LIGHTHOUSE EVOLUTION & TYPOLOGY

by Dr. Robert Browning, Historian

INTRODUCTION

The need of lighted beacons to guide water craft along the coasts must have suggested itself to mankind as soon as there was much venturing upon the water. The lofty Pharos of Alexandria, near the mouth of the Nile, was completed under Ptolemy II, about 280 B.C. In height and fame it has never been surpassed by any other lighthouse and is considered one of the seven wonders of the world. Many of the world's early lighthouses may have looked like this Roman lighthouse that still stands in Dover, England.

The number of lights in the world, however, was relatively small when the first lighthouse in the North American colonies was established on Great Brewster Island at Boston in 1716.

One of the most frequently asked questions is how many lighthouses have been built. This is not a question that can be easily answered because almost every lighthouse has been rebuilt at one time or another. How much change has to take place before the old structure loses its identity and becomes a new one? For example, the Point Bonita light was built on a promenade too high above the sea to be effective. A shorter tower, the one pictured, was erected at a lower site and the lantern house--the top third of the structure--was removed from the original tower and placed on top of the new structure. Is this one or two lighthouses? Another lighthouse which clouds the count is Matinicus Rock light. The two towers which connected to the keepers quarters were capped and new towers, which were also attached to the keepers quarters were built. How many lights is this--one, two, or four? A number of sites had two unconnected towers and one even had three.>

I believe that nearly 1,500 lighthouse sites have existed in the United States at one time or another. I will not hazard a guess as to have many towers have been built but I am bold enough to try to group them. Lighthouses may be categorized in many ways, one of which is by types of construction. The evolution of lighthouses has taken centuries and is profoundly influenced by the development of technology.

Lighthouses as you know are very personal. They come in many shapes and sizes and everyone has his own definition and these vary sufficiently. When one thinks of

lighthouses, the average person conjures up an image of a tall white tower on a point of land. Actually, lighthouses in this country were built in many shapes, sizes, and heights including cylindrical, conical, square, octagonal, and even triangular shaped, with towers that stand as high as 208 feet. Politics, special needs, cost, location, geography at the site, and available technology at the time of construction also influenced lighthouse design.

Today, one need only review the literature to discover that most lighthouse books approach the subject on a regional basis. Few lighthouse books, because of their regional approach, however, have a need to address trends in lighthouse construction. Permit me to offer a technological approach to the history of lighthouses.

PRE-FEDERAL ERA LIGHTHOUSES (1716-1789)

EXAMPLES: Sandy Hook, Boston, Cape Henry.

Twelve lighthouses were built in the United States before the Constitution became the law of the land. It was at this time that lighthouse control passed from the states to the federal government. No two were constructed from the same set of plans and all were built from local materials. By examining the one which remains, and the evidence of those which have not survived, reveals that these lighthouses shared some common features.

All the early lighthouses were constructed of wood or stone. Those built of wood fell victim to fire sooner or later. The stone towers were built simply by piling one stone on top of another. These stones were held together by mortar. Since the walls apparently contained no additional support such as reinforcing rods, they had to be tapered as they rose in order for the base to support the ever increasing weight and to prevent the tower from becoming unstable. Therefore, the higher they wished to build the light, the thicker the tower had to be at the base.

Given the flat nature of east coast geography, where all pre-federal lights were built, there was a need to build the lighthouses as tall as possible. Since colonial lights peaked at about 90 feet, we may assume that this was the maximum practical height for a tower built during this era.

It is surprising how little we know about pre-Federal era lighthouses. While we have almost no construction details, we do have one remaining tower to study, that of Sandy Hook, New Jersey, and there are many unanswered questions.

- Were their thick walls, up to seven feet at the base, solid or are there air spaces within them? Since the Sandy Hook light, the lone survivor does not have any weep holes to allow moisture to escape, it would seem that this structure is solid.
- For those not built on rock, what type of foundations did they have? If lighthouse construction paralleled building practices of this era, first pilings were driven, then the builders laid tiers of timber diagonally to each other, and then they added a few tiers of dressed stones laid on top of the timbers. The walls were then constructed on top of this foundation.

But all of this is mere guesswork.

EARLY FEDERAL ERA LIGHTHOUSES (1789-1820)

Examples: Portland Head, Old Cape Henry, Georgetown Harbor.

Lighthouses built between 1789 and 1820 deserve close attention. 1789 was the year that the federal government took over responsibility from the states whereby the government placed the administration under the Treasury Department. 1820 is when the administrative Fifth Auditor of the Treasury became responsible for lighthouses.

President George Washington took an active interest in lighthouses but it wasn't too long before the President had to delegate this responsibility. First the responsibility passed to the Commissioner of the Revenue and then it went to the Secretary of the Treasury. For quite some time, Albert Gallatin, the Secretary from 1801 until 1814, personally played an active role in lighthouse administration.

Hardly a year went by when one or two new lighthouses were constructed. During this era, cut stones and brick were used for the first time. This permitted the construction of taller and stronger towers because the weight could be more evenly distributed. Of the first forty towers built, only a handful survive today. These include Portland Head (1790), the old abandoned Cape Henry tower (1792), and Georgetown Harbor (1795). Most of the early federal lighthouses did not survive the U.S. Civil War. Considering that the builders were not plagued with the teething problems of any new technology and that half of these towers were built in the north where a solid foundation could usually be found, this is not really an impressive record of survival.

Of the first forty masonry towers constructed in the United States only eleven survive.

THE FIFTH AUDITOR OF THE TRESURY'S LIGHTHOUSES (1820-1852)

Examples: Matinicus.

A villain emerged from the Camelot-like interpretation of the early days of lighthouse construction; it is the Fifth Auditor of the Treasury, Stephen Pleasanton. From 1820 through 1852, he was responsible for the administration of the lighthouses. Lighthouse administration had become too large to remain a direct responsibility of the Secretary of the Treasury and was assigned to the Fifth Auditor.

The Fifth Auditor of the Treasury was a bookkeeper and a financial zealot. After all, one would hardly expect to find a philanthropist in the Treasury Department. The Fifth Auditor prided himself that for many years he was able to return funds appropriated for the construction and repair of lighthouses to the Treasury unspent. Given todays Federal budgets many would argue that this brand of Civil Servant is extinct. The Fifth Auditor, however, was a lighthouse novice when assigned the task, and unfortunately he did little to improve his knowledge of lighthouse technology during his 32-year tenure.

This period, which begins in 1820, might well be labeled the era of "the lowest bidder," and the lighthouses built during this period were inferior structures constantly in need of replacement. In addition, the lighting system used was not only grossly inferior too, but far less expensive than that employed in Europe.

A July letter from Lieutenant David D. Porter, later of Civil War fame, summarized the inadequacy of American lighthouses.

"Hatteras light, the most important on our coast is, without a doubt, the worst light in the world. …The first nine trips I made I never saw Hatteras light at all, though frequently passing within sight of the breakers, when I did see it, I could not tell it from a steamer's light, excepting that a steamer's lights are much brighter."

Not surprisingly, there are few examples of the Fifth Auditor lighthouses which have survived today. However, the Matinicus Rock light does show evidence of this era, and the evolution of this light is a good example of the fate of most constructed during the rein of the Fifth Auditor.

The current tower is the third lighthouse to be built on Matinicus Rock. You can see the remains of the second tower which has been capped. The second tower, in fact, did nothing to solve the problems of the first tower. Both were far too short and the towers

were too close together. The problems were not solved until the third structure was constructed which is the present lighthouse.

Being a bureaucrat I am compelled to offer a few words in defense of the Fifth Auditor. Remember, the survival record of towers constructed by earlier administrators wasn't really much better. In 1820, when the Fifth Auditor became responsible for the lighthouses only, 3 of the 12 pre-Federal towers were standing and during his tenure, the Fifth Auditor had to rebuild many of the towers constructed by his immediate predecessors.

Adding to the Fifth Auditor's problems was the fact that during his tenure as the administrator of lighthouses, the U.S. continually added territories that required lighthouses needing the most successful technology of the day. The massive stone towers built in the past, had little value. For example, of the 40 or so brick towers built in the South, at least 25 either blew over or sank into the soft ground.

THE ERA OF THE LIGHTHOUSE BOARD

(1852-1903)

In 1851 a special committee of professionals, appointed by Congress, conducted an investigation into the lighthouse system and concluded that it was grossly inadequate.

In 1852 Congress created a nine-member Lighthouse Board and with it a new era in American lighthouse construction began. During the next few decades American lighthouse construction went through its most dynamic period. As we examine each advance in lighthouse construction, you will see that the specific technology already existed, but it had not yet been applied to lighthouse construction.

PILE FOUNDATION

A Quaker and wealthy Liverpool merchant, John Phillips, erected a lighthouse on Smalls Rock in 1773, in the British Channel off the west coast of Wales. Instead of hiring an engineer to design the structure, he chose a musical instrument maker, Henry Whiteside, who built the lighthouse on piles rather than using conventional masonry tower. Phillips' choice and Whiteside's design were to prove revolutionary. Construction began in June 1775 and, when finished, the lighthouse consisted of nine oak posts each twenty-four inches in diameter and forty feet in length with a small two-story octagonal

wooden cabin built on top. The first floor was where the keepers lived and the top floor housed the light. It stood for eighty-five years.

Brandywine Shoal Lighthouse, built in 1828 in Delaware Bay, and destroyed in ice in the same year, is an example of a standard wooden straight-pile driven foundation. One of the last wooden straight-pile lighthouses built was the Desdemona Sands Lighthouse, Columbia River, Oregon. It was completed in 1902 and dismantled shortly after World War II.

PROTECTED SCREW PILE LIGHTHOUSES
(1850- ?)

Example: Drum Point.

More familiar as the protected, screw-pile lighthouse. It was introduced into the United States in 1850 during the closing days of the Fifth Auditor's reign.

Alexander Mitchell invented the screw-pile, a major improvement over the standard straight pile. With his son, he patented his cast iron screwpile design in the 1830s. By 1840 Mitchell combined his cast iron screwpile moorings with another pile construction technique and built the first screwpile lighthouse type 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 cast iron screwpile devise. Completed in 1841, his structure was the first lighthouse to be built upon a screwpile foundation made entirely of iron.

A protected, screw-pile lighthouse was typically a light-weight, wooden tower on iron stilts, the legs of which are tipped with cork-screw like flanges. These legs are turned into the soft ground of protected waters, such as bays and sounds. This new type of lighthouse was dependent upon the development of wrought-iron columns for the legs and cast-iron for the screw-like flanges. This technology permitted the construction of lighthouses on sites too soft to support the weight of a heavy tower.

The pile technology as mentioned was introduced in the United States at Brandywine Shoals in the Delaware Bay in 1850. Within a few decades, perhaps as many as 100 protected screw-pile lighthouses were built throughout the United States, principally in the Carolina sounds and Chesapeake Bay. This type of structure was particularly suited to slow moving, shallow water which was not subject to freezing. Screw-pile lighthouses

could also be found in the Gulf of Mexico and one was even built in the Great Lakes at Maumee Bay, but survived only one season.

The principal enemies of this type of structure were fast-flowing water, ice, and fire.

The screwpile lighthouse construction technique became especially popular after the American Civil War when the Lighthouse Board adopted a policy to replace light vessels in the interior waters with screwpile lighthouses.

Today, four of three screw-pile lighthouses survive, all in the Chesapeake. They are Thomas Point, Drum Point which now rests at the Calvert Maritime Museum, Hooper Strait at the Chesapeake Bay Maritime Museum, and Seven Foot Knoll, recently moved to Baltimore.

EXPOSED, SCREW-PILE LIGHTHOUSES
(1852-1880)

Examples: Carysfort Reef (1852); Sombrero Key (1857); Fowey Rocks (1873).

The screw-pile lighthouse design for exposed sites evolved two years after its less complex cousin, the type built for protected waters.

The exposed, screw-pile lighthouse was designed for and used in the Florida coral reefs. This structure varied in two important ways from the style designed for the protected bays and sounds. First, the lighthouse structure was a tall, skeleton iron tower and not a squat wooden structure. The screw-pile lighthouse in the bays and sounds did not need to project their lights more than a few miles, so the height of the lens was not a major concern. But this was not true for the Florida reef lights. These structures were to be major coastal lighthouses with first order lenses weighing a number of tons. Therefore, they had to be tall structures. The second major difference was in the screw flange. Large, iron foot plates were added above the screw tip in order to diffuse the pressure caused by the weight of the tower.

The first screwpile skeletal tower type to be built was the Carysfort Reef Light, off Miami, Florida, designed by I. W. P. Lewis. It was started in 1848 and completed in 1852. The entire structure was first erected in Philadelphia to prevent the need of fitting the parts together at the isolated site and it cost $105,069 to complete. This was the first tall tower built on the dangerous stretch of reefs between Cape Florida and Key West, Florida, and the oldest existing screwpile type light in the United States. Carysfort Reef Lighthouse, with its skeletal foundation, presented relatively little resistance to wind and

waves and served as a prototype for the string of lights that now mark the reefs off Florida.

Six screw-pile lighthouses for exposed sites were constructed in the Florida reefs, three before the Civil War and three afterward. Also, one light was built in the Gulf of Mexico at Ship Shoal, Louisiana, in 1858. Those built before the war are much simpler in appearance than those built two decades later.

Straight-Pile Tubular Skeletal Towers

Examples: Sombrero Key, Southwest Reef.

A close cousin to the screw-pile lighthouses were the straight-pile skeletal towers. Straight-pile tubular skeletal tower lights were built, usually of cast iron but also with wrought iron piles, both on shore and off shore, typically on soft bottoms such as mud, sand, and swamp. Early surviving examples of non-screwpile tubular skeletal tower types include: Sombrero Key Lighthouse (1858), Florida, built on iron piles; and the Southwest Reef Lighthouse (1858), Louisiana, also built on iron piles.

WAVE-SWEPT LIGHTHOUSES
(1850-1906)

Examples: Minots Ledge, Saint Georges Reef, Mile Rock.

>Another lighthouse type is the offshore wave swept tower built on rocks just above or slightly below the ocean's surface and subjected to the full fury of the sea. In 1759, John Smeaton, an Englishman, built the first successful wave swept tower in the English Channel at Eddystone Rock. This was the first interlocking masonry block tower. Later Smeaton developed (after the Romans) a cement that would set up in water. These two inventions revolutionized open sea lighthouse construction and remained the principal method for their construction until concrete and steel came into use.

The wave-swept lighthouse probably conforms closer to our mental image of the classical lighthouse than any other type. But only a few were built. The greatest engineering achievement in this country, given the difficulty of the task, and the technology available, had to be the construction of Minots Ledge lighthouse.

The first attempt to put a lighthouse on Minots Ledge was during the closing days of the Fifth Auditor. An iron tower on stilts was placed there and was destroyed by a storm just over one year after completion. The wrought-iron legs were embedded in the rock ledge. But during a violent storm in April 1851 the legs broke, washing the two keepers to their death.

The second Minots Ledge structure was begun in 1855 and completed in 1860. A good part of its foundation is underwater. Work on preparing the ledge took three years before the first course of stones was laid. The granite blocks are dove-tailed together and bounded vertically by bolts. The first forty feet of the tower are solid stone. This tower is ninety-seven feet tall and has been topped by waves several times. It is the most expensive lighthouse that was ever built. In the late 1980s the Coast Guard removed the top twenty feet, remortered the stones and replaced them. Of particular interest was its early signal—a single flash; a pause-then 4 flashes-a pause- and then 3 flashes. Because of this signal, it was called the "I Love You Lighthouse" symbolizing the eight letters in the phrase.

Other examples of wave swept lights are St. Georges Reef near Crescent City, California, and Mile Rock near San Francisco, California.

TALL BRICK TOWERS
(1857-1876)

Examples: Pensacola, Fire Island, Cape Hatteras.

When the 1803 Cape Hatteras Lighthouse tower was heightened to 150 feet in 1854 it was the first of the original "tall tower" lights to be built in the United States. The original tower was replaced by a 1870 tower that stretches over 190 feet above the ground.

Beginning with the new Lighthouse Board in 1852, they began the construction of brick towers of increasing height. By 1859 nine brick towers over 160 feet had been built and six more were constructed after the Civil War.

These towers are conical in shape, except for Cape Romain, South Carolina, which is six-sided. None of the towers which they replaced had topped 100 feet.

One would suspect that some engineering or technological breakthrough had occurred in the 1850s which allowed this more than 60-foot increase in the height of a coastal tower. This does not seem to be the case. Apparently, some had solid walls and others

were constructed with air spaces between inner and outer walls. Yet these construction techniques had existed long before the 1850s.

Then why did it take until 1850 to increase the height of towers? Permit me to suggest a few possible reasons why towers grew at this time. Perhaps engineers had improved their undertaking of mathematics and this permitted them to conclude that the existing technology could support another sixty feet. More likely the Lighthouse Board made available the money for the additional sixty feet while the Fifth Auditor had not. Another possibility is that perhaps the introduction of the Fresnel lens now made it practical to raise the towers.

All fifteen towers were built along the Atlantic Coast, as far north as Fire Island, New York, and as far south to Dry Tortugas, Florida. The tallest of these towers, Cape Hatteras at 193 feet, is also the tallest lighthouse constructed in the United States. Interestingly, all but one of the fifteen towers remain standing—although erosion is threatening several of these.

CAST IRON LIGHTHOUSES

Examples: Brandywine Shoals.

The use of cast iron in lighthouse construction probably began in the late 1830s or early 1840s. In 1844 a cast iron tower was built on Long Island Head in Boston Harbor. The 1848 tower at Brandywine shoals, the first screw pile lighthouse in the United States, had a cast iron tower. Also, the three Florida reef lights and the first Minots Ledge lighthouse, all built in the early 1850s, incorporated much cast iron in their construction.

The advantages of cast iron were that it was light when compared to stone and brick, it was inexpensive, it was strong, it was water tight and it had a slow rate of deterioration. A number of cast iron towers were lined with brick because engineers of the day could not adequately calculate the stress load and added the brick as a safety factor. Cast iron towers were especially adapted to locations where a relatively light pile structure was required in mud, sand, swamp, or coral. In these locals, skeletal tubular iron towers were often built. At least one dressed stone light was sheathed in iron plate. It was Destruction Island Lighthouse, Washington, built in 1891. It was gradually accepted that the cast-iron built lighthouses, though cheaper to build than masonry, were not as structurally sound for exposed sites, but rather more acceptable for secured headlands and harbor locations.

CRIB LIGHTHOUSES

Examples: Spectacle Reef, Poe Reef, White Shoal.

Beginning in the 1870s crib foundation construction was used extensively on the Great Lakes. Wooden cribs were constructed ashore, towed to the site, and then filled with stone. Once the crib had settled to the bottom, it was capped with concrete or some other masonry. Frequently once the crib had settled it was necessary to level the structure by adding weight to one side or another.

From an engineering view point, the two most significant crib lighthouses in the Great Lakes are Spectacle Reef and Standard Rocks. The first was completed in 1874 and the second eight years later. Spectacle Reef is 10 miles from the nearest land and Standard Rocks is 23. Each required a number of years to complete.

White Shoal lighthouse, guarding the western entrance of the Straits of Mackinac, is also crib type. Its foundation is a timber crib 72 feet square, supporting a reinforced concrete pier which extends 20 feet above the lake level. The 105 foot tower, completed in 1910, is steel, backed with brick, and faced with terra cotta.

COFFERDAM LIGHTHOUSES

Examples: Robbins Reef, Craighill Channel, Upper Range.

Cofferdam construction was used where it was desired to build the foundation on a dry site and where it was not necessary to penetrate the sea-bed to any great depth. This method could only be used in very shallow water. The wooden walls of the cofferdam were constructed ashore, taken to the site, assembled into a box in the water, bolted together and sealed, and the water pumped. Workmen then entered this open-topped structure and prepared the foundation for the lighthouse. The light pictured here is the Robbins Reef Light.

UNDER-WATER FOUNDATION LIGHTHOUSES

Examples: Stratford Shoal, Race Rock, New London Ledge.

Three lighthouses were constructed upon man-made foundations built upon under-water ledges. There were Stratford Shoal, Race Rock, and New London Ledge. The

under-water islands upon which these lighthouses were built, were raised stone by stone and had to absorb the constant pressure of strong currents.

Under-water foundation lighthouses were horrendously expensive to build and took years to prepare. Thousands of stones weighting 3 to 5 tons apiece had to be laid under water at each site. The 10,000 ton foundation at Race Rock took 5 years to prepare and cost to build $250,000 in 1875 just to prepare the foundation. And the lighthouse tower still needed to be built. In these lighthouses, the tower itself did not need to be designed to sustain the force of waves crashing against it, as was the case for the wave-swept lighthouses that we looked at earlier.

CAISSON LIGHTHOUSES

Examples: Bloody Point, Brandywine Shoal, Lubec Channel.

The ability to roll iron into large plates revolutionized the construction of lighthouses in northern bays and sounds because it significantly reduced the cost of building a lighthouse foundation in the water to a fraction of what it had been. The screw-pile structure had revolutionized lighthouses in the bays and sounds of southern waters; however, this technology was not applicable in northern waters due to the screw-pile's vulnerability to swift currents and ice.

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 which allowed the tube to sink deeper into the sea bottom. 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 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.

As noted, the expense of preparing a foundation at an underwater site was prohibitively expensive. By comparison a hollow rolled-iron shell could be sunk to the sea-bed in water up to thirty feet and filled with sand, rock, or concrete. Iron was selected because of its ability to resist corrosion in salt water. A lighthouse, typically of iron, was then placed on top of the caisson.

The first caisson lighthouse built in the United States is believed to be the Duxbury Lighthouse in Massachusetts. It was built in 1872, at the end of a breakwater in relatively shallow water. By the 1870s, these caisson lighthouses had spread through the northern waters of the nation. Approximately, fifty caisson lighthouses were built.

SUBMARINE SITE (PNEUMATIC CAISSONS) LIGHTHOUSES

Examples: Fourteen Foot Bank, Smith Point, Wolf Trap.

Most of the caisson bases were simply lowered to the sea-bed and filled with concrete. However, sites where the sea-bed was uneven, unusually soft, or exposed to strong currents and waves required special preparation.

For these lights, known as submarine site or pneumatic lighthouses, a caisson containing a double bottom was sunk in position. Once stood upright, air was pumped into the caisson, forcing the sea water out through the bottom. Workmen then entered the top of the caisson through an air-lock system and prepared the foundation. The bottom rim of the caisson acted as a cutting edge which settled into the sea-bed as workmen excavated sand and mud from inside the caisson. Water was kept from seeping under the edge and into the work chamber by air pressure. The excavated soil was hauled out or sucked through an airtight shaft. The workmen might sink the caisson structure as much as 33 feet below the sea-bed floor.

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 water collected from the roof gutter and down spout system. The first level was usually partitioned into a sitting room, kitchen, and storage area, and completely surrounded by a gallery. The second and sometimes third floor was dedicated to sleeping areas and storage. The level directly below the lantern room was the watch room.

Caisson lighthouses were more complicated and on average about four to five times more expensive to build than screwpile lights but they were better able to withstand the pressure of flowing ice.

The first submarine, or pneumatic, site lighthouse was constructed at Fourteen Foot Bank, Delaware, in 1887. The pneumatic method had been used 21 years earlier to repair the timber crib foundation at Wangoshance light on Lake Michigan. Eleven submarine site caisson structures were built in all. The most exposed in Sabine Bank,

LA, which was 15 miles offshore in the Gulf of Mexico and is known as the "spark plug" of the Gulf.

BREAKWATER LIGHTHOUSES

Examples: Delaware Breakwater, Grand Haven Pier, Cleveland Harbor.

The breakwater lighthouse presented some unique challenges that were not solved until iron was introduced as a building material.

The breakwater lighthouse had to be relatively light in order to avoid stress on the foundation; the structure had to be strong in order to withstand the impact of the waves and vibrations; and the lighthouse had to be compact because of the limited space available for the structure. Frequently, the keepers quarters were in town, because breakwaters were generally too small to attach the keeper's quarters to the tower.

The majority of breakwater lighthouses were constructed in the Great Lakes.

SKELETON TOWER LIGHTHOUSES

Examples: Cape Charles, Marblehead, Cape Fear Sturgeon Bay.

The skeleton tower, first made of iron and later steel, found great favor with the Lighthouse Board in the second half of the 19th century. The structure could be pre-fabricated and taken to the construction site in pieces. The height of the tower could be increased simply by adding sections to the bottom. Also, this type of tower offered low wind resistance, a definite asset at windy locations. It should come as no surprise that the tallest of these towers are found in areas frequented by hurricanes.

The tallest skeleton towers were Cape Charles and Hog Island, Virginia, built in the 1890s. These towers were 191 feet tall--just two feet shorter than the tallest tower in the country, the brick one at Cape Hatteras. The Cape Charles tower is still standing.

At least in theory, the skeleton tower could be disassembled and moved to a new location should the need arise. Many skeleton towers remain today. The one at Coney Island, New York, is given special notoriety by the presence of the last civilian lightkeeper, Frank Schubert.

REINFORCED CONCRETE LIGHTHOUSES (1908-1948)

Examples: Point Arenas, Cape Decision, Cleveland Ledge, Oak Island.

The introduction of reinforced concert once again changed the direction of lighthouse construction. This material was in many ways superior to iron and steel. It was cheaper and required much less maintenance. Also, it was extremely strong. Many lighthouses built in places susceptible to earthquakes were made of reinforced concrete. Therefore, most major concrete towers are found on the west coast.

Reinforced concrete towers began to replace brick masonry towers at the beginning of the 20th century. The first reinforced concrete tower was built at Point Areas, California, in 1910. It is 115 feet tall, one of the two tallest towers on the West Coast. The tallest reinforced concrete tower is Navassa in the West Indies. This tower is 150 feet tall. A series of reinforced concrete towers of art deco design were constructed in Alaska during the 1920s and 1930s. One of these, Scotch Cap, was destroyed by a tidal wave in 1946; killing five men.

The newest reinforced concrete tower is Oak Island, North Carolina. This 169-foot tower was completed in 1958. This silo-style tower was erected by using a Swedish-developed moving slip-form method. Concrete was poured and once that section dried, the form was moved up and another section was poured. The color is integrated into the concrete. The lantern room is aluminum.

OFF-SHORE "TEXAS TOWER" STRUCTURES

Examples: Brenton Reef, Buzzard Point, Ambrose, Chesapeake, Savannah, Diamond Shoals, Frying Pan Shoals.

Post World War II technology permitted lighthouses to be built at locations previously served by lightships.

These off-shore light structures are based upon technology developed in the oil industry. Their legs are driven 170 feet into the seabed. The towers are designed to withstand 65 foot seas and 125 miles per hour winds. Seven towers have been built and all have either been removed or are scheduled to be removed in the next several years.

THE ALUMINUM LIGHTHOUSE

(1960—??)

Aluminum was introduced into lighthouse construction following World War II, primarily in the lantern room area. The Charleston tower completed in 1960 was the first structure where aluminum was extensively used in the construction of the tower.

The skeleton of this 140 foot tower is made of high strength steel and the panels are aluminum. The tower is designed to withstand winds up to 160 mph and it is the only lighthouse in the United States with an elevator.

FIBERGLASS TOWERS

In an effort to keep maintenance costs down, the English introduced the concept of the fiberglass tower which was later 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 in order 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 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 Code Cannal Breakwater Light, Massachusetts. The first plastic lighthouse, Deer Island Light, a white tower built in 1982, replaced an iron tower on a caisson. It was replaced by a red-brown plastic tower in 1984.

CONCLUSION

Large Navigational Buoys, LORAN, and global positioning have all helped to diminish the importance of lighthouses as guides for mariners. Lighthouses, however, are and will always be very personal. Everyone approaches them from a different perspective. I hope that my technological approach has provided you an overview of the diversity of America's lighthouses.