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THE EDDYSTONE LIGHTHOUSE.

Of all the dangerous rocks by which the coasts of Great Britain are begirt, the Eddystone Reef, a few miles off Plymouth, is one of the most formidable. It is a long jagged ridge, stretching for hundreds of yards across the track of channel-going vessels. The first beacon house built upon this rock was constructed by Henry Winstanley, an eccentric self-taught mechanic. It was a polygonal column of about 100 feet in height, adorned with carving, gilding, and painting, but it was deficient in the most necessary requirement, strength, for in the great storm of 1703 it was swept completely away, and its builder, who, having been informed that rough weather was approaching, had determined to spend the night with the keepers, like them lost his life. The next lighthouse, mainly constructed of oak, was commenced in 1706 by John Rudyerd, a London silk mercer,

is employed for putting the stones ashore, and pumping out the water from the work on the rock. Her crew have worked together for a long time, and the order and smartness with which everything is done is wonderful. An irregular circle of brickwork has been built as a shelter, and inside this the rock is quarried out and grooved to receive the stones, all of which are dovetailed, and fit into each other like the pieces of a puzzle. In the center of all is a core of masonry supporting the crane used for lowering the heavy stones into their places.

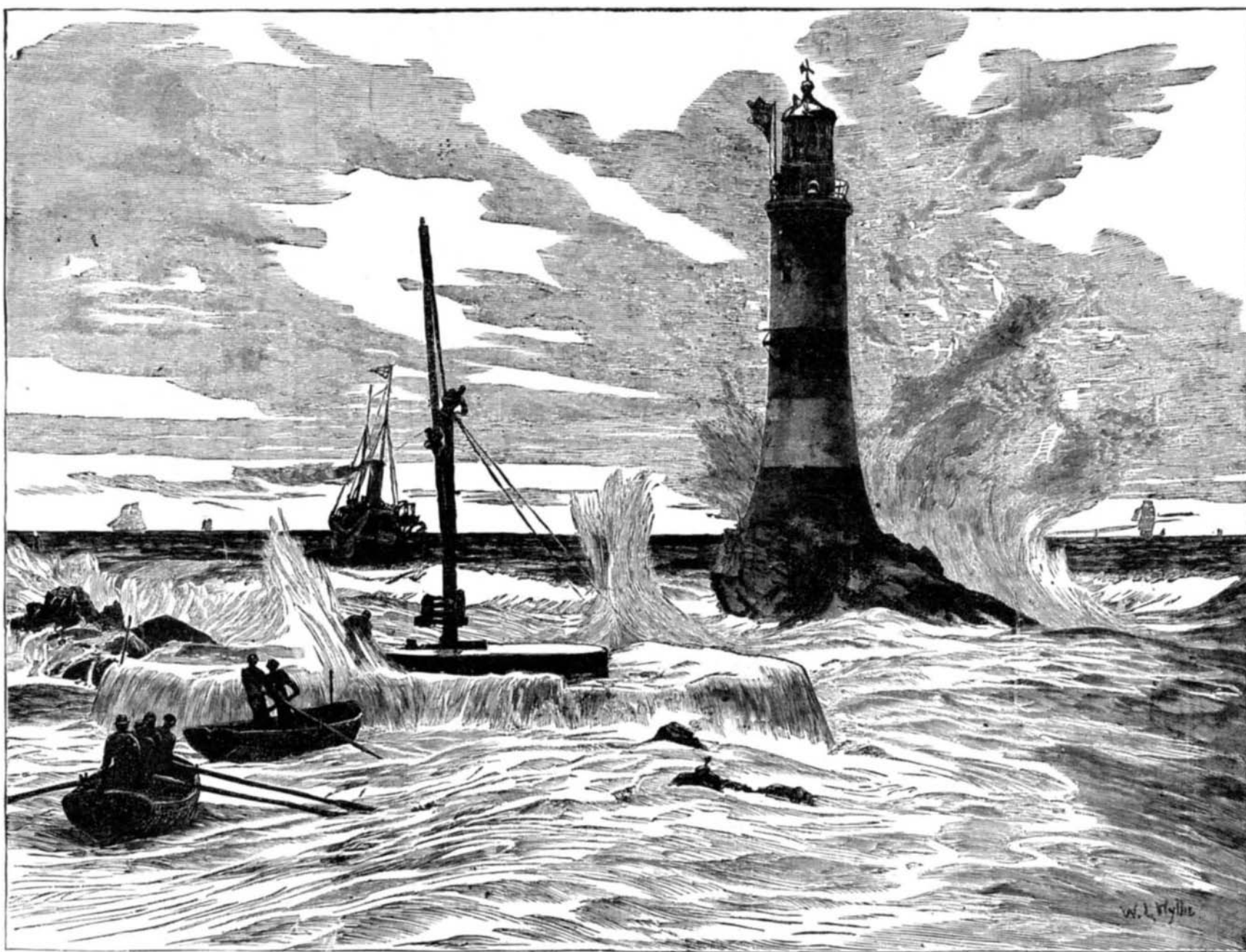
The whole is covered with water except at low tide, and even then if the sea is at all rough it breaks over the rock with great force, as is shown in our sketch, which was taken on the 20th of June, when Mr. Douglas, of the Trinity House, the designer of the new lighthouse, accompanied by his son and Mr. Edmond, the engineer in charge of the works, landed to make all secure before the rising gale.

MINOT'S LEDGE LIGHTHOUSE.

By J. G. BARNARD, U. S. A.*

The lighthouse on Minot's Ledge is the most important engineering work that belongs to our lighthouse system; and indeed it ranks, by the engineering difficulties surmounted in its erection, and by the skill and science shown in the details of its construction, among the chief of the great sea-rock lighthouses of the world.

"Minot's Rocks"—or, as they are generally designated, 'the Minots'—lie off the southeastern chop of Boston Bay. . . . These rocks or ledges, with others in their immediate vicinity, are also known as the 'Cohasset Rocks,' and have been the terror of mariners for a long period of years; they have been, probably, the cause of a greater number of wrecks than any other reefs or ledges upon the coast, lying as they do at the very entrance to the second city of the



FOUNDATION OF THE NEW EDDYSTONE LIGHT, WITH VIEW OF THE OLD LIGHTHOUSE.

was completed in 1709, and after braving the fury of the elements for nearly half a century, was destroyed by a fire, which originated in the lantern. The three light-keepers were rescued by fishermen from the coast, but to two of the three the disaster proved fatal, one being driven mad by fright, and dying in that condition, and another, an old man of ninety-four, succumbing to the effects of the molten lead which ran down his throat while he was trying to extinguish the flames. His story was disbelieved, but he died in great agony, and half a pound of lead was found in his stomach. The third lighthouse, which is still standing, was erected by John Smeaton, also a self-taught man, though an engineer by profession. It was commenced in 1756, and finished in 1759, and has thus for six score years fulfilled its mission of warning to the mariner. It is built of stone, each piece being dovetailed into its fellows, and into the rock beneath, and it is as strong now as ever; but its stability is endangered by the inroads which have been made by the sea upon the natural rock on which it stands, and the Corporation of the Trinity House have, therefore, begun the construction of a new one to supply its place. Our illustration shows the relative position of the old and new lighthouses, and also some of the difficulties of the work. A twin-screw steamer, the Hercules, fitted with every sort of ingenious contrivance,

Nothing is trusted to subordinates, and the management of the boats in broken water was perfection itself. Were it not so the task would be by no means a safe one.

On the 21st of June the Prince of Wales and the Duke of Edinburgh went to Plymouth with the intention of laying the foundation of the new lighthouse, but the weather was too rough to allow of anything of the kind being done. Their Royal Highnesses, however, visited the works at Oreston, where the stones are cut and fitted prior to being taken out to the reef, and the Duke of Edinburgh not only promised to perform the ceremony at some later day, probably in August, but also that the Duchess should lay the top stone when the building is completed.—*London Graphic*.

PROF. ROOD divides the spectrum of white light into 12 parts, and multiplies the space occupied by each part by the relative luminous intensity. In that way he obtains the following numbers: Red, 54; orange red, 140; pure orange, 80; orange yellow, 114; yellow, 54; greenish yellow, 206; yellowish green, 121; green and greenish blue, 134; prussian blue, 32; blue, 40; violet approaching to ultramarine, 20; pure violet, 5. The quantity of light in the "warm" colors is thus three times greater than that in the "cold" colors.

United States in point of tonnage, and consequently where vessels are continually passing and repassing. The Minots are bare only at three-quarters ebb, and vessels bound in with the wind heavy at northeast, are liable, if they fall to the leeward of Boston Light, to be driven upon the reefs. The rock selected for the site of the lighthouse is called the 'Outer Minot,' and is the most seaward of the group. At extreme low water an area of about 30 feet in diameter is exposed, and the highest point in the rock is about 3½ feet above the line of low water. It is very rare, however, that a surface greater than 25 feet in diameter is left bare by the sea. The rock is granite, with vertical seams of trap rising through it."

This work is one of peculiar engineering interest. The site had been occupied by an iron skeleton lighthouse, built (1848) by Captain W. H. Swift, of the United States Topographical Engineers, and carried away by the great storm of 14th, 15th, 16th, 17th of April, 1851. The history of this work, and of the catastrophe which befell it, is briefly given in the article "Lighthouse Construction," in Johnson's Cyclopedia.

The structure of which the model was exhibited succeeded the work just alluded to.

*Transactions of the American Society of Civil Engineers.

The difficulties of the work will be best appreciated from the following statement of the engineer.*

"It was a more difficult work of construction than either the Eddystone, the Bell Rock, or the Skerryvore, for the Eddystone was founded all above low water, part of its foundation being up to high-water level. The foundation of the Bell Rock was about 3 feet above low water, while the Skerryvore had its foundation above high-water level; whereas a good part of the foundation of the Minot's light was below low water. There had to be a combination of favorable circumstances to enable us to land on the Minot Rock at the beginning of that work—a perfectly smooth sea, a dead calm, and low spring tides. This only could happen about six times during any one lunation—three at full moon and three at the change. Frequently, one or the other of the necessary conditions would fail, and there were at times months, even in summer, when we could not land there at all. Our working season was from April 1 to September 15."

Both an elevation and a vertical section are given herewith. The shaft is purely conical, the limited bottom area forbidding the expansion required for the tree-like spread to the base—which is usual in European sea-rock lighthouses.

The structure is solid (around a central well) up to the level of the entrance-door. Above that there is a hollow cylindrical space, 14 feet in diameter, arched over at the level of the cornice. This space is divided into five stories by four iron floors. These five compartments, and a sixth, immediately under the lantern, constitute the keeper's rooms, store-rooms, etc. There is here shown an elevation and vertical section of the tower, and also horizontal sections showing the "bond" of the stonework of the solid parts, also of the Eddystone, Bell Rock, Skerryvore, and

Number tons of rough stone 3,514
Number tons of hammered stone 2,367
Number stones in lighthouse 1,079

The first stone was laid July 9, 1857; the lowest stone was laid July 11, 1858:

Whole height from bottom of lowest stone to top of
pinnacle 114' 1"
Height of focal plane above lowest point 98' 1"
" " " mean high water 84' 7"
Diameter of third (or first full) course 30'
" " " top of twenty-second course (solid part) 23' 6"

Observations made at Boston Lighthouse from June 7 to October 27, 1847, furnish the following results:

Rise of highest tide 14 ft. 7 in.
Mean rise and fall of tides 9 " 4 "
" " " spring tides 10 " 8 "
" " " neap " 8 " 3 "

Besides the Minot's but one other specimen of that kind of lighthouse construction is offered by the Lighthouse Establishment of the United States. That one (Spectacle Reef), of which the model of the caisson and coffer dam used in building the foundation, and of the finished structure, were exhibited. This is not properly a "sea-rock" lighthouse, nor are the destructive agencies it has to encounter sea-waves, but chiefly ice packs.

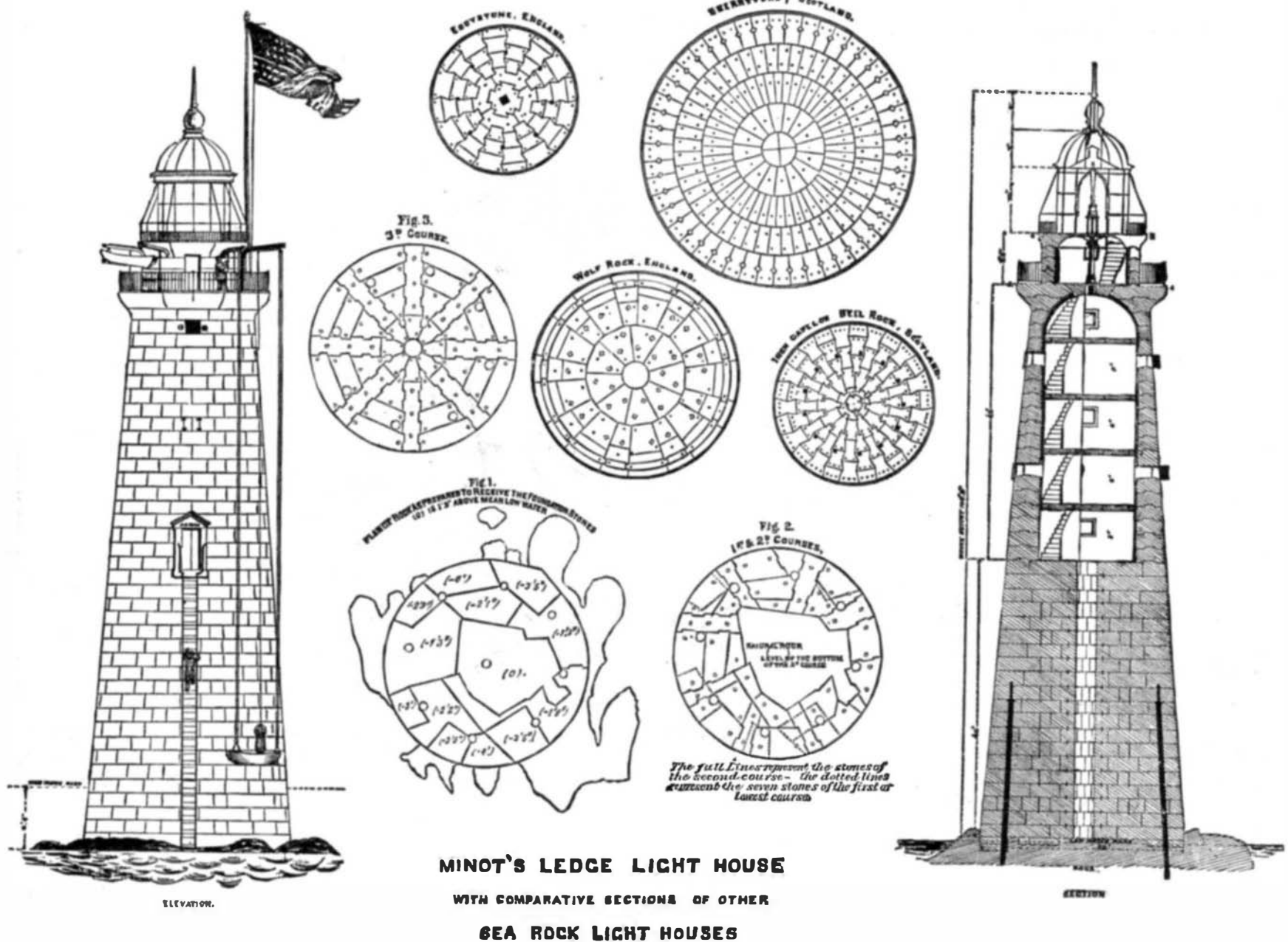
It stands upon a reef in the northern part of Lake Huron, off the eastern end of the Straits of Mackinac. It is built upon the southern extremity of the most northerly of two shoals (limestone rock *in situ*, covered with a layer of about two feet in thickness of bowlders), so situated with reference to each other as to suggest the name, "Spectacle Reef."

GAS ENGINES.

At a congress in Brussels, in 1877, of the chief engineers of the French and Belgian associations for inspecting steam boilers, it was the opinion of the meeting that steam engines are not the motors for small industries. The reasons given for this opinion were that small boilers are difficult to examine, their repairs are very costly, and their life is comparatively short. It was agreed that the small motor of the future is to be found in electric, hot air, compressed air, hydraulic, or gas engines. The last mentioned was justly regarded as that which has met with the greatest success.

It is only natural that the stringent laws which regulate the application and working of steam boilers on the Continent, should have the effect of increasing the demand for any practicable form of motor that does not come under harsh government inspection with its severe tests and penalties, but we were scarcely prepared to find boiler engineers going, we might almost say, out of their way to advocate the use of gas engines, as it is obviously against their interest, in some measure at least, to do so.

Notwithstanding the favorable opinion of gas engines entertained by steam-boiler engineers on the Continent, there still exists a very strong prejudice against gas engines among engineers in general on this side of the Channel. This prejudice arose from the failure of the first gas engines introduced from France some time ago. These engines were wrong in principle. It was overlooked by their inventors that the sudden but unsustained pressure consequent upon the explosion of a strong mixture of coal gas and air exerted against a piston was not so suitable as the sustained pressure of steam for obtaining a steady motion of a crank and fly-wheel. To this oversight, as well as to a considerable amount



Wolf Rock towers. There is, besides, a plan of the Rock itself as prepared to receive the foundation stones, in which the numbers (with the plus or minus sign) indicate the level of the respective areas—e. g. (—1' 3") indicate 1 foot 3 inches below the zero; which zero, however, is itself 1' 9" above mean low water. The small black disks mark the holes for the iron shafts of the old structure. In these, continuous dowels were inserted, which ascended as far as the twelfth masonry course. In the horizontal section the gun-metal dowels are marked, by which each course of the solid part was secured to the one above or beneath. The courses of the shell above the solid part were each joggled by a middle annulus with the course above. The following details are given for reference.

The first blow was struck on the ledge Sunday morning at sunrise, July 1, 1855:

Hours worked on ledge in excavating foundation pit during 1855	130 hours.
Hours worked on ledge in excavating foundation pit during 1856	157 hours.
Hours worked on ledge in excavating or laying four stones during 1857	130 h. 21 m.
Hours worked on ledge in excavating pit and in laying six courses during 1858	208 hours.
Hours worked on ledge in laying twenty-six courses of stone during 1859	377 hours.
	1,102 h. 21 m.

*In a succeeding number of the "Transactions" will be found the only connected "memoir" left by the engineer, the late Lieutenant-Colonel B. S. Alexander (Brevet Brigadier-General, U. S. A.), on the history of the construction of this found

The least depth of water on the shoal is about 7 feet but at the site selected for the lighthouse the rock was found at a depth of 11 feet. The nearest land is the southeasterly point of Bois Blanc Island, distant 10½ miles. The greatest exposure to waves is to the southward, from which direction the seas have a range of about 170 miles. Were there no other destructive agency, sufficient stability would have been easily secured. But, under certain meteorological conditions, currents having a velocity of from 2 to 3 miles per hour are developed here, which during the inclement season serve to move to and fro ice fields which frequently have an area of thousands of acres and a thickness of as much as two feet. This ice, formed in fresh water, is of great solidity, and when moving in the mass, and with the velocity named, has a "living force" which is almost irresistible. The aim was to oppose to it a structure against which the impinging ice would be crushed and packed till it should ground upon the shoal itself, and form a barrier against subsequent action. To give some idea of the necessity for this, it may be mentioned that in the spring of 1875 the ice was piled up against the lighthouse to the height of 30 feet above the water, or 7 feet above the sill of the doorway, which is 23 feet above the lake, and when the keepers went to the station to exhibit the light (not in operation during the winter) they were able to obtain entrance to the tower only by first cutting a passage through the pile of ice referred to.

One of Heslop's winding and pumping engines, a patent for which was granted in 1790, has been presented by the Earl of Lonsdale to the Patent Office Museum, South Kensington.

of complication, necessity for skilled attendance, trouble from heating, and expense of working, the failure of these first gas engines was mainly due. There are still about a score of these engines working in this country, but most of those set to work have been abandoned or converted into steam engines, a change which their construction readily admitted.

The defect in principle has been entirely removed in the gas engines of the present day, of which we have given a description from time to time as they made their appearance.

Nearly all the drawbacks attendant upon the use of steam, especially for small powers, are due to the risk, attention, and anxiety inseparably connected with the use of the boiler, and it must have occurred to many steam users what a blessing it would be if the steam engines could be used without a boiler. Now, it is just this desideratum that a good gas engine is designed to meet, and the success which has attended the introduction of at least one type of gas engine, renders it easy to predict with certainty that a large new field will be opened out for the employment of motive power that many small industries will be greatly developed and extended and new industries created, now that a cheap motive power can be employed without the risk and trouble of having a steam boiler on the premises. For instance, the advantage of being able to start a gas engine at full power by lighting a jet and turning the flywheel, instead of having to wait till steam is raised, renders it of great value as a fire engine in country mansions and other isolated buildings, where it can also be used daily for pumping, lifting, laundry work, and ventilating. The gas engine appears to offer to architects a way out of the difficulty they have hitherto found