Screwpile foundation

Alexander Mitchell invented the screwpile, a major improvement over the standard straight pile construction type. With his son, he patented his wrought-iron screwpile design in the 1830s, which he described as follows,

> *A bar of iron having at its lower extremity a broad plate or disk of metal in a spiral . . . on the principle of a screw, in order that it should enter into the ground with facility, thrusting aside any obstacles to its descent, without materially disturbing the texture of the strata it passed through, and that it should at the same time offer an extended base, either for resisting downward pressure or an upward strain.*[45]

He further stated that his screwpile was a device for "obtaining a much greater holding power than was possible by any pole or mooring then in use." William Johnstone, harbormaster at Glasgow stated in a letter to Mitchell and his son on May 7, 1837,

> *The great strain they bear . . . the safety for vessels grounding above them, the unexpected ease with which they are put down, and their exemption from frequent lifting, to which other moorings are liable, will make me recommend them.*[46]

By 1840, Mitchell combined his wrought-iron screwpile moorings with Whiteside's pile construction technique and built the first screwpile lighthouse at the mouth of the Wyre, an important harbor in Lancashire, England. Mitchell used 36-inch-diameter wooden timbers on whose bottoms were attached his wrought-iron screwpile device. The piles were inclined toward the center as in Whiteside's standard straight pile design.[47]

Mitchell later noted, "by reason of the various descriptions of sea-worms which everywhere infest our coast" wrought-iron piles were necessary. This led to his next and best-remembered achievement, the Maplin Sands Lighthouse. In partnership with James Walker who was responsible for the superstructure, Mitchell contracted with the Trinity Corporation (England's lighthouse authority) to build a lighthouse at the mouth of the Thames River, an area subjected to high winds, strong currents, and consisting of a soft bottom. Completed in 1841, this structure was the first lighthouse to be built upon a screwpile foundation made entirely of iron. The hexagonal dwelling was supported by one central and eight surrounding iron piles, either five or six inches in diameter, each tipped with a 4-foot-diameter flanged screw and each turned 22 feet into the sandy bottom. Unlike the Wyre Lighthouse, these piles were screwed vertically into the bottom, and capped with hollow cast iron columns which not only formed the foundation but supported the dwelling as well. The Maplin Sands Lighthouse became a prototype for other screwpile lighthouses.[48]

---

[45] Bergin, p. 11.

[46] Bergin, p. 11.

[47] Bergin, pp. 11-12.

[48] Bergin, p. 12; Douglas B. Hague and Rosemary Christie, *Lighthouses: Their Architecture, History and Archeology* (Wales: Gamer Press, 1975), and Naish, p. 127. Note, Naish gives the date of completion of the Maplin Sands Lighthouse as 1836 on page 127 and 1848 on page 128, F. Ross Holland, Jr., *Americas Lighthouses: An Illustrated History* (New York, Dover Publications, Inc., 1988 edition) p. 99 gives the date 1838, Bergin gives the date 1841, and Hague and Christie gives the date 1838 on page 221 and 1841 on page 137. These various dates may reflect the experimental nature of several adaptations in the development of the screwpile type lighthouse at Maplin

The first mention of Mitchell's screwpile invention in the United States may be in an 1842 report on buoys written by engineer I. W. P. Lewis,

> *The use of screw moorings are yet unknown in this country, while England has availed herself of this valuable invention . . . as a means of founding lighthouses upon shoals hitherto considered inaccessible to the engineer.*[49]

Congress was willing to give the screwpile technique a try at Flynn's Knoll in New York Harbor but the project died with little support outside of Congress, most people believed nothing more than a buoy was needed. The first screwpile lighthouse type built in the United States was at Brandywine Shoal, Delaware Bay, an area served by a lightship since 1823 and an ordinary straightpile lighthouse which stood briefly there in 1828 but was destroyed by ice. Major Hartman Bache, a distinguished engineer of the Army Corps of Topographical Engineers, began work in 1848 and completed the task in 1850; construction cost $53,317. Alexander Mitchell served as consultant. A 4-foot capstan worked by 30 men turned the screwpiles. To protect the structure from ice floes, an icebreaker consisting of a pier of 30 iron screwpiles 23 feet long and five inches in diameter were screwed down into the bottom and interconnected at their heads above the water reinforcing them together. This cost an additional $11,485.[50]

The screwpile lighthouse is an example of early iron truss technology and became especially popular after the Civil War when the Lighthouse Board adopted a policy to replace inside (bays, sounds, and rivers) light vessels with screwpile lighthouses.[51] This lighthouse type was built in ice-free, shallow, slow moving sheltered waters, where soft bottom shoals stood too far offshore to be protected by the more traditional onshore lighthouse structure. When built in areas prone to ice flow, moving ice occasionally destroyed these relatively lightweight structures. Other enemies of the screwpile lighthouse were fire, fast flowing water that could scour bottoms and undermine foundations, and even collision by vessels.[52]

Screwpile lighthouses were relatively inexpensive, easy to construct, and comparatively quick to build. A temporary platform or stage was constructed to facilitate the work. Most screwpile lighthouses were made with iron piles, though a few were made with wooden piles covered with metal screw sleeves (these sleeves were probably adopted because they were less expensive and easier to insert into the bottom, plus the sleeve protected the wood from marine-boring invertebrates). The typical screwpile lighthouse was hexagonal or octagonal in plan consisting of a central pile which was set first and then the six or eight perimeter piles were screwed in place around it. Occasionally, two additional fender piles were set, one on each of the ebb and flow sides of the structure for additional stability against ice. The York Spit Lighthouse (1870) had two extensions built over these additional piles, one for the

---

Sands, but also reflect the tendency for the British to use starting date of construction while Americans use the date of the first lighting.

[49] Bergin, p. 12

[50] Johnson, 26; Holland (1972), p. 99; Bergin, pp. 12-13; and Putnam, p. 84.

[51] Frank N. Schubert, *The Nation Builders: A Sesquicentennial History of the Corps of Topographical Engineers 1838-1863*, Office of History, United States Army Corps of Engineers, Fort Belvoir, Virginia, 1988, p. 30; and Holland (1988), p. 128.

[52] Scheina, p. 19.

placement of a fog signal and the other as a landing deck fitted with davits to accommodate a station boat.

Cottage type screwpile

There are two principal types of screwpile lighthouses: the spider-like, cottage type and the exposed tall skeletal tower type. The spider-like, cottage-type screwpile lighthouse consisted of a screwpile foundation built over open water upon which a wooden cottage for the keeper's quarters was constructed.[53] Initially the cottage was a one-story building surmounted by a lantern room, but later a one-and-one-half-story cottage surmounted by a lantern room became more popular. The first floor was divided into a sitting room, kitchen, storeroom, and sleeping room. A central enclosed spiral staircase connects the first floor to the second half-story where a sleeping room, oil room, and storage area was located. The interior walls and ceilings were of finished tongue-and-groove beaded board paneling. The circular stairwell continued to the cast-iron lantern room which was surrounded by an exterior gallery deck and railing. The lantern room had glass panes set in cast-iron mullions covered with vertical tongue-and-groove wood paneling on the inside and sheet metal on the outside. At least two 2-story square cottages with Mansard roofs were also built; both in Long Island Sound. The cottages were almost uniformly hexagonal in shape though there were at least seventeen exceptions.

Perhaps as many as 100 spider-like, cottage-type (1 and 1/2 story wooden dwelling) screwpile lighthouses were built throughout the Carolina sounds, the Chesapeake Bay, Delaware Bay, along the Gulf of Mexico, at least two in Long Island Sound and one even at Maumee Bay (1855), Lake Erie, Ohio.[54] However, the Chesapeake, with 42, has the distinction of having had the most spider-like, cottage-type screwpile lighthouse structures of any area in the world.[55] At least 15 of this type were built in North Carolina.[56] Seven Foot Knoll Lighthouse is believed to be the oldest surviving screwpile cottage-type lighthouse in the United States, and although moved to shore, its most important feature, the screwpile foundation which survives from the water level up (the portion of the piles below the water are still in place), remains unpreserved and unrestored.

The beginning of the end of screwpile cottage type lighthouses came in 1894 when the Lighthouse Board stated in its annual report,

> *In view of recent damages by ice to screwpile structures in Chesapeake Bay, the Board is now of the opinion that only caisson structures should be used where such dangers exist.*[57]

---

[53] The only exceptions known are the Brandywine Shoal Lighthouse (1850), Delaware Bay, and the Seven Foot Knoll Lighthouse (1855) which have a cylindrical iron keepers quarters similar to those used on a caisson foundation.

[54] Scheina, pp. 20-21; and Clifford, p. 372.

[55] Ralph E. Eshelman, *A History of Drum Point Lighthouse* (Solomons, Maryland, Calvert Marine Museum, 1978), p. 1.

[56] David Stick, *North Carolina Lighthouses* (North Carolina Department of Cultural Resources, Division of Archives and History, Raleigh, 1980), pp. 60-61.

[57] U.S. Lighthouse Board, *Annual Report*, 1894 (Washington, Government Printing Office, 1894).

The last spider-like, cottage-type screwpile lighthouse built was Ragged Point Lighthouse (1910), Maryland, constructed in the Potomac River (in waters of Maryland but closer to Virginia shore) near Chesapeake Bay.[58]

Tall skeletal tower type screwpile

An exposed skeletal tower with a screwpile or driven pile foundation was designed specifically for offshore reefs of Florida. They came into use a few years after the cottage screwpile design. Many of these offshore screwpile skeletal towers had large iron footplates or disks that were attached to the pile above the screw tip to diffuse the pressure caused by the weight of their tall towers that were mounted with first-order lenses weighing several tons. Cottage-type screwpile lights were short, squat, and mounted, principally, with small, relatively light, fourth order lenses and needed only to project their light over a few miles of open water in protected bays and sounds. The tall skeletal screwpile tower type was built in exposed open water at major coastal sites where visibility over ten miles was required. Six screwpile skeletal towers were built in Florida; three before and three after the American Civil War, as well as one in the Gulf of Mexico off Louisiana prior to the Civil War.

The first of the screwpile tall skeletal towers to be built was the Carysfort Reef Lighthouse, on the dangerous stretch of reefs between Cape Florida and Key West, Florida.[59] Designed by I. W. P. Lewis, it was started in 1848 and completed in 1852. The entire structure was first erected in Philadelphia "so as to obviate the necessity of fitting parts at its isolated site." It cost $105,069 to complete. Carysfort Reef Lighthouse, with its skeletal foundation, presented relatively little resistance to wind and waves and served as a prototype for the string of lighthouses that now mark these reefs off Florida. Similarly, some onshore lighthouse towers also used an external skeletal support to broaden their foundation on soft sands or other unstable substrate foundations. Skeletal screwpile foundation lighthouses can be classified as a skeletal tower type and/or a screwpile type; thus the type classification used here can and does overlap with other construction types.

Straightpile skeletal type

Non-screwpile (straightpile) tubular skeletal tower lighthouses were built, usually of cast-iron but also of wrought-iron piles, both onshore and offshore, typically on soft bottoms such as mud, sand, and swamp. The method of construction is well described by the Lighthouse Board when it built the Fowey Rock Lighthouse in Florida in 1878:

> *Fowey Rocks . . . is of iron; rests on nine piles driven about 10 feet into the live coral rock . . . 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 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*

[58] Holland (1993), p. 8. Holland gives no name for this lighthouse but Ragged Point is the only lighthouse listed for 1910 in Clifford p. 368 and deGast p. 156.

[59] Johnson, pp. 26-27; and Hans Christian Adamson, *Keepers of the Lights* (New York, Greenberg, Publisher, 1955), p. 180; Holland (1993) p. 43 and (1994), p. 19 states Lt. George G. Meade started work on Carysfort Reef Lighthouse but Johnson, p. 26 states Capt. Howard Stansbury started the work and Maj. Thomas B. Linnard completed it. The 1915 report of the U.S. Lighthouse Service on page 25 indicates the Carysfort Reef Lighthouse was a straight-pile built tower; this is apparently incorrect.

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 poles 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 were completed.

Caisson foundation

The caisson construction method for lighthouses is based on the idea developed by Lawrence Potts, an English physician and inventor, who in 1845 sank a section of hollow tubing from the surface of the ocean to the sea floor. He then attached a powerful pump to the open end extending above the water, and as he pumped air and water from the tube, it drew up sand that allowed the tube to sink by gravity deeper into the sea bottom. Charles Fox, a civil engineer for sinking railroad bridge supports, adopted this idea. The method was then employed in 1850 during the construction of bridge support towers at Rochester, New York. Workmen soon discovered that large rocks obstructed the descent of the tube so the engineer in charge, J. Hughes, reversed Pott's process. He pumped air into the tube forcing the water out so his men could descend into the tube and remove the rocks, sand, and mud, allowing the tube to sink under its own weight into the river. The foundation for the Brooklyn Bridge in New York City, as well as many bridge foundations, were built using this same pneumatic method. Pott's modified method was also used to build caisson lighthouse foundations, particularly in unconsolidated soft-bottomed environments such as mud or sand.[60]

The first application of the caisson technology in the United States for lighthouse-related work was for Waugoshance Lighthouse (1870), Michigan, built on a timber crib. When the crib foundation became damaged, William Sooy-Smith (who was the first to use the pneumatic process in the United States when he built a bridge over the Savannah River in 1859) used a temporary caisson in 1867 to enable his workers to repair the crib foundation with a masonry protection wall. Craighill Channel Lower Front Range Lighthouse (1873), Maryland, built near the Patapsco River and marking the entrance to Baltimore, Maryland, used a permanent caisson and is considered a greater feat of engineering as it was built in deeper water under more difficult conditions.[61] The caisson lighthouse was sturdier and better able to withstand the stresses exerted by ice flow. It is not surprising that caisson lighthouses are numerous from the northern coast of Maine to the Chesapeake Bay. At least one, Rock of Ages Light Station (1908), Michigan, was built on the Great Lakes. Only one caisson lighthouse was built south of the Chesapeake Bay, Sabine Bank Lighthouse (1906), Texas. The last caisson lighthouse built in the United States was the Cleveland East Ledge Lighthouse (1943), Massachusetts, using an art modern style.

---

[60] Cohen, p. 17.

[61] Holland (1993), p. 9; *Aids to Navigation 1945*, p. 323; and U.S. Lighthouse Board, *Annual Report, 1873* (Washington, D.C., Government Printing Office, 1873), pp. 45-46. Holland, *Maryland Lighthouses of the Chesapeake Bay* (Maryland Historical Trust Press and Friends of St. Clements Island Museum, Inc., Crownsville, MD, 1997), p. 67. states that the Craighill Channel Lower Front Range Lighthouse is the first caisson built. Almqvist and Sutton-Jones, p. 19 states the "first caisson structure to be constructed ashore, floated and installed out at sea" was at Rothersand, Outer Weser estuary near Bremerhaven, Germany, completed in 1885. Craighill Channel Lower Front Range Lighthouse built in 1873 predates this. Elinor De Wire, Sentinels on Watch - 2, states Major David Heap of the Army Corps of Engineers, designed and completed in 1888 Fourteen Foot Bank, Delaware Bay, the first caisson type lighthouse in the United States.

Of the 100 or so cottage screwpile lighthouses built, only one, Thomas Point Shoal Lighthouse (1875), has survived intact and in its original location. Most have been destroyed or only the foundation remains; four have been moved ashore. Virtually all the caisson type lighthouses have survived, withstanding hurricanes and severe ice conditions.[62]

Caisson foundations for lighthouses were constructed by fabricating the cylinder plates from grey iron and typically cast in the form of 1-to-1 and 1/2-inch-thick plates, 6 feet in height, with 6-inch vertical and horizontal flanges 1 and 1/4-inch thick to insure water tightness. These plates were either totally or partially pre-assembled on shore to ensure proper fitting, then disassembled, shipped to the designed site and re-erected. Depending on bottom conditions and depth of water, the cylinder was either fitted with a temporary watertight bottom or permanent wooden crib, called a caisson, described later. Launched from ways, the cylinder was then towed to its desired location and sunk by controlled flooding of the interior achieved through a valve located in the chamber and/or by ballasting. The cast-iron cylinder was partially filled with stone and trimic concrete to provide the desired ballast during towing.[63]

In some instances the open-ended cylinder was carefully sunk into a muddy bottom under its own weight until it met refusal, and if necessary leveled by placing stone on the inner high side of the cylinder. External water jetting under the high side could also be employed to help level the cylinder. Once the cylinder was leveled, riprap stone was placed around the outside to add stability and prevent bottom scour by currents. Then the sand and mud within the cylinder was pumped out. Water hoses or jets were sometimes used to clear debris around the outer side of the cylinder to assist in the settling of the assembly. More stone and concrete was added to assist in the settling. Additional plates could be added to the cylinder as it settled in order for it to reach the desired height above the water surface. Though not common, this technique was sometimes used on land to sink a cylinder that was then used as a foundation pier. The foundation piers of the 1894 Cape Charles exoskeleton lighthouse used this technique. A 21-foot-diameter cylinder made of boilerplate iron was sunk ten feet into the sand by excavating the sand from within it while pumps kept water from filling the cylinder.

Where bottoms were harder, contained rocks, and/or greater depth of penetration into the substrate was desired, the pneumatic process was used. A wooden open-ended box-like crib contraption called the caisson was attached with the open side of the box facing down from the bottom of the cast-iron-plated cylinder. Typically the timbers forming the caisson were one foot square in dimension. The entire caisson was sheathed and sealed with mineral pitch to make it essentially watertight. In later years the caisson was occasionally made of steel. The lower sides or rim of the caisson were tapered near the bottom to ease the settling of the caisson into the bottom sediments. Water was forced out of the caisson by means of pressurized air. The tubular cylinder fitted on top of the caisson was then partially filled with cement. The added weight further settled the assembly into the substrate.[64]

An airtight shaft built in the center of the assembly (caisson and attached cylinder) was big enough for men to climb up and down. It provided access to the caisson where they would haul out, or suck out with hoses, the debris from inside the bottom of the caisson. Removal of these bottom sediments

---

[62] Holland, *Maryland Lighthouses of the Chesapeake Bay* pp. 67 and 101; and Clifford, pp. 143 and 373. Holland refers to Cleveland East Ledge Lighthouse as the "Cleveland Ledge" Light.

[63] "Chesapeake Bay Lighthouses," Gredell & Associates: Structural Engineers (Wilmington, Delaware, 1991), p. 12; file on copy at the National Maritime Initiative Office, National Park Service, Washington, D.C.

[64] Johnson, pp. 37-40.

allowed the assembly to slowly sink further into the bottom, typically about one to two feet a day. The digging continued until the caisson had sunk to the desired depth, usually about 30 feet into the substrate. The contraption was also outfitted with an air lock to maintain the needed air pressure to keep water out of the caisson as well as an air pipe to the surface to maintain fresh air supplies. Once this work was completed the air chamber in the caisson was completely filled with compacted sand and the air and worker access shafts as well as the cylinder were filled with concrete. This type of submarine foundation is called pneumatic. The first pneumatic caisson lighthouse built in the United States was at Fourteen Foot Bank Lighthouse (1887), Delaware.[65]

Eleven pneumatic caisson lighthouses were built in the United States. In some areas where the bottom was unstable even at great depth, timber piling was used to transfer the loads even deeper into more stable strata.[66] Some caisson type lighthouses were built on rocks just above the water.

On average, the caissons were approximately 70 feet in height and 35 feet in diameter and the wooden crib approximately 10 feet high, 40 feet square, and 5 feet thick. This cast iron assembly served as a form for concrete, stone, and/or brick masonry that was added to anchor the caisson to the bottom; the form was not intended to function as a load-bearing element.[67]

On these caisson platforms, the builders erected several different styles of lighthouse towers. In the Chesapeake Bay, two dominated: conical metal lighthouses, often called coffee pots because their configuration suggested such, and brick structures suggestive of the Second Empire style. Elsewhere the superstructure was a slightly conical squat tower. All of these structures had work and storage space, and adequate water storage, as well as living quarters for the keepers.[68]

In the cast-iron structures, the casting was often lined on the interior with double wythe (masonry term for double lining or width) of brick masonry. Floor framing of rough timber was set in the framing bearing pockets formed in the masonry. Floor framing for the cast-iron quarters was often achieved by bolting radial sections of iron plates together to form a circular diaphragm that was supported by the cast iron walls and sometimes a central column.[69]

Depending on the height, caisson lighthouses had different levels. Often within the caisson a cellar was built within the upper 12 feet and enclosed with at least 6 feet of thick masonry or concrete walls. Occasionally recessed windows also were added for lighting purposes. These cellars were often used for fuel storage such as wood or coal bins and often a cistern for collecting water from the roof gutter and downspout system. The first level was usually partitioned into a sitting room, kitchen, and storage area, and completely surrounded by an exterior gallery deck. The main entrance was also located on this level. The second and sometimes third floor was dedicated to sleeping areas and storage. The level

---

[65] Scheina, p. 23; and Clifford, p. 43. Johnson pp. 36-40 gives a good description of the construction of this pneumatic caisson lighthouse.

[66] "Chesapeake Bay Lighthouses," Gredell & Associates: Structural Engineers (Wilmington, Delaware, 1991), p. 12; file on copy at the National Maritime Initiative Office, National Park Service, Washington, D.C.

[67] "Chesapeake Bay Lighthouse Foundation Inspection," DTCG83-91-C-3WF269, Han-Pardon Associates (New York, New York, July 1992), p. 1.

[68] Holland, *Maryland Lighthouses of the Chesapeake Bay*, Chapter 4.

[69] "Chesapeake Bay Lighthouses," Gredell & Associates: Structural Engineers (Wilmington, Delaware, 1991), p. 12; file on copy at the National Maritime Initiative Office, National Park Service, Washington, D.C.

directly below the lantern room was the watch or service room. The fog bell operating equipment, if required, was often housed here. The lantern room was usually made of cast iron, surrounded with storm panels, and typically octagonal in shape. The cast-iron quarters usually had a spiral staircase that hugged the brick lining of the cast iron tower while the brick masonry type had a tight winder or straight run staircase between floors.[70]

Caisson lighthouses were more complicated and on average about four to five times more expensive to build than screwpile lighthouses, but they were better able to withstand the pressure of flowing ice. For this reason, many screwpile lighthouses in the Chesapeake and Delaware Bays were replaced with caisson type lighthouses. The Sharps Island (1882) caisson lighthouse, built to replace the 1866 screwpile lighthouse destroyed by ice in 1881, leans from ice damage that occurred in 1897.[71] Twelve caisson lighthouses were built on the Chesapeake Bay. Five of them replaced screwpile type lighthouses in Virginia waters and two in Maryland waters.[72] In all, 47 caisson lighthouses were built in the United States, 11 pneumatic and 36 non-pneumatic.

The caisson lighthouse, though superior to the screwpile lighthouse as far as stability is concerned, especially in northern locations where ice flow conditions exist, did not prove worthy for offshore ocean locations because of severe bottom scouring. For years a lighthouse had been suggested to replace the buoys off Diamond Shoals, 13 miles off the shore from Cape Hatteras, North Carolina. In the late 1880s a pneumatic caisson foundation with a tall steel light tower was designed for this location and $200,000 authorized by Congress in 1889 with the provision that the total sum did not exceed $500,000 an enormous amount of money for a lighthouse at this time. The caisson was 54 feet in diameter and 45 feet in height. It was sunk in 25 feet of water but the current action over the bottom soon scoured the site and tilted it out of level. A few days later, a storm, accompanied by large waves, washed over the top of the caisson and carried off the machinery. The contractors gave up in disgust, as did the Lighthouse Board, after a few more unsuccessful attempts. A lightship and then a Texas tower (discussed below) were finally placed on the shoal.[73]

Crib foundation

Wooden cribs constructed onshore, towed to the site, and then filled with stone to sink them in place was a lighthouse foundation type used extensively in the Great Lakes, many replacing lightships. This foundation type was especially well adapted to hard rock bottoms. Once settled and leveled, the cribs were capped with concrete or some other masonry upon which the lighthouse structure was constructed. Perhaps the two most significant crib foundation type lighthouses are the 93-foot Spectacle Reef Lighthouse (1874), Lake Huron, Michigan, located 10 1/2 miles from the closest land; and the 110-foot

---

[70] "Chesapeake Bay Lighthouses," Gredell & Associates: Structural Engineers (Wilmington, Delaware, 1991), p. 12; file on copy at the National Maritime Initiative Office, National Park Service, Washington, D.C.

[71] Clifford, p. 132; and deGast, p. 131.

[72] Cohen, p. 17; and Holland (1993), p. 11.

[73] Johnson, pp. 11 and 40; and Wayne C. Wheeler, "Diamond Shoal Lighthouse: The Lighthouse That Never Was," *Keeper's Log* (1988) 4(3):24-29.

Stannard Rock Lighthouse (1882), Lake Superior, Michigan, located over 30 miles from the nearest land.[74]

Cofferdam and other miscellaneous foundation types

In shallow water, cofferdams were sometimes used to facilitate the construction of foundations providing a dry protected area in which to construct a permanent foundation made of stone or other masonry material. The temporary cofferdam was usually made of wood partially assembled on shore, brought to the site, bolted together, sealed, and the water pumped out. Many of the lighthouses with granite foundations in the Great Lakes were built this way, including Stannard Rock Lighthouse (1882) and Spectacle Reef Lighthouse (1874). Once the foundation was constructed safely above the water level, the cofferdam was dismantled, and the lighthouse tower built on top of the foundation. There were at least three granite and concrete foundation lighthouses which probably made use of cofferdams; the earliest apparently is Craighill Channel Lower Range Rear Lighthouse (1873), Maryland; followed by Hudson-Athens Lighthouse (1874), New York; and Robbins Reef Lighthouse (1883), New York.[75] The Craighill Channel Upper Range Front Lighthouse (1938) is unusual as the tower was built on the granite foundation base of an earlier range light built on land in 1824, but over the years the land has receded around the base so that the 1938 structure built on the earlier foundation is now located several hundred feet offshore. At least three lighthouse foundations were made of stone below the surface of the water without using a cofferdam.

Texas tower

A relatively recent technological development in lighthouse construction is the Texas tower type which replaced lightships in open ocean conditions in waters greater than 30 feet. These so-called Texas towers were modeled after offshore oil drilling platforms first employed along the Texas coast. All the major components of these structures were prefabricated in sections and towed to the site.

The first Texas tower lighthouse in the United States is the Buzzards Bay Lighthouse, located in Buzzards Bay, Massachusetts, and commissioned on November 1, 1961. It is anchored to the ocean bottom by four 33-inch-diameter steel pipes, and cross-braced with 16- and 18-inch-diameter steel pipes both horizontally and diagonally. Through each of the main 33-inch pipes a 30-inch-diameter steel pile was driven to bedrock, a depth of 268 feet below mean low water. The piles were partially filled with concrete. Upon this foundation, 66 feet above the water, is the platform, consisting of two decks. The lower deck houses water and fuel and the upper deck, the living quarters. On top of the top deck is a helicopter landing deck and to one corner are the light and radio tower, foghorn, and radiobeacon. The focal plane of the light is 101 feet above the water, visible 16 miles at sea, with a capacity for 400,000 candlepower under normal conditions and 5,000,000 candlepower under low visibility conditions. The open ocean waves pass under and around the open pile foundation.

Five additional Texas towers have been constructed including: Savannah Lighthouse (1964) off Georgia; Chesapeake Bay Lighthouse (1965), off the mouth of the Chesapeake; Ambrose Channel Lighthouse (1967), off New York City; and Diamond Shoal Lighthouse (1967), replacing a lightship station. These

---

[74] Scheina, p. 22; Johnson, pp. 32-34; "Historically Famous Lighthouses", pp. 54-57; and Clifford, pp. 202 and 206. Note Scheina lists Stannard Rock Lighthouse as Standard Rock Lighthouse. Wayne Wheeler, personal communication, February 28, 1998.

[75] Clifford, pp. 126, 238 and 246-47; and Holland, *Maryland Lighthouses of the Chesapeake Bay*, p. 90.

Texas towers were built with an expected life span of about 30 years. Buzzards Bay Lighthouse has been extinguished and is scheduled for dismantlement. It is to be replaced by a newer non-Texas type tower which will resemble the tower that marks the entrance to the harbor at Valdez, Alaska. Ambrose Lighthouse is also scheduled to be demolished. These Texas-tower type lighthouses were expensive to construct, and not a large number of them were erected.[76]

Fiberglass towers

In an effort to keep maintenance costs down, the English introduced the concept of the fiberglass (glass-reinforced plastic) light tower which was adopted by the Coast Guard. The color of the tower is molded into the plastic with pigments so painting is not necessary. Little, if any metal, is used to keep saltwater corrosion to a minimum. The light lens is plastic and no storm panes are required for protection. The result is very low maintenance light towers. The first use in the United States of a fiberglass light tower was apparently in northern California in the 1960s. Three were built in New England in the early 1980s: Great Salt Pond Light, Block Island, Rhode Island; Deer Island Light, Boston Harbor, Massachusetts; and Cape Cod Canal Breakwater Light, Massachusetts. The first plastic Deer Island Light, a white tower built in 1982, replaced an iron tower on a caisson. The present red-brown plastic tower replaced the white plastic tower in 1984. The Cape Cod Canal Light is a plastic red tower built in 1986, which replaced a metal skeletal tower, now used for the fog signal.[77]

Light Station Components

The U.S. Lighthouse Service in 1915 regarded lighthouses as stations where resident keepers were employed.[78] With today's automated lights, under this same definition, very few lights would be classified as lighthouses. The 1995 *Light List* defines lighthouse as a lighted beacon of major importance. Buoys and lights housed outside of buildings are not considered lighthouses. The former light at Dutch Gap on the James River near Richmond, Virginia, consisted of a tiny lantern suspended from a 10-foot tripod. It was serviced by the keeper via a small ladder. While this light was considered a minor aid to navigation, it was not a lighthouse.[79]

The concept of the "light station" came into being during the period that the Lighthouse Board administered aids to navigation, 1852-1910. A station consisted of the light tower, a dwelling, a garden site, a place to store oil, and maybe a chicken house and shelter for a milk cow. The increased complexity of operation, with the introduction of the more sophisticated Fresnel lens and fog signal in the 1850s, particularly the steam-operated ones, brought about a need for more personnel, which in turn required additional housing and other support buildings such as fog signal buildings, workshops, cisterns and water catchment basins, storage buildings, garages, radio buildings, boathouses and tramways, among others. By the 1920s and 1930s, however, the majority of light stations had electric service,

---

[76]LNBs, large navigational buoys, were often employed instead of Texas towers. These are typically 40 foot in diameter, equipped with a radiobeacon signal, a horn fog signal, a RACON for identification, and a light 42 feet above the water which can be seen 14 miles away.

[77] Robert Fraser, "Plastic Towers," *Lighthouse Digest*, volume 4, number 1 (January, 1995), p. 7; and Barnes, p. 13.

[78] de Gast, p. viii; and *United States Lighthouse Service 1915* (Government Printing Office, Washington, D.C., 1916), p. 18.

[79]Eshelman, "Lighthouse Construction Types," unpublished monograph, 1997.

reducing the number of staff necessary to operate the station. As ancillary buildings at many stations, especially shore stations, were rendered useless, the makeup of the light station began to change. Electrification and automation of many light stations led to the removal or demolition of many obsolete light station buildings.

Light tower

The tower served principally as a support for the lantern that housed the light. The lantern was typically a cast-iron round, square, octagonal, or decagonal-shaped enclosure surrounded by an exterior stone or cast iron gallery with railing. Access to the lantern at the top of the tower was via stone, wood, or cast iron stairs which either wind around a central column or spiral along the interior sides of the tower walls (a few had straight sets of stairs which ran from landings around the tower interior). Windows in the tower were positioned to provide daylight onto the stairs. For taller towers, landings were provided at regular intervals. The top landing ended at the watch room where the keeper on duty ensured the optic was functioning properly. The lantern room above was usually reached via a ladder.

The most recognizable lighthouse type is the stand-alone tower such as Cape Hatteras Lighthouse. Lighthouses of this type come in many shapes including conical, square, octagonal, cylindrical, and even one triangular. Lighthouse towers may also be attached or integral to the keepers' dwellings, and in a few cases, fog signal buildings. Attached towers are those connected to a keeper's quarters to another structure, often by a hyphen; whereas integral towers are those structurally built into the structure with the tower extending through the roof.

Lantern

In the early days, lanterns were made of thin copper frames that held small panes of glass. The glass framing extended from the gallery deck to above the lighting equipment it held. A copper dome topped by a ventilator served as the roof of the lantern. Its design has given it the appearance of a birdcage, and in more recent years, it has been known by that name. In addition to using small panes of glass that were of poor quality, these lanterns were generally not of adequate size to hold Fresnel lenses. Consequently, when the Fresnel lens was introduced wholesale in the 1850s, most of the old style lanterns were replaced with new lanterns designed to hold the larger and heavier Fresnel lenses. Today only a few of the old-style lanterns survive on lighthouses, including Prudence Island Lighthouse in Portsmouth, Rhode Island; Baileys Harbor Lighthouse, Lake Michigan; and Selkirk Lighthouse in Pulaski, New York.

There were four sizes of lanterns created to accommodate the seven standard sizes or orders of Fresnel lenses--a separate design for the first-, second-, and third-orders, and one design for the fourth- through sixth-order lenses. Made of cast iron plate, they were six-, eight-, and ten-sided lanterns, although round and square lanterns were sometimes used for range lights. They had large panes of glass, one pane to a side for the smaller lanterns, and as many as three panes (one over the other) per side for the two largest size lanterns. Typically the section of the lantern slightly below the level of the bottom of the lens was covered with iron plates in the smaller sized lanterns. One of the metal panels was hinged to serve as a doorway providing access to the gallery or walkway on the exterior of the lantern.[80] The roof of the

[80] On larger lanterns, the glass panes continued to floor level; one pane might be hinged to serve as a doorway. For first and second order lanterns the lantern was usually circular. Also, on these lanterns there was another, narrower, outer gallery walkway at the level of the bottom of the glass which permitted the keepers to reach the glass for cleaning and repair purposes.

lantern, sometimes dome like and at other times a low peaked pyramidal roof, was usually made of copper. A ventilation device often a finial ball on the roof and slots in the parapet wall permitted proper ventilation. A lightning rod surmounted the ventilator device. At the roof's edge small gargoyle heads occasionally served as downspouts.

In the late 19th century, the helical bar lantern was introduced. Rather than having vertical astragals, they had diagonal ones. On the larger lanterns, the astragals crossed. The lighthouse officials believed these types of lanterns gave off a brighter light when housing rotating lenses because the light beam was only partially blocked at any one time by the diagonal astragals versus a split second total eclipse of the light beam by vertical astragals.

Keeper's dwelling

Second in importance to the light tower, dwellings for light keepers and their families were generally, in the early days, simple 1 and 1/2-story wooden or stone structures. Since lighthouses had only one keeper, there was only one dwelling. After 1852 with the coming of the Fresnel lens and the Lighthouse Board, more keepers began to be assigned to light stations, and, of course, it became necessary to have more living accommodations. Keeper's quarters could be single, double, triple, or even quadruple dwellings; they reflected the prevailing architectural styles, adaptations to geographical conditions, or regional tastes. Complaints by keepers concerning lack of privacy for their families finally persuaded the Lighthouse Board not to build tri-plex housing. By 1913, the U.S. Lighthouse Service stressed that a recent practice favors detached houses, insuring greater privacy, and giving better opportunity for yards and gardens.

For all practical purposes, prior to 1852 there were two types of land-based lighthouses: either a detached dwelling or an integral dwelling with the light tower rising out of the roof. The early integral towers had the tower supported by the roof system. As time went on with the lighting apparatus getting heavier, particularly with the advent of the Fresnel lens, the tower was supported from the foundation of the keeper's dwelling. The plans for Blackistone Island Lighthouse in the Potomac River, designed in 1852, clearly shows the support system ascending from the ground. The two-story dwelling had the wood tower rising through its center. Fortunately, this lighthouse needed only one keeper, even after the introduction of the Fresnel lens. In colder climates, such as New England and the Great Lakes, the light tower often was either attached to the dwelling or an enclosed passageway was built between the two structures.

Oil house

During the early days oil was often stored in the lighthouse. The contract to erect the Cape Henry Lighthouse in 1792, however, called for the oil to be stored in an underground vault with a shed built above it.[81] As late as the early 1850s, plans for the first west coast lighthouses called for the oil storage area to be in the basement. Some lighthouse towers were constructed with attached oil room and workroom structures that were generally one-story, constructed of masonry, had gable roofs, and were modest in detailing; examples include Pensacola, Pigeon Point, and Yaquina Head Lighthouses.

---

[81] Watson and Henry Associates, *Historic Structure Report for the Old (1792) Cape Henry Lighthouse, Virginia Beach, Virginia*, July 1990, Association for the Preservation of Virginia Antiquities, Richmond Virginia, p. 22. This type structure did not work well at this site which is a sand covered area, for by 1794 the oil was reported as being stored in Norfolk.

By 1890, all except a few lighthouses in the United States were using kerosene. The volatile nature of kerosene necessitated the construction of separate oil houses, which were usually built of fireproof materials such as brick, stone, iron plate and concrete. Congress issued a series of small appropriations for the construction of separate fireproof oil houses at each lighthouse station. Installation of these structures began in 1888 and was completed about 1918. The 1902 *Instructions to Light-Keepers* stated: "All mineral oil belonging to the Light House Service shall be kept in an oil house or a room by itself. The oil house shall be visited daily to detect loss by leakage or otherwise, and every precaution taken for the safe keeping of the oil."

Though they varied in size, lighthouses with smaller lenses had relatively small oil houses and those stations with the large lenses, had relatively larger oil houses. Constructed of stone, brick, cast iron, and concrete, oil houses were small, simple, and functional, usually with a gabled or a pyramid roof. When oil was no longer required, the structures were used for other storage purposes, often paint storage. In some instances, these buildings were torn down after becoming obsolete.

Fog signal building

Fog signals were developed to assist mariners when fog obscured the light. Fog signals included bells, cannons, sirens, diaphragm horns, and trumpets, and were usually housed in separate buildings, which were either attached to the light tower or free-standing. The equipment for large coastal stations was provided in duplicate to guard against breakdowns that might cause an interruption in fog signal operation.

Light stations began to get a little more complex with the introduction of fog signals. The first fog signal was a cannon placed at Boston Harbor light in 1719. Over the years a few other light stations had a cannon to warn seamen. In the 1820s, a bell fog signal was apparently introduced at West Quoddy Head Lighthouse in Maine.[82] Subsequently, other fog bell signals were added around New England and down to Chesapeake Bay; south of the bay, fog occurs much less frequently.

In the very early days, fog bells were rung by striking the bell by hand; the bell installed at Pooles Island Lighthouse, Maryland, in the mid-1820s was operated by mechanical means, using a clockwork system. A tower on which the fog bell hung was built near the shore. A rope ran from a striker to the top of the tower where weights were attached. As those weights slowly fell, they would activate the striker so that it struck the bell periodically. When the weights hit bottom after 45 minutes, sometimes an hour and a half, the keeper cranked the weights back to the top to start the process over again. Later, Daboll, Stevens, and Gamewell invented clockworks that were advertised as good for 10,000 blows of the fog bell with one winding. With a rapid characteristic, i.e., a blow every 10 seconds, a day could pass between windings; with a characteristic of a blow every 30 seconds, four days could pass before another winding.[83] In time, electricity was applied to fog signals that eased the burden of tending them. In the 1920s, a device that turned the bell on automatically came into use. It was a hygroscope measuring moisture in the air that activated the bell.

---

[82] This statement is based on the correspondence of the fifth auditor when the fog bell was being installed at the Pooles Island Lighthouse in Chesapeake in the 1820s. In this letter the fifth auditor said that the only other fog bell that he was aware of was at Passamaquoddy. See F. R. Holland, *Maryland Lighthouses of the Chesapeake Bay*, p. 16. Obviously the lighthouse he was referring to was the West Quoddy Head light near the Passamaquoddy Bay, for in 1820 Congress authorized an appropriation to install a fog bell at West Quoddy Head lighthouse. See George R. Putnam, *Lighthouses and Lightships of the United States* (Boston and New York: Houghton Mifflin Co., 1917), p. 228.

[83] Personal communication, Wayne Wheeler, February 28, 1998.

The earliest fog signal structures were wooden bell towers; later designs included iron construction.[84] The towers were usually a tapering square shape topped by a pyramidal metal roof. The tower structure was often exposed except for the enclosed upper level area that protected the bell-striking mechanism. These towers were built in exposed marine environments and subjected to heavy vibrations from the striking of the bell. They had to be replaced frequently and few survive. For the most part, the ones that survive are metronome in shape.

On stations built offshore such as caisson and screwpile structures, the fog bell was usually mounted outside the top half-story of the dwelling (just below the lantern) and struck by machinery mounted on the inside. The striker hammer passed through a hole in the wall. In screwpile lighthouses, the weights that drove the striking machinery were usually suspended by wire down through a wooden square shaft and/or in a closet. In many caisson lighthouses, the weights were suspended by wire through a central hollow structural support column. The weights were usually suspended through the first level deck of a screwpile lighthouse or to the cellar level of a caisson lighthouse. When electric fog signal horns began to replace the fog bells, the new devices were often mounted on the deck of the lantern gallery, or in the case of a caisson lighthouse on the deck of the lower gallery, or in the case of a crib lighthouse on the crib foundation platform.

During the latter half of the 19th century, the Lighthouse Board experimented with various types of fog signals, including whistles, trumpets, and sirens. At first, whistles were not successful; mainly, the board later determined, because the tests were run on too small a steam whistle. Some years later, it ran more tests, this time with the largest railroad steam whistle. The tests were successful, and the steam whistle was installed at a number of light stations. These fog signals continued in service into the 20th century. A modified version of this signal continues in use, but operated by compressed air, not steam.

Daboll's trumpet was also experimented with, but it too apparently was not successful for it was not put into general use. This fog signal had a reed that was vibrated by compressed air and the sound came out of a large trumpet, one order measuring 17 feet long and 38 inches across the opening. The siren fog signal was first used in 1868 and was most successful.[85]

Another fog signal used until recently, the diaphone, a Canadian development, gives off a two-tone sound that was made popular in the hey-day of radio by a Lifebuoy soap advertisement. It was available in several sizes and used a single tone, two-tone, and chime signal. These fog signals with their steam or compressed air apparatuses, switchboards, work benches, storage cupboards, generators, engines, air and water tanks, pumps, tools, and signal equipment occupied near barn-like buildings. The sound equipment was usually attached to the waterside of the building. Built of masonry or wood, these structures were usually plain and highly functional, with the interiors being mostly open space until filled with concrete machinery mounts, tools, and equipment. Some fog signal buildings were built integral to the light tower. The Cape Arago Light Station and the octolateral brick stucco fog signal at Coquille River Light Station, Oregon, are examples. In a few instances, a fog signal station was established without a light.

---

[84] A few stone fog signal towers were also constructed but none survive.

[85] F. R. Holland, *America's Lighthouses: Their Illustrated History Since 1716* (Brattleboro, VT: Stephen Greene Press, 1972), pp. 204-205.

Today fog signals, for the most part, are intended to aid small vessels and boats that do not have the advanced electronic gear such as radio direction finders, radar, sonar, and satellite guidance. As a result, the fog signal is being downsized. Today, the only fog signal the Coast Guard operates is the electronic horn; the ELG300 and ELG 500 have a three to five mile range and the FA 232 has a 1/4 to one mile range.[86]

Radiobeacon

About 200 radiobeacons located mostly at lighthouses, and formerly on lightships, were established on all ocean coasts and the Great Lakes. Commissioner George R., during his administration of aids to navigation, put the evolving use of the radio as one of his proudest accomplishments; he considered the radiobeacon the definitive guidance during fog for vessels that could afford radio direction finders. A vessel could search out a signal from a radiobeacon and determine his position in relation to that station. This system is considered short range, effective between 10 and 175 miles.[87] The equipment at the station consisted of antennas and transmitters and occupied space on the grounds and in a building. With the advent of new and better technology, the Coast Guard has taken all of their radiobeacons out of service.

Storehouse

Many onshore stations had separate frame or masonry storehouses where provisions, spare parts, and other items could be stored. Offshore stations made use of nearly every available space for storage. Caisson light stations used the cellars for storage of oil, coal, wood, provisions, and other items. Screwpile light stations usually had a wooden secondary landing built into the spider-like foundation below the first-level of the cottage. Here fuel, live animals, and other items could be stored. In times of storms, however, these areas were vulnerable to water damage. For offshore stations, the closets, the watchroom, and the eaves under the upper half-story were used to store necessary materials.

Boat and boathouse

In the early days, the light keeper who tended an offshore lighthouse could justify a boat to go back and forth to the mainland. But if a keeper was responsible for a light on the mainland, he would have to have strong justification, no matter how isolated the lighthouse may be, to be successful in obtaining a locally made boat from the government. These boats usually had a sail and could be rowed. At the lighthouse, these boats were pulled ashore when not in use and left in the open.

The Lighthouse Board was more generous in size and number of boats, partly because of increase in personnel. The Board also began providing boathouses to shelter the boats. The boathouses were simple gabled-roofed sheds with iron rails on which to pull the boat into the shed. Such structures became more important as technology advanced and the engine-powered boat came into use. These early boats were rather cranky, and the engine would often stop running at inopportune times. Boats were supplied to offshore lighthouses such as the screwpile, caisson, waveswept, and crib types as well as the Florida reef lights. Occasionally, isolated shore light stations without road access received boats so keepers could travel to nearby towns. Two boats were usually assigned to each offshore station, and they hung suspended from davits on opposite sides of the station so that the keeper could maintain a lee

---

[86] Personal communication, Wayne Wheeler, February 28, 1998.

[87] U.S. Coast Guard, *Light List, Gulf of Mexico*, pp. xxiii-xxiv.

for safer leaving and arriving, regardless of wind conditions. Canvas covers supplied protection from the weather.

There were several reasons for justifying two boats at an offshore light station, and one of them was the increase in rescues of fishers and boaters in trouble, and in some sections of the country, pilots of planes forced down in nearby waters. The engine-powered boats, which appeared soon after the turn of the century, could get to an accident quicker. One cannot but be impressed with the number of rescues by keepers that were recorded in the *Lighthouse Service Bulletin*, the internal newsletter of the Lighthouse Service.

Barn and garage

Some of the light stations received government-built barns where horses and perhaps a cow could be sheltered. With the coming of the automobile, light stations began to receive garages. Because they are recent, a number of garages survive; certainly more garages survive than barns. These structures were simple, standard garage structures with up to three bays. Many barns were converted to garages including Pensacola Light Station, Florida and Montauk Point Light Station, New York. The resourcefulness of lighthouse personnel is illustrated by the 1950s conversion of a garage into living quarters at Cove Point Light Station, Maryland. The garage had been moved and remodeled into a dwelling.

Privy

The necessary house for shore stations was generally no different than any other privy. Usually they were simple wooden frame structures, but on occasion they could be fancy, following the style of the dwelling. Currituck Light Station had one that was of Queen Anne design to match the keeper's quarters. Some were made of brick, a material not used for privately constructed privies.
For offshore stations, the privy was usually constructed so it cantilevered over the lower exterior gallery rail. The privy hole dropped directly into the water. They were small, accommodating only one user at a time. Those at screwpile lighthouses were made of wood, while the ones at caisson lighthouses were made of iron plate. On the latter, the privy was sometimes used as part of the electrical grounding system. A metal cable ran from the lightning rod down the roof of the lantern, then from the roof of the dwelling to the top of the privy that was attached to the iron-plated caisson tube. With more stringent environmental laws and newer technology, indoor plumbing came to land-based light stations. By the 1970s, offshore light stations began to convert interior spaces for restrooms. Holding tanks and electric commodes were used. The former privy was sometimes converted for storage or used as a paint locker. With the erection of the Texas tower type lighthouses, indoor plumbing became standard.

Water collection system

All lighthouses needed water. Some stations used wells. At other stations, water was piped in from nearby springs. Often, water collection systems provided water for drinking, washing, and for steam powered fog signals. Rainwater was often collected from the roof of light station structures channeling the water from gutters and downspouts to pipes going to the water reservoirs. Rainwater was usually not collected immediately; rather, the rain was allowed to fall for a while uncollected so the roof would be washed. Periodically the rooves were cleaned by manual means. At other light stations, particularly in drier regions such as California, water was not only caught by roof runoff but also by large catch basins connected to storage cisterns and tanks were used to trap the rainwater. These catch basins were generally constructed of brick, later covered with cement or made only of cement. The Old Point Loma

Lighthouse in San Diego still has the remains of its old brick-lined underground cistern that held 10,000 gallons. Its 2800 square-foot catch basin was attached to it. Other examples of existing catch basins are found at Point Reyes, San Luis Obispo and East Brothers Light Stations, all in California.

Where the underground water level was too high, a light station may have wooden water storage tanks aboveground. The water system for the Anacapa Island Light Station off southern California consists of a 30,000-square-foot concrete rain catchment basin and two round 50,000-gallon redwood tanks housed in a specially built water tank building. As the average rainfall is only eight inches providing only 18,000 gallons of water a year, lighthouse tenders supplied the additional water that was pumped into the storage tanks.

At offshore stations such as screwpile and caisson stations, the gutters and downspouts were attached to a water collection system inside the structure. In screwpile structures, the system was connected to water tanks, usually one in each of three or four rooms of the first-floor of the cottage. The tanks were made either of cypress or metal. A spigot at the base of each tank was positioned over a metal funnel cut into the floor so that any dripping or overflow could be controlled without flooding the cottage floors. These funnels are still intact in the Thomas Point Shoals Light Station (1875), Maryland.

In the caisson light stations, the cisterns were constructed into the concrete fill of the caisson cylinder just below the cellar level. There were usually two cisterns for each caisson light station. Like the screwpile structures, the cisterns were connected to the downspouts. A hand pump in the kitchen, connected to the cellar cistern provided water to the kitchen sink. In times of drought, buoy tenders would provide freshwater to top off the cisterns and other station water storage tanks.

Tramway

A number of light stations had tramway tracks running from landings to the light station. The tramways were principally used to unload supplies and equipment from the lighthouse tender. A few of the tracks survive at a number of light stations, including Point Reyes, California, and Split Rock, Minnesota.

Lighthouse Depot

From the beginning of the service, lighthouses had to be supplied with oil, wicks, extra chimneys for lamps, glass panes for the lantern and other equipment and materials such as brushes, brooms, oil containers, lucernes, clocks, dust pans, feather dusters, cleaning liquids and solids, paint, and wick trimmers. All these items were required to keep these aids to navigation in operation. Fresnel lenses were more complex and with their installation came a substantial increase in required tools and equipment. As the lighthouse service grew, the number of lighthouse depots increased. A tender assigned to each district inspector supplied the light stations, placed and replaced lightships, and positioned and replaced buoys and daymarks.[88] In addition, an inspector would arrive by a tender for his white glove inspection of the light station.

Lighthouse depots came into use in the midst of the Civil War with one per district. At the general depot on Staten Island, oil and lamps and other equipment were tested and often developed. All depots purchased supplies, including oil, and dispersed them to the districts. Those supplies destined for the east and Gulf coasts went largely by water, while those going to the Great Lakes and the west coast

---

[88] Lighthouse Board, *Instructions to Light-Keepers and Masters of Light-House Vessels, 1902* (Washington: Government Printing Office, 1902), p. 22.

districts went largely by rail.[89] Surviving examples of lighthouse depots include Staten Island Depot, New York (the first and general depot for the service); Detroit Depot, Michigan; and St. Josephs Depot, Michigan.

Some light stations were also used as buoy depots. Point Lookout Light Station, Maryland, became a buoy depot in 1883. Extant structures from the depot include a former coal shed (1884), used to resupply tenders, a buoy repair shed (1883), and remnants of the wharf piles and the concrete shore apron of the former rail delivery system.

Miscellaneous Structures

Other typical station outbuildings might include piers, smokehouses, wood and coal sheds, and carpenters' and blacksmiths' workshops. Relatively newer station buildings exist at some light stations such as signal/radiobeacon/generator buildings.

Regional Adaptations and Variations

Height of tower

The purpose of a light tower is to get a light high enough to be of sufficient aid to the mariner. Consequently, the East Coast from Long Island, New York, southward to the Florida Keys and around the Gulf of Mexico is very low, generally just a few feet above sea level, and requires relatively tall towers for its coastal lights. But in parts of New England and on the west coast, the high coastline requires relatively short towers. For example, the Block Island Southeast tower is 67 feet tall, but the site elevation raises the focal plane height of the light to 201 feet. Cape Cod, or Highland, light tower is 66 feet tall, but the bluff on which it rests lifts the focal plane height of the light to 183 feet. Sankaty Head and Gay Head light towers are relatively short, but the elevation of their sites raise the focal plane height of the lights to well over 160 feet. The light tower on Monhegan Island off the coast of Maine is but 47 feet tall, but the height of the focal plane is 178 feet above sea level. These coastal lights were usually fitted with first- or second-order lens.[90]

On the west coast, sites at high elevations and short towers abound. Indeed, the two lighthouses that have held the "title" of highest lights in the United States are on the California coast. The Old Point Loma Lighthouse in San Diego, a 40-foot tower built on a high promontory supported a third-order lens at a focal plane of 462 feet above sea level. Shortly after being lighted, it was reported as being seen from 25 miles and 39 miles.[91] When the Old Point Loma Lighthouse went out of service in 1891 because low clouds often obscured its light, the Cape Mendocino Lighthouse in northern California, also located on a high cape, became the highest light. Its 43-foot tower held a first-order lens. The focal plane of the light was 422 feet above sea level.[92]

---

[89] George R. Putnam, *Lighthouses and Lightships of the United States (*Boston: Houghton Mifflin, 1917), p. 48; F. R. Holland, Jr., *America's Lighthouses: Their Illustrated History Since 1716* (Brattleboro, VT: Stephen Greene Press, 1972), p. 36.

[90]U. S. Coast Guard, *Light List, Atlantic and Gulf Coasts, 1946* (Washington, Government Printing Office, 1946), pp. 100-101; Dept. of Commerce, *Light List, Atlantic and Gulf Coasts, 1933*, pp. 44-45, 50-51, 16-17.

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

[92]U.S. Coast Guard, *Light List, Pacific Coast, 1943*, (Washington: Government Printing Office, 1943), pp. 94-95.

Typically, tall towers are coastal towers 150 feet or more in height while harbor, bay, sound, and river lighthouses are typically less than 100 feet in height. Some lighthouses along New England coast did not reach 150 feet but were still considered coastal lights. Cape Elizabeth Lighthouse with a focal plane height of 129 feet above sea level, Petit Manan Lighthouse at 123 feet, and Boon Island Lighthouse at 133 feet are three examples. Each was fitted with second-order lenses.[93]

Though a few lighthouses in the Great Lakes achieved a focal plane height of over 150 feet, this was accomplished by building towers on high elevations. Though important coastal lights were built on the Great Lakes, the towers were only 90 to 110 feet tall. The only lighthouse to exceed that height was the 121-foot tower erected on a crib foundation at White Shoal in Lake Michigan.

Harbor entrances and bay or river traffic were marked with short towers no matter what the elevation. Chesapeake Bay, Delaware Bay, Hudson River, and Puget Sound are large bodies of water that had numerous lighthouses that were relatively short towers. Like the tall towers, these short towers came in many shapes, including conical, round, multi-sided, and square and were built of a variety of materials, brick, stone, wood, and metal predominating. They included the 36-foot Eastern Point Lighthouse at the entrance to Gloucester Harbor in Massachusetts, the 35-foot Pass Manchac Lighthouse at Lake Pontchartrain in Louisiana, the 27-foot square Point No Point Lighthouse in the Puget Sound, and the 43-foot conical Concord Point Lighthouse at Havre de Grace, Maryland, in upper Chesapeake Bay.

Placement of lighthouses

As aids to navigation, lighthouses serve to assist the mariner in fixing his position; warn the mariner of hazards or danger; and/or indicate a harbor entrance. The placement of lighthouses may also be affected by political and public pressure or building technology present at time of construction. Some lighthouses are located at significant landfalls. For example, transatlantic steamers bound for New York aim for the Fire Island Lighthouse, generally the first lighthouse this traffic sees. Kilauea Point Lighthouse is the landfall light for traffic bound to Hawaii from the Orient.

The most important reason for the location of a lighthouse is to mark dangerous shoals and reefs. Cape Hatteras Lighthouse marks the dangerous offshore Diamond Shoals and Minots Ledge Lighthouse marks a dangerous, hard to detect, submarine reef. Lighthouses were also built to mark the entrance to a river, bay, or harbor. These entrances often have two lighthouses, one for each side of the entrance. Cape Charles Lighthouse marks the northern and Cape Henry Lighthouse the southern entrance to Chesapeake Bay. Inside the Chesapeake Bay some of the tributaries have two lights, others just one, marking an entrance. The mouth of the Potomac River has Point Lookout Lighthouse on the Maryland side and Smith Point Lighthouse on the Virginia side. Delaware Bay is marked on the north by Cape May Lighthouse and on the south by Delaware Breakwater Lighthouse. (Cape Henlopen Lighthouse was the first and only lighthouse to mark the Bay's entrance when first built; it eroded into the ocean in 1926.) No less than five lighthouses mark San Francisco Bay entrance.

Range lights consist of a pair of towers, a lower front range and a taller rear range. When the lights are lined up one above the other, they assist the mariner in keeping their vessel in the channel, navigating twisting rivers, staying in channels running through shallow waters, and entering narrow harbors.

---

[93]Ibid.,pp. 22-23, 10-11, 24-25.

Sometimes the entrance to a very busy harbor such as Baltimore, Maryland, has multiple aids to navigation.[94]

Architectural styles

The United States has the most diverse collection of lighthouse architecture than any other country in the world. A number of well-known styles of architecture are reflected in the structures at light stations. A sampling of many of these architectural styles follows.

The Cape Cod style consists of a 1 1/2-story Cape Cod style dwelling constructed around an integral light tower. This style was used often in the Chesapeake Bay and in New England as well as among the first lighthouses built on the west coast. Examples include the now-demolished Greenbury Point Lighthouse (1848), Maryland; and Point Pinos Lighthouse (1855), California. A non-integral Cape Cod style is represented by the keeper's quarters at Scituate Lighthouse (1811), Massachusetts; and Burnt Coat Harbor (1872), Maine.

The Gothic Revival style is represented by Block Island Southeast Lighthouse (1873), Rhode Island; keeper's quarters at Eastern Point Lighthouse (1879), Massachusetts; keeper's quarters at Nauset Beach Lighthouse (1875), Massachusetts; keeper's quarters at Straitsmouth Island Lighthouse (1835), Massachusetts; Sand Island Lighthouse (1881) in the Apostles Islands, Wisconsin; keeper's quarters at Yerba Buena Island Light Station (1873), California; and the Dunkirk Light Station keeper's quarters (1875) in upstate New York. Variations of the Gothic style include the Gothic Victorian style found in the keeper's quarters at Point Montara Lighthouse (1875), California. The Carpenter Gothic style is found in the keeper's quarters at Stratford Point Lighthouse (1881), Connecticut; and keeper's quarters at Sandy Neck Light Station (1880), Massachusetts. The Stick Gothic style is found in the keeper's quarters at Mispillion Lighthouse (1873), Delaware; and keeper's quarters at Fenwick Island Light Station, Delaware. The Norman Gothic style is represented by the keeper's quarters at Passage Island Light Station (1882), Michigan; and keeper's quarters at Sand Island Light Station (1881), Wisconsin.

The Queen Anne style is present in the keeper's quarters at Cape Cod Lighthouse (1857), Massachusetts; keeper's quarters at Fort Niagara Light Station (1897), New York; and the keeper's quarters at Hospital Point Light Station (1871), Massachusetts.

Eastern Stick style is illustrated by the keeper's quarters at Tybee Island Light Station (1881), Georgia; integral tower and keeper's quarters at Hereford Inlet (1874), New Jersey; keeper's quarters at Currituck Beach Light Station (1876), North Carolina; and keeper's quarters at Boston Harbor Light Station (1884), Massachusetts.

Elements of the Second Empire can be seen at New London Ledge Light Station (1909), Connecticut; keeper's quarters at Barbers Point Light Station (1873), New York; Southwest Ledge Light Station (1877), Connecticut; Esopus Meadows Light Station (1872), Hudson River, New York; and caisson lighthouses in Chesapeake Bay such as Sandy Point (1883), Point No Point (1905), and Baltimore (1908).

The Romanesque Revival style is exhibited by the Toledo Harbor Lighthouse (1904), built on a submarine crib foundation in Lake Erie, Ohio; and the fog signal building (1889) at Point Sur Light

[94] An interesting article on range lights is Wayne Wheeler, "Range Lights," *The Keeper's Log*, v. II, no. 1, pp. 9-10.