Surveyor

Published quarterly by the
American Bureau of Shipping

February 1981
Volume 15 Number 1



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New York, New York 10006 U.S.A.

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Cover
A model propeller undergoes tests in a water filled tunnel at The Swedish Center for Advanced Maritime Research. The masses of vapor bubbles spiral off the trailing edge of the rapidly rotating propeller blades, showing the presence of the phenomenon of cavitation, which can cause loss of thrust, pitting of blades, and excessive vibration. An article on marine model testing appears on page 2.

2 Model testing provides full-scale answers
Miniature hulls, propellers, and offshore structures are tested in tanks which duplicate conditions encountered at sea to verify the performance of designs and to research problems in hydrodynamics.

10 Crude oil washing
Cleaning cargo tanks on a tanker with jets of crude oil reduces ocean pollution and recovers valuable oil previously lost as sludge and clingage. If adopted worldwide, crude oil washing could cut wastage by an estimated 444,000 metric tons of oil a year.

14 Profile: Peter George Goulandris
Six generations of his family from the Greek island Andros have been engaged in maritime commerce. He went to sea thirty-five years ago and gained an understanding of seamen and the shipping business to which he attributes his successful management of an international fleet.

16 The sea-swept lighthouse of Minots Ledge
This New England lighthouse perched on a rocky outcropping two miles off the coast has withstood the force of wind and sea for 121 years. The granite tower was erected in the face of enormous odds after an earlier lighthouse made of cast iron was swept into the ocean during a storm.

22 National Cargo Bureau
In 1952 the U.S. Coast Guard, maritime shipping companies, and regional boards of underwriters co-operated to institute this national cargo inspection service. Break bulk and containerized cargoes, bulk grain and ore, chemicals, and scrap metal are now less hazardous to ship because of the efforts of NCB surveyors.

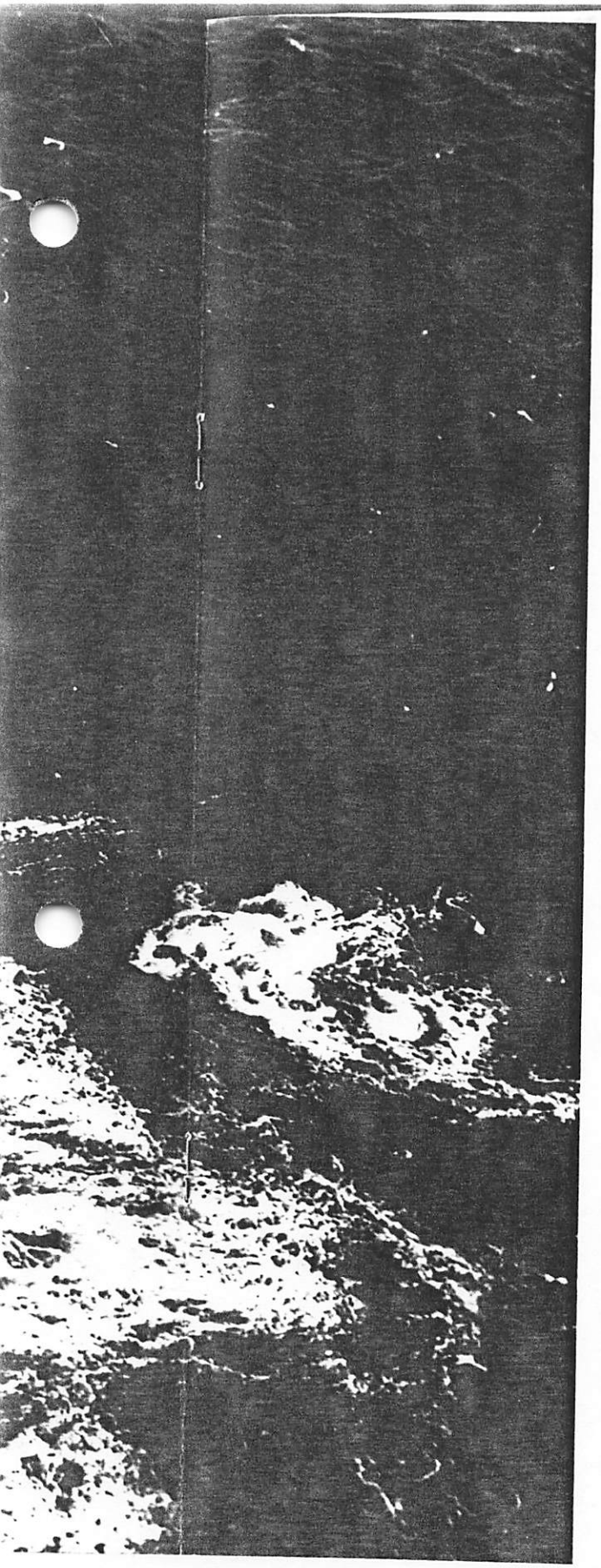
28 Whale strandings: accidental or intentional?
Why whales beach is a question that is thousands of years old, but only recently have marine mammologists developed theories to explain this behavior.

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ABS to certify containers built in People's Republic of China/Three companies sign contracts to access survey status system/ABS publishes 1980 edition of Rules for vessels on rivers and intracoastal waterways.

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The sea-swept lighthouse of Minots Ledge

Exposed to the full fury of the ocean, this beacon tower off the Massachusetts coast has endured because of the courage and skill of its builders.

Lighthouses, like grandchildren, are each unique, and those causing the greatest problems are usually the most loved. Built on a sea-swept rock twenty miles Southeast of Boston, the towering lighthouse of Minots Ledge has been winning admirers since 1860 when its lamp first beamed light out to sea. "The lighthouse rises out of the sea like a beautiful stone cannon, mouth upward, belching forth only friendly fires," wrote Henry Wadsworth Longfellow after a visit to the lighthouse in 1871. Waves have often topped the 97-foot tower during its long history, causing windows to break and the structure to shudder, but the lighthouse has won all confrontations with the sea.

Lighthouses tend to be built in inaccessible areas, and each offers its builders a unique challenge. However, the difficulties involved in building a lighthouse on dry land are easily solved when measured against those of the sea-swept lighthouse. Only a handful of these have been built in the United States, the first and most famous being Minots Ledge lighthouse.

Minots Ledge, barely twenty-five feet wide and dry for only a few hours on the calmest of days, is one of the Cohasset Rocks that lie two miles offshore from the town of Cohasset at a latitude of 42° 16.2′ N and a longitude of 70° 45.6′ W. This reef had long terrorized mariners, as a heavy wind from the northeast could easily drive ships bound from Europe to Boston upon the rocks. In the years between 1830 and 1840 alone, forty ships were lost in this area. In 1843, the Lighthouse Service, part of the U.S. Treasury Department, decided that the time was right to build a lighthouse to mark this hazard to navigation. The need had certainly been there since the Pilgrims had landed at Plymouth Rock in 1620, but only in the 1840s did the technology exist to carry out the difficult task—at least, that is what Captain William H. Swift of the U.S. Topographical Bureau believed. Swift recommended that the Service build a lighthouse of a new design, a skeleton tower made of wrought-iron stilts. He argued that such a structure would offer less resistance to the fury of the sea than the traditional stone tower.

To build the lighthouse on Minots Ledge, holes to support the stilts had to be drilled into the granite rock. A scaffolding was erected on the rock to support machinery, and four men began work drilling the holes on twenty-minute shifts. Twice during summer storms in 1847, the rock was swept clear of man's intrusion. But by August 1848, nine holes had been drilled into the rock, each twelve inches in diameter and five feet in depth. Eight of these holes had been placed in a circle twenty-five feet in diameter, while a ninth hole was placed in the center. Iron legs about sixty feet in height and ten inches in diameter were then cemented into each hole. The outer eight legs slanted toward the center, forming a fourteen-foot circumference thirty-eight feet above the ledge. These legs were held together by braces at three places. A cast-iron platform weighing five tons was placed atop the legs. Then, like a thirty-ton layer cake, a storage room, keepers' quarters, and a sixteen-sided lantern room were positioned on the platform. A Fresnel lens was installed in the lantern room, and the beacon was first lighted on 1 January 1850.

Although generally considered a great technological achievement at the time, the finished tower did not inspire confidence in those who tended the light. The first lighthouse keeper, Isaac Dunham, experienced on 6 April 1850 "an ugly sea which makes the lighthouse reel like a drunken man." He noted four months later: "Higgens (an inspector) came on to the lighthouse. Very rough and had to swing from the lighthouse on a rope and drop on the boat. It would have frightened Daniel Webster." Dunham demanded that the structure be strengthened, but his letters were ignored. He

soon resigned.

Others with steadier nerves were found to tend the light. The new keeper, Captain John W. Bennett, openly scoffed at his predecessor's fears. An English seafarer of twenty-five years experience, Bennett hired new assistants: Joseph Wilson, an Englishman, and Joseph Antoine, a Portuguese. A few days after taking charge of the lighthouse, however, Bennett changed his mind and suggested that additional iron legs should be sunk into adjacent ledges to brace the tower. Although Bennett's suggestions proved impractical, many cross braces were removed from the tower and taken ashore to be straightened and strengthened.

On 16 March 1851 a terrible storm began. At two in the morning, the keepers were awakened by wind and snow beating against the lantern. The sea was wild by dawn. On the second day of the storm, the lantern room was leaking badly, and the tower was shaking as if it were afflicted with a nervous disorder. The keepers were forced to retreat to the storeroom where they cowered for four days and nights, only occasionally climbing up to the lantern to repair damage. The storm finally abated, and the keepers worked feverishly to tighten the braces holding the tower legs together.

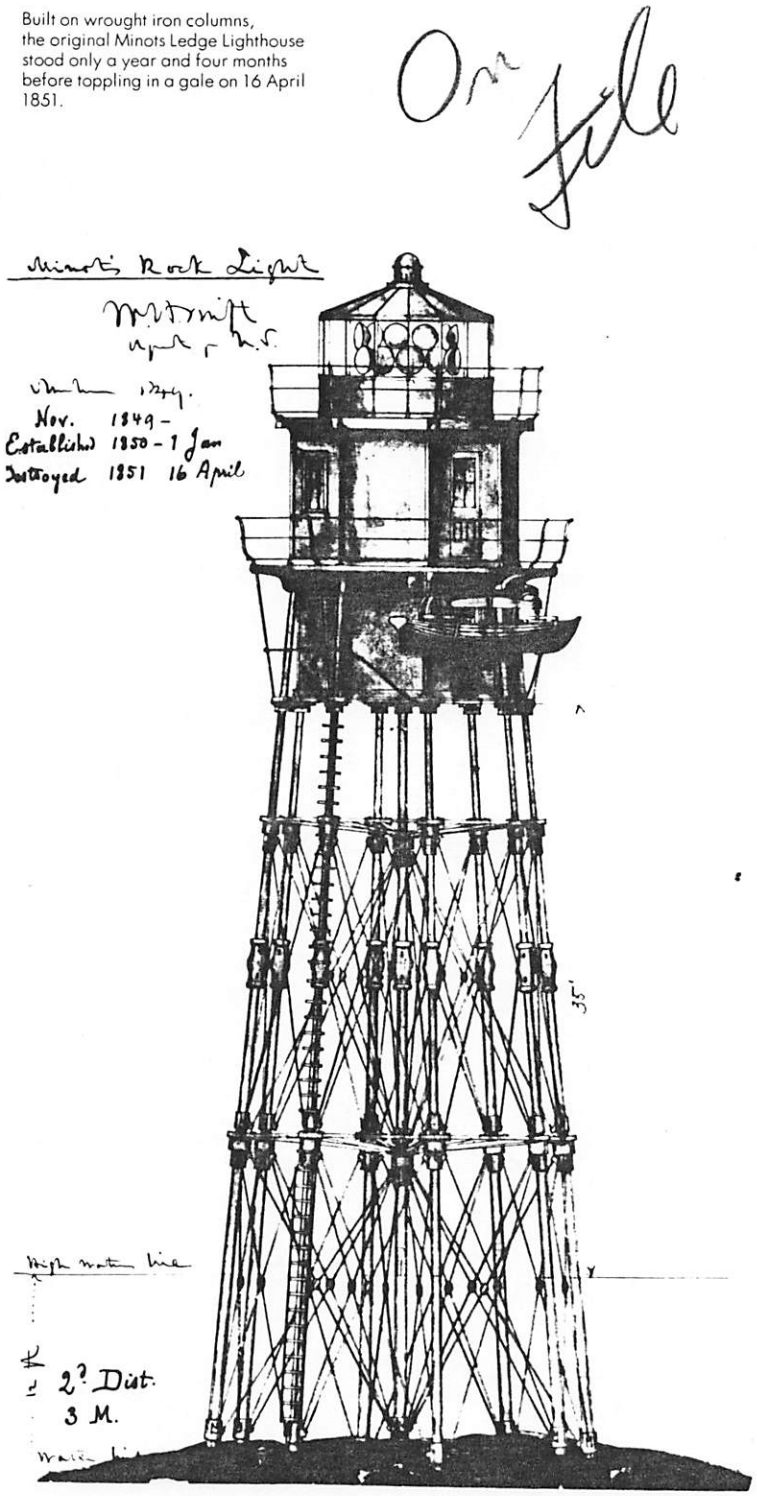
On 8 April the wind began to blow again. The storm soon increased in fury, battering much of the New England coastline. Houses were washed into the sea at Cohasset and Pleasant Beach. Boston was cut off from the mainland; bridges at Charlestown and Chelsea were submerged by abnormally high tides. Keeper Bennet, who had gone to the mainland for supplies, attempted in vain to return to the lighthouse. At Minots Ledge, the assistant keepers, Wilson and Antoine, kept the light burning and the bell ringing. The high tide sent wave after wave crashing over Minots Ledge, and the tower rocked back and forth.

Probably at about eleven o'clock on the night of 16 April, the central leg of the tower snapped, leaving the thirty-ton lantern structure to weave back and forth on its spindly legs. The keepers, probably realizing that the end was near, began pounding furiously on the lighthouse bell, a sound heard above the howl of the wind by the residents of Cohasset. Around one o'clock in the morning of 17 April, the ringing bell was silenced as the great Minots Ledge lighthouse slid into the sea. The t
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Built on wrought iron columns, the original Minots Ledge Lighthouse stood only a year and four months before toppling in a gale on 16 April 1851.

into the sea. The two keepers, wearing life preservers, dropped into the tumultuous waters only to die of exposure and drowning.

For the next ten years, Minots Ledge was guarded by a lightship. A temporary lightship was replaced in 1854 by the 232-ton *Minots Ledge*. This ship was one of the first lightships built by the Lighthouse Board, which Congress had established in 1852 to replace the Treasury Department's inefficient Lighthouse Service. The lightship was fitted with two lanterns, each of which had eight lamps and twelve-inch reflectors. Positioned on masts, the lanterns shone almost forty-two feet above sea level. Lightships, however, were poor substitutes for permanent lighthouses, since they were very expensive to maintain and could be driven from their stations.

Three years after the first Minots Ledge lighthouse was destroyed, the confrontation was renewed. The Lighthouse Board commissioned a study of the Cohasset Rocks to determine the best location for a stone lighthouse. Horizontal curves were measured every three inches, and the seams and stratification of the rock were analyzed. Six-thousand soundings were taken in a four-square mile area around the rock. The Lighthouse Board concluded that the same location as the first lighthouse would be the best. The study showed that a lighthouse having a base diameter of twenty-two foot could be built at extreme low tide but that such a base would be inadequate for either safety or utility. The study, however, demonstrated that a foundation with a thirty-foot diameter could be placed on the rock by going outside and below the low-water mark of Minots Ledge. The second, and more difficult, alternative was decided upon, and General Joseph G. Totten of the Lighthouse Board drew up designs for a tower made of granite. Model makers fabricated a miniature of the proposed stone tower for testing. Finally, Lieutenant Barton S. Alexander of the U.S. Army Corps of Engineers was chosen to supervise construction of the second Minots Ledge lighthouse.

After an enforced wait of twelve days because of sea swells, Lieutenant Alexander was able to visit Minots Ledge on 13 May 1855. The stumps of the broken legs of the old lighthouse bore witness to the earlier defeat, and the remains of the wrecked structure could be seen beneath the water. After a scant hour, the rising tide drove the reconnoitering party off the ledge. The brief on-site inspection showed that the engineering challenge was great, since the working area was minimal. As the survey had indicated, a part of the ledge was under water at all times, while the remainder was bare only for one or two hours on certain days of the month and under favorable circumstances. A perfectly smooth sea, a dead calm, and low spring tides were required conditions. This happens only six times during any one lunation — three times at the full moon and three at the new moon. Frequently, one of the necessary conditions failed, even in summer, resulting in a delay of weeks when no landing could be made.

The same party of stonecutters were assigned the work of preparing the ledge for the foundation and the cutting of the granite for the tower. When weather and tide permitted, the stonecutters were employed on the rock; the remainder of the time, they worked on the mainland. A site in Cohasset as close as possible to Minots Ledge was prepared with a wharf, living quarters, storerooms, workshops and stoneyard. There, all of the stones were cut and fitted together, each stone being placed in the exact position that it would take in the completed tower. Stones were marked and laid aside in the stoneyard in the order in which they would be needed in constructing the tower.

The first workmen landed on the ledge on 12 June 1855. They loosened the wedges around the stumps of the legs from the old lighthouse and removed the mussels from the top of the ledge. The season was too far advanced to accomplish much more on the rock. Still, the small party of workers gained valuable experience and laid out work for the intense effort scheduled for the following year. The rock was worked 130 hours during 1855.

The second working season began 1 April 1856. Before construction of the tower could begin, the uneven ledge had to be cut into steps and two partial courses of stone had to be laid before the first complete one. Temporary cofferdams made of sandbags were built around small areas of the ledge to facilitate work on the foundation. (A permanent cofferdam was impossible due to exposure to the sea.)

In June, an iron scaffold was erected to provide safety for the workmen and a temporary haven in case of a workboat accident. The scaffold was also expected to serve as a platform for the derrick needed to lay the lower courses of masonry in the tower. Nine wrought-iron legs were inserted into the foundation holes of the old lighthouse. These piles would serves as huge bolts to secure the lighthouse to the rock foundation. The scaffolding, rising twenty feet above the low-water mark, was bound together at the top by a strong wrought-iron frame. In addition to the scaffold, ropes were crisscrossed about three feet above the ledge in order to give the workmen a handhold when unexpected waves broke over the rock. The rock was worked 157 hours in 1856.

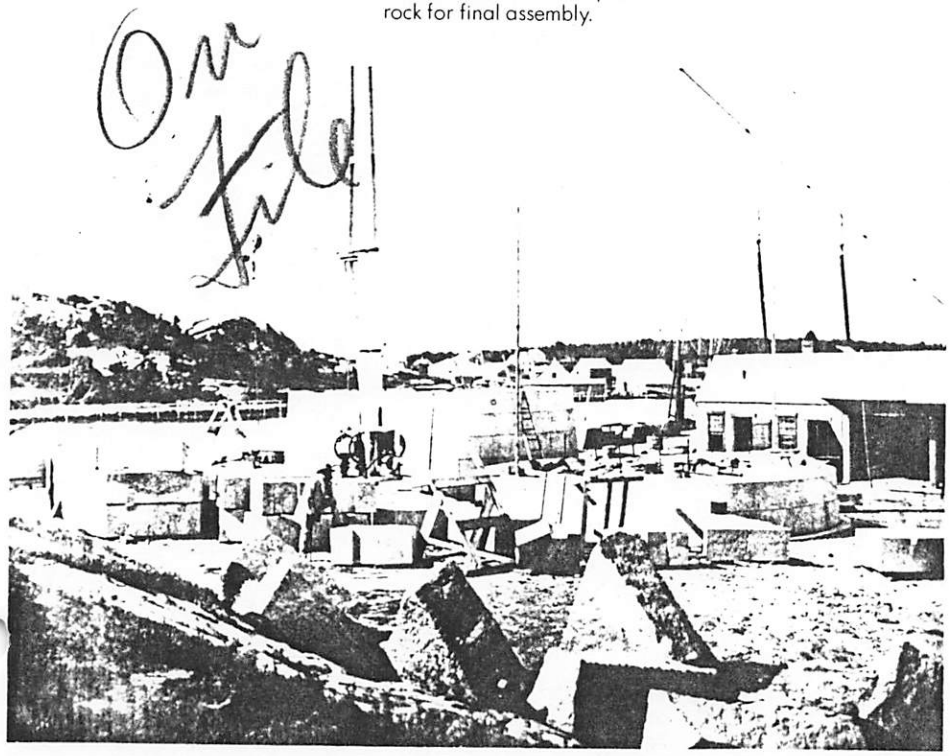
The scaffold built in the summer did not survive the winter. On 19 January 1857, the rigging of the bark *New Empire* crashed against the scaffold during a storm. Though the bark survived, the scaffold legs broke off in much the same way as those of the first lighthouse, and areas of the "dressed" rock were shattered. In the spring, workmen found that much of the cutting done the previous year had to be reworked. They recut the two bottom partial courses of stone, which had to fit into the rock like teeth in a jaw. A new scaffold was prepared but never fully erected. The eight outer legs of the scaffold, however, were stepped and were eventually incorporated into the stone tower to hold it firmly in the rock. During this most unfavorable season, the rock was worked on for only 130 hours, but the foundation pit was nearly completed, with four stones of the foundation in place.

A nagging problem for Lt. Alexander was how to adhere the stones to that part of the rock that lay underwater. At the wharf, experiments were conducted in which stones were cemented together under water, and a solution was eventually worked out. A large piece of thin muslin was laid out and covered with a layer of mortar. The finished stone was laid on the cloth, and the vertical sides of the stone were plastered. The muslin was then folded up and laid smooth around the stone. This package set in five to ten minutes, with the cloth adhering to the stone. When the stone was laid on the rock, the cloth acted as an envelope to



To commemorate the laying of the lowest stone in the base of the lighthouse, workmen gathered on the rock to have this photograph taken Sunday morning 11 July 1858

At the mainland working site the 1,079 stones used to build the lighthouse were cut, pieced together, disassembled and transported to the rock for final assembly.



protect the mortar from the dissolving action of the seawater.

During the 1858 season, workmen used a derrick to lay the lower courses of stone. The iron mast of the derrick was set in the center hole originally excavated for the old lighthouse. A lifting machine was built on a raft so that it could be floated to and from the rock daily. In the 208 hours worked during 1858, the foundation pit was finished, and the tower was completed to the sixth course. In the 377 hours worked during the 1859 season, the tower was completed to the thirty-second course, rising sixty-two feet above low tide. On 29 June 1860, five years after Lt. Alexander first landed on Minots Ledge, the last stone was laid. The lighthouse rose ninety-seven feet into the air. The tower's first forty feet were solid granite, while the next forty feet contained living quarters, storerooms and working space. Resting on top was the lantern room, where the new lantern and lens were installed that summer. The light from the new stone tower was exhibited for the first time at sunset on 15 November 1860.

The total cost of constructing the tower and building keeper's houses ashore had been $270,000, leaving $30,000 unexpended of the original appropriation. The surplus money was to

have been devoted to preparing a history of this engineering masterpiece, but the outbreak of the Civil War in 1861 made this project impractical.

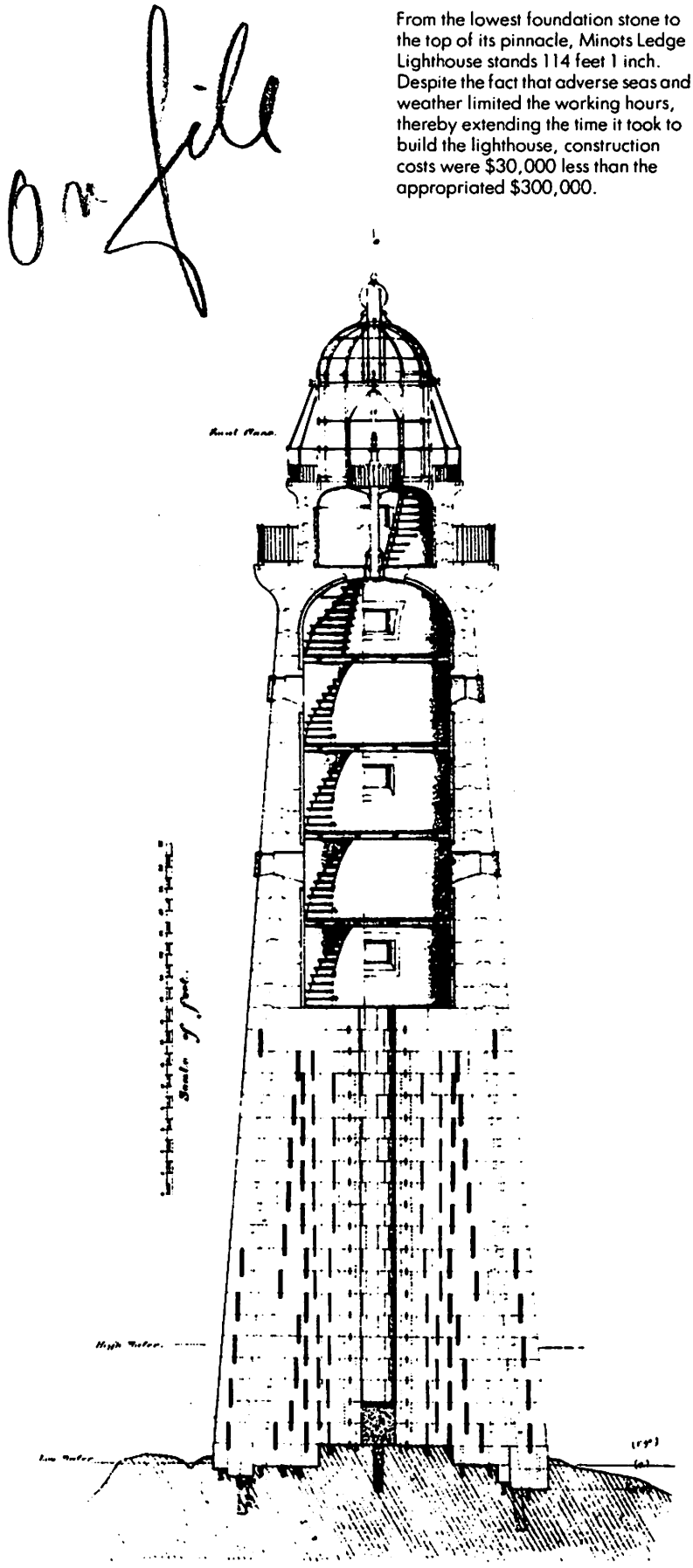
Neither loss of life nor serious injury curred during construction. Strict safety rules had been enforced: no one was hired who could not swim or handle a small boat; workboats never operated singly; and, a small boat manned by three men was always stationed on the leeward side of the rock when workmen were on the ledge.

The lighthouse was equipped with a third-order Fresnel lens that weighed almost a thousand pounds and was the size of a fifty-five gallon drum. The twelve-panel lens rotated around the center light by means of weights suspended on ropes extending down the tower core — in much the same way as the gears of a grandfather clock are rotated. On 1 May 1894, the lighthouse acquired a new characteristic, a light signal that flashed in a sequence of one-four-three. To this day, local residents insist that this signal means "I love you," and they have resisted efforts in recent decades to change the light characteristic to one of less complexity.

In 1947 the U.S. Coast Guard, heir to the Lighthouse Bureau, automated Minots Ledge lighthouse. Because the original Fresnel lens did not lend itself to automation, it was removed and a modern, if less powerful, lens put in its place. A more intense lamp was required to maintain the effective range of the light. An official report at the time justified this radical changing of the guard by describing the structure as *one of the most undesirable shore assignments that can be given a man ... The tower provides very limited quarters, the natural rain water supply is poor, there is no electricity or central heat, sanitary facilities are meager and, although it is only about one mile or so from shore, it is isolated, there being times when landing is impossible for periods of as much as three weeks.*

Although the light keepers are long gone and electricity has replaced oil, Minots Ledge lighthouse remains an engineering triumph of the nineteenth century. Confronting gales and hammering waves, it stands today as testimony to its builders' skill, courage, and dedication to the safety of ships navigating treacherous waters. ✠

ROBERT SCHEINA



From the lowest foundation stone to the top of its pinnacle, Minots Ledge Lighthouse stands 114 feet 1 inch. Despite the fact that adverse seas and weather limited the working hours, thereby extending the time it took to build the lighthouse, construction costs were $30,000 less than the appropriated $300,000.