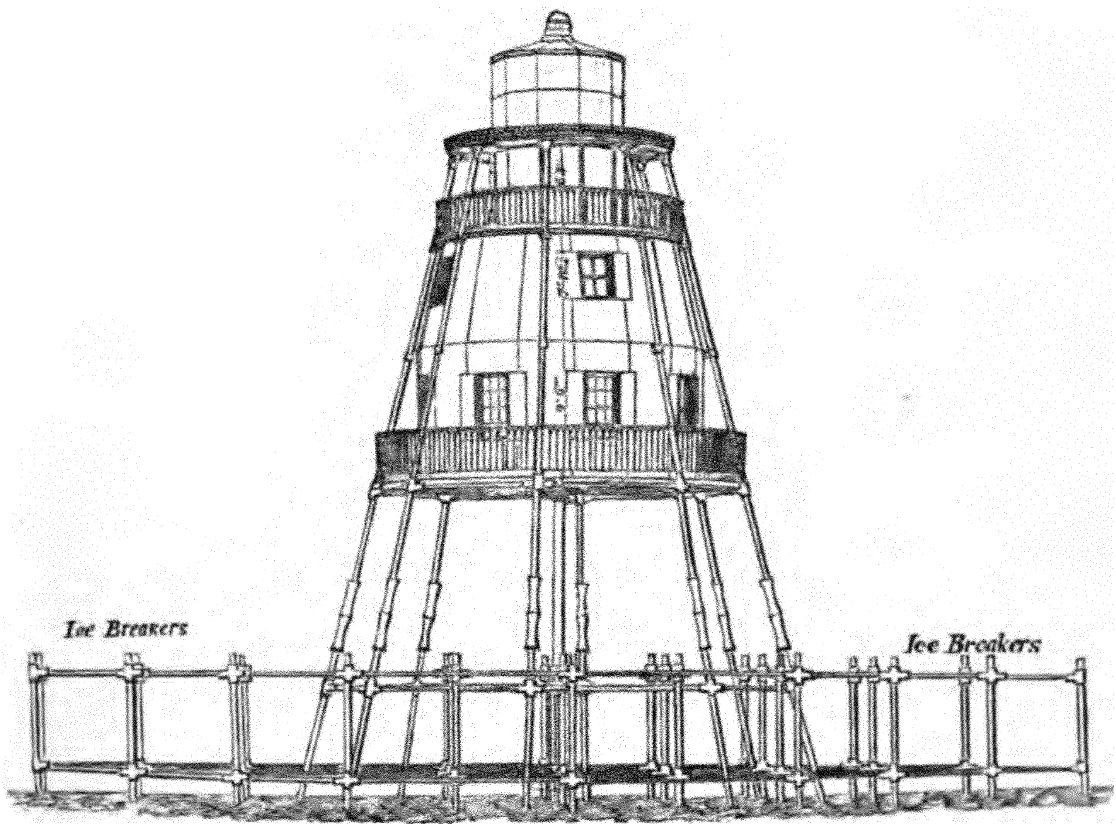
A pile structure was also erected on Minot's Ledge in the open sea, near Boston Bay, in 1847–'48, by Captain Swift, but it was destroyed by the storm of 1851, and the keepers lost their lives. It was based on the solid rock by drilling holes, 5 feet deep, in which one center and eight periphery 8-inch wrought-iron foundation piles were wedged, and so placed as to form an octagon 25 feet in diameter at the bottom and 14 feet at the top, which had an elevation of 60 feet. On this was placed the lantern, making the height of the whole edifice about 70 feet. The structure was stiffened by a complex system of diagonal bracing connecting the piles. Whatever may have caused the overthrow of the light-house—and that is still a mooted question—it does not appear to have been owing to any fault of the rock fastenings, as the piles were broken or twisted off, leaving stumps from 4 to 6 feet long in their original places.

BRANDYWINE SHOAL LIGHT-HOUSE.

Brandywine Shoal light-house, in Delaware Bay, about 8 miles from the ocean, was begun in 1848 and lighted in 1850, costing $53,317 for the light-house, and $11,485 for the surrounding ice-breaker. This was the first light-house built in the United States on Mitchell's screw-pile, which takes its name from the inventor of its broad helicoidal flange, like an auger pod, which, by merely turning, is bored into a sand, mud, or other penetrable bottom, so as to form a foundation with a broad bearing, on which the weight of a columnar structure may be safely diffused, and to which it is firmly fastened. This structure has a light 46 feet above sea-level, and is independent of the ice-breaker, which is a pier of thirty screw-piles, each twenty-three feet long, 5 inches through, connected at their heads, and near low water by spider-web braces, by which a shock on one pile is communicated to all. The light-house is in good condition, but the ice-pier has been re-enforced. It was designed and built by Maj. Hartman Bache, then of the Corps of Topographical Engineers of the Army.

CARYSFORT REEF LIGHT-HOUSE.

An iron-pile light-house was begun for Carysfort Reef, Florida, in 1848 and finished in 1852. It stands on a coral reef in the Gulf Stream in 4½ feet of water, and is 112 feet high. It is founded on a hard exterior coral crust above a softer mass of calcareous sand; hence, screw-piles bored through the crust would have an insufficient bearing. On this account, large iron foot-plates were used to diffuse the pressure over the 130 square feet of surface crust, and the piles, passing through center-eyes in the plates, were driven 10 feet into the sand, or until their under shoulders were lodged on the bed-plates. Nine 8-inch piles constitute the center of an octagon, and the aggregate column gets rigidity from a peculiar system of cross-ties and braces. The structure was begun by Capt. Howard Stansbury, and was completed by Maj. Thomas B. Linnard, of the Engineer Corps, assisted by Mr. I. W. P. Lewis, a civil engineer. The keepers



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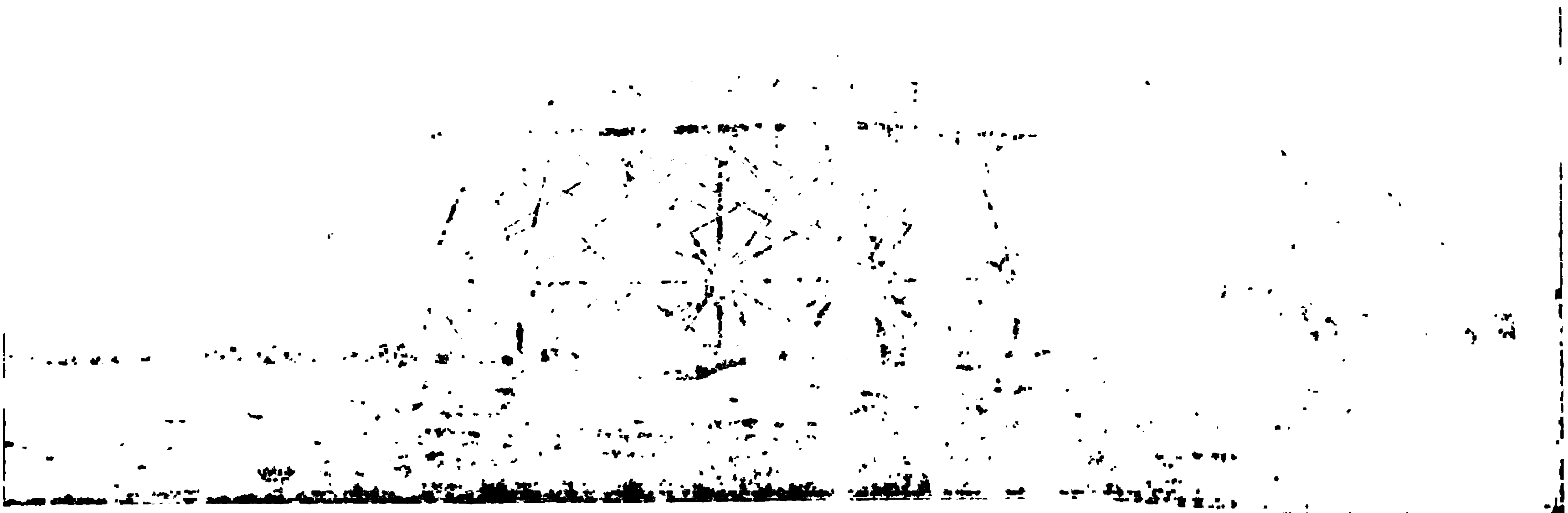


THIMBLE LIGHT-HOUSE, HAMPTON R[illegible] live on the structure in an elevated house. The whole was made, framed, tied together, and set up for trial in Philadelphia, so as to obviate the necessity of fitting parts at its isolated site. Its cost is stated at $105,069 for the entire structure.

SAND KEY LIGHT-HOUSE.

Sand Key light-house is built on a plan somewhat like that of Carysfort, but it stands in deeper water, on screw-piles; its focal plane is 121 feet above the foundation; it cost $101,520; was completed in 1853, and it has proved its complete stability. It was built by the late Maj. Gen. George G. Meade, then a lieutenant of Topographical Engineers, who also built an iron screw-pile light-house on the flats in Key West Harbor, and the important pile beacon on Rebecca Shoals, since destroyed and rebuilt, and several other light-houses.

SOMBRERO KEY LIGHT-HOUSE.

But the most important light-house built by General Meade was that on Coffin's Patches, or Sombrero, Key, on the Florida Reefs, about 50 miles east of Key West. It stands in 8 feet of water and shows a light about 140 feet above the water, giving a range of over 20 statute miles. The 12-inch wrought-iron foundation-piles rest centrally on cast-iron disks 8 feet in diameter, and go 10 feet into the rock. They stand at the angles and center of an octagon 56 feet across and are braced by horizontal radial and periphery ties of 5-inch round iron. The frame rises from this foundation pyramidal in shape, in six sections, with a diameter of 56 feet at the bottom, tapering to 15 feet at the top. All the shafts, except those of the lower series, are of hollow cast-iron. The keeper's dwelling, in the second section, is 30 feet square, and of boiler-iron lined with wood. A circular stairway ascends to the lantern, in a cylinder of boiler iron lined with wood. The entire structure, illuminating apparatus included, cost about $120,000, and it is still standing, and is in excellent condition.

SCREW-PILE LIGHT-HOUSES.

There are now, principally in the Southern waters, more than seventy light-houses; some with and some without screws, and of a variety ot detail and size. A fair specimen of the screw-pile, river, or harbor light-house is given in the following plate. It is a representation of the light-house on Thimble Shoal, off the entrance to Hampton Roads, Va.

FOWEY ROCKS LIGHT-HOUSE, COAST OF FLORIDA.

Fowey Rocks light-house is shown in the following plate. It was commenced in 1875, and was finished and lighted on June 15, 1878. It is on the extreme northern point of the Florida Reefs; is of iron; rests on nine piles driven about 10 feet into the live coral rock, and is built from plans made in the office of the Light-House Board. The different parts were made by three different contractors, and they were finally fitted together and set up before the structure was shipped to its site.

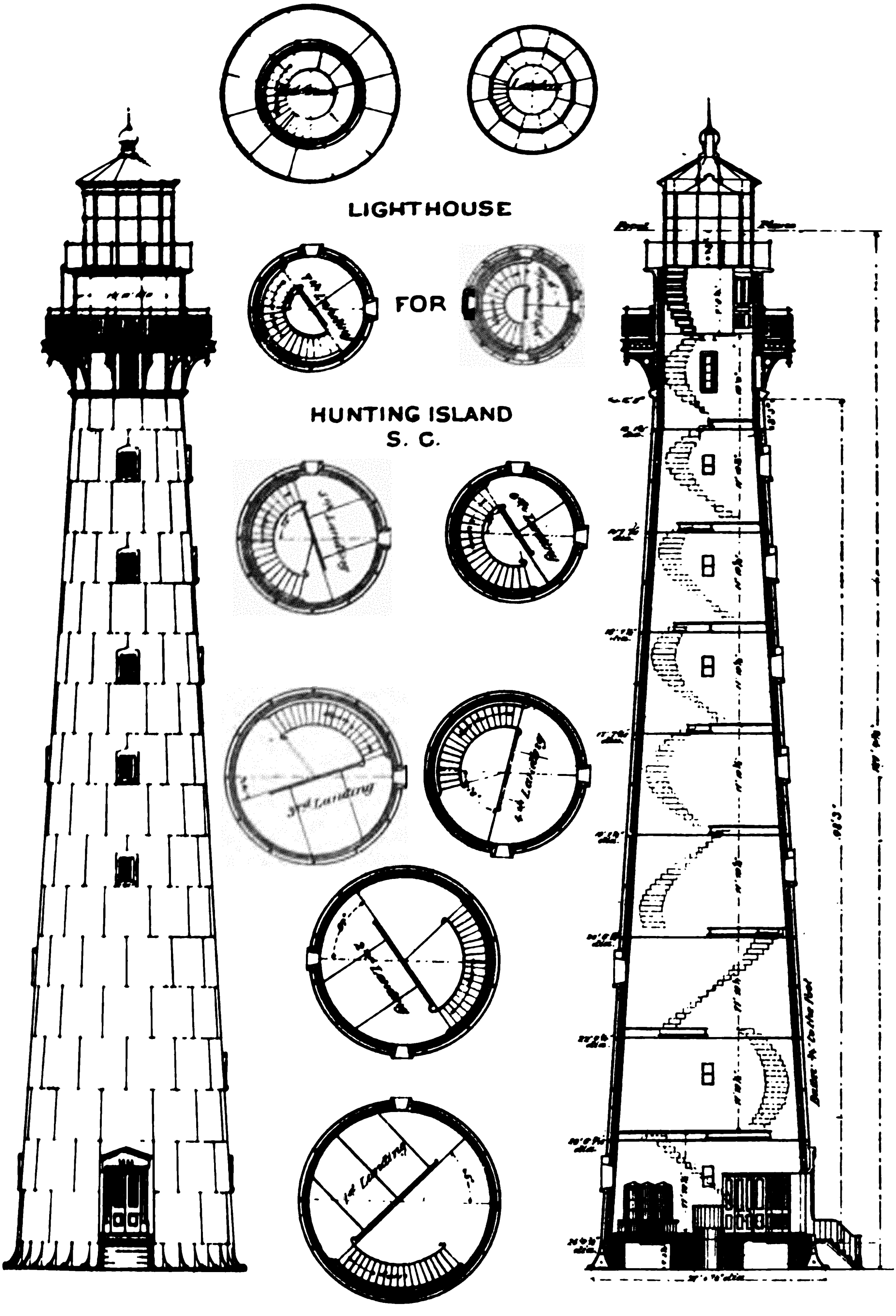
The lower series of piles were put in place in the summer of 1876. A working platform, about 80 feet square, was erected on the site, 12 feet above low water, on iron-shod mangrove piles driven into the coral. The disk for the central iron foundation-pile was then lowered to its place, and through this disk the first iron pile was driven. A perimeter disk was then located by a gauge, and then the first perimeter pile was driven through the center of this disk. After every blow of the pile-driver the pile was tested with a plummet, and the slightest deviation from the vertical was rectified. In locating the disk for the next perimeter pile two gauges were used to get the proper distance from the center pile, and to maintain it from the perimeter pile just driven. The disks were dragged along the bottom until their outer edges just touched the free edges of the gauges. Each pile was then driven through the center of its disk. When all were driven their tops were leveled by cutting off each to the line of the lowest. The piles were then capped with their respective sockets; the horizontal girders were inserted, the diagonal tension-rods were placed and screwed up, and the foundation series was completed.

Two months were occupied in placing the wooden platform and this series. During this time they had a smooth sea, but afterwards the main difficulty was with the bad weather. Finally, that problem was solved by pitching tents on the working platform, leaving a force of workmen there high and dry above the running sea, supplied with material, and with a small hoisting-engine to work their derrick, and their shears which had been erected in the single day of good weather they had out of a month. The material was stored at Soldier Key, 4 miles distant, and it was delivered by lighters towed by a steam-launch, which waited with steam up day and night to tow them out when the weather would permit. On March 16 the derrick and shears were sent up, and a cargo of iron delivered; and in the course of the next sixteen days five more cargoes were landed on the platform, and the first series of columns, girders, sockets, and tension-rods were placed in position. On April 7 the skeleton of the second series and the cylinder to the top of the series were up; and in another week all the iron up to and including the service-room floor was on the platform. On April 30 the dwelling was finished; on May 25 the illuminating apparatus was in position, and on June 15 the work was completed and the light was exhibited. The whole structure was completed with celerity, in spite of the trying circumstances accompanying its construction.

IRON LIGHT-HOUSES.

The use of iron plates for building light-houses on dry foundations, though not uncommon abroad, met, early, with little favor in this country. But, in later years, when a greater knowledge of iron as a material for construction obtained here, it came into larger use. Among the more prominent of the iron towers are those at Cape Canaveral, Florida, designed in 1860, and built in 1868, 150 feet high; that at Bolivar Point, Tex., built in 1872, 120 feet high; that at Hunting Island, S. C., built in 1875, 130 feet high, and the tower erected at Cape Henry, Va., which is 165 feet high.

LIGHT HOUSE ON FOWEY ROCKS, FLA.


LIGHTHOUSE
FOR
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HUNTING ISLAND LIGHT-HOUSE.

The following description of the tower at Hunting Island, a representation of which is given in the plate, will show how these iron towers are put up, and this is a good specimen, as the necessity of taking it down to remove it further back, if the encroachments of the sea make it necessary, was considered at the time of its erection. The shell of the tower is composed of cast-iron panels of about 1,200 pounds each, of exactly the same size in each section, that they may each occupy any position in the ring which they form when put together. These panels vary in thickness, in the different sections, those of the lower section being 1½ inches thick and of the highest three-quarters of an inch. They are provided with flanges so as to connect the several tiers of plates, and the plates of each tier with each other by bolts through them, and the flanges are made smooth, with true planed surfaces. The base of the first tier of panels consists of a flange 3 feet wide. This flange extends 1 foot and 4 inches beyond the outside of the tower, and contains the holes for the foundation-bolts, which are strengthened by bosses and vertical knees extending upward to the top of the castings. The top flange is 6 inches by 1¾ inches. The lower flange of the second section is 1 foot 2 inches wide. The top flange of this tier and the flanges of the third section are six inches by one and three-quarter inches. The flanges of succeeding sections are similar. The side flanges correspond in size with the top flange of each panel.' The horizontal flanges have strengthening knees. A 9-inch interior lining of brick is built between the lower flanges. The whole structure rests on an eight-inch concrete foundation, to which the lower iron section is secured by thirty-six anchor-bolts built into the concrete. Its original cost was $102,000.

This light-house was built in 1875 on a site fully a quarter of a mile back from the sea. The Light-House Board was then criticised for placing it so far from the water. But it would have been wiser to have made the distance much greater, as it has since been forced to take the structure down and to set it back a mile and a quarter to the southward, because of erosion of the land by the sea. This was done at a cost of $51,000.

IRON SKELETON TOWERS.

SOUTHWEST PASS LIGHT-HOUSE, MOUTH OF THE MISSISSIPPI RIVER.

Iron skeleton towers are used on land where the soil affords an inadequate support for a masonry foundation, and where great cheapness was required. That at the Southwest Pass of the Mississippi may be regarded as typical. Its foundation consists of a grillage of timber resting on piles and covered with concrete, on which are secured the iron socket disks from which start eight external and one central shaft of the skeleton. A two-story dwelling for the keepers was placed within the shafts and a staircase was carried up to the lantern through a tube as in case of the similar lights on submarine foundations. These towers are found to meet the purpose for which they were intended, and are practicable where heavier structures would not answer, offering less resistance to the wind and being much cheaper to build.

PARIS ISLAND RANGE-LIGHT, SEA COAST OF SOUTH CAROLINA.

An interesting specimen of these skeleton iron structures was erected in 1880 at Paris Island, Port Royal Sound, South Carolina, and exhibits the rear light of the Paris Island ranges. Altogether it is the most economical structure of its kind in the history of light-house construction. The plan was born of necessity, it being found that the appropriation made by Congress was not sufficient to put up the kind of structure which it was usual to place in such a position. The light exhibited is simply a locomotive head-light in form of a powerful parabolic reflector. It is claimed, however, that it is possible to use on it a lenticular apparatus. The tower is composed of columns, sockets, struts, and tension-rods, framed in the form of a triangular pyramid. It rests on six circular iron disks, anchored to a concrete foundation. The top sections of the side facing the channel, for which the tower is the guide, are provided with horizontal slats to increase the visibility of the beacon by day. The light, which runs up and down in rails in the plane of the structure, is housed by day and at night is hoisted to its place at the apex of the triangle by machinery worked in the oil-house. The large foundation-plates are about 40 feet 4 inches apart. The focal plane of the light is 120 feet above the sea level, but the top of the structure is 132 feet from the ground. The cost of the iron work set up is $9,400, and that of the structure complete and lighted about $12,000.

BRICK TOWERS.

ST. AUGUSTINE LIGHT-HOUSE, FLORIDA.

St. Augustine light-house was built of brick and iron, on Anastasia Island, on the eastern coast of Florida. Its base is a frustum of an octagonal pyramid, on which rests the frustum of a cone. The interior of the tower is lighted by five windows. Eight flights of spiral stairways furnish access to the watch-room, the first seven of which make half a revolution of a spiral, but the eighth a whole revolution. This arrangement does away with the incumbrance of a central shaft to support a winding stairway, and allows of a better lighted interior and of more room. The structure is 150 feet high from base to focal plane, and 165 feet above the level of the sea, shows a first-order light, and cost about $100,000 for its erection. The spiral stripes shown in the plate are added to distinguish it, as a day-mark, from adjacent sea-lights.

Many brick light-houses of this type have been built, among which are those at Cape Hatteras, Currituck Beach, and Body's Island, North Carolina; Morris Island, South Carolina; Sand Island, Alabama; Cape Foulweather, Point Arena, and Pigeon Point, on the Pacific coast.

STONE TOWERS.

MINOT'S LEDGE, MASSACHUSETTS.

Minot's Ledge light-house was almost the first, if not the first, important structure erected by the Light-House Board. It was its most important engineering work, and, according to General Barnard, himself

TH CAROLINA.

. . . tures was erect . . . and exhib . . . Altogether it is the . . . light-house construction. . . being found that the appropriation . . . the kind of structure which . . . The light exhibited is . . . parabolic reflector. It is . . . a lenticular apparatus . . . struts, and tension-rods . . . It rests on six circular iron . . . The top sections of the side . . . the guide, are provided with . . . the beacon by day. The light, . . . of the structure, is housed . . . at the apex of the triangle by . . . foundation-plates are . . . plane of the light is 120 feet . . . is 152 feet from the ground. . . . and that of the structure com-

. . . FLORIDA.

. . . brick and iron, on Anastasia . . . is a frustum of an oc- . . . frustum of a cone. The interior of . . . Eight flights of spiral stairways . . . of which make half a . . . revolution. This arrange- . . . central shaft to support a . . . interior and of more room. . . . place, and 165 feet above . . . and cost about \$100,000 for its . . . are adopted to distinguish . . .

. . . have been built, among which . . . Currituck Beach, and Body's Island, North . . . South Carolina; . . . Sand Island, Alabama; Cape . . . and . . . Point, on the Pacific coast.

. . . TOWERS

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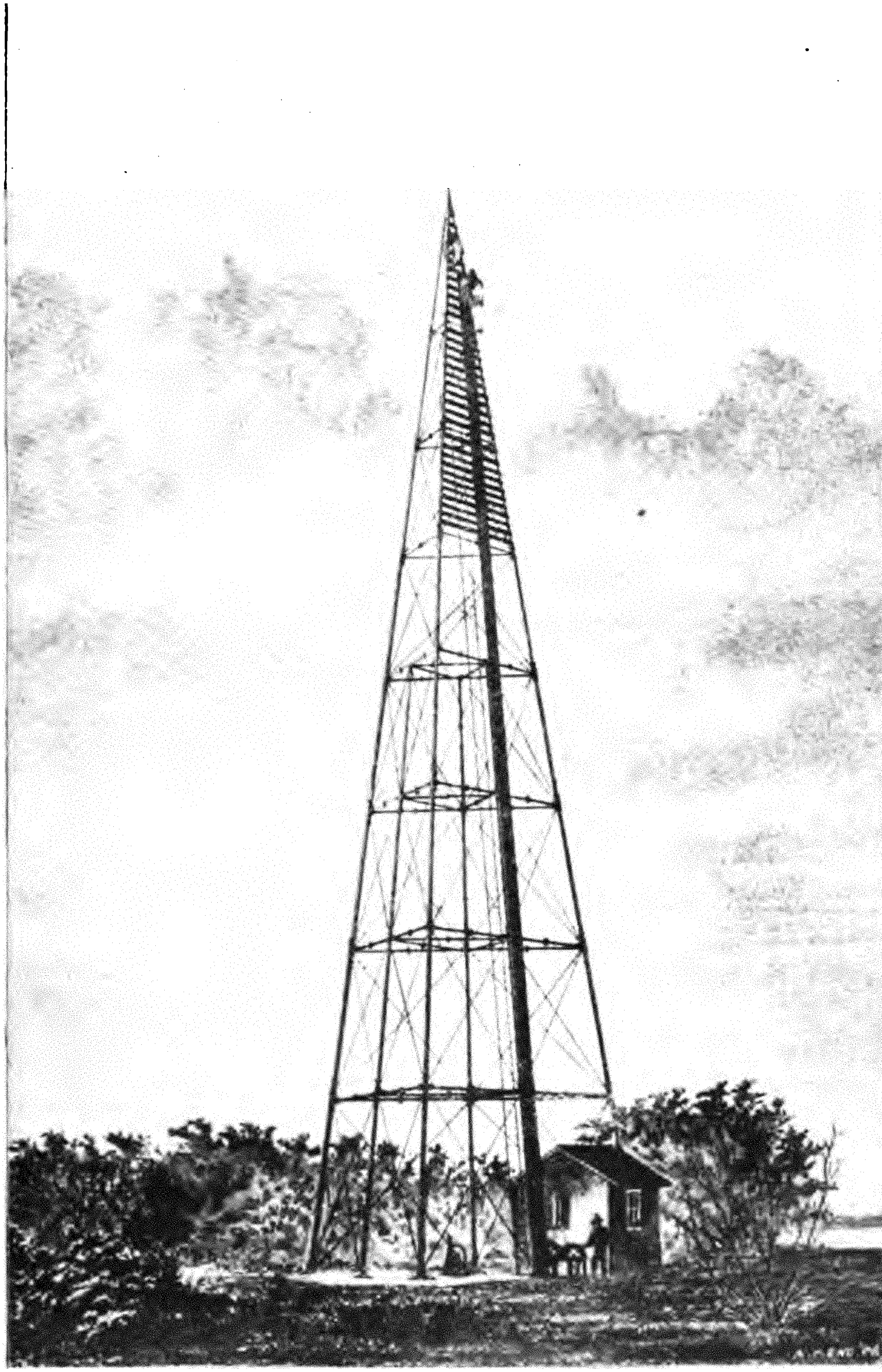


REAR BEACON, PARIS ISLAND RANGE, SOUTH CAROLINA.

FIRST ORDER LIGHT HOUSE AT ST. AUGUSTINE, FLORIDA.

an engineer of wide fame, "it ranks, by the engineering difficulties surrounding its erection, and by the skill and science shown in the details of its construction, among the chief of the great sea-rock light-houses of the world." The Board gave to the plan and its execution its freshest and best powers, and the combined energies of all its members. A careful survey of the rock was made under the orders of the Board by Major Ogden, U. S. Army. Then, after a full consideration of all the difficulties by the full Board, the preparation of the plan was devolved on the chairman of its Committee on Engineering, General Totten, then Chief of the Engineers, U. S. Army, who planned the masonry tower for this difficult position, and so successfully that, with the exception of the lower stones of the foundation, which had to be studied out of the rock itself, and some details of the construction, the tower was built throughout by B. S. Alexander, then Lieutenant of Engineers, according to the plans of General Totten. The brief memoir left by Colonel Alexander seems to be the only authentic record of the construction of the tower, but, brief and modest as it is, it shows that the skill and ability of the builder equaled that of the designers, and the great tower is likely to long stand as a monument to both and to the Board that availed itself of their powers.

The last stone was laid June 29, 1860, five years from its commencement, and its cost, including the keepers' houses on shore, was about $300,000.

LAKE LIGHT-HOUSES.

There are many light-houses on the Northern Lakes, of types peculiarly fitted to those great "unsalted seas." There are two hundred and eighteen lights on the lakes, but large as that number may seem, it is much less than is demanded by the lake commerce. The total tonnage of these lakes on June 30, 1888, as given by the Bureau of Navigation, was 874,102.72 tons.

In the commercial statistics appended to the annual report of the Chief of Engineers, U. S. Army, it appears that for 1888 the arrivals and departures of vessels from the port of Chicago, Ill., alone aggregated 20,000, and those from the port of New York 23,000. Allowing seven and a half months in the year as the period of lake navigation, it being frozen up the rest of the time, the average daily movement of vessels at Chicago was 89, as compared with 63 at New York.

The records at St. Mary's Falls Canal, which is the outlet of Lake Superior, show for the fiscal year which closed on June 30, 1888, the passage of 8,832 vessels, of nearly six and a quarter millions registered tonnage, and 7,000,000 freight tonnage.

During the navigation season of 1888, 31,404 vessels, with a registered tonnage of over 19,000,000, passed the Lime Kiln Crossing of the Detroit River, the outlet for the three lakes, Huron, Michigan, and Superior, corresponding to an average daily movement of 140 vessels, a number believed to be unexampled elsewhere in the world.

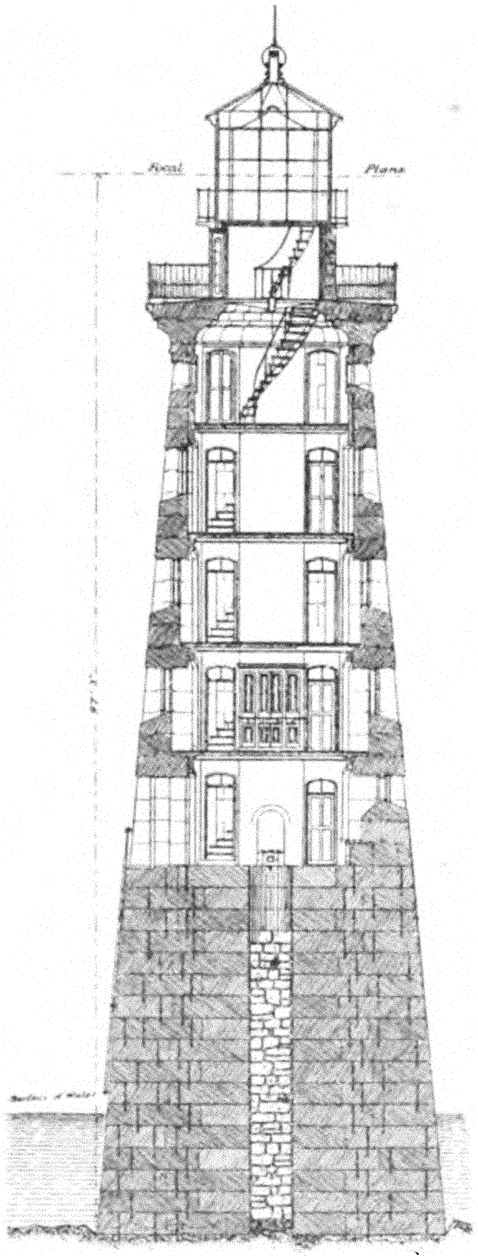
At the recent Water Ways Convention at West Superior, Wis., a compilation of official data was submitted to show that the lake commerce aggregated over $1,000,000,000 in value, with a tributary territory of over 1,000,000 square miles, and 17,000,000 of population.

A point that strikes one conversant with sea-board requirements, but unfamiliar with the lake region, is the character of the navigation. Lake Superior, in round numbers, is 400 miles in length; Michigan, 350 miles; and Huron and Erie, 250; but the average width does not exceed fifty miles. While, therefore, the total area of water surface is large and the distances great; for example, Chicago to Duluth, 800 miles; Chicago to Buffalo 900 miles, and Buffalo to Duluth 1,000 miles—equal to the distance from Sandy Hook to Cape Canaveral, or the longer axis of the Gulf of Mexico—the voyages are made in constant proximity to the land, which, in fact, is seldom out of sight. Furthermore, for long stretches the navigation, from the numerous islands and shoals, is exceedingly complicated and difficult, and the entrances to nearly all the ports are comparatively shallow and barely sufficient to admit loaded vessels. In addition, the lakes in the spring and fall are infested with fogs, which often shut in suddenly and last for several days. It may be stated also that, owing to the frequent voyages and changes of cargo—much of it metal and iron ore—the compass is much less reliable than at sea, while the comparative shallowness of the lakes and the variations in depth reduce the value of the lead line as a guide. In other words the lake navigator is engaged in a coasting trade with land on both sides of him, and makes his voyages under conditions of exceptional difficulty.

These facts have been thoroughly recognized in United States light-house expenditures. Up to 1883 there had been spent in placing lights on the waters of the State of Michigan, which has more lake coast than any other, the enormous sum of $2,353,207.77, a much larger amount than was spent in lighting the shores of any other State on ocean, gulf, or lake. And still the heavy expenditures which are continuously being made for lighting the Great Lakes does not keep pace with the unexampled growth of lake commerce.

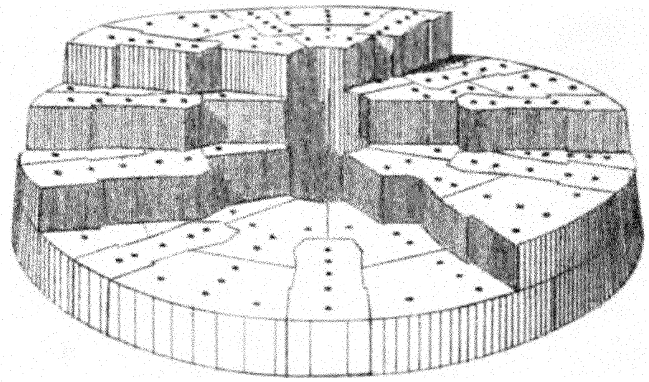
SPECTACLE REEF LIGHT-HOUSE, LAKE HURON, MICHIGAN.

This is a similar structure to that on Minot's Ledge. It stands on a limestone reef at the northern end of Lake Huron, near the Straits of Mackinac, which join it to Lake Michigan. The nearest land is 10½ miles distant, but it is 16 miles from Scammon's Harbor, where the work for it was prepared. The waves have a fetch of 170 miles to the south-eastward, but the ice-fields, which are here moved by a current and which are thousands of acres in area, and are often 2 feet thick, had to be specially provided against, as, when moving in mass, they have a force which is almost irresistible. But it is overcome by interposing a structure against which the ice is crushed, and then its motion is so impeded that it grounds on the shoal, on which there is but 7 feet of water, and forms a barrier against other ice-fields. The tower is in shape the frustum of a cone, 32 feet in diameter at the base, and 18 feet at the spring of the cornice, 80 feet above the base. The cornice is 6 and the parapet 7 feet high. The focal plane is 4 feet 3 inches above the top of the parapet. The entire height of the masonry above the base is 93 feet, and of the focal plane 97 feet 3 inches; the base is 11 feet below, and the focal plane 86 feet 3 inches above the water. For the first 34 feet the tower is solid, from thence it is hollow, and in it are 5 rooms one above the other, each 14 feet in diameter, with different heights, from 9 feet 2 inches to 7 feet 8 inches. The walls of the

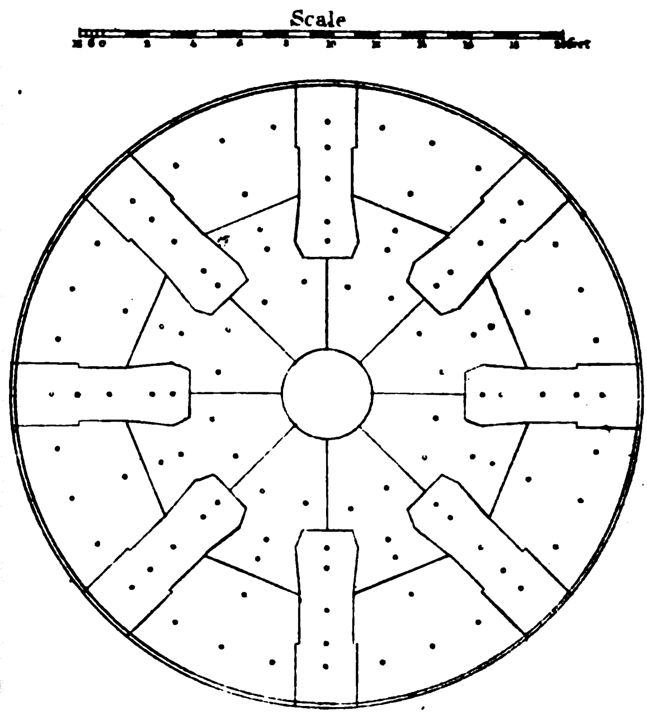


SECTION.

DETAILS OF MASONRY.



PERSPECTIVE VIEW OF COURSES 14, 15 & 16.



GROUND PLAN OF COURSE 14.

hollow portion are 5 feet 6 inches at the bottom, and taper to 18 inches at the spring of the cornice. The interior is lined with a 4-inch brick wall, between which and the masonry is a 2-inch air space.

The blocks of stone below the cornice are all 2 feet thick. Those of the solid portion of the tower were cut to form a lock on each other in each course and the courses are fastened together with wrought-iron bolts 2½ inches thick and 2 feet long, while the lower course is bolted to the foundation-rock with bolts 3 feet long, which enter the bed-rock 21 inches, the other courses receiving the bolts for 9 inches. Each bolt is wedged at both ends, and the bolt-holes, which were made with the diamond drill after the stones were in place, are plugged with Portland cement, which is now as hard as the stone itself. Hence the tower is in effect a monolith. The stones were cut, as were those of Minot's Ledge, at the depot and fitted course by course on a platform of masonry, and the work was so well done there that a course could be, under favorable circumstances, set, drilled, and bolted in three days. The main difficulty, however, lay, as in Minot's Ledge tower, in the preparation of the foundation. This was overcome by a pier of protection inclosing a coffer-dam. The pier was a crib-work of 12-inch timbers built upon ways at the depot, as a ship might have been, when it was launched, and towed by a number of steamers to the reef and grounded on its site. It was of wood, 92 feet square and 24 feet high, having a space within 48 feet square, and was divided into compartments, which were ballasted to make it firm. Thus a protected pond was formed for the coffer-dam, designed by Gen. W. F. Raynolds, of the U. S. Engineers, and a landing wharf was afforded for material, as well as for the reception of quarters for the men, all 12 feet above water, and out of reach of ordinary waves.

The coffer-dam was 36 feet across, and cylindrical in form. It was made of jointed staves 14 feet long, 4 inches thick, and 6 inches wide, held in place by three iron hoops, like a tub, and braced and stayed inside against a center post, the axis of which coincided with the axis of the cylindrical coffer. It was built at the surface of the water, and suspended exactly over the site of the tower. A loosely-twisted inch and a half rope of oakum was tacked to the lower end of the staves, and then the cylinder was lowered to the bed-rock, which had such irregularities on its surface that some of them were 3 feet high. All these were compensated by driving the jointed staves home, with a heavy top-maul, the oakum rope serving as calking; and this was made approximatively water-tight by an ingenious arrangement of a loosely-twisted 4-inch hay-rope and a canvas flap, which was attached in part to the outside of the lower edge of the cylinder, and which lay in part flat on the rock, and which was forced into the angle by the outside pressure when the pumps commenced lowering the water in the dam. The work was commenced in May, 1870, and the light was first exhibited from the finished structure in June, 1874; but the available working time spent on this light-house was but about twenty months. This tower, which cost, including the steamer and appliances of all kinds, about $375,000, is our best specimen of monolithic stone masonry. It was planned and built by Gen. O. M. Poe, he who was General Sherman's chief engineer in his march to the sea. Its strength has been thoroughly tested by the ice push already. When the keepers returned to the tower on the 15th of May, 1874, they found the ice piled against it to a height of 30 feet, which is 7 feet higher than the doorway, and they could not effect an entrance to the tower until they had cut through the iceberg, of which the light-house formed the core.

STANNARD'S ROCK LIGHT-HOUSE, LAKE SUPERIOR.

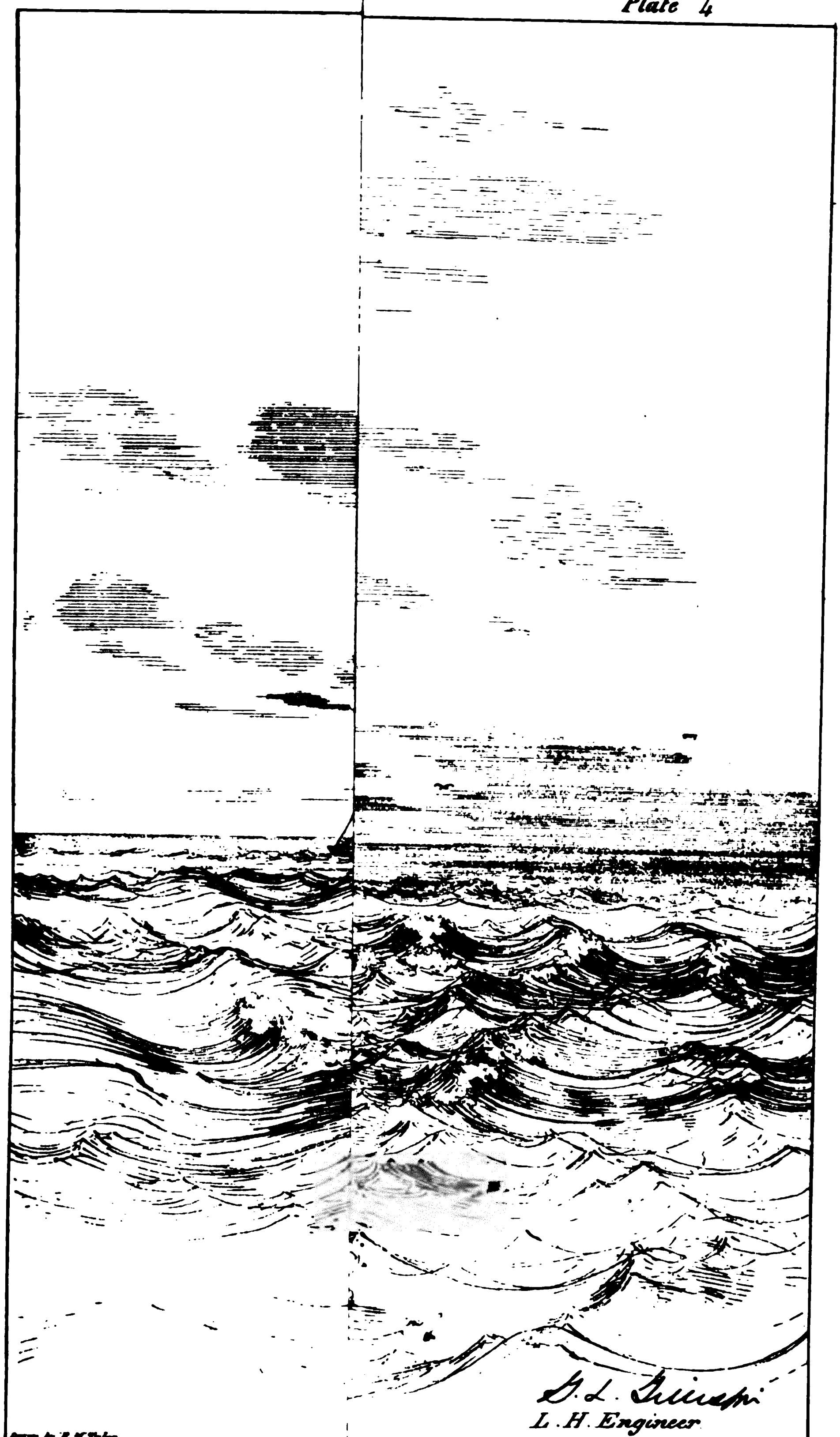
The Board has since built a similar structure in Lake Superior on Stannard's Rock, 28 miles from shore, for which the steamer and the plant used in erecting the light on Spectacle Reef were used. It is 101½ feet in height, and cost about $300,000. It shows a flashing white light of the second order, visible about 18 miles.

TILLAMOOK ROCK LIGHT-HOUSE, OREGON.

Tillamook Rock light-house, Oregon, is placed on an isolated basalt rock high out of water, about 1 mile from the main-land, in 15 fathoms of water, and about 20 miles south of the mouth of Columbia River. It is divided above low water into two unequal parts by a wide fissure with vertical sides running east and west, standing 100 feet above the sea, with a crest capable of such reduction as to accommodate a structure not larger than 50 feet square. A landing could with difficulty be made on the side next the shore during a smooth sea. The rugged character of the headland, the tendency of the sea face to land-slides, and the great distance from Astoria, the nearest supply-point, made the execution of the work a task of labor, difficulty, danger, and expense. The drowning of the foreman on the day of the landing of the first working party tended to confirm the prejudices of the local public against the enterprise, and to increase the difficulty of obtaining the services of skilled workmen. On October 21, 1879, however, four workmen, with hammers, drills, bolts, provisions, fuel, a stove, and some canvas to protect them and their supplies from the weather, were landed, and a few days later five more men and a small derrick were got to the rock, from which time the commencement of the work may be dated. For the first nine days after reaching the rock the nine quarrymen had no shelter from the rain and spray, except that of the canvas lashed to ringbolts. But during this time they cut a shallow niche in the north and east sides, in which they set up a strong timber shanty, which they bolted to the rock, covered with canvas, and secured to ringbolts. From this they secured safety, but got little comfort.

After setting up the main derrick and cutting a pathway up the face of the rock, they opened a bench around it by suspending the workmen on staging supported by bolts let into the rock's crest. The bench once formed, the reduction was pushed to the center. The outer surface of the rock was easily removed with moderate charges of black powder, but the nucleus was hard and firm, and giant powder was necessary to open the mass, when large charges of black powder acted satisfactorily. The working party, in spite of their rude, uncomfortable quarters, worked diligently through the winter with good results. But the work was much delayed by spells of weather so bad that little could be done. The coast was visited by a tornado in January, which caused the waves, reflected from the rock, to be carried by the wind over its crest, so that for many days continuously the receding floods poured over the eastern slope, making work impossible. On one such day this cataract carried away the

Plate 4



-house, and even endangered the quarters of the working party. ore than two weeks at this time it was impossible for the steam- which supplied their wants to cross the bar at the mouth of the ıbia River to go to their assistance; when, after sixteen days, com- ation was reopened, the party was found to be safe, but much in of fresh provisions. These were supplied by an endless line running en the mast of the supply-vessel and a ringbolt driven into the top e rock, in water-tight casks suspended by slings from a traveler, h was made to move along the line.

ı May the top of the rock was leveled and a foundation made about feet above the sea, and, on the 31st, three masons, four derricks, a small ine, and the appliances for laying the masonry, were landed. The ne, a fine grained, compact basalt, quarried near Portland and cut to nensions by contract, was delivered at Astoria and shipped to the rock the tender. The first cargo was landed on June 17; on the 22d the rner-stone was laid, and then the rest of the material was shipped to the ck as the weather permitted.

The building is a square one-story keeper's dwelling, with a rectangular xtension for the duplicate siren fog-signal apparatus. In the center of he keeper's dwelling rises the tower, which is crowned by a gallery and ı lantern containing a first-order lens apparatus. The material used is stone, cut to dimensions on the shore, for the outer walls, and brick, iron, and wood for the interior. The light is 48 feet above the base of the tower and 136 feet above mean sea-level. It was shown for the first time on February 1, 1881. If it had been finished a month earlier it would possibly have saved the English iron bark Lupata, of 1,039 tons burden, which was dashed to pieces on the main shore, not a mile from the light-house, with a loss of the vessel, its freight, and every one of the twenty persons on board. The bark came so near the rock that the creaking of the blocks and the voices of the officers giving orders were distinctly heard, but the night was so dark that nothing could be seen except her lights. The superintendent of construction had a bon-fire built on the rock as soon as possible, but the vessel was probably lost before the signal could be seen. It was on this night that the working-party lost their supply-house and came so near losing their quarters, if not their lives.

LIGHT-HOUSES ON TUBULAR FOUNDATIONS.

SOUTHWEST LEDGE.

Southwest Ledge light-house is built on a rock in Long Island Sound, at the mouth of the harbor of New Haven, Conn., about a mile from the land. The surface of the ledge is made to approximate a level by a layer of concrete at least 4 feet thick. Two courses of masonry, each 18 inches thick, are laid on the concrete. The upper surface of the masonry is 4 feet below mean low water, 10 feet below mean high water, and 11 feet 3 inches below extreme high water. The foundation cylinder rests directly on the masonry. It is composed of cast-iron plates, 6 feet high, 4 feet wide, and 2 inches thick, with a curve of 15 degrees; and they are bolted together. This cylinder is 24 feet in diameter, and about 30 feet high. The top of its gallery is a fraction over 18 feet above extreme high tide.

It is filled in solid with concrete to the top. An enrockment of about 3,000 tons of large granite blocks surrounds the pier. The tubular foundation is surmounted by an irregular octagonal house and tower, from which is shown a fourth-order fixed white light, 57 feet above the level of the sea. On January 1, 1878, it was lighted for the first time.

The peculiarity of this structure is that, being round, it offers slight obstruction to floating ice, and that it is a monolith of artificial stone, surrounded by a veneering of iron sufficient to retain it in place until the concrete filling gained the requisite hardness by age. This was the first of a number of the kind; and its stability was thoroughly tested in the hurricane of September last.

LIGHT-HOUSES ON SUBMARINE STONE FOUNDATIONS.

RACE ROCK.

Race Rock light-house, in Long Island Sound, 8 miles from New London, Conn., was built under great difficulties. It is off Fisher's Island Sound, at the mouth of the Race, where the waters of the sound rush both ways, according to the tide, with great velocity and force, and where in heavy weather the waves run high and with great power.

The ledge on which the light-house is built is under water. It has one large and several smaller spurs of rock rising above the general surface. The least depth at mean low water on the principal spur, or Race Rock proper, is 3 feet. The greatest depth at mean low water within the circle of 69 feet is 13 feet.

The ledge was, with the help of divers, made approximately level with small broken stone and riprap. Upon this is placed a circular-stepped mass of concrete, 9 feet thick, built in 4 concentric layers. The lower layer is 69 feet in diameter and 3 feet thick. To form the layers of concrete, cylindrical bands of half-inch iron, of the height and diameter required for the respective layers, were used. The upper surface of the concrete, 8 inches above mean low water, carries a conical pier, 30 feet high, 57 feet in diameter at the base, and crowned by a projecting coping 55 feet in diameter. The pier is made of heavy masonry backed with concrete, in which cisterns and cellars are formed.

The pier is surmounted by a granite dwelling one story and a half high. From the center of its front the granite light-tower ascends. A landing-pier, 53 feet long and 25 feet wide, built of heavy masonry, gives access to the light-house. The whole structure is surrounded and protected by riprap. The tower, which is square at the base and octagonal at the top, carried a fourth-order flashing light, which is 68½ feet above the sea-level. This work, which was commenced in 1872, was finished in 1878, and lighted for the first time on the night of January 1, 1879.

PENFIELD REEF.

Penfield Reef light-house stands on the reef of that name about 2 miles from land, in Long Island Sound, off the harbor of Bridgeport, Conn. It was built in 1872–'73, on a riprap foundation 108 feet in diameter at the base, and extending up to low-water mark. A pier was built on this of cut stone, in nine courses. It is 48¾ feet in diameter at the base, by 46½ feet at the top, and it is 18 feet high. It is surmounted by a granite dwelling and tower, from which is shown a flashing red light at an elevation of 54 feet above the sea-level.

RACE ROCK LIGHTHOUSE.

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Bids for [illegible] for $112 [illegible] estimate [illegible] The tower [illegible] top [illegible]

DETROIT RIVER LIGHT-HOUSE, MICHIGAN.

This structure stands in 22 feet of water, on a wooden crib filled with concrete, on which is placed a pier of stone masonry. The crib was built on shore, of heavy timbers, with a tight bottom, and was launched like a ship. It is 90 feet long, 45 feet wide, and 18 feet high, and when filled with concrete and sunk to its bearings its top was 4 feet below high water. The pier of cut stone was erected on the crib, and on the pier the cast-iron conical light-tower was built, which was surmounted by a 4th-order lantern. The main feature in this work was its wooden crib and its successful placing. Its settlement was quite uneven at first, it being 16 inches out of level, so it was loaded with stone, the greater part being on the high side, and so left during the winter. In the spring the pier was level, and has so remained.

LIGHT-HOUSES BUILT UPON A CAISSON FOUNDATION.

The Light-House Board had long been contemplating the approaching need of building light-houses on shoals distant from land, in the open ocean. Tentative plans had been made for use at various sites, but no practical action was taken, when Congress made an appropriation of $175,000 for the erection of a light-house on Fourteen-Foot Bank, which is some 20 miles from the nearest harbor, between the Capes of the Delaware. The time came to put into practical operation the plans which had before only existed in theory. Mean-time the Germans were engaged in making plans for a similar work in the North Sea, at the mouth of the Weser River, and at about the same distance from land. And the Light-House Board, after a careful study of those plans, determined to build Fourteen-Foot Bank light-house upon the same lines, but from special plans made to fit the particular case. It will be well, therefore, to give some account of the building of the Rothersand light-house.

THE ROTHERSAND LIGHT-TOWER AT THE MOUTH OF THE WESER RIVER, GERMANY, IN THE NORTH SEA.

Bids for doing the work were called for in September, 1880, and the contract was given to the lowest bidders, a new company, which took the job for $112,500, while the next highest bid, that of the Harkoort Company, an established firm of large experience, full equipment, and immense capital, was for about $35,000 more.

The tower was to be built on a sandy bottom 38 feet below the water-level, to be 93 feet above low water, and to be strong enough to resist heavy seas and floating ice, and it was to be filled with concrete 13 feet 6 inches above the low-water line. By August 4, 1881, it had been sunk 44 feet into the sand, bringing it 70 feet below low-water mark, a greater depth than was originally contemplated. But while the work was going on, the height of the cylinder and the quantity of concrete filling was but slightly increased, and little was done to protect the caisson from the approaching storms. The concrete filling had only been brought up to the top of the shoal. So the hollow iron cylinder stood unprotected against the combined action of the wind and the sea, except by its insufficient timber bracing.

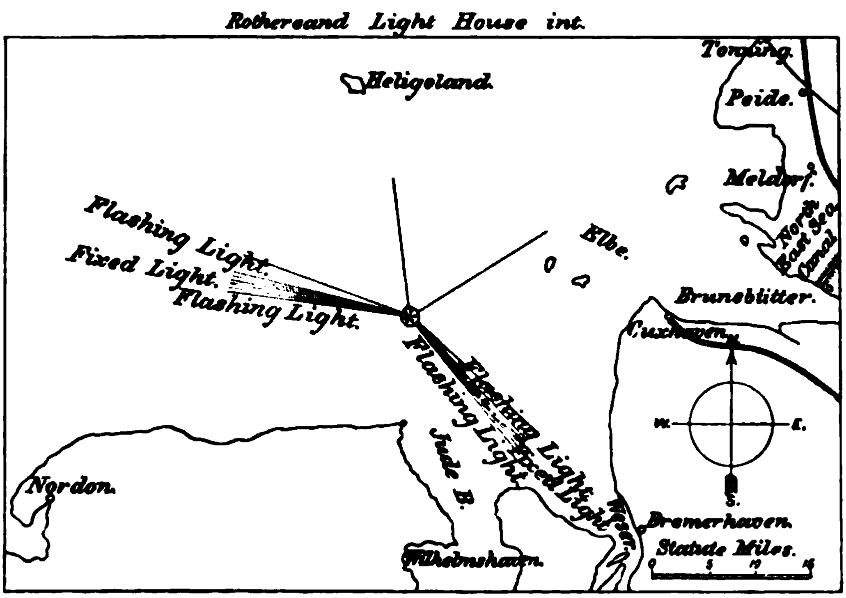
The contractors were warned of these defects and deficiencies, but did not remedy them, preferring to continue the sinking of the caisson, as according to agreement they could draw money by partial payments, the amounts being proportioned to the distance the cutting edge penetrated the sand.

On October 9, 1881, so heavy a storm prevailed that the waves ran over the top of the iron cylinder, which was but 8 feet above the water at high tide, and about noon the cylinder disappeared from sight. Examination made in fair weather by divers showed that the cylinder had been broken off 7 feet above the bottom of the sea.

The low price at which the contract was taken was the principal cause of its failure. The contractors were compelled to save in the construction of details, which should have been executed in the best manner, and were forced to neglect important preparations for which they had failed to estimate.

The expenditure on this abortive attempt to build a light-house on Rothersand was $95,500 up to the date of the disaster.

The authorities were not daunted by this failure. The next March the contract was given to the Harkoort Company, at their own price, a fair one by the way, to build the light-house on the Rothersand. The total price for the complete structure, ready for occupancy, not including the illuminating apparatus, was $216,750. The contract was signed on September 21, 1882, and on October 23, 1885, the tower was accepted by the Government.

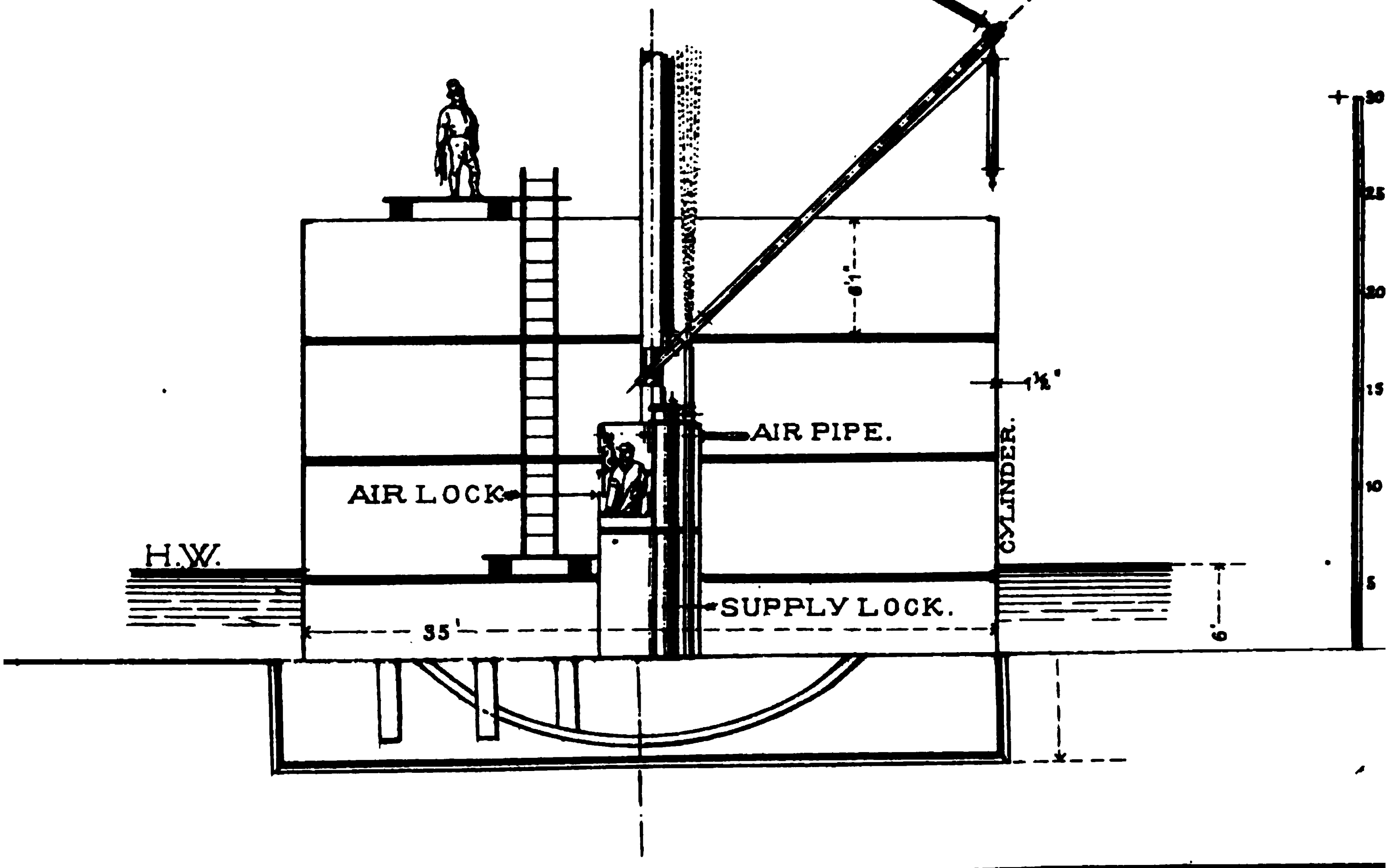


FOURTEEN-FOOT BANK LIGHT-HOUSE.

This light-house was built in the following manner:

First they built a caisson of timbers each a foot square. This was in effect a raft nearly 40 feet square, 5 feet thick, with a rim 7 feet deep, forming the cutting edge, of which much will be said. This caisson then was like a tin pan upside down, and the space between the rim, the bottom of the raft, and the sand was 7 feet high, and nearly 40 feet square in area, and constituted the working chamber underneath the caisson. This cais-

SECTION.



Fourteen-Foot Bank Light-House.

son was lined and filled in between joints with mineral pitch, and the whole thing was sheathed, so it was in effect water-tight. Through the center ran a 5-foot air-shaft, giving access to the working chamber below. This caisson was built on ways, the bottom of the working chamber was temporarily floored over, and it was launched like a ship.

On this caisson a 35-foot iron cylinder was built up from 1½-inch iron plates, which were 6 feet high. When three courses of plates were in position they made a cylinder 18 feet high. Then a 9-inch layer of concrete was dumped in as ballast, and the structure was towed to its site. Its displacement was about 400 tons, and its draught was 15½ feet.

The site at Fourteen-Foot Bank, was 20 miles away from Lewes, Del., the point of departure. There was a 6-foot rise and fall of tide, of which all possible advantage was taken. It took two steam-tugs six hours to tow this structure out there.

When the caisson was sunk to the surface of the shoal, the top of the cylinder was but 16 inches above the water, and two additional series of iron plates were at once put in place, bringing the top about 20 feet above the sea-level. The sinking was done by letting water in, which brought it down and made it touch bottom.

It did not, owing to the scour of the currents, strike the bottom on a level. The cutting edge of the caisson did not rest upon the shoal for a considerable part of its length, and at times the cylinder was 12 degrees out of the vertical. Hence there was some danger that it would upset. Then were brought to bear all the skill, experience, and appliances at the command of the contractors. It was the pivotal point of the enterprise. A little less skill, a trifle less power, a slight lack of experience, a failure in that self-possession which is born of previous success, and the enterprise would have ended in disaster. As it was, broken stone provided for making concrete, which was on hand ahead of time, was loaded in on the upper side, and thus the structure was brought down all around to the sand. Then a hole was cut in the air-chamber so that the water ballast within rose and fell with the tide, and the structure could not be lifted by the tide; the cutting edges penetrated the sand and took such hold on the shoal that the structure was steadied, and after that all else was a question of detail.

The cylinder when finished was 35 feet in diameter and 73 feet high. At low tide it stood 30 feet out of water and penetrated into the shoal nearly half its length. It was filled in solid with concrete some 40 feet above the caisson, except as to the space occupied by the air-chamber, which was filled with sand, and thus the cylinder became a monolith with a veneer of iron an inch and a half thick. To give it greater stability and to prevent possibility of scour from currents, some 6,000 tons of riprap stone were placed around the structure.

As soon as practicable, air was forced into the working chamber and three gangs of men were engaged in it on eight-hour shifts, so the work was carried on continuously at the bottom of the sea throughout the twenty-four hours. They dug the sand out from under the structure, when it was blown through a 4-inch pipe to the top and thence over into the ocean. In this way the structure was sunk into the sand at the rate of from 1 to 2 feet per day until it had penetrated to the required depth, about 33½ feet below the original surface of the shoal.

The cutting edge was then tightly under-rammed, the working chamber and air-shaft were completely packed with sand, and the latter was sealed with concrete at a level of about 33⅓ feet above the caisson roof.. The cylinder was filled with concrete to a point about 10 feet below its top, and on this the arches were sprung, on which the superstructure was erected, commencing with the cellar story.

The appropriations for Fourteen-Foot Bank light-house were $175,000. Its entire cost, including everything, was but $123,811.45, and the balance, more than $50,000, was returned to the Treasury. The structure was finished and lighted in the fall of 1887.

OUTER DIAMOND SHOAL LIGHT-HOUSE, OFF CAPE HATTERAS, NORTH CAROLINA.

The United States Congress at its last session authorized the Light-House Board to erect a light-house at this point and placed $500,000 at its disposal for this purpose. The shoal is about 7½ miles from the pitch of the Cape, in the open ocean, and considering the currents, the distance from a harbor, and the terrible storms so frequently met there it is the most serious and difficult work ever attempted. The Light-House Board is preparing to do the work on the lines of that done at Fourteen-Foot Bank.

The following is an extract from an appendix to its last Annual Report, in which the subject is fully treated:

> It is proposed to build the Hatteras Shoal light-house much in the same way that the Fourteen-Foot Bank light-house was built. If it is, it will be an iron cylinder resting on a caisson; it will be filled with concrete, and it will be sunk into the sand of the shoal for about half its length. The Government will then furnish the cylinder plates. The contractor will build his caisson, put up three or more courses of the cylinder on it, float it to its site, sink it to its place, and build it up and sink it down simultaneously, as was done at Fourteen-Foot Bank, furnishing all the appliances and labor, and will have no pay if he is not successful. But this work is to be vastly more difficult and dangerous than the other. That was towed 20 miles through an open sea with no obstruction but the weather. This will be taken over a bar on which at high tide there is but 8 feet water, and past shoals on either hand, through broken water, across rapid currents and at a point where the wind is quite variable. The chances of success are not as good as at Fourteen-Foot Bank, and the danger to life as well as to the property used is vastly greater. The pivotal point on which success turned in the Fourteen-Foot Bank case was small. In this case it will be still smaller. In that case great skill, foresight, and experience were used. They had plentiful appliances, large capital, and they were favored by good weather. And yet they were barely successful. In this case all these should be had in an increased degree to insure success.
>
> In addition to all the danger of properly setting the structure that was met in that case, there is in this case a still greater danger. The caisson, which will draw from 15 to 2C feet, must be lifted over an 8-foot bar by camels, pontons, or some such appliances, and they must be of a kind that can be dispensed with on gaining the open water. This is entirely within the scope of modern marine engineering, but it requires great skill and the use of the best appliances.

It is stated in this appendix that two well-known firms of great experience, large and varied plant, and heavy capital, offer to contract to do the work in twelve months for the amount appropriated, under heavy bonds, and to receive no payment until the light-house is finished, tested, and accepted by the Government. The working plans for the structure are now under consideration.

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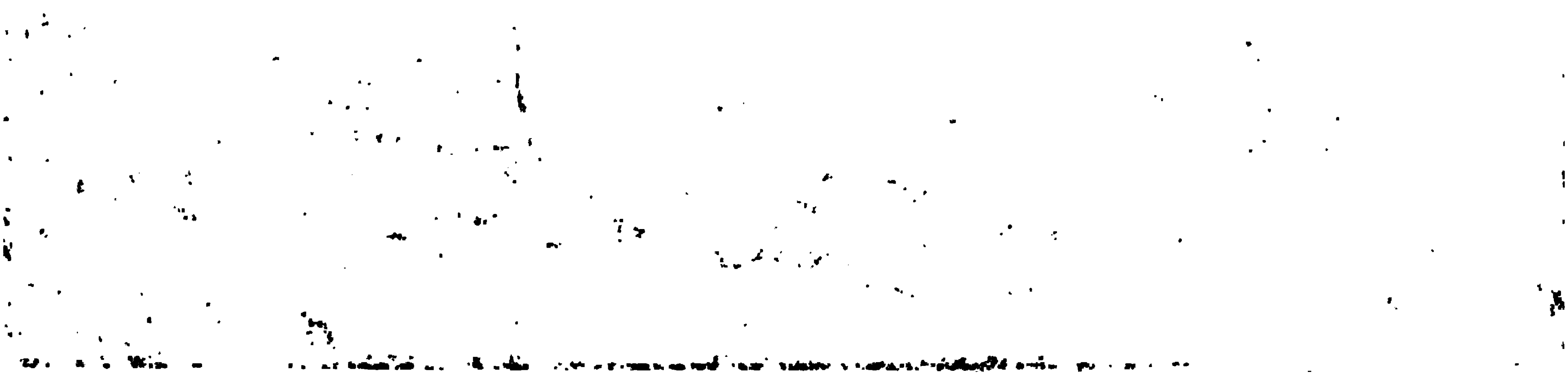


[illegible] WITH STEAM FOG-SIGNAL, NANTUCKET [illegible]

Chapter V.

LIGHT-VESSELS.

The purpose of a light-ship is to do the work of a light-house in a place where one is necessary, but where it has not been erected because of the great difficulty, not to say expense, of such a structure. But the light-ship should have the permanency and efficiency of a light-house, and should give as good a light in clear weather and sound as far-reaching a fog-signal in thick. To insure permanency of position is a matter of great difficulty. When moorings have been made too heavy to drag, chains have broken; when they have held, mooring-bitts have been torn out; when they have held, the ship has foundered at her anchors, or the cable has been slipped, and the ship has sought a harbor or gone to sea for safety. But under the present rules of the Light-House Board rigid inspection is frequently made of the riding-gear of the light-ships, and the absence of a light-ship from her moorings is now quite unusual.

The Board has thirty-two light-ships of various sizes on duty in the service. The smaller, slighter-built, and older vessels are moored in sounds and bays. The larger, stronger, and later-built are anchored in the open ocean. Among the latter is that on New South Shoals, some 21 miles at sea, the nearest land being Nantucket Island; Pollock Rip light-ship, moored at the eastern entrance to Nantucket Sound; another is moored at the western entrance to Vineyard Sound; another at Sandy Hook entrance to New York Bay; two off the mouth of Delaware Bay; another on Winter Quarter Shoal, off the coast of Virginia; another off the entrance to Chesapeake Bay, Virginia; another on Frying-Pan Shoal, off the mouth of Cape Fear River, North Carolina; another on Rattle-snake Shoal, off the entrance to Charleston, S. C.; another off Martin's Industry Shoal, at the entrance to Port Royal, S. C.; and another on Trinity Shoal, off the coast of Louisiana. Several light-ships have fog-signals which are in effect locomotive steam-whistles of great size and power. The Board is now building at a cost of about $60,000 each, three light-vessels, one is to be placed on Great Round Shoal, in the open ocean off Nantucket; another is to be placed on Bush's Bluff Shoal, Hampton Roads, Va.; and the third is to be located off the bar of the Columbia River, in the Pacific Ocean. These vessels are each to have steel frames, will be sheathed with wood, and will have all the modern improvements, including 12-inch steam fog-signals. They are intended to be the most powerful and complete light-vessels ever built.

Each light-ship shows either one or two lights. Each light is composed of eight renectors, each 12 inches in diameter, set upon a ring which encircles the mast, and can be lighted and hoisted to the mast-head by night, and lowered and housed by day. These reflectors are illumined by a kind of argand lamp, in which the sperm oil formerly burned was succeeded by lard oil, and that is now superseded by mineral oil, burned in a lamp specially adapted to the purpose. The lighting apparatus is inclosed in a lantern, with large panes of glass which protect the light from the wind.

The light-ship shown in the accompanying plate is that upon Pollock Rip Shoal. It was built in 1877, is about 120 feet long, nearly 27 feet beam, 12 feet 5 inches hold, and is of 410 tons burden. She is schooner-rigged, with a lighting apparatus upon each mast supplied with eight burners and reflectors. It has been found so difficult to keep this vessel from dragging her anchors that she is now fitted with as heavy moorings as she would be if she were a frigate. In spite of her brilliant lights and her powerful fog-signal she has been repeatedly run into by passing vessels and more or less damaged, as have most of the other light-ships in the service. She has a master, a mate, two engineers, and a crew of six men. Her cost was $50,000, and it requires about $5,000 a year to maintain her exclusive of repairs—a larger sum than is needed for smaller ships, or for those without fog-signals.

It is estimated, however, that it costs $8,000 per year to maintain and keep in repair each of the first-class light-ships in the service, and this is urged as a reason for replacing them as fast as possible with light-houses.

Certain of the British light-ships show revolving lights, some of which are red. Each ship has four or eight reflector-lights in a lantern to produce a fixed light. When a revolving light is required a number of these reflectors are fixed to the side of a triangular or quadrangular frame, and the whole is caused to revolve around the mast in regular periods by clock-work. The reflectors on each side of the revolving frame, from four to eight in number, are thus successively directed to every point of the horizon. The combined result of their rays is to form a flash of greater or less duration, according to the rapidity of their revolution.

The apparatus on board the Shambles light-vessel is composed of eight 21-inch reflectors, with double-wick Trinity House Douglass argand mineral-oil lamps, six being arranged in one group for the long flash, and two for the short flash. The maximum intensity of each flash is, approximately, 11,000 candles, and the duration of the flashes and eclipses is as follows:

	Seconds.
Long flash	5
Eclipse	6
Short flash	$1\frac{1}{2}$
Eclipse	$17\frac{1}{2}$
Total	30

The Light-House Board of the United States has not thus far found it necessary to use revolving lights on its light-ships, but it is experimenting in that direction. Its theory is that light-ships should, as rapidly as possible, be replaced by light-houses.

TENDERS.

The Board has a fleet of twenty-eight steamers and two schooners, ranging from 18 to 550 tons burden. It is the business of some of these steamers to attend to the buoyage of the coast, replacing the buoys which have gone adrift, exchanging every buoy for a fresh one once a year, and

placing new buoys. They are also used to supply the light-houses with provisions, fuel, and minor supplies, and on them the inspectors visit the light-stations to make their regular quarterly inspections and to pay the keepers. Certain of the tenders are used for construction purposes, freighting building material to light-house sites, and conveying building and repairing parties from station to station. Twenty-two of these vessels are employed on the Atlantic and Gulf coasts, three on the lakes, three on the western rivers, and two on the Pacific coast. Twenty-two of these vessels have been built for light-house purposes since 1870, and are in tolerable condition. Five of the steamers and one of the schooners are poorly adapted for the service, quite old, and are only kept on duty until they can be replaced by others. The Board is now building two steel screw steamers, one for the New England coast to cost about $80,000, and the other for the Great Lakes to cost about $85,000. The latter, called the *Marigold*, is to be 150 feet long 27 feet beam, is to draw 10 feet 3 inches aft, and 9 feet 3 inches forward, when loaded, and to run 11 knots an hour. She is to have triple expansion engines, two cylindrical tubular boilers, to carry 150 pounds pressure of steam. She is also to have eight water-tight compartments with a trimming tank forward. The tender intended for the New England coast is to be a similar steamer in many respects. Of those now in use three are under 100 tons burden, two are between 100 and 200, nine between 200 and 300, ten between 300 and 400, five between 400 and 500, and one between 500 and 600.

The Board's largest steamer, the *Fern*, is used to supply the light-stations on the Atlantic and Gulf of Mexico coast with illuminants, visiting each station that is accessible yearly for that purpose. The others are supplied by the district tenders. This work has outgrown the capacity of the *Fern*. The steel steamer *Armeria*, now on the stocks, is to take her place, when the *Fern* will again be used as a district tender, the purpose for which she was originally built. The *Armeria* is 201 feet 8 inches long, 34 feet 9 inches beam, and 16 feet deep. She is to have twin screws and a speed of 12 knots. She is designed with an inside keel to lessen her draught and to strengthen her throughout. Her engines will be of the compound type, independent of each other, of 1,250 indicated horse-power. Her boilers will be the Scotch cylindrical, and designed for high pressure. It is expected that she will be ready for use before the close of the present year.

The steam-tender *Manzanita*, which is represented in the accompanying plate, was built in Baltimore in 1878-'79, and was sent through the Straits of Magellan to the Pacific coast, where, by reason of her size and power, she is used for inspection, supply, and construction purposes. Her length is 152 feet, beam 26 feet, and hold nearly 12 feet. She is a screw steamer, schooner-rigged, built of wood, and cost, when equipped, about $60,000. She has a derrick attached to her foremast, operated by a hoisting-engine which takes its steam from her boiler. She is manned by a captain, mate, two engineers, and twenty-one others. The *Manzanita* may be considered as typical of the tenders of the future, rather than of the past or present, as she is one of the best in the service.

CHAPTER VI.

BUOYS.

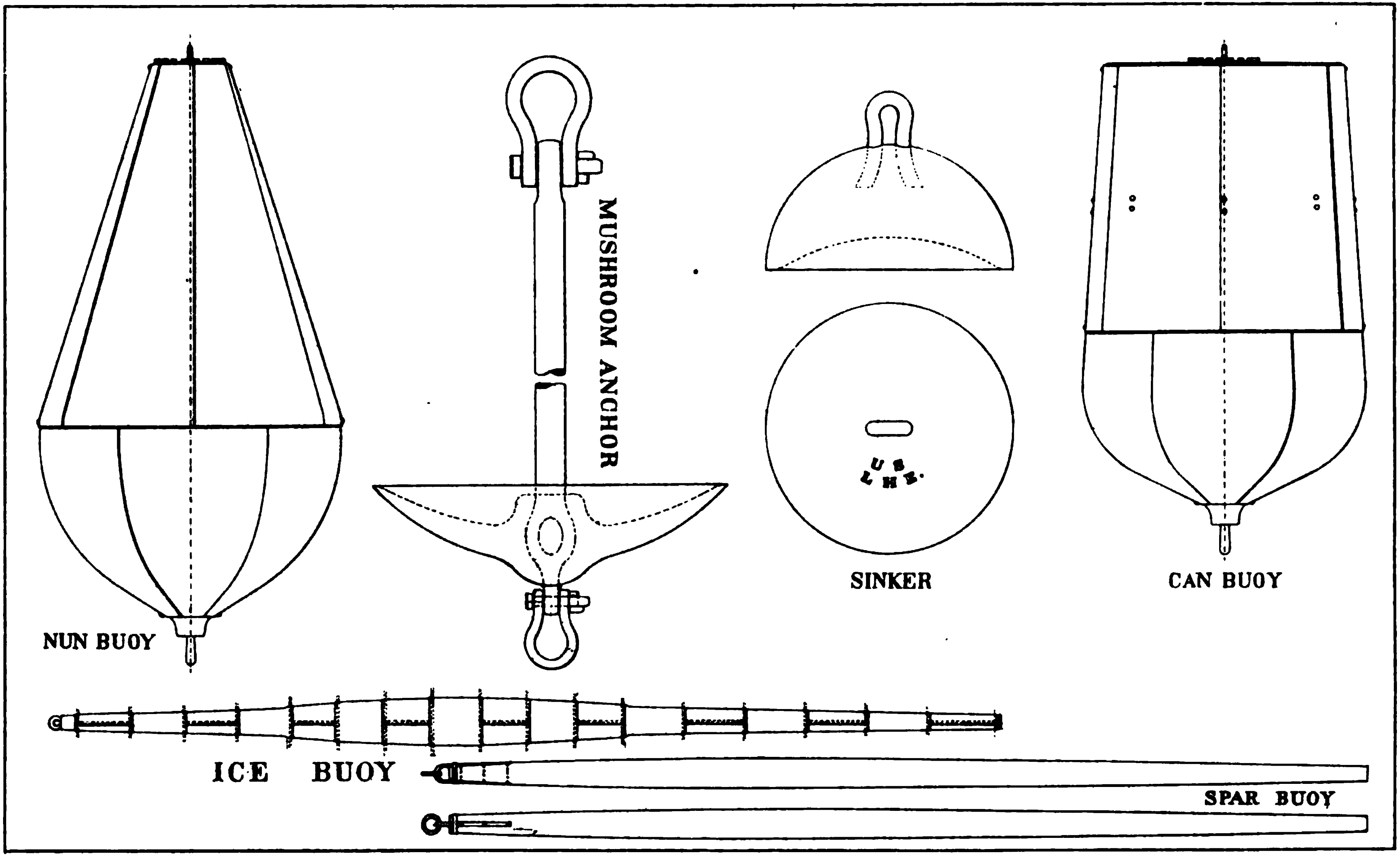
The buoy is to the seaman by day what the light is at night, and what the fog-signal is in thick weather. It tells him by its size, form, color, and number how to avoid the rocks and shoals, and shows the way in and out of harbor.

The growth of the buoy service may be measured by its cost, which was, for the five years preceding the organization of the Board, in 1852, about $75,000 per year, and for the five years after about $82,000 per year.

In 1842 the Light-House Board had nearly 1,000 buoys in position; in 1858 it had 1,034; in 1860 it had 1,738; during the war of the Rebellion it lost those on the Southern coasts, but in 1867 it had so far replaced and added to them that it had 2,044; in 1875 it had 3,002; and on June 30, 1889, it had 4,309 buoys in the waters of the several districts. An appropriation of $325,000 was made for maintaining the buoyage of the United States coasts during the year ending June 30, 1889.

The buoy service has its own code of laws, State and national, a fleet of small steamers for its maintenance, besides a corps of contractors to attend to the buoyage of coves and inlets impracticable to the tenders. It has its depots for the storage of iron buoys, where they are painted and numbered, or repaired, and also where wooden buoys are made ready for service. It has its own directory printed yearly, in 13 volumes, distributed gratuitously for the benefit of commerce, in which each one of the more than 4,300 buoys is mentioned by name, located by station, and is described by size, shape, color, number, and vicinity. The problems connected with its improvement, as well as its maintenance, are considered as of grave importance, and are made the subject of deep consideration by the best scientific aid at the disposition of the Light-House Board.

Buoys are of wood or iron. The wooden buoys now in use are sticks from 12 to 60 feet long, of pine or spruce, but preferably of cedar. The Board frequently contracts for the delivery at one of its depots of a cargo of logs, in the rough, at from $10 to $15 each, where they are freed of their bark, smoothed of their protruding knots, painted to the pattern required to tell their allotted story, fitted at the larger end with an iron sleeve, to which the stone or iron anchor can be attached by a mooring-chain, when they are packed in classes or sizes on skids to season, and finally to take their tour of duty in the water to replace others which are to rest a while on shore, be freed from acquired barnacles, take on a fresh suit of paint, and, by drying, recover their buoyancy. Spar-buoys are classified first by length and thickness, and then by acquired color; but they are interchangeable within these conditions. The following cuts represent the buoys and their appendages.


NUN BUOY
MUSHROOM ANCHOR
U.S.
L.H.E.
SINKER
CAN BUOY
ICE BUOY
SPAR BUOY

Iron buoys are hollow, with air-tight compartments, and are made of three shapes, called nun, can, and ice buoys. The nun-buoy is almost conical in form; the can-buoy is in shape the frustum of a cone, nearly approaching a cylinder, and the ice-buoy is found much like a spar-buoy, of great length, slight thickness, and of largest diameter near its middle. Each shape is classified by size, and diversified by color and number. They were once made of wooden staves, like barrels, but their rapid destruction by the *Teredo navalis* caused the substitution of boiler-iron. The cost of these buoys varies with the price of iron and the cost of labor. The Board's last contract for buoys, with all their attachments, except mooring-chains, was made at the following rates:

For first-class can-buoys, 6 feet across, and 9 feet 6 inches high..............	$150.00
For second-class can-buoys, 4 feet 4 inches across, and 7 feet high .	88.77
For third-class can-buoys, 3 feet 2 inches across, and 4 feet 10 inches high...	41.81

Congress prescribed by act of September 28, 1850, that red buoys, with even numbers, be placed on the right-hand side, and black buoys, with odd numbers, on the left-hand side of channels approached from seaward; that buoys placed on wrecks or other obstructions, having a channel on each side, be painted with red and black horizontal stripes; that those buoys placed in mid-channel, and which indicate that they must be passed close-to to avoid danger, be painted with white and black perpendicular stripes; and, finally, that perches, with balls, cages, etc., when placed on buoys, will indicate a turning-point, the color and number of the buoy showing the side on which they are to be passed.

Buoys are exposed to many dangers, not the least of which is that of being run down and ripped open by passing steamers. As the iron buoys are made with compartments, they are rarely sunk, but their line of floatation is often lowered, and their usefulness accordingly decreased. Spar-buoys frequently lose a portion of their length, which is cut off by strokes of colliding propeller-blades. Despite State and national statutes forbidding it, vessels will sometimes make fast to buoys, thus gradually dragging them off their bearings. A buoy has sometimes been set adrift that a reward might be obtained for its recovery; but this is not a profitable operation, as the reward paid is varied with the circumstances of each case.

The buoys' worst enemy, however, is ice, when moving in mass, and with a tide or current. A well-made, well-moored buoy, at the mouth of a narrow river can create an ice-gorge; but usually, when the ice moves in force, the buoys met have their mooring-loops torn out, their mooring-chains broken, or their mooring-anchors weighed; and in each case the buoys are carried out to sea, when the buoy-tenders give chase, and, if successful in their capture, return them to position. The sea-going qualities of the large iron buoys are shown by their volunteer voyages. One is now anchored off the coast of Ireland, where it was picked up, about six weeks after it had been wrenched from its place in New York Harbor, and turned over to the Irish light-house establishment, by which it was reported to the United States Light-House Board, when it was presented to the Irish Board, who simply added to its former marks their own, and moored it near the point where it came ashore, in commemoration of its peculiar voyage.

The importance of keeping New York Harbor and Bay well marked has moved the Board to keep its iron buoys in position, notwithstanding their danger during the winter, but with a spar-buoy beside each iron buoy, as the ice that carries away the one passes over the other, and allows it to resume its position, and indicate to passing vessels where the iron buoy should be, and also to show the buoy tenders exactly where it is to be replaced. New York Harbor was twice swept clean of iron buoys during the winter of 1880–'81, and, though some of them were recovered, the Board was put to large expense to replace those which were lost. Still, it recognizes the fact that the loss of one steamer might cause a destruction of property many times greater than the cost of the buoys, to say nothing of the loss of life that the absence of buoys might occasion. The iron ice-buoy is made of boiler iron, and is divided into compartments, so that any one may be pierced without sinking the buoy. That of the first class costs $275, is 50 feet long, and stands 22 feet out of water. That of the second class costs $181, is 40 feet long, and stands 17 feet out of water. As with wooden spar-buoys, the ice passes over them without carrying them away; but, unlike the wooden buoys, they break the propeller blades which strike them instead of being broken, and thus, defending themselves, last many times longer than spar-buoys, and, though costing more at first, are more economical in the end.

For the purpose of obtaining a cheap and efficient ice-buoy, a first-class spar-buoy was securely sheathed with heavy yellow metal over one-half its circumference, from a point below the water-line to the head of the buoy, and the buoy was attached to the sinker by a swivel. This buoy was placed off Craven's Shoal, Lower Bay, New York. There was very little ice during the winter, so that the value of this sort of buoy could not be satisfactorily determined. It is believed, however, that a spar-buoy with sheathing will answer the purpose.

Experiments were made with wire rope for mooring the heavier iron buoys, so far with every prospect of success. The action of automatic buoys moored in this way is greatly improved, and the method is highly appreciated on this coast where so many of them are moored in quite deep water.

The use of wire rope for moorings has made it possible to place buoys in very deep water without immersing them so deeply that their efficiency is in any way curtailed. Three-inch galvanized iron wire ropes are used, two for each buoy, one right-handed and one left-handed, with swivels at each end, and the two ropes are securely seized together every 6 feet. The lower swivel is not allowed to approach nearer the bottom than 18 feet, where from seven to ten fathoms of 2¼-inch chain is shackled on to take the chafe of the bottom. The remainder of the chain to the sinker does not exceed 1½ inch in size. About three fathoms of 1-inch chain is shackled to the whistling buoy to take the chafe of the cylinder. The double wire ropes weigh about 15 pounds to the fathom, and 1-inch chain weighs 63 pounds to the fathom, or as one to four, a great economy in weight with no loss in strength.

CHAPTER VII.

RIVER LIGHTS.

The commerce of the western rivers was mainly restricted to motion by daylight, because of the difficulty in keeping steam-boats in the tortuous channels and in avoiding the obstructions with which the channels abound. There were in 1873–'74 on the Mississippi, Missouri, and Ohio Rivers, 1,100 steam-boats, of 258,000 tons; 832 licensed barges, of 179,000 tons, and coal barges and other craft of 750,000 tons, making a total of about 1,200,000 tons. The total value of the cargoes carried by them was estimated at $400,000,000 per year. The coal sent to market yearly by the Ohio River alone amounted to 4,000,000 of tons. Hence, when those interested in river commerce took vigorous measures, they had little difficulty in procuring Congressional action. In 1874 an appropriation of $50,000 was made for a survey of the Mississippi, Ohio, and Missouri Rivers, and to establish on them temporary lights and buoys. The survey was made, a favorable report followed, and two light-house districts were duly established, one, the fourteenth, extending from Pittsburgh to Cairo, on the Ohio River, and the other, the fifteenth, comprising the Mississippi and the Missouri Rivers. The boundaries of each have since been increased and another district, the sixteenth, has been carved out of the other two districts. An inspector and an engineer were appointed for each district; a steamer hastily fitted for the work was furnished to each inspector, and they proceeded to light up the rivers.

The navigation of these waters was of the most intricate character. The crossings were numerous; and, at some, technically called "blind crossings," where the banks show no diversity of outline and where the channel is narrow, pilots were frequently delayed and could not always avoid disaster. At many points, previous to the establishment of the lights passage was never attempted on a dark night; but by means of the lights the passages are made practicable at all times. The hidden obstructions are numberless, and in many places barely leave room for the passage of large steamers. There are many consecutive miles on these rivers where the wrecks average more than one to the mile. Keepers for the river lights are selected from among the people living on and owning property along the river, and they have generally been found trustworthy and awake to the demands of the service.

The fixed lights used are substantially made lens lanterns, which are suspended from an arm projecting from a post, or placed on the post at an elevation of from 8 to 10 feet from the ground. They are of most service during low water, though they afford important aid at other times. At points where the channel is made very narrow by permanent obstructions, and the passage dangerous, buoys have been placed as day marks, to which floating lights are attached at night. From the testimonials received from officers and managers of different steam-boat lines, boards of trade, and others interested in the navigation of those waters, these lights and buoys appear to be a great benefit to river commerce.

In 1875 $100,000 was appropriated to maintain the lights on the western rivers, $150,000 in 1876, $140,000 in 1877, the same in 1878, but $130,000 in 1879, $140,000 again in 1880, and $150,000 was appropriated in 1881. There were on June 30, 1880, on the Ohio, Mississippi, and Missouri Rivers, eight hundred and nineteen of these lights, each having an average cost for its maintenance of $156.28 per year, and all of them costing in the aggregate $128,000 for that year. The tonnage on the western rivers, according to the Bureau of Navigation, was 305,082.86 on June 30, 1888.

On June 30, 1889, there were on the various rivers one thousand five hundred and seventy-seven lights, and Congress that year made the following appropriation for the current fiscal year:

For establishing, supplying, and maintaining post-lights on the Hudson and East Rivers, New York; the Raritan River, New Jersey; the Delaware River, between Philadelphia and Bordentown, New Jersey; Connecticut River, Connecticut; the Elk River, Maryland; Cape Fear River, North Carolina; Savannah River, Georgia; St. John's and Indian Rivers, Florida; at the mouth of Red River, Louisiana; at Chicot Pass, and to mark navigable channel along Grand Lake, Louisiana; on the Mississippi, Missouri, Ohio, Tennessee, Illinois, and Great Kanawha Rivers; on the Columbia and Willamette Rivers, Oregon; Sacramento and San Joaquin Rivers, California; and on Puget Sound, Washington Sound, and adjacent waters, Washington Territory; the Light-House Board being hereby authorized to lease the necessary ground for all such lights and beacons as are for temporary use or are used to point out changeable channels, and which in consequence can not be made permanent, $254,000.

The river light is treated as separate and distinct from other lights, is put in a class by itself, as it is temporary as to its life and shifting as to its place. It is to be found in most of the light-house districts, but it is maintained from a separate fund, and it is governed in most respects by different regulations. But there are nearly twice as many of these as there are of the others, and they are destined to increase in greater proportion. It is claimed, as cheaply as they are maintained, that they are doing an immense deal of good. They meet a popular want quickly and well, and serve their purpose admirably.

The following is a statement of the rivers that are lighted, the length that each is lighted, and the number of lights maintained on each river:

Rivers.	Distance lighted.	Number of lights.
	Miles.	
Connecticut River, Connecticut	42	3
East River, New York	15	6
Hudson River, New York	153	26
Delaware River, Pennsylvania	130	9
Elk River, Maryland	9	2
Cape Fear River, North Carolina	23	22
Savannah River, Georgia	15	17
St. John's River, Florida	166	71
Red River, Louisiana	9	6
Chicot Pass and Grand Lake, Louisiana	....	5
Mississippi River	1,943	736
Missouri River, Missouri	386	30
Ohio River	968	452
Kanawha River	74	83
Tennessee River	222	36
Illinois River, Illinois	226	44
Columbia River, Oregon	86	40
Willamette River, Oregon	10	9
Puget and Washington Sounds, Washington	....	30
	4,477	1,677

Chapter VIII.

ILLUMINATING APPARATUS AND ILLUMINANTS.

The illuminating apparatus used by the Light-House Establishment varies with the dates of its use. The beacon on Point Allerton, Massachusetts, was illumined in 1673 by "fier bales of pitch and ocum" [*sic*], burned in open braziers. The light-house on Little Brewster Island, Boston Harbor, erected in 1715-'16, was first lighted by tallow candles. Then followed the spider lamp, burned in the lantern as it might have been in a window. In 1812 the Government bought of Mr. Winslow Lewis, for $20,000, the patent for his "magnifying and reflecting lantern." This is described as consisting of a lamp, a reflector, and what was called the magnifier. The reflector was of a thin sheet of copper, commonly segments of a sphere, plated over with a slight film of silver, though the copper was so thin that its compression between the arms of its iron supports materially altered its form, and its silvered concave surface had much the grain and luster of tin-ware, and would reflect no distinct image. The patentee of 1812 made no pretension to a knowledge of optics as now understood, and his reflectors came about as near to a true paraboloid as did a barber's basin. The lamp, roughly constructed on the principle of Argand's fountain-lamp, burning from 30 to 40 gallons of oil per year, had a three-quarter inch burner, and was attached to a circular iron frame in front of the reflector. Before the lamp was a so-called lens, of bottle-green glass, shaped like the bull's-eye let into ship's decks, from 2½ to 4 inches thick through the axis and 9 inches in diameter, which was supposed to have some magnifying power. This apparatus was inclosed in a massive wrought-iron lantern, glazed with panes 10 by 12 inches in size. The effect of the whole was characterized by one of the reporting inspectors as making a bad light worse. But its main merit seems to have been that of economy, as the patentee, who had fitted thirty-four light-houses with his apparatus, contracted in 1816 to maintain the lights on receiving one half the oil previously consumed, and again, in 1821, for one third of the old allowance.

This apparatus is spoken of more respectfully in a report to the House of Representatives in 1842, made by its Committee on Commerce, from which it appears that "the improvement in the character of the light and the economy in saving oil were subjects of high commendation by the Government." It also appears that the use of the magnifying bull's-eye was gradually done away with, so that but few remained in 1838, and the last one was removed in 1840. The administration of the system was largely improved. The reflectors were made on true optical principles, approximating, if not reaching, the paraboloid in form, were heavily silvered, and were properly placed. The heavy lantern frames were replaced by lighter ones, the small panes of glass by large ones, and the ventilation of the towers was so largely improved that obscuration by smoke was no longer unpreventable. The system, largely improved, was retained, but its administration was good only where it had faithful, intelligent, and honest administrators. Finally, the reflectors were so well made and so well placed that, in certain instances, it is now a question whether a better light was possible than was then furnished. Some of the old reflectors then used appear from recent examination to have an enormous candle-power. But a poor light was the rule, and a good light the exception. War was made on the system of reflectors, and when the Light-House Establishment was turned over to the Light-House Board in 1852 the reflectors were replaced by the Fresnel lenticular apparatus, found so successful in France and more or less throughout the world. The adoption in this country of the lenticular apparatus made it possible for a light-keeper of average capacity to keep a good light, and impossible for him to keep a bad one, unless by violation of plain rules and avoidance of routine duties. Besides this, the saving in oil effected by use of the lenses over reflectors was so great that the expense of exchanging the one for the other was saved in a few years, although the first cost of the lenses was quite large.

It was shown, in a report made to Congress in 1858, that the mean average cost of each light-house for the five and a quarter years preceding the organization of the Light-House Board, was $1,302, with oil at an average of $1.13 per gallon, while for the same period after the Board took charge it was but $1,286, with oil at $1.62 per gallon. Thus it appeared that under the Board the average cost of maintaining each light was about $16 per year less than under the previous management, although oil was about .50 cents per gallon more; and it was broadly claimed by the Board, and the claim does not appear to have been disputed, that by the change it furnished under the new system "at least four times as much light for the benefit of the navigator as the best system of reflector lights which has been devised, and at the same time at a consumption of not more than one-fourth the quantity of oil required for the best system of reflector lights."

THE LENS SYSTEM.

The lenticular apparatus consists of a central, powerful lamp, emitting luminous beams in every direction, around which is placed an arrangement of glass, so formed as to refract these beams into parallel rays in the required directions. When a ray of light passes out of a rarer into a denser medium, or *vice versa*, it is refracted from its original direction, and assumes that which is induced principally by the density of the second medium. This is shown in the bent appearance of an oar or a mooring under water. The glass lens appears to bend the rays which fall on and emerge from its two surfaces. The bull's-eye lantern confines its rays to one direction by the use of this principle. As the normal figure of the lens is that to which its powers are due, the polyzonal lens must be considered as a complete lens with the unnecessary portions cut away. Thus the original lens is much diminished in weight, and it also has the greater certainty of the more uniform density of the material from which it is made. It affords also the means for correcting the aberration for sphericity, a great point in the manufacture of lenses. This is the principle of the polyzonal lens. They are applied to control the luminous rays of a lamp, by building them into a square figure for such lenses as are for revolving lights.

For a revolving light, eight of such lenses, which, for a light of the first order, have a focal length of 3 feet 0.25 inch, are formed into an octangular drum. This surrounds the central lamp, which is placed in their common focus, and it is the principal portion of the controlling apparatus.

Another adaptation of the principle is used for a fixed light. A section of the lens surrounds the focal point, and in the same plane. This produces a series of horizontal belts, with their vertical section similar to that of the lens in its circular form. This when applied to a central lamp causes a continuous belt of light in azimuth, instead of a series of beams parallel, or nearly parallel, to the axis of the circular lenses, as in the case of the revolving apparatus. In the focus of this belt, or drum of glass, the lamp is placed.

"Nothing can be more beautiful," says the great Scotch light-house engineer, Mr. Alan Stevenson, "than an entire apparatus for a fixed light of the first order. It consists of a central belt of refractors, forming a hollow cylinder 6 feet in diameter and 30 inches high; below it are six triangular rings of glass, ranged in a cylindrical form, and above a crown of thirteen rings of glass, forming by their union a hollow cage, composed of polished glass, 10 feet high and 6 feet in diameter. I know of no work of art more beautiful or creditable to the boldness, ardor, intelligence, and zeal of the artist."

In coast lights, the light is not generally required all around the horizon. Over the land in the rear there would be a waste of the light from the great lamp, which is sufficient to illuminate the whole horizon. This is avoided in the reflector-light, as a small number of lamps is used. But in the dioptric apparatus the light is economized by the use of spherical mirrors placed on that side. They are generally of silvered copper curved to a radius equal to that of the focal lenses to which they are applied, having the flame as a center. Thus they reflect the rays back again through the flame upon the lenses on the opposite side, and flame, being perfectly transparent, there is in this no loss of power.

THE LIGHT-HOUSE LANTERN.

In the early days the lantern consisted of a cylinder of heavy wooden frames, holding small, thick panes of plate-glass. These window-bars and supporting-posts interfered with the light. In some directions it was nearly obscured. This defect was remedied to a great extent by the substitution of diagonal metal frame-work in the lantern for that formerly used. Glass made in triangular panes was fixed in gun-metal frames, which, by crossing the light diagonally, did not obscure all the perpendicular beam, as did that in the older light-rooms. This drawback was still further minimized by arranging a series of lozenge-shaped panes, supported by steel frames, bent to the curvature of the lantern, which presented the thinnest possible edge towards any point of the horizon. The panes of glass held by these frames are also bent to the curve of the light-room, and are ground to the size of the frame. The lantern thus made forms a very strong cylinder, and its frame-work, from a short distance, is almost invisible to one immediately in the front.

A first-order lenticular apparatus is a most beautiful object. It stands nearly 12 feet high, and is 6 feet in diameter, and involves in its structure some of the highest principles of applied science.

A first-order-light apparatus, as above said, is 12 feet high and 6 feet in diameter, and the cost of the lenses alone varies from about $4,250 to $8,400.

A second-order-light apparatus is 4 feet 7 inches in diameter; the lens costs from about $2,760 to $5,530.

A third-order apparatus, diameter 3 feet 3⅜ inches, costs from about $1,475 to $3,650 for lenses alone.

A fourth-order or harbor light is 19⅝ inches in diameter and costs from about $350 to $1,230 for the lenses.

A fifth-order harbor light, 14½ inches in diameter, costs for the lenses from about $230 to $840.

The sixth-order or smallest size of harbor lens light is 11¾ inches in diameter and costs from about $190 to $315.

The lenticular apparatus was invented and constructed in France, and for many years France supplied the world. England now obtains its supply, it is said, from the house of Chance Bros., of Birmingham. The United States Light-House Establishment have made some experiments with the illuminating apparatus made by this firm, but it has seen no reason for change. It still orders its lenticular apparatus from the French houses of Henri Lepaute, Barbier & Fenestre, or Sautter, Lemonier et Cie., as it has done from its early days.

The distance from which the principal lights can be seen is only limited by the horizon. They might be seen 60, 80, or even 100 miles if sufficient elevation could be gained from which to view them. It is deemed that 250 feet is the maximum height necessary or advisable to give a light; this gives a horizon 18 miles distant. This can be extended to 20 miles or more by ascending to mast-head. When a light is unduly elevated it is, however, often obscured by clouds and fogs.

In the tables the height of the flame above the highest tide high-water level is given, so that it is the minimum range of the light. To this elevation 10 feet is added for the height of the deck of the ship above the sea. Besides the increased distance to which low water will cause the light to be seen, the effect of refraction will also sometimes increase their range.

A question has arisen of late as to whether the reflection of a light upon the clouds, sometimes seen at twice or even three times the distance that the light itself can be seen, is not as useful as the light itself. But as this reflection can only be seen under indeterminate conditions of the atmosphere, the question, at least as yet, is hardly of a practical nature.

Table of distances, in nautical miles, at which objects can be seen at sea, according to their respective elevations and the elevation of the eye of the observer.

Height.	Distance.	Height.	Distance.	Height.	Distance.
Feet.	*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Miles.*
5	2.555	70	9.562	250	18.070
10	3.614	75	9.897	300	19.795
15	4.426	80	10.222	350	21.381
20	5.111	85	10.536	400	22.857
25	5.714	90	10.842	450	24.244
30	6.260	95	11.139	500	25.555
35	6.761	100	11.428	550	26.802
40	7.228	110	11.986	600	27.994
45	7.666	120	12.519	650	29.137
50	8.081	130	13.030	700	30.237
55	8.476	140	13.522	800	32.325
60	8.852	150	13.997	900	34.286
65	9.214	200	16.162	1,000	36.140

If it be required to know the distance at which a light of a given height can be seen by a person on a given level, it is only needful to add together the two numbers in the column of distances corresponding to those in the column of heights, which represent, respectively, the height of the observer's eye and the height of the focal plane above the sea. When it is desired to find the height which will render a light visible at a given distance, first seek for the number corresponding to the height of the observer's eye, and deduct this from the whole proposed range of the light, and opposite the remainder in the column of distances seek for the corresponding number in the column of heights.

Distances of visibility, corresponding to heights not included in the above tables, may be found by the formula $D=\frac{8}{7}\sqrt{H}$, in which D is the distance in nautical miles, and H is the height in feet of the focal plane above the sea; thus: For a light of 1,600 feet, add to 40, which is the square root of 1,600, one-seventh of 40, or 5.7. The sum 45.7 will be the distance of visibility, in nautical miles, under the ordinary conditions of atmospheric refraction.

		Nautical miles.
Example 1.	Height of Sandy Hook light, 90 feet, visible	10.8
	Add for the height of observer's eye on deck, 15 feet	=4.4
	Distance of light	15.2
Example 2.	Height of Sankaty Head light, 150 feet, visible	14.0
	Add for the height of observer's eye at the mast-head, 60 feet	=8.9
	Distance of light	22.9

LIGHT-HOUSE ILLUMINANTS.

The illuminant of the Light-House Establishment has been changed whenever a better one has been found. The "fier-balls of pitch and ocum" used in the open brazier at Point Allerton, in 1673, were succeeded by tallow candles at Little Brewster Island in 1716, which gave way to fish-oil, burned in spider-lamps, with solid wicks suspended by iron chains from the dome of Sandy Hook light-house as late as 1760; and this was in turn succeeded in 1812 by sperm-oil burned in a sort of argand lamp in Winslow's "patent magnifying and reflecting lanterns;" and this illuminant was continued until the beginning of the latter half of the present century, when the reflector system, much as it was improved, was itself superseded by the Fresnel lenticular apparatus now in use.

When the Light-House Board came into power one of the first subjects which received its best attention was that of obtaining a new illuminant of less cost than sperm-oil. The yearly diminution of the whale catch, and the increased use of sperm-oil as a lubricant, made it more and more expensive. The Board therefore called in the aid of such scientists as Professors Morfit and Alexander, of the University of Maryland.

Their analyses, quantitative and qualitative, chemical, photometric, etc., of sperm, whale, shark, fish, seal, colza, olive, lard, and mineral oils, of various grades and combinations, were published by the Board in 1855, and these are still regarded by the trades as high authority on those subjects.

It was found from these examinations that colza, the oil expressed from the seed of several plants, but especially from that of the wild cabbage (*brassica oleracea*) was largely used in France, and would comply with all the required conditions except that of being of home production. This difficulty the Board overcame by stimulating the cultivation of the plant and the manufacture of the oil from its seed as a private industry.

In 1861 the Board purchased and used over 5,000 gallons of colza-oil at $1.10 per gallon; in 1862, 2,000 gallons at $1 per gallon, and 10,000 more at $1.10 per gallon, and that too while sperm-oil was selling at $1.64½ per gallon; and it speedily became evident that the country would soon supply all the colza-oil wanted for light-house consumption at $1 per gallon as a maximum price.

Meantime the Board had experimented with lard-oil, and with such success that it appeared that this oil of a certain grade was a more desirable illuminant than colza, and it gave equally good results, was more certain in quantity and production, and was more economical in price.

The principal manufacturer who, after several attempts, had succeeded in making colza-oil, and who to do so had put up expensive machinery at the Board's instance, finally wrote to the Board that the result of its experiments had convinced him that the Government could not afford to use colza-oil in preference to lard oil, and that he would abandon its further manufacture for light-house purposes, though he had demonstrated its success in all respects except competition with lard-oil, if the Board would purchase from him the colza he then had on hand. This was done, and lard-oil became the established illuminant.

Oil for the year is usually purchased by contract in the autumn, after advertisements for proposals, and is made deliverable in large lots at different times and places, to suit the convenience of the establishment. When delivered it is subjected to careful and exact test to ascertain its purity; and its light-giving power in light house lamps is ascertained by photometric measurement. The best oil of commerce is not always the best for light-house lamps, and the dealers have much difficulty in meeting the precise wants of the establishment; hence it is not unusual that some oil is rejected. Taking the oil purchased in open market to meet sudden demands, which it is cheaper to meet by purchase than by transportation, together with that purchased by contract, the establishment bought on an average about 100,000 gallons of oil yearly. The highest price it has paid for sperm-oil was $2.43½ per gallon; the lowest, $1.09. The highest that it has ever paid for lard-oil is $2.27, and the lowest, 48½ cents per gallon.

The lard-oil purchased by the Light-House Establishment from 1867 *to* 1889, *both inclusive.*

Year.	Gallons.	Average cost per gallon.	Total cost.	Year.	Gallons.	Average cost per gallon.	Total cost.
1867	75,000	$1.2927	$96,950.00	1879	106,000	$0.5265	$55,805.20
1868	55,000	1.2773	69,980.00	1880	67,000	.6934	46,455.80
1869	60,000	1.4941	89,425.00	1881	44,000	.7447	32,889.00
1870	80,000	1.8710	149,140.00	1882	61,000	.9103	46,406.40
1871	91,000	1.2635	115,197.50	1883	73,000	.8413	61,418.20
1872	91,000	.9325	85,345.00	1884	38,000	.7271	27,631.00
1873	95,000	.7826	75,020.00	1885	24,500	.7094	17,381.00
1874	99,000	.875	88,060.00	1886	38,500	.5465	21,039.25
1875	113,000	1.2125	167,575.00	1887	29,800	.5037	15,012.00
1876	85,000	1.1755	99,930.00	1888	20,000	.5445	10,490.00
1877	110,000	.9643	109,282.50	1889	16,000	.5700	9,120.00
1878	107,000	.7052	71,459.90				

The tests applied by the Light-House Board to the oil it purchased were so thorough and effective that the Navy and War Departments and the Revenue Marine and the Life-Saving Service Bureaus of the Treasury Department arranged to procure the oil they used, both for lubricating and illuminating purposes, through the Light-House Establishment. This made it necessary for the Board to purchase during the last three years much lard-oil and some mineral oil that was not for its own use.

The Light-House Establishment from its inception had a tendency to the use of petroleum. As early as 1807 there was a correspondence between Mr. Gallatin, then Secretary of the Treasury, and the owners of the good ship *Corlomande*, from Rangoon, in the kingdom of Ava, relative to 5,000 gallons of earth oil, which is commended as the "best article known for burning in light-houses, making a very strong, clear, and bright flame, emitting at the same time a great volume of smoak." It may be that then, as often since, the "great volume of smoak" prevented the use of the earth oil. In 1855 the Board made some unsuccessful experiments with the various forms of petroleum. Meantime the price of lard-oil had so far increased that a cheaper illuminant became a necessity. It was only necessary, however, as a matter of economy, since lard oil had proved itself acceptable in every other respect. The matter was approached with much caution, as the volatile, inflammable, explosive nature of mineral oil was well known. The keeper of one of the lights on Lake Michigan had, in 1864, on his own motion, substituted for the usual lard-oil lamp one burning kerosene. Soon after commencing its use he attempted to extinguish the lamp by blowing down its chimney, when it exploded. He had scarcely reached the foot of the staircase, with his clothes on fire, when another explosion took place, which blew the whole lantern from the tower and effectually destroyed the lenticular apparatus. But as mineral oil was, in one form or another, in successful use in European light-houses, the Board set about solving the problems connected with its uniform and economical combustion, its purchase in the large quantities needed, the tests as to purity, and the degrees of heat at which it should burn and flash, the degrees of cold at which it should remain limpid, methods for its transportation and storage, and the other questions connected with its safe and economical use.

The first difficulty was that of the lamp in which it should be burned. At the outset a claim was set up that mineral oil could not be burned in a light-house without infringing on a certain patent. The Board, always ready to encourage inventive genius when applied to light-house matters, asked the necessary authority to deal with the patentee, when the Secretary of the Treasury, as the custom is, referred the legal questions involved to the Attorney-General. Thus a legal controversy arose which continued some three years, running through the Patent Office, and was finally adjudicated in the courts, where it was decided that mineral oil could be burned in any light-house lamp except one without infringing any patent. Meantime the Board had, after much experimentation in its own laboratory and workshops, succeeded in producing a mineral-oil lamp capable of consuming all the carbon it set free, and introduced it into the light-houses.

The Chairman of the Board, the venerable Professor Henry, who was also the Secretary and head of the Smithsonian Institution, had been during this time dealing with other difficulties practically and personally in laboratory and workshop, and in them had more than once endangered his person, if not his life, and thus the Board reached in advance certain determinate results. It fixed the flashing test of the mineral oil that would be accepted for light-house use at 140° Fahr., the fire-test at 154°, and the freezing test, at which it should remain limpid, at zero.* Litmus paper immersed in it for five hours must, by remaining unchanged in color, show its freedom from acid, its specific gravity must not be less than 802°; and it is to be paid for by weight, at the rate of $6\frac{8}{10}$ pounds net weight to the gallon. The difficulty of storing and transporting such quantities in bulk was conceded, but its danger was evaded by having the oil placed at once in 5-gallon cans, where it was to remain until transferred to the light-house burners for combustion. Mineral oil is now used throughout the light-house establishment. It is claimed that 5 gallons of mineral oil will give as much light as 4 gallons of lard-oil, while mineral oil at the present writing costs about 8½ cents and lard-oil about 57 cents per gallon. Thus it may be stated roughly that mineral oil, as compared with lard-oil, gives one-fifth more light and costs only one-seventh as much money.

The highest price paid for mineral oil since the Board commenced to use it in large quantities was 30 cents per gallon; the lowest 6¼ cents.

The following is the mineral oil used by the Light-House Establishment from 1880 to 1889, both inclusive:

Year.	Gallons.	Average cost per gallon.	Total cost.	Year.	Gallons.	Average cost per gallon.	Total cost.
1880	48,000	$0.1763	$8,460.00	1885	232,609	$0.1480	$34,430.70
1881	75,000	0.1428	10,710.00	1886	256,450	0.1471	37,731.90
1882	148,455	0.1860	27,601.63	1887	296,480	0.0669	19,849.60
1883	125,133	0.1624	20,328.80	1888	303,191	0.0662	20,059.37
1884	227,276	0.1257	28,573.08	1889	331,960	0.0892	29,596.27

EIGHT-DAY BURNERS.

There is a class of lights shown on the heads of long piers, built out into lakes and sounds to make harbors. The outer ends of these piers are difficult and dangerous to reach in heavy weather, especially as they are often swept by waves as well as the winds. Hence it has been found necessary to build elevated walks on trestles, often at a cost far exceeding the light-houses themselves. This is no longer done, as a burner has been invented on the constant-level principle, which will keep a light burning four, six, and even eight days and nights, so that the light need only be visited in safe weather. Still the Light-House Board requires that its keepers shall visit those lights daily, when possible, that they may keep them clean and bright, and that they may put the automatic machinery in thorough working order.

These burners are used at some twenty places on the east and west coasts and on the lakes.

GAS.

The propriety of using gas as a light-house illuminant has several times been considered. An effort was made in 1844 to use a rosin gas at the Christiana light station, near Wilmington, Del., but after something less than a year of trial it was abandoned as impracticable. Another unsuccessful attempt was afterward made at the light station on Reedy Island, mouth of Delaware River.

From time to time light-houses near cities have been illumined with gas from the city gas-works; it is now used in but three stations, namely, Cleveland, Ohio, Alexandria, Va., and Newburyport, Mass., and even at these three it has been found necessary to guard against the accident to gas-pipes, most likely to happen in very bad weather, by keeping a set of oil-lamps ready to take the place of the gas-burners at a moment's notice. But while the Board has not found the use of gas practicable thus far, it keeps itself informed as to the progress made in its manufacture and its combustion.

The Board is using compressed gas to light the ten lights at the northern entrance to Currituck Sound, North Carolina. This gas is made and compressed at its own gas-works, and it is carried to each of the beacons in tanks, built into a scow, which is towed by a steam-launch, manned by the keepers of these ten small lights, who reside on board.

The gas in each will burn for ten days and nights if need be. Though the action of the illuminant is not unsatisfactory, it can hardly be said that it has yet passed beyond the point where there is not something more desired.

THE LIGHTED BEACON ON THE DRY ROMER SHOAL, NEW YORK HARBOR.

The structure is an iron pier, 30 feet in diameter and 16 feet high, surmounted by a skeleton iron tower 25 feet high, from which is shown a fixed white fifth-order light, the focal plane of which is 41 feet above mean low water, and which should be seen some 11 miles. It was first lighted on the night of July 15, 1886. It is lighted with compressed gas from a tank which holds about a ninety-days' supply. It cost to build the pier and tower $10,586.60; the compressed gas apparatus of the Pintsch system cost $3,750, making the cost of the whole station but $14,336.60, much less than the cost of a light-house, and its cost for maintenance has been much less, as no keeper is needed. It has worked fairly well, but it has not been duplicated.

GAS MACHINE.

The combination gas-machine is used to furnish the light to some of the stations on the northwestern lakes, among others that at the Maumee Range lights, Lake Erie, Ohio; at the Marquette Breakwater pierhead, Lake Superior, Michigan, and at the St. Louis River pierhead, Lake Superior, Minnesota. This machine works automatically, making the gas from gasoline and furnishing a light which can burn, according to the size of the machine, from thirty to ninety days without attention. It is used at stations which may be inaccessible for days, during stormy weather, without great danger to the keepers who live on shore, and it saves the need of building long and expensive covered ways, or elevated walks, to approach the light, as was customary before the gas-machine came into use. The keepers, however, are required to visit the station daily when practicable, to keep it clean and to see that the machinery is working properly. It is inexpensive in proportion to its utility, and thus far it has worked so well that it will probably come into more general use.

THE ELECTRIC LIGHT.

The Light-House Board has watched the experiments made in other countries with the electric light as a light-house illuminant, and while it does not consider that this light can be seen farther than its own best lights, which are seen, located, and identified as far as the curvature of the earth will allow; and while it is not yet convinced that the electric light can be located or identified better, or even seen in fog farther, than its oil lights, still, for purposes of practical experimentation, it has—unsuccessfully, however—for several successive years, asked Congress for such an appropriation as would enable it to erect and put in operation an electric light by the side of and in competition with an oil light. Meantime it has tested every prominent American-built machine for making the electric light, that it might be ready to use the best when Congress had provided the funds for that purpose. The results of its experiments are published in its annual reports for 1879 and for 1880.

HELL GATE ELECTRIC LIGHT.

The tallest skeleton iron tower erected by the United States Light-House Service was at Hell Gate, Astoria, N. Y., in 1883–'84. Its height was 255 feet and five-eighths of an inch. It was built in the form of a frustum of a cone of a pyramid, and was 54 feet square at the bottom and 6 feet square at the top. It cost about $11,000 to build, counting everything. It showed nine electric lights, each of 6,000-candle power, and was designed to illuminate the narrow, intricate, and dangerous channel as by artificial daylight. At night when lighted the effect was grand. The tower itself could not be seen and the light appeared as if hung from the heavens. It accomplished all that was intended, and more, for the light was so brilliant that it dazzled the eyes of the pilots and prevented them from seeing objects beyond the circle illuminated. The shadows thrown were so heavy that they took the form of obstacles. So the light was discontinued in 1886, at the instance of those who had obtained its establishment. The tower was sold as it stood for old iron; but it was so strongly built that dynamite had to be used to accomplish its overthrow.

THE STATUE OF LIBERTY ENLIGHTENING THE WORLD.

This statue, which was presented by the French to the United States, when received by the President was, by order of November 7, 1886, "placed under the care and superintendence of the Light-House Board from thenceforth to be maintained by said Board as a beacon," and the order was carried into effect. There are nine duplex electric lights in the torch held in the hand of the statue above its head at a height of 305 feet above the sea-level, and is visible 24½ miles at sea, or more than 10 miles beyond the outside light-ship. Besides this there are five single arc lamps on the salients of the fort within which the statue stands on Bedloe's Island, which are shielded from the water side, so that they will not dazzle the eyes of the pilots, and so that the light will be thrown on the statue, thus making it even more striking by night than by day. This beacon is not included in the system of lights for New York Harbor.

ELECTRIC LIGHTED BUOYS IN GEDNEY'S CHANNEL, NEW YORK HARBOR.

A system of buoys lighted at night by means of electric lamps operated through submarine conductors connecting with a generating apparatus on shore, was devised for the purpose of defining the main entrance to the harbor of New York.

The harbor has two communications with the ocean which are practicable for sea-going vessels, one by way of Long Island Sound, through the East River and Hell Gate, and the other through the Narrows, between the Staten Island and Long Island shores. This latter entrance is approached by way of channels crossing the bar which extends from Sandy Hook to Coney Island, across the opening of the lower bay, and being the more direct and accessible from seaward of the two entrances it is by far the more important and is the only one practicable for vessels of the larger class, but all deep-draught vessels must enter and go out by the less direct route through the Gedney's and main channels. The entrance through Gedney's channel has heretofore been practically unmarked at night except by unlighted buoys, and this channel has therefore been practically of no use at night, and the harbor has been regarded as closed to deep-draught vessels except in daylight.

After a variety of experiments it was found that the best chance for lighting this channel lay in the use of lighted buoys, and that the most practicable form of light for the purpose was an incandescent electric lamp operated by a current generated on shore and conveyed through a cable laid on the bottom of the sea.

This form of lighted buoy having been decided upon as the one giving greatest promise of success in solving the problem of rendering Gedney's channel available at night, experiments were instituted to put the idea to a practical test.

An armored cable containing two copper conductors insulated with gutta-percha was procured and laid from the light-house depot on Staten Island to a spar-buoy planted near the Robbins's Reef light-house, a distance of about 6,000 feet. The buoy was fitted with an iron cage at the top, inclosing a heavy glass jar, in which was placed the lamp. The cable was laid in a groove cut in the side of the buoy and connection made with the lamp at the top. The other end of the cable was connected with the dynamo by short lengths of overhead wire.

A variety of lamps were tried under different conditions and in varying states of the weather at different seasons, and these experiments resulted in developing a system of buoys adapted to meet the conditions obtaining at Gedney's channel. The necessary cables, buoys, machinery, etc., were then procured, an engine-house and land line were erected at Sandy Hook, and the system was regularly installed.

The lights on either side of the channel are red and white, so that in case of failure of the lights any three may become extinguished and the remaining ones will still indicate the position of the channel, since a pilot familiar with the arrangement can distinguish which particular ones are burning.

Should a buoy be dragged from position at night the cable would probably part and the lamp be extinguished, or at all events the keeper on watch could in ordinary states of the weather ascertain whether the buoys were in place or not, and extinguish such as might become moved so as to be dangerous to navigation.

The buoys are made of juniper, a timber of great buoyancy and straightness of growth. The buoys average about 45 feet in length, 10 inches in diameter at the butt, 15½ inches at the largest section, and 11 inches at the top. They are shackled at the bottom to a hemispherical cast-iron sinker weighing 4,500 pounds. To the top of the buoy is firmly screwed the protecting cage, which is composed of flat iron ribs riveted to two iron bands which encircle the spar, with a third ring at the top of the cage. The upper part of the ribs and the top ring are turned so as to present the edge to the lamp, in order to secure greater strength and obscure the light as little as possible. The ribs are given a peculiar curved shape in order to allow ice and drift-wood to run over the buoy without injury.

The lantern consists of a circular base and stout frame-work of brass, having curved panes of thick glass in the sides and segmental panes in the top, with a ring at the top to serve as a handle. Three short legs attached to the bottom ring fit into holes in brass ears riveted to the ribs. Holes for ventilation are provided at the top and bottom. The lantern is secured in place by two hinged screw clamps, fitting over brass tongues, which are also secured to the ribs. In removing the lantern it is lifted bodily out of the top of the cage, and this removal of the lantern brings away everything liable to need repair or other attention.

The lamp is rated at one hundred candle-power, and the peculiar shape of the carbon filament was designed to secure as uniform and advantageous distribution of the light as possible, and to reduce the obscuration of the light by the ribs of the cage and the bars of the lantern to a minimum. One terminal wire of the lamp is electrically connected to the base of the lantern, and the other is carried through an opening having an insulating bushing and connects with the core of the cable. One of the armor wires of the cable is soldered to a rib of the cage to insure a complete electric circuit through the core of the cable, the lamp, and the lantern and frame to the cable armor.

The cable is securely fastened by wire staples in a deep groove cut in the buoy, and is covered by a strip of wood fitted to the groove and held in place by short iron strips let in flush with the surface and secured by screws. For a distance of several feet, at the lower end of the buoy, the cable is closely served with iron wire, over which is wound spun yarn to prevent injury from chafing on the shackle and sinker.

From each buoy the single conductor cable is led to a cast-iron junction box, where connection is made with one of the three cores of the triple conductor cable. To insure the least possible resistance in that part of the circuit through the armor wire or "earth," a separate copper wire of large cross section is soldered to the armor wires at the shore end and carried to the dynamo room with the other wires on the pole line.

Each buoy is painted and lettered and marked in accordance with the system adopted for the iron buoys, which have heretofore been used near the position now occupied by the spars.

To warn vessels against anchoring over the cables a large sign has been put up at Sandy Hook, near the shore end of the cables, and a red sector in the east beacon light covers the water occupied by the buoys and cables.

Each dynamo has a switch, which enables either machine to be readily connected with cut-off from the main leading wires.

Each lamp is on an independent circuit, in which is placed, besides the lamp, an ampere meter, a safety plug, and a controlling resistance for adjusting the potential of each lamp separately.

This adjustment is necessary on account of the inequalities of the line resistance due to the unequal lengths of cable to the different lamps.

There is also provided an ampere meter for the entire current and a volt meter.

Wires are led from each circuit wire to a test board, where connections are provided which enable the voltage or pressure of each circuit to be measured separately when the lamps are running, and also enable tests of line resistance, etc., to be conveniently made.

The buoy lights were first exhibited on the night of November 7, 1888, and since that date they have been in successful and continuous operation.

On account of their frequent failures, the red incandescent lamps were abandoned, and red glass was substituted for white in the lanterns. On January 1, 1889, the color of the lamps was changed, so as to have all red lamps on the starboard hand, and white ones on the port hand passing in. The electric plant is in excellent condition, and has given great satisfaction at all times. Such vessels as the *City of New York*, *Bourgoyne*, *Lahn*, and many other large vessels, have used the Gedney's Channel at night. The number of vessels which passed out between sunset and sunrise from December 14, 1888, to June 30, 1889, was 53; passed in, 179; total 224. To represent the efficiency of the lamps, taking the number burning each night as 6, the total number of nights 234, gives 1,404 lights for a single night. The number which went out in service estimated by night gives 49. 1,404 : (1,404—49) : : 100 : 96.50, percentage of efficiency.

SANDY HOOK EAST BEACON.

The Sandy Hook East Beacon, on the point of Sandy Hook, New York Harbor, is now lighted by electricity, instead of oil. The change has but recently been made. It was occasioned by the fact that the dynamos from which the electric-buoys were supplied were close at hand, and could be utilized without much trouble or expense. The light is of but the fourth-order, and it is hoped that it will not be found too dazzling by the pilots.

ELECTRIC SCIENCE.

The Light-House Establishment keeps itself fully informed of the advance made in electric science. It maintains an electric laboratory at its general depot in New York Harbor, in which one of the brightest young officers of the Corps of Engineers of the U. S. Army, Lieutenant John Millis, who has been detailed for that purpose, devotes his time to the superintendence of practical electric work. It was under his supervision that the great tower at Hell Gate was lighted, that the Statue of Liberty in New York Harbor was lighted, that the buoys in Gedney's Channel and the station at Sandy Hook were lighted, and that the work-shops and offices at the depot were lighted. Thus the Board will be ready for any work in the way of placing electric lights in its towers or ships, whenever it may be authorized to do so by Congress.

EXPERIMENTS WITH ILLUMINANTS.

The British Government in 1885 created a commission to inquire into and report upon the relative merits of electricity, gas, and mineral oil as light-house illuminants. It was made up of members of the Trinity House and of scientific experts. The United States sent an officer of its Navy, Commander F. E. Chadwick, to witness the experiments, and report upon them, which he did at length. His report is printed as an appendix to the annual report of the Light-House Board for 1885. The secretary of the commission, Mr. Price-Edwards, sent a paper to the British Society of Arts, which was read at its meeting of March 10, 1886, and which appears in its transactions, in which is found an authoritative résumé of the observations and conclusions of the commission.

The experiments covered a wide range of conditions, such as fine, clear weather, haze, fog, and dense fog, and the conclusions arrived at established the fact that, under the most adverse state of things, dense fog, *all* lights are *useless* to navigators, and that the advantage of the most powerful illuminant, electricity, was reduced to a nominal and unsatisfactory element equally with the gas and oil illuminants, the electric light being visible only a few hundred feet farther than either of the other lights under such conditions.

It appears that the penetrative power of light through fog differs according to the varying conditions of its homogeneity, or, in other words, the greater or less size of the particles of aqueous vapor in suspension. The effect is similar to that produced upon the *siren fog signal*, which may be almost totally extinguished at a short distance, or may be heard many miles.

There is no greater danger at sea for steam navigation than the presence of fog, and the mariner can not mistrust too much his own estimate of position and distance of the sources of lights and sound signals under these circumstances.

The commission indicated that the electric light stands first in the rank of light-house illuminants during clear weather. It claims that for first-class points of coast lighting nothing can be more desirable, if expense be no matter of consideration, on the ground that its range, definition, and, where a distinctive character is employed, as group-flashing, its superiority to all other modes of illumination pronounce its excellence and pre-eminence.

The definition of any area of electric light is so exact that a man may at a moderate distance, without changing his position, move his head so as to be in full glare or in perfect darkness.

The United States Light-House Board was, however, forced to abandon its attempts to light the Hell Gate Channel by electricity for this very reason, as the strong light so dazzled the eyes of the pilots, and as the shadows thrown were so heavy, that the pilots found that the electric light was not only more of a hindrance than a help, but that it was a positive source of danger. This matter is more fully discussed in another place.

The mineral oil light in these trials fully justified the confidence reposed in it by the Trinity House and the United States Light-House Board authorities, after many years of careful experience. The commission found it to be at once the most serviceable illuminant, the most economical, the safest, and easiest for storage, no machinery or skilled labor required in its use, and equally available for rock, floating, or coast light stations. The lamp in which this material is used has been so perfected under British and American engineers as to be comparatively equal to the electric and gas lights, in its capability of increase of power, to adapt it to the varying atmospheric conditions.

The gas light as adopted by the Irish Board is the invention of Mr. Wigham, of Dublin, and is used in several stations upon the coast of Ireland. Cannel coal gas, manufactured and stored on the spot, is conveyed to the burners, which are capable of increase of power varying from twenty-eight to one hundred and eight jets, according to the power necessary for the station or for the state of the atmosphere. This system is open to objections, although its efficiency is allowed to be of considerable value. Its brilliancy is very satisfactory, but the expense of installation and continued production place it between the electric light and the mineral oil light. It is not practicable to employ it upon rock and floating stations. In coast stations the very great heat emitted in the light-room, causes fracture of lenses and inconvenience to the attendants. Its effective power is equaled by the mineral oil light, and at a considerable diminution of cost. Gas is used in but very few of the United States lights, and they are of minor importance. As is stated elsewhere, the experiments made with gas have failed to show its practicability for use as a light-house illuminant in America.

The official report of the Commission ends with the following summary:

Finally, your committee beg thus to sum up their opinion in regard to the relative merits of electricity, gas, and oil as light-house illuminants:

(1) That the electric light, as exhibited in the A experimental tower at South Foreland, has proved to be the most powerful light under all conditions of weather, and to have the greatest penetrative power in fog.

(2) That for all practical purposes the gas light, as exemplified by Mr. Wigham's multiform system in B experimental tower, and the oil light, as exemplified by the Trinity House Douglass six-wick burners in multiform arrangement up to triform in C experimental tower, when shown through revolving lenses, are equal light for light in all conditions of weather; but that quadriform gas is a little better than triform oil.

(3) That when shown through fixed lenses, as arranged in the experimental towers, the superiority of the superposed gas light is unquestionable. The larger diameter of the gas flames, and the lights being much nearer to each other in the gas lantern, give the beam a more compact and intense appearance than that issuing from the more widely-separated oil-burners.

(4) That for light-house illumination with gas, the Douglass patent gas-burners are much more efficient and economical than the Wigham gas-burners.

(5) That for the ordinary necessities of light-house illumination, mineral oil is the most suitable and economical illuminant, and that for salient head-lands, important land-falls, and places where a powerful light is required, electricity offers the greatest advantages.

CHAPTER IX.

Fog Signals.—Aberrations in Audibility.

The sound-signals generally used to guide mariners, especially during fogs, are, with certain modifications, sirens, trumpets, steam-whistles, bell-boats, bell-buoys, whistling-buoys, bells struck by machinery, cannons fired by powder or gun-cotton, rockets, and gongs.

GONGS.

Gongs are somewhat used on light-ships, especially in British waters. They are intended for use at close quarters. Léonce Reynaud, of the French light-house service, has given their mean effective range as barely 550 yards. They are of most use in harbors, short channels, and like places where a long range would be unnecessary. They have been used but little in United States waters. The term "effective range" is used here to signify the actual distance at which, under the most unfavorable circumstances, a signal can generally be heard on board of a paddle-wheel steamer in a heavy sea-way.

GUNS.

The use of guns is not so great as it once was. Instances are on record in which they were quite serviceable. Admiral Sir A. Milne said he had often gone into Halifax Harbor, in a dense fog like a wall, by the sound of the Sambro fog-gun. But in the experiments made by the Trinity House off Dungeness, in January, 1864, in calm weather, the report of an 18-pounder, with 3 pounds of powder, was faint at 4 miles. Still, in the Trinity House experiments of 1865, made in light weather with a light gun, the report was clearly heard 7 miles away. Dr. Gladstone records great variability in the range of gun-sound in the Holyhead experiments. Professor Henry says a 24-pounder was used at Point Boneta, San Francisco Bay, California, in 1856–57, and that, by the help of it alone, vessels came into the harbor during the fog at night as well as in the day, which otherwise could not have entered. The gun was fired every half hour, night and day, during foggy and thick weather in the first year, except for a time when powder was lacking. During the second year there were 1,582 discharges. It was finally superseded by a bell-boat, which in its turn was after a time replaced by a siren. A gun was also used at West Quoddy Head, Maine. It was a carronade, 5 feet long, with a bore of 5½ inches, charged with 4 pounds of powder.

The gun was fired on foggy days when the Boston steamer was approaching the light-house from St. John, and the firing was begun when the steamer's whistle was heard, often when she was 6 miles away, and was kept up as fast as the gun could be loaded, until the steamer answered with its whistle. The report of the gun was heard from 2 to 6 miles.

"This signal was abandoned," Professor Henry says, "because of the danger attending its use, the length of intervals between successive explosions, and the brief duration of the sound, which renders it difficult to determine its direction with accuracy." In 1872 there were three fog-guns on the English coast, iron 18-pounders, carrying a 3-pound charge of powder, which were fired at intervals of fifteen minutes in two places, and of twenty minutes in the other. The average duration of fog at these stations was said to be about six hours, and as it not unfrequently lasted twenty hours, each gun required two gunners who had to undergo severe labor, and the risk of remissness and irregularity was considerable. In 1881 the interval between charges was reduced to ten minutes. The Trinity House, in its experiments at South Foreland, found that the short 24-pound howitzer gave a better sound than the long 18-pounder. Professor Tyndall, who had charge of the experiments, sums up as to the use of the guns as fog-signals by saying:

> The duration of the sound is so short that, unless the observer is prepared beforehand, the sound, through lack of attention rather than through its own powerlessness, is liable to be unheard. Its liability to be quenched by local sound is so great that it is sometimes obliterated by a puff of wind taking possession of the ears at the time of its arrival. Its liability to be quenched by an opposing wind, so as to be practically useless at a very short distance to windward, is very remarkable. * * * Still, notwithstanding these drawbacks, I think the gun is entitled to rank as a first-class signal.

The minute-gun at sea is known the world over as a signal of distress. The English light-ships fire guns to attract the attention of the life-boat crew when shipwrecks take place in sight of the ships, but out of sight of the boats; and guns are used as signals of approaching floods at freshet times in various countries.

ROCKETS.

As a signal in rock light-houses, where it would be impossible to mount large pieces of apparatus, the use of a gun-cotton rocket has been suggested by Sir Richard Collinson, deputy master of the Trinity House. A charge of gun-cotton is inclosed in the head of a rocket, which is projected to the height of perhaps 1,000 feet, when the cotton is exploded, and the sound shed in all directions. Comparative experiments with the howitzer and rocket showed that the howitzer was beaten by a rocket containing 12 ounces, 8 ounces, and even 4 ounces of gun-cotton. Large charges do not show themselves so superior to small charges as might be expected. Some of the rockets were heard at a distance of 25 miles. Professor Tyndall proposes to call it the Collinson rocket, and suggests that it might be used in light-houses and light-ships as a signal by naval vessels.

BELLS.

Bells are in use at most United States light-stations, and at many they are run by machinery actuated by clock-work, made by Mr. Stevens, of

Boston, who, at the suggestion of the Light-House Board, has introduced an escapement arrangement moved by a small weight, while a larger weight operates the machinery which strikes the bell. These bells weigh from 300 to 3,000 pounds. There are about one hundred and twenty-five in use on the coasts of the United States. Experiments made by the engineers of the French light-house establishment in 1861–62 showed that the range of bell-sounds can be increased with the rapidity of the bell-strokes, and that the relative distances for 15, 25, and 60 bell-strokes a minute were in the ratio of 1, 1.14, and 1.29. The French also, with a hemispherical iron reflector, backed with Portland cement, increased the bell-range in the ratio of 147 to 100 over a horizontal arc of 60 degrees, beyond which its effect gradually diminished. The actual effective range of the bell-sound, whatever the bell-size, is comparatively short, and, like the gong, it is used only where it needs to be heard for short distances. Mr. Cunningham, secretary of the Scottish light-house establishment, in a paper on fog-signals, read in February, 1863, says the bell at Howth, weighing 2¼ tons, struck four times a minute by a 60-pound hammer falling 10 inches has been heard only 1 mile to windward against a light breeze during fog, and that a similar bell at Kingston, struck eight times a minute, had been so heard 3 miles away as to enable the steamer to make her harbor from that distance. Mr. Beaseley, C. E., in a lecture on coast fog-signals, May 24, 1872, speaks of these bells as unusually large, saying that they and the one at Ballycottin are the largest on their coasts, the only others which compare with them being those at Stark Point and South Stack, which weigh 31¾ cwt., and 41½ cwt., respectively.

Mr. Cunningham, speaking of the fog-bells at Bell Rock and Skerryvore light-houses, says he doubts if either bell has been the means of saving a single vessel from wreck during fog, and he does not recall an instance of a vessel reporting that she was warned to put about in the fog or that she ascertained her position in any respect by hearing the sound of the bell in either place. General Duane, U. S. Army, says a bell, whether operated by hand or machinery, can not be considered an efficient fog-signal on the sea coast. In calm weather it can not be heard half the time at a greater distance than one mile, while in rough weather the noise of the surf will drown its sound to seaward altogether. The use of bells is required by the international code on ships of all nations at regular intervals during fog. But Turkish ships are allowed to substitute the gong or gun, as the use of bells is forbidden to the followers of Mohammed.

WHISTLING-BUOYS.

The whistling-buoy now in use was patented by Mr. J. M. Courtenay, of New York. It consists of an iron, pear-shaped bulb, 12 feet across at its widest part, and floating 12 feet out of water. Inside the bulb is a tube 33 inches across, extending from the top through the bottom to a depth of 32 feet, into water free from wave-motion. The tube is open at its lower end, but projects, air-tight, through the top of the bulb and is closed with a plate having in it three holes, two for letting the air into the tube and one between the others for letting the air out to work the 10-inch locomotive whistle with which it is surmounted. These holes are connected with three pipes which lead down to near the water-level, where they pass through a diaphragm which divides the outer cylinder into two parts. The great bulb which buoys up the whole mass rises and falls with

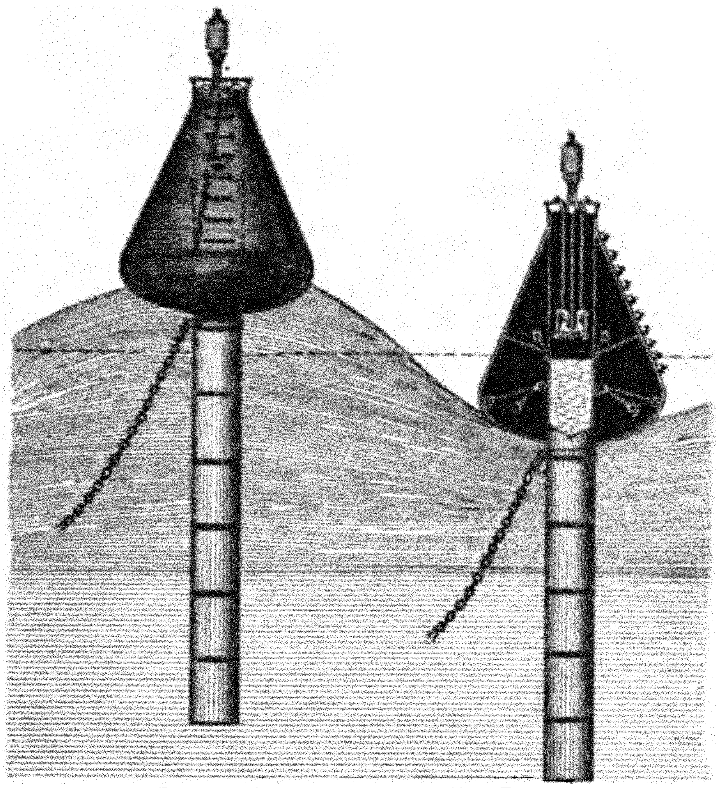


FIG. 1.—Courtenay's Whistling-Buoy.

the motion of the waves, carrying the tube up and down with it, thus establishing a piston-and-cylinder movement, the water in the tube acting as an immovable piston, while the tube itself acts as a moving cylinder. Thus the air admitted through valves, as the buoy rises on the wave, into that part of the bulb which is above water, is compressed, and as the buoy falls with the wave it is further compressed and forced through a 2½-inch pipe, which, at its apex, connects with the whistle. The dimensions of the whistling-buoy have recently been much diminished without detracting materially from the volume of sound it produces. It is now made of four sizes. The smallest in our waters has a bulb 6 feet in diameter and a tube 10 feet in length, and weighs but 2,000 pounds. The largest and oldest whistling-buoy has a 12-foot bulb, a tube 32 feet long, and weighs 12,000 pounds.

There are now sixty-two of these whistling-buoys on the coast of the United States, which have cost about $1,075 each. It is a curious fact that, in proportion as they are useful to the mariner, they are obnoxious to the house-dweller within ear-shot of them, and that the Light-House Board has to weigh the petitions and remonstrances before setting these buoys off inhabited coasts. They can at times be heard 15 miles, and emit an inexpressibly mournful and saddening sound.

The then Inspector of the first light-house district, Commander Picking, established a series of observations at all the light-stations in the neighborhood of the buoys, giving the time of hearing it, the direction of the wind, and the state of the sea, from which it appears that in January, 1878, one of these buoys was heard every day at a station 1⅛ miles distant, every day but two at one 2¼ miles distant, fourteen times at one 7½ miles distant, and four times at one 8¼ miles distant. It is heard by the pilots of the New York and Boston steamers at a distance of from one-fifth of a mile to 5 miles, and has frequently been heard at a distance of 9 miles, and even, under specially favorable circumstances, 15 miles.

The whistling-buoy is also used to some extent in British, French, and German waters with good results. The latest use to which it has been put in this country has been to place it off the shoals of Cape Hatteras, where a light-ship was wanted but could not live, and where it does almost as well as a light-ship would have done. It is well suited for such broken and turbulent waters, as the rougher the sea the louder its sound. But after three buoys had been carried away by the heavy seas the attempt to keep one there was given up.

BELL-BUOYS.

The bell-boat, which is at most a clumsy contrivance, liable to be upset in heavy weather, costly to build, hard to handle, and difficult to keep in repair, has been superseded by the Brown bell-buoy, which was invented by the officer of the Light-House Establishment whose name it bears. The bell is mounted on the bottom section of an iron buoy 6 feet 6 inches across, which is decked over and fitted with a frame-work of 3-inch angle-iron 9 feet high, to which a 300-pound bell is rigidly attached. A radial grooved iron plate is made fast to the frame under the bell and close to it, on which is laid a free cannon-ball. As the buoy rolls on the sea this ball rolls on the plate, striking some side of the bell at each motion with such force as to cause it to toll. Like the whistling-buoy, the bell-buoy sounds the loudest when the sea is the roughest, but the bell-buoy is adapted to shoal water, where the whistling-buoy could not ride; and, if there is any motion to the sea, the bell-buoy will make some sound. Hence the whistling-buoy is used in roadsteads and the open sea, while the bell-buoy is preferred in harbors, rivers, and the like, where the sound-range needed is shorter and smoother water usually obtains. In July, 1889, there were seventy of these bell-buoys in United States waters. They now cost, without fitments and moorings, about $300 each. This buoy has been much changed and improved of late.

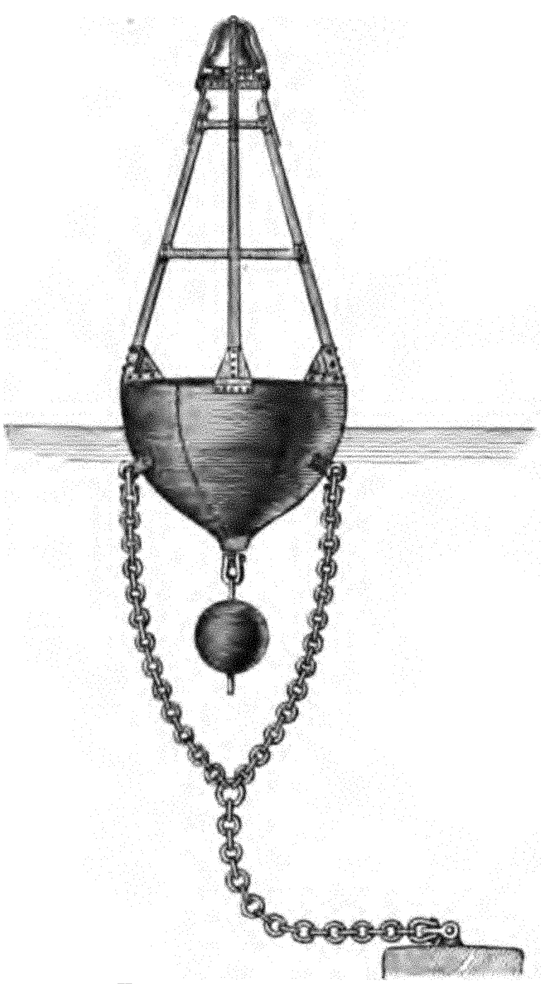


FIG. 2.—Brown's Bell-Buoy.

LOCOMOTIVE WHISTLES.

It appears from the evidence given in 1845, before the select committee raised by the English House of Commons, that the use of locomotive whistles as a fog-signal was first suggested by Mr. A. Gordon, C. E., who proposed to use air or steam for sounding it, and to place it in the focus of a reflector, or a group of reflectors, to concentrate its sound into a powerful phonic beam. It was his idea that the sharpness or shrillness of the whistle constituted its chief value. And it is conceded that Mr. C. L. Daboll, under the direction of Professor Henry, and at the instance of the United States Light-House Board, first practically used it as a fog-signal by erecting one for use at Beaver Tail Point, in Narragansett Bay. The sounding of the whistle is well described by Price-Edwards, a noted English light-house engineer, "as caused by the vibration of the column of air contained within the bell or dome, the vibration being set up by the impact of a current of steam or air at a high pressure." It is probable that the metal of the bell is likewise set in vibration and gives to the sound its timbre or quality. It is noted that the energy so excited expends its chief force in the immediate vicinity of its source, and may be regarded, therefore, as to some extent wasted. The sound of the whistle, moreover, is diffused equally on all sides. These characteristics to some extent explain the impotency of the sound to penetrate to great distances. Difference in pitch is obtained bv altering the distance between the steam orifice and the rim of the drum. When brought close to each other, say within half an inch, the sound produced is very shrill, but it becomes deeper as the space between the rim and the steam or air orifice is increased.

Professor Henry says the sound of the whistle is distributed horizontally. It is, however, much stronger in the plane containing the lower edge of the bell than on either side of this plane. Thus, if the whistle is standing upright in the ordinary position, its sound is more distinct in a horizontal plane passing through the whistle than above it or below.

The steam fog-whistle is the same instrument ordinarily used on steamboats and locomotives. It is from 6 to 18 inches in diameter, and is operated by steam under a pressure of from 50 to 100 pounds. An engine takes its steam from the same boiler, and by an automatic arrangement shuts off and turns on the steam by opening and closing its valves at determined times. The machinery is simple, the piston-pressure is light, and the engine requires no more skilled attention than does an ordinary stationary engine.

The Crosby automatic fog-signal, a recently invented machine, is designed to take the place of the engine in the steam-whistle. There are four sets of them now used in the United States Light-House Service, two on the Atlantic coast and two on the Lakes, and they have given such satisfaction that it is evident that they will come into more general use. The apparatus consists of a steam cylinder about 8 inches long by 2 inches in diameter, a small single-action balanced piston-valve being fitted to the lower end.

The steam admitted through the valve is controlled by a spring motor, consisting of a simple clock mechanism occupying a space about 6 inches square. The motor is provided with a code-cam, or wheel, which makes one revolution every two minutes, and can be set to actuate the valve admit steam to the cylinder, and raise the piston, producing blasts at such intervals and of such length as shall have been previously determined. The valve in the whistle is opened by means of a cord attached to the lower end of the piston. The motor is self-winding, so that the machine will continually run and give the required signal so long as steam is admitted. These signals are furnished for about $200 each.

"The experiments made by the Trinity house in 1873–'74 seem to show" Price-Edwards says, "that the sound of the most powerful whistle, whether blown by steam or hot air, was generally inferior to the sound yielded by other instruments," and consequently no steps were taken to extend their use in Great Britain, where several were then in operation. In Canadian waters, however, a better result seems to have been obtained, as the deputy minister of marine and fisheries, in his annual report for 1872, summarizes the action of the whistles in use there, from which it appears that they have been heard at distances varying with their diameter from 3 to 25 miles.

The result of the experiments made by Professor Henry and General Duane for the United States Light-House Board, reported in 1874, goes to show that the steam-whistle could be heard far enough for practical uses in many positions. Professor Henry found that he could hear a 6-inch whistle 7½ miles with a feeble opposing wind. General Duane heard the 10-inch whistle at Cape Elizabeth at his house in Portland, Me., 9 miles distant, whenever it was in operation. He heard it best during a heavy northeast snow-storm, the wind blowing then directly from him, and toward the source of the sound. General Duane also reported that "there are six fog-signals on the coast of Maine; these have frequently been heard at the distance of 20 miles;" which distance he gives as the extreme limit of the 12-inch steam-whistle.

TRUMPETS.

The Daboll trumpet was invented by Mr. C. L. Daboll, of Connecticut, who was experimenting to meet the announced wants of the United States Light-House Board. The largest consists of a huge trumpet 17 feet long, with a throat 3½ inches in diameter, and a flaring mouth 38 inches across. In the trumpet is a resounding cavity and a tongue-like steel reed 10 inches long, 2¾ inches wide, 1 inch thick at its fixed end, and half that at its free end. Air is condensed in a reservoir and driven through the trumpet by hot air or steam machinery at a pressure of from 15 to 20 pounds, and is capable of making a shriek which can be heard at a great distance for a certain number of seconds each minute by about one-quarter of the power expended in the case of the whistle. In all his experiments against and at right angles and at other angles to the wind, the trumpet stood first and the whistle came next in power. In the trial of the relative power of various instruments made by General Duane in 1874, the 12-inch whistle was reported as exceeding the first-class Daboll trumpet. Beaseley reports that the trumpet has done good work at various British stations, making itself heard from 5 to 10 miles. The engineer in charge of the light-houses of Canada says:

> The expense for repairs, and the frequent stoppages to make these repairs during the four years they continued in use, made them (the trumpets) expensive and unreliable. The frequent stoppages during foggy weather made them sources of danger instead of aids to navigation. The sound of these trumpets has deteriorated during the last year or so,

General Duane, reporting as to his experiments in 1881, says:

The Daboll trumpet, operated by a caloric-engine, should only be employed in exceptional cases, such as at stations where no water can be procured, and where from the proximity of other signals it may be necessary to vary the nature of the sound.

Thus it would seem that the Daboll trumpet is an exceptionally fine instrument, producing a sound of great penetration and of sufficient power for ordinary practical use, but that to be kept going it requires skillful management and constant care.

THE SIREN.

The siren was adapted from the instrument invented by Cagniard de la Tour, by A. and F. Brown, of the New York City Progress Works, under the guidance of Professor Henry, at the instance and for the use of the United States Light-House Establishment, which also adopted it for use as a fog-signal. The siren of the first class consists of a huge trumpet, somewhat of the size and shape used by Daboll, with a wide mouth and a narrow throat, and is sounded by driving compressed air or steam through a disk placed in its throat. In this disk are twelve radial slits; back of the fixed disk is a revolving plate containing as many similar openings. The plate is rotated 2,400 times each minute, and each revolution causes the escape and interruption of twelve jets of air or steam through the openings in the disk and rotating plate. In this way 28,800 vibrations are given during each minute that the machine is operated; and, as the vibrations are taken up by the trumpet, an intense beam of sound is projected from it. The siren is operated under a pressure of 72 pounds of steam, and can be heard, under favorable circumstances, from 20 to 30 miles. "Its density, quality, pitch, and penetration render it dominant over such other noises after all other signal-sounds have succumbed." It is made of various sizes or classes, the number of slits in its throat-disk diminishing with its size. The dimensions given above are those of the largest.

The experiments made by General Duane with these three machines show that the siren can be, all other things being equal, heard the farthest, the steam-whistle stands next to the siren, and the trumpet comes next to the whistle. The machine which makes the most noise consumes the most fuel. From the average of the tests it appears that the power of the first-class siren, the 12-inch whistle, and the first-class Daboll trumpet are thus expressed: siren 9, whistle 7, trumpet 4; and their relative expenditure of fuel thus: siren 9, whistle 3, trumpet 1.

Sound-signals constitute so large a factor in the safety of the navigator that the scientists attached to the light-house establishments of the various countries have given much attention to their production and perfection, notably Tyndall in England and Henry in this country. The success of the United States has been such that other countries have sent commissions here to study our system. That sent by England in 1872, of which Sir Frederick Arrow was chairman, and Captain Webb, R. N., recorder, reported so favorably on it that since then "22 sirens have been placed at the most salient light-houses on the British coasts, and 16 on lightships moored in position where a guiding signal is of the greatest service to passing navigation."

The trumpet, siren, and whistle are capable of such arrangement that the length of blast and interval, and the succession of alternation, are such as to identify the location of each, so that the mariner can determine his position by the sounds.

In this country there were in operation in July, 1889, eighty-one fog-signals operated by steam or hot air, and the number is to be increased in answer to the urgent demands of commerce.

USE OF NATURAL ORIFICES.

There are, in various parts of the world, several sound-signals made by utilizing natural orifices in cliffs, through which the waves drive the air with such force and velocity as to produce the sound required. One of the most noted is that on one of the Farallon islands, 40 miles off the harbor of San Francisco, which was constructed by General Hartmann Bache, of the United States Engineers, in 1858–'59, and of which the following is his own description:

Advantage was taken of the presence of the working party on the island to make the experiment, long since contemplated, of attaching a whistle as a fog-signal to the orifice of a subterranean passage opening out upon the ocean through which the air is violently driven by the beating of the waves. The first attempt failed, the masonry raised upon the rock to which it was attached being blown up by the great violence of the wind-current. A modified plan with a safety-valve attached was then adopted, which it is hoped will prove permanent. * * * The nature of this work called for 1,000 bricks and 4 barrels of cement.

Professor Henry says of this:

On the apex of this hole he erected a chimney, which terminated in a tube surmounted by a locomotive whistle. By this arrangement a loud sound was produced as often as the wave entered the mouth of the indentation. The penetrating power of the sound from this arrangement would not be great if it depended merely on the hydrostatic pressure of the waves, since this, under favorable circumstances, would not be more than that of a column of water 20 feet high, giving a pressure of about 10 pounds to the square inch. The effect, however, of the percussion might add considerably to this, though the latter would be confined in effect to a single instance. In regard to the practical result from this arrangement, which was continued in operation for several years, it was found not to obviate the necessity of producing sounds of greater power. It is, however, founded on an ingenious idea, and may be susceptible of application in other cases.

There is now a first-class siren in duplicate at this place.

The eighty-one steam fog-signals in the waters of the United States have been established at a cost of more than $600,000, and are maintained at a yearly expense of more than $100,000. The erection of each of these signals was authorized by Congress in an act making special appropriations for its establishment, and Congress was in each instance moved thereto by the pressure of public opinion, applied usually through the member of Congress representing the particular district in which the signal was to be located. And this pressure was occasioned by the fact that mariners have come to believe that they could be guided by sound as certainly as by sight. The custom of the mariner in coming to this coast from beyond the seas is to run his ship so that on arrival, if after dark, he shall see the proper coast-light in fair weather, and, if in thick weather, that he shall hear the proper fog-signal, and, taking that as a point of departure, to feel his way from the coast-light to the harbor-light, or from the fog-signal on the coast to the fog-signal in the harbor, and thence to his anchorage or his wharf. And the custom of the coaster or the Sound steamer is somewhat similar.

LIGHT WITH FOG-BELL WAVE MOTOR.

There are many places where a light or a fog-bell or both would be valuable aids to navigation, but where they have not hitherto been established on account of the expense of building a structure to support a keeper's dwelling and tower. This device is intended for localities where there is some wave motion, and which could be visited at least once every three or four days, when a light is used, in order that the wicks may be trimmed and the lamp refilled. It is not anticipated that the wave motor which rings the bell would need such frequent attention. The structure supporting the light and motor consists of six screw piles, a platform on which a lens-lantern is placed and under which the bell is hung, and another platform below on which is the motor, actuated by the vertical motion of a float. This float is guided by the three interior piles so that it can have no lateral motion, but only rise and fall with the waves. The striking device consists of a horizontal shaft on which there are three wheels; the center one is fixed to the shaft. To its periphery rollers are attached which, as they pass under the prolongation of the hammer-arm, raise it and let it fall, thus ringing the bell. The other two wheels are arranged with ratchets, so that they can move freely in one direction, but when they revolve in the opposite direction they will move the shaft with them, and consequently the center wheel mentioned above. Two chains are attached to the float and pass over the last-mentioned wheel, one from right to left, the other from left to right. To the free ends of these chains are attached weights. The action is as follows: When the float rises these two wheels revolve in opposite directions. One revolves the shaft, the other turns freely, being moved by the weights. When the float falls these two wheels reverse their motion, being moved by the float. The one which before turned freely now revolves the shaft and the other turns freely. Whether the float rises or falls the shaft and, of course, the fixed wheel are always turned in the same direction, and thus the bell is kept continuously ringing so long as there is any wave motion. Experiments show that a very slight wave motion will actuate the device, and that when the waves are at all high the bell is rung violently and frequently. The wave motor could be readily attached, at slight expense, to the existing screw-pile structures where the characteristics of the stroke are not important, and could be so arranged that the keeper could lift the float out of the water when there is no fog, and thus stop the bell from ringing. This device is cheap, simple, and not liable to derangement, and also has the advantage of being automatic in localities where it is applicable. It is possible that its action might be stopped or that it might be injured by the ice. Should an actual test prove this to be so, there are still many places where it could be used during eight months of the year on our Northern coasts and all the year round on the Southern coasts.

ABERRATIONS OF AUDIBILITY OF FOG-SIGNALS.

The excuse for here writing in the first person is that the following is the substance of a paper read by your writer before the Philosophical Society of Washington, D. C., and that which was republished by the United States Government; that it was republished in various languages, in whole or in part, and has received the indorsement in various ways of several scientific bodies, and that it seems better to present it in the same form in which it has heretofore appeared:

Among our erroneous popular notions is one which occasionally brings practical men, even ship-masters, to grief. It is the idea that sound is always heard in all directions from its source according to its intensity or force, and according to the distance of the hearer from it. Instances of this fallacy have accumulated, and they are emphasized by shipwrecks caused by the insistance of mariners on the infallibility of their ears, who have accepted unquestioned the guidance of sound signals during fog as they have that of light-houses during clear weather. The fact is, audition is subject to aberrations, and under circumstances where little expected. We have learned by sad experience that implicit reliance on sound signals may, as it has, lead to danger if not to death.

The wreck of the steamer *Rhode Island* on Bonnet Point, in Narragansett Bay, which happened on November 6, 1880, when a million dollars in property was lost, was caused, it was said, by the failure of the fog-signal on Beaver Tail Point to sound at that time. Thereupon the Light-House Board, which has charge of the eighty and more fog-signals on our coasts, made an investigation, which showed that the fog-signal was in full operation when the wreck took place; but it also brought out the fact that while there was no lack in the volume of the sound emitted by the signal, there was often a decided lack in the audition of that sound, so much so that it would not be heard at the intensity expected, nor at the place expected; indeed it would be heard faintly where it ought to be heard loudly, and loudly where it ought to be heard faintly; that it could not be heard at all at some points, and then further away it could be heard better than near by; that it could be heard and lost and heard and lost again, all within reasonable ear-shot, and all this while the signal was in full blast and sounding continuously.

The following table, A, will give the results obtained by the officer of the Navy who investigated these phenomena, and reported to the Light-House Board:

TABLE A.—*Observations on Beaver Tail fog-signal, Rhode Island, made on November* 16, 1880, *from a sail-boat.*

[Thermometer at beginning 58°, ending 67°; wind moderate from the west; weather clear and cold, with a bright sun. Time, beginning 11.15 a. m.]

No. of observation.	Distance from Beaver Tail fog signal in statute miles.	Intensity of sound in scale of 10.	Remarks.
1	1/8	10	
2	7/8	2	
3	1 1/16	1	
4	1 1/4	10	
5	1 3/8	1	
6	1 1/2	0	
7	1 5/8	0	
8	1 7/8	1	Close to Bonnet Point changed course and ran almost due south.
9	1 1/8	1	1½ miles from last station.
10	1	0	One-quarter mile from last station.
11	7/8	1	Do.
12	5/8	4	Do.
13	3/8	10	Do.
14	3/8	10	About opposite Beaver Tail, one-half mile from last station, and in the axis of trumpet.
15	1/2	10	About one-half mile from last station, and running for Newport, heading nearly northeast.
16	1	10	About one-half mile from last station.
17	1 1/4	5	Do.
18	1 1/2	2	About one-quarter mile from last station.
19	1 7/8	2	Do.
20	2 3/8	1	About one-half mile from last station.
21	2 3/4	0	About one-quarter mile from last station.
22	3 1/4	0	About one-half mile from last station.
23	3 3/4	2	Do.
24	4	10	About one-quarter mile from last station, just off Fort Adams.
25	4 1/4	10	Under the lee of Fort Adams.
26	4 3/8	2	
27	4 5/8	2	
28	4 7/8	2	
29	5	2	Newport.

Figures 4, 5, 6, and 7 were prepared from diagrams made and sent the writer by the eminent chief of the French light-house service, Émile Allard, inspecteur-général des ponts et chaussées, directeur du service central des phares et balises. M. Allard made them from the diagrams in the writer's paper on the Aberrations of Audibility of Fog-Signals, in which the intensity of sound at each point was indicated by Arabic numerals in a scale of 10. The writer submits Allard's diagrams, because they convey the desired meaning better than do his own diagrams.

Last summer (1881) I had an opportunity while on a light-house steamer to experience something of the variations in the audition of the Beaver Tail fog-signal. When the steamer left the light-house landing, the fog-signal was to sound for a given time, and to commence when the steamer had reached a given point half a mile distant. When that point was reached, we could see by the steam-puffs coming from the escape-pipe that the signal was being blown; but we could not hear its sound; nor did we, as we continued on our course, running away from the light station for the next five minutes. When near to Whale Rock, less than a mile and a half distant from the signal, the steamer was stopped, silence was ordered fore and aft, and we all listened intently. The expert naval officers thought they heard a trace of the fog-signal, but my untrained ears failed to differentiate it from the moan of the whistling buoy close to us. Yet the blasts of the 10-inch steam-whistle, for which we were listening, can often be heard at a distance of 10 miles.

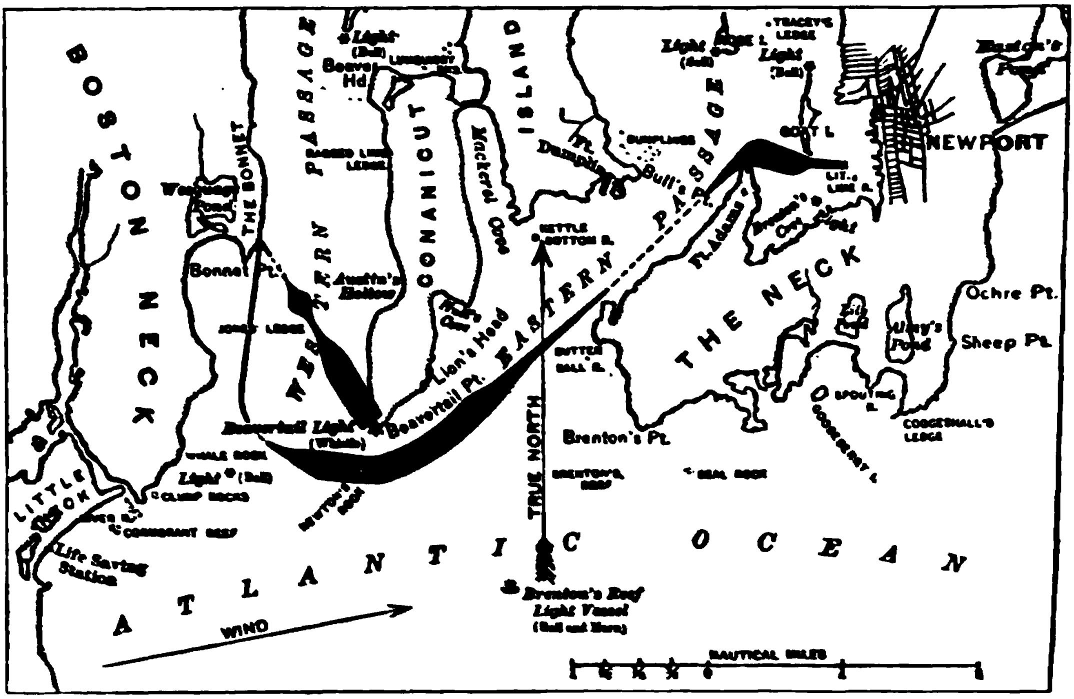


FIG. 3.—This diagram shows the result of observations made by Lieutenant-Commander Chadwick, U. S. Navy, on Beaver Tail fog-signal, Rhode Island, made November 16, 1880, from a sail-boat. Thermometer at beginning, 58° Fahr.: ending, 67°. Wind, moderate, from the west. Weather, clear and cold, with bright sun. Time, beginning at 11.15 a. m.

Soon after I had another opportunity to further observe the operations of this signal. We left Narragansett Pier, Rhode Island, on August 6, 1881, at 4 p. m., in a dense fog, with a strong breeze from the W. S. W., and a heavy chop sea. We wished to ascertain how far the Beaver Tail fog-signal could be heard dead to windward and in the heaviest of fogs. At Whale Rock, 1½ miles from it, we did not hear a trace of it. Then the steamer was headed directly for Beaver Tail Point, and we ran slowly for it by compass, until the pilot stopped the steamer, declaring we were almost aboard of the signal itself. Every one strained his ears to hear the signal but without success; and we had begun to doubt of our position when, the fog lifting slightly, we saw the breakers in altogether too close proximity for comfort. We passed the point as closely as was safe; and, when abreast of it and at right angles with the direction of the wind, the sound of the fog-signal broke on us suddenly and with its full power. We then ran down the wind to Newport, and carried the sound with us all the way. The fog continuing during the next day, the signal kept up its sound, and we heard it distinctly and continuously at our wharf, though 5 miles distant.

On the night of May 12, 1881, about midnight, the *Galatea*, a propeller of over 1,500 tons burden, with a full load of passengers and freight, bound through Long Island Sound from Providence to New York, grounded in a dead calm and a dense fog on Little Gull Island, about one-eighth of a mile from and behind the fog-signal, and got off two days later without damage to herself or loss of life or freight. It was, as usual, alleged that the fog-signal, a steam siren at Little Gull light, was not in operation at the time of the accident, and the Light-House Board, also as usual, immediately ordered an investigation. This was made by the assistant inspector of the light-house district, a naval officer, who reported that, after taking the sworn evidence of the light-keepers at Little Gull and the other light-stations within hearing distance, of other Government officers who were, for the time being, so located that they might have had knowledge of the facts, and of the officers of vessels that were within ear-shot, including those of the *Galatea*, he reached the conclusion that the fog-signal was sounding at the time of the accident; and that, although the fog-signal was heard at Mystic, 15 miles distant in another direction, and although it was heard on a steam-tug a mile beyond the *Galatea*, that it was heard faintly, if at all, on that vessel; and if heard at all, was so heard as to be misleading, though the *Galatea* was but one-eighth of a mile from the source of the sound.

This report is in itself full of interest. It appears that this officer spent several days steaming around Little Gull while the fog-signal was in full blast, in various kinds of weather, and that he found the aberrations in audition here were as numerous and even more eccentric than those before mentioned as experienced at Beaver Tail. The results of his observations are given in Tables B and C; and in each case the condition of the atmosphere as to humidity, pressure, temperature, and motion are shown, as is also the then tidal condition.

TABLE B.—*Fog-signal tests at Little Gull Island, Long Island Sound, July* 11, 1881.

[Time, 10 a. m.; wind, NNE, force 2; barometer, 29.77; thermometer, 61°; weather at commencement, dark, overcast with squalls of Scotch mist from NNE. It began to clear at 11.30 a.m.]

No. of observation.	Time of observation.	Distance from Little Gull Island fog-signal in statute miles.	Intensity of sound in scale of 10.	Remarks.
	h. m.			
1	10 10	1⅝	1	
2	10 15	2⅜	½	A faint murmur is put at one-half of one, in scale of 10.
3	10 18	2¼	0	
4	....	3⅜	0	
5	10 25	3⅝	0	
6	....	3[illegible]	0	
7	....	3[illegible]	½	About one-half mile from last station.
8	10 50	3[illegible]	1	
9	....	3[illegible]	0	
10	....	3[illegible]	1	Do.
11	....	3¾	2	Do.
12	11 09	3½	2	Changed course and ran a little S. of W.
13	....	3¾	3	
14	11 15	2⅞	3	
15	11 25	2[illegible]	4	
16	....	2¾	5	
17	11 35	2½	7	
18	....	2[illegible]	7	
19	....	1¼	8	
20	11 55	[illegible]	9	
21	....	[illegible]	10	
22	12 03	[illegible]	10	About one-half mile from last station.
23	12 07	[illegible]	7	
24	....	1¾	2	

TABLE B.—*Fog-signal tests at Little Gull Island, etc.*—Continued.

No. of observation.	Time of observation.	Distance from Little Gull Island fog-signal in statute miles.	Intensity of sound in scale of 10.	Remarks.
	h. m.			
25	12 14	1⅝	1	
26	12 19	2¼	1½	
27	12 23	2¾	½	Changed course.
28	12 40	2¾	½	Faint murmur.
29	12 52	3¼	0	Changed course.
30	1 01	2	½	
31	1 06	1⅝	½	
32	1 12	1⅜	5	
33	1 18	¾	10	
34	....	⅝	10	Almost west of fog-signal.
35	....	1¼	10	
36	1 35	1⅛	8	Changed course.
37	....	1⅜	8	
38	1 42	⅞	10	Stood northeast; sound gradually increasing.
39	1 52	⅛	3	
40	1 55	⅞	2	Changed course.
41	....	¾	2	
42	2 01	⅝	2	
43	2 02	⅛	10	
44	....	⅝	10	
45	....	¾	8	
46	....	1	7	
47	....	1¼	5	
48	4 29	2	2	
49	....	2¾	1	
50	4 38	3⅜	0	Lost the sound.
51	....	3¾	0	
52	4 45	4¼	0	Bartlett's Reef light-ship; wheels stopped and no sound.

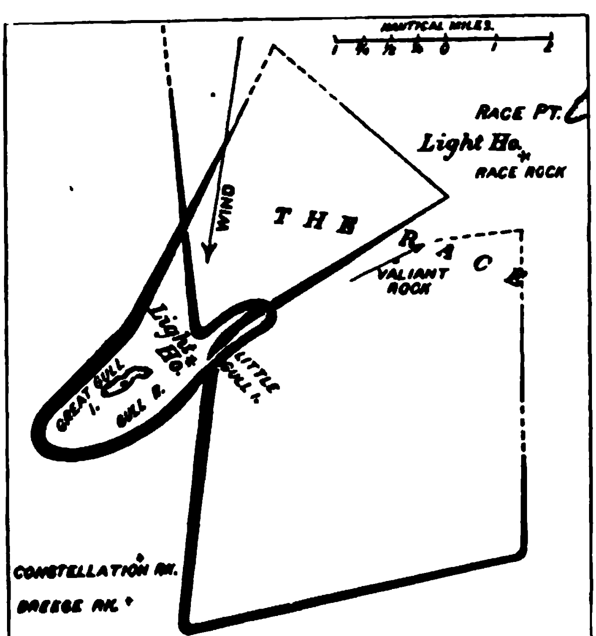


FIG. 4.—This diagram shows the result of fog-signal tests at Little Gull Island, Long Island Sound, July 11, 1881. Time, 10 a. m.; wind, NNE.; force, 2; barometer, 29.77; thermometer, 61° Fahr. Weather at beginning dark, overcast with squalls of Scottish mist from NNE. It began to clear at 11.30 a. m.

TABLE C.—*Observations at Little Gull Island, Long Island Sound, July 15, 1881, commencing at 6.30 a. m.*

[Thermometer, 50° Fahr.; barometer, 29.80; wind, WNW, force 3, hauling to the westward and increasing gradually.]

No. of observation.	Time of observation.	Distance from Little Gull fog-signal in statute miles.	Intensity of sound in a scale of 10.	Remarks.
	h. m.			
1	6 32	1¾	10	
2	6 57	2¼	10	Changed course, running S. by W. ½ W.
3		2¼	8	About one-half mile from last station.
4		2⅝	7	
5		3¼	4	
6	7 17	3¾	3	Changed course, running E.
7		3⅛	2	About one-half mile from last station.
8		3¾	1	Do.
9		3⅛	5	Do.
10	7 28	3⅛	7	Changed course, running N. by W. ½ W.
11		2½	8	
12		2¼	5	About one-half mile from last station.
13		2	5	Changed course, running W.
14	7 50	2⅜	5	
15		2⅞	3	
16		3⅛	2	
17	8 00	3⅜	0	Sound lost.

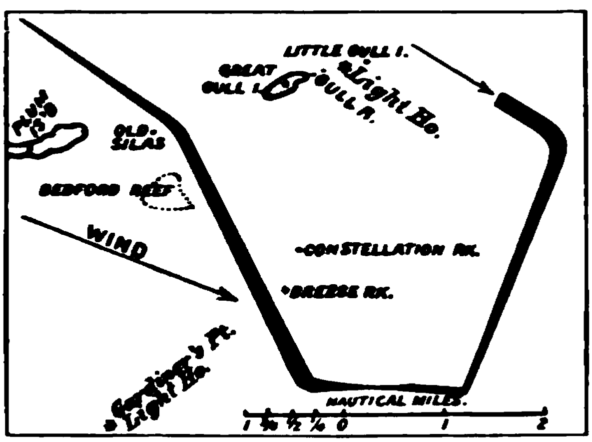


FIG. 5.—This diagram shows the result of observations at Little Gull Island, Long Island Sound, July 15, 1881, beginning at 6.30 a. m. Thermometer, 50° Fahr.; barometer, 29.80; wind, WNW.; force, 3, hauling westward and increasing gradually.

On August 3 I had an opportunity to hear this fog-signal myself, and to note its audibility. The wind was from the south and very light; the air was damp, smoky, hazy, and, as the sailors say, hung low; the barometer stood at 29.90; the tide was about flood. Our steamer was run for 6 miles in the axis of the siren's trumpet, which was sounded for our benefit at its full force. Note was made every third minute in a scale of 10 of the intensity of the sound, and it was found that the audition decreased normally with the distance for the first 2 miles; at 2½ miles it had fallen off one-half; at 3 miles it had fallen to one-tenth its power; at 3½ miles away we could hear but a faint murmur, and when 4 miles distant we had lost it completely; and yet there seemed to be no reason why we should not have heard it clearly at three times that distance.

The next morning was calm, but heavy with white fog, yet we heard the Little Gull siren distinctly, though it was 10½ miles off, as we lay at our dock in New London. The steamer ran out of the harbor, but was compelled to anchor, so thick was the fog; yet we heard Little Gull, though 7½ miles off, at a force of 6 in the scale of 10, and the sound was so clear cut and distinct that we could differentiate it from the siren at the New London light, which was much nearer to us. The steamer worked round to inspect the neighboring lights, and we heard the Little Gull siren when at North Dumpling light-station, 7 miles off, at a force of 6; at Morgan's Point light, 10 miles off, at a force of 5, and we continued to hear it at an intensity of from 5 to 6 as we worked around among the other lights, within a compass of 10 miles, till the fog broke and the siren ceased.

Opportunity soon occurred for making more critical experiments. On a fine day we ran out to Little Gull, had the siren started under full steam, and then, following out a pre-arranged programme, ran round Little Gull Island in such way as to describe a rectangle of about 8 by 10 miles, its longest side running nearly north and south. No fixed rate of speed was maintained, but the steamer slowed, backed, or, stopped, as was necessary. The atmosphere was what the sailors call lumpy, and Professor Tyndall calls non-homogeneous. Professor Henry, when writing of a like condition, said: "As the heat of the sun increases during the first part of the day the temperature of the land rises above that of the sea, and this excess of the temperature *produces upward currents of air*, disturbing the general flow of wind, both at the surface of the sea and at an elevation above." Observations were made and noted in a scale of 10, of the force or intensity of the signal's sound as it reached us at the end of each minute. The following (Table D) shows a sufficient number of the results for our purposes, taken from the tabulated schedule of our notes. The table also shows the condition of the atmosphere during our observations.

TABLE D.—*Observations at Little Gull Island, Long Island Sound, August* 9, 1881, *commencing at* 10 *a. m.*

[Thermometer, dry bulb, 73°.09; wet bulb, 73° Fahr. Barometer, 29.77. Wind, SW.; force, 3, Cir. strat. clouds about the horizon.]

No. of observation.	Time of observation.	Distance from Little Gull Island in statute miles.	Intensity of sound in scale of 10.	No. of observation.	Time of observation.	Distance from Little Gull Island in statute miles.	Intensity of sound in scale of 10.
	h. m.				*h. m.*		
1	10 30	0¼	10	16	12 04	2⅝	9
2	10 32	0⅓	10	17	12 08	2¼	9
3	10 34	0½	10	18	12 13	2⅛	5
4	10 36	1	10	19	12 20	2⅛	3
5	10 37	1¼	0	20	12 28	3¼	1
6	10 48	2	0	21	12 35	3½	0½
7	10 57	3	0	22	12 41	3⅜	0
8	11 02	3	0	23	12 45	3	1
9	11 08	3 1/16	1	24	12 57	2⅛	0
10	11 15	3⅛	3	25	12 58	2⅜	0
11	11 23	4⅛	4	26	1 02	1⅞	1
12	11 38	....	8	27	1 20	1¾	0½
13	11 42	2¾	9	28	1 24	1⅝	0½
14	11 54	3	9	29	1 30	0¾	0
15	11 57	3¼	9	30	1 32	0¼	10

At 4 p. m. two of us went in a row-boat to Little Gull from the steamer which lay to her anchor half a mile off, and verified the fact that the fog-signal had been in full operation during the time of our observations by the report of the steamer's mate, who had been left there for that purpose. It then occurred to us to investigate still more closely what appeared to be a space—a circle of silence—in which we had, during the experiments

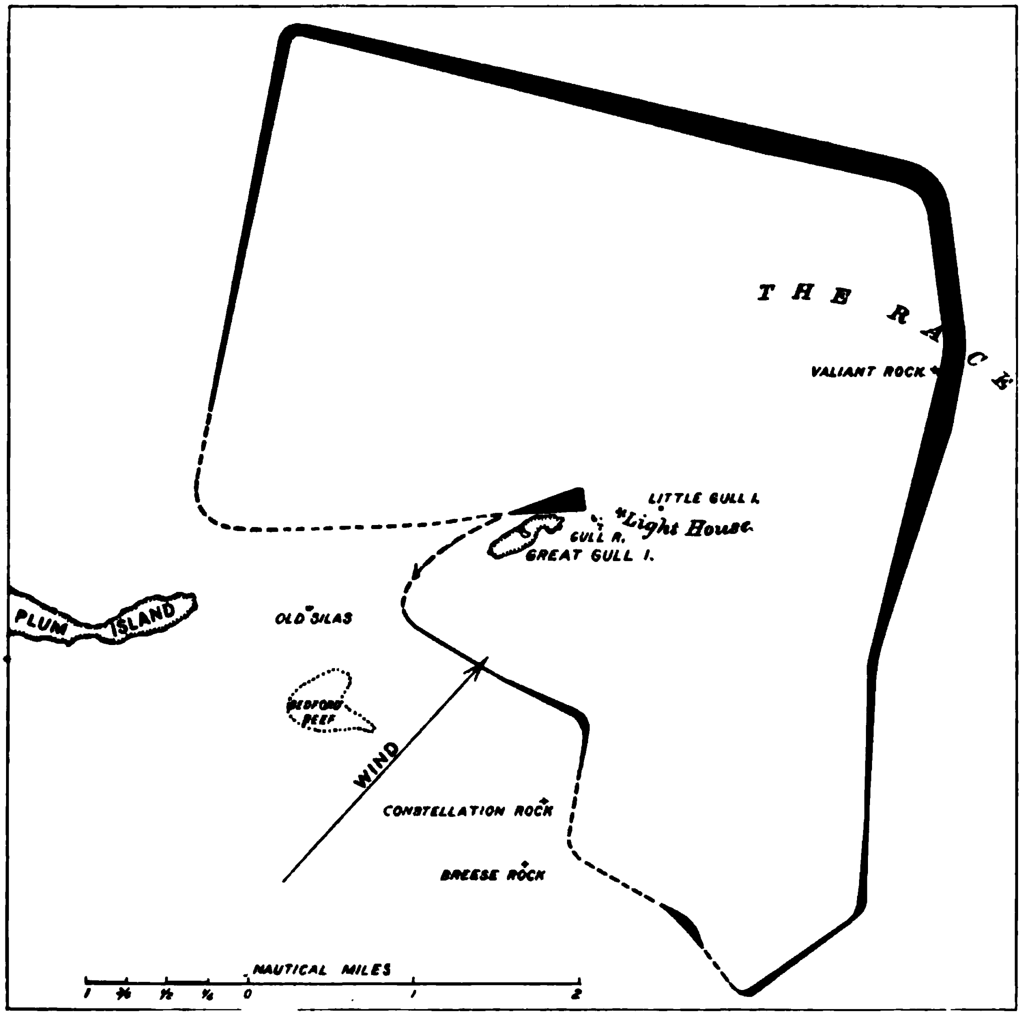


FIG. 6.—This diagram shows the result of observations at Little Gull Island, Long Island Sound, August 9, 1881, beginning at 10 a. m. Thermometer, dry bulb, 73.09°; wet bulb, 73° Fahr.; barometer, 29.77; wind SW., force 3. Cir. strat. clouds about the horizon.

of the morning, failed to hear the signal. After having had the siren put in full operation again, we pulled toward the nearer end of Great Gull Island, the siren sounding meantime with earsplitting force. When about 600 yards away we suddenly lost the sound as completely as if the signal had stopped. Pulling toward the steamer, not more than 200 yards, we reached a position at right angles with the axis of the siren's trumpet, when we suddenly heard the sound again at its full force. Thus, in pulling 500 yards, we passed from complete audition of the signal to absolute inaudition; and then we passed back again to complete audition by pulling 200 yards in another direction. All this took place within half an hour in open water, always in full view of the signal station, and without any visible obstacle being interposed or removed.

While on the island we learned that one of the light-house keepers, who had been on leave, had just returned from Sag Harbor, 20 miles away to the southeast. He had failed to hear the signal at all until opposite the eastern end of Great Gull Island, and until he was within half a mile of the siren which was in full operation.

On the next morning our steamer anchored about a mile north of Little Gull; the wind was light, the air was clear, and the day was warm and beautiful. As it had been preceded by a warm night the atmosphere was homogeneous, and it was expected that we should have a day of normal audition and barren of curious phenomena. After the siren had commenced its noise we ran down to a point within half a mile of the light-house, and then steamed for Plum Island, running a little south of east for 6 miles, when we returned as nearly as might be on our own track. The results were curious. We lost half the force of the sound when within a quarter of a mile of the siren; a moment later we had lost four-fifths of it. Running another half mile we were off the middle of Great Gull Island, and the sound had increased to a force of 4; in five minutes more it had dropped to 3; from that on, until we reached the end of our 6-mile run, it gradually weakened, and it had dropped to a force of 2 when we turned and ran back to our anchorage. It is particularly curious that the sound had the same intensity at three-sixteenths of a mile from its source, and at 6 whole miles from that point, while it varied from 2 to 10 in a scale of 10 between those points. The results of the trip are more fully and exactly given in Table E.

Thinking that possibly this peculiarity might have been induced by those differences of temperature in the strata of the atmosphere suggested by Dr. Tyndall as probable cause for such phenomena, effort was made to ascertain something of these differences by sending a thermometer to the upper air. In the course of the afternoon we made a kite some 6 feet high, attached to it a self-registering thermometer, and after a number of trials succeeded in getting it up about 500 feet, and in hauling it safely in again after it had been up over an hour. The thermometer had a wet bulb, and beside was protected from the direct rays of the sun; but it registered only half a degree more of heat at its highest point than it had done in the pilot-house. The course the kite took showed no difference between the air currents alow and aloft.

TABLE E.—*Observations at Little Gull Island, Long Island Sound, August 10, 1881, commencing at 10.30 a. m.*

[Dry bulb thermometer, 76°; wet bulb, 75°. Barometer, 29.40. Wind, W. by N., force 3, and steady throughout. Day clear and beautiful.]

No. of observation.	Time of observation.	Distance from Little Gull Island in a direct line in statute miles.	Intensity of sound in a scale of 10.	No. of observation.	Time of observation.	Distance from Little Gull Island in a direct line in statute miles.	Intensity of sound in a scale of 10.
	h m.				*h. m.*		
1	10 36	1 1/16	10	7	10 59	2 1/16	2 to 3
2	10 40	0¾	10	8	11 07	2⅛	2 to 3
3	10 44	0¼	5	9	11 29	2¾	2 to 3
4	10 45	0 3/16	2	10	11 45	5 1/16	2 to 3
5	10 49	0¾	4	11	11 52	5⅛	2
6	10 53	1¼	3	12	12 02	6	2

The Light-House Board has known from the first that aberrations in audibility might occur near any fog-signal. When the fog-trumpet was set up at Beaver Tail Point in 1856, the Naval Secretary of the Board, then Lieutenant, now Rear-Admiral Jenkins, U. S. Navy, in company with Mr. Daboll, its inventor, found, in returning to Newport, that they lost the sound of the signal between Beaver Tail and Fort Adams, and recovered it again between the fort and Newport, as did later observers, and that this failure to hear it did not result from any failure of the signal to operate.

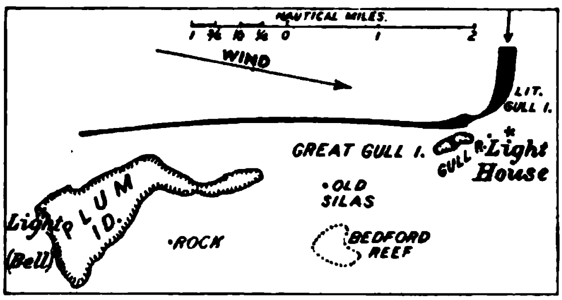


FIG 7.—This diagram shows the result of observations at Little Gull Island, Long Island Sound, August 10, 1881, beginning at 10.30 a. m. Thermometer, dry bulb, 76°; wet bulb, 75° Fahr.; barometer, 29.40; wind W. by N., force 3, and steady throughout. Day clear and beautiful.

The Board's publications show that Professor Henry, its scientific adviser, had the subject for many years continuously under advisement, and that between 1865 and 1878 many experiments were made, and various reports on them were submitted to the Board as to the use and value of its several kinds of fog-signals. In 1870 the Board directed General Duane, of the U. S. Engineers, to make a series of experiments to ascertain the comparative value of its different signals. In his report the general said, speaking of the steam fog-signals on the coast of Maine:

There are six steam fog-whistles on the coast of Maine; these have been frequently heard at a distance of 20 miles, and as frequently can not be heard at the distance of 2 miles, and this with no perceptible difference in the state of the atmosphere.

The signal is often heard at a great distance in one direction, while in another it will be scarcely audible at the distance of a mile. This is not the effect of wind, as the signal is frequently heard much farther against the wind than with it; for example, the whistle on Cape Elizabeth can always be distinctly heard in Portland, a distance of 9 miles, during a heavy northeast snow-storm, the wind blowing a gale directly from Portland toward the whistle.

* * * * * * *

The most perplexing difficulty, however, arises from the fact that the signal often appears to be surrounded by a belt, varying in radius from 1 to 1½ miles, from which the sound appears to be entirely absent. Thus, in moving directly from a station, the sound is audible for the distance of a mile, is then lost for about the same distance, after which it is again distinctly heard for a long time. This action is common to all ear-signals, and has been at times observed at all the stations, at one of which the signal is situated on a bare rock 20 miles from the main land, with no surrounding objects to affect the sound.*

Professor Henry, in considering the results of General Duane's experiments and his own, some of which were made in company with Sir Fred'k Arrow and Captain Webb, H. B. M. Navy, both of the British Light-House Establishment, who were sent here to study and report on our fog-

* Annual Report Light-House Board, 1874, pp. 99–100.

signal system, formulated these abnormal phenomena. He said they consisted of:

(1) The audibility of a sound at a distance and its inaudibility nearer the source of sound.
(2) The inaudibility of a sound at a given distance in one direction, while a lesser sound is heard at the same distance in another direction.
(3) The audibility at one time at a distance of several miles, while at another the sound can not be heard at more than a fifth of the same distance.
(4) While the sound is generally heard further with the wind than against it, in some instances the reverse is the case.
(5) The sudden loss of a sound in passing from one locality to another in the same vicinity, the distance from the source of sound being the same.*

These experiments were not confined to our own shores. Dr. Tyndall, the well-known English physicist, who stood in the same relation to the British Light-House Establishment that Professor Henry did to our own, writes:

With a view to the protection of life and property at sea, in the years 1873 and 1874 this subject received an exhaustive examination, observational and experimental. The investigation was conducted at the expense of the Government, and under the auspices of the Elder Brethren of the Trinity House [the governing body of the British Light-House Establishment].

The most conflicting results were at first obtained. On the 19th of May, 1873, the sound range was 3½ miles; on the 20th it was 5½ miles; on the 2d of June, 6 miles; on the 3d, more than 9 miles; on the 10th, 9 miles; on the 25th, 6 miles; on the 26th, 9½ miles; on the 1st of July, 12¾ miles; on the 2d, 4 miles, while on the 3d, with a clear, calm atmosphere and smooth sea, it was less than 3 miles.†

The officer who made the reports as to the fog-signals at Beaver Tail and Little Gull, after the accidents to the steamers *Rhode Island* and *Galatea*, heretofore mentioned, was the assistant Inspector of the third light-house district, Lieut. Commander F. E. Chadwick, U. S. Navy, and it was he who had charge of the light-house steamer while the foregoing observations were being made, after Capt. George Brown, U. S. Navy, the Inspector—to whom I am indebted for many courtesies on this trip—was called elsewhere by other official duties. Mr. Chadwick brought to this work an unbiased mind, trained in the severest schools of scientific investigation. His object in all his experiments was simply to ascertain the exact truth for practical official purposes. He had not proposed, even to himself, to make any generalizations from his observations. But he kindly answered certain of my questions as to the opinions which had forced themselves upon him, and his answers are here set down for the consideration of those who use these fog-signals overmuch as a guide for their ships:

It seems to me [he said] that navigators should understand that when attempting to pick up a fog-signal attention must be given to the direction of the wind, and that if they are to windward (in a moderate breeze) the chances are very largely against hearing it, unless close to; that there is nearly always a sector of about 120° to windward of the signal in which it either can not be heard at all or in which it is but faintly heard. Thus, with the wind east-southeast, so long as they are bearing from the signal between northeast and south, there is a large chance that the signal will not be audible until it is very close.

As they bring the signal to bear at right-angles with the wind, the sound will almost certainly, in the case of light wind, increase, and it will soon assume its normal volume, being heard almost without fail in the leeward semicircle.

Fog, to my mind, and so far as my experience goes, is not a factor of any consequence whatever in the question of sound. Signals may be heard at great distances

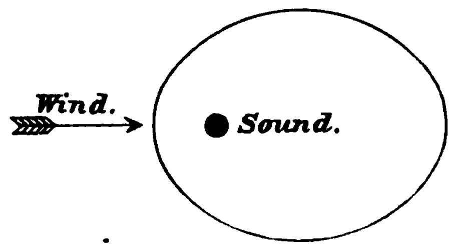
* Light House Board Annual Report, 1875, p. 106.
† Sound, by Tyndall: 3d ed., English, p. 324.

through the densest fogs, which may be totally inaudible in the same directions and at the same distances in the clearest atmosphere. It is not meant by this last statement that the fog may assist the sound; as at another time the signal may be absolutely inaudible in a fog of like density, where it had before been clearly heard. That fog has no great effect can easily be understood when it is known (as it certainly is known by observers), that even snow does not deaden sound, there being no condition of the atmosphere so favorable for the far reaching of sound signals as is that of a heavy northeast snow-storm, due supposably to the homogeneity produced by the falling snow.

It seems to be well established by numerous observations that on our own northern Atlantic coasts the best possible circumstances for hearing a fog-signal are in a northeast snow-storm, and, so far as these observations have extended, they seem to point to the extraordinary conclusion that they are best heard with the observer to windward of the signal; and that in light winds the signal is best heard down the wind, or at right angles with the wind.

The worst conditions for hearing sound seem to be found in the atmosphere of a clear, frosty morning on which a warm sun has risen and has been shining for two or three hours.

The curve of audibility in a light or moderate breeze, in general, is similar to that plotted by Professor Henry, as in the accompanying diagram.



I think it is established that there are two great causes for these phenomena, non-homogeneity of the atmosphere and the movement of the wind; how this latter acts no one can say. The theory of retardation of the lower strata of the atmosphere near the earth's surface, as advanced by Professor Stokes, of England,* seems good for moderate winds, but it hardly holds in cases where the siren is heard from 18 to 20 miles to windward during northeast gales.

While the mariner may usually expect to hear the sound of the average fog-signal normally as to force and place, he should be prepared for occasional aberrations in audition. It is impossible at this point in the investigations which are still in progress to say when, where, or how the phenomena will occur. But certain suggestions present themselves even now as worthy of consideration.

SUGGESTIONS.

It seems that the mariner should, in order to pick up the sound of the fog-signal most quickly when approaching it from the windward, go aloft, and that when approaching it from the leeward the nearer he can get to the surface of the water the sooner he will hear the sound.

It also appears that there are some things the mariner should not do.

He should place no negative dependence on the fog-signal; that is, he should not assume that he is out of hearing distance because he fails to hear its sound.

He should not assume that because he hears a fog-signal faintly he is at a great distance from it.

*See Henry on Sound, p. 533; or Smithsonian Report, 1878, p. 533; or Light-House Board Report for 1875, p. 120. See Henry on Sound, p. 512, and Taylor in Am. Jour. Sci., 3d series, Vol. XI, p. 100; also Rept. Brit. Assoc., XXIV, 2d part, p. 27.

Neither should he assume that he is near to it because he hears the sound plainly.

He should not assume that he has reached a given point on his course because he hears the fog-signal at the same intensity that he did when formerly at that point.

Neither should he assume that he has not reached this point because he fails to hear the fog-signal as loudly as before, or because he does not hear it at all.

He should not assume that the fog-signal has ceased sounding because he fails to hear it even when within easy ear-shot.

He should not assume that the aberrations of audibility which pertain to any one fog-signal pertain to any other fog-signal.

He should not expect to hear a fog-signal as well when the upper and lower currents of air run in different directions; that is, when his upper sails fill and his lower sails flap, nor when his lower sails fill and his upper sails flap.

He should not expect to hear the fog-signal so well when between him and it is a swiftly flowing stream, especially when the tide and wind run in opposite directions.

He should not expect to hear it well during a time of electric disturbance.

He should not expect to hear a fog-signal well when the sound must reach him overland, as over a point or an island.

And, when there is a bluff behind the fog-signal, he should be prepared for irregular intervals in audition, such as might be produced could the sound ricochet from the trumpet, as a ball would from a cannon; that is, he might hear it at 2, 4, 6, 8, and 10 miles from the signal, and lose it at 1, 3, 5, 7, 9, and 11 miles distance, or at any other combination of distances, regular or irregular.

These deductions, some made, as previously mentioned, by several of the first physicists of the age, and some drawn from the original investigations here noted, are submitted for consideration rather than given as directions. They are assumed as good working hypotheses for use in further investigation. While it is claimed that they are correct as to the localities in which they were made, it seems proper to say that they have not been disproved by the practical mariners who have given them some personal consideration, and who have tried to carry them into general application. Hence these suggestions have been set down in the hope that others with greater knowledge and larger leisure may give the subject fuller attention, and work out further results.

If the law of these aberrations in audibility can be evolved and some method discovered for their correction, as the variations of the compass are corrected, then sound may be depended upon as a more definite and accurate aid to navigation. Until then, the mariner will do well when he does not get the expected sound of a fog-signal, to assume that he may not hear a warning that is faithfully given, and then to heave his lead, and resort to the other means used by the careful navigator to make sure of his position.

These suggestions, which have been republished many times and in various languages, without so far as is known evoking any hostile criticism, appeared on the Pilot Chart of the North Atlantic Ocean, issued in August, 1889, by the U. S. Navy Department, with the following heading:

Fog-signals.—Recent reports of the seeming failure of certain fog-signals render it desirable to give the conclusions of an expert on this subject. We extract the following from a paper read before the Philosophical Society of Washington, October, 1881, by Mr. Arnold B. Johnson, chief clerk of the Light-House Board.

A paper which your writer submitted to the Philosophical Society of Washington, subsequent to the foregoing, was also printed, and there is made from it certain extracts, as they embody the results of further experiment and riper discussion of the subject.

M. Allard, director of the French Light-House Service, in his "Mémoire sur la Portée des Sons et sur les Caractères à attribuer aux Signaux sonores," recently published by his Government, records some curious experiments with various fog-signals made in France, Germany, and England, as well as in this country. He has compared, in tabular form, the results of these experiments, and gives the range of sound of each instrument under a variety of conditions, taking into consideration the intensity and pitch of the sound, the direction and force of the wind, and its angle of action on the phonic beam. He has established a mathematical formula for the calculation of the range of the sound of each instrument, under certain given circumstances, in which he expresses what he styles the acoustic transparency of the atmosphere by a co-efficient, and he has also expressed graphically the set of results obtained, thus assisting largely the intelligent discussion of the general subject.

Tillamook Rock light and fog-signal station is on an isolated rock about half a mile west of the coast of Oregon, and about 20 miles south of the mouth of Columbia River. The signal is a steam-siren. The surface of the rock is about 86 feet above the water, and the trumpet, which points almost westward, has an elevation of fully 100 feet. Colonel Gillespie, of the Corps of Engineers, U. S. Army, who built the tower and put in the illuminating and fog-signal apparatus, tested the latter, steaming to the west directly from it on a clear bright day, and found that the sound became practically inaudible at a distance of 2 miles. In a letter addressed to your writer, dated November 6, 1882, he wrote:

My first attention was called to the defects of audibility by the captain of the *Shubrick*, who stated, in May, 1881, that, when anchored in a small bight south of the rock near Arch Rock and about 1 mile distant, he could hear the sound but faintly. On my next visit I directed the engineer to get up steam, and when he had a pressure of 50 pounds, to whistle and then set the machinery in motion. On receiving the signal, I made a circuit of the rock and then proceeded westward under slow bell, recording my distance by interval of sound at each blast. At 2 miles the sound became quite weak, and at the next blast no sound was received. Our engine was not stopped when receiving the sound, and my station was aft, quite near the propeller; the day was bright and clear, without any wind. The temperature was 65 degrees or thereabout; don't know the barometer reading. On receiving the next sound, the boat was at rest, that is, just as soon as the puff was noticed the engine was stopped, and we waited for the sound. A very faint sound was noticed up to 4 miles, and beyond that nothing was heard.

I was then on the point of returning to the rock to examine the machinery personally, when it struck me that I ought to go out to the estimated limit of the range. On resuming our course, nothing was heard until we were out 7 miles approximately, when the sound became audible again—a clear, resonant sound, but low-toned. We carried this characteristic sound for another 4 miles, when it likewise disappeared. The engineer afterward told me that he carried at least 60 pounds of steam. It was growing late, and as the sea and rising winds gave promise of a squall, we hurried back to get inside of the bar. * * * The sea-captains on the iron vessels plying to San Francisco reported later that they were able to hear the sound at a distance of 8 miles. * * * My impression is that the cliffs of the east side are too far distant to affect the sound one way or the other. I have never heard an echo there, and I believe that the distance is too great to have the noise of the surf upon the rocky beach deaden the sound seaward of the station.

The ends of the trumpet are bent toward the horizon, terminating in bell-shaped lips. The sound is propagated therefrom in a horizontal plane, and previous experiments have shown that the sound produced is as strong as if the whole trumpet lay horizontally.

This is quoted as showing that the sound, which on one occasion intermitted at 2 miles from its source, was heard faintly at 4 miles, and then again distinctly at 7 miles, and was carried out to 11 miles, when the steamer turned back without ascertaining how much farther the sound might be carried. This is deemed a peculiar and important instance, as there was practically no land or other thing in front of the source of sound, unless it be an opaque cloud from which the sound could rebound, or which could cast a sound-shadow, for hundreds of miles.

Some curious experiments have taken place off Whitehead light and fog-signal station, which is in the Atlantic, on a small island, about 1½ miles from the coast of Maine. The fog-signal is on the southeastern slope of the rock, and about 75 feet above mean tide. The phenomena observed by Professor Henry consisted in great variation of intensity of sound while approaching and receding from the station. One instance occurred during a thick night fog in 1872, when, approaching the station in the steamer *City of Richmond* at a distance of 6 miles, the fog-signal, a 10-inch steam-whistle, was distinctly heard and continued to be heard with increasing intensity until within 3 miles, when the sound suddenly ceased to be heard, and was not heard again until the steamer was within a quarter of a mile of the station, though it was known that the signal had been sounding during the whole time. The wind was from the south, or almost opposed to the sound, but during the whole of this time the fog-signal keeper could hear the sound of the steamer's 6-inch whistle.

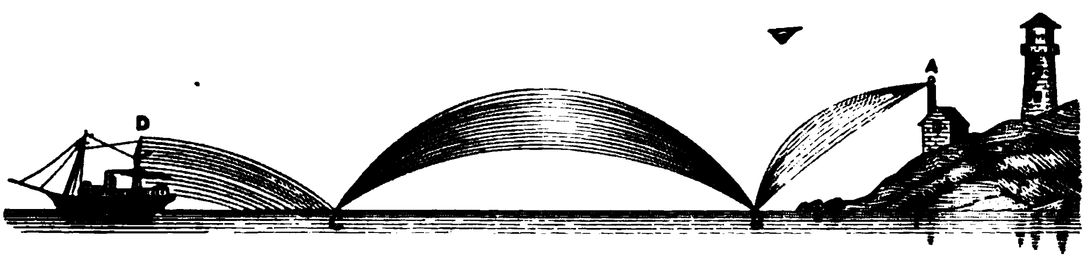
Commander H. F. Picking, U. S. Navy, then Inspector of the first light-house district, having frequently received complaints from ship-masters that they lost the sound of the Whitehead fog-signal, determined to ascertain the facts by personal investigation, and in July, 1877, approached Whitehead from the southeast during a fog. He reports that he heard the sound distinctly from 6 to 4 miles, then lost it, and could hear nothing until within a quarter of a mile of the island, when the blast of the whistle burst forth in full sound. The wind was then against the sound.

Previously, General Duane, since Chief of the Corps of Engineers, U. S. Army, then Engineer of that light-house district, reported that, approaching the signal from the southwest, he heard the sound at about 6 miles' distance, then lost it, and did not hear it again until within about a quarter of a mile. The wind was then also against the sound.

On September 4, 1877, Professor Henry, secretary of the Smithsonian Institution, and chairman of the Light-House Board, made further experiments at Whitehead. The weather was clear, the wind west-southwest, with a velocity of from 10 to 12 miles, remaining nearly constant during the day. The barometer stood at 28.9; the thermometer at 67° Fahr. in the open air, and about 57° in the water. As they steamed from the station directly to windward, the sound slightly diminished. When they were between a quarter and a half mile distant, they lost the sound completely, and it continued inaudible for about a mile, when it was faintly heard, and continued to increase in loudness until they were 4 miles off, when it was heard with clearness, but on going on, it diminished gradually. They then went back over their course, and observed the phenomena in the reverse order. Experiments tried on three other days showed curious results, which differed somewhat from those previously made, of which a full report is given in the Annual Report of the Light-House Board for 1877, together with Professor Henry's views as to the cause of each observed phenomenon. A full account of the matter is also given in the book entitled "Henry on Sound."

Col. C. E. Blunt, Corps of Engineers, U. S. Army, then Engineer of the first light-house district, was also at a later date struck by the peculiarity in the audition of the sound from this signal. Writing to your writer from Portland, Me., on September 28, 1882, he said:

The peculiarities of Whitehead whistle have already been noted. Quite recently I have myself noted one of them. Leaving there for Portland, in the *Myrtle*, early on the morning of the 2d instant, the whistle having been blown during fog part of the previous night for the first time, with its new characteristics (four-second blast and twenty-six-second interval), the keeper kept it going for a short time after the weather had cleared, as I wished to test it. It was bright sunshine, with the light air from the southeast, I think. Leaving the Head, the whistle was plainly heard for 2 or 3 miles; when, still in plain sight, the sound began to grow fainter, and at length was quite inaudible, though it was plainly blowing. In a few minutes the sound was again faintly heard, and, increasing in volume, soon came out in full force, and so continued. It was clearly deflected upward, and then downward, as I imagined, thus:



Area of audibility. Area of inaudability. Area of audibility.

FIG. 8.—BLUNT'S DIAGRAM.

With regard to snow, it is thought by seamen in this vicinity that it is favorable to sound; certainly, Portland Head trumpet is very distinctly heard here during violent northeast snow-storms, when it is directly to the leeward.

Professor Henry made observations at a number of light-stations for various purposes connected with the investigation of the laws of sound, from his report of which it appears that he noted a number of instances of remarkable aberrations of audition of several fog-signals. These are recorded at length in "Henry on Sound," in the reports of the Light-House Board of 1874–'75, and in the reports of the Smithsonian Institution for several years.

The experiments were not confined to our own shores. Professor Tyndall, who stood in the same relations with the British Light-house establishment that Professor Henry did to our own, reported thus:

With a view to the protection of life and property at sea in the years 1873–'74, this subject received an exhaustive examination, observational and experimental. The investigations were conducted at the expense of the Government, and under the auspices of the Trinity House. The most conflicting results were at first obtained. On the 19th of May, 1873, the sound range was 3¼ miles; on the 20th it was 5¼ miles; on the 2d of June, 6 miles; on the 3d, more than 9 miles; on the 10th, 9 miles; on the 25th, 6 miles; on the 26th, 9¼ miles; on the 1st of July, 12¾ miles; on the 2d, 4 miles; while on the 3d, with a clear, calm atmosphere and smooth sea, it was less than 3 miles.

From the letters received from officers of the navy and of the merchant marine service, also from officers of the English, Scotch, and French light-house establishments, it is evident that public attention is being given to the subject, and that observations are being made as to such aberrations simultaneously in various parts of the world.

Dr. Welling, president of Columbian University, in a paper read before the Washington Philosophical Society, November 5, 1881, said:

In a paper presented to the Royal Society in 1874, Professor Reynolds showed that the form of the sound-wave is liable to flexure from changes in the temperature of the atmosphere, as well as from the unequal motion of the wind. These abnormal phenomena of sound, considered in connection with the hypothesis of Professor Stokes, as enlarged and applied by Professor Henry, may be reduced in the following generalizations, which, if accurate in point of logical form and true in point of the facts to which they are applied, may be stated under the guise of aphorisms, as follows:

(1) Where the condition of the air is nearest that of a calm, the larger will be the curve of audition, and the nearer will the shape of the curve approach to a circle, to which the point of origin of the sound, or the point of perception, will be the center. (This aphorism is stated abstractly from any consideration of temperature refraction, which, so far as it exists, will always tend to modify the shape of the curve of audition.)

(2) Apart from all consideration of temperature refraction, a sound will be heard farthest in the direction of a gentle wind, because the portion of the sound-wave thrown down from above, in this case, is reinforced by the sound reflected from the surface, and will thus more than compensate for the loss by friction.

(3) Other things being equal, the area of audition will be proportionately diminished in the case of sounds moving against winds more or less strong, because the sonorous waves will be refracted above the ears of the observer.

(4) The area of audition will be diminished in the case of a sound moving with an overstrong favoring wind, because the sound-waves in this case will be so rapidly and strongly thrown to the ground that the intensity of the sound will suffer more diminution from absorption and friction than can be supplied by the upward reflection of the sound-rays conspiring with the gradual downward flexure of the sound-waves, as in the case of a gentle favoring wind.

(5) Sounds moving against a gentle wind will, *cæteris paribus*, be heard farther than similar sounds moving with an overstrong favoring wind, for reasons already implied, because the downward flexure of the sound-waves, being excessive in the latter case, tends to extinguish the conditions of audibility more rapidly than is done by the slight upward refraction in the former case.

(6) When sounds moving against the wind are heard farther than similar sounds moving with a wind of equal strength, it is because of a dominant upper wind blowing at the time in a direction opposite to that at the surface.

(7) A sound moving against the wind, and so refracted as in the end to be thrown above the head of the observer, will, at the point of its elevation, leave an acoustic shadow. But this acoustic shadow, at a still further stage, may be filled in by the lateral spread of the sound-waves, or may be extinguished by the downward flexure of the sound-waves, resulting from an upper current of wind moving in an opposite direction to that at the surface, or resulting in a less degree from an upper stratum of still air. Under these circumstances, there will be areas of silence inclosed within areas of audition.

(8) As sounds may be refracted either by wind or by changing temperatures, or by both combined, it follows that, under many circumstances, a sound lost at one elevation may be regained at a higher elevation.

(9) As sounds moving against the wind are liable to become inaudible (by being tilted over the head of the observer), even before their intensity has been extinguished, we may find in this fact an explanation of the statement made by Reynolds that "on all occasions the effect of wind seems to be rather against distance than distinctness."

(10) As sounds may be inaudible at certain distances and elevations, without being wholly extinguished, it follows that the comparative inaudibility of sounds at different times can not always be cited as an evidence of their relative intensities. The comparative inaudibility may be a function of variable refraction, rather than of

variable intensity. Hence the law of inverse squares, though perfectly true in its theoretical application to the measurement of the intensity of all sounds, can not always be legitimately used to calculate backward from the audibility of a sound, as empirically ascertained at a given point and elevation, to its relative intensity as previously heard at the same point and elevation.

(11) The hypothesis of Stokes, as applied by Henry, does not exclude the hypothesis of Humboldt, but reduces the latter to a very subordinate and inappreciable place in interpreting the abnormal phenomena of sound.

(12) The hypothesis of Stokes, as applied by Henry, does not exclude the reasoning or the experimental proofs by which Professor Reynolds demonstrates that differences in temperature exert a refracting power in sound, but finds in that refraction an influence which may sometimes accelerate and sometimes retard the refraction produced by wind.

The following authorities were consulted in the preparation of this paper:

"Documents relating to Light-houses," vol. i; Annual Reports of the Light-house Board; Parliamentary Papers, 1864; Stevenson's "Light-house Illumination;" Tyndall on "Sound;" "Transactions of the Royal Scottish Society of Arts," vol. vi; "Coast Fog-signals," a lecture at the Royal United Service Institution, by Alexander Beazeley; "Signaling by means of Sound," a lecture by E. Price Edwards; "Philosophical Society's Transactions," vol. xxvi; "Annales de Chimie et de Physique," tome xiii, and 1816, vol. i; "Wirkungen aus der Ferne;" "Encyclopædia Metropolitana;" "Smithsonian Reports and Miscellaneous Collections;" Henry on "Sound;" "Proceedings of the British Association," 1857: "Washington Philosophical Society's Transactions," vol. v; Dublin "Philosophical Magazine," vol. 1; "American Journal of Sciences," third series, vol. xi; "Reports of the British Association," xxiv, second part; "Phares Électriques et les Signaux Sonores," par MM. Sautter et Lemonnier; "Mémoire sur la Portée des Sons et sur les Caractères à attribuer aux Signaux Sonores," by Émile Allard.

From these experiments and discussions, and others subsequently made, which it is unnecessary to go into here, your writer has reached the conclusion that while the unassisted ear could not locate the source of sound or the direction from which it came, yet, that like the eye, the ear can be aided by mechanical contrivances until it shall be able to do both.

After much correspondence and research your writer found that a number of appliances had been invented, any of which might, if properly used, prevent collisions between ships at sea in darkness or fog.

These views are embodied in the following paper, which your writer read before the American Association for the Advancement of Science, at its meeting in New York City, in August, 1887. The substance of the paper was subsequently printed in the Popular Science Monthly for May, 1888, and still more lately was translated into the Spanish and was published at Madrid in the Revista General de Marina for July, 1888. In that paper your writer advocated the remission of this and similar questions to an International Marine Congress, and your writer is now able to congratulate the commercial world, as that Congress was called and is soon to meet in this city.

Chapter X.

THE DIFFICULTY IN DETERMINING THE SOURCE OF THE SOUND OF FOG-SIGNALS AT SEA—HOW TO REMEDY THE DIFFICULTY.

The difficulty in determining the true and exact direction of the sounds we hear meets us in various ways. The hunter hears the note of a bird, the hiss or whistle of a deer, and the sound indicates identity and proximity, but not direction. The hunter waits for repeated renewal of the sound to ascertain its exact position, and even then verifies his audition by his vision. The hunter by his camp-fire may aim between the luminous dots of reflected light, which he knows to be the eyes of a wolf, but he would scarely be able to aim at or even very near that spot on simply hearing the howl from the wolf that owns the eyes.

The plainsman hears a shout in the distance. He may recognize it as the voice of a comrade and fix the general direction as north, east, south, or west, but hardly more. He may shout back, and the two may come together; but if it be dark and there is no fire or other signal, the shouting back and forth must be frequently repeated, and varied from a simple to a complex sound, that each may correct the error of his own audition, eliminate his personal equation, and the sound will appear to swing, pendulum-like, right and left, with shorter and shorter stroke, till the comrades come together.

The average child, returning from school, on entering the house calls, "Mamma!" The mother, perhaps, replies, "Yes!" "Where are you?" is the next question, and the reply informs the child not only as to the floor, but as to the room in which the mother can be found. The child can not determine its mother's location by the sound of her voice. This exaggerated instance may be owing to the reflection of the sound, not only from the walls, but from the strata of air differing in temperature and humidity.

How many of us going to the next street, running at right angles to the car-tracks, can tell, from hearing the bell of the approaching street-car before the car comes in sight, whether that car is going north or south? It does not seem that animals can determine the direction of sound much better than man. The sleeping dog, roused by his master's call, is all abroad as to his master's location, and determines it by sight or scent, or both, frequently running in several different directions before hitting the right one. The deer, on being startled by the unseen hunter's tread, is not always right in his selection of the route to get out of harm's way. A flock of geese, ducks, or other birds, on hearing a gun, is as likely to fly toward as from the sportsman, if he has kept entirely out of sight and the flash of his piece has not been seen.

It is a question whether the blind are better able to determine the direction of sound by ear than are seeing people. It is possible that their senses of touch and smell are so highly developed that their instantaneous action with that of the ear give them a decided advantage over seeing people in this matter. I have known a blind man to be so sensible of the current of air put in motion by the speaking of a single word in a room that he could select the speaker by his location though others were present. So, too, I have known a blind man to locate and identify the various people in the room, he saying he did it by the different scent evolved from each, the seeing people there not being sensible of any scent from any one. And yet he, when standing in the middle of the room with his nose stopped, could not give the direction of one single speaking person.

Prof. Alexander Graham Bell reports, in a paper he read before the American Association for the Advancement of Science, at Saratoga, in 1879, a series of experiments in binaural audition, showing, among other things, that direction can not be appreciated by monaural observation; that when the source of sound is at the nadir of the observer, the perception of its direction is absolutely unreliable, and that not one of the many on whom he tried the experiment had the slightest idea of the true direction of a sound produced beneath him.

We are so much accustomed to the aid of our other senses, especially that of sight, that we incline to give more value to audition in determining direction than it deserves. That is one reason why we err so largely when so placed that the eye can not correct the error of the ear; in fact, many people seem to be unaware that they have any inability tó locate sound by the ear until they have learned the fact by experience, and even then they appear to consider marked instances as abnormal.

It is sufficiently easy to account for aberrations of audition as to the direction of sound from objective causes, such as reflection, diffraction, and deflection of sound waves. But it may also often be accounted for by what Professor Henry called subjective causes, such as induce belief that an anticipated sound has come from a specified direction. when it has really come from quite another direction. Here the personal equation of the listener must be largely taken into consideration. The success of the ventriloquist may also depend upon subjective causes.

President Welling tells us something of how Professor Henry, when at Princeton, induced subjective causes in his pupils, to their bewilderment, making them believe, for the moment, that a given sound came from a specified corner of the class-room, when it really came from quite a different direction.

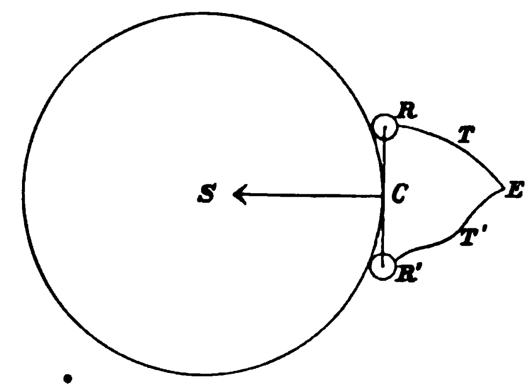
Mariners are beginning to accept the fact that they may err in assigning the true direction to sound; but their ideas on the subject are still vague and indeterminate. Hence occur collisions between ships at sea, and law-suits between their owners on shore. The collision at 10 p. m. on September 21, 1882, between the Dutch steamer *Edam* and the British steamer *Lepanto*, on George's Bank, Atlantic Ocean, when the former was sunk by the latter, resulted in a suit in the United States district court at New York City, in which the case turned on an erroneous location of the *Edam* by the *Lepanto*, on hearing the sound of her fog-horn. The court dismissed the case with costs, holding that "an error of five points in locating a vessel's position by the sound of her whistle in a fog is not necessarily a fault under the proved aberrations in the course of sound." The judge, in his decision, quotes, among others, papers read before the Washington Philosophical Society as his authority for certain statements he makes as to these laws of sound bearing on the case.*

As it seems evident that the unassisted ear is likely to err in determining the location of sound, the question arises, Can the ear be aided in this matter? Apparently this is possible. Professor Mayer, of the Institute of Technology at Hoboken, N. J., has, to a certain extent, solved this problem by the construction of an instrument called the "topophone," by the use of which Professor Morton, President of that Institute and a member of the Light-House Board, was enabled to locate within ten degrees, or less than one compass point, the sound of a fog-signal, when in the cabin of a steamer at sea, 7 miles away, and that, too, after he had purposely deprived himself of a knowledge of even the direction of the shore by having the steamer turned in her course from time to time. President Morton describes it thus:

This apparatus consisted of the following parts: A vertical rod passing through the roof of the deck-cabin, on the upper end of which was attached a horizontal bar carrying two adjustable resonators. Below these was a pointer set at right angles with the above bar. Rubber tubes passed through the roof of the cabin and were connected with a pair of ear-tubes. A handle attached to the vertical rod served to turn it in any direction.

The principle upon which the operation of this apparatus depends was first announced by Professor Mayer in 1872 (see American Journal of Science and Art, November, 1872, p. 387), and its general operation may be explained as follows:

Let S of the diagram be the source of a sound, and let the circle represent a wave-surface produced by that sound. On this surface all the molecules of air have, at the same instant, the same direction and the same velocity of vibratory motion. If we can accurately determine two points, R and R′, on this wave-surface, and this wave-surface be a spherical one, that is, be not deformed, then a perpendicular, C S, erected to the center of a chord drawn between these two points, will, when produced, pass through the source S. The method consists in determining these two points on a sonorous wave-surface, as follows:



Let R and R′ be two resonators accurately tuned to the note given by the vibratory body at S. Suppose both resonators at the same instant on the wave-surface, then they both receive at the same instant the same phase of vibration on the planes of their mouths. If two tubes of equal length lead from the resonators and join into one tube just before they reach the ear E, then the sound-pulses will act together, being of the same phase, and the ear will receive double the action which it would if only one resonator were connected with the ear. But suppose that one of these tubes, T′, differs in length from the other tube, T, by one-half of a wave-length of the tone given out by S, then the same pulses will no longer work together at E, but will be opposed to each other in their action, neutralizing each other's dynamic effect, and producing silence at the ear E. This last condition is the one used in the apparatus above described.

We connect the two resonators, R and R′, by a rigid rod, and it is evident, if a pointer be placed at the center of this rod at right angles to its length, that when the resonators, R and R′, are on the wave-surface, the rod C S will point toward the source of sound at S. The rigid rod connecting the resonators R and R′, turns on a vertical rod passing through C. This arrangement was described by Professor Mayer before the National Academy in April, 1876.

While this contrivance may not yet be entirely practicable, its use, as detailed, makes the fact evident that some apparatus can be arranged by

* See Federal Reporter, October 28, 1884, p. 651.

which the aberration in the audition of the mariner may be so corrected that he can locate the source of the sound which is made to assure his safety, but which, misheard, may, as in the case of the *Edam* and *Lepanto*, insure his destruction.

It seems evident from President Morton's statements that if the fog-signals of the maritime world, or even of one country, or even those located in the approaches to one of our great harbors, were tuned to one note, and if the ships frequenting those waters were fitted with topophones, or some similar instrument, arranged so as to be in unison with the fog-signals, that aberrations in audition, at least as to direction, might be corrected so as to determine the location of sound to within at least one compass point.

Since the development of the topophone a number of other instruments have been invented for determining for the mariner the direction of sound made to warn him from danger. For some time some of our best ocean steamers have been supplied with an instrument giving sounds of wonderful pitch and intensity, called the siren. It was adapted from the instrument invented by Cagniard de la Tour, by A. and F. Brown, of the New York City Progress Works, under the guidance of Professor Henry, at the instance and for the use of the United States Light-House Establishment, which also adopted it for use as a fog-signal. The siren of the first class consists of a huge trumpet, somewhat of the size and shape used by Daboll, with a wide mouth and a narrow throat, and is sounded by driving compressed air or steam through a disk placed in its throat. In this disk are twelve radial slits; back of the fixed disk is a revolving plate containing as many similar openings. The plate is rotated 2,400 times each minute, and each revolution causes the escape and interruption of twelve jets of air or steam through the openings in the disk and rotating plate. In this way 28,800 vibrations are given during each minute that the machine is operated; and, as the vibrations are taken up by the trumpet an intense beam of sound is projected from it. The siren is operated under a pressure of 72 pounds of steam, and can be heard under favorable circumstances from 20 to 30 miles. "Its density, quality, pitch, and penetration render it dominant over such other noises after all other signal sounds have succumbed." It is made of various sizes or classes, the number of slits in its throat-disk diminishing with its size. This instrument is now used as a fog-signal by most maritime nations, they having frankly copied from and in some instances obtained it through the United States Light-House Establishment; and it has been recently adapted to the use of ocean steamers. But to make it thoroughly useful M. Edme Genglaire, a student of the Naval School of Medicine at Toulon, has combined with the siren what purports to be the leading idea of the topophone by fixing an invariable standard for comparison. The siren being in communication with the boiler, the current of steam can be governed by an ordinary valve. The sounds produced vary in pitch and intensity in proportion to the quantity of steam emitted, so that sounds of any given pitch can be obtained. A set of resonators completes the apparatus.

It is well known that two identical resonators vibrate together for the same sound and for that only. Starting with this principle, in two similar frames containing several resonators the corresponding resonators will vibrate or sound only when the note corresponding to them is produced.

The siren will produce these sounds causing vibrations in the resonators. and two distant ships, or a shore station and a ship, or two land stations, supplied with sirens of a similar model and identical frames of resonators, could most conveniently communicate. For this end each resonator should have attached to it an invariable signification, the same for all the frames.

All the naval and commercial vessels possessing sirens and a frame carrying the same number of resonators, each marked with a number having its signification, might be prepared to communicate with each other or with the shore.

This is the practical way of carrying the theory out as proposed by M. Genglaire: In front of each resonator will be placed two metallic reeds, one rigid, the other thin and producing extended oscillations with the least effort. Each of these pieces of steel communicates with one pole or battery by means of the circuit wire. When the resonator vibrates the thin reed oscillates, touches the other bar, and the two poles of the battery being connected, an electric bell rings, thus giving a signal, so that the call, whether from ship or shore, can be recognized, while the bell of the signaling-station by its sounds shows that the desired vibration or note has been produced. This account of Genglaire's siren is condensed from the account published in Électricité.

Colladon made a series of experiments * at Lake Geneva in 1826 to determine the velocity of sound in water. He had a bell weighing about 150 pounds suspended some 5 feet under water from the side of a boat, and struck by a hammer attached to the end of a lever. Stationed in another boat he listened for the bell-sounds, propagated beneath the surface, which were conveyed from the water by a cylindrical tube of tin some 9 feet long and 6 inches in diameter, one end of which terminated in an orifice for insertion in the ear, and the other was spread out somewhat in the form of a spoon, its opening being closed by a flat, elliptic plate of tin, about 2 square feet in area. By attaching a suitable weight to the lower end of the tube it was easily retained in a vertical position with about four-fifths of its length submerged, its flat plate being turned toward the boat carrying the bell. With this simple apparatus, Colladon was able to hear with perfect distinctness the blows of the hammer on the bell across the widest part of Lake Geneva, when the calculated distance between the two boats was not less than 8 miles.

The sounds heard by Colladon appeared as if they had been caused "by some metallic body striking the bottom of the tube," and they were "as distinct and brief at 13,000 meters as at 100 meters from the bell." One set of observations were made during a strong wind; the lake, which was at first calm, became violently agitated and it was necessary to keep the boat in position by means of several anchors, yet in spite of the noise of the waves which struck the tube he took other observations with the same accuracy as when the air and water were still. And he states, "I am convinced that by employing a bigger bell, and improving or enlarging the hearing apparatus, easy communication could be effected under the water of a lake or of the sea up to 15 or 20 leagues."

* "Memoirs of the Institute of France," vol. v, 1838, pp. 329-399; Sir John Herschel, "Sound," sections 94, 95; Journal of Science, vol. i, 1828, pp. 480, 481; Edinburgh New Philosophical Journal, vol. v, 1828, pp. 91-94.

In February, 1883, Prof. Lucien I. Blake,* now of the University of Kansas, but then in Berlin, while investigating the experiments of Colladon and also of Sturm, as to the velocity of sound through the waters of Lake Geneva, thought of making a practical use of water as a means of communication between vessels at sea. He then devised several methods, assisted by Dr. Konig, of the Physical Laboratory of the Royal University, which he tried on his return to this country, and he has been experimenting in that direction from time to time since that date as opportunity served.

His plan, in brief, was as follows: A sound-producing apparatus was to be attached to each vessel, and to be worked under the surface of the water. In times of fog or at night a code of signals would be produced by it which would be transmitted in all directions through the water with a velocity four to five times that in the air. Each vessel, in addition to the sound-producing apparatus, would be provided with a sound-receiving apparatus, which would take up out of the water the signals arriving from neighboring vessels. As boys in swimming communicate the sound of the striking of stones together under water, so is it possible to send musical tones from one ship to another.

For steam-ships the sound-producing apparatus was designed to be a steam fog-horn or whistle, specially constructed to sound under water, and to be heard at least from 6 to 8 miles. From the nature of its tone it would be easily distinguishable from other sounds always more or less present under water, such as from breakers, waves, etc. With such whistles a Morse alphabet of long and short blasts and pauses was to provide a means of extended communication, while a simple universal code would indicate a ship's course. Since ignorance of the very presence of a ship, rather than incorrect estimates of her course, has been the principal cause of ocean collisions, the simple hearing of the sound would prove a most excellent general safeguard. Bell-buoys were to have a second bell added under water, while light-ships, light-houses, and any headlands might also be provided with submerged bells which could be rung from the shore, when necessary. Sailing-craft, both large and small, would have bells; and, since an ordinary locomotive-bell can be heard, according to experiments, at least 2 miles under water, these simple means would seem to afford sufficient limits for protection for such vessels.

As to the receiving apparatus with which each vessel was to be provided, the original plan of 1883, and which has not been changed, was to employ some form of telephone acting as a transmitter under water and connected with a receiver within the vessel. The surface of the transmitter exposed to the water, and which must receive the sound-waves, should be protected against ice, barnacles, heavy waves, etc. One design was: One or more vertical pipes in different parts of a ship were to extend from the vessel's interior through the hull, near the keel, and be open to the free admission of water at their lower ends. Their upper ends were to extend within the vessel a little way above the keel, and were to be plugged, so that the water could not overflow into the vessel. These pipes would then provide columns of water always still and would com-

* Professor Blake read a paper on this subject before the American Association for the Advancement of Science at the meeting in New York in August, 1887, from which, with his kind permission, this abstract has been made.

municate directly with the water outside. Sound would then enter and pass up these pipes and would encounter microphonic transmitters placed suitably in them. Wires from the transmitters would run to a small room, secluded, where convenient, in the ship, away from disturbing noises, and here telephone receivers would be placed, and observers stationed here in night or fog.

For small craft it was found that a pipe shaped much like a powder-horn, with a thin, flexible membrane stretched tightly across its broad end, made a successful receiver. With the small end made to fit the ear and the diaphragm end only a few inches below the water the sound of a hand-bell has been received nearly a mile distant. Colladon and Sturm used a somewhat similar receiver and heard a heavy bell 10 miles away.

It was necessary to devise a better form of receiving apparatus. The Bell receiver and the Blake transmitter will not work under water. The first success was obtained by a form of transmitter resembling the Ader.

With this Professor Blake transmitted and received signals between boats half a mile apart on the Taunton River in 1883. The transmitter was weighted to float at different depths, but in all positions as regards the approaching sound-waves it received equally well. Up to half a mile the signals from an ordinary dinner-bell were distinctly heard. These experiments seemed to indicate that a transmitter dependent upon a variable contact might yet be made which would work with satisfaction. This line was consequently followed up, and apparatus was devised by which signals were transmitted between boats a mile distant off Stone Bridge, near Newport, R. I., in the same summer of 1883 through a rough sea and in a dense fog. Various forms of microphonic transmitters were constructed, and experiments on Long Island Sound and on the Wabash River at Terre Haute, Ind., were conducted as opportunity permitted. One form of transmitter which worked fairly well consists merely of a diaphragm having within itself the elements of a microphone. It is placed in simple voltaic circuit with a Bell receiver. This diaphragm is made of hard carbon in granules about the size of smallest shot. A paste is made of these with rubber cement, and this in a mold and die under heat and pressure becomes a hard, thin, elastic disk. This diaphragm takes up the sound-vibrations quite well out of the water. The action is similar to that of a multiple contact transmitter. On the river, however, through a long distance these did not seem sufficiently satisfactory. This difference in action between a long and short distance led to the thought that, as the advancing front of the sound-wave is an arc, approaching in curvature nearer and nearer the tangent to its circle, a large diaphragm would receive more sonorous energy and thus probably prove more effective. This is the point to which the experiments have now been carried, and the next trials will be with a diaphragm 18 inches square. In October, 1885, signals were transmitted and received 1½ miles on the Wabash River from a locomotive-bell around three or four windings of the river, so that the operators were out of each other's sight, and the sound could not be heard through the air, yet could be with fair distinctness through the telephone.

It is to be hoped that Professor Blake may find opportunity to continue his experiments, as he seems to be on the verge of producing a practical and accurate instrument of value to mariners.

Methods of using the Morse code of dots and dashes, as represented by long and short sounds of a fog-whistle or other similar contrivance, have been made public. The best one I have met is that of Mr. Frank Purinton, of Providence, R. I., and it is one of the best because it is the simplest. The idea is that, when two ships meet in fog and make known their proximity to each other by their fog-signals, each shall indicate to the other the way she is steering by the length and the intermission of the sounds made by her fog-signal. The following is the code in part, the long blast being represented by the [—] dash, the short one by the [-] dot:

CODE.

North	—	One dash.
Northeast	— — —	Three dashes.
East	— —	Two dashes.
Southeast	- — —	One dot and two dashes.
South	-	One dot.
Southwest	- - -	Three dots.
West	- -	Two dots.
Northwest	— - -	One dash and two dots.

The thirty-two points of the compass are represented by variations of the collocations of dots and dashes on the chart, and with long and short sounds with intervals, in practice. These signals can be given by the ordinary steam-whistle or by automatic apparatus already invented and in use. Mr. Purinton claims that his system will, if followed, prevent collisions. The four cardinal points of the compass are so represented that opposite courses have opposite signals. One long sound means north; a short one, south. Two long sounds mean east, and two short ones mean west. Other points of the compass are indicated by the synthesis or natural combination made by adding the necessary cardinal signals for the intermediate points or courses.

Another device, which may be called the echo-maker, that of Mr. De la Torre, has been examined by a board of naval officers, of which Commander Bainbridge Hoff, U. S. Navy, was the head, and report was made to the Navy Department of a somewhat favorable nature. It may consist of a flaring funnel screwed on the muzzle of a rifle. It is operated by firing the rifle in the direction of the supposed obstacle, such as a rock, an iceberg, another ship, or a cliff. If the obstacle is there, the beam of sound projected through the funnel strikes the obstacle and rebounds; and as the echo is more or less perfect in proportion as the obstacle is more or less parallel to the ship from which the gun is fired, and as it is near or remote, the position of the obstacle may thus be inferred. The board reported that De la Torre's method was firing a blank cartridge from a rifle in the presence of objects as small as a spar-buoy and as large as a fort, and catching the return sound or echo. He claims that a sharp sound projected at or nearly at an object, and only when so directed, will in every case return some of the sound sent, so that theoretically there will always be an echo, and the difference in the time between the sound sent and the echo will indicate the remoteness of the object. The board found that a return sound could be heard from the side of a fort a half mile off, from passing steamers a quarter mile off if broadside-to, from bluffs and sails of vessels about the same distance, and from spar-buoys 200 yards away.

The board further states that the sound from the different kinds of masses is different in most cases, and that the ear could be educated to detect quite a range of different objects, as the echo from a sail was different from the echo from a buoy or a bluff. If two objects were near the line of projection at different distances, an echo would be received from each. The horizontal limit of the return of sound seemed to be about two points on each side of the axis of projection.

If Mr. De la Torre should see fit to construct his instrument for hearing feeble echoes, the board indicated that it would recommend that it be fitted soon to some vessel of the North Atlantic Station, and that further and, if possible, exhaustive experiments ought to be made to practically determine the use of the echo as a means to discover obstacles to navigation. It was also stated that steam-whistles could be heard much farther than the echo; but it was said that where the obstacle could not make the sound, as in the case of an iceberg, the echo would be of the greatest use, and experiments looking to its utilization are demanded by the conditions of navigation in time of fog.

Steamers are constantly running among the islands on the coast of Maine during the summer. This is the season of thick and persistent fog. When pilots can hardly see the length of their vessels, they keep up a constant noise with their fog-signals. The open sea gives back no sound. But the near or remote vicinity of cliffs, bluffs, or even high shores, is indicated by the strength of the echo received back from them. In fact, running by echo is recognized as one of the neccessities of the navigation of those waters.

This method is also used to some extent by steamers on the great rivers; and it is practiced on the Great Lakes to some extent, notably at a certain bluff jutting out into Lake Superior. Passing steamers, knowing themselves to be in the vicinity, when befogged, feel out these bluffs by sounding their fog-signals until they get back an echo; then they use the bluffs as a new point of departure.

In this connection I may say that in the summer of 1886 I experimented in making echoes while on a light-house steamer on Long Island Sound, and found I could get a good echo by sounding the whistle of my steamer when passing a sailing-vessel, preferably a schooner, on a parallel course. Wave-sounds striking her sails at right angles to her course gave a good echo at 500 yards or less, and the sound of the echo was more or less good within that distance, in proportion to the angle made by the courses of the two vessels when their courses were not parallel. When off Block Island cliffs, which overhang somewhat, I got a good echo when about a mile distant. Hence I infer that the position of suspected dangers of certain kinds can be determined by the production of echoes under specified circumstances.

Recent papers state that Mr. H. B. Cox, an electrician, whose laboratory was at Fernbank, some 10 miles from Cincinnati, but who is now a resident of New Haven, Conn., has invented a trumpet to be used for telephoning at sea, on which he has been at work for some years. The invention is the outgrowth of his discovery of the great distance an echoed or reverberated sound will carry, and the discovery that speaking-trumpets, if made to give the same fundamental note, would vibrate and produce the phenomenon known in acoustics as "sympathy."

With this trumpet conversation in an ordinary tone of voice was carried on between parties 4¼ miles apart. People a mile away, conversing in an ordinary tone, could be distinctly heard, and in two instances they were told the nature of their conversation, and admitted that such had taken place. The whistle of a train was traced beyond Fernbank to Lawrenceburgh, Ind. It was found that the instrument has a well-defined range of 26 miles, that is, a loud sound like a locomotive-whistle or the rumbling of a train, can be distinctly heard at a distance of 13 miles in every direction. Conversation was readily carried on between two gentlemen on high hills on opposite sides of the Ohio River, distant about 4½ miles apart. Tests made on the water, of various kinds, showed that the trumpet was even more available than on land.

Mr. Cox has within the last year made experiments from steamers in the open ocean, and during heavy weather, getting good results. It is expected that he will exhibit and explain his instrument to the International Maritime Congress which is soon to meet in this city.

It is generally understood that Mr. Thomas A. Edison, the electrician, who has invented so many good things, is now at work, and has made promising progress, on the production of what may be called a water-telephone, by which he proposes to enable ships within hearing distance to communicate without wires, but still by electricity, sent and received through the water. He is said to have signaled through a mile of the Caloosahatchie River, in Florida, during his experiments.

The object of this paper is to call attention to the practical impossibility of the mariner determining, by his unassisted ears, in a fog or in darkness, the position of another ship from the noise she makes, and the necessity that he should use some of the appliances named, or better ones as they appear, to assist his ears, and thus to prevent the collisions which are now so frequent and so disastrous. The *Celtic* and *Britannic* steamers would not have run into each other had such appliances been used; nor would the steamer *City of Brussels* have been run down in the English Channel by the steamer *Kirby Hall* had they been thus supplied, to say nothing of the steamer *Oregon* sunk off Fire Island, and other like cases within easy recollection. These vessels carried no such appliances.

It is desirable that public opinion should be brought to bear on this subject with such force that ships shall be *required* to carry some appliance, so that an error of five compass-points in fixing a ship's position will no longer be possible, or, if possible, will be held to be criminal negligence.

It is also desirable that public opinion should be brought to bear on this subject with so much force that ships will be required to carry and use proper appliances for ascertaining the position and course of ships within ear-shot, as they are now required to carry lights for a like purpose.

And why should not Governments take some steps in this direction, that the dread all now feel of collision at sea, in the fog or the darkness, may in some measure be eliminated?

Chapter XI.

THE PERSONNEL OF THE UNITED STATES LIGHT-HOUSE ESTABLISHMENT—WHAT THEY DO AND HAVE DONE.

The first light-keeper in this country, of whose regular appointment there is authentic information, was George Worthylake, husbandman, aged forty-three years, who was made keeper of the light-house on Little Brewster Island, Boston Harbor, in 1716, at £50 per year, by the order of the general court of the Province of Massachusetts Bay; and it seems that the keepers of the other seven light-houses of ante-Revolutionary times were appointed in the same manner.

When the Federal Government had assumed charge of the Light-House Establishment the appointment of keepers was made by the President, and quite a number of the commissions bear the signature of George Washington, who took great interest in light-house affairs. One of the first official acts Washington, as President, performed, was to write to the keeper of Sandy Hook light, directing him to keep it burning until Congress had opportunity to provide for its continuance. Jefferson also took personal interest in light-house affairs, and in its personnel. There are hanging in the office of the Light-House Board, at Washington, several letters from Washington and Jefferson on light-house matters. Among them is a letter on which is the following indorsement:

> The above is accompanied by two other letters dated respectively May 30 and June 1, 1808, which strongly recommend Jared Hand's appointment (as keeper of Montauk Point light) to succeed his father, which were duly submitted to the President for his approval or rejection.

On the original letter the following indorsement appears:

> I have constantly refused to give in to this method of making offices hereditary. Whenever this one becomes actually vacant, the claims of Jared Hand may be considered with those of other competitors.
>
> Thomas Jefferson.

As their number increased the nominations of keepers were made by collectors of customs, who were the local superintendents of lights; but the appointments were made by the Secretary of the Treasury. That usage crystallized into law, and still obtains; but the nomination of the collector is forwarded to the Light-House Board, where it receives an indorsement, which procures for it favorable or adverse action. The appointment, however, is but temporary, and continues only until the candidate has been examined, after which, if he passes, a full appointment is given him; otherwise he is dropped from the service.

The appointment of light-house keepers is restricted to persons between the ages of eighteen and fifty, who can read, write, and keep accounts, are able to do the requisite manual labor, to pull and sail a boat, and have enough mechanical ability to make the necessary minor repairs about the premises, and keep them painted, whitewashed, and in order. After three months of service, the appointee is examined by an inspector, who, if he finds that he has the qualities needed at that especial station, certifies that fact to the Light-House Board, when, upon its approval, the full appointment is issued by the Treasury Department.

Although but one grade of keeper is recognized by law, usage has divided keepers into a number of grades, with different pay as well as different duties, and with promotion running through the various grades. At one light-house there may be but one keeper; at another, a principal keeper and an assistant; and there is a station where there is a principal keeper with four assistants, the fourth having the lowest grade and the lowest pay, and the others having been appointed at that grade, and promoted as merit was shown and vacancies occurred; or they may have been transferred and promoted from another station. Although persons are appointed to the service and assigned to a given station, they are frequently transferred from one station to another, as the interest of the service may demand, and while it is usual to consult a keeper's wishes in his assignment, there is nothing in the regulations to prevent the transfer of a man appointed in Maine to a station in Georgia; and occasionally keepers are, with their own consent, transferred from one district to another at a great distance. Young men who have seen some sea service are preferred as assistants at the larger stations; and at stations requiring but one keeper, retired sea captains or mates who have families are frequently selected. At those stations where there are fog-signals it is customary, however, to have one assistant who is able to operate its machinery and keep it in repair; and he is usually one who has a certificate as a steam engineer, and is something of a machinist. Such persons are graded and paid at a higher rate on their original entry in the service than others.

While there are numerous light-stations located on submarine sites, the greater number of lights have connected with them a little land, which the keepers are encouraged to cultivate. Hence small farms or gardens are often connected with stations, which are cultivated by the keepers' families.

Keepers are forbidden to engage in any business which can interfere with their presence at their stations, or with the proper and timely performance of their light-house duties; but it is no unusual thing to find a keeper working at his station as a shoe-maker, tailor, or in some similar capacity, and there are light-keepers who fill a neighboring pulpit, who hold commissions as justices of the peace, and there are still others who do duty as school teachers without neglecting their light-houses. As the dwellings of the light-keepers are often tastefully planned, well-built, and located on picturesque sites, people in search of summer quarters have so besought keepers for accommodation that the Board has been compelled to prohibit them from taking boarders under any circumstances.

The Board has done much to make keepers comfortable. They are furnished with quarters for themselves, and in certain cases for their families, and when so far distant from market as to make its carriage equal or exceed its cost, with fuel and rations. Suitable boats are furnished stations inaccessible by land; and at those stations on shore, distant from markets, barns are built for their cattle and horses. Something also has been done for the intellectual needs of the keepers and their families by supplying them with libraries. These are arranged in cases so constructed that they make rather a neat appearance when set upright on a table, and they only need be closed and locked to be ready for transportation. They contain on an average about fifty volumes each, of a proper admixture of historical, scientific, poetical, and good novels, together with a Bible and a prayer-book. One of these libraries is left at a station for some three months, when it is exchanged, and the first is passed on to another station. This is usually done when the inspector makes his quarterly inspection; so each of the stations to which libraries are furnished sees some two hundred different books each year. There are now five hundred and fifty of these libraries in circulation through this Establishment, and more are being prepared. In their distribution preference is given to those stations most distant from towns or villages. The Board has made no attempt as yet to pension those who become maimed or worn out in its service. Keepers are under the law paid an average sum of $600 a year; but the rates range in individual cases from $100 to $1,000 a year. In March, 1889, Congress appropriated $625,000 for the payment of its 1,150 keepers.

UNIFORMS FOR THE PERSONNEL OF THE UNITED STATES LIGHT-HOUSE ESTABLISHMENT.

In 1883 the Board prescribed dress and fatigue uniforms for its keepers, and required them to wear one or the other on all proper occasions. A suit of each, including hats, was presented to each keeper then in the service. The measure of each man was taken, and his uniforms were made to fit him. The Board, however, failed to prescribe or furnish uniforms for the female light-keepers in its employ. Although the first suits were furnished each keeper, they were required to procure all subsequent suits at their own expense. And all keepers coming into the service after that date had to furnish themselves with uniforms.

The following is a description of the kind of suits prescribed, with their insignia and cost as supplied by the contractors. Keepers, however, can obtain their uniforms where they please, provided they come up the to required standard.

On May 1, 1884, the following regulation went into effect:

The uniform for male keepers and assistant keepers of light-stations, and the masters, mates, engineers, and assistant engineers of light vessels and tenders, will consist of coat, vest, trousers, and a cap or helmet. The coat will be a double-breasted sack, with five large regulation buttons on each side—the top buttons placed close to the collar, the lower ones about 6 inches from the bottom, and the others at equal spaces between the top and lower buttons. It will be of the length of the extended arm and hand, and will be provided with two inside breast pockets and two outside hip pockets, the latter to have flaps so arranged as to be worn inside the pocket if desired. Each sleeve will have two small buttons on the cuff-seam.

The vest will be single-breasted, without a collar, and cut so as to show about 6 inches of the shirt. It will have three pockets and five small regulation buttons.

The trousers will be cut in the prevailing style.

All of the above will be made of suitable dark indigo-blue kersey or flannel.

The cap will be made of dark-blue cloth, with a cloth-covered visor and an adjustable chin-strap of cloth held by yellow-metal regulation buttons. A yellow-metal light-house badge will be worn in the middle of the front of the cap. Masters of tenders will wear a gold-lace chin-strap instead of one of cloth.

During the summer months in northern latitudes and during the entire year in southern latitudes, there may be worn canvas helmets of authorized shape and color, with the prescribed buttons and the yellow-metal light-house badge in the middle of the front.

All masters and mates of vessels are directed to wear the prescribed uniform at all times when on duty, and all engineers and assistant engineers at all times, except when at work in the engine-rooms, when they may wear the prescribed working-suit.

Keepers and assistant keepers of light-stations will wear the prescribed uniform at all times, except that the coat will be taken off and the regulation apron worn when at work cleaning, and the prescribed brown working-suit will be worn when at ordinary out-door work.

The crews of light-vessels and tenders will wear dark, indigo-blue kersey or flannel trousers, and dark, indigo-blue guernsey shirts. The cap for the crew will be of dark, indigo-blue cloth, of authorized shape, with cloth visor, and a ribbon marked "Light-House Service" in front. During the summer months in northern latitudes and during the entire year in southern latitudes, brown linen caps of the same pattern may be worn, but all of the crew of each vessel shall wear the same kind of cap.

This uniform will be worn by the crew at all times, except when working, when the prescribed working-suit will be worn.

Those holding acting appointments, those employed temporarily, and substitutes will not be allowed to wear the uniform.

The Board assumed the cost of the first clothing for the employés then in the service; all succeeding renewals were at the expense of the employé. In order that an equivalent of service might be rendered for the articles thus supplied, it was provided that if an employé should leave the service within one year after uniform was issued to him the value of the clothing should be deducted from any salary then due him. Any further articles of clothing required could be obtained of the manufacturers at the following prices:

Kersey coats............each..	$9.75	Masters' chin-straps..each..	$0.75
Kersey vests ....do...	2.75	Linen helmets, with badge, each	1.75
Kersey trousers...........do...	5.50	Cloth caps, with ribbon (crew) each...	1.50
Flannel coats ....do...	7.00	Brown linen caps (crew), each	.75
Flannel vests ....do...	2.25	Collar ornaments ....each..	1.00 to 1.25
Flannel trousers..........do...	4.50	Coat-buttons ......per doz..	.50
Blue woolen working trousers (crew) ....each..	3.75	Vest-buttons ....do....	.25
Guernsey shirts ....do...	1.75	Button-fasteners .....do....	.25
Canvas working suits ...do...	1.25		
Cloth caps, with badge (officers, keepers, and assistant keepers) ....each..	2.00		

Blank forms for measurement were furnished by the inspectors of the several light-house districts, through whom the articles were ordered.

Any persons thereafter entering the Service were required to furnish their own uniform. In nominating persons for appointment, superintendents of lights informed them of the conditions under which they entered the service.

Some few changes, suggested by experience, have been made in the uniform, especially in the head-gear. Now the whole force is in uniform, and it is found that it adds much to the appearance of the *personnel*, and does much to raise the *esprit du corps*, and to preserve its discipline.

The discipline of the Service is somewhat rigid and severe, and has been from the beginning. On December 31, 1806, Mr. Gallatin, then Secretary of the Treasury, placed the following indorsement on a letter:

The part which relates to the conduct of the keeper of Cape Henry light-house is submitted to the President for his decision.

It was returned indorsed:

"I think the keepers of light-houses should be dismissed for small degrees of remissness, because of the calamities which even these produce, and that the opinion of the collector in this case is of sufficient authority for the removal of the present keeper.

"TH. JEFFERSON."

Now the class of men from whom keepers are selected is so good that the punishment of dismissal is infrequently inflicted. But it follows swiftly in two cases. A keeper found intoxicated is not only summarily dismissed the service, but he is instantly ejected from the station; and a keeper who allows his light to go out is dismissed without regard to his excuse or his previous good conduct.

The Board considers it the duty of every light-keeper to stand by his light as long as the light-house stands, and that for him to desert it when in danger is as cowardly as for a soldier to leave his guns on the advance of an enemy.

His failure to keep his light burning, especially in time of danger, may cause the wreck of vessels looking for it, and result in the loss of much property and many lives.

Keepers are trained to consider the care of the light and the light-house property their paramount duty, beyond any personal consideration; and the *esprit du corps* is such that instances have happened where the keepers on duty have, as in the case of the first light on Minot's Ledge, gone down with their light-house and died at their post; others, where the keeper has saved his lens, letting his family shift for themselves; and there are repeated instances where the keeper has saved his light-house property and lost his own. An instance of heroism is that of the keepers of Sharp's Island light-house, in Chesapeake Bay. It was lifted from its foundation, thrown over on its side, and carried away by ice early in February, 1881. The keeper and his assistant clung to the fallen house, and, although one of their boats remained uninjured, they were adrift in the bay sixteen and a half hours without fire or food, always in imminent danger, as the heavy floating ice often piled up against and threatened to swamp the house. It grounded, however, on an island shortly after midnight, at high tide, and was full of water. Being satisfied that it would not float off again, the two keepers went ashore in their boat, and when the tide had fallen they returned, saved and took to the shore the lens, its pedestal, the oil, the library, much damaged by water, and even the empty oil-cans, and then reported the facts through their inspector to the Board. Meantime the keepers of another light-house, fearing the ice, had deserted their post, and gone on shore. The fact that no vessels could have needed their light while the ice remained unbroken, and that they returned to their post when the danger had passed did not avail them. So soon as the fact of their desertion was determined they were dismissed the service, and the two keepers who had spent those terrible hours afloat in Sharp's Island light-house, and then had saved its apparatus, were highly complimented by a letter direct from the Board itself, and then were appointed to the deserters' places.

LIGHT-HOUSE INSPECTORS.

The light-house inspector is an officer of the Navy, the detail being changed, as a rule, every three years. It is now considered that the time an officer spends on light-house duty goes to make up his education and to contribute to his efficiency. Hence this duty is sought in times of peace by ambitious young officers of judgment, tact, and habits of study who can do the Light-House Establishment good service The sixteen inspectors now on duty are all officers of the Navy; one a captain, nine are commanders, four are lieutenant-commanders, and two are lieutenants. They serve without any other than their naval shore-duty pay. It is the duty of an inspector to attend, under the directions of the Board, to supplying the lights of their respective districts; to maintain its buoyage; to keep up the discipline of the light-keepers; to inspect the light-stations, light-ships, and light-tenders, and all the light-house people and property in his district each quarter; to attend to the examination, promotion, and transfer of the keepers; to answer the calls made on him by the Board for special information as to the needs of commerce at specified points; to make the numerous reports to the Board on blanks provided for that purpose; to act as purchasing and disbursing officer, and to pay each keeper his salary each quarter.

He is a disbursing officer, and is responsible for very large sums of money. No pecuniary bond is required of him, as his commission is at stake for the proper performance of his duty. The confidence of the Government is not misplaced, for it has never lost a cent intrusted to any of these officers.

LIGHT-HOUSE ENGINEERS.

There is no specified time for which an officer of the Corps of Engineers shall serve as a light-house engineer, as he often has at the same time charge of fortification or harbor engineering works. His light-house duties are to prepare plans and specifications for light-house structures, and submit them to the Board; to purchase the material, arrange for the labor, and take charge of their erection or repair; to set up and keep in repair the illuminating apparatus of each light-station in his district, and to purchase and care for the real estate, light-house sites, etc., of the Establishment in his district. He reports to the Board, when requested, as to the necessity and cost of establishing new aids to navigation. The coasts of the country show with what success the engineers have grappled with the problems of light-house engineering, not only on land but on submarine foundations.

He is required to disburse large sums of money for purposes of construction and repair, but no bond is reauired of him, for the same reason as is given in case of the inspector, ana with the same good reason.

The duties of the Inspectors and the Engineers are not only difficult but are often dangerous. Two Inspectors recently lost their lives while on duty, Lieutenant-Commander Wright by yellow fever, and Commander McDougal by drowning, and General Babcock was also drowned while trying to land at the site of a light-house which was being built under his charge.

HOW THE ESTABLISHMENT OF A LIGHT-HOUSE IS DETERMINED.

It is not only the duty of the Board to build light-houses when authorized by Congress, but it is customary for the Board to give Congress the existing reasons for refusing appropriations for building unnecessary light-houses. Each light-house is established by Congressional enactment. A petition from those interested, usually ship-owners and ship-masters, is presented by the Representative in Congress in whose Congressional district it is proposed that the light-house should be located. The House of Representatives or Senate refers the petition to its Committee on Commerce, which asks the opinion of the Secretary of the Treasury on the matter. He refers the question to the Light-House Board, which in turn calls on the inspector and engineer of the proper light-house district to examine and report on the necessity, practicability, and cost of the proposed structure. Their reports, with such other information on the subject as the Board may have at hand, is referred to its own committee on location, when a formal report and recommendation is made to the Board, which report is transmitted to the Secretary of the Treasury, who in turn sends both his own opinion and the Board's recommendation to the committee of the Senate or lower House, asking the information, and on the report of that committee, if it is favorable, is based the report of the Committee on Appropriations and the action of Congress. But frequently the reports are unfavorable, and it has happened that the Board has been interpellated on the same matter by several successive Congresses, and has been required to build the light-house it has reported was not needed.

The Board often received from those interested statements bearing on a case intended to affect favorably its report as to the need for a proposed light-house. Thus the Board often weighs rather than finds evidence, and supplements rather than institutes investigation.

THE CONNECTION OF THE LIGHT-HOUSE BOARD WITH THE TREASURY DEPARTMENT.

The Board has been called on several times to show cause why it should not be transferred from the Treasury to some other department. It has already made report against its transfer to the Navy Department and to the War Department. A bill once came before Congress providing for its transfer to the Interior Department, and the Forty-third Congress rejected a bill providing for abolishing the Board and placing the Establishment again under the charge of a superintendent.

But Congress has constantly held that as the Light-House Establishment was primarily for the benefit of commerce, and as commerce is under the charge of the Treasury Department, that the lights should also remain under the same Department. The fact that engineer officers of the Army are detailed to build light-houses and keep them in repair, and that naval officers are assigned to the charge of maintenance of the lights and to keep up the proper discipline of the personnel of the Establishment, has not been regarded as a good reason for placing the Service under the charge of either the War or Navy Department. Indeed, it has been found that while there is some friction when officers of the Navy serve under the Secretary of War and when Army officers serve under the Secretary of the Navy, there is less, if any, when they serve under the head of another department. The officers of both Army and Navy serve thus together under the Treasury Department with harmony and without difficulty as to precedence of rank. The system works well, and there is little likelihood of any change.

The United States Light-House Board has its own drafting room, where it prepares the plans and specifications of many of its more difficult light-houses and light-ships, and where it examines and revises, if need be, the plans submitted by its engineers.

The Board has had the honor to receive officers sent from several of the nations represented in this Congress, as well as the officers of countries from over the sea, and to furnish them with such of its plans of light-houses and light-ships, fog-signals and other aids to navigation as they desired. Mexico, Brazil, and Chili have availed themselves of these opportunities, as well as have France and England.

There are 9,959 nautical miles of lighted coast on the ocean, gulf, bay, sound, lake, and river shores, not counting the Ohio, Mississippi, and Missouri Rivers, which are lighted on a different and cheaper plan. The sums actually expended in lighting and buoying these 9,959 miles of coast during the year ending June 30, 1879, amounted to $1,708,700. And in this sum the $97,000 expended in maintaining the fifty-four fog-signals operated that year are not included. Hence the cost of lighting and buoying the United States coast was for that year $171.57 per nautical mile. That year, 1879, is taken, as it gives an opportunity for comparing the cost of maintaining the Light-House Establishment of the United States with that of France.

M. Allard, inspecteur-général des Ponts et Chaussées, the managing head of the French light-house establishment, gives, in the "Annales des Ponts et Chaussées" for October, 1880, some statements from which it appears that there are 1,150 nautical miles of coast lighted and buoyed by the French Bureau des Phares, at a cost during 1879 for maintenance of 1,790,000 francs, or of 1,155 francs per nautical mile. Taking the franc at 5.20 to the dollar, it seems that it cost France $222.11 to the mile, while it cost the United States $171.57 per mile.

But then France had that year twenty-five light-houses and fifty-three buoys to the 100 miles of coast, while the United States had in that year but nine light-houses and forty-two buoys per 100 miles of coast. Then, again, France had but four fog-signals, while the United States had fifty-four, and France had no river lights worth mentioning, according to M. Allard, while the United States maintained 737 during that year.

The average sum paid for maintaining an average light station of each class was during the year ending June 30, 1889:

For a first-order light-station	$3,842.00
For a second-order light-station	2,711.12
For a third-order light-station	1,568.77
For a fourth-order light-station	1,107.83
For a fifth-order light-station	635.05
For a sixth-order light-station	552.17
For an outside light-ship of recent build	7,078.28
For an inside light-ship of old build	3,546.32
For an average fog-signal operated by steam or hot air	2,260.59
For a steam-tender of recent build	15,126.83

The appropriations made by act of March 2, 1889, for the maintenance of the United States Light-House Establishment for the year ending June 30, 1890, amounted to $3,503,994.12, of which $1,286,294.12 was appropriated for new works or for finishing those previously commenced and not then finished.

A question having arisen as to the length of our coast line, the Board on August 13, 1889, asked the Coast and Geodetic Survey to furnish it with a statement of the length, in statute miles, of the general sea-coast of the Atlantic, Gulf, Pacific, and Alaskan waters, and also the coast line in statute miles of the same coasts, including islands, bays, rivers, etc., to the head of tide-water. On August 15, 1889, the Coast and Geodetic Survey replied, sending the following statement:

General sea-coast of the United States.

	Stat. miles.
Atlantic Ocean	2,043
Gulf of Mexico	1,852
Pacific Ocean	1,810
Alaska	4,750

Including islands, bays, rivers, etc., to the head of tide-water:

	Stat. miles.
Atlantic Ocean	36,516
Gulf of Mexico	19,143
Pacific Ocean	8,900
Alaska	26,376

This mileage does not include the more than 3,000 miles of the lake coasts nor the nearly 5,000 miles of rivers which are lighted, but it does include the Alaskan coasts which are not lighted.

In the office of the Light-House Board at Washington are preserved, bound in some 800 volumes of from five hundred to one thousand pages each, the letters it has received, and in as many more volumes the copies of letters it has written. In those received is recorded the results of the experience of the Light-House Establishment. The Board has made that available by a peculiar subject-card index. It is contained in 6 cases, each of which has 32 drawers, in each of which is an average of 2,100 cards, all containing something over over 400,000 cards. In addition to this subject-index, which of course has many cross-entries and therefore many duplicates, it has a chronological personal index of the same matter running through some 34 volumes, in which there are, say, about 300,000 entries. The Board thus has access to the wealth of material contained in this library of correspondence on the techniques of its art, which otherwise would be buried in its own bulk.

Aids to navigation maintained by the United States Light-House Establishment on June 30, 1888.

Aids.	First district.	Second district.	Third district.	Fourth district.	Fifth district.	Sixth district.	Seventh district.	Eighth district.	Ninth district.	Tenth district.	Eleventh district.	Twelfth district.	Thirteenth district.	Fourteenth district.	Fifteenth district.	Sixteenth district.	Atlantic and Gulf coasts.	Pacific coast.	Lake coast.	Western rivers.	Total for entire coast 1888.	Total for entire coast 1887.	Increase.
Electric lights	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	1	1	......
First-order lights	2	4	6	5	6	6	9	2	......	......	......	7	5	......	......	......	40	12	......	......	52	51	1
Second-order lights	9	3	1	......	......	1	......	4	1	......	2	1	......	......	......	......	18	1	3	......	22	20	2
Third-order lights	4	1	5	3	......	4	5	3	8	6	8	3	1	......	......	......	25	4	22	......	51	52	—1
Three-and-a-half order lights	......	2	1	......	......	......	......	......	3	1	4	......	......	......	......	......	3	......	8	......	11	11	......
Fourth-order lights	19	23	33	13	32	8	6	14	26	23	25	9	7	......	......	......	145	16	77	......	238	235	3
Fifth-order lights	20	15	17	8	23	6	......	14	12	6	15	2	2	......	......	......	100	4	36	......	140	139	1
Sixth-order lights	1	6	32	3	14	6	1	2	19	20	13	......	......	......	......	......	57	......	60	......	117	124	—7
Lens lanterns	......	1	47	10	18	40	......	17	1	2	12	......	49	......	......	......	128	49	20	......	197	78	119
Range-lenses	......	......	6	8	2	......	......	......	......	......	......	......	......	......	......	......	16	......	......	......	16	17	—1
Reflectors	......	10	......	8	4	16	......	2	......	8	......	......	......	......	......	......	40	......	8	......	48	46	2
Lanterns	1	......	17	......	......	46	9	......	......	2	......	......	......	512	385	335	58	......	17	1,232	1,307	1,282	75
Light-vessels in position	......	8	7	4	1	3	......	2	......	......	1	......	......	......	......	......	25	......	1	......	26	24	2
Lighted buoys	......	1	......	......	1	2	......	......	......	......	......	......	......	......	......	......	4	......	......	......	4	4	......
Total lighted aids	56	74	173	62	101	138	30	60	70	68	80	22	64	512	385	335	660	86	252	1,232	2,230	2,034	196
Fog-signals operated by steam or hot air	10	7	11	5	2	......	......	2	10	1	14	12	6	......	......	......	37	18	25	......	80	77	3
Fog-signals operated by clock-work	13	8	39	8	56	3	......	6	4	5	4	4	2	......	......	......	133	6	13	......	152	140	12
Day-beacons	96	61	42	2	13	27	42	20	......	......	1	47	35	......	......	......	303	82	1	......	386	361	25
Whistling-buoys	9	8	5	4	1	5	2	3	......	......	......	7	3	......	......	......	37	10	......	......	47	44	3
Bell-buoys	14	9	9	4	2	12	4	1	......	......	1	3	1	......	......	......	55	4	1	......	60	51	9
Other buoys	533	480	526	169	1,124	267	201	84	50	168	139	58	172	......	......	......	3,384	230	357	......	3,971	3,791	180
Total unlighted aids	675	573	632	192	1,198	314	249	116	64	174	159	131	319	......	......	......	3,949	350	397	......	4,696	4,464	232
Total number of aids	731	647	805	254	1,299	452	279	176	134	242	239	153	283	512	385	335	4,609	436	649	1,232	6,926	6,498	428

Chapter XII.

LIGHT DUES.

The heavy tax laid on American commerce by Great Britain in the way of light dues has provoked American merchants into taking steps for retaliation. Hence the Light-House Board has several times been called on to show cause why light dues should not be charged upon British shipping coming into American ports, and also why the Light-House Establishment should not be made self-supporting by charging light dues against our own commerce. It has uniformly responded that light should be as free as air, that its work was done not only in the interests of commerce, but for the sake of science and humanity, and that it should be supported from the national treasury as is the Army, the Navy, or as is the Coast Survey or Life-Saving Service.

It appears that light-houses were first erected in Great Britain by private parties for personal purposes. Then lights were erected at the instance of cities and for local purposes; finally in the same interests, and by similar methods, coast lights were established. They were all, however, in due time recognized by the Government, and as a rule, those who erected them were authorized to exact toll from passing vessels as a repayment for their expenditures. Then certain lights were built at the expense of the Crown. Thus there grew up a complex system, operating differently in the various parts of the kingdom, and subject to constant change. The one fact, however, remains that each vessel must pay toll to each light it passes, or might pass, in making or leaving a British port.

Parliament, recognizing this anomalous condition, from time to time passed acts under which most of the private lights were brought under public control. It was in 1836, however, that what may be styled the organic act of the light-house establishment of Great Britain was passed. It made provisions for bringing all the light-houses of England and Wales under the direction of the Trinity House Corporation, for giving it certain control over the Irish and Scotch lights, and for placing the building of future lights under its orders. And by the same act it transferred the crown lights to the Trinity House Corporation, as the British light-house establishment is called, and empowered that body to buy up all the light-houses belonging to private individuals. It also gave to the Trinity House the power to collect light dues through the custom-houses, but required it to account to the owners of the private lights for their share of the light dues.

These dues differ with the importance of the lights, the size of the passing vessels, and the kind and quantity of their cargo. It does not appear, however, that there is any discrimination made as to nationality. British vessels pay equally with American.

The rates paid by each vessel for each light vary from six-tenths of a penny to a penny per ton. But in addition to the tonnage tax is a certain other tax levied on each keel, and in case of certain Irish lights a separate tax of 3 shillings is "levied on every entry, cocket, or warrant for goods, inward or outward bound," with again certain other exceptions. But empty vessels, or vessels in ballast, as a rule, are nearly exempted from light dues.

The regulations under which the light dues are levied, collected, and paid may, however, be changed at will by the Trinity House in every respect, including place and time of payment, as well as rate. So it can hardly be said that any settled system of rates prevails. The Board of Trade, to which the Trinity House attorns, occasionally re-adjusts the rates, even at this time. The changes, however, have generally taken the nature of reduction and the form of abatement. Several years ago there was an abatement of 60 per cent. ordered; now, however, the abatement on the light dues is but 55 per cent.

A full statement of the light dues levied, collected, and paid may be found in a Blue Book of some three hundred pages, made up of tabular statements, already so consolidated that further intelligible consolidation seems impracticable. It is entitled "Consolidated table of duties for lights, buoys, and beacons in Great Britain and Ireland, chargeable on oversea and coasting vessels, prepared under the direction of the Corporation of Trinity House, London, with the assistance of the light-house boards of Edinburgh and Dublin."

It is difficult, if not impossible, to determine, except from experience, what a given ship must pay as light dues for a given voyage, as the rates are calculated upon, not only the lights she actually must pass in the course she does take, but those lights she might pass if she followed the sinuosities of the coast. This is governed by the rules made by the Board of Trade and enforced through the Trinity House; for instance, at this time vessels going from Portland, Me., to Liverpool pay light dues to Cape Race light, though they may not pass within several hundred miles of it.

Payment of light dues is made to and enforced by the customs officers, and they are a lien on ship and cargo. They usually appear in the bill of port charges.

The light dues actually paid by American shipping differ as to the ports they enter, since by that means it is ascertained to what lights they must make payment.

How much has been paid by American ships as light dues to Great Britain it is hard to say. Mr. Abbott Lawrence, then minister to England, in his discussion with Lord Palmerston in 1851, stated that in the previous year the light dues collected by Great Britain amounted to between £400,000 and £500,000, and that the United States had paid one-fourteenth of all. This would make our payment, say, $160,000 for that year.

I have been unable to find any tabulated statistics showing the amount paid by American shipping as light dues. But, as an instance, it may be said that the American Steam-ship Line of Philadelphia paid as light dues on its four steamers during 1875, 1876, and 1877 $36,000, being at the rate of $250 per voyage for each of the one hundred and forty-six voyages made by them. But the amount paid directly as light dues is only a small proportion of what has been paid indirectly. This fact is thoroughly recognized by the British Government, and was well formulated by Sir

Robert Lowe, in the winter of 1871–'72, in his reply as chancellor of the exchequer to a deputation of British ship-owners, who urged the assumption of light dues by the treasury, when he said "that the ship-owners do not pay the light dues, but that they ultimately fall on the consumers, in consequence of the proportionate increase in rates of freight;" and on that ground Sir Robert declined to recommend that the Government take any action in the matter. Hence, it may be safely assumed that the United States pays the light dues on all it sends to and receives from Great Britain, whether carried in American or foreign bottoms.

The question of the abolishment of light dues is not a new one, nor is it confined to one country. The English themselves are very restive under their collection. In 1822 it was considered in connection with other questions relating to shipping interests by a parliamentary committee; and it was discussed again in 1834, then in 1845, and still again in 1860. In 1858 an inquiry was made on the subject by a royal commission, which reported in 1861. Each of the select committees and the royal commission reported in effect "that the levying of light dues was unjust in principle." The select committee of 1860 approved "the sound and liberal policy" recommended by the committee of 1845, "that the nation generally should pay the cost of maintenance of lights," and the select committee of 1845 took much evidence, which was printed August 1, 1845, with a voluminous report, holding the following language:

Your committee are of opinion that the relief to the shipping, the benefit to the coasting trade, and the advantage to the naval service by taking off light dues altogether from commercial shipping, and paying the expense of maintenance from the Treasury would be great, and is most desirable to be effected.

On December 31, 1850, the minister from the United States at the Court of St. James, Mr. Abbot Lawrence, as authorized by the Secretary of State, Mr. Webster, addressed Lord Palmerston, principal Secretary of State for Foreign Affairs, on the subject of abolishing the light dues charged American vessels. The dispatch discusses the subject with such cogency and enforces the demand with such facts that Lord Palmerston in his reply of February 6, 1851, did not attempt to refute the argument or deny the facts, but contented himself with replying that in many cases the power to levy light dues had become a vested right which could not be readily extinguished, and that "Her Majesty's Government have no right or power to order these corporate bodies to abstain from levying these duties."

The discussion was closed for the time being by the report of Mr. Lawrence to his Government that—

The application was not successful, but at the same time it was not met by a positive refusal; and I am not without hope, since other foreign powers, as well as British ship-owners, are united with us, that at an early day a way will be found for effecting this reform.

Lord Palmerston, it appears from the language he used in debate in Parliament on the subject some years after, changed his views somewhat, for he is quoted as saying "he thought the nation ought to pay the expense of lighting the coast."

The plea of Lord Palmerston that "the power to levy light dues had in many cases become a vested right, and could not be readily extinguished," can hardly be used now, as the Trinity House has, by the power vested in it by the act of 1836, before referred to, the power to buy up all the light-houses belonging to private individuals, and these individuals are compelled, under the act, to sell at prices to be fixed by arbitration. And it further appears that the Trinity House, in the six years succeeding the passage of the act, actually paid out £1,250,000 for this purpose; but it does not appear that the Trinity House continued to exercise its power, and it may be that many light-houses are yet owned by private parties.

It has been suggested that the English light dues charged against American ships may be extinguished by purchase. While no opinion is expressed as to the propriety of this course, it is submitted that the following precedents seem to bear on the subject.

Under the treaty of Washington, of April 11, 1857, it was agreed that $393,011 be paid to Denmark to extinguish what were known as the Sound dues.

Under the treaty of Berlin, of 1868, it was agreed that about $36,000 should be paid to Hanover to extinguish what were known as the State dues, heretofore levied on our trade on the Elbe River.

Under the treaty with Belgium, made at Brussels July 20, 1863, it was agreed that the United States should participate in the benefits of the treaty made on the 19th of April, 1839, between the King of the Belgians and the King of the Netherlands, by which it was agreed that $550,000 should be paid to the King of the Netherlands, in annual installments, in return for the extinguishment of the Scheldt dues. Of this sum the United States agreed to pay its proper share; and, doubtless, the payment to Belgium of $61,584, mentioned in the disbursement for 1872 for the extinguishment of the Scheldt dues, closes the account.

While the dues thus extinguished were of various kinds, light dues in each case entered into them as one of their items, and the governments to which the dues were paid, bound themselves by the treaties requiring their payment, to keep the lights and aids to navigation in good order perpetually thereafter.

It has been suggested that retaliatory steps should be taken, and that each country should charge light dues against British shipping so long as Great Britian makes this charge against the shipping of other countries. It is hoped that no such backward steps will be taken by the nations represented in this Congress.

The stand was taken in the early days, that civilization required that the United States should by her Light House Establishment, her harbor improvements, her Coast Survey, and her Life-Saving Service, do what she could, as a duty to humanity at large, to ensure safety to those who sought her shores. No reason is seen for changing the policy at this day.

When Mr. Lawrence, in 1851, approached Her Majesty's Government as to the abolishment of light dues, he stated that there were "more than three hundred light-houses, with a proportionate number of floating lights, buoys, etc., which are given to the use of the world by the United States without tax or charge." Now, the United States maintains some seven hundred light-houses, two hundred and thirty-eight fog-signals, three hundred and eighty-eight day-beacons, and some forty-three hundred buoys on its 64,000 miles of coast line (including bays, islands, and rivers), besides its two hundred and fifty lights on the Great lakes and its thirteen hundred lights on the Western rivers; and the countries to the south of the United States maintain some one hundred and eighty-nine light-houses, and other aids to navigation in proportion.

It is therefore suggested that this International Congress take the proper steps to urge each country represented in its deliberations to consider the propriety of taking the necessary measures to make and keep its lights free to the commerce of the world.

In Great Britain, prior to 1836, the charge was from one-sixth of a penny per ton to 1 penny per ton, on all ships at each time of passing a light, but by the act of that date a uniform charge of half a penny per ton was laid, except ships passing Bell Rock light-house, which are charged double that rate. The light dues are collected by the customs officers.

The United States charges shipping no light dues.

France charges shipping no light dues.

Spain charges shipping no light dues.

Denmark charges shipping no light dues, except at Bandholm, where 24 skillings per ton loaded and 4 skillings in ballast are charged. At Thisted 1½ skillings inward and outward are charged as buoy-money. One skilling is equal to three-fourths of a cent United States currency.

Belgium charges our shipping entering its ports no light dues. Belgium has light dues, but United States shipping is exempted from them under reciprocal treaty regulations.

Austria levies a tax, which is collected by the deputies of the exchange at Trieste. The charge for vessels of from 50 to 100 tons is 1 kreuzer per ton; for vessels over 100 tons, 1¾ kreuzer. One hundred kreuzers are equal to 48 cents in gold, or 33.6 cents in silver.

In Mexico foreign vessels pay light-house duty for entering and departing from each port where there is a light-house, $25. Steamers pay, when they bring merchandise, a light-house duty, where there is a light-house, of $100, and for sailing, after discharging, a light-house duty of $100. Sailing vessels, coming loaded with stone coal, pay only light-house duty where there is a light-house. Passing vessels carrying dye-woods and other national products to one or more ports of the republic are exempt from the payment of light-house dues. These dues are collected by the custom-houses.

Honduras charges 12½ cents per ton, register.

Guatemala apparently charges no light dues; if so, they are embraced in anchorage dues collected through the customs.

Nicaragua charges a half real per ton, register. But under a treaty, vessels of the most favored nations are exempted.

Costa Rica charges a half real, or 6 cents, per ton.

The United States of Colombia charges light dues of 5 cents per registered ton for the first 100 tons, and 2½ cents for each ton in excess of 100.

Venezuela charges light dues of 6 cents per ton at La Guayra, although there are no light-houses near the port.

In British Guiana there are apparently no light dues.

French Guiana charges 20 centimes per ton.

Dutch Guiana charges a light fee of $10.

Brazil charges vessels entering its ports light dues of 100 reis or 5½ cents per ton. Light and anchorage dues are not levied on vessels putting into port, or on vessels bringing one hundred colonists. These dues can not be collected in all the ports of Brazil over six times in one year.

Uruguay charges light dues of 4 cents per ton on every vessel coming from, or proceeding to, places outside the Capes.

Argentine charges light dues of 8 cents per ton, register. "Ocean vessels pay light and port dues at the first custom-house of the republic at which they touch, and, should they enter the rivers, bound for a riveraine state port, without touching at a national (Argentine) custom-house, they will, in that case, pay these dues at the Argentine consulates established in such ports, and the cousuls, with a view to carrying out this law, will take what measures may be necessary."

Chili charges light dues of 10 cents per register ton, incurred only by vessels with cargo, and payable on discharge of the same. Should the quantity discharged not exceed 25 packages, or 25 tons of cargo in bulk, tnen the only exaction is 25 cents per package or ton.

Peru charges at Callao 1¼ cents per register ton every time a ship enters a port.

Ecuador: At Guayaquil the dues are 37½ cents per ton. When a vessel shall have paid the port dues in one port of the republic, and shall proceed to another to finish discharging cargo, it shall be free in the second port from tonnage dues, but not from any other.

Falkland Islands: Port Stanley was, prior to 1870, a free port. Now there is a charge of 6 pence per register ton, which includes light, pilotage, and harbor dues. The light dues are not given separately.

San Salvador: Port charges are 10 cents per ton. The light dues, if any, are included in this amount. The charges are not itemized, but under treaty regulations United States merchant vessels are to be treated as national vessels, and as the ships of the most favored nations, which practically exempts them from light-house dues.

Netherlands: Light, beacon, and tonnage dues are abolished. No charge is made for the placing of buoys, lights, or beacons in navigable waters, except (1) light dues charged at particular places for the lighting of harbor lights not in the interests of general navigation of the channel, but for facilitating approach to those places, and (2) beacon dues for placing beacons in creeks and small channels leading to particular places and exclusively for facilitating approach to those places.

Russia: The light dues charged at Russian ports in the Black Sea are per ship of whatever tonnage from 10 tons to 1,000 tons, 7 roubles and 15 kopecs (or $5.36¼) per ship. At Archangel the charge for buoy money is 60 kopecs (or 45 cents) per ship.

Finland: There is no fixed charge for lights. It depends on the number of lights passed before arrival at destination. At Wiborg, a vessel of 227 tons was charged for lights and signals in the gulf, 46 marks 8 penni, and a vessel of 177 tons was charged for lights and beacon dues 61 marks 50 penni; at Uleaborg, a vessel of 200 tons was charged for beacon dues 60 marks. One hundred penni are equal to 1 mark, which is equal to 1 French franc.

Germany makes a charge for light dues of about 6¾ cents per ton.

Italy makes a charge for light dues of 50 centimes, or 10 cents, per ton; but at Leghorn the charge is but 20 centimes per ton.

At Gibraltar vessels are charged $1 coming in, and the same going out of port for light dues.

At Port Adelaide, Australia, vessels pay 3 pence per ton as light dues.

China: There are no light dues levied as such, but the light-houses are supported from a tonnage-tax levied on all vessels visiting the open ports, as are the harbors and the like. Junks are not taxed, but native vessels built in foreign style pay the same tonnage as that levied on foreign vessels.

CHAPTER XIII.

LIGHT-HOUSE ADMINISTRATION.

In treating of this subject that of the United States is first mentioned and at the greatest length, simply because the most authentic material is at hand.

THE UNITED STATES.

The Light-House Board, which has charge of all lights and other aids to navigation, is, under the organic act of August 31, 1852, composed of two officers of the Navy of high rank, two officers of the Corps of Engineers of the Army, two civilians of high scientific attainments, whose services may be at the disposal of the President, and an officer of the Navy and an officer of the Engineers of the Army, as secretaries, the Secretary of the Treasury being *ex-officio* president, and in his absence a member, as chairman, elected by the Board to preside.

The following is a list of the members of the Light-House Board, at the present writing:

Hon. William Windom, Secretary of the Treasury and *ex-officio* president of the Board; Rear-Admiral David B. Harmony, U.S. Navy, chairman; Brig.-Gen. Thomas Lincoln Casey, Chief of Engineers, U. S. Army; Mr. Walter S. Franklin, Baltimore, Md; Col. William P. Craighill, Corps of Engineers, U. S. Army; Capt. Robert L. Phythian, U. S. Navy, superintendent of the Naval Observatory; Prof. Thomas C. Mendenhall, superintendent of the U. S. Coast and Geodetic Survey; Commander George W. Coffin, U. S. Navy, Naval Secretary; Maj. James F. Gregory, Corps of Engineers, U. S. Army, Engineer Secretary.

The light-house districts are divided and officered thus:

First district.—Extends from the northeastern boundary of the United States to include Hampton Harbor, New Hampshire; covers the coasts of Maine and New Hampshire. Inspector, Frank Wildes, Commander, U. S. Navy, Portland, Me.; Engineer, William S. Stanton, Major of Engineers, U. S. Army, Boston, Mass.

Second district.—Extends from Hampton Harbor, New Hampshire, to Sakonnet Point, Rhode Island; covers the coast of Massachusetts, except a small portion of Narragansett Bay and Taunton River. Inspector, Albert S. Barker, Commander, U. S. Navy, Boston, Mass.; Engineer, William S. Stanton, Major of Engineers, U. S. Army, Boston, Mass.

Third district.—Extends from Sakonnet Point, Rhode Island, to include Squan Inlet, New Jersey; covers the sea and sound coasts of Rhode Island, Connecticut, and New York, Narragansett and New York Bays, Taunton, Providence, Connecticut, and Hudson Rivers, Whitehall Narrows, and Lakes Champlain and Memphremagog. Inspector, Frederick Rodgers, Commander, U. S. Navy, Tompkinsville, Staten Island, N. Y., Engineer, David P. Heap, Major of Engineers, U. S. Army, Tompkinsville, Staten Island, N. Y.

Fourth district.—Extends from Squan Inlet, New Jersey, to include Metomkin Inlet, Virginia; covers the sea-coast of New Jersey below the Highlands of Navesink, the bay shores of New Jersey and Delaware, the sea-coasts of Delaware and Maryland, and part of the sea-coast of Virginia. Inspector, John J. Read, Commander, U. S. Navy, Philadelphia, Pa.; Engineer, Edward Maguire, Captain of Engineers, U. S. Army, Philadelphia, Pa.

Fifth district.—Extends from Metomkin Inlet, Virginia, to include New River Inlet, North Carolina; embraces part of the sea-coasts of Virginia and North Carolina, all of Chesapeake Bay, the sounds of North Carolina, and the rivers tributary thereto. Inspector, Silas Casey, Captain U. S. Navy, Baltimore, Md.; Engineer, John C. Mallery, Captain of Engineers, U. S. Army, Baltimore, Md.

Sixth district.—Extends from New River Inlet, North Carolina, to include Cape Canaveral light-house, Florida. Covers part of the coast of North Carolina, the coasts of South Carolina and Georgia, part of the coast of Florida, and the Savannah and St. John's Rivers. Inspector, R. D. Hitchcock, Lieutenant-Commander, U. S. Navy, Charleston, S. C.; Engineer, John C. Mallery, Captain of Engineers, U. S. Army, Charleston, S. C.

Seventh district.—Extends from Cape Canaveral to include the Perdido River, Florida; covers the coast of Florida, except that from Cape Canaveral northward. Inspector, Gottfried Blocklinger, Lieutenant, U. S. Navy, Pensacola, Fla.; Engineer, Walter L. Fisk, Captain of Engineers, U. S. Army, New Orleans, La.

Eighth district.—Extends from the Perdido River, Florida, to the southern boundary of Texas; covers the coasts of Alabama, Mississippi, Louisiana, and Texas, Mississippi Sound, Lakes Borgne and Pontchartrain, Mobile, Atchafalaya, Galveston, and Matagorda Bays, and the Mississippi River from its mouth to New Orleans, La. Inspector, William W. Mead, Lieutenant-Commander, U. S. Navy, New Orleans, La.; Engineer, Walter L. Fisk, Captain of Engineers, U. S. Army, New Orleans, La.

Ninth district.—Includes all aids to navigation on Lake Michigan, Green Bay, and tributary waters lying west of a line drawn across the Straits of Mackinac at the narrowest part east of McGulpin's Point light-station. Inspector, Charles E. Clark, Commander, U. S. Navy, Chicago, Ill.; Engineer, William Ludlow, Major of Engineers, U. S. Army, Detroit, Mich.

Tenth district.—Extends from the mouth of St. Regis River, New York, to include Grassy Island light-house, Detroit River, Mich. Covers the American shores and waters of Lakes Erie and Ontario, and the St. Lawrence, Niagara, and lower part of Detroit Rivers. Inspector, Charles V. Gridley, Commander, U. S. Navy, Buffalo, N. Y.; Engineer, L. Cooper Overman, Major of Engineers, U. S. Army, Cleveland, Ohio.

Eleventh district.—Extends from Grassy Island light-station, Detroit River, to the head of Lake Superior. Covers the American shores and waters above Grassy Island light-house, Detroit River, Lakes St. Clair, Huron, and Superior, Straits of Mackinac, and River St. Mary. Inspector, Horace Elmer, Commander, U. S. Navy, Detroit, Mich.; Engineer, William Ludlow, Major of Engineers, U. S. Army, Detroit, Mich.

Twelfth district.—Extends from the boundary of Lower California to the southern boundary of Oregon; covers the coast of California and San Francisco and San Pablo Bays. Inspector, Nicoll Ludlow, Commander, U. S. Navy, San Francisco, Cal; Engineer, William H. Heuer, Major of Engineers, U. S. Army, San Francisco, Cal.

Thirteenth district.—Extends from the southern boundary of Oregon to British Columbia; covers the Pacific coast of Oregon and Washington, Puget Sound, Columbia River, and the American shores and waters of the Strait of Juan de Fuca. Inspector, William W. Rhoades, Lieutenant-Commander, U. S. Navy, Portland, Oregon; Engineer, Thomas H. Handbury, Major of Engineers, U. S. Army, Portland, Oregon.

Fourteenth district.—Includes all aids to navigation on the Ohio, Tennessee, and Great Kanawha Rivers. Inspector, Holman Vail, Lieutenant-Commander, U. S. Navy, Cincinnati, Ohio; Engineer, William E. Merrill, Lieutenant-Colonel of Engineers, U. S. Army, Cincinnati, Ohio.

Fifteenth district.—Includes all aids to navigation on the Mississippi, Illinois, and Missouri Rivers. Inspector, Charles S. Cotton, Commander, U. S. Navy, St. Louis, Mo.; Engineer, Charles R. Suter, Lieutenant-Colonel of Engineers, U. S. Army, St. Louis, Mo.

Sixteenth district.—Includes all aids to navigation on the Red River and the Mississippi River from New Orleans to the mouth of the Ohio River. Inspector, Edward M. Hughes, Lieutenant, U. S. Navy, Memphis, Tenn.; Engineer, Charles R. Suter, Lieutenant-Colonel of Engineers, U. S. Army, St. Louis, Mo.

ADMINISTRATION.

Great Britain.—The Trinity Corporation, which developed the English system under the advice and assistance of eminent engineers and philosophers, existed in the reign of Henry VII, as a respectable company of mariners in the college at Deptford, having authority by charter to prosecute persons who destroyed sea-marks, etc.; and Henry VIII, May 20, 1514, formed them into a perpetual corporation by the name and style of the "Masters, Wardens, and Assistants of the Guild or Fraternity of the most glorious and undivided Trinity, and of St. Clement, in the parish of Deptford Strond, in the county of Kent." This corporation is now popularly known as the Trinity House; it has entire control of the light-houses of England and Wales, and certain powers over the Irish and Scotch lights.

Scotland.—The Commissioners of Northern Light-Houses, incorporated by the act 38th George III, c. 58, have charge of the Scottish lights.

Ireland.—The Ballast Board of Dublin, were by the 23d George III, c. 19, put in charge of the Irish lights.

France.—The light-house service here is under the ministry of Public Works, and a special commission, called "Commission des Phares," which body consists of naval officers, marine engineers, hydrographers, members of scientific bodies, and other gentlemen distinguished for their scientific attainments in various professions, all of which have to do with branches of science connected with coast illumination. The general conduct of the service is under an officer called Directeur Général des Phares, who is an engineer, and has other engineers under him.

Sweden.—The lights are under the Admiralty, and managed by a director and officers who have military rank, and engineers.

Norway.—The service is under the Royal Marine Department.

Turkey.—The light-house service is under the Admiralty; and the system is now in the course of development.

Spain.—Here the system of administration is almost the same as that of France. It is under the control of the Department of Public Works, to which is attached a standing committee of the roads, canals, and ports corps, and of the officers of the Royal Navy of high rank. This committee has a voice in the decision of questions of high importance, such as a change in the general plan of lighting, the establishment of lights of new kinds, the adoption of new illuminants, and the like. In other matters the work is left to the engineers assigned to the different sections of the coast. Engineers of a higher grade, called inspectors, supervise the district engineers and their work, and visit them from time to time. The captains of the ports watch and report to the engineers, and to the home office as to the action of the lights and beacons.

Denmark.—The Ministry of Marine has charge of the light-house service. They decide directly upon all matters relating to the establishment of new lights, the alteration of old ones, the personnel of the establishment, and buoyage.

Holland.—The Ministry of Marine also has charge of this light-house service. There are under it, however, district inspectors and an inspector general, who inspects each district from time to time.

Belgium.—The Minister of Public Works has charge of this light-house service, which is exercised through the corps in charge of roads and bridges, called the *Ponts et Chaussées.* The navy has charge of the light-houses after they are built, and is responsible for their maintenance. The personnel is under the charge of the inspectors of pilotage and the general director of the navy, to whom the inspectors report infractions of discipline, inflict punishment, which can only be remitted by the minister. Radical changes in the system can only be made by the Department of Foreign Affairs and that of Public Works in consultation.

Austria.—The Imperial Royal Admiralty has charge of the Austrian light-house system, which is exercised through the deputies of the exchange at Trieste. They erect light-houses, make repairs, attend to the appointment, discipline, and payment of light-house keepers, and collect light-house dues. No new light-houses can be erected, nor can any material change be made in an old one, without the approval of the Admiralty, to which the matter is submitted by the Commission of Exchange.

Russia.—The Hydrographic Department has charge of the Russian light-house service.

China.—The lights on the coasts of China are under the charge of the Inspector General of the Imperial Maritime Customs, whose headquarters are at Peking. He has under him an Engineer in Chief who is responsible for construction and repair and the Coast Inspector who is charged with the maintenance and the personnel of the stations. There are other officers under them who carry out their orders.

All the South American countries have organized more or less complete systems for lighting their coasts, and generally the existing lights are well maintained.

The present systems contemplate many proposed or intended lights (particularly on the coasts of Brazil and Chili), which will probably be put in operation as the needs of commerce require or the means of the governments admit.

The following tabular statement of the number of lights maintained in each country, and the number against which reports are recorded as to their reliability, will show comparatively the extent and efficiency of the existing service or system:

Nationality.	No. of lights.	Reported irregular or unreliable.	Nationality.	No. of lights.	Reported irregular or unreliable.
Mexico:			British Guiana	4	....
East coast	12	3	Dutch Guiana	2	....
West coast	4	1	French Guiana	5	....
Belize and coast of British Honduras	10	2	Brazil	64	....
			Uruguay	13	1
Costa Rica:			Argentine	11	1
East coast	1	....	Chili	20	....
West coast	1	1	Peru	10	1
United States of Colombia:			Ecuador	9	....
East coast	8	2	Nicaragua	2	2
West coast	2	....	San Salvador	3	2
Venezuela	7	3	Guatemala	1	1

These lights, taken all together, may be thus described: There are 106 fixed lights, 5 flashing lights, 18 revolving lights, 18 lights which are fixed and varied by flashes, 3 lights which show intermittently, and 3 lights the character of which is not given.

Generally speaking, the dangers and the fairways in the approaches to the South American ports, as well as those in Mexico and Central America, are buoyed or have been buoyed. There is often great delay in replacing buoys when adrift, in many localities, especially in the mouths of rivers, and too little attention paid to the publication of changes in buoyage or other aids to navigation. There is a lack of uniformity in buoyage, and a uniform system is desirable; also a uniform system of reporting and publishing changes, particularly in regard to locating the buoys. In this particular a uniform system of reporting position or bearings of all aids to navigation is very important. It is seldom that the geographical position and the bearings given can be made to accord in the reports received from the Spanish speaking countries.

Chapter XIV.

LIGHT-HOUSES IN CENTRAL AND SOUTHERN AMERICA.

It is unnecessary to recount to this distinguished assemblage the names or the character of the magnificent, costly, and highly useful lights recently established in the south. They are too interesting not to be well known to all, but it may not be out of place to quote the following from the publications of the British Admiralty and of the Hydrographic Office of the United States Navy:

LIGHTS OF THE SOUTHERN NATIONS.

Tampico.—A tower of iron frame-work, on the north shore of Tampico River entrance, a flashing white light, at an elevation of 141 feet above the sea, and visible in clear weather from a distance of 18 miles; second order.

Vera Cruz.—A white tower, 60 feet high, on the west angle of the castle of San Juan de Ulloa, a revolving white light, attaining its greatest brilliancy every 45 seconds; 80 feet above the sea, and visible from a distance of 15 miles in clear weather.

Vera Cruz.—A fourth-order fixed and flashing light, intervals between flashes one minute, shown from the old convent of San Francisco, in the city of Vera Cruz, at an elevation of 102 feet above high-water level, and in clear weather the light should be seen from a distance of 15 miles.

Vera Cruz.—An electric light shown from an iron skeleton tower, at a height of 170 feet above the sea, three-fourths of a mile south of San Francisco convent, and should be visible in clear weather from a distance of 19 miles.

Frontera de Tabasco.—From a light-house erected at the harbor, a fixed white light, varied by a flash every forty seconds, is exhibited at an elevation of 77 feet above the sea, and should be visible in clear weather—the fixed light from a distance of 11 miles, and the flash from a distance of 13 miles.

Laguna de Terminos—Carmen Island.—From Sagatal point the coast trends west by north 2½ miles, to a small Indian village, having in it a light-house, with the lower part red, and the upper part and lantern white, from which a revolving white light is shown, at an elevation of 100 feet above the sea, every half minute, visible in clear weather from a distance of 14 miles.

Campeche.—A fixed white light is shown from the town of Campeche, at 95 feet elevation, and is visible 14 miles.

Aspinwall (Colon)—Limon or Navy Bay.—On the northwestern extremity of Manzanillo Island, and SW. ½ S., nearly 3 miles from Point Longarremos, a fixed white light is placed on the top of an open frame-work, at an elevation of 60 feet above high water, and should be visible, in favorable weather, at a distance of about 10 miles; it is often difficult to distinguish this light from the ordinary white light carried by steamers.

Cartagena—Boca Chica.—From a light-house situated on the tower of the disused convent of La Merced is exhibited a revolving white light, with flashes every 15 seconds; it is elevated 160 feet above the sea, and should be visible, in clear weather, from a distance of about 15 miles.

Galera Zamba.—A flashing light (white and green alternately every minute) is exhibited from a light-house on the main-land, southeast side of Galera de Zamba Bay. The light is visible over an arc of 135° between the bearings N. 71° E. and S., 26° W.

Savanilla.—From a light-house near Cupino Beach, which extends northeast from the red cliffs, a fixed and flashing white light is exhibited at an elevation of 98 feet. The characteristics of this light are as follows: Fixed thirty-five seconds, eclipsed nine seconds, flash three seconds, and eclipsed nine seconds. The flash is visible 15 miles; the fixed light not so far. The light is obscured when bearing south of SE. by S. This light is not to be relied upon.

Porto Belillo.—A skeleton tower, painted red, on Point Belillo. A fixed light, 60 feet above the sea, and should be visible from a distance of 15 miles in clear weather.

Puerto Cabello.—A quadrangular structure on Brava Point. A light exhibiting red and white flashes alternately at intervals of forty seconds. The light is 82 feet above the sea-level, and should be seen in clear weather from a distance of 14 miles.

Port el Roque.—A light is exhibited from a light-house on the northeast hill of El Roque. The light is revolving white, attaining its greatest brilliancy once every minute; it is elevated 208 feet above the level of the sea, and in clear weather should be seen from a distance of 15 miles.

Orinoco River.—A two-masted light-vessel, painted red, is moored in 3 fathoms of water between Sabaneta Bank and Barima Point, 7 miles from the latter, from which is shown, at an elevation of 50 feet above the sea, a fixed white light, visible in clear weather 9 miles.

Demerara River.—The light-vessel off the mouth of the river lies NNE., ¾ E.; distant 8½ miles from George Town light-house, in 3¼ fathoms of water, and exhibits a fixed white light, which in clear weather should be visible from a distance of 10 miles. The vessel has one mast and is painted red. The pilots reside on board.

The light-house at George Town is octagonal and painted with red and white alternate vertical stripes; it is 100 feet high, and exhibits a revolving white light every minute, at 103 feet above the mean level of the sea, visible from a distance of 16 miles; on the summit of the light-house there is a semaphore signal post.

Berbice River.—From the light-vessel at the entrance of Berbice River is exhibited a fixed white light, visible in clear weather from a distance of 10 miles. The vessel is moored in 22 feet of water, at 9 miles NE. by N. from St. Andrew Point (the east entrance point), and may be recognized by being painted red, with the name Berbice on each quarter; the vessel is roofed over, and during daylight carries a white flag with a red ball in the center.

Paramaribo.—At the entrance of Surinam River a light-vessel is moored in 14 feet, at low-water spring tide, from which is exhibited a fixed white light at an elevation of 25 feet above the sea, which may be seen in clear weather from a distance of 4 miles. The vessel has two masts, is painted red, and has on each side in white letters the name Surinam. A red ball is placed on each mast-head. From the vessel Braam Point bears SE. by S., distant 4½ miles. The position of this light-vessel is not to be depended upon.

Maroni River.—From a white pyramid-shaped structure on Les Hattes Point a fixed white light is shown, elevated 75 feet, and visible in clear weather from a distance of 10 miles between the bearings of E. by N. through south to W. by S. A fixed white light is also shown from a white pyramid-shaped structure on Kaimar Head. This light is elevated 75 feet, and should be visible in clear weather from a distance of 10 miles, between the bearings S. ¾ E. and W. ¾ S.

Braganza Shoal—Eastern or Para Mouth.—A light-vessel is moored in 15 fathoms, about 1½ miles northwestward of the north side of Braganza shoal, with Tijoca Point bearing S. by E. and Coruza Point SE. ½ E. The light-vessel is painted red, has two masts, and exhibits a fixed white light, visible from a distance of about 4 miles. The position of this vessel can not be depended upon, as she frequently drifts, and in stormy weather moves under the lee of the banks, and sometimes enters the river.

Cape St. Roque.—On Atalaia Point is a light-house, which exhibits a revolving white light, varied by a flash every two minutes, and should be seen in clear weather from a distance of 17 miles. The light shows steady for seventy seconds, followed by an eclipse of sixteen seconds, then a flash for twelve seconds, and another eclipse for twenty-two seconds; total, one hundred and twenty seconds.

San João Islands.—From a light-house erected near the northeast extremity of San João Islands is exhibited, at an elevation of 78 feet above high water, a fixed white light, visible in clear weather from a distance of 14 miles. The light-house, constructed of iron, is hexagonal in shape, and painted red; the keeper's dwelling is white.

San Marcos or Maranham Bay.—Near the shore in the vicinity of Morro Itacolomi, on the western side of San Marcos Bay, stands a large two-storied white house surmounted by a square tower, which exhibits, at an elevation of 149 feet above the sea, a fixed white light, varied by a white flash every two minutes, and should be visible in clear weather from a distance of 18 miles. On point and fort San Marcos, at 1½ miles northeast of the entrance to San Luiz Harbor, is a light-house which exhibits, at an elevation of 119 feet, a fixed white light, visible 15 miles.

Santa Anna Island and Reefs.—From a cylindrical tower, 148 feet high, painted white, situated about 1 mile within the east point of Santa Anna Island, is exhibited, at an elevation of 190 feet above high water, a flashing light, showing in succession two white flashes and one red flash of equal power, with an interval of thirty seconds between the flashes. It should be visible in clear weather from a distance of 20 miles.

Rio Camocim.—From a light-house on Point Pedra do Sal is exhibited a fixed white light, visible in clear weather from a distance of 10 miles. A reef which dries lies 1½ miles north-northeast of the point.

Rio Grande do Norte.—At the entrance of Rio Grande do Norte, on Fort Santos Reis Magos, is a round tower which exhibits, at the height of 43 feet above the sea, a fixed white light, said to be visible in clear weather from a distance of 10 miles.

Cape Branco.—From a light-house painted red, with vertical and horizontal narrow white stripes, erected on Pedra Secca rocks, the northern extremity of the off-lying reef, is exhibited, at an elevation of 52 feet above high water, a revolving white light every minute, and should be visible in clear weather 12 miles. From a distance the light-house appears red.

Rio Doce.—On the old fort of Montenegro, on Olinda Point, is exhibited an occulting white light, giving alternate flashes of thirty and three seconds, with eclipses of five seconds, visible in clear weather from a distance of 18 miles.

Pernambuco.—On the reef, 50 yards northward of Fort Picao, is a white octagonal tower, standing on a rock covered at quarter flood, which exhibits a revolving light, showing twice a white face and once a red face alternately every minute, but is reported to be irregular in its action. The light should be seen in clear weather from a distance of 15 miles.

Cape St. Agostinho.—From an iron tripod light-house, painted white, and 160 feet in height, is exhibited, at an elevation of 344 feet above the sea, a fixed white light, and should be visible in clear weather from a distance of 25 miles.

Maceió.—On the southwestern point of the hill which overhangs the town of Maceió is a light-house, which exhibits, at the height of 208 feet above the level of the sea, a light of the third order, which should be seen in clear weather from a distance of 22 miles. The light is fixed, with a flash every two minutes. It shows a steady white light for seventy seconds; it is then eclipsed for sixteen seconds; then a white light for twelve seconds; another eclipse for twenty-two seconds; then again the steady light, thus completing its phases in an interval of two minutes.

Port Aracaju.—From an iron, octagonal tower, painted white, on SamOca Point, southwest side of entrance to the river, is exhibited, at an elevation of 59 feet above the sea, a fixed white light, which should be visible in clear weather from a distance of 10 miles.

On Piraboca rock one cable from the shore near Itapuan Point is a round iron light-house, painted red, which exhibits, at an elevation of 68 feet above high water, a fixed white light, visible from a distance of 14 miles.

A light is exhibited from Fort San Antonio at the height of 140 feet above high water, and in clear weather begins to be seen as a faint light from a distance of 18 miles, but this distance can not be depended on. The light is revolving, showing two white faces and one red in succession, which are distinctly seen at about the distance of 6 miles, the interval between each face being eighty seconds; the red light will thus be visible once every four minutes. The light is obscured by the land northward of W. by N. ½ N.

Morro San Paulo.—On the high cliff at the northern extremity is a light-house 80 feet high, painted white, which exhibits, at the height of 276 feet above high water, a revolving white light, visible in clear weather from a distance of 20 miles. The light revolves every minute, showing a bright light for fifteen seconds, followed by an eclipse of forty-five seconds. At a distance less than 8 miles the eclipses are not total.

Sometimes, when the light-house is first seen above the horizon, it appears like a vessel under sail.

Santa Barbara.—On the eastern part is an iron circular tower 50 feet high, surrounded by a dwelling, which exhibits, at the height of 189 feet above high water, a revolving white light, which attains its greatest brilliancy every minute, and should be seen in clear weather from a distance of 20 miles. Within 7 miles a faint continuous light is seen; westward of the light a small sector is obscured by Redonda Islet when within 3 miles.

Espirito Santo Bay.—On the hill of Santa Luzia, on the south side of Espirito Santo Bay, is a light-house which exhibits, at an elevation of 66 feet above high water, a fixed white light, visible in clear weather from a distance of 12 miles.

Francesca Islet.—On the southern part, from a quadrangular stone light-house, is exhibited, at an elevation of 155 feet above the sea, a fixed white light, visible in clear weather from a distance of 14 miles.

Cape St. Thomé.—A light-house in the shape of a truncated cone, of a red color, supported on iron columns, is erected on Cape St. Thomé. The keeper's dwelling, painted white, is in the lower part of the structure. The light exhibits white flashes every minute with total eclipses, and should be visible in clear weather from a distance of 19 miles.

Cape and Port Frio.—On Focinho do Cabo Point, the southern extreme of Cape Frio Island, is a round tower 53 feet high, painted light stone color, which exhibits, at the height of 300 feet above the mean level of the sea, a white flashing light every minute and a half, visible seaward through an arc of 225 degrees, or between the bearings of SW. ⅓ W. and E. ⅓ S. The duration of the eclipse is forty-five seconds, and the exhibition of light, which gradually attains its greatest brilliancy, is forty-five seconds. The light should be seen in clear weather from a distance of 25 miles. The light is not visible in the vicinity and westward of Ancoras and Papagayos Islands.

Raza Island.—The light-tower on Raza Island is 50 feet high and exhibits, at the height of 315 feet above high water, an electric revolving light, showing two white flashes and one red flash of about four seconds duration each, with an interval of about eleven seconds between each flash. The light should be seen in clear weather from a distance of 24 miles.

Moella Islet.—On Moella (Gizzard) Islet, a mile southeast of Manduba Point, is a white tower, 40 feet high, which exhibits at the height of 334 feet above high water, a fixed white light, which may be seen in clear weather from a distance of 12 to 14 miles.

Cananéia.—A square tower above the keeper's dwelling, standing on Bom Abrigo Islet. A revolving light showing two white flashes, followed by one red flash, with intervals of fifteen seconds between the flashes. It is 505 feet above the sea, and should be seen in clear weather from a distance of 14 miles.

Paranaguá Bay.—On Conxas Point, the east point of Ilha do Mel, is an iron light-house 69 feet high, which exhibits, at an elevation of 262 feet above the sea, a fixed white light, visible in clear weather from a distance of 20 miles. There is a pilots' flag-staff at the light-house.

Arvoredo Islet.—From a light-house colored white, 48 feet high, on the south point of Arvoredo Islet, is exhibited a fixed white light, varied alternately by white and red flashes every two minutes; visible through an arc of 291 degrees, or between the bearings of S. 12° E. through west, and S. 81° E. It is elevated 292 feet above the sea, and should be visible in clear weather from a distance of 23 miles.

Santa Catharina Island.—On Point dos Naufragados, south point of Santa Catharina Island, from a circular building 149 feet above the sea, is exhibited a revolving light, attaining its greatest brilliancy every minute, visible in clear weather from a distance of 18 miles.

Rio Grande do Sul.—At about 1 mile within the east point of entrance of Rio Grande do Sul, from a reddish tower, is exhibited, at an elevation of 96 feet above the sea, a revolving light. The light is visible seventy seconds and eclipsed fifty seconds, and may be seen in clear weather from a distance of 14 miles. A square watch tower, whitewashed, with flagstaffs and yards for signals, stands near the light-house. Moveable bar marks are also erected on the point.

Cape Polonio.—On Cape Polonio, from a light-house constructed of gray masonry, with three white horizontal bands, is exhibited a fixed white light elevated 137 feet above the sea, and should be visible in clear weather from a distance of 20 or 22 miles. The light-house appears like a sail when sighted from the northward, and the bands, from want of whitewash, are scarcely to be distinguished.

Cape Santa Maria.—On Cape Santa Maria, from a light-house 125 feet high, is exhibited, at an elevation of 132 feet above the sea, a revolving white light, which attains its greatest brilliancy once in every minute, and should be visible in clear weather from a distance of 18 miles.

San José Ignacio.—From a light-house on San José Ignacio Point, at an elevation of 103 feet above the sea, is exhibited a fixed white light, visible in clear weather from a distance of 15 miles. This light-house is reported to have two narrow white bands around the upper part, and one around the lower part.

Maldonado Bay.—A tower 90 feet high on the east point of the bay. An intermittent light of the first order, showing bright for one and a half minutes and then eclipsed for twenty-five seconds. Visible from a distance of 18 miles.

Flores Island.—On the southwest extremity of Flores Island, from a white light-house, 65 feet in height, is exhibited at an elevation of 106 feet above the sea, a revolving white light every minute, and should be seen 12 miles in clear weather. The light (being better attended than formerly) may now, it is said, be depended on.

Montevideo.—A fixed and flashing light, showing a flash every three minutes, which lasts for fifteen seconds, is exhibited from a brown tower within the fort on the summit of the Cerro, at an elevation of 486 feet above the sea, and should be visible in clear weather at a distance of from 20 to 25 miles. This light, on account, perhaps, of its great height, is not to be depended upon.

La Panela.—A light vessel is moored about 1 cable NNW. ½ W. from the shoalest part of Panela Reef, and exhibits a fixed white light, 17 feet above the sea, visible 5 or 6 miles. The light vessel is frequently out of position after bad weather.

Colonia.—From a white light-house at Colonia, near the southwest angle of the plaza, is exhibited at an elevation of 110 feet above the sea, a white revolving light, which attains its greatest brilliancy every three minutes; the light is visible in clear weather at a distance of 10 miles. The period of revolution is said to be irregular.

Also, from a light-house on Farallon Island, there is exhibited at an elevation of 83 feet above the sea, a fixed white light, visible in clear weather from a distance of 13 miles.

Buenos Ayres.—At 5.8 miles E. ½ N. from Retiro Point, at Buenos Ayres, in a depth of 15 feet, is a hulk or stationary guard-ship, painted black, with two masts, which shows a fixed white light about 20 feet high, visible 7 miles.

English Bank.—About one-third of a mile off the north end of English Bank, in about 7 fathoms of water, is a vessel painted red, having three masts, and which exhibits a fixed white light, visible from 8 to 12 miles in clear weather. The light vessel drags from time to time during heavy gales; and, it would seem, is generally left in the position to which she drifts. No confidence, therefore, can be placed in her as a guide to clear the bank; and as the jib and spanker are sometimes set to keep the vessel steady, it is then difficult for a stranger to recognize her as a light vessel. [S. A. Pilot, Part 1, 1885, British Admiralty.]

Cuirassier Bank.—Between Indio Point and Ortiz Bank (about 2 miles southward of Cuirassier Bank), a vessel painted red, with two masts, having a black ball at the main mast-head 40 feet above water, is moored on a bearing NE. by N., distant about 10 miles from the high grove of trees on Indio Point. This vessel, locally known as Indio Point light vessel, exhibits at the height of 33 feet above the sea a fixed white light, visible 10 miles in ordinary clear weather, but under certain conditions of the atmosphere as much as 14 miles. This light vessel often drifts from her position, and if much displaced returns to it, mooring on the same bearing of the grove, but her distance from it may vary considerably, as they have no means but estimation of ascertaining the distance from shore, nothing but the grove being seen from the light vessel. [*Ibid.*]

Chico Bank.—A light vessel painted black, with two masts, is moored in 4½ fathoms water 1 mile off the northeast end of the Chico Bank, and 16½ miles N. ½ W. from Magdalena Church. The vessel exhibits a fixed white light, visible 10 miles, and under certain conditions of the atmosphere as much as 14 miles. The vessel's position is often doubtful after gales.

Martin Garcia Island.—From a light-house erected on the summit of Martin Garcia Island is exhibited at an elevation of 141 feet above the level of the river a fixed white light, which should be visible in clear weather from a distance of 14 miles.

Ceará Bay.—On the extremity of Macoripe Point is a light-house 50 feet high, which exhibits at an elevation of 85 feet above the sea a revolving white light of the fourth order, attaining its greatest brilliancy every half minute, and is visible in clear weather from a distance of 12 or 13 miles.

Staten Island.—Off the SE. extremity of the American Continent. From a light-house on the western entrance point of St. John Harbor, at an elevation of 200 feet above the sea, is exhibited a fixed white light, visible between the bearings of SE. ¾ E. and SW. ½ S., and should be seen in clear weather from a distance of about 14 miles.

Sandy Point Road, Magellan Strait.—The light-house (also called the block-house), painted with red and white horizontal bands, stands on the east side of the settlement about a quarter of a mile from the shore, and exhibits at an elevation of 79 feet a fixed white light, visible between the bearings N. by W. through west to S. ½ W., and should be seen from a distance of 3 miles. A red light, elevated 69 feet above high water and visible 3 miles, is shown from a position seaward of the white light, and when the two lights are in line bearing NW. by W., lead a quarter of a mile eastward of the wreck of H. M. S. *Doterel* sunk in the roads. A fixed white light, elevated 26 feet above the sea, and visible 10 miles, is exhibited at the extremity of the new pier.

Port San Carlos, Chili.—A fixed white light, varied every two minutes by a flash, is exhibited from the light-house on Corona Head. From the light-house Huechucucui Head, seen over Huapacho Point, bears W. by S. The light is elevated 224 feet above high water, and is visible in clear weather from a distance of about 12 miles. The light tower is 32 feet high, circular, and painted white.

Galera Point.—The light-house, a tower 62 feet high and colored white, stands on the most projecting extremity on the south side of the point, and exhibits from an elevation of 180 feet a fixed and flashing white light, showing a flash every minute, and in clear weather should be seen from a distance of 20 miles.

Santa Maria Island.—An iron cylindrical structure, supported on an iron tripod from the center of the keeper's dwelling, standing on the summit of the hill, north point of the island. It is 258 feet above the sea, and exhibits a flash of fifteen seconds duration with an eclipse of forty-five seconds duration.

Lota Point.—An iron light-house, 44 feet high, painted white, forming a good landmark, stands on Lota Point, and from which is exhibited a revolving white light every fifteen seconds, visible in clear weather from a distance of 18 miles. The light is obscured from the northward by the heights of Chambique, bearing N. by W. from the light-house.

Quiriquina Island.—The light-house, 36 feet high, with keeper's dwelling attached, standing on the northern point of Quiriquina Island, is circular and colored white. From the lantern is exhibited at an elevation of 213 feet above the sea a revolving white light of the fourth order, attaining its greatest brilliancy every thirty seconds, the duration of light being nine seconds, and that of eclipse twenty-one seconds, and in clear weather should be seen from a distance of 15 miles.

Angeles Point.—From a light-house on Angeles Point is exhibited a fixed white light, showing a flash every two minutes. The flash is preceded and followed by a short eclipse. The tower is circular, 49 feet high, colored white, with a green top. The light is 180 feet above high water, and in clear weather should be visible from a distance of 16 miles.

Tortuga Point.—The light-house on Tortuga Point is square, built of wood, painted white with a green top, and is 25 feet high. It stands about 200 yards within the extremity of Tortuga Point, and exhibits, at an elevation of 106 feet above high water, a fixed and flashing white light, showing a flash of five seconds' duration every fifteen seconds, the partial eclipse lasting ten seconds, and in clear weather should be seen from a distance of 12 miles between the bearings of NE. by E.½ E., through south to SW.½ W.

Caldera Point.—A light-house 43 feet high stands on Caldera Point, the west entrance point of port Caldera; it is built of wood, square, and painted white. From the lantern is exhibited, at an elevation of 123 feet above high water, a fixed and flashing white light, the flashes taking place at intervals of eighty seconds, and in clear weather should be seen from a distance of 15 miles.

Iquique Island.—A cylindrical iron light-house 72 feet high, painted white, stands near the center of the island, and exhibits, at an elevation of 96 feet, a fixed and flashing light showing a flash every thirty seconds. The light is visible through an arc of 180 degrees, and in clear weather should be seen from a distance of 16 miles.

Cape San Lorenzo.—The light-house on Cape San Lorenzo is a wooden octagonal tower, 60 feet high, on the summit of the cape, and exhibits, at an elevation of 980 feet above high water, a fixed white light, visible in clear weather from a distance of 12 miles. Between the bearings of NW. ¾ N., and W. by N.¾ N., it is hidden by the peak of the island; and when just open bearing W. by N.½ N., it leads through the Boqueron in 4½ fathoms. From its lofty position, however, this light is not always seen, being often enveloped in the thick fog or haze which hangs over the high land, causing it at night to appear like a star only.

Amortajada Island.—The light-house on Amortajada or Santa Clara Island is an octagonal tower painted white. It stands on the summit of the island, and exhibits, at an elevation of 256 feet above the sea, a fixed and flashing white light, showing a flash of four seconds' duration every half minute, and in clear weather should be seen from a distance of 22 miles. In order to maintain this light sailing vessels entering the Gulf of Guayaquil must pay a tax of 6¼ cents per registered ton. Steam vessels are required to pay half that sum.

Arena Point.—On Arena Point, close to the water's edge, stands a square tower, from which is exhibited, at an elevation of 65 feet above the sea, a revolving red light, showing a flash of sixteen seconds' duration and obscured forty-four seconds in each minute, and in clear weather should be seen from a distance of 14 miles. This light is said to be obscured when bearing westward of W. by N. ½ N.

Santa Élena.—A light-house is erected on the hill over Santa Élena Point, from which is exhibited, at an elevation of 470 feet above the sea, a fixed white light, with flashes at intervals of two minutes, and in clear weather should be visible from a distance of 25 miles.

Acapulco.—There is a white light on the white wooden tower of Roquet Island, operated by the Pacific Mail Steam-ship Company, and lighted only when one of their steamers is expected or about leaving the port. This light is visible in clear weather about 20 miles.

Mazatlan.—A square structure rising from the center of a square white building, lantern red, standing on Creston Island. A fixed light of the fourth order, visible 20 miles.

Cape Haro.—Southern extremity of the eastern part of the cape, approach to Guaymas. A skeleton iron tower, 345 feet above the sea. A fixed light of the fourth order, varied by a flash every half minute, visible about 24 miles.

LIGHTS HOPED FOR.

Your writer trusts that he may be pardoned if he enumerates some of the points where the world of commerce hopes to see lights established in due time and in proper order.

In the Gulf of Mexico, the Campeche Bank is a great danger to vessels trading with Mexico. A light on Alacran Reef, the northeastern danger on this bank, and a light on Cay Nuevo, at the northwestern edge of this bank, would mark the northerly limit of danger and enable vessels to safely skirt or cross the bank.

In the Caribbean Sea, a light on Serrana Bank or cay (approximate position, latitude 14° 25′′ north, longitude 80° 20′′ west) would enable vessels, particularly sailing vessels, returning from Aspinwall and the ports on the north coast of South America to verify their position, avoid the dangers to leeward, and set a clear course for Cape San Antonio light, on the west end of Cuba.

At the mouth of the Magdalena River, New Granada, United States of Colombia, a light-vessel might be established with pilots on board. The bar is very dangerous, numerous wrecks occur, many lives have been lost, and no aids to navigation exists.

At the mouth of the Rio de la Plata, Argentine might establish a light-vessel on "Rouen Bank." A light-vessel is maintained on "English Bank" by the Government of Uruguay, and with one on "Rouen Bank" also, vessels making the Argentine ports could pass safely southward of "English Bank," and all vessels could approach the mouth of the river without fear of the old bugbear "French Bank."

Magellan Straits and the Patagonian Channels might be lighted. But one regular light is maintained in Magellan Straits, and there are no lights in the Patagonian Channels. The Chilian system contemplates numerous lights, but none have been put in operation. These channels have not been well surveyed, and they might be kept well buoyed and lighted. Numerous wrecks have occurred there.

There are no lights on the coasts of Lower California. A light on the west coast at point St. Eugenio or on Cerros Island, and one at the south extreme on Cape San Lucas would be of great service to coasters and to vessels making the Gulf of California; and for the same reason a light would be of service on Cape Corrientes, south side of Banderas Bay, west coast of Mexico, there being no light in that vicinity.

The Colombian Government would do well to establish a light in the approach to Panama. The two small lights at Panama are the only lights on the Pacific coast of the United States of Colombia.

All the above lights to be of the greatest use should be of the first order.

Of course it will be evident that all these lights can not be established, certainly at any early day, by the nations on whose shores they would stand, entirely at their own expense, as such lights are so clearly for the benefit of all rather than for any one country.

There is ample precedent for co-operative work in the Old World which this Congress will readily call to mind. Among them are the lights at Cape Spartel and Tangier, on the coast of Morocco, which are maintained by several commercial nations, the United States included, which make a yearly appropriation for their support.

The lights so built will guide past, as well as to, near harbors. Therefore the establishment of the more costly and much needed coast-lights might be an international labor done at international expense and maintained at international cost.

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