Station, California. The Neo-Classical style is represented by keepers' quarters at the following Puerto Rico light stations: Arecibo (1898); Cape Rojo (1882); Cape San Juan (1880); Cardona Island (1889); Guanica (1893); and Muertos Island (1887); and the quarters at Browns Point Lighthouse (1903), Washington.

The Craftsman/Colonial Revival style is represented by the keeper's quarters (1902) converted from the 1889 engine house at Point Sur Light Station, California; keeper's quarters at Marcus Hook Range Rear Light (1918), Delaware; Marshall Point keeper's quarters (1896), Maine; and keeper's quarters at Reedy Island Range Rear Light (1906), Delaware. The Dutch Colonial style is illustrated by the keeper's quarters at Wood Island (1857, remodeled 1906), Maine; and keeper's quarters at Presque Isle Light Station (1870), Michigan.

The Spanish Revival style can be seen in structures at Point Conception (1882), Point Vicente (1926), near Los Angeles, and Anacapa Light Station (1932), Anacapa Island, all in California.

The Greek Revival style is illustrated by the keeper's quarters at Liston Range Rear Light (1907), Delaware; keeper's quarters at Ida Lewis Rock Light Station (1856), Rhode Island; and integral tower and dwelling at Patos Island (1898), Washington. The Egyptian Revival style is represented by the Southwest Reef Lighthouse tower and keeper's quarters (1858), Louisiana. The Moorish Revival style is found in the integral tower at Port San Juan (1908), Puerto Rico.

The Victorian style is found in many light stations including the integral keeper's quarters at San Luis Obispo Light Station (1890), California; Cape Elizabeth keeper's quarters (1878), Maine; Cape Neddick keeper's quarters (1879), Maine; and Great Captain Island Lighthouse (1868), Connecticut. The Italianate Victorian style is found at Point Fermin Lighthouse (1874), California; and keeper's quarters at Block Island Lighthouse (1867), Rhode Island. The Italianate style is illustrated by the Grosse Point Lighthouse keeper's quarters (1873), Illinois; and the keeper's quarters at Saugerties Lighthouse (1869), New York.

The Mission Revival style is represented by the keeper's quarters at Point Loma (new) Light Station (1891) in California. The Flemish Revival style is illustrated by the keeper's quarters at Grand Traverse Light Station (1899), Michigan. The Federal Revival style is found in the keeper's quarters of Bristol Ferry Lighthouse (1855), Rhode Island.

The Art Deco style is represented by the keeper's quarters at Milwaukee Breakwater Lighthouse (1926), Wisconsin; and several Alaska light stations such as Cape Decision (1932), Cape Hinchinbrook (1934), Cape Spencer (1925), Cape St. Elias (1916), Five Finger Islands (1935), Point Retreat (1923), Sentinel Island (1935) and Tree Point (1935). The Art Modern style is represented by the last caisson lighthouse built in the United States, Cleveland East Ledge Lighthouse (1943), Massachusetts; and Huron Harbor Lighthouse (1936), Ohio. The Beaux Art style is found in the Huntington Harbor (Lloyds Harbor) Lighthouse (1912), New York.

Many dwellings at light stations are plain structures and quite functional. The Bungalow and Ranch style of keepers houses can be found in a number of light stations around the country. Bungalow-style living quarter examples include Pigeon Point (1960), California; Dry Tortugas (1922), Florida; Boca Grande (1890), Florida; Molokai (1909), Hawaii; New Canal (1901), Louisiana; Ship Shoal (1859), Louisiana; and Diamond Head (1921), Hawaii. Ranch style living quarter examples include Piedras Blancas (1960), California; Plymouth (1963), Massachusetts; and Egmont Key (date unknown), Florida. The Rambler style is represented by the keeper's quarters at Sankaty Head (1960), Massachusetts. The

Cottage style is represented by the keeper's quarters at Owls Head (1854), Maine; and the Dutch Colonial Cottage style by the keeper's quarters at Whitlocks Mill (1909), Maine.

Duplication of lighthouse designs

George Putnam stated that the early lighthouses are representative of some of the best architecture in this country (simple, honest, dignified and strikingly located).[95] Early on there was no uniformity in lighthouse design although architects tended to use similar plans when they designed more than one lighthouse. For example, the first Cape Henry Lighthouse (1792) was designed by the John McComb, Jr., the same architect who later planned Montauk Point (1796) on the tip of Long Island and Eatons Neck (1799), also on Long Island, New York. All were built in the 1790s; all are still standing and similar in design.

The fifth auditor used contracts and specifications from recently built lighthouses to prepare contracts and specifications for newly authorized lighthouses. With the coming of the Lighthouse Board, which did complete detailed specifications and construction plans for each light station built, duplication of lighthouses became just a matter of taking a plan off the shelf, making changes to meet local conditions and sending them out for bid. Light stations under the Lighthouse Board were either designed at headquarters or in the district offices; in some instances, designs were bid out to contractors.

In the Long Island Sound and Connecticut area, the two-story keepers' quarters with attached light tower at one end were used at least eight times. Plans for screwpile and caisson lighthouses were used over and over again. The slightly modified plans for the screwpile Hooper Strait Lighthouse were used to build several other screwpile lighthouses in the Chesapeake Bay including Drum Point, Janes Island, as well as Laurel Point, a lighthouse apparently never built. The original Hooper Strait Lighthouse plans contain the hand written name of all of these screwpiles. The caisson lighthouse with the squat, slightly conical tower called by some a spark plug or coffee pot lighthouse is another example. It is found in New England, the Long Island Sound, Chesapeake Bay and the Hudson River. Smith Point and Wolf Trap caisson lighthouses were built from the same plans, as were the Bloody Point Bar and Sharp Island caisson lighthouses, all on the Chesapeake Bay.

There was duplication in the tall towers as well. The original drawings for Yaquina Head (1873), Oregon, were titled Bodie Island Lighthouse - North Carolina; Bodie Island (1872), was crossed out and Cape Foulweather (Yaquina Head) transcribed above the original title. While Bodie Island Lighthouse is taller than Yaquina Head Lighthouse, the details are virtually identical. Heceta Head Lighthouse (1894), Oregon, and Umpqua River Lighthouse (1894), Oregon, are nearly identical. The plans drawn in 1891 are titled Umpqua River, later the title is crossed out and Heceta Head penciled above it.

Lighthouses built of similar design are found in large areas with similar topography or site conditions. The depth of the water, solidity of the bottom, tendency for ice, availability of certain building materials, or other such environmental factors influenced the design chosen.

New England

Most of the lighthouses built in the colonies were concentrated in New England because of its relatively larger population center and because of its heavy involvement in the shipping industry. Its rocky coastline with its offshore islands and shoals was more hazardous to navigation than the rock free coast

[95] Quote given in de Gast without source.

further to the south. The earliest lighthouses were constructed principally of stone and built on rocky outcrops. The first lighthouse built, in what today is the United States, was the Boston Harbor Lighthouse (1716), a stone light tower built on Little Brewster Island, marking the entrance to Boston Harbor. Destroyed by the British during the Revolutionary War, the present rubblestone tower was constructed in 1789, the second oldest standing operational tower in the United States after Sandy Hook Lighthouse (1764), New Jersey. Boston Harbor Lighthouse is also the only officially manned light station in the United States. The first waveswept lighthouse tower in the United States was built on Minots Ledge in 1860, replacing an earlier unsuccessful pile foundation lighthouse. This stone tower is considered a feat of American lighthouse engineering.

Portland Head Lighthouse (1791), Maine, is considered one of, if not the most, photogenic of American lighthouses. It exemplifies the typical New England light station; a stone tower built on a rocky promontory. New England, however, possesses nearly every major lighthouse construction type. While Brant Point Lighthouse (1746), Nantucket, Massachusetts, was the first wooden light tower built, the oldest surviving wooden tower is generally considered to be the Plymouth (Gurnet) Lighthouse (1843), Massachusetts. The Boston Harbor Lighthouse (1716) was the first rubblestone light tower built, and the 89-foot New London Harbor light tower (1801), Connecticut, is built of cut brownstone with brick lining as is the 46-foot Faulker Island light tower (1802), Connecticut. While New England possesses numerous masonry towers, none are considered tall towers, that is, towers over 150 feet in height. Nor are any concrete masonry towers represented in New England.

Other examples of New England wave swept towers include Halfway Rock Lighthouse (1871), Maine; Whaleback Ledge Lighthouse (1872), Maine; Stratford Shoal Lighthouse (1877), Connecticut; Ram Island Lighthouse (1883), Maine; Graves Lighthouse (1905), Massachusetts; and New London Ledge Lighthouse (1909), Connecticut. Examples of cast-iron-plate lighthouse construction include Monomoy Point Lighthouse (1855), Massachusetts, with brick lining; Sandy Neck Lighthouse (1857), Massachusetts; Cape Elizabeth Lighthouse (1874), Maine; Edgartown Lighthouse (1875), Massachusetts; Nobska Point Lighthouse (1876), Massachusetts, with brick lining; Race Point Lighthouse (1876), Massachusetts, with brick lining; Chatham Lighthouse (1877), Massachusetts, with brick lining; East Chop Lighthouse (1877), Massachusetts; and Portsmouth Harbor Lighthouse (1877), New Hampshire.

Marblehead Lighthouse (1896), Massachusetts is the only known skeletal metal tower in New England. Only one screwpile lighthouse was built in New England, the Narrows (1856). It was built in Boston Harbor, Massachusetts, burned in 1929, and replaced with an automated light. New England does not possess any straightpile or disk-pile-type lighthouses.

Because of the colder climate and associated problems of ice flow damage, most offshore New England lighthouses built in protected waters such as harbors and bays are caisson types. Caisson lighthouses in New England include Duxbury Lighthouse (1871), Massachusetts; Southwest Ledge (New Haven Breakwater) Lighthouse (1877), Connecticut; Borden Flats Lighthouse (1881), Massachusetts; Stamford Harbor (Chatham Rock) Lighthouse (1881), Massachusetts; Stamford Harbor Lighthouse (1882), Connecticut; Conimicut Shoal Lighthouse (1883), Rhode Island (cast iron and granite); Latimer Reef Lighthouse (1884), Connecticut; Sakonnet Lighthouse (1884), Rhode Island; Saybrook Breakwater Lighthouse (1886), Connecticut; Hog Island Shoal Lighthouse (1886), Rhode Island (cast iron and granite); Goose Rocks Lighthouse (1890), Maine; Lubec Channel Lighthouse (1890), Maine. The last caisson lighthouse built in the United States was the Cleveland East Ledge Lighthouse (1943), Massachusetts, which was built in an art modern style. Of the eleven pneumatic caisson lighthouses built in the U.S., Plum Beach Lighthouse (1899), Rhode Island is the only New England example.

Granite and concrete caisson lighthouses made with cofferdams in New England include Penfield Lighthouse (1874), Connecticut, a granite caisson; Portland Breakwater Lighthouse (1875), Maine; Stratford Shoal Lighthouse (1877), Connecticut, granite ashlar caisson; Ram Island Lighthouse (1883), Maine; Doubling Point Lighthouse (1899), Maine; and New London Ledge Lighthouse (1909), Connecticut. A submarine caisson foundation type lighthouse is Cleveland East Ledge Lighthouse (1943), Massachusetts, made of reinforced concrete. The first Texas tower lighthouse in the United States is the Buzzards Bay Lighthouse (1961), located in Buzzards Bay, Massachusetts.

Hudson River

The Hudson River, with its maintained 30-foot-deep channel, is navigable to commercial vessels from New York City north over 150 miles to above Albany, New York. The Erie Canal (1825) and Delaware and Hudson Canal (1825-1828) provided important connections to the interior of the United States. Existing lighthouses along the Hudson River include Stony Point (1826), deactivated in 1925; Saugerties (1869), station first established in 1836; Esopus Meadows (1872), station first established in 1839; Hudson-Athens (1874); Tarrytown (1883), deactivated in 1961; Roundout Creek II (1915), station first established in 1835; and Jeffreys Hook (1921), station first established in 1889, located under George Washington Bridge and made famous by the children's book *The Little Red Lighthouse and the Great Gray Bridge*.

Delaware River and Bay[96]

The Delaware River has one of the most extensive range light systems in the world dating back to at least 1876. Range lights were being used in Great Britain by the early 1800s, and apparently were first introduced to the United States at Wolf's Island Range (1882), Georgia. The adoption of range lights, however, was slow to develop in the United States until their use on the Delaware River in 1876 when the Deepwater Point and New Castle Ranges were first placed in operation. Port Penn and Finns Point Ranges were added to the Delaware River range system in 1877, followed with the construction of the Cherry Island, Schooner Ledge, Tinicum Island, and Mifflin Bar Cut Ranges in 1880. The Horseshoe East Group and West Group Ranges were added to the Delaware River range system in 1881, and finally a pair of range lights called the Delaware Breakwater Range was added in 1885 near Lewes, Delaware.

As improvements to the Delaware River channel, or changes in alignment of the channel, were made, ranges were either added, abandoned, or moved. The Marcus Hook Rear Range Light (1920) Wilmington, Delaware, was the last manned lighthouse built along the Delaware River. The addition of the Marcus Hook Range completed the chain of high-powered ranges guiding ships from the Ship John Shoal Light Station (1874) in the Upper Delaware Bay to the port cities of Philadelphia and Camden. A series of minor ranges continues on from there to take shipping traffic upriver to a point just below Trenton, New Jersey.

The only remaining older exoskeletal tower rear range lights include Liston Range (1877), Delaware; Finns Point Range (1878), New Jersey; Tinicum Island Range (1880), New Jersey; Bellevue Range (1909), Delaware; Reedy Island Range (1910), Delaware; and Marcus Hook Range (1918)(reinforced concrete tower), Delaware. The only remaining older type front range lighthouse is Liston Front Range Lighthouse (1877) which became a private residence in the 1950s. All of the ranges have either red or

[96] This section taken from Jim Gowdy, *Guiding Lights of the Delaware River and Bay* (privately printed, Mizpah, New Jersey, 1990).

green lights except the Liston Range, which has white lights (white is easier to see over long distances). The Liston Range is the longest of the Delaware River ranges, and one of the longest in the entire world. All turns from range to range are made near turn buoys that are lit with rapidly flashing lights.

The Delaware Bay is relatively shallow and full of shoals. A lighthouse established at Cape Henlopen, Delaware, in 1767, lighted the entrance to Delaware Bay. Buoys were also used to mark the Bay at this date. Cape Henlopen Lighthouse survived until 1926 when the tower was destroyed by erosion. The north side of the Bay is lit by Cape May Lighthouse (1859), New Jersey. The first lighthouse at Cape May was established in 1823; while the present tower dates from 1859. From the entrance through the bay to the Delaware River, the channel is marked by caisson lighthouses such as Delaware Breakwater (1926), Delaware; Brandywine Shoal (1914), New Jersey; Fourteen Foot Bank (1888), Delaware; Miah Maull Shoal (1913), New Jersey; and Ship John Shoal (1877), New Jersey. Many of these caissons replaced earlier screwpile lighthouses.

Chesapeake Bay[97]

During the height of America's maritime commerce early in the 19th century, the Chesapeake Bay served as a major commercial waterway for the shipment of raw materials and finished goods between the Piedmont and Mid-Atlantic States.[98] Light stations played an important role in the economic development of the Chesapeake Bay region. The opening of the Chesapeake and Delaware Canal in 1829, the opening of the Susquehanna and Tidewater Canal in 1839, and associated aids to navigation on the Chesapeake Bay, played an important role in the economic development of southeastern Pennsylvania and Delaware as well.
Prior to the 1770s, there were no known publicly sponsored aids to navigation in the Chesapeake Bay, and from the 1770s until Cape Henry Lighthouse was first lit in 1792, there were only six buoys in the entire Chesapeake Bay, and those marked shoals at the entrance to the Bay.[99] Individuals, plantations, and some ports, no doubt used simple poles and/or branches to mark shoals and other hazards to navigation but these were not regulated and largely only understood by locals. The first buoys provided by the federal government in Maryland waters are believed to be those authorized by Congress in an act dated March 3, 1819 for marking the Patapsco River. The first lightship in the United States was placed at Willoughby Spit at the entrance to Elizabeth River, Chesapeake Bay, Virginia, in 1820.

The Chesapeake Bay with its soft bottom muds and sands was ideally suited for cottage-type screwpile lighthouse technology. No less than 49 such structures were built in the Chesapeake, more than any other body of water in the world. Many of these structures replaced lightships. Most cottage-type screwpile lighthouses have since been destroyed by ice, demolished and/or replaced by caisson lighthouses. The oldest standing cottage-type lighthouse remaining in its original location is Thomas Point Shoals Lighthouse (1875). Three cottage-type lighthouses have been moved to museum settings: Seven Foot Knoll Lighthouse (1855), Hooper Strait Lighthouse (1879) and Drum Point Lighthouse (1883). The only nuclear powered lighthouse in the United States was Baltimore Lighthouse (1908), a caisson lighthouse.

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[97]This section is derived from Ralph Eshelman's draft multiple property documentation form for Maryland Lighthouses.

[98] Ralph D. Gary, *The National Waterway: A History of the Chesapeake and Delaware Canal, 1769-1965*, University of Illinois Press, 1967.

[99] Morrison and Hanson, pp. 9, 19, 25, 47, 62.

The entrance to the Chesapeake Bay is marked on the north side by Cape Charles Lighthouse (1895); at 191 feet in height, it is the tallest exoskeletal tower lighthouse in the United States. The present tower is the third built at this site, the first dating from 1828. The southern entrance to the Bay is marked by the Cape Henry Lighthouse (1881); at 163 feet in the height, it is the tallest cast-iron lighthouse in the United States. The first tower, constructed in 1792, represents the first federal works project and still stands.

Mid Atlantic

The mid and South Atlantic coast is low and sandy, requiring tall light towers to raise the light at a height that mariners could identify at great distances out to sea. The tallest light tower in the United States, Cape Hatteras (1870); the tallest cast iron light tower in the United States, Cape Henry (1881); and the largest concentration of tall coastal towers in the United States (150 feet or taller), are all located along this stretch of the coast. Because the topography was generally uniform and undistinguished, day marks were especially important along this section of the coast as well. The unique black and white diamond pattern on Cape Lookout Lighthouse (1859), black and white spiral pattern on Cape Hatteras Lighthouse (1870), black and white vertical rectangular pattern on Cape Henry Lighthouse (1881), the black and white horizontal bands on Bodie Island Lighthouse (1872), and the red and white horizontal bands on Assateague Lighthouse (1867), make the mid Atlantic coast line the most diverse collection of daymarks in the country and possibly the world.

South Atlantic

By the end of the American Revolution, the southeastern coast was marked by only two lighthouses: the Charleston Lighthouse (1767) on Morris Island, South Carolina, and Tybee Lighthouse (1773) near Savannah, Georgia.[100] The entire coastline south of the Tybee Lighthouse remained unmarked for the next 50 years, as the Spanish government had done nothing to mark the harbors or the coastline of Florida. The United States established harbor lighthouses at St. Augustine (1824) and St. Johns River (1830), but both were not adequate for coastal navigation until St. Johns River Lighthouse was rebuilt in 1859 and St. Augustine Lighthouse in 1874.

No initial action was taken to achieve a system of lights along the southeastern coast of the United States until a lighthouse was constructed at Mosquito Inlet (Ponce de Leon Inlet) in 1835. However, this light never functioned as oil for the lamps was not delivered when the light was completed or before a storm undermined the tower's foundation, and it collapsed. A new lighthouse was not established at that site until 1887, in part because of the Seminole Indian Wars. Cape Canaveral Lighthouse (1848) was so ineffectual that many vessels ran up on the surrounding shoals as they searched for the light. The Jupiter Inlet Lighthouse (1860) was the most effective seacoast lighthouse in Florida outside of the Keys.

[100]Tybee Island was the site of an early daymark tower 90 feet in height dating from 1736. The tower also served as a rear range for the Wolf Island Range in 1822. The present 1867 tower is built on the base of the third 1773 tower. The daymark was not lit until 1790.

Florida Keys[101]

Sailing southwest and westward along the Florida Keys at night could be dangerous because vessels must hug the treacherous coral reefs lying offshore to avoid the strong current of the Gulf Stream flowing in the opposite direction. In daylight and in clear weather, navigation was easier because of the distinct color contrasts in these waters. Shallow water over the reefs is light green, mottled with brown. The deep waters of the Gulf Stream are dark blue. At night and in storms, these color guides disappear.

When the United States acquired the Louisiana Territory in 1803, new ports along the Gulf Coast developed, and the Florida Straits became one of the busiest shipping routes in the world. Flatboats carrying lumber, livestock, and farm produce from inland states down the Mississippi River to New Orleans unloaded their cargo onto sailing vessels to be shipped to eastern seacoast ports and to Europe. All the ships sailed along the dangerous coast of the Florida Keys, vulnerable to piracy and to the navigational hazards of the reefs. Wrecks abounded. Salvaging, referred to as "wrecking," became almost as lucrative as piracy.

In 1819, Spain ceded all of Spanish Florida to the United States. Lighthouses were established at Cape Florida (1825), Key West harbor (1825), Sand Key (1826), and Garden Key (1825) in the Dry Tortugas; a beacon and buoys were placed between the Dry Tortugas and the Florida coast; and a lightship was stationed at Carysfort Reef (1825).

In 1848, Stephen Mallory, the collector of customs at Key West, emphasized in his report to Congress that three-fifths of the cargoes lost on the Florida reef had come down the Mississippi River, and three-fourths of the vessels salvaged were owned in the northern and eastern states. He urged Congress to appropriate funds for a survey of the Florida reef for the purpose of compiling up-to-date hydrographic charts of the area. Mallory called the passage along the Florida Keys "a great highway of commerce," and pointed out that along this sea route "property of every section of our Union is afloat." He urged Congress to make every effort to make the route thoroughly safe and to "remove every excuse for shipwrecks." In addition, appropriations were approved in 1847 for rebuilding the lighthouses at Key West and Sand Key, which had been destroyed in an 1846 hurricane, and for erecting a lighthouse at Carysfort Reef. Further appropriations for lighthouses were made during the next four decades.

Difficult as it was to build lighthouses on land, the task was even more demanding in the Florida Keys, where eight submarine sites were chosen. Of the original lighthouses built from Cape Florida to the Dry Tortugas, six still stand and are functioning today: Carysfort Reef (1852), Sombrero Key (1858), Dry Tortugas (on Loggerhead Key) (1858), Alligator Reef (1873), Fowey Rocks (1878), and American Shoal (1880). The Sand Key Lighthouse (1853), another exoskeletal tall tower screwpile lighthouse, was extensively damaged by fire in 1989, but not destroyed. The lighthouses built at Cape Florida and at Key West to replace the ones destroyed by storms have both been discontinued, but the sea route between Cape Florida and the Dry Tortugas is well marked by daymarks and lighted beacons.

Caribbean

Through the years, the United States has acquired territories that had ongoing or incipient lighthouse systems. The most advanced of these foreign systems was in Puerto Rico. In 1853, the Spanish erected the first lighthouse in Puerto Rico atop the old fortification of El Morro at the entrance to San Juan

[101] Taken from Love Dean, *Lighthouses of The Florida Keys* (Historic Florida Keys Foundation, Inc. Key West, Florida, 1992).

Harbor. Other lighthouses were placed around the island as marks into harbors and as warnings to hazards. These were complete light stations with quarters for the keepers and their families, and the towers were equipped with Fresnel lenses. With 13 light stations in place and two under construction, only a single lighthouse had to be added when the U.S. Lighthouse Board took over administration of Puerto Rico's aids to navigation.[102]

The Virgin Islands, while under rule by Denmark, had five lighthouses erected, most in the early part of the twentieth century. As in Puerto Rico, these lights were satisfactorily placed, and over the years, the United States has had only to add small lights, such as harbor, range and buoy lights.[103] The Navassa Island Lighthouse (1917), Windward Passage, West Indies, at 162-feet in height, was the tallest reinforced concrete tower when built.

Gulf of Mexico[104]

When the French owned the Louisiana Territory, there is some evidence that a lighthouse existed at "The Balize" which is a French word for beacon. Reportedly, a light tower had been built at the mouth of the Mississippi River by 1721, perhaps earlier.[105] The first lighthouse in the U.S., built outside the 13 original English colonies, was completed at Bayou St. John on August 5, 1811. The first U.S. lighthouses built along the Gulf of Mexico were copies of the proven New England brick towers; however, the softer soil of the Gulf Coast could not support the weight of these towers. Of the 40 or more constructed, 25 sank into the bottom or blew over, having no solid footing. By the 1840s, integral lighthouses, consisting of frame dwellings with the lantern mounted on top, were used. These could be moved to escape erosion. Iron screwpile lighthouses appeared along the coast prior to the Civil War. These offered a more stable foundation and were built either according to the cottage style used in the Chesapeake Bay or as tall iron skeletal towers.[106]

The opening up of the Midwest spurred a boom in commercial activity. Ports handling outbound cotton and inbound consumer goods grew rapidly. By the 1830s, the small ports along the Gulf were shipping as much cotton as the entire state of South Carolina; within 30 years, cotton accounted for 57 percent of all U.S. exports -- virtually all of it shipped out of the Gulf. The cotton trade spurred the lighthouse-building boom in the 1830s. Steam-powered riverboats were becoming increasingly common. The rivers became the "interstate highways" of the first half of the 19th century. Initially, the surge of railroads throughout the heartland increased trade flowing into and out of the Gulf. As the century progressed, the United States spent less and less on the construction of canals and toll roads (turnpikes) and more and more on the improvement of aids to navigation, especially lighthouses. The introduction and perfection of steam dredging permitted the Corps of Topographical Engineers to deepen the Gulf's shallow harbors. The federal government scrambled to light up the waterways and the new ports that

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[102] Wayne Wheeler, personal communication, February 28, 1998.

[103]Holland, *America's Lighthouses*, pp. 200-201; Lighthouse Service, *Light List, Atlantic and Gulf Coasts, 1933*, pp. 528-530.

[104] Taken from David L. Cipra, *Lighthouses, Lightships, and the Gulf of Mexico* (Cypress Communication, Alexandria, Virginia, 1997).

[105]David L. Cipra, *Lighthouse and Lightships of the Northern Gulf of Mexico* ([Washington]: Government Printing Office, c1983), p. 32.

[106] David Cipra, *Lighthouses, Lightships, and the Gulf of Mexico*, pp. 7-8.

were drawing in so much foreign income -- St. Marks, Apalachicola, St. Joseph, Pensacola, Mobile, Mississippi Sound, Lake Pontchartrain, the Mississippi River, and Atchafalaya Bay.

By the 1850s, technology had a direct impact on lighthouse construction. The new screwpile foundation was introduced into the Gulf, permitting, for the first time, the erection of lightweight structures (compared to stone and brick) in shallow, slow-moving water, on a mud, sand, or coral bottom. Three screwpile lighthouses were built in Galveston Bay in 1854.

The next lighthouse construction technology to be introduced in the Gulf was that of cast iron towers. Like the screwpile, a few had been built before the Civil War, but none in the South. Cast iron tower construction offered numerous advantages over the classic stone and brick towers. First, it was lighter and could be made watertight. Second, it could be produced and prefabricated in the convenience of a workshop and then transported to the building site. Third, a cast iron tower was strong and allowed for the standardization of designs. Fourth, it could be dismantled and moved if threatened by erosion. The first tall, skeleton tower lighthouse to be built in the Gulf was completed at Southwest Pass, Louisiana, in 1873. This design possessed the same advantages as the conical cast iron tower but was lighter.

In 1851, a provisional lighthouse board surveyed the Gulf and recommended that 14 new lights be added. The goal was to place a light every 50 miles along the coast. Lighthouses were built at 10 of the sites, and the others were marked by unmanned, minor lighted aids. At the turn of the decade before the Civil War, with commerce still booming, the potential for additional lighthouse construction in the Gulf looked bright. New Orleans was the fifth largest city in the United States; bumper crops of cotton were carried out of Gulf ports in both 1859 and 1860. The saga of lighthouses in the Gulf radically changed on July 8, 1861, when Confederates seized Ship Island, renamed it Fort Twiggs, and extinguished the light in the lighthouse. With the beginning of the Civil War, other lighthouses were extinguished one by one, and darkness fell on the Gulf Coast that would last for over five years.

Without economic recovery in the South following the Civil War, new lighthouses would not have been built in the Gulf. And recovery was not easy. Many in the North, which controlled the federal purse strings, held ill will towards the recently defeated South. Also, the rapidly expanding railroads were challenging the cost-effectiveness of waterborne transportation. Although the number of steamboats using the river system which drained into the Gulf dramatically declined during the second half of the 19th century, the volume of goods carried by water increased as powerful towboats pushed and pulled barges, each one doing the work of several side-wheel steamers. By the 1880s, barges carried one-third of all cargo on the lower Mississippi, and the percentage continued to increase. Waterborne trade on the upper Mississippi and its tributaries declined as new railroad lines increasingly made Chicago the hub of the Midwest. Also, cotton gave way to coal as the most important cargo, and that, in turn, gave way to petroleum produced during the second half of the 20th century. Although these new trade patterns had a negative impact on the shipbuilding industry in the Gulf, the need for lighthouses and other navigational aids to guide the barge traffic increased. Also, Louisiana had once again become the state through which the most waterborne traffic passed.

Great Lakes

The Great Lakes "offer more variety of dangers than any other ocean. Their violent storms, including winter gales, as well as fog and ice, match anything found on the seven seas. The Lakes' many narrow

and shallow passages, combined with the great volume of traffic, have produced another set of dangers."[107]

Completion of the Erie Canal in 1825 that linked New York City with Buffalo on Lake Erie, marked the start of explosive growth in the Great Lakes region.[108] The canal provided a direct cheap route between the Middle West and the Atlantic Coast. Within a few years, shipments of grain, lumber, and coal, increased from West to East, and manufactured goods from East to West. In 1855, the opening of the St. Mary's Falls Ship Canal at Sault Ste. Marie touched off the rapid development of the enormous iron ore and copper deposits found on Lake Superior. The Great Lakes linked the natural resources and agricultural lands of the Middle West with the industrialized East Coast and the rest of the world.[109]

The development of a system of lights on the Great Lakes came with the expansion of shipping and settlement. The construction of lighthouses was not only parallel to the growth in commerce, but a prerequisite. Forty-three lights were in operation by 1840 including 17 on Lake Erie, 11 on Lake Michigan, nine on Lake Ontario, four on Lake Huron, one on Lake St. Clair, and one on the Detroit River. Thirty-three more were introduced from 1841 to 1852 with Lake Superior receiving six. In 1852, 76 of the 331 lights operating nationally were in the Great Lakes. In 1860, the lights numbered 102. At the turn of the century, the Great Lakes had 334 major aids, 67 fog signals, and 563 buoys.[110] Virtually all the light stations in use today on the Great Lakes were built by 1925.[111]

Total shipments on the Great Lakes increased from 4 million tons in 1852 to 80 million tons in 1910. Tonnage reached 169 million tons in 1941, and by the early 1970s, shipments averaged more than 200 million tons per annum with iron ore making up half the total. Through the 1870s, lumber and grain accounted for three-quarters of the total shipments, and by 1910, iron ore accounted for half the tonnage, with coal making up another quarter. Iron mines in the Lake Superior region produced three-quarters of American ore after the turn of the century, and it was transported by water to major iron and steel plants. During the 1888 navigation season, the port of Chicago had approximately 20,000 arrivals and departures of major vessels in an eight-month period compared with 23,000 in New York City. In 1910, the Great Lakes fleet made up more than one-third of the tonnage of the entire American merchant fleet.[112]
For the most part, the light stations in the Great Lakes were made of masonry (some of stone but the great majority of brick). Wooden ones were built such as Mission Point (1870), Michigan, and the half wood-half brick Michigan City Lighthouse (1858), Indiana, on Lake Michigan, the Round Island Lighthouse (1895), on St. Mary's River, Michigan, and some of the range lights. A few were made of metal plates or towers covered with metal plates to protect the brick under them. Pierhead lights erected

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[107]Charles K. Hyde, *The Northern Lights: Lighthouses of The Upper Great Lakes* (Detroit: Wayne State University Press, reprint 1995), p.194.

[108] Hyde, p. 15.

[109]National Register Nomination, "United States Coast Guard Lighthouses and Light Stations on the Great Lakes" 1983.

[110] Hyde, pp. 15-16, 20.

[111] National Register Nomination, "United States Coast Guard Lighthouses and Light Stations on the Great Lakes" 1983; Hyde, p. 38.

[112] Hyde, pp. 15-16, 20; National Register Nomination, "United States Coast Guard Lighthouses and Light Stations on the Great Lakes" 1983.

on piers projecting out into the lakes served to guide vessels into the harbors along the coasts. Pierhead lights are occasionally used on the east coast, but normally there is only one at the head of the pier. Also, the lights guiding vessels into east coast harbors are usually lighthouses erected on land. On the Great Lakes, pier head lights often come in pairs, an outer light and an inner light to help guide vessels through the harbor entrance, and are normally made of metal plates. They come in several different forms. Some have the configuration of a house with a light tower on it such as the Holland Harbor Lighthouse (South Pierhead) (1936), Michigan, which is actually a structure that has been covered with metal to help preserve and protect the original fabric. Others are typical lighthouse towers, some round, some square. Another type that is common is a metal clad square structure with an octagonal metal tower rising out of the center of the pyramid roof. The Michigan City (1858), Indiana, pierhead is typical of this type. Breakwater lights are first cousins to the pierhead lights. They are usually at the head of the breakwater and are single lights. They can be different shapes, but, generally, they are tower-like.[113]

Many lighthouses on the Great Lakes were built to the same designs. Most variation was between harbor and coast lights. Before 1870, the most common design consisted of a frame or brickkeeper's dwelling with the lantern mounted directly atop the dwelling or on an attached 25- to 40-foot square tower. Taller coastal towers were conical masonry (generally brick), often connected to the keeper's dwelling by a covered passageway. A few large skeletal towers were built before 1870. Few tall towers were built after the turn of the century, and those that were utilized steel skeletal frames.[114]

After the Civil War, the Lighthouse Board moved most harbor lights from the mainland onto newly built piers and breakwaters. Pier lights were generally simple wooden or metal towers manned by a keeper who lived in an onshore residence. Few of the early pier and breakwater lights survive because of numerous pier extensions and the destructive effects of storms and ice. In the first two decades of this century, most of the harbor lights were replaced with steel-framed structures encased in cast-iron or steel plates.[115]

Offshore lights were designed with the assistance of U.S. Army Corps of Engineers personnel. Most challenging to construct were those with a submarine crib foundation beginning with Waugoshance Shoal Lighthouse (1851). The Great Lakes, with its hard rocky bottoms, has the largest number of crib foundation lighthouses in the United States. Before the use of crib foundation, lightships were used in extremely hazardous locations where lighthouses were considered too costly to build.[116]

West Coast[117]

Prior to the building of the transcontinental railroad in 1869, the west coast of the United States was dependent upon maritime transportation for its connection to the rest of the world. North-south railroad links were not completed until 1887. Even road networks were not sufficiently developed until well into

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[113]Holland, Chapter 1, 1993 draft National Historic Landmark context study on lighthouses.

[114] Hyde, p. 23; National Register Nomination, "United States Coast Guard Lighthouses and Light Stations on the Great Lakes" 1983.

[115] Ibid.

[116] Hyde, pp. 23-24.

[117] Holland

the 20th century. With this heavy dependence on water shipping, it is not surprising lighthouses were relatively early developments for the west coast.

Francis A. Gibbons of Baltimore, in addition to building Love Point Lighthouse (1872), and repair work on Point Lookout (1830) and Sharps Island (1838) lighthouses in Maryland, also built Bodie Island Lighthouse (1847), North Carolina, and Egmont Key Lighthouse (1848), Florida. Pleasonton said, Gibbons "has done some work very faithfully for us." Gibbons most ambitious lighthouse endeavor, however, was obtaining a contract in partnership with Francis X. Kelly in 1852 to construct the first eight lighthouses on the West Coast of the United States. They obtained a bark appropriately named *Oriole*, acquired materials and laborers, and sailed for the West Coast. Despite the wrecking of *Oriole* at the mouth of the Columbia River, these two Marylanders completed all eight lighthouses by 1856.[118]

The first lighthouses on the west coast, designed at about the same time as the one at Blackistone Island (1851), Maryland, were intended to use the Argand lamp and parabolic reflector lighting system. The masonry tower rose from the foundation, through the center of the dwelling and through the roof. The towers of the eight lighthouses were each substantial enough to stand by themselves. The lanterns were not, however, of a proper size to support the recently adopted Fresnel lens. The District Inspector, Major Hartman Bache, was a pragmatic person, and solved the problems in different ways. At Farallon Islands, he tore down and rebuilt the lighthouse to receive a first-order lens. At the Point Loma Lighthouse (1855) in San Diego, California, he decided to use the smaller third-order lens. But even with the smaller and lighter lens, he had to have the tower strengthened by increasing the thickness of the domical arch (the ceiling of the tower) to support a third order lens.[119] Many later West Coast light towers were integral to the fog signal building. Examples include Point Sur Lighthouse (1889), California; and Coquille River Lighthouse (1896) and Cape Arago Lighthouse (1934), both in Oregon.

Steel, in concrete structures, provides the tensile properties concrete lacks. Most major reinforced concrete towers are found on the West Coast where they are best adapted to the dangers of earthquake damage. Examples include Point Arena (1908) and Point Arguello Lighthouse (1934), both California. A series of art-moderne reinforced concrete lighthouses were built along the Alaska coast in the 1920s and 1930s, replacing earlier deteriorated wooden structures.[120] Examples include Cape Decision (1932), Cape Hinchinbrook (1934), Cape Spencer (1925), Cape St. Elias (1916), Five Finger Islands (1935), Point Retreat (1923), Sentinel Island (1935) and Tree Point (1935).

On the west coast, a number of lighthouses have been placed where coasting traffic makes a course change or leaves the coast. These are major lights, usually of the first order. Cape Mendocino (1868) in northern California was a turning point for both north and southbound traffic. This light was particularly important because it also guards vessels against nearby dangerous waters. Point Sur (1889) and Piedras Blancas (1879) are two lighthouses marking the point for departure or return to the coast, depending on the direction in which the vessel is traveling.

The west coast has several lighthouses built just offshore on rocks that are serious hazards to navigation. Tillamook (1881), Oregon, and St. George (1892), California, are two such lighthouses, and they were

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[118] Holland, chapter 3, p. 24.

[119] F. Ross Holland, *The Old Point Loma Lighthouse* (San Diego: Cabrillo Historical Assn., 1978), pp. 16-19.

[120] Clifford, pp. 3, 4, 5, and 6; and Jack Bookwalter, Light Stations of California, Multiple Property National Register Nomination, 1989, p. F. II 5.

difficult and expensive to build because of their offshore location and rough seas. Tillamook served as a warning of the rock and as a guide to the Columbia River. St. George, on an offshore reef, guarded ships against a larger area of rocks and shoals.

Hawaii

The first Hawaiian lighthouse was a 9-foot wooden tower built in 1840 at Lahaina, a prosperous whaling port. Built by Kamehameha III, this light was also the first lighthouse constructed in the Pacific. The U.S. Lighthouse Board assumed responsibility for navigational aids in Hawaii in 1904. By 1917, there were 58-lighted aids, and that number tripled by the 1980s. Three of the most prominent ones were the Molokai Lighthouse (1909) on the north shore of Molokai Island, Makapuu Point Lighthouse (1909) on the eastern end of Oahu Island to guide traffic from the east, and Kilauea Point Lighthouse (1913), another coastal light serving traffic from the west. Makapuu Point Lighthouse exhibits a hyper-radiant lens, the largest of the Fresnel type, and the only one ever used in an American lighthouse. The lack of fog allowed lighthouses to be built at elevations not practical at other sites. The Lehua Rock lighted aid is 704 feet above sea level, and the Kaena Point Lighthouse on Oahu is 931 feet above sea level. [121]

PART III. EVOLUTION OF LIGHTHOUSE OPTICS

Early lights

The most important advances in lighthouse technology over the years concerned the light. The earliest lights were primitive -- consisting of a flame at night and smoke during the day. The first navigational aids were probably fires on a hillside or hilltop. When the first known lighthouse structure, the Pharos of Alexandria, was erected, the fuel -- animal dung, bundles of reeds or fiber such as cotton soaked in oil -- was transported to the top of the structure, which may have had some sort of covering that kept rain from dampening the flames. Constructed at the entrance of the Egyptian harbor near the mouth of the Nile around 280 B.C., this lighthouse was estimated to have a height of 450 feet. Out of service by 800 A.D., an earthquake destroyed the tower in 1340. Later towers that were erected used open fires, but some began to use torches.[122] The use of the open fire, fueled by coal and wood, continued on some light towers until well into the 19th century in Britain, Sweden, and Norway.[123]

There is no evidence that American colonial lighthouses used open fires on their towers. Rather, candles were used in American lighthouses until after the Revolution. Spider lamps came into use in the 1790s. These flat bowls of oil had four or more protruding wicks, which when seen from a distance appeared as a single light source. The use of several wicks and/or lamps was necessary because the candlepower of a single lamp, even with a reflector, was insufficient to provide adequate navigation light at great distances. Acrid smoke from these spider lamps irritated the eyes and nose of the keepers. Nevertheless, these lamps were the principal means of illuminating lighthouses in this country until the

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[121] A comprehensive and excellent book on Hawaii's lighthouses is Love Dean, *The Lighthouses of Hawaii* (Honolulu: University of Hawaii Press, c.1991); see pages 1-2. Ross R. Aikin, *Kilauea Point Lighthouse: Landfall Beacon on the Orient Run* (Kilauea Point Natural History Assn., c.1988) is a similarly fine book on an individual Hawaii lighthouse.

[122] D. Alan Stevenson, *The World's Lighthouses Before 1820* (London: Oxford University Press, 1959), pp. 5, 8.

[123] Douglas B. Hague and Rosemary Christie, *Lighthouses: Their Architecture, History and Archeology* (Wales: Gomer Press, 1975), p. 150.

introduction of a version of the Argand lamp and parabolic reflector system by Winslow Lewis, an unemployed sea captain and New England businessman.[124]

Argand lamps and parabolic reflectors

The Argand lamp, developed in 1781 by Ami Argand of Switzerland, was unique because it had a round hollow wick. Such a wick permitted oxygen to flow up both the outer and inner sides of the wick, giving off a brighter, relatively smoke-free light. One lamp was equivalent to the brightness of seven candles. A metal reflector, purportedly parabolic in form, was placed behind the lamp, and in front of it was a lens. The lens was relatively worthless, since its greenish tint actually diminished the light, but many years passed before they were removed from active lights.

The tests of Lewis's new lighting system were conducted at the Cape Ann, Massachusetts, twin lights established in 1771. In addition to giving a brighter light, the new lamps also burned about half the oil of the spider lamps. Boston Collector of Customs, Henry Dearborn, observed the test and was so impressed that he convinced the Secretary of the Treasury to acquire Lewis's patent.[125]

In 1815, Winslow completed the installation of his new lighting system in all the country's lighthouses. The Lewis lighting apparatus installed in the Thomas Point Shoals Light Station in 1825 consisted of 13 Argand lamps backed by 16-inch-diameter reflectors. From the beginning, these lights were under nearly constant criticism. Part of the problem was caused by the optics themselves and the rest by the lack of training for keepers at that time. The reflectors were supposed to be parabolic, but one lighthouse historian, who worked for the Lighthouse Board and wrote a history of the lighthouse service, said the reflectors approached the paraboloid about as closely as did a barber's basin.[126] Moreover, the keepers generally did not keep the lamps, reflectors, and lantern glass panes clean. The powder given to them to clean the reflectors, when used, was abrasive and tended to wear the silvered coating off the reflectors.[127] Many mariners objected to the lighting system and urged that the United States adopt the Fresnel lens in the country's lighthouses. But Pleasonton, who was influenced by his friend Lewis, felt the new lenses were too expensive and too difficult for the keepers to tend.[128]

The Fresnel lens

The Fresnel lens, developed in the 1820s by Augustin Fresnel, a French physicist, is made up of a collection of glass prisms set in a brass frame in a beehive or clamshell shape. The prisms are mathematically arranged to capture 65 to 70% of the light emitting from the central light source or lamp. The light rays are bent by the prisms into one horizontal sheet of light that in a fixed lens shows a steady light and in a revolving produces a flash or a characteristic. Fresnel lenses were eventually produced in seven standard orders or sizes, numbered one through six. Orders one through three, the largest, were

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[124] F. R. Holland, Jr., *America's Lighthouses; Their Illustrated History Since 1716* (Brattleboro, VT: Stephen Greene Press, 1972), p. 14.

[125] Holland, *America's Lighthouses*, p. 15.

[126] Johnson, p. 23 .

[127] Holland, *America's Lighthouses*, p. 16.

[128] Ibid., p. 18.

used in coastal lights, while four through six were used in harbor or bay lights. Later a three-and-a half order lens was developed, which were used most often on the Gulf coast and the Great Lakes.[129]

Sizes of Fresnel Lenses		
Order	**Inside Diameter**	**Height**
1st	72 7/16-inches	7-foot, 10-inches
2nd	55 1/8-inches	6-foot, 1-inches
3rd	39 3/8-inches	4-foot, 8-inches
3 1/2	29 1/2-inches	3-foot, 8-inches
4th	19 11/16-inches	2-foot, 4-inches
5th	14 3/4-inches	1-foot, 8-inches
6th	11 3/4-inches	1-foot, 5-inches

In March 1851, Congress prescribed that lens lights be installed in all new lighthouses and all lighthouses not having illuminating apparatuses.[130] With the legislation establishing the Lighthouse Board to manage the country's aids to navigation, came authorization to install Fresnel lenses in all lighthouses. By the Civil War, all lighthouses had been fitted with Fresnel lenses.[131]

Fresnel lenses were illuminated by one lamp, and the lamps were of varying sizes and had one to five concentric wicks (technology borrowed from Argand's lamp). The size of the lamp used depended upon the size of the lens. A sixth order lens had a lamp with one wick, while a first order lens had a lamp with five circular wicks, one inside the other.[132]

Modern lenses

Many lighthouses still have their classic Fresnel lenses; in others, large aerobeacons or small plastic-type lenses have replaced the glass lenses. Coastal light towers use aerobeacon-style lenses which can be seen 25 miles, while lighthouses needing a smaller range are equipped with small acrylic lenses (generally, 250 mm which can be seen for 17 miles); 300 mm lights are used in backup systems in major coastal lights.[133] Now that larger vessels usually have more sophisticated equipment such as GPS, radar, radiobeacons, and electronics gear that can communicate with the navigation satellite, it is the smaller vessels without this equipment that rely on lighthouses for navigation.

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[129] Two larger orders or sizes were developed later: the meso-radial (none in the U.S.) and hyper-radial (one at Makapuu Light, HI). Personal communication, Wayne Wheeler, President, U.S. Lighthouse Society, February 28, 1998.

[130] *Report of the Officers Constituting the Lighthouse Board*, Feb. 5 1852, *32nd Congress, 1st Session, Senate Executive Document No. 28* (Serial #617), p. 125.

[131] Holland, *America's Lighthouses*, p. 21.

[132] U.S. Lighthouse Board, *Instructions to Light-Keepers and Masters of Light-House Vessels, 1902* (Washington: Government Printing Office, 1902), plates 1-8. (Photo reproduction by the Great Lakes Lighthouse Keepers Assn., Allen Park, MI, 1989).

[133] Wayne Wheeler, personal communication, February 28, 1998.

The acrylic-type Fresnel lenses contain small bulbs or lamps that are about the size of a Christmas tree bulb. Two to six of these lamps are attached to a rotary so when one burns out, another moves into position automatically. These lights are often powered by solar batteries. The teams that check these lights could probably visit a lighthouse once a year and expect to find everything working normally, but Aids to Navigation teams visit more frequently for safety reasons.

Visibility

The focal height is the height of the lens' focal plane above high water. The theoretical visibility of a light under good conditions depends on the focal height of the light, the intensity of the light source, the strength of the lens, the clarity of the atmosphere, and the height of the observer. The geographical range of a light is determined by the height while the luminous range is determined by the intensity. In general, the luminous range is greater than the geographical range. Heights above 250 feet gain little advantage due to the curvature of the earth. Theoretically, the focal plane of a light at 100 feet above sea level has a geographical range of 11.5 nautical miles; a light at 250 feet has a geographical range of 18.2 nautical miles, and a light at 350 feet a range of 21.5 nautical miles. The most powerful lenses today have the capacity to be seen up to 26 miles but would need to be placed in towers over 500 feet in height. However, the *Light List* indicates the 193-foot tall focal plane for the Cape Hatteras Lighthouse, North Carolina, has a range of 20 miles and the Makapuu Point Lighthouse, Hawaii, with a focal plane of 420 feet, has a range of 28 miles.

In the early days of lighthouse development, there were very few lighthouses making it relatively easy to distinguish one light from another. Multiple lights, generally twin towers, were an early means to distinguish lights. Among the more well known in the United States are the Three Sisters Lights (1838), consisting of three separate towers on Cape Cod, Massachusetts; Navesink Twin Lights (1862), consisting of two attached towers at Highlands, New Jersey; and Cape Ann (Thachers Island) twin towers, Massachusetts. As lighthouses increased in numbers and the possibility of lighthouse lights being confused with other bridge, tower, city, street, and other lights, variations in lighthouse light characteristics were developed to distinguish them apart. Flashing lights with various periods of eclipses enabled lights to be better distinguished from one another. Perhaps the most famous is Minots Ledge Light which flashes one-four-three pattern or I LOVE YOU, every 30 seconds. Red and green glass was also used to distinguish one side of the harbor channel from another. Prudence Lighthouse, (1852), Rhode Island, had maintained a green colored light since 1939. Red panes of ruby glass, and later red acrylic plates, are used to indicate dangerous sectors of a light. A vessel observing a red sector knew it had to move in a different direction to get into the white, or safe, sector of the light upon approaching or passing the lighthouse. Coast Pilots and *Light Lists* contain light characteristic information for each lighthouse.

Illuminants

When first introduced in this country, lamps burned whale oil, specifically head or case oil from the sperm whale. When the Fresnel lens was introduced into this country, the sperm whale fishery was on a decline and sperm oil, the finest oil known at the time, was increasing in price. In 1851, it was $1.30 to $1.50 per gallon. Four years later, it was $2.25 per gallon. The investigating committee, recognizing that the price would continue to rise, asked Professors Morfit and Alexander, of the University of Maryland, to study the problem. They conducted a set of experiments utilizing several grades and combinations of whale, shark, fish, seal, colza, lard, and mineral oils. They recommended colza oil, feeling it had the greatest potential since it was in use in the French lighthouse service, and testing by distinguished lighthouse engineers and scientists, such as Fresnel and Robert Stevenson, established it to

be better than sperm oil. Moreover, it was less expensive than sperm, having been obtained recently from France at about 60 cents a gallon. The board recognized that colza oil came from rape seed and rape, or wild cabbage, not grown in this country. The board dismissed this factor with the thought that rape is suitable for growing in nearly all sections of the United States, and if a market were created, farmers would start planting rape.[134] Farmers did not respond as the board had anticipated and did not cultivate enough rape to supply the needs of the lighthouses.

Gas was also experimented with. The first gas tests were in 1818 when David Melville ran tests on the use of gas made from resin at Beavertail Lighthouse in Rhode Island. Apparently successful, the government nevertheless did not want to adopt gas because of the negative impact it might cause to the whalefishing industry.[135] In 1841, Pleasonton installed a furnace and retort at Christiana Lighthouse in Delaware Bay and conducted a test on the use of gas made from resin. It would appear he was not familiar with the Beavertail Lighthouse experiment. In the late 1840s, three other lighthouses were equipped with furnaces and retorts. These tests were not successful because Pleasonton believed, "the keepers were averse to making and burning gas, but preferred the oil lamps." Though the gas was produced cheaply, he recommended the experiment cease.[136] The Jones Point Lighthouse in Alexandria, Virginia used gas from a local supplier from the end of the Civil War until 1900 when it was changed to an oil lamp. In 1919, it was converted to acetylene.[137]

The Lighthouse Board turned to other potential fuels for the lighthouse lamps. Joseph Henry, a member of the board, resumed experiments on the use of lard oil. Previous tests had not been successful, because the oil did not burn satisfactorily. But from the renewed testing, Henry found out that the lard oil burned quite well if heated to a high enough temperature. The board was delighted and quickly began using that oil in the lamps of the larger lenses, and by 1867, lard oil was in use in all the lighthouses.[138]

A few years later, the board began experimenting to find other fuels and focused on mineral oil, or kerosene. Kerosene had been known as a fuel for some years previous to these tests, but a serious accident in 1864 in a Great Lakes lighthouse made the Lighthouse Board suspicious of this fuel. The new tests showed that it could burn quite well and safely. It would, however, be necessary to alter the lamps to use the oil. The conversion to mineral oil began in the smaller lamps in 1878 and ended with the converting of the lamps in first order lenses, completing this work in 1885.[139]

The next step, and an important one, was the development in France in 1898 of the incandescent oil vapor (IOV) lamp. The principle of this lamp is the same as the Coleman lantern so popular with today's campers. "In this lamp," said Commissioner Putnam, "the kerosene, forced into the vaporizer by air pressure, is heated and vaporized, and is burned mixed with air under a mantle, which is then brought to a brilliant incandescence." The light from this lamp was far brighter than that from the oil lamp. The

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[134] *Report of the Officers Constituting the Lighthouse Board*, pp. 119-120.

[135] Sarah C. Gleason, *Kindly Lights: A History of the Lighthouses of Southern New England* (Boston: Beacon Press, c.1991), pp. 61-77, has a full and interesting discussion of this experiment and the opposition to it.

[136] *Report of the Officers Constituting the Lighthouse Board, 1852*, pp. 273-274.

[137] F. Ross Holland, Jr., *Great American Lighthouses* (Washington: The Preservation Press, c.1989), pp. 157-158.

[138] Holland, *America's Lighthouses*, p. 23.

[139] Putnam, *Lighthouses and Lightships of the United States*, pp. 185-186.

candlepower of the Cape Hatteras light went from 27,000 to 80,000 after the IOV lamp was installed. Furthermore, the consumption of oil dropped dramatically. It was first used in an American lighthouse in 1904 at the North Hook beacon on Sandy Hook, New Jersey.[140]

The next step, and one that led to the wholesale automating of lighthouses, was the introduction of electricity. Electricity was first used in an American lighthouse in 1886 with the completion of the Statue of Liberty. The light emanated from panels cut in the flame of the torch. The statue was not satisfactory as a lighthouse, and after 17 years, the lighting equipment was removed. Other experiments were conducted over the years, but there was little movement toward electrifying lighthouses. As late as 1915/ the Lighthouse Service felt that the IOV lamp was the illuminant of choice in lighthouses, and the only primary lighthouse using electricity at that time was the Twin Lights of the Navesink.[141]

The Service thought electricity too expensive to install. But as power lines spread over the country, the cost of installing electricity began to drop, and in the 1920s and 1930s more and more lighthouses became electrified. Some lighthouses used electricity from generators. In time, automation of some of these lights began to occur. A timer would be placed in the light tower to turn the light on a little before sunset and off shortly after sunrise. In the center of the lens where there was once the oil lamp, a small stand held a rotary lamp changer that held two 1,000-watt bulbs or lamps as they are officially called. When a bulb burnt out, the rotary lamp changer automatically moved another lamp into place. About once a week, Coast Guard personnel checked the light tower to be sure everything was functioning properly, and at that time changed any burned out lamps.

Acetylene was first used in this country in 1902 and has since served usefully. It was used in automating several lighthouses, but it was primarily used to light buoys and small beacons, some of which were equipped with sun valves or sun relay, a temperature-sensitive device, activated by the heat of the sun. When the device cooled at night, the fuel valve opened fully, providing adequate fuel to illuminate the light. When the sun came up, the device was heated, closing the fuel valve so that only the pilot light was lit. The electric relay switch was a similar device that turned the light on and off. These devices began the automation process of light stations in earnest.

Automation has been a main theme in lighthouse history for nearly 100 years. The government has felt that if a lighthouse could be automated successfully, then considerable money, in personnel costs as well as support costs, could be saved. During the developing days of automation, citizens complained about keepers not being in the area with eyes to seaward to spot boaters in trouble or ships in distress. The government contended that with this modern age of electronics there were many forms of communication over which distress messages could travel and alert the Coast Guard to dispatch help.

In the 1960s, the Coast Guard experimented with using nuclear power to light a lighthouse. The test station was Baltimore Lighthouse in Chesapeake Bay. The test ran for a year, after which the nuclear equipment was removed from the lighthouse. The Coast Guard has not attempted to use nuclear power since.

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[140] Ibid., p. 187.

[141] Ibid., pp. 188-187.

PART IV: EXAMPLES OF SIGNIFICANT PERSONS

Architects, Engineers, and Contractors

From the colonial period to the advent of the Lighthouse Board, contractors who bid on the projects built lighthouses. The person who supervised the contractor was the local collector of customs who also served as superintendent of lighthouses for his region. Some of the collectors were conscientious about their responsibilities; others were not. The important factor in getting a good lighthouse for the government's money seemed to be the quality of the builder and not necessarily the construction supervisor. The Treasury Department usually advertised in newspapers when it was looking for a contractor to build a lighthouse. The local superintendent of lighthouses arranged for advertising and had general specifications printed in the newspaper. Usually, these specifications guided the successful bidder in the construction. He reviewed the bids and rejected the ones he felt could not satisfactorily complete the work. He notified the fifth auditor of his rejections, selection, and the reasons for his decision. The reasons for rejection were varied: the contractor would not be able to make bond; he was too inexperienced as a builder; he had done faulty work in the past, etc. These, of course, are subjective reasons, and one wonders whether the superintendent may at times have been trying to eliminate lower bidders to get a contractor who was a political friend. Though the final selection of a contractor was made in Washington, more often than not, the superintendent's recommendation was accepted, and the contract, including specifications, was approved and let by the superintendent of lighthouses.

John McComb, Jr., a famous architect-builder, erected several lighthouses, including the one at Cape Henry (1792) at the entrance to Chesapeake Bay, Virginia; at Montauk Point (1796) on the tip of Long Island; and at Eatons Neck (1799), also on Long Island, New York. All were built in the 1790s, and all are still standing.

Alexander Parris, a noted architect-engineer (1780-1852), erected several lighthouses, including ones on Mount Desert Rock (1847), Libby Island (1848), Monhegan Island (1851), Matinicus Rock (1857), and Saddleback Ledge (1839). Parris probably also built Whitehead Lighthouse (1848). All of these waveswept lighthouses, erected in the middle part of the last century off the coast of Maine, were made of local granite and are still standing. Benjamin Latrobe, the nation's first professional architect, in 1788, unsuccessfully bid on the construction of Old Point Comfort Lighthouse (1802), Virginia. In 1805, Latrobe designed a lighthouse for the mouth of the Mississippi River at the request of Albert Gallatin, Secretary of the Treasury. Latrobe's son Henry and pupil William Strickland went on to design lighthouses; the latter built the first lighthouse at Brandywine Shoal (1828), Delaware Bay.

John Donahoo, a commercial fisherman and builder, erected 12 of the first 17 lighthouses in Maryland. He was the low bidder on all the contracts on which he bid, and he was a favorite of Stephen Pleasonton. Donahoo built very well, for all of his lighthouses, except five, still stand. Of the five, two were lost to erosion, one to a winter storm when it was well over 100 years old, one to demolition, and one to fire 24 years after it had gone out of service. Lighthouses built by Donahoo include Pooles Island (1825), Thomas Point (1825), Fog Point (1827), Concord Point (1827), Cove Point (1828), Point Lookout (1830), Lazaretto Point (1831), Clay Island (1832), Turkey Point (1833), Piney Point (1836), Blackistone Island (1851), and Fishing Battery (1853).

Winslow Lewis, a Boston ropemaker, inventor, and chandler who supplied inferior patented reflector-lamps and sperm oil to lighthouses on the Atlantic coast, became in the eyes of at least one historian a

premier lighthouse builder in America and perhaps in the world.[142] Lewis, who had a special relationship with the fifth auditor, received contracts to erect about 24 lighthouses, some using the Latrobe design, but few of his lighthouses remain standing today. This is, in part, because of the early period in which he worked, the lack of modern technology, and the difficulty of the soft eroding muds of the Mississippi delta on which he built most of his lighthouses. Lewis built the three short lighthouse towers on Cape Cod that came to be called the "Three Sisters" (1838), the only tri-tower lighthouse station in the United States. The government's supervisor for the project found the work on the three structures to be shoddy, and refused to sign off on the work. He was directed to do so by the Boston collector of customs. The fifth auditor had already accepted the work. Other government officials later complained about these three towers, but Lewis and the fifth auditor seemed little bothered by the criticism.[143] Other lighthouses built by Winslow Lewis include Franks Island (1818 and 1822), Louisiana; Pensacola (1825), Florida; St. Marks (1831), Florida; Southwest Pass (1832), Louisiana; South Pass (1831 and 1842), Louisiana; Pass Christian (1831), Mississippi; Choctaw Point (1830), Alabama; Cat Island (1831), Mississippi; St. George Island (1833), Florida; Sand Island (1838), Alabama; Dog Island (1838), Florida; and St. Josephs Bay (1838), Florida. Lewis subcontracted most of his lighthouse work. He also conducted the first survey for the location of the Romer Shoals day-beacon (1838), New York, which was later determined to be built about a mile from its correct position.[144]

Isaiah William Penn Lewis, better known as I.W.P. Lewis, civil engineer, nephew and severe critic of Winslow Lewis, was directed by the Treasury Department in 1843 to inspect and report on most of the lighthouses of the New England coast. This was apparently the first instance in which an engineer had been employed with any important capacity in the Lighthouse Establishment. Lewis also designed the Carysfort Lighthouse (1852), and Sand Key Lighthouse (1853), both in the Florida Keys, both exoskeletal tall tower screwpile lighthouses.

Francis A. Gibbons of Baltimore erected a number of lighthouses. His early lighthouses exhibited faulty construction, but it may not have been his fault. Before Gibbons had begun to build the Bodie Island Lighthouse (1848), North Carolina, Pleasonton had directed the collector of customs to use piles for the foundation if mud were found at the site. When Gibbons found a viscous substance he thought to be quicksand, the collector of customs directed him to lay a foundation of bricks two layers high. Pleasonton was not pleased with the collector's decision, but by the time he found out what had happened, the work on the lighthouse was completed. Lighted in 1848, the lighthouse had to be rebuilt in 1859, apparently because of foundation problems.[145] In 1848, Gibbons erected the Egmont Key Lighthouse (1848), Florida, but within ten years shifting sand, induced by two hurricanes virtually back to back, undermined the tower, and it had to be replaced in 1858. Gibbon's next foray into lighthouse construction was in the early 1850s when he went into partnership with Francis X. Kelly of Baltimore to build the first eight lighthouses on the west coast.

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[142] Robert G. Bachand, *Northeast Lights: Lighthouses and Lightships Rhode Island to Cape May*, New Jersey (Sea Sports Publications, Norwalk, Connecticut, 1989), p. 137.

[143] A. Berle Clemensen, et al., *Historic Structure Report: Three Sisters Lighthouses, Cape Cod National Seashore, Massachusetts*, Department of the Interior, National Park Service, January 1986, pp. 11-14, 17. The brick sisters served for over 50 years before being replaced by wooden structures.

[144] Bachand, p. 301.

[145] Kevin M. McCarthy, *Florida Lighthouses* (Gainesville: University of Florida Press, c.1990), p. 93; Holland, *Great American Lighthouses*, p. 202.