
CONQUESTS OF SCIENCE

LIGHTSHIPS AND LIGHTHOUSES

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THE 43,000,000 CANDLE-POWER BEAMS THROWN FROM THE HELIGOLAND LIGHTHOUSE.

Being projected from a height of 272 feet above the sea, the beacon has a range of 23 miles, and on a clear night the rays are seen from Büsun, 35 miles away.

Frontispiece.

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LIGHTSHIPS AND LIGHTHOUSES

BY

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"MOVING PICTURES," "RAILWAY CONQUEST OF THE WORLD," "THE STEAMSHIP CONQUEST OF THE WORLD," ETC.

ILLUSTRATED

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PREFACE

ROMANCES innumerable have been woven around the flaming guardians of the coast, but it is doubtful whether any purely imaginative work is so fascinating and absorbing as the plain unvarnished narrative of how some famous lightship or lighthouse has been brought into existence. And the story of construction is equalled in every way by that relating to the operation and maintenance of the light, against all odds, for the guidance of those who have business upon the ocean.

This volume is not a history of lightships and lighthouses; neither is it a technical treatise. Rather my object has been to relate how the difficulties, peculiar and prodigious, have been overcome by the builders in their efforts to mark some terrible danger-spots, both on the mainland and isolated sea-rocks.

While the lines of the lightship and lighthouse are familiar to all, popular knowledge concerning the internal apparatus of the building or ship is somewhat hazy. Therefore I have explained, with technicalities simplified as much as possible, the equipment of the tower and vessel, and the methods whereby both visual and audible warnings are given. The very latest developments in this field of engineering and science are incorporated, so as to render the subject as comprehensive as possible within the limits of a single volume.

In the compilation of this book I have received the heartiest assistance from those who are prominently associated with the work of providing adequate aids to navigation, and am particularly indebted to the engineers to the Commissioners of Northern Lights, Messrs. D. and C. Stevenson;

Lieutenant-Colonel William P. Anderson, the Engineer-in-Chief to the Lighthouse Department of the Canadian Government; the various officials of the Lighthouse Board of the United States of America; the Engineer-in-Chief to the French Service des Phares; the lighthouse authorities of New South Wales and New Zealand; Mr. Gustaf Dalén and his assistants; Messrs. Chance Brothers and Company, Limited, of Birmingham; Messrs. Edmondsons, Limited, of Dublin; Samuel Strain, Esq., the Director of the Lighthouse Literature Mission, Belfast; the *Scientific American*, and the *Syren and Shipping*, etc.

FREDERICK A. TALBOT.

June, 1913.

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CHAPTER I

THE ORIGIN OF THE LIGHTHOUSE

THE mariner, in pursuit of his daily business, is exposed to dangers innumerable. In mid-ocean, for the most part, he need not fear them particularly, because he has plenty of sea-room in which to navigate his ship, and in case of thick fog he can ease up until this dreaded enemy lifts or disperses. But in crowded coastal waters his position is often precarious, for he may be menaced by lurking shoals or hidden reefs, which betray little or no indication of their whereabouts, and which may be crossed with apparent safety. If the ship blunders on in ignorance, it is brought up with a thud as it buries its nose in the sucking sand, or gives a mighty shiver as it scrapes over the rocky teeth, perhaps to be clasped as in a vice, or to be battered and broken so fearfully that, when at last it tears itself free and slips off into deep water, it can only founder immediately. Here, if fog blots out the scene, the ship is in danger of being lured to certain destruction by currents and other natural forces, since the captain is condemned to a helplessness as complete as of a blind man in a busy street.

It is not surprising, then, that the captain, as he approaches or wanders along a tortuous shoreline, scans the waters eagerly for a glimpse of the guardian monitor, which, as he knows from his reckonings and chart, should come within sight to guide him on his way. The danger-signal may be one of many kinds—a misty, star-like glimmer thrown from a buoy dancing on the waves, the radiant orb from a lightship bobbing up and down and swinging rhythmically to and fro, a fixed flare-light, or dazzling, spoke-like rays revolving across the sky. If sight be impossible owing to fog, he must depend upon his ear for the measured tolling of a bell, the shriek of a whistle, the deep blare of a siren, or the sharp report of an explosive. When he has picked up one or other of these warnings, he feels more at ease, and proceeds upon his way, eyes and ears keenly strained for warning of the next danger ahead.

The lighthouse is the greatest blessing that has been bestowed upon navigation. It renders advance through the waters at night as safe and as simple as in the brilliancy of the midday sun. But for these beacons the safe movement of ships at night or during fog along the crowded steamship highways which surround the serrated shores of the five continents would be impossible. It is only natural, therefore, that the various nations of the world should strenuously endeavour to light their coasts so adequately that the ship may proceed at night as safely and as comfortably as a man may walk down an illuminated city thoroughfare.

Whence came the idea of lighting the coastline with flaring beacons? It is impossible to say. They have been handed down to modern civilization through the mists of time. The first authentic lighthouse was Sigeum, on the Hellespont, which undoubtedly antedates the famous Pharos of Alexandria. The latter was a massive square tower, 400 feet high, and was known as one of the Seven Wonders of the World. It was built about 331 B.C. The warning light was emitted from a huge wood fire, which was kept burning at the summit continuously during the night; the illumination is stated to have been visible for a distance of forty miles, but modern knowledge disputes this range. The precise design of this wonderful tower is unknown, but it must have been a huge structure, inasmuch as it is computed to have cost the equivalent in modern money of over £200,000, or $1,000,000.

For sixteen hundred years it guided the navigators among the waters from which it reared its smoking crest, and then it disappeared. How, no one knows, although it is surmised that it was razed by an earthquake; but, although it was swept from sight, its memory has been preserved, and the French, Italian, and Spanish nations use its name in connection with the lighthouse, which in France is called *phare;* in the other two countries mentioned, *faro.*

The Romans in their conquest of Gaul and Britain brought the lighthouse with them, and several remains of their efforts in this direction are to be found in England, notably the pharos at Dover.

In all probability, however, the lighthouse in its most primitive form is at least as old as the earliest books of the Bible. Undoubtedly it sprang from the practice of guiding the incoming boatman to his home by means of a blazing bonfire set up in a conspicuous position near by. Such a guide is a perfectly obvious device, which even to-day is practised by certain savage tribes.

When the Phœnicians traded in tin with the ancient Britons of Cornwall, their boats continually traversed the rough waters washing the western coasts of Spain, where, for the safer passage of their sailors, doubtless, they erected beacons upon prominent headlands. The oldest lighthouse in the world to-day, which in some quarters is held to be of Phœnician origin, is that at Corunna, a few miles north of Cape Finisterre. Other authorities maintain that it was built during the reign of the Roman Emperor Trajan. In 1634 it was reconstructed, and is still in existence.

At the mouth of the Gironde is another highly interesting link with past efforts and triumphs in lighthouse engineering. The Gironde River empties itself into the Bay of Biscay through a wide estuary, in the centre of which is a bunch of rocks offering a terrible menace to vessels. This situation achieved an unenviable reputation in the days when ships first ventured out to sea. Being exposed to the broad Atlantic, it receives the full force of the gales which rage in the Bay of Biscay, and which make of the Gironde River estuary a fearful trap. The trading town of Bordeaux suffered severely from the ill fame attached to the mouth of the waterway upon which it was dependent, for both the sea and the roads exacted a heavy toll among the ships which traded with the famous wine capital of Gascony. How many fine vessels struck the rocks of

Cordouan and went to pieces within sight of land, history does not record, but the casualties became so numerous that at last the firms trading with Bordeaux refused to venture into the Gironde unless a light were placed on the reef to guide their captains. Alarmed at the prospect of losing their remunerative traffic, the citizens of Bordeaux built a tower upon the deadly reef, with a beacon which they kept stoked with wood, four men being reserved for its service. In return the authorities exacted a tax from each vessel arriving and leaving the port, in order to defray the expense thus incurred. Probably from this action originated the custom of lighthouse dues.

This bonfire served its purposes until the Black Prince brought Gascony under his power. He demolished the primitive beacon, and erected in its place another tower, 40 feet high, on which the *chauffer* was placed, a hermit being entrusted with the maintenance of the light at night. Near the lighthouse—if such it can be called—a chapel was built, around which a few fishermen erected their dwellings. When the hermit died, no one offered to take his place. The beacon went untended, the fishermen departed, and the reef once more was allowed to claim its victims from shipping venturing into the estuary.

In 1584 an eminent French architect, Louis de Foix, secured the requisite concession to build a new structure. He evolved the fantastic idea of a single building which should comprise a beacon, a church and a royal residence in one. For nearly twenty-seven years he laboured upon the rock, exposed to the elements, before he (or rather his successor) was able to throw the welcome warning rays from the summit of his creation. This was certainly the most remarkable lighthouse that has ever been set up. It was richly decorated and artistically embellished, and the tower was in reality a series of galleries rising tier upon tier. At the base was a circular stone platform, 134 feet in diameter, flanked by an elegant parapet surrounding the light-keepers' abode. This lower structure was intended to form a kind of breakwater which should protect the main building from the force of the waves. On the first floor was a magnificent entrance hall, leading to the King's apartment, a *salon* finely decorated with pillars and mural sculptures. Above was a beautiful chapel with a lofty roof supported by carved Corinthian columns. Finally came the beacon, which at that date was about 100 feet above the sea-level.

Access to the successive floors was provided by a beautiful spiral staircase, the newels of which were flanked by busts of the two French Kings, Henry III. and Henry IV., and of the designer de Foix. The architect died not long before his work was completed, but the directions he left behind him were so explicit that no difficulty was experienced in consummating his ideas, and the Tour de Cordouan shed its beneficial light for the first time over the waters of the Bay of Biscay in 1611. So strongly was the building founded that it has defied the attacks of Nature to this day, although it did not escape those of the vandals of the French Revolution, who penetrated the tower, where the busts of the two Henrys at once excited their passion. The symbols of monarchy were promptly hurled to the floor, and other damage was inflicted. When order was restored, the busts were replaced, and all the carvings which had suffered mutilation from mob law were restored. At the same time, in accordance with the spirit of progress, the tower was modified to bring it into line with modern lighting principles; it was extended to a height of 197 feet, and was crowned with an up-to-date light, visible twenty-seven miles out to sea. For more than three centuries it has fulfilled its designed purpose, and still ranks as the most magnificent lighthouse that ever has been built. Its cost is not recorded, but it must necessarily have been enormous.

In Great Britain the seafarer's warning light followed the lines of those in vogue upon the older part of the Continent, consisting chiefly of wood and coal fires mounted on conspicuous lofty points around the coast. These braziers were maintained both by public and by private enterprise. Patents were granted to certain individuals for the upkeep of beacons in England and Scotland, and from time to time the holders of these rights came into conflict with the public authority which was created subsequently for the maintenance of various aids to navigation around the coasts. In England these monopolies were not extinguished until 1836, when the Brethren of Trinity House were empowered, by special Act of Parliament, to purchase the lights which had been provided both by the Crown and by private interests, so as to bring the control under one corporation.

The *chauffer*, however, was an unsatisfactory as well as an expensive type of beacon. Some of these grates consumed as many as 400 tons of coal per annum—more than a ton of coal per night—in addition to vast quantities of wood. Being completely exposed, they were subject to the caprices of the wind. When a gale blew off the land, the light on the sea side was of great relative brilliancy; but when off the water, the side of the fire facing the sea would be quite black, whereas on the landward side the fire bars were almost melting under the fierce heat generated by the intense draughts. This was the greater drawback, because it was, of course, precisely when the wind was making a lee shore below the beacon that the more brilliant light was required.

When the Pilgrim Fathers made their historic trek to the United States, they took Old World ideas with them. The first light provided on the North American continent was at Point Allerton, the most prominent headland near the entrance to Boston Harbour, where 400 boatloads of stone were devoted to the erection of a tower capped with a large basket of iron in which "fier-bales of pitch and ocum" were burned. This beacon served the purpose of guiding navigators into and out of Boston Harbour for several years.

When, however, the shortcomings of the exposed fire were realized, attempts were made to evolve a lighting system, which does in reality constitute the foundation of modern practice. But the beacon fire held its own for many years after the new principle came into vogue, the last coal

Photo by permission of Messrs. Bullivant & Co., Ltd.

HOW THE BEACHY HEAD LIGHTHOUSE WAS BUILT.

To facilitate erection a cableway was stretched between the top of Beachy Head and a staging placed beside the site of the tower in the water. A stone is being sent down.

Photo by permission of Messrs. Bullivant & Co., Ltd.

WORKMEN RETURNING BY THE AERIAL CABLEWAY TO THE TOP OF BEACHY HEAD.

fire in England being the Flat Holme Light, in the Bristol Channel, which was not superseded until 1822.

In Scotland the coal fire survived until 1816, one of the most important of these beacons being that on the Isle of May, in the Firth of Forth, which fulfilled its function for 181 years. This was a lofty tower, erected in 1636, on which a primitive type of pulley was installed for the purpose of raising the fuel to the level of the brazier, while three men were deputed to the task of stoking the fire. It was one of the private erections, and the owner of the Isle of May, the Duke of Portland, in return for maintaining the light, was allowed to exact a toll from passing vessels. When the welfare of the Scottish aids to navigation was placed under the control of the Commissioners of Northern Lighthouses, this body, realizing the importance of the position, wished to erect upon the island a commanding lighthouse illuminated with oil lamps ; but it was necessary first to buy out the owner's rights, and an Act of Parliament was passed authorizing this action, together with the purchase of the island and the right to levy tolls, at an expenditure of £60,000, or $300,000. In 1816 the coal fire was finally extinguished.

The English lights are maintained by the Brethren of Trinity House, and their cost is defrayed by passing shipping. This corporation received its first charter during the reign of Henry VIII. Trinity House, as it is called colloquially, also possesses certain powers over the Commissioners of Northern Lights and the Commissioners of Irish Lights, and is itself under the sway, in regard to certain powers, such as the levy of light dues, of the Board of Trade. This system of compelling shipowners to maintain the coast lights is somewhat anomalous ; it possesses many drawbacks, and has provoked quaint situations at times. Thus, when the *Mohegan* and the *Paris* were wrecked on the Manacles within the space of a few months, the outcry for better lighting of this part of the Devon and Cornish coasts was loud and bitter. The shipowners clamoured for more protection, but at the same time, knowing that they would have to foot the bill, maintained that further lighting was unnecessary.

The British Isles might very well emulate the example of the United States, France, Canada, and other countries, which regard coast lighting as a work of humanity, for the benefit of one and all, and so defray the cost out of the Government revenues. Some years ago, when an International Conference was held to discuss this question, some of the representatives suggested that those nations which give their lighthouse services free to the world should distinguish against British shipping, and levy light-dues upon British ships, with a view to compelling the abolition of the tax upon foreign vessels visiting British ports. Fortunately, the threat was not carried into execution.

The design and construction of lighthouses have developed into a highly specialized branch of engineering. Among the many illustrious names associated with this phase of enterprise—de Foix, Rudyerd, Smeaton, Walker, Douglass, Alexander, and Ribière—the Stevenson family stands pre-eminent. Ever since the maintenance of the Scottish coast lights was handed over to the Northern Commissioners, the engineering chair has remained in the hands of this family, the names of whose members are identified with many lights that have become famous throughout the world for their daring nature, design, and construction. Moreover, the family's contributions to the science of this privileged craft have been of incalculable value. Robert Louis Stevenson has written a fascinating story around their exploits in "A Family of Engineers."

It was at first intended that the great author himself should follow in the footsteps of his forbears. He completed his apprenticeship at the drawing-table under his father and uncle, and became initiated into the mysteries of the craft. At the outset he apparently had visions of becoming numbered among those of his family who had achieved eminence in lighthouse construction, and he often accompanied his father or uncle on their periodical rounds of inspection. Probably the rough and tumble life in a small tender among the wild seas of Scotland, the excitement of landing upon dangerous rocks, the aspect of loneliness revealed by acquaintance with the keepers, and the following of the growth of a new tower from its foundations, stirred his imagination, so that the dormant literary instinct, which, like that of engineering, he had inherited, became fired. Mathematical formulæ, figures, and drawings, wrestled for a time with imagination and letters, but the call of the literary heritage proved triumphant, and, unlike his grandfather, who combined literature with lighthouse construction, and who, indeed, was a polished author, as his stirring story of the "Bell Rock Lighthouse" conclusively shows, he finally threw in his lot with letters.

The fact that for more than a century one family has held the exacting position of chief engineer to the Northern Commissioners, and has been responsible for the lights around Scotland's troublous coasts, is unique in the annals of engineering. Each generation has been identified with some notable enterprise in this field. Thomas Smith, the father-in-law of Robert Stevenson, founded the service, and was the first engineer to the Commissioners. Robert Stevenson assumed his mantle and produced the "Bell Rock." His son, Alan Stevenson, was the creator of the "Skerryvore." The next in the chain, David Stevenson, built the "North Unst." David and Thomas Stevenson, who followed, contributed the "Dhu-Heartach" and the "Chicken Rock" lights; while the present generation, David and Charles, have erected such works as "Rattray Briggs," "Sule Skerry," and the Flannen Islands lighthouses. In addition, the latter have developed lighthouse engineering in many novel directions, such as the unattended Otter Rock lightship, the unattended Guernsey lighthouse, and the automatic, acetylene, fog-signal gun, which are described elsewhere in this volume.

Some forty years ago the Stevensons also drew up the scheme and designed the first lighthouses for guarding the coasts of Japan. The essential optical apparatus and other fittings were built and temporarily erected in England, then dismantled and shipped to the East, to be set up in their designed places. The Japanese did not fail to manifest their characteristic trait in connection with lighthouses as with other branches of engineering. The structures produced by the Scottish engineers fulfilled the requirements so perfectly, and were such excellent models, as to be considered a first-class foundation for the Japanese lighthouse service. The native engineers took these lights as their pattern, and, unaided, extended their coast lighting system upon the lines laid down by the Stevensons. Since that date Japan has never gone outside her own borders for assistance in lighthouse engineering.

CHAPTER II

BUILDING A LIGHTHOUSE

OBVIOUSLY, the task of erecting a lighthouse varies considerably with the situation. On the mainland construction is straightforward, and offers little more difficulty than the building of a house. The work assumes its most romantic and fascinating form when it is associated with a small rocky islet out to sea, such as the Eddystone, Skerryvore, or Minot's Ledge; or with a treacherous, exposed stretch of sand, such as that upon which the Rothersand light is raised. Under such conditions the operation is truly herculean, and the ingenuity and resource of the engineer are taxed to a superlative degree; then he is pitted against Nature in her most awful guise. Wind and wave, moreover, are such formidable and relentless antagonists that for the most momentary failure of vigilance and care the full penalty is exacted. Then there are the fiercely scurrying currents, tides, breakers, and surf, against which battle must be waged, with the odds so overwhelmingly ranged against frail human endeavour that advance can only be made by inches. The lighthouse engineer must possess the patience of a Job, the tenacity of a limpet, a determination which cannot be measured, and a perseverance which defies galling delays and repeated rebuffs. Perils of an extreme character beset him on every hand; thrilling escape and sensational incident are inseparable from his calling.

The first step is the survey of the site, the determination of the character of the rock and of its general configuration, and the takings of levels and measurements for the foundations. When the rugged hump is only a few feet in diameter little latitude is afforded the engineer for selection, but in instances where the islet is of appreciable area some little time may be occupied in deciding just where the structure shall be placed. It seems a simple enough task to determine; one capable of solution within a few minutes, and so for the most part it is—not from choice, but necessity—when once the surface of the rock is gained. The paramount difficulty is to secure a landing upon the site. The islet is certain to be the centre of madly surging currents, eddies, and surf, demanding wary approach in a small boat, while the search for a suitable point upon which to plant a foot is invariably perplexing. Somehow, the majority of these bleak, wave-swept rocks have only one little place where a landing may be made, and that only at certain infrequent periods, the discovery of which in the first instance often taxes the engineer sorely.

Often weeks will be expended in reconnoitring the position, awaiting a favourable wind and a placid sea. Time to the surveyor must be no object. He is the sport of the elements, and he must curb his impatience. To do otherwise is to court disaster. The actual operations on the rock may only occupy twenty minutes or so, but the task of landing is equalled by that of getting off again—the latter frequently a more hazardous job than the former.

The west coast of Scotland is dreaded, if such a term may be used, by the engineer, because the survey inevitably is associated with bitter disappointments and maddening delays owing to the caprices of the ocean. This is not surprising when it is remembered that this coastline is of a cruel, forbidding character and is exposed to the full reach of the Atlantic, with its puzzling swell and vicious currents. The same applies to the west coast of Ireland and the open parts of the South of England. The Casquets, off the coast of Alderney, are particularly difficult of approach, as they are washed on all sides by wild races of water. There is only one little cove where a landing may be effected by stepping directly from a boat, and this place can be approached only in the calmest weather and when the wind is blowing in a certain direction. On one occasion, when I had received permission to visit the lighthouse, I frittered away three weeks in Alderney awaiting a favourable opportunity to go out, and then gave up the attempt in disgust. As it happened, another month elapsed before the rock was approachable to make the relief.

When the United States Lighthouse Board sanctioned the construction of the Tillamook lighthouse on the rock of that name, off the Oregon coast, the engineer in charge of the survey was compelled to wait six months before he could venture to approach the island. In this instance, however, his time was not wasted entirely, as there were many preparations to be completed on the mainland to facilitate construction when it should be commenced. Early in June, 1879, the weather moderated, and the Pacific assumed an aspect in keeping with its name. Stimulated by the prospect of carrying out his appointed task, the engineer pushed off in a boat, but, to his chagrin, when he drew near the rock he found the prospects of landing to be hopeless. He cruised about, reconnoitring generally from the water, and then returned to shore somewhat disgusted.

A fortnight later he was instructed to take up his position at Astoria, to keep a sharp eye on the weather, to take the first chance that presented itself of gaining the rock, and not to return to headquarters until he had made a landing. He fretted and fumed day after day, and at last pushed off with a gang of men when the sea where it lapped the beach of the mainland was as smooth as a lake; but as they drew near the Tillamook it was the same old story. A treacherous swell was running, the waves were curling wickedly and fussily around the islet; but the engineer had made up his mind that he would be balked no longer, so the boat was pulled in warily, in the face of terrible risk, and two sailors were ordered to get ashore by hook or by crook. The boat swung to and fro in the swell. Time after time it was carried forward to the landing spot by a wave, and then, just as the men were ready to jump, the receding waters would throw it back. At last, as it swung by the spot, the two men gave a leap and landed safely. The next proceeding was to pass instruments ashore, but the swell, as if incensed at the partial success achieved, grew more boisterous, and the boat had to back away from the rock. The men who had landed, and who had not moved a yard from the spot they had gained, became frightened at this manœuvre, and, fearing that they might be marooned, jumped into the sea, and were pulled into the boat by means of their life-lines, without having accomplished a stroke.

The engineer chafed under these disappointments, and himself determined to incur the risk of landing at all hazards. With his tape-line in his pocket, he set out once more a few days later, and in a surf-boat pulled steadily into the froth and foam around the rock ; while the men sawed to and fro the landing-place, he crouched in the bow, watching his opportunity. Presently, the boat steadying itself for a moment, he made a spring and reached the rock. He could not get his instruments ashore, so without loss of time he ran his line from point to point as rapidly as he could, jotted down hurried notes, and, when the swell was growing restive again, hailed the boat, and at a favourable moment, as it manœuvred round, jumped into it.

The details he had secured, though hastily prepared, were sufficient for the purpose. His report was considered and the character of the beacon decided. There was some discussion as to the most favourable situation for the light upon the rock, so a more detailed survey was demanded to settle this problem. This task was entrusted to an Englishman, Mr. John R. Trewavas, who was familiar with work under such conditions. He was a master-mason of Portland and had been engaged upon the construction of the Wolf Rock, one of the most notable and difficult works of its kind in the history of lighthouse engineering.

He pushed off to the rock on September 18, 1879, in a surf-boat, only to find the usual state of things prevailing. The boat was run in, and, emulating the first engineer's feat, he cleared the water and landed on the steep, rocky slope ; but it was wet and slippery, and his feet played him false. He stumbled, and stooped to regain his balance, but just

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THE SANGANEB REEF LIGHTHOUSE IN THE RED SEA.

It indicates a treacherous coral reef, 703 miles from Suez. It is an iron tower 180 feet high, with a white flashing light having a range of 19 miles.

THE ALCATRAZ LIGHTHOUSE UNDER CONSTRUCTION.

THE ALCATRAZ LIGHTHOUSE COMPLETED.

This tower off the Californian coast is one of the latest works of the American Lighthouse Department. It has a range of 21 miles.

then a roller curled in, snatched him up and threw him into the whirlpool of currents. Life-lines were thrown, and the surf-boat struggled desperately to get near him, but he was dragged down by the undertow and never seen again. This fatality scared his companions, who returned hastily to the mainland. The recital of their dramatic story stirred the public to such a pitch that the authorities were frantically urged to abandon the project of lighting the Tillamook.

Mr. David Stevenson related to me an exciting twenty minutes which befell him and his brother while surveying a rock off the west coast of Scotland. They had been waiting patiently for a favourable moment to effect a landing, and when at last it appeared they drew in and clambered ashore. But they could not advance another inch. The rock was jagged and broken, while its surface was as slippery as ice owing to a thick covering of slimy seaweed whereon boots could not possibly secure a hold. Having gained the rock with so much difficulty, they were not going away empty-handed. As they could not stand in their boots, they promptly removed them, and, taking their line and levels, picked their way gingerly over the jagged, slippery surface in their stockinged feet. Movement certainly was exceedingly uncomfortable, because their toes displayed an uncanny readiness to find every needle-point on the islet; but the wool of their footwear enabled them to obtain a firm grip upon the treacherous surface, without the risk of being upset and having a limb battered or broken in the process. Twenty minutes were spent in making investigations under these disconcerting conditions, but the time was adequate to provide all the details required. When they had completed the survey and had regained their boat—a matter of no little difficulty in the circumstances—their feet bore sad traces of the ordeal through which they had passed. However, their one concern was the completion of the survey; that had been made successfully and was well worth the toll exacted in the form of physical discomfort.

As a rule, on a wave-swept rock which only shows itself at short intervals during the day, the preparation of the foundations is not an exacting task. A little paring with chisels and dynamite may be requisite here and there, but invariably the engineer takes the exposed surface as the basis for his work. The sea has eaten away all the soft, friable material in its ceaseless erosion, leaving an excellent foundation to which the superstructure can be keyed to become as solid as the rock itself.

When the beacon is to be erected upon a sandy bottom, the engineer's work becomes more baffling, as he is compelled to carry his underwater work down to a point where a stable foundation may be secured. When the Leasowe lighthouse was built on the sandy Wirral shore, the builders were puzzled by the lack of a suitable foundation for the masonry tower. An ingenious way out of the difficulty was effected. In the vicinity an incoming ship, laden with a cargo of cotton, had gone ashore and had become a total wreck. The cotton was useless for its intended purpose, so the bales were salvaged and dumped into the sand at the point where the lighthouse was to be erected. The fleecy mass settled into the sand, and under compression became as solid as a rock, while its permanency was assured by its complete submersion. The stability of this strange foundation may be gathered from the fact that the tower erected thereon stood, and shed its welcome light regularly every night, for about a century and a half, only being extinguished two or three years ago as it was no longer required.

In the Old World, and, indeed, in the great majority of instances, the lighthouse is what is described as a "monolithic structure," being built of courses of masonry, the blocks of which are dovetailed together not only laterally, but also perpendicularly, so that, when completed, the tower comprises a solid mass with each stone jointed to its fellow on four or five of its six sides. This method was first tried in connection with the Hanois lighthouse, off the Guernsey coast, and was found so successful that it has been adopted universally in all lighthouses which are exposed to the action of the waves.

The upper face and one end of each block are provided with projections, while the lower face and the other end are given indentations. Thus, when the block is set in position, the projections fit into corresponding indentations in the adjacent blocks, while the indentations receive the projections from two other neighbouring pieces. The whole is locked together by the aid of hydraulic cement. Consequently the waves, or any other agency, cannot possibly dislodge a stone without breaking the dovetails or smashing the stone itself. For the bottom layer, of course, the surface of the rock is pared away sufficiently to receive the stone, which is bedded in cement adhering to both the rock and the superimposed block. A hole is then drilled through the latter deep into the rock beneath, into which a steel rod or bolt is driven well home, and the hole is sealed up with cement forced in under such pressure as to penetrate every interstice and crevice.

The iron supports constitute the roots, as it were, of the tower, penetrating deep into the heart of the rock to secure a firm grip, while the tower itself resembles, in its general appearance, a symmetrical tree trunk, this form offering the minimum of resistance to the waves. The lower part of the tower is made completely solid by the dovetailing of the integral blocks, and is cylindrical in shape up to a certain predetermined level which varies according to the surrounding conditions and the situation of the light. Some years ago the lighthouse assumed its trunk-like shape at the bottom course, rising in a graceful concave curve to the lantern; but this method has been abandoned, inasmuch as, owing to the decreasing diameter of the tower as it rose course by course above its foundations, the lowest outer rings of masonry did not have to withstand any of the superimposed weight, which naturally bears in a vertical line. By carrying the lower part to a certain height in the form of a cylinder, and then commencing the concave curve of the tower, the pressure of the latter is imposed equally upon the whole of its foundations. The latter may be stepped—*i.e.*, one tier of stones may project a little beyond that of the one im-

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mediately above—but this arrangement is adopted in order to break the smashing force of the waves.

The conditions attending the actual building operations upon the rock, which may be accessible only for an hour or two per day in calm weather, prevent the blocks of granite being shaped and trimmed upon the site. Accordingly, the lighthouse in the first place is erected piecemeal on shore. A horizontal course of stones is laid to see that each dovetail fits tightly and dead true. The next course is laid upon this, and so on for perhaps eight or ten courses, the trimming and finicking being accomplished as the work proceeds. Each projection has to be only just big enough to enter its relative indentation, while the latter must be exactly of the requisite dimensions to receive the projection, and no more. Each stone is then given an identification mark, so that the masons on the rock may perceive at a glance its precise position in a course, and to what ring of stones it belongs. Therefore the mason at the site has no anxiety about a stone fitting accurately ; he has merely to set it in position upon its bed of cement.

On shore—generally in the quarry yard—when a series of courses have been temporarily built up in this manner and have received the critical approbation of the resident engineer, the topmost course is removed and retained, while the other blocks are despatched to the site. This topmost course forms the bottom ring in the next section of the lighthouse which is built up in the yard, and the topmost course of this section in turn is held to form the bottom course of the succeeding part of the tower, and so on from foundation to lantern parapet.

During the past two or three years reinforced concrete has been employed to a certain extent for lighthouse construction, but granite of the finest and hardest quality still remains the material *par excellence* for towers erected in exposed, sea-swept positions. The Russian lighthouse authorities have adopted the ferro-concrete system in regard to one or two shore lights, especially on the Black Sea, while another fine structure upon this principle was built by the French *Service des Phares* in 1905 at the entrance to the River Gironde. The system has also been adopted by the Canadian lighthouse authorities; one or two recent notable lights under their jurisdiction have been constructed in this material, although on somewhat different lines from those almost invariably followed, so far as the general design is concerned.

While the masonry or monolithic structure is the most durable and substantial structure, it is also the most expensive. In many parts of the world, notably along the Atlantic coastline of the United States, what are known as "screw-pile lighthouses" are used. These buildings vary in form, some resembling a huge beacon, such as indicates the entrance to a river, while others convey the impression of being bungalows or pavilions on stilts. The legs are stout, cylindrical, iron members, the lower ends of which are shaped somewhat after the manner of an auger, whereby they may be screwed into the sea-bed—hence the name. This system has been employed for beacons over dangerous shoals; and while they are somewhat squat, low-lying lights, they have proved to be highly serviceable.

Iron has been employed also for lighthouse constructional work, the system in this case being a combination of the screw pile and the tower, the latter, extending from a platform whereon the living-quarters are placed and mounted clear of the water, on piles, being a huge cylindrical pipe crowned by the lantern. One of the most interesting and novel of these iron lighthouses is the Hunting Island tower off the coast of South Carolina. In general design it resembles the ordinary lighthouse wrought in masonry, and it is 121½ feet in height from the ground to the focal plane. It is built of iron throughout, the shell being in the form of panels, each of which weighs 1,200 pounds.

This type of tower was selected owing to the severe erosion of the sea at the point where it is placed. When it was erected in 1875, at a cost of £20,400, or $102,000, it was planted a quarter of a mile back from the sea. This action was severely criticized at the time, it being maintained that the light was set too far from the water's edge to be of practical value ; but the hungry ocean disappointed the critics, because in the course of a few years the intervening strip of shore disappeared, and the necessity of demolishing the light and re-erecting it farther inland arose. On this occasion the engineers determined to postpone a second removal for some time. The tower was re-erected at a point one and a quarter miles inland, and the sum of £10,200, or $51,000, was expended upon the undertaking. The iron system, which was adopted, proved its value in this work of removal piece by piece, because, had the tower been carried out in masonry, it would have been cheaper to set up a new light, as was done at Cape Henry.

Some of the American coast lights are of the most primitive and odd-looking character, comprising merely a lofty skeleton of ironwork. The lamp is a head-light, such as is carried by railway engines, fitted with a parabolic reflector. Every morning the lamp is lowered, cleaned, and stored in a shack at the foot of the pyramid, to be lighted and hauled into position at dusk. This is the most economical form of lighthouse which has been devised, the total cost of the installation being only about £2,500, or $12,500, while the maintenance charges are equally low. Lights of this description are employed for the most part in connection with the lighting of waterways, constituting what is known as the " back-light " in a range or group of lights studded along the river to guide the navigator through its twists and shallows, instead of buoying of the channel.

The task of constructing a sea-rock lighthouse is as tedious and protracted an enterprise as one could conceive, because the engineer and his workmen are entirely at the mercy of the weather. Each great work has bristled with its particular difficulties ; each has presented its individual problems for solution. Few modern lighthouses, however, have so baffled the engineer and have occupied such a number of years in completion, as the Ar-men light off Cape Finisterre. This tower was commenced in 1867, but so great and so many were the difficulties involved in its erection that the

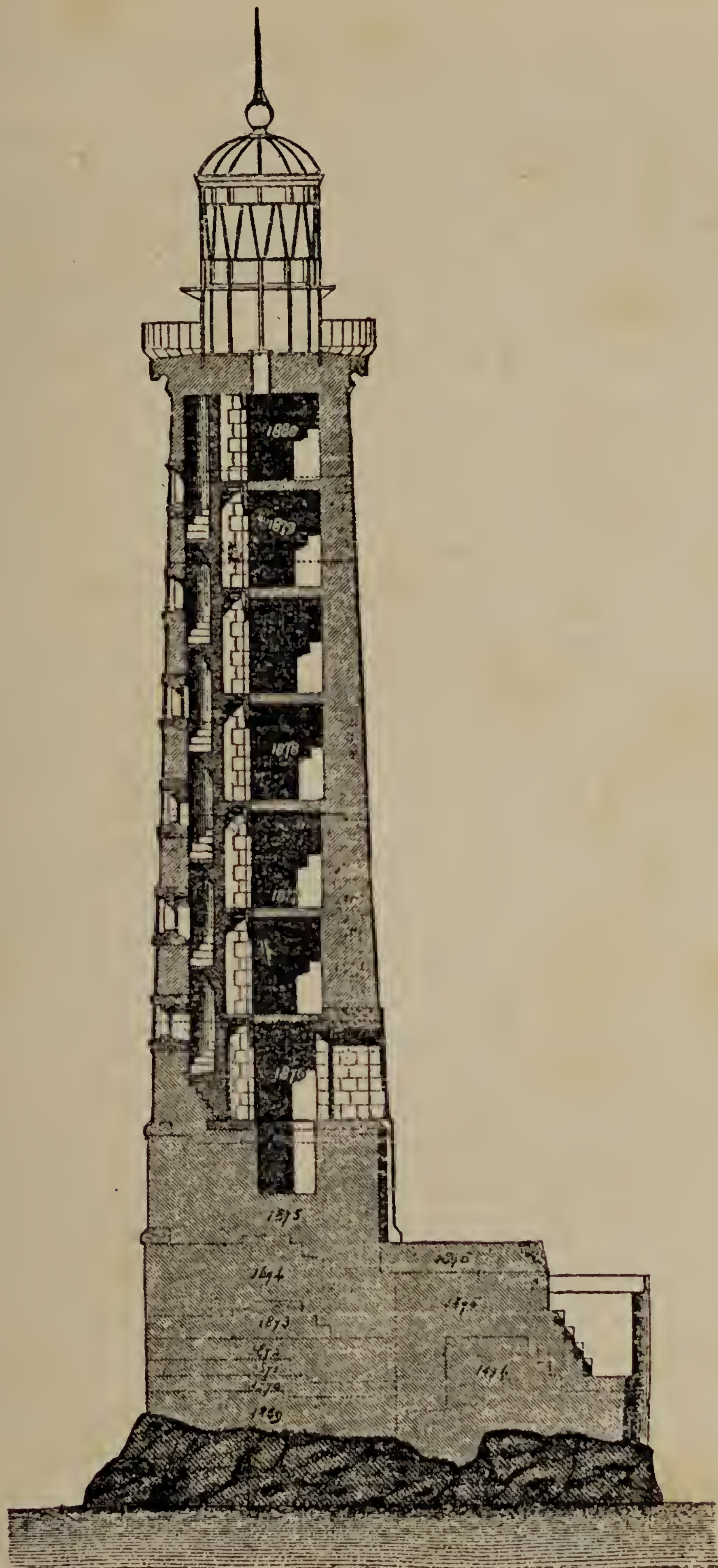


Fig. 1.—Sectional Diagram of the Ar-men Lighthouse, showing Yearly Progress in Construction.

It guards the "Bay of the Dead," off Cape Finisterre. Commenced in 1867, it was not finished until 1881.

light was not first thrown over the Atlantic from its lantern until 1881.

This light is situated at one of the most dreaded parts of a sinister coast. At this spot a number of granite points thrust themselves at times above the water in an indentation which has received the lugubrious name Bay of the Dead. The title is well deserved, for it is impossible to say how many ships have gone down through fouling these greedy fangs, or how many lives have been lost in its vicinity. The waters around the spot are a seething race of currents, eddies, and whirlpools. It is an ocean graveyard in very truth, and although mariners are only too cognizant of its terrible character, and endeavour to give this corner of the European mainland a wide birth, yet storms and fogs upset the calculations of the most careful navigators.

As the streams of traffic across the Bay of Biscay grew denser and denser, it became imperative to provide a guardian light at this spot, and the engineers embarked upon their task. They knew well that they were faced with a daring and trying enterprise, and weeks were spent in these troubled waters seeking for the most favourable site. As a result of their elaborate surveys, they decided that the rock of Ar-men offered the only suitable situation; but what a precarious foundation upon which to lift a massive masonry tower! The hump is only 25 feet wide by 50 feet in length; no more than three little pinnacles projected above the sea-level, and at low-tide less than 5 feet of the tough gneiss were exposed. Nor was this the most adverse feature. The rock is in the centre of the bad waters, and is swept from end to end, under all conditions of weather, by the furious swell. Some idea of the prospect confronting the engineers may be gathered from the fact that a whole year was spent in the effort to make one landing to take levels.

When construction was taken in hand the outlook was even more appalling. It was as if the sea recognized that its day of plunder was to draw to a close. The workmen

THE THIMBLE SHOALS LIGHT.

A typical example of the American iron screw pile system. A vessel ran into this beacon and wrecked it ; the ruins caught fire, and the keepers only escaped in the nick of time.

By permission of Messrs. Bullivant & Co., Ltd.

SETTING THE LAST STONE OF THE BEACHY HEAD LIGHTHOUSE.

were brought, with all materials and appliances, to the nearest strategical point on the mainland, where a depot was established. Yet in the course of two years the workmen, although they strove day after day to land upon the rock, only succeeded twenty-three times, while during this period only twenty-six hours' work was accomplished! It is not surprising that, when the men did land, they toiled like Trojans to make the most of the brief interval. The sum of their work in this time was the planting of the lighthouse's roots in the form of fifty-five circular bars, each 2 inches in diameter and spaced $3\frac{1}{4}$ feet apart at a depth of about 12 inches in the granite mass. By the end of 1870 the cylindrical foundation had crept a few feet above the highest projection; this plinth was 24 feet in diameter, 18 feet in height, and was solid throughout. A greater diameter was impossible as the wall was brought almost to the edge of the rock.

By dint of great effort this part of the work was completed by the end of 1874, which year, by the way, showed the greatest advance that had been attained in a single twelvemonth. As much of the foundations was completed in this year as had been achieved during the three previous years. Although the heavy gales pounded the structure mercilessly, so well was the masonry laid that it offered quite effective resistance. Upon this plinth was placed the base of the tower. This likewise is 24 feet in diameter, and about 10 feet in height. It is also of massive construction, being solid except for a central cylindrical space which is capable of receiving some 5 tons of coal.

The base was completed in a single year, and in 1876 the erection of the tower proper was commenced, together with the completion of the approaching stairway leading from the water-level to the base of the structure. The latter, divided into seven stories, rises in the form of a slender cone, tapering from a diameter of $21\frac{1}{2}$ feet at the bottom to $16\frac{1}{2}$ feet at the top beneath the lantern. Some idea of the massive character of the work which was demanded in order to resist the intense fury of the waves may be realized when it is mentioned that the wall at the first and second floors is $5\frac{1}{2}$ feet in thickness, leaving a diameter of 10 feet for the apartment on the first floor, which is devoted to the storage of water, and of 7 feet for that on the second floor, which contains the oil reservoirs for the lamps. The living-rooms have a diameter of 11 feet, this increased space being obtained by reducing the thickness of the wall to $2\frac{1}{2}$ feet. The erection of the superstructure went forward steadily, five years being occupied in carrying the masonry from the base to the lantern gallery, so that in 1881 for the first time powerful warning was given of a danger dreaded, and often unavoidable, from the time when ships first sailed these seas. Fifteen years' labour and peril on the part of the engineers and their assistants were crowned with success.

Whereas the Ar-men light off Cape Finisterre demanded fifteen years for its completion, the construction of the Beachy Head lighthouse off the South of England coast was completed within a few months. It is true that the conditions were vastly dissimilar, but the Sussex shore is exposed to the full brunt of the south-westerly and south-easterly gales. This lighthouse thrusts its slender lines from the water, its foundations being sunk into the chalk bed of the Channel, 550 feet from the base of the towering white cliffs, which constitute a striking background. This beacon was brought into service in 1902, its construction having occupied about two years. The light formerly was placed on the crown of the precipice behind, but, being then some 285 feet above the water, was far from being satisfactory, as its rays were frequently blotted out by the ruffle of mist which gathers around Beachy Head on the approach of evening.

Indeed, this is one of the great objections to placing a light upon a lofty headland. In such a position it does not serve as an aid, but more often than not as a danger, to navigation, owing to the light being invisible at the time when its assistance is required and sought most urgently. Consequently lighthouse engineers endeavour to set their towers at such a level that the light is not raised more than from 160 to 200 feet above the water. In the case of Beachy Head, a further reason for a new structure was the disintegration of the cliff upon which the light stood, under the terrific poundings of the sea, huge falls of chalk having occurred from time to time, which imperilled the safety of the building.

When the new lighthouse was taken in hand, investigation of the sea-bed revealed an excellent foundation in the dense hard chalk, and accordingly a hole 10 feet deep was excavated out of the solid mass to receive the footings of the building. As the site is submerged to a great depth at high-tide, the first operation was the erection of a circular dam carried to a sufficient height to enable the men to toil within. By this arrangement the working spells were lengthened considerably, labour only being suspended at high-tide. When the sea ebbed below the edge of the dam, the water within was pumped out, leaving a dry clear space for the workmen. Excavation had to be carried out with pickaxe and shovel, blasting not being permitted for fear of shattering and splitting up the mass forming the crust of the sea-bed.

Beside the site a substantial iron staging was erected, and from this point to the top of the cliffs behind a Bullivant cableway was stretched, up and down which the various requirements were carried, together with the workmen. This cableway, designed by Mr. W. T. H. Carrington, M.I.C.E., consulting engineer to Messrs. Bullivant and Co., Ltd., facilitated rapid and economical construction very appreciably. The span was about 600 feet between the erecting stage and the cliff summit, and there were two fixed ropes stretched parallel from point to point. One rope, 6 inches in diameter, had a breaking strain of 120 tons; the second, 5½ inches thick, had a breaking strain of 100 tons. At the seaward end the cables were anchored into the solid chalk. Everything required for the constructional operations was handled by this carrying system, and when it is recalled that some of the blocks for the lower courses weighed from 4½ to 5 tons, it will be recognized that such a method of handling these ungainly loads, with the care that was demanded to preserve the edges and faces from injury, solved an abstruse problem completely.

The base of the tower, the diameter of which is 47 feet, is solid to a height of 48 feet, except for a central circular space for storing drinking water. It was designed by Sir Thomas Matthews, M.I.C.E., the Engineer-in-Chief to the Trinity Brethren, and is a graceful building, the tower rising in a curve which is described as a "concave elliptic frustum." From the base to the lantern gallery is 123½ feet, and 3,660 tons of Cornish granite were used in its construction. The over-all height to the top of the lantern is 153 feet. The building is provided with eight floors, comprising the living and sleeping quarters for the keepers, storage of oil, and other necessaries. The light, of the dioptric order, is of 83,000 candle-power, and the two white flashes given every fifteen seconds are distinguishable for a distance of seventeen miles, which is the average range of modern British lighthouses.

Although the constructional work was frequently interrupted by rough weather, every advantage was taken of calm periods. While from the point of daring engineering it does not compare with many of the other great lights of the world, yet it certainly ranks as a fine example of the lighthouse builder's skill. Owing to the elaborate precautions observed, the achievement was not marred by a single fatality, although there were many thrilling moments, the sole result of which, however, was the loss of tools and sections of the plant, which in the majority of cases were recovered when the tide fell. The most serious accident was a crushed toe, which befell one of the masons when a stone was being bedded.

Although the lighthouse is subjected to the full fury of wind and wave, if skilfully erected it will withstand the ravages of both without creating the slightest apprehensions in the engineer's mind. The stones are prepared so carefully that they fit one another like the proverbial glove, while the cement fills every nook and cranny. Occasionally, however, the cement will succumb to the natural disintegrating forces, and, becoming detached, reveal a point vulnerable to attack. The air within the interstice becomes compressed by the surging water, and thereby the fabric is liable to be shattered. Some years ago one or two of the lighthouses guarding the Great Lakes of North America were found to have become weakened from this cause. A novel remedy was evolved by an ingenious engineer. He provided each tottering lighthouse with an iron overcoat, enveloping it from top to bottom. The metal was not laid directly upon the masonry, but was so placed as to leave about a quarter of an inch between the inner face of the metal and the surface of the masonry. Liquid cement was then admitted under pressure—"grouting" it is called—into this annular space, and penetrating every crack and crevice in the masonry, and adhering both to the metal and the stonework, it practically formed another intermediate jacket, binding the two so firmly together as to make them virtually one. This novel procedure absolutely restored the menaced building to its original homogeneity and rigidity, so that it became as sound as the day on which it was built.

Nowadays, owing to the skill in designing and the workmanship displayed, one never hears of a modern lighthouse collapsing. Expense is no object; the engineer does not endeavour to thwart the elements, but follows a design wherein the minimum of resistance is offered to them.

CHAPTER III

THE LIGHT AND ILLUMINANTS

While it is the tower that probably creates the deepest impression upon the popular mind, owing to the round of difficulties overcome associated with its erection, yet, after all, it is the light which is the vital thing to the navigator. To him symmetry of outline in the tower, the searching problems that had to be solved before it was planted in a forbidding spot, the risks that were incurred in its erection—these are minor details. His one concern is the light thrown from the topmost height, warning him to keep off a dangerous spot and by its characteristic enabling him to determine his position.

I have described the earliest type of light, the open wood or coal fire blazing on an eminence. In due course the brazier gave way to tallow candles. This was an advance, certainly, but the range of the naked light was extremely limited. Consequently efforts were made to intensify it and to throw it in the desired direction. The first step was made with a reflector placed behind the illuminant, similar to that used with the cheap wall-lamp so common in village workshops. This, in its improved form, is known as the "catoptric system," the reflector being of parabolic shape, with the light so disposed that all its rays (both horizontal and vertical) are reflected in one direction by the aid of a highly polished surface. While the catoptric system is still used on some light-vessels, its application to important lighthouses has fallen into desuetude, as it has been superseded by vastly improved methods. But the reflector, made either of silvered glass set in a plaster-of-Paris mould or of brightly polished metallic surfaces, held the field until the great invention of Augustin Fresnel, which completely revolutionized the science of lighthouse optics.

Fresnel was appointed a member of the French Lighthouse Commission in 1811, and he realized the shortcomings of the existing catoptric method only too well. Everyone knows that when a lamp is lighted the luminous rays are diffused on every side, horizontally as well as vertically. In lighthouse operations the beam has to be thrown in a horizontal line only, while the light which is shed towards the top and bottom must be diverted, so that the proportion of waste luminosity may be reduced to the minimum. While the

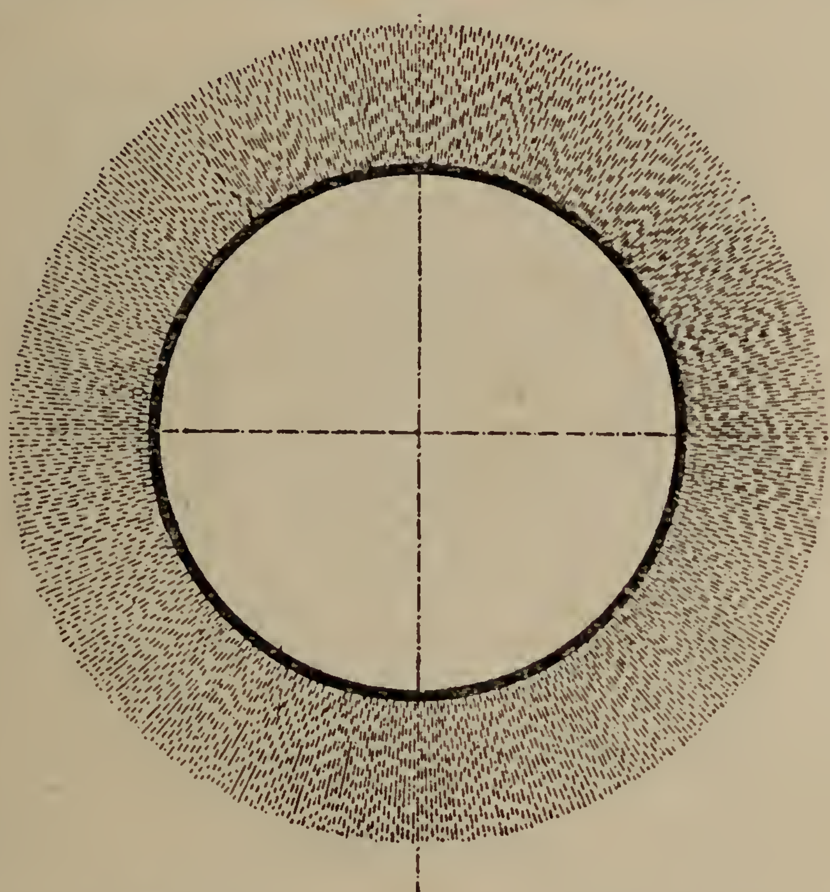


FIG. 2.—FIXED APPARATUS OF 360 DEGREES.
Shows one ray throughout the complete circle.
(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

parabolic reflector achieved this end partially, it was far from being satisfactory, and Fresnel set to work to condense the whole of the rays into a horizontal beam. Buffon, a contemporary investigator, as well as Sir David Brewster, had suggested that the end might be met by building up a lens in separate concentric rings, but neither reduced his theories to practice.

Fresnel invented a very simple system. He took a central piece of glass, which may be described as a bull's-eye, and around this disposed a number of concentric rings of glass. But these rings projected beyond one another. Each constituted the edge of a lens which, while its radius differed from that of its neighbour, owing to its position, yet was of the same focus in regard to the source of illumination. The parts were shaped with extreme care and were united in position by the aid of fish glue, the whole being mounted in a metal frame. The advantage of the system was apparent in the first demonstrations. The lenses being comparatively

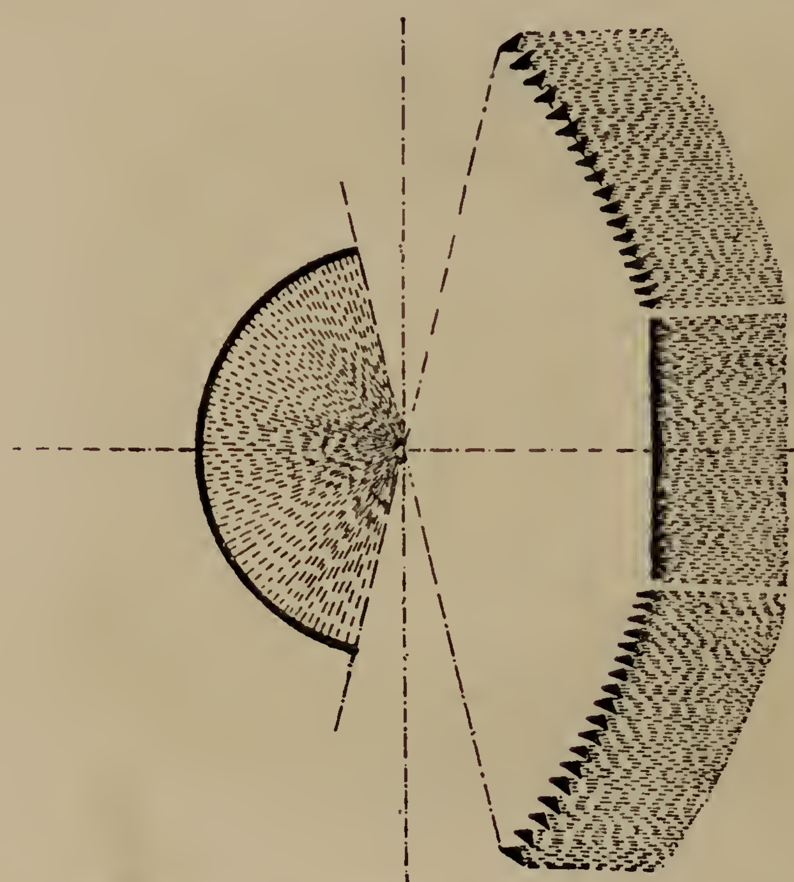


FIG. 3.—SINGLE FLASHING APPARATUS (ONE PANEL AND MIRROR).

(By permission of Messrs. Chance Bros. and Co., Ltd.)

thin, only one-tenth of the light passing through was absorbed, whereas in the old parabolic reflectors one-half of the light was lost.

This revolutionary development was perfected in 1822, and in the following year it was submitted to its first practical application on the tower of Cordouan in the Gironde. Several modifications were made by the inventor for the purpose of adapting his system to varying conditions. One of the most important was the disposition of lenses and mirrors above the optical apparatus for the purpose of collecting and driving back the rays which were sent out vertically from the illuminant, so that they might be mingled with the horizontal beam, thereby reinforcing it. At a later date similar equiangular prisms were placed below the horizontal beam so as to catch the light thrown downwards from the luminous source, the result being that finally none, or very little, of the light emitted by the illuminant was lost, except by absorption in the process of bending the rays into the desired direction.

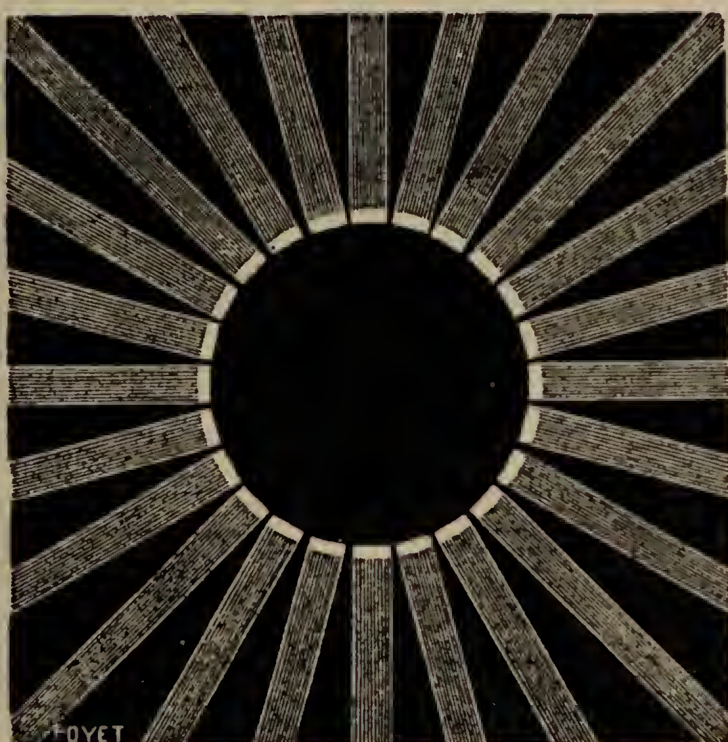


Fig. 4.—A Twenty-Four Panel Light, which was introduced into Certain French Lighthouses.

In this ingenious manner the circle of light is divided into sections, called "panels," each of which comprises its bull's-eye and its group of concentric rings and prisms. The extent of this division varies appreciably, as many as sixteen panels being utilized in some instances. In this direction, however, subdivision can be carried too far. Thus, in some of the French lighthouses no less than twenty-four panels were introduced. The disadvantage is obvious. The total volume of light emitted from the luminous source has to be divided into twenty-four parts, one for each panel. But the fewer the panels, the more light is thrown through each, and the correspondingly greater power of the beam. Thus, in a four-panel light each beam will be six times as powerful as that thrown from a twenty-four panel apparatus of the same type.

Fresnel also introduced the system of revolving the optical apparatus, and by the introduction of suitable devices was able to give the light a flashing characteristic, so that it became possible to provide a means of identifying a light from a distance entirely by the peculiarity of its flash. The French authorities were so impressed with the wonderful

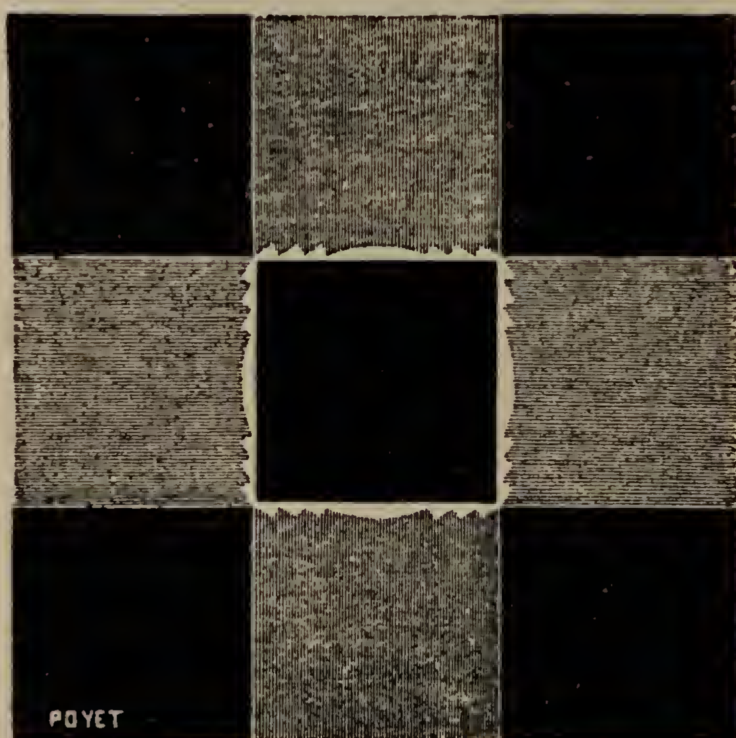


FIG. 5.—A FOUR-PANEL LIGHT.

The ray thrown through each panel is six times as powerful as the beam thrown through a twenty-four panel apparatus.

improvement produced by Fresnel's epoch-making invention that it was adopted immediately for all French lights. Great Britain followed suit a few years later, while other countries embraced the system subsequently, so that the Fresnel lens eventually came into universal use.

But the Frenchman's ingenious invention has been developed out of recognition. To-day only the fundamental basis is retained. Marked improvements were made by Mr. Alan Stevenson, the famous Scottish lighthouse engineer. In fact, he carried the idea to a far greater degree than

Fresnel ever contemplated, and in some instances even anticipated the latter's subsequent modifications and improvements. This was demonstrated more particularly in the holophotal revolving apparatus, the first example of which he designed for the North Ronaldshay lighthouse in 1850, a similar apparatus being devised some years later by Fresnel. In 1862 another great improvement was made by Mr. J. T. Chance, of the well-known lighthouse engineering firm of Birmingham, which proved so successful that it was

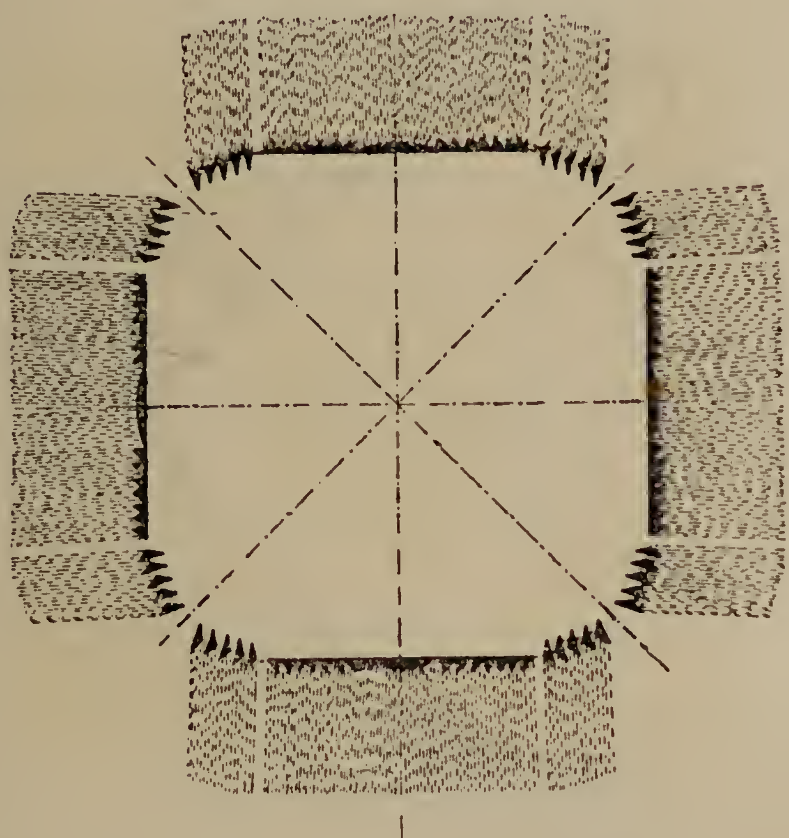


FIG. 6.—SINGLE APPARATUS IN FOUR PANELS.

(By permission of Messrs. Chance Bros. and Co., Ltd.)

incorporated for first and third order apparatuses in the New Zealand lights designed by Messrs. Stevenson in the same year.

The French and British investigators, however, were not having things entirely their own way. The United States played a part in these developments, although they did not enter very successfully into the problem. The first lighthouse at Boston Harbour carried candles until superseded by an ordinary lamp, which was hung in the lantern in much the same way as it might have been suspended behind the window of a private dwelling. An inventor, Mr. Winslow Lewis, who confessed that he knew nothing about lighthouse optics, patented what he called a "magnifying and reflecting lantern" for lighthouse work, which he claimed was a lamp, a reflector, and a magnifier, all in one. It was as crude a device as has ever emanated from an inventive brain, but the designer succeeded in impressing the Government so effectively that they gave him £4,000, or $20,000, for his

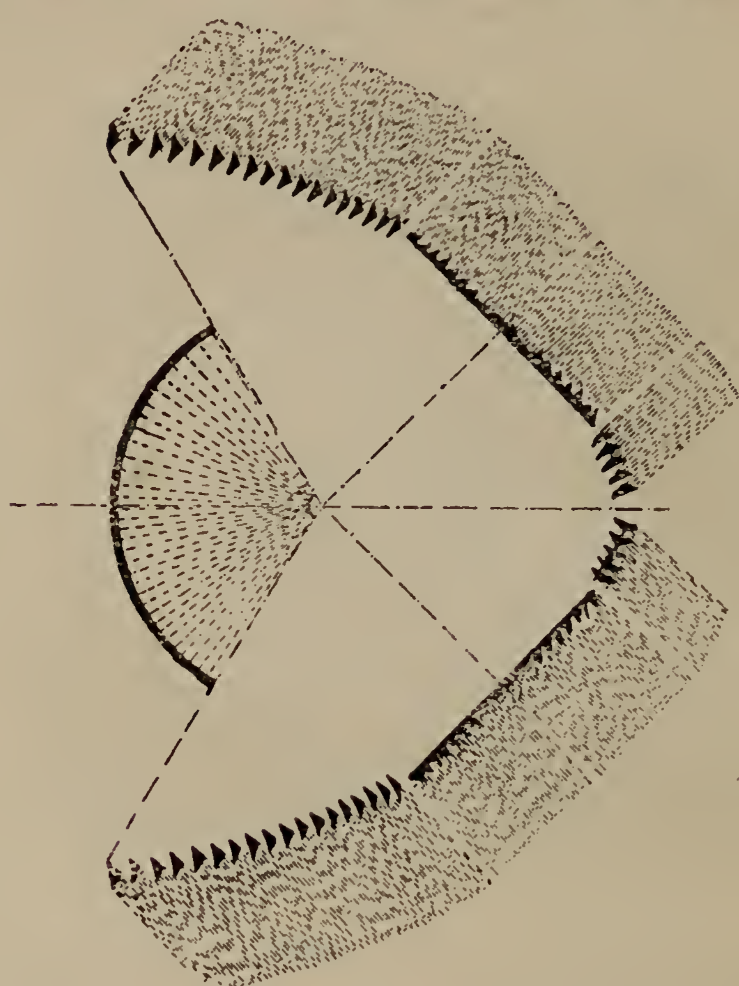


FIG. 7.—DOUBLE FLASHING APPARATUS: TWO PANELS AND MIRROR.

(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

invention. The reflector was wrought of thin copper with a silvered surface, while the magnifier, the essence of the invention, was what he called a "lens," but which in reality comprised only a circular transparent mass, 9 inches in diameter, and varying from 2½ to 4 inches in thickness, made of bottle-green glass. The Government considered that it had acquired a valuable invention, and was somewhat dismayed by the blunt opinion of one of its inspectors who held contrary views concerning the magnifier, inasmuch as he reported cynically that its only merit was that it made "a bad light worse."

The inventor did not manifest any antagonism to this criticism, but immediately pointed out the great economy in the consumption of oil that was arising from the use of his idea. Indeed, he prosecuted his claims so successfully that he clinched a profitable bargain to himself with the

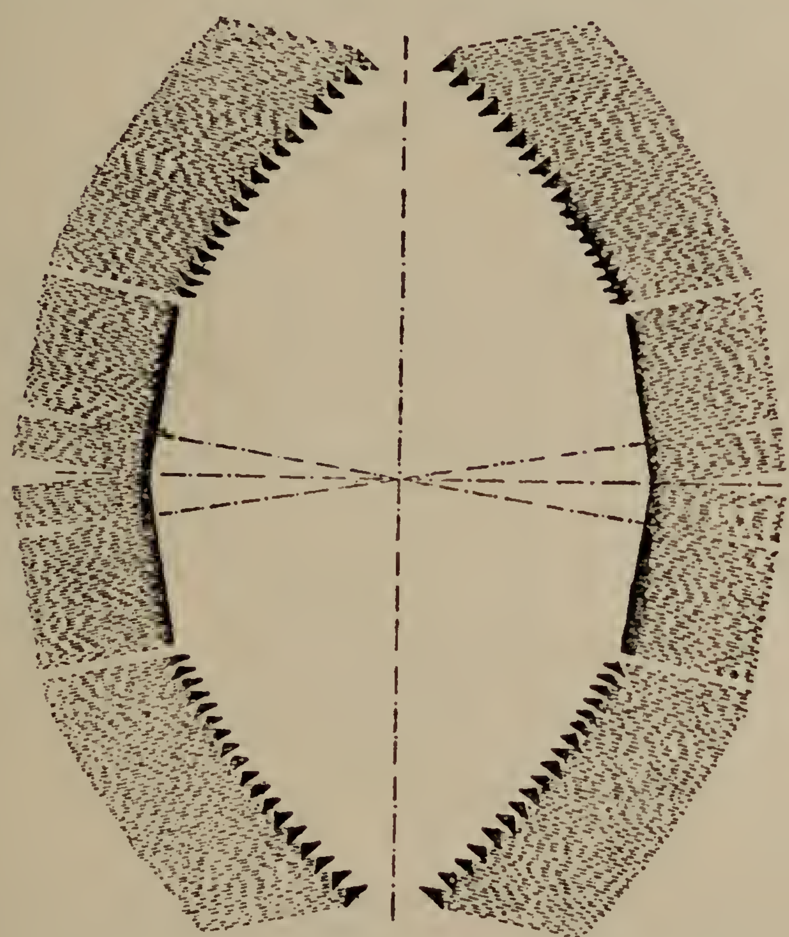


FIG. 8.—DOUBLE FLASHING APPARATUS: TWO GROUPS EACH OF TWO PANELS.

(By permission of Messrs. Chance Bros. and Co., Ltd.)

Government. His apparatus had been fitted to thirty-four lights, and he contracted to maintain them on the basis of receiving one-half of the oil previously consumed by the lamps which his invention superseded. This arrangement was in vogue for five years, when it was renewed, with the difference that on this occasion the Government, concluding that the inventor was making too much out of the transaction, reduced the allowance to one-third. Subsequently the invention received higher commendation from the officials than that advanced by the critical inspector, although it must be pointed out that meanwhile the magnifying bull's-eye had been abandoned, and a new type of reflector introduced, so that the sole remaining feature of the wonderful invention was the lamp. Even that had been modified. When the Lighthouse Board was established in 1852 it

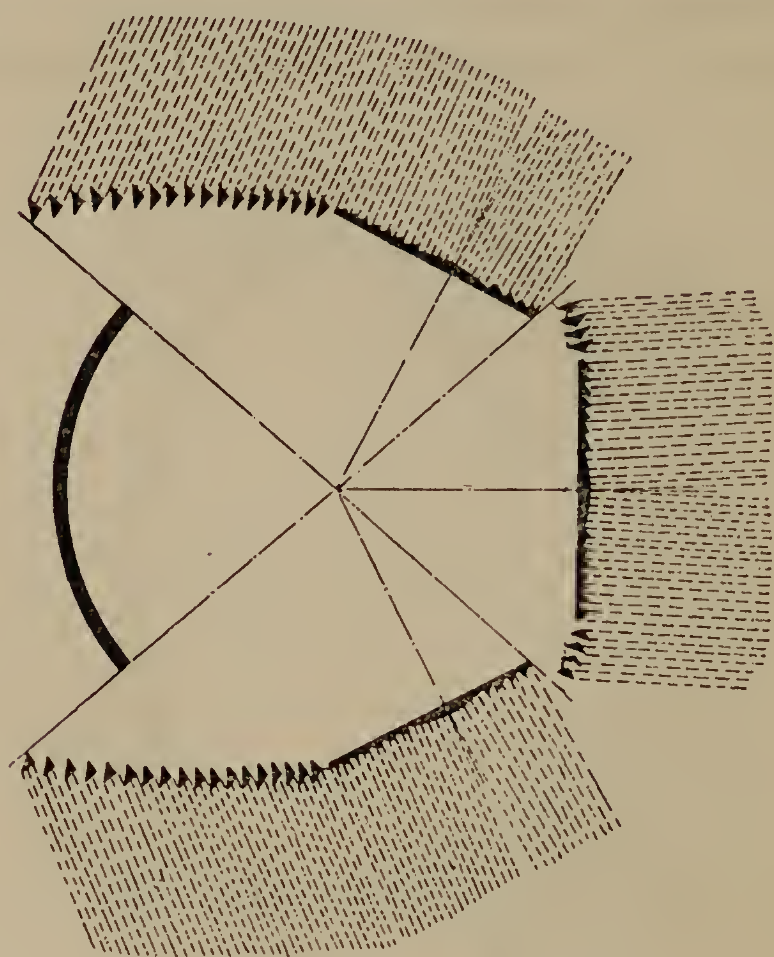


FIG. 9.—TRIPLE FLASHING APPARATUS: THREE PANELS AND MIRROR.

(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

abolished the much-discussed invention, and introduced the Fresnel system, bringing the United States into line with the rest of the world.

One feature of the subject cannot fail to arrest attention. This is the possibility of producing a variety of combinations by the aid of the lenses to fulfil different requirements. The Fresnel, Stevenson, and Chance developments in the science of lighthouse optics facilitated this work very significantly. Accordingly, to-day a variety of lights, evolved from the variations in the mounting of the lenses, is in vogue. For purposes of identification they have been divided into a number of classifications, and, for the convenience of the navigator, are described as lights of the first order, second order, and so on. Broadly speaking, there are seven main groups, or orders, the rating only applying to dioptric or catadioptric lights, indicating the bending of the luminous rays in the desired direction, either by refraction and reflection through the medium of prisms, or a combination of both. Actually there is a distinction between these two, the true dioptric system referring only to refraction, where the ray is bent in the desired direction by a glass agent, known as a "refracting prism." In the catadioptric system, on the other hand, both methods are employed, since the prism performs the dual purpose of reflecting and refracting the rays. However, in modern lighthouse parlance both are grouped under the one distinction "dioptric."

The rating or classification of the lights varies according to the inside radius or focal distance of the lens—in other words, the distance from the centre of the light to the inner surface of the lens. The main groups are as follows:

Hyperradial,	1,330	millimetres	(52·3 inches)	focal distance.
1st order,	920	,,	(36·2 ,,)	,,
2nd ,,	700	,,	(27·6 ,,)	,,
3rd ,,	500	,,	(19·7 ,,)	,,
3½ ,,	375	,,	(14·7 ,,)	,,
4th ,,	250	,,	(9·8 ,,)	,,
5th ,,	187·5	,,	(7·4 ,,)	,,
6th ,,	150	,,	(5·9 ,,)	,,

The most powerful apparatus used to-day, however, is that known as the "hyperradiant," and it is the largest which has yet been devised. For this, lighthouse engineering is indebted to Messrs. Stevenson, the engineers to the Commissioners of Northern Lighthouses. It was first suggested as far back as 1869, and experiments were carried out which emphasized the fact that such an apparatus was required, since it was found that when large gas-burners were used much of the light in revolving apparatuses was out of focus and escaped condensation. The Scottish engineers thereupon suggested that an apparatus should be used having a focal distance of 1,330 millimetres, or 52·3 inches. In fact, they went farther and suggested even larger apparatuses, but this idea has not matured. But it was not until 1885 that Messrs. Stevenson had such a system manufactured, and then it was tested at the South Foreland beside the powerful lenses which had just been built for the new Eddystone and the Mew Island lighthouses. The merits of the theories advanced by Messrs. Stevenson were then

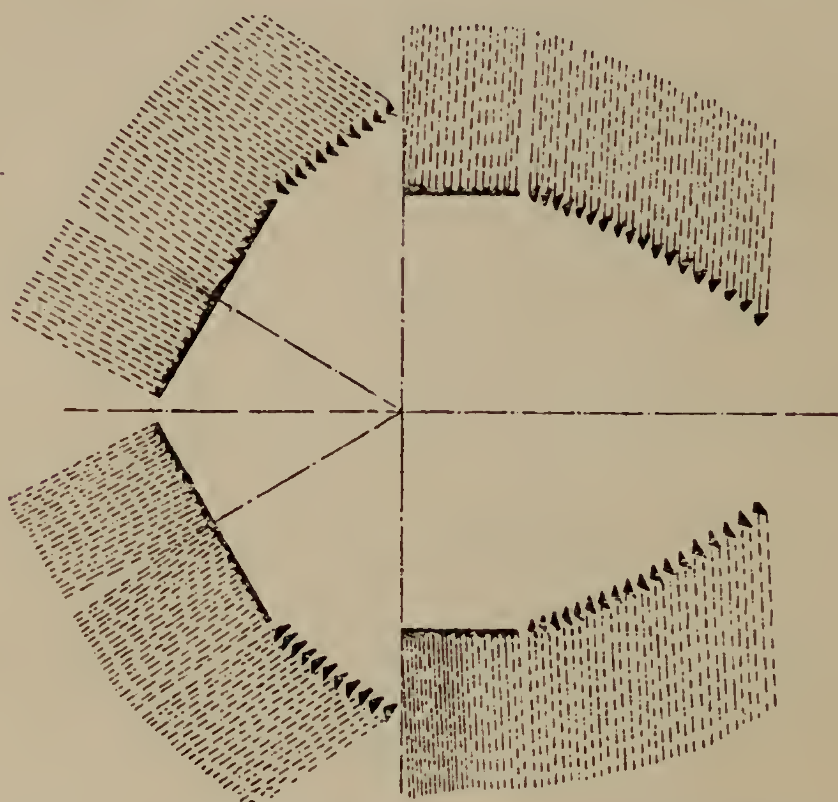


FIG. 10.—QUADRUPLE FLASHING APPARATUS: FOUR PANELS.

(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

completely proved, for it was found that with a ten-ring gas-burner the hyperradiant apparatus threw a light nearly twice as powerful as that given by the rival lenses with the same burner.

At the present moment the hyperradiant is regarded as the *ultima thule* of lighthouse optical engineering, and Messrs. Chance Brothers and Co., of Birmingham, have built some very magnificent apparatuses of this order. At present there are not more than a dozen such powerful lights in operation. Three are on the English coast, at Bishop Rock, Spurn

Point, and Round Island, respectively ; two in Scotland, at Fair Isle and Sule Skerry ; two in Ireland, at Bull Rock and Tory Island ; one in France, at Cap d'Antifer ; one in China, at Pei Yu-shan ; one in India, at Manora Point, Karachi ; and the Cape Race light in Newfoundland. The hyper-radiant apparatus is a massive cage of glass, standing some 12 feet in height, and, as may be supposed, is extremely expensive.

There is another point in lighthouse optics which demands explanation. This is the term " divergence," which plays an important part in the duration of the flash. In speaking about focus, the engineer follows somewhat in Euclid's footsteps in regard to the definition of a point ; in a way it is equally imaginary. The focal point does not mean the whole of the flame, but the centre of the luminous source, and, as is obvious, it is impossible to secure a flame without dimensions. It may be an attenuated, round, oval, or fan-shaped light—the result is the same. The focal point is the theoretical centre of the luminous source, and the rays, coming from the top, sides, and bottom of the flame cannot come from the true focus. If they did, all the light from one panel would be emitted in absolutely parallel lines, and therefore in a revolving apparatus the beam would pass any given point on the horizon in an infinitely short period of time—to be precise, instantaneously. But the ex-focal rays of the flame, in passing through the lens, emerge at an angle to those coming from the absolute centre, so that the whole beam becomes " diverged," and throws a cone of light from the lens. Consequently the beam occupies an appreciable period of time in passing a given point on the horizon.

As may be supposed, the intricate character of the lenses constituting the optical apparatus of the modern lighthouse demands the highest skill and infinite care in their preparation, while the composition of the glass itself is a closely guarded secret. There are less than half a dozen firms in the world engaged in this delicate and highly specialized work, of which France claims three, Germany one, and Great Britain one. All the lighthouse authorities of the various nations have to secure their requirements from one or other of these organizations. The industry commenced in France, and for many years the French reigned supreme. Then it contrived to make its entrance into England, and was taken up by the family of Chance in Birmingham, who soon proved themselves equal to their French leaders.

The British firm has established a unique reputation, as it has been responsible for the majority of the great lights of the world, some of which are not only of huge dimensions and weight, but also of novel form. The hyperradial ap-

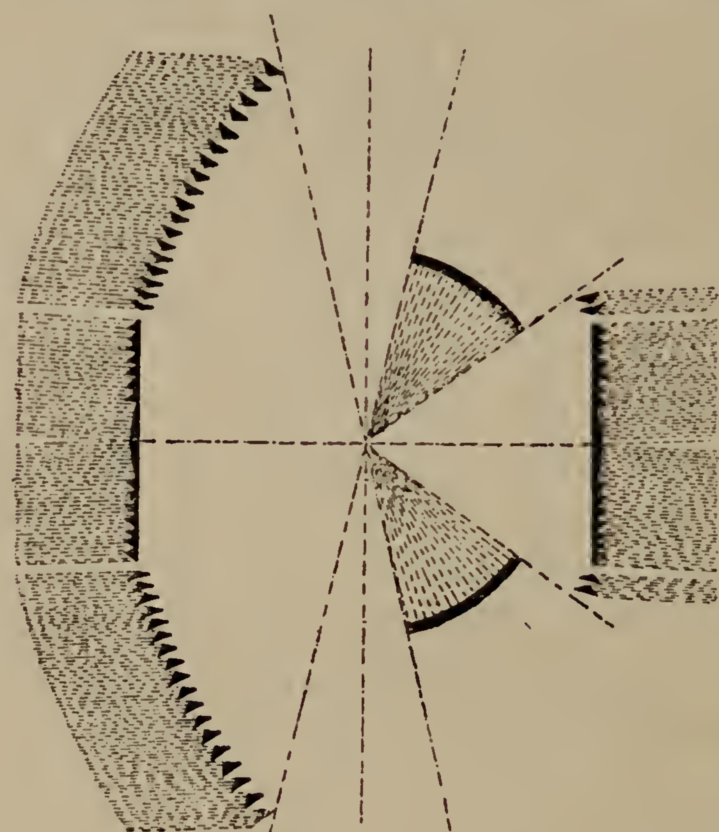


FIG. 11.—RED AND WHITE FLASHING APPARATUS.
(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

paratuses which have been placed recently in the towers of Manora Point and Cape Race probably rank as the most powerful and the finest in existence. These are used in conjunction with the petroleum vapour incandescent burner. The Cape Race light, for instance, comprises a revolving optic of four panels, subtending a horizontal angle of 90 degrees, with a vertical angle of 121½ degrees. Each lens comprises the central disc, or bull's-eye, around which are placed nine rings of glass, giving a total refracting angle of 57 degrees. In order to bend the vertical rays into a horizontal path twenty-two catadioptric reflecting prisms are disposed above the lens, while below are thirteen similar prisms. The total amount of glass worked into the four panels is about 6,720 pounds, and the prisms are mounted in gun-metal frames, which weigh approximately 4,800 pounds, so that the total weight of the glass portion and its mounting alone, standing some 12 feet in height, is over 11,500 pounds. The installation completed for the equipment of the Manora Point lighthouse, Karachi, is very similar.

In some cases the demand for a powerful light has been met with a system differing from the "hyperradiant." The lenses and respective groups of refractors are superposed, each tier having its individual burner and flues for carrying off the products of combustion. In this way we have the biform, comprising two such panels arranged one above the other, as in the Fastnet and Eddystone lights; and the quadriform, wherein four tiers are built one above the other, as installed at the Mew Island light in Ireland. The advantage of this arrangement is that a beam of great intensity is secured with a lantern of comparatively small diameter.

The French authorities adopted a modification of this system. Instead of placing two lenses and refractors one above the other, they ranged them side by side, the effect being analogous to a couple of squinting eyes, the panels being parallel and therefore throwing out parallel beams. But these adaptations have not come into extensive use, as they have been superseded by more simple means of achieving similar requirements with an even more powerful ray. The hyperradiant stands as the finest type of apparatus yet devised, and therefore is employed when an extremely powerful light is required.

While the design and arrangement of the optical apparatus is certainly a most vital and delicate task, the mounting thereof upon a substantial support in such a way that it may perform its work with the highest efficiency is equally imperative, since the finest apparatus might be very adversely affected by being improperly mounted.

Obviously, owing to the great weight of the glass, the support must be heavy and substantial. A massive cast-iron pedestal is employed for this purpose. When the light is of the revolving character, means have to be incorporated to secure the requisite rotation. In the early days the turntable upon which the lens is mounted ran upon rollers, but now a very much better system is universally employed. This has been brought to a high standard of perfection by Messrs. Chance of Birmingham, who have carried out un-

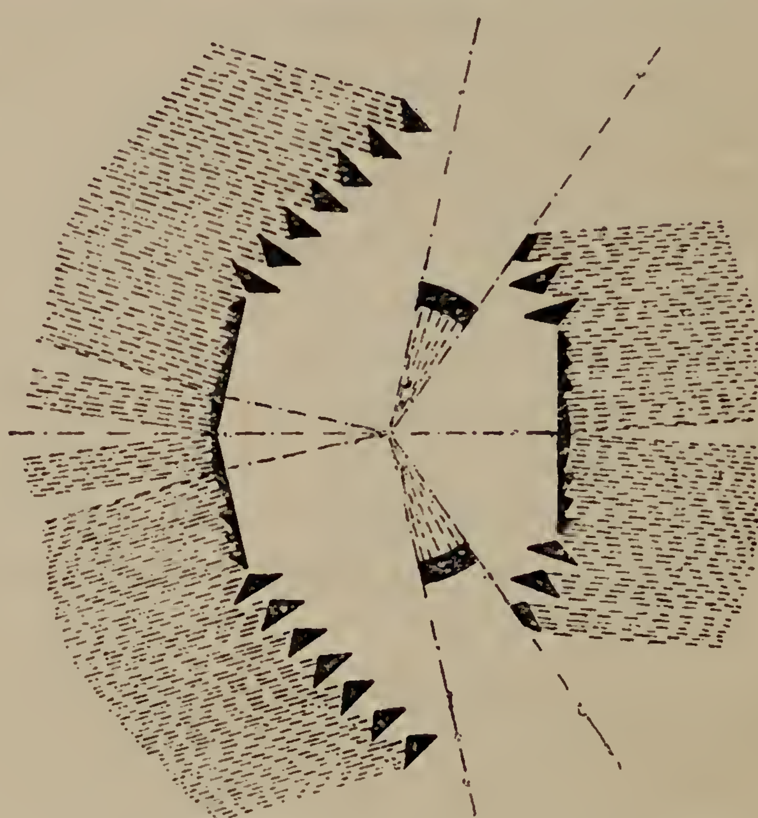


FIG. 12.—APPARATUS SHOWING A DOUBLE FLASH, FOLLOWED BY A SINGLE FLASH.

(By permission of Messrs. Chance Bros. and Co., Ltd.)

ceasing experiments in this field. The objection to rollers was the enormous friction that was set up, and the great effort that was required, not only to set the lenses revolving, but to keep them rotating at a steady pace. In the modern apparatus the rollers are superseded by an iron trough filled with mercury, upon which floats the turntable carrying the lenses. When the apparatus is properly built and balanced, the friction is so slight that the turntable can be set in motion by the little finger, notwithstanding that several tons have to be moved. Although the optical part of the apparatus floats upon the bed of quicksilver in the same way as a cork lifebelt floats upon water, it is provided with rollers which serve to hold the whole apparatus steady and to overcome any oscillation.

In the case of an immense apparatus such as a hyper-radiant lens, which, together with the turntable, may have a total weight of 17,000 pounds, an enormous quantity of mercury is required. The trough of the Cape Race hyper-radiant light carries 950 pounds of quicksilver, upon which the lantern is floated. In such an instance, also, the pedestal is a weighty part of the apparatus, representing in this case about 26,800 pounds, so that the complete apparatus utilized to throw the 1,100,000 candle-power beam from the guardian of the Newfoundland coast aggregates, when in working order, some 44,000 pounds, or approximately 20 tons.

Within the base of the pedestal is mounted the mechanism for rotating the optical apparatus. This is of the clockwork type driven by a weight. The latter moves up and down a tube which extends vertically to a certain depth through the centre of the tower. The weight of the driving force and the depth of its fall naturally vary according to the character of the light. In the Cape Race light the weight is of 900 pounds, and it falls 14½ feet per hour. Similarly, the length of time which the clock will run on one winding fluctuates. As a rule it requires to be rewound once every sixty or ninety minutes. A longer run is not recommended, as it would demand a longer weight-tube, while many authorities prefer the frequent winding, as the man on duty is kept on the alert thereby. As the weight approaches the bottom of its tube it sets an electric bell or gong in action, which serves to warn the light-keeper that the mechanism demands rewinding.

The weight and clockwork mechanism perfected by Messrs. Chance is regarded as one of the best in service. The rotation is perfect and even, owing to the governing system incorporated, while the steel wire carrying the weight is preferable to the chain, which is subject to wear and is noisy

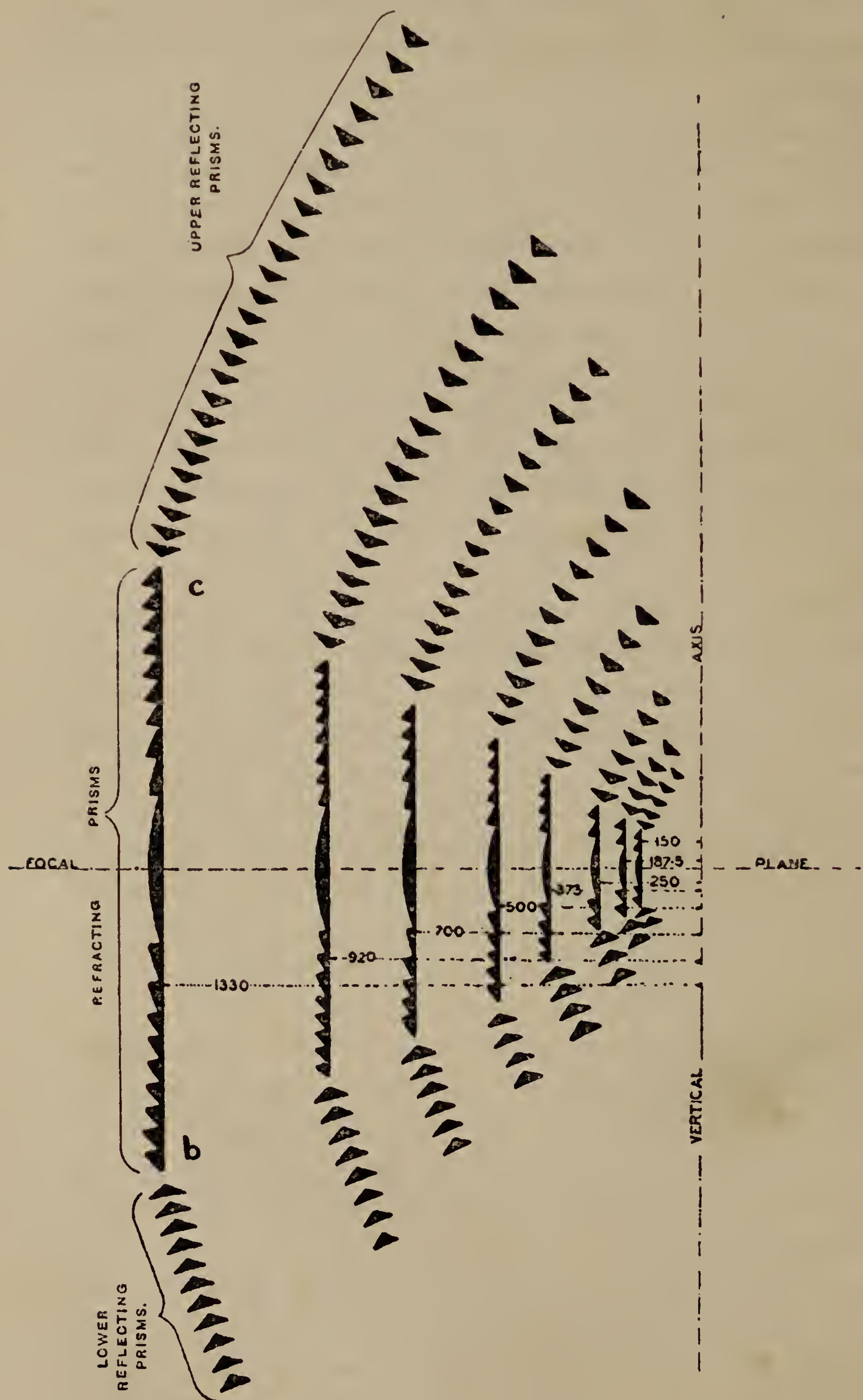


FIG. 13.—THE CLASSIFICATION OF LIGHTS, SHOWING THE RESPECTIVE RADIUS OR FOCAL DISTANCE OF LENS FROM 150 TO 1,330 MILLIMETRES.

(By permission of Messrs. Chance Bros. and Co., Ltd.)

in action. In the Chance clockwork gear the weight is just sufficient to start the apparatus from a state of rest, the advantage of such a method being that, should the apparatus be stopped in its revolution from any untoward incident, it is able to restart itself.

Of course, the clockwork mechanism is required only in those cases where the lenticular apparatus has to be revolved. This introduces the question of avoiding confusion between lights. When beacons were first brought into service, the lights were of the fixed type, and the navigator, although warned by the glare to keep away from the spot so marked, was given no information as to his position. Accordingly, lighthouse engineers sought to assist him in this direction during the blackness of the night by providing a ready visual means of identification. Owing to the ingenuity which has been displayed, it has been rendered possible to ring the changes upon a light very extensively.

These may be subdivided broadly as follows :

Type of Light.	Symbol.	Characteristics.
Fixed	F.	A steady continuous light.
Flashing	Fl.	A revolving light showing a single flash at regular intervals, or a fixed light with total eclipses.
Fixed and flashing	F.Fl.	A fixed light varied at regular intervals by a single flash of greater brilliancy.
Group flashing ..	Gp.Fl.	Various combinations of flashes shown at regular intervals.
Occulting	Occ.	A steady light suddenly and totally eclipsed at regular intervals.
Group occulting ..	Gp.Occ.	A steady light suddenly and totally eclipsed by a group of two or more eclipses.

In the foregoing classifications only a white light is used. But it may so happen that the lighthouse, owing to its position and the dangerous character of the spot which it marks, carries a light which changes colour from white to red or green, which are shown alternately in various combinations. These characteristics are indicated as follows :

Type of Light.	Symbol.	Characteristics.
Alternating ..	Alt.	White and colour alternating.
Alternating flashing	Alt.Fl.	Flashing alternations by revolving mechanism.
Alternating fixed and flashing	Alt.F.Fl.	Fixed and flashing alternating.
Alternating group flashing	Alt.Gp.Fl.	Group flashing alternating.
Alternating occulting	Alt.Occ.	Occulting alternately with white and coloured light.

In timing a revolving or flashing light, the cycle is taken from the beginning of one flash to the beginning of the next. In these readings the flash is always shorter than the duration of the eclipse, while an occultation is shorter than, or equal to, the length of the light interval. Since flashing and occulting may be carried out with a fixed light suddenly extinguished or eclipsed, the characterization is determined solely according to the relative duration of light and darkness, irrespective of the type of apparatus employed or the relative brilliancy. There is one peculiarity of the flashing light which may be remarked. At short distances and in clear weather a faint continuous light may be shown.

Hand in hand with the development of the optical apparatus has been the wonderful improvement in regard to the illuminants and the methods of producing a brilliant clear flame. The fuel first used upon the introduction of the oil lamp was sperm or colza oil, the former being obtained from the whale, and the latter from seeds and a wild-cabbage. Both were very expensive, so that the maintenance of a light was costly—so much so that the United States authorities devoted their efforts to the perfection of a high-class lard-oil. This proved highly satisfactory, possessing only one drawback. In winter it congealed so much under the low temperature that it had to be heated before it could be placed in the lamp; but once the light was set going, the heat radiated from the burner served to keep the oil sufficiently fluid to enable it to mount the wick to the point of combustion under capillary action.

So far as the American authorities were concerned, the advantages of lard-oil sufficed to bring a cheaper medium than colza-oil into vogue. A company, which had been induced by the Government to install an elaborate and expensive plant for the production of colza-oil, after prolonged experiment and efforts to reduce the cost of production, announced that it could not compete with the lard-oil, and suggested that the latter should be employed in preference to the colza. The Government agreed, but, to compensate the company for its trouble, purchased the plant which the latter had laid down.

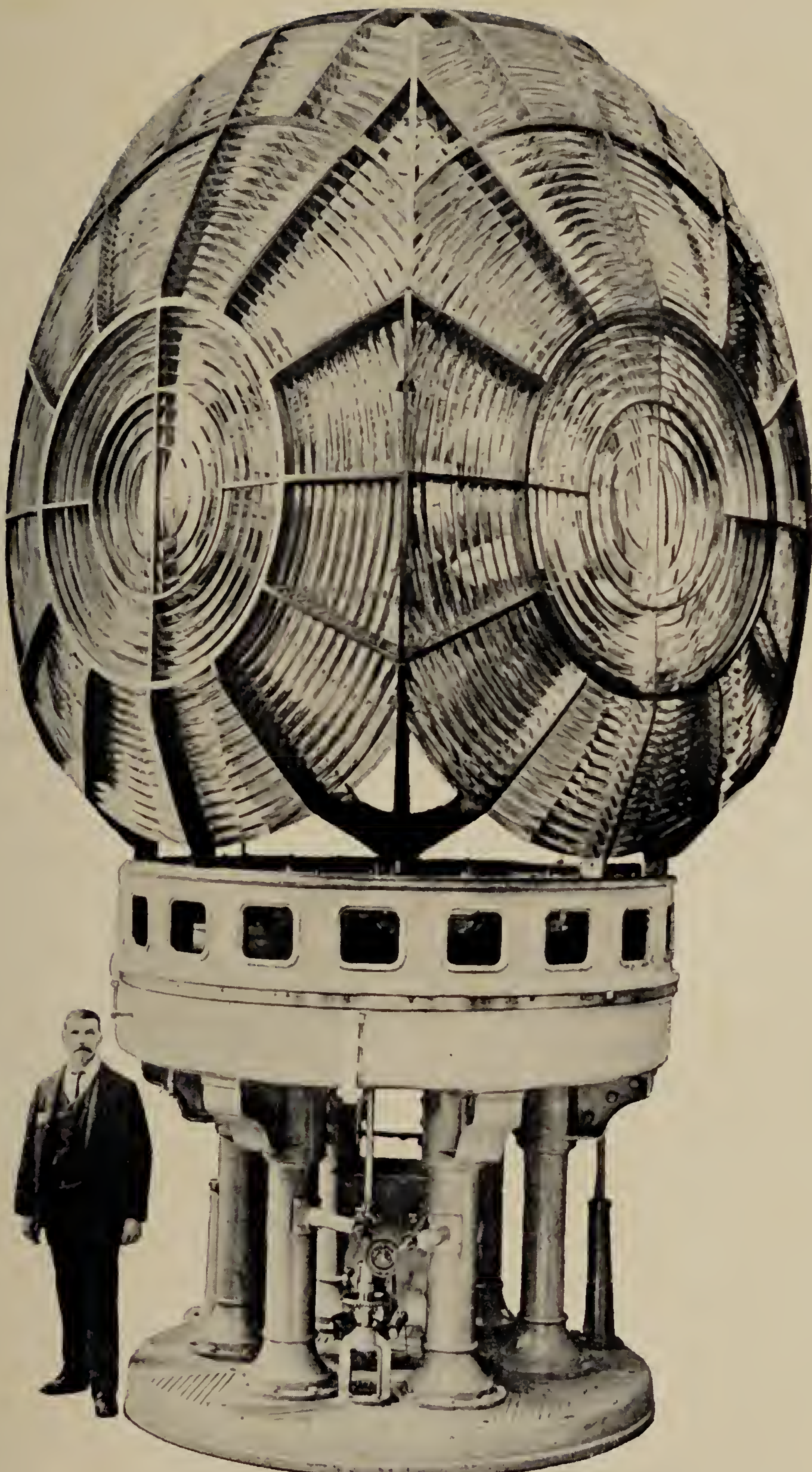
The advances in the processes for refining petroleum, and the exploitation of the extensive resources of the latter, led to "earth-oil," in some form or other, being employed for lighthouse purposes. The attempt was facilitated by the invention and improvement of the Argand burner, whereby a brilliant white annular sheet of flame is produced. Various lighthouse engineers devoted their attention to the improvement of this burner in conjunction with paraffin. Their results were completely successful, and at last paraffin became universally utilized as the cheapest and most efficient illuminant known.

The general method of feeding the lamps was to pump the oil from a low level to the burner, thereby producing practically a pressure-feed system in preference to the capillary action which is used in the ordinary household lamp. By increasing the number of rings the intensity of the flame was increased, until at last it was thought that with this development perfection had been attained so far as lamps were concerned.

Then came another radical revolution. The invention of the incandescent gas mantle by Dr. von Auer, and the complete change that it wrought in connection with gas lighting, induced lighthouse engineers to experiment in this field. As they could not use coal-gas, they devoted their investigations to the perfection of a gas from petroleum, which should be capable of combustion with the incandescent burner. Many years were devoted to these experiments, and many petroleum vapour systems were devised. One of the best known, most successful, and most scientifically perfect, is the Chance incandescent light. This burner is used in many of the most powerful lights of the world and has given complete satisfaction. The mantle varies in size with the size and type of the light, ranging from 35 to 85 millimetres in diameter, the latter, in conjunction with a hyperradial apparatus, producing a light exceeding 1,000,000 candle-power.

Not only was a far more powerful light obtained in this manner with the assistance of the petroleum vapour burner and incandescent mantle, but the cost of maintaining the light was reduced, owing to the great economy in oil consumption that was effected thereby, the largest mantle and burner—85 millimetres—burning only 2½ pints of oil per hour. The light thus obtained, while being vastly superior to that derived from a six-wick oil-burner, enables a saving of nearly £48, or $240, per annum to be recorded, taking the cost of the petroleum at 1s., or 25 cents, per gallon delivered to the lighthouse.

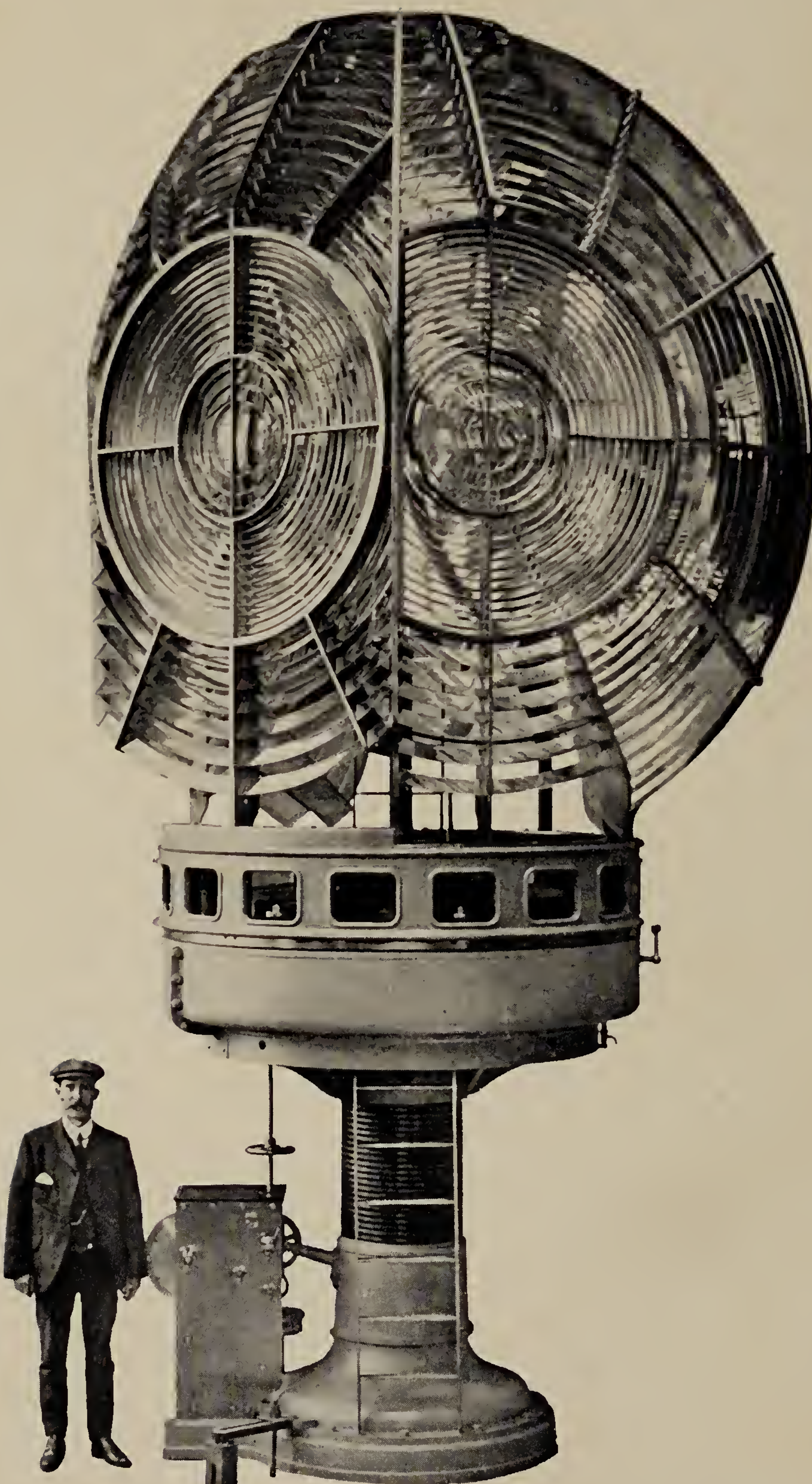
While petroleum is generally used, some countries have adopted other oil fuels for small permanent lights. Thus, in Germany compressed oil-gas, water-gas associated with benzine vapour, and Blau liquid gas, are utilized. The last-named is coming very extensively into vogue, also, in Holland, Denmark, and Austria. Blau gas has the advantage that it can be transported in small steel tanks under extremely high pressure—up to 100 atmospheres, or approximately 1,400 pounds per square inch. It is an extract of oil-gas produced at a low pressure in the gas retorts, and then compressed so severely that it liquefies. The fuel, as it is drawn from the cylinder in which it is stored, has the pressure reduced by means of a valve, so that it reaches the burner



By courtesy of Messrs. Chance Bros. & Co., Ltd.

THE HYPERRADIAL APPARATUS FOR THE MANORA POINT LIGHT, KARACHI, INDIA.

Of 1,330 millimetres focus, this is the most powerful and largest lighthouse apparatus made.



By courtesy of Messrs. Chance Bros. & Co., Ltd.

FIRST ORDER TRIPLE FLASHING LIGHT OF 920 MILLIMETRES FOCAL DISTANCE FOR CHILANG LIGHTHOUSE, CHINA.

in a gaseous form at a pressure equivalent to that of the coal-gas used in private houses, and is burned in the same way with an incandescent mantle. The advantage of this method lies in the facility with which large volumes of gas may be transported, a steel cylinder containing 7,500 cubic feet weighing only 132 pounds. It is also inexpensive, a bottle of the foregoing capacity costing only 12s. 6d., or $3. In some cases the incandescent mantles, the average life of which is about a fortnight, are of large diameter, running up to 100 millimetres, or about 4 inches.

Recently Mr. Gustaf Dalén, of the Gas Accumulator Company of Stockholm, the inventor of the Dalén flasher and sun-valve, which are described elsewhere, has introduced a new illuminant, which is coming into vogue, especially on the Continent. This is called "Daléngas," and is a mixture of 9 per cent. dissolved acetylene and 91 per cent. atmospheric air. Here the dissolved acetylene gas is conducted from a storage reservoir or high-pressure gas cylinder, of special construction, to a governor, where the pressure is reduced, and then to the mixing apparatus, where the acetylene gas is associated with the air in the above proportions. The idea of this combination and method is to enable an acetylene gas mixture to be used with the ordinary incandescent mantles.

The advantage of the Daléngas, according to present experience, is the increased candle-power that is obtainable as compared with other systems, the superiority being about 75 per cent. under ordinary conditions. With the largest Fresnel lenses a lighting power of 200,000 Hefner candle-power is secured, while with revolving lenses of the latest type a beam of 3,000,000 candle-power can be obtained. The flame is small, and thus becomes concentrated more in the focus of the lens, so that the divergence of the light may be diminished if desired. When a light of a certain range is to be installed, the optical apparatus can be made smaller for Daléngas than for other illuminants, and the cost is reduced correspondingly. Similarly, if the system is introduced into an existing light, the latter can be made appreciably

4

more powerful, without changing the optical apparatus or affecting the divergence.

In this system the gas is conducted into the lens apparatus from above, and the lighting arrangement is quite independent of, and does not interfere in any way with, the revolving apparatus, while the time spent in changing the mantle is less than half a minute.

All combustible gases, mixed with air in certain proportions, may produce more or less violent detonations when fired. But the quantity of mixed gas in this instance is confined in the length of piping between the burner and the mixing apparatus, and this quantity is so small that an explosion cannot be dangerous. In fact, all such danger has been guarded against completely—is, indeed, impossible in any circumstances.

Electric light has been adopted in one or two cases; but while the foremost authorities agree that it throws the best, most brilliant and most powerful beam of light, the system is generally impracticable on account of its great cost. When tests with this light were made some years ago in comparison with the light thrown from oil burners, it was claimed that the latter, owing to its reddish-yellow tinge, was the most suitable from the all-round point of view, and that it could penetrate to a greater distance in foggy weather. I have been informed by several authorities, who have gone more deeply into this question since, that this is a fallacy, and that the advantage rests completely with electric light. Experience in Germany, which has two magnificent electric lighthouses, and in Scotland, certainly supports this contention, and I have been assured that the sole reason why electric lighting has not been adopted more widely is the heavy cost, both of installation and of maintenance. When electric lighting is rendered cheaper and is brought more to the level of existing lighting arrangements, one may expect another complete change in lighthouse practice. In this direction, as explained in another chapter, the Germans have carried out practical experiments in their characteristic manner, and have brought the cost of maintaining a most powerful electric light to the minimum.

One very great advantage of the electric light is the ease with which the power of the beam may be increased during thick weather, so as to secure penetration to the greatest distance, and decreased to suit easier conditions in clear weather.

This point raises the question, "From how far can a light be seen out at sea?" This factor is influenced by climatic conditions, and also by the curvature of the earth. The higher the light, or the spectator, or both, is elevated above the water, the greater the distance from which the light can be seen. The table on p. 52, prepared by Mr. Alan Stevenson, the eminent Scottish lighthouse engineer, gives the distances at which objects can be seen at sea, according to the respective elevations of the object and the eye of the observer.

For instance, the passenger on a liner the boat-deck of which is 40 feet above the water, approaching the English Channel, will sight the Bishop Rock light from a distance of about 22 miles, because the focal plane—that is, the bull's-eye of the lens—is 163 feet above the water, which, according to the following table, equals about 14½ miles, to which must be added the height of the boat's deck, 40 feet representing 7·25 miles. Similarly, the ray of the Belle Ile light will come into view when the vessel is 32½ miles distant—height of focal plane of light, 470 feet = 25 miles, + eye of observer on board the liner, 45 feet = 7·69 miles; while the Navesink light, being 246 feet above the water, may be picked up by the captain of a liner from a distance of 28 miles. The range of many lights, however, owing to the curvature of the earth, is greatly in excess of their geographical range, and with the most powerful lights the glare of the luminous beams sweeping the clouds overhead may be seen for a full hour or more before the ray itself comes into view.

So far as the candle-power of any light is concerned, the method of determining this factor, varying according to the

TABLE OF DISTANCES AT WHICH OBJECTS CAN BE SEEN AT SEA, ACCORDING TO THEIR RESPECTIVE ELEVATIONS AND THE ELEVATION OF THE EYE OF THE OBSERVER.

Heights in Feet.	Distances in Statute or English Miles.	Distances in Geographical or Nautical Miles.	Heights in Feet.	Distances in Statute or English Miles.	Distances in Geographical or Nautical Miles.	Heights in Feet.	Distances in Statute or English Miles.	Distances in Geographical or Nautical Miles.
5	2·958	2·565	70	11·067	9·598	250	20·916	18·14
10	4·184	3·628	75	11·456	9·935	300	22·912	19·87
15	5·123	4·443	80	11·832	10·260	350	24·748	21·46
20	5·916	5·130	85	12·196	10·570	400	26·457	22·94
25	6·614	5·736	90	12·549	10·880	450	28·062	24·30
30	7·245	6·283	95	12·893	11·180	500	29·580	25·65
35	7·826	6·787	100	13·228	11·470	550	31·024	26·90
40	8·366	7·255	110	13·874	12·030	600	32·403	28·10
45	8·874	7·696	120	14·490	12·560	650	33·726	29·25
50	9·354	8·112	130	15·083	13·080	700	35·000	30·28
55	9·811	8·509	140	15·652	13·570	800	37·416	32·45
60	10·246	8·886	150	16·201	14·220	900	39·836	34·54
65	10·665	9·249	200	18·708	16·220	1,000	41·833	36·28

By permission of the "Syren and Shipping."

LOOKING UP THE LANTERN OF THE NEEDLES LIGHTHOUSE.

By courtesy of Messrs. Chance Bros. & Co., Ltd.

FIXED APPARATUS OF THE FOURTH ORDER FOR SARAWAK.

The focal distance is 250 millimetres, and the diameter of lantern inside glazing 6 feet 7¾ inches.

calculating methods adopted, is somewhat misleading. So far as Great Britain is concerned, the practice of setting out the candle-power of any light in the official list has been abandoned, the authorities merely stating that such and such a light is of great power. The United States and Canada, on the other hand, indicate the approximate candle-power.

By combining and arranging the integral parts of the optical apparatus, the lighthouse engineer is able to accomplish many astonishing results. Thus, while the various types generally follow accepted broad lines, coinciding with the order which they represent, here and there some very striking divergences are made. The Bell Rock light is perhaps the most interesting example in this direction. It was designed by Messrs. D. and T. Stevenson, and built by Messrs. Chance Brothers and Co. The light is alternating, the colours being white and red. Externally the optical apparatus appears to be bizarre, yet it is one of the most perfect which has ever been installed. In its design and construction almost all the known lighthouse optical elements are incorporated, including the equiangular refractor, the reflecting prism, the double-reflecting prism, and the dioptric mirror. Another noteworthy fact is that, by an exceedingly ingenious arrangement, the absorption of the rays by the glass used in producing the red flashes is neutralized to such a vast degree that the white and red flashes are of equal intensity.

The subsidiary light is another striking feature which the lighthouse engineer has introduced. For instance, a light may be shown from a dangerous reef, and give the mariner all the warning desired. But some distance away may lurk another isolated rock, which it is just as imperative to indicate, and yet on which another tower cannot be erected. This necessity is met by the subsidiary light. A portion of the light from the main apparatus is deflected and thrown to the desired spot by an ingenious arrangement of the prisms. On the west coast of Scotland, at Stornoway, a stream of light used to be deflected from the lantern in a vertical

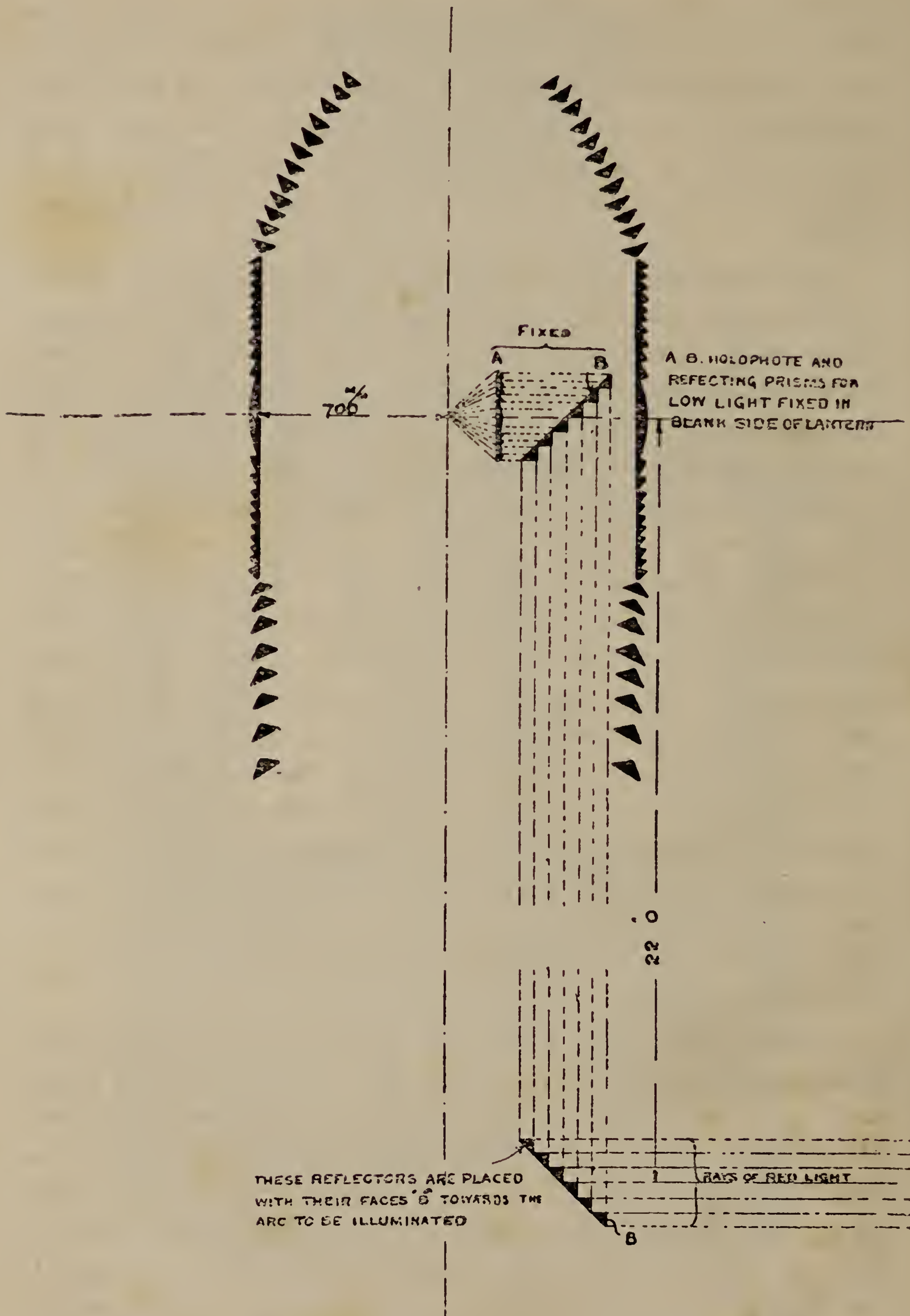


FIG. 14.—THE MEANS WHEREBY THE RAYS ARE DEFLECTED FROM THE MAIN LIGHT TO FORM A SUBSIDIARY LIGHT.

(*By permission of Messrs. Chance Bros. and Co., Ltd.*)

direction down the tower, and there bent at right angles, to be thrown through a lower window and fall upon a prism placed on the crest of a rock several hundred feet distant. From the deck of a vessel, the effect of the light striking the prism was akin to that produced by a beacon. Similarly in the case of St. Catherine's light in the Isle of Wight : a portion of the light, which would otherwise be wasted over the area on the landward side, is carried vertically down the tower by a disposal of lenses and prisms, and is projected horizontally through a small window, after being coloured into a red ray by passing through some glass of the desired tint, to mark a danger spot some distance away. This method, however, is not favoured now, as the peril can be more efficiently marked by means of an independent beacon, a system which has become feasible owing to the vast improvements that have been made in automatic lights requiring no attention for several weeks or months at a time.

But in those instances where the latter expedient is not adopted, the practice is to cover the danger with a ray thrown from an entirely different light. When the present Eddystone tower was completed, a "low-light room," as it is called, was incorporated, and a low-powered light was thrown from two Argand burners and reflectors through a window to mark a dangerous reef some three miles distant. But perhaps the best example of a subsidiary light is that which was carried out by Messrs. Chance in connection with the Cap de Couedie lighthouse. In this instance two dangers had to be indicated in a subsidiary manner, one being covered with a red, the other with a green, ray. The red sector marks a danger spot known as Lipson's Reef, lying $8\frac{3}{4}$ miles distant, while the green light indicates Casuarina Island, $1\frac{3}{4}$ miles away. This installation, it may be pointed out, has proved highly successful, and certainly is very economical.

There is another point which deserves mention—the duration of the flash in a revolving light. There was considerable discussion and difference of opinion upon this question some years ago. It was maintained that the shorter the duration of the flash, and the more rapidly it were thrown, the better it would be for the mariner. The Scottish engineers realized the significance of this problem, and, despite the hostile criticism of contemporary engineers, adopted a specific principle which was to give a flash of two and three-quarter seconds' duration. Subsequently it was reduced to one second. The introduction of the mercury float enabled the optical apparatus to be revolved faster, and also facilitated the reduction in the number of panels or faces, so that ultimately the Scottish engineers reduced the flash to one of four-tenths of a second.

When Mr. Bourdelles devised the mercury float which enabled rotation to be accelerated, the French authorities rushed to the opposite extreme. They reduced the faces to four, and arranged for the apparatus to be revolved at a high speed, so that the duration of the flash was only one-tenth of a second at rapidly-recurring intervals. This type of light was called the *feu-éclair*, and was adopted as a result of prolonged laboratory investigation. But this was an instance where laboratory experiments and scientific reasoning failed to go hand in glove with practical experience and navigation, where the mariner has to contend with all sorts and conditions of weather. The seafarer expressed his opinion of the one-tenth of a second flash in uncomplimentary terms, displaying an indifferent appreciation of artificially-produced sheet-lightning.

Eventually there was a general agreement, among all those countries which had investigated the problem closely, that a flash of about three-tenths of a second was the most satisfactory, and this has since become tacitly standardized. The French authorities recognized the fallacy of their idea, and soon came into line with the other countries.

CHAPTER IV

FOG-SIGNALS

NOTWITHSTANDING the wonderful ingenuity that is displayed in the concentration of light into powerful beams, these all count for nothing when fog settles upon the sea. The ray of 1,000,000 candle-power is almost as futile then as the glimmer from a tallow dip.

Fog is the peril of the sea which the mariner dreads more than any other. The blanket of mist, descending upon the water, not only shuts everything from sight, but deadens every sound as well. The sea is absolutely calm, so that no intimation of danger ahead is conveyed by the breaking of the waves upon rock, shoal, sandbank, or iron-bound coast.

It is in times of fog that the navigator must be given the greatest protection. As this is impossible to accomplish visually, appeal must be made to his ear. In the early days of lighthouse engineering the methods of conveying audible warning were very crude. The discharge of a gun was the most popular, but it was neither serviceable nor reliable, and was made upon somewhat haphazard lines. Thus, in the case of a dangerous headland on the North American coast, which the Boston steamer had to round on its journey, the keepers mounted guard at the probable time of the vessel's arrival off this point. They listened eagerly for the steamer's whistle, and when it came screaming over the water they began hurriedly firing a carronade, keeping up the blank-cartridge bombardment until another shriek told them that those on the vessel had heard their signals. Sometimes the whistle was heard from a distance of six miles; at others from not more than two miles away. It depended upon circumstances. Obviously, such a primitive system was attended with considerable danger, as an accident was liable to happen to the men in their feverish haste to load and discharge the gun, while the plight of the boat was far from being enviable at times.

In the early days every lighthouse tower was provided with a heavy bell. Indeed, the ponderous dome of metal projecting from the lantern gallery was considered indispensable. The bell varied in weight from 1,200 to 2,240 pounds, was fitted with a massive clapper, and when struck emitted a deep musical note. In order to enable the seafarer to gain some idea of his whereabouts, the fog-signals were given a sound-characteristic somewhat upon the lines of those in connection with the light. Thus, one lighthouse would give one stroke every ten seconds ; another would give two strokes in quick succession, followed by a long silence, and so on. This system suffers from the severe handicap that the sound does not travel very far during foggy weather.

Another ingenious engineer recommended the utilization of the locomotive whistle, giving a high-toned, ear-piercing shriek, but the same objection as attended the use of the bell prevailed : the sound could not be heard more than a short distance away. The British lighthouse authorities submitted the idea to a series of searching investigations to ascertain its possibilities, but eventually were compelled to conclude that it was not superior to, if as good as, the other systems then in vogue. The United States authorities, as a result of their independent experiments, expressed a similar opinion ; but in Canada practical application gave this whistle a favourable verdict.

Rockets also have been adopted, and are highly successful. Indeed, this method of conveying audible warning prevails still in many countries. The practicability of such a means of throwing sound over a wide area was advanced by Sir Richard Collinson, when Deputy-Master of Trinity House, and his idea comprised the insertion of a gun-cotton charge, timed to explode at a given height, in the head of the rocket. The height could be varied up to about

1,000 feet, and the weight of the charge fluctuated according to requirements. The rocket system was tested very severely, and in some instances the report was heard as many as twenty-five miles away. It received the approbation of Professor Tyndall, and, although superior methods of signalling have been devised since, there remain one or two lighthouse stations where it is considered to be the most satisfactory fog-signalling device, notably the station on the island of Heligoland, where the rocket is hurled into the air to explode at a height of nearly 700 feet.

In many lighthouses the detonation of gun-cotton constitutes the means of conveying warning to passing vessels, but is accomplished in a different manner. The charge, instead of being sent into the air to be exploded, is attached to a special device which is supported upon a simple frame at a point above the lantern, so that no damage may be inflicted upon the glass of the latter from the concussion. The apparatus is fitted with a safety device which prevents premature explosion, so that the keeper is preserved from personal injury, and, unless culpable negligence is manifested, the charge cannot be ignited until it has been raised to its designed position. The report is of great volume, and as a rule can be heard a considerable distance ; but in this, as in all other cases, the atmosphere plays many strange tricks. Still, it has not been superseded yet for isolated sea-rock lighthouses, such as the Eddystone, Skerryvore, and Bell Rock, where there is lack of adequate space for the installation of any other equally efficient fog-signalling facilities.

In the early seventies an American investigator, Mr. C. L. Daboll, contrived an entirely new system, which developed into the foundation of one of the most successful fog-signalling devices for lighthouses which has been discovered—the siren. The Daboll invention was a huge trumpet, recalling a mammoth phonograph horn. It was 17 feet in length, and its mouth was 38 inches in diameter. In the lower end of this trumpet—the throat—was placed a tongue of steel measuring 10 inches in length and secured at one end to form a reed. It was blown by air compressed in a reservoir to the desired degree, and then permitted to escape through the trumpet. The mad rush of the expanding air through the constricted passage set the reed vibrating violently, causing the emission of a penetrating, discordant bellow. When Daboll commenced his experiments, he suffered from the lack of a suitable mechanical means for compressing the air, and made shift with a donkey for this purpose until the hot-air engine was improved, when the latter was substituted.

Trinity House adopted the idea and found it serviceable; but the Canadian authorities, after four years' experiment, dissented from this view, remarking that the trumpet was expensive to maintain, unreliable in working, and liable to break down when most urgently needed. In fact, they characterized the Daboll trumpets which they had installed as "sources of danger instead of aids to navigation."

From the trumpet to the siren was not a very big step. The history of the latter's invention is somewhat obscure, but it was brought before the United States Government in a primitive form. The American engineers, recognizing its latent possibilities, took it up, and endeavoured to improve it to such a degree as to render it suitable for lighthouse work. Their efforts were only partially successful. The solution of the many difficulties attending its perfection was effected in Great Britain by Professor Frederick Hale Holmes, whose magneto-electric machine brought electricity within reach of the lighthouse as an illuminant, and it was due to the efforts of this scientist that the siren became one of the most efficient sound-producing instruments which have been discovered for this class of work.

The reason that made Professor Holmes bring his energies and knowledge to bear upon this subject was somewhat curious. The siren in its first form made its way from the United States to Great Britain. The British Admiralty realized the power and penetration of its sound, and forthwith adopted it in the navy, operating it by steam instead of by air. At this there arose a great outcry from the mercantile marine. Captains argued that the similarity of the signals confused and often misled them, as they could not tell in the fog whether the sound proceeded from a warship or a lighthouse. The Board of Trade was forced to intervene, but, as it had no jurisdiction over the Admiralty, it sought to extricate itself from an awkward situation by inviting Professor Holmes to perfect a siren which would emit a distinctive sound. His efforts were crowned with complete success.

Professor Holmes exhibited his wonderful device at the Paris Exhibition of 1867. He installed it in working order, and the visitors displayed an anxiety to hear it. It was brought into action, and those around never forgot the ex-

A B

FIG. 15.—THE FIXED (A) AND REVOLVING (B) PARTS OF THE SIREN.

perience. It was the most diabolical ear-splitting noise which had been heard, and, apprehensive that serious results might arise from its demonstration when the buildings were thronged with sight-seers, the authorities refused to permit it to be sounded again. The humorous illustrated papers did not suffer such a golden opportunity to escape. Grotesque and laughable cartoons appeared depicting the curious effects produced by the blast of the instrument, one showing the various statues being frightened off their pedestals proving exceptionally popular.

The siren in its simplest form is an enlarged edition of the "Deviline" toy whistle. There is a Daboll trumpet with a small throat, in which is placed horizontally, not a reed, but a metal disc, so as to fill the whole circular space of the throat. The sheet of metal is pierced with a number of radial slits. Behind this disc is a second plate of a similar character, and likewise pierced with radial slits of the same size, shape and number ; but whereas the first disc is fixed, the second is mounted on a spindle. The free disc rotates at high speed, so that the twelve jets of air which are driven through the throat are interrupted intermittently by the blanks of the revolving disc coming over the openings in the fixed disc, while when the two slits are in line the air has a free passage. If the revolving disc completes 3,000 revolutions per minute, and there are twelve slits in the discs, then a total of 36,000 vibrations per minute is produced while the instrument is in operation. The speed of the revolving disc, as well as the number and size of the openings, varies according to the size and class of the siren ; but in any case an intensely powerful, dense and penetrating musical tone is emitted, which can be heard a considerable distance away. The blast of a high-powered large siren has been heard at a distance of twenty to thirty miles in clear weather, though of course in thick weather its range is reduced.

While Professor Holmes was experimenting with this device, another investigator, Mr. Slight, of Trinity House, was wrestling with the same problem. Indeed, he may be described as the inventor of the modern siren. Although he effected only an apparently slight modification, it was the touch which rendered the instrument perfect, while it also removed the possibility of a breakdown at a critical moment, as he rendered the moving part freer in its working and eliminated the severe strains to which it was subjected. The improvement was appreciated by Professor Holmes, who adopted it immediately.

While these indefatigable efforts were in progress, ingenious attempts were made to press Nature herself into operation. As is well known, there are many " blowing-holes " distributed throughout the world, where the water by erosion has produced a long, narrow cavern in the base of a rock, with a constricted outlet into the outer air. The waves, rushing into the cave, compress the air within, which, in its escape at high velocity through the small vent, produces a bellowing sound. It was this curious phenomenon which gave the Wolf Rock its name. General Hartmann Bache, of the United States Engineers, attempted in 1858 to make use of a blowing-hole on one of the Farallon Isles, lying forty miles off the entrance to San Francisco Bay. A chimney was built with bricks above the orifice, through which the air compressed by the waves below made its escape, and on top of this shaft a locomotive whistle was placed. The first effort was a dead failure, because the force of the rush of air was so great that it carried away the chimney ; but in the second attempt success was achieved, and an excellent automatic whistle blared out night and day almost continuously and was audible for some distance out to sea. The only drawback was that in foggy weather, when the most intense sound was required, the signal was dumb owing to the smoothness of the water. This novel signal was maintained for some time and then was superseded by a powerful siren.

One of the most interesting fog-signalling installations in service is that on the bald formidable hump of rock lying in the estuary of the Clyde, known as Ailsa Craig. For years this rock constituted a terrible menace to the crowded shipping of this important marine thoroughfare, and its victims were numerous. While the Commissioners of Northern Lighthouses mitigated its terrors as far as possible by the provision of a powerful light, they recognized the fact that a visual warning did not meet the situation completely. But the installation of a fog-signal was a somewhat peculiar problem, owing to the configuration of the rock. A single station would not meet requirements, because it was necessary to throw the warning from both sides of the obstruction. The provision of two sound-stations would have been an expensive matter, even if it had been feasible, which it was not, owing to the precipitous nature of the cliffs.

An ingenious solution was advanced by Mr. Charles Ingrey, C.E. He proposed to erect a central power-station and to control the sounding of two sirens, placed on opposite sides of the island, therefrom, the compressed air being led through underground piping. The plans were submitted to Messrs. Stevenson, the engineers to the Northern Lighthouse Board, who, after examining the proposal thoroughly, gave it their approval. But when it came to obtaining the sanction for the requisite expenditure from the Board of Trade, that august body, despite the fact that the project had been investigated and had received the approbation of the engineers to the Northern Lighthouse Commissioners, declined to permit public money to be expended upon an untried scheme. Such is the way in which pioneering effort and ingenuity are stifled by Government departments.

Many another engineer would have abandoned the project after such a rebuff, but Mr. Ingrey without any delay laid down a complete installation upon the lines he contemplated on the island of Pladda, where a Holmes fog-horn was in service. With the aid of a workman whom he took from Glasgow, the light-keepers and some farm labourers, this trial installation was completed, the piping being carried round the island from the air-compressing plant to the fog-signal. The work occupied about a fortnight, and then, everything being ready to convince the sceptical Board of Trade, the inspecting engineers were treated to a comprehensive and conclusive demonstration. They were satisfied with what they saw, appreciated the reliability of the idea and gave the requisite sanction. Forthwith the Ailsa Craig Island installation was put in hand and duly completed.

This plant possesses many ingenious features. As the light is derived from gas distilled from crude oil, a small gas-making plant is installed on the island, and this is used also for driving a battery of five eight-horse-power gas-engines —four are used at a time, the fifth being in reserve—to supply the thirty-horse-power demanded to operate the fog-signal. The energy thus developed drives two sets of powerful air-compressors, the four cylinders of which have

THE ACETYLENE FOG-GUN.

The latest ingenious device for giving both audible and visual warning automatically.

THE RATTRAY HEAD LIGHTHOUSE.

A very exposed Scottish rock tower. It is unique because a full-powered siren fog-signal is installed therein.

By courtesy of Messrs. D. and C. Stevenson.

SULE SKERRY LIGHT.

A lonely light of Scotland. The nearest land is the Butt of Lewis, 30 miles distant.

a bore of 10 inches by a stroke of 20 inches, the air being compressed to 80 pounds per square inch and stored in two large air-receivers which hold 194 cubic feet. From this reservoir pipes buried in a trench excavated from the solid rock extend to the two trumpets, placed on the north and south sides of the island respectively. The length of piping on the north side is 3,400 feet, and on the south side 2,500 feet. At places where the pipe makes a dip, owing to the configuration of the rock, facilities are provided to draw off any water which may collect. Extreme care had to be displayed in connecting the lengths of piping, so that there might be no leakage, in which event, of course, the pressure of the air would drop and thereby incapacitate the signal.

Each signal is mounted in a domed house built of concrete, the mouth of the trumpet extending from the crown of the roof. Within the house is an air-receiver 9 feet in height by 4½ feet in diameter, of about 140 cubic feet capacity, which receives the compressed air transmitted through the piping from the compressing-station. It also contains the automatic apparatus whereby the signal is brought into action at the stipulated intervals, so as to produce the requisite sound characteristic. This is a self-winding clockwork mechanism which admits and cuts off the supply of air to the trumpets, its chief feature being that the clock is wound up by the compressed air itself, so that it is entirely free from human control. However, as a breakdown even with the best-designed and most-carefully-tended machinery cannot be circumvented entirely, there is a duplicate electrical mechanism, also automatically controlled from the power-generating station, the electric cables for which are laid in the pipe trenches. This acts as an emergency control.

The two signals are not sounded simultaneously; neither are they alike nor of the same tone. The north signal gives a single blast of high tone, lasting five seconds, and then is silent for 175 seconds. On the south side the siren gives a double note, although there are three blasts—viz., high, low, high—corresponding to the letter R of the Morse code. The notes are sounded for two seconds, with similar intervening periods of silence, and silence for 170 seconds between the groups. The complete signal from the two stations is given once in three minutes, the north signal commencing to sound ninety seconds after the south signal has ceased. The high note corresponds to the fourth E in the musical compass, there being 38,400 vibrations per minute ; while the low note is tuned to the third D in the musical compass, with 16,800 vibrations per minute. The notes are purposely timed more than an octave apart and made discordant, as thereby the sound is more likely to attract attention and to be readily distinguished.

About eighteen minutes are required to bring the apparatus into operation—that is, to start compressing and to raise the pressure of the air to the requisite degree—but, as fogs descend upon the Clyde with startling suddenness, the signals may be started within five minutes of the fog-alarm. The air-reservoirs are kept charged to the working pressure, the machinery being run once or twice for a short time every week for this purpose and to keep the plant in working order.

Up to this time it had been the practice to place the siren in close proximity to the air-compressing machinery, but the installation at Ailsa Craig proves conclusively that this is not essential to success ; also it demonstrates the fact that a number of signals can be operated reliably and effectively from a central station. Indeed, this Scottish plant aroused such widespread interest that the Pulsometer Engineering Company of Reading, who had acquired Professor Holmes's patents and who carried out the above installation, received several inquiries from abroad with regard to its suitability for similar situations. In one instance the compressed air was to be transmitted for a distance of nearly four miles.

While the siren has been adopted and found adequate by the majority of nations, the Canadian Government has installed a far more powerful instrument upon the River St. Lawrence, as the ordinary siren signals originally established near the mouth of the river, although of great power, were found to be inadequate. The new apparatus, which is known as the "diaphone," gives an extraordinarily powerful sound. It comprises a cylindrical chamber, in the walls of which are cut a number of parallel slits. Concentrically disposed within the chamber is a cylindrical hollow piston, with similar slits and a flange at one end, the whole being enclosed in an outer casing. Air under pressure is admitted into the outer casing, and drives the piston backwards and forwards with great rapidity. The result is that the air effects its escape through the orifices, when they come into line, in intermittent puffs.

While the broad principle is not unlike that of the conventional siren, the main difference is that in the latter there is a rotary motion, whereas in the diaphone the action is reciprocating. The great advantage of the latter is that all the vibrations are synchronous, owing to the symmetrical disposition of the slits, and consequently the note produced is very pure. The mechanism is so devised that the piston's motion is controlled to a nicety, and the sound is constant. Experience has proved that the best results are obtained by using air at a pressure of 30 pounds per square inch. The sound thus produced is intensified to a markedly greater degree by means of a resonator properly attuned.

This instrument has displaced the siren among the stations upon the St. Lawrence River. The general type of apparatus has a piston 4½ inches in diameter, and uses 11 pounds of air per second during the sounding of the blast. But at more important stations a far larger and more powerful class of apparatus is used, the diaphone at Cape Race having a piston 8½ inches in diameter and using 27 feet of air per second while sounding. This does not indicate the limit of size, however, since the builders of this terrible noise-producer are experimenting with an apparatus having a piston 14 inches in diameter. The sound issuing from such a huge apparatus would be almost as deafening as the report of a big gun and should succeed in warning a mariner several miles away.

The atmosphere, however, plays many strange pranks with the most powerful sound-producing instruments. To-day, for instance, a fog-signal may be heard at a distance of ten miles; to-morrow it will fail to be audible more than a mile away. This aberration of sound is extraordinary and constitutes one of the unsolved problems of science. Innumerable investigations have been made with the object of finding the cause of this erratic action, but no conclusive explanation has been forthcoming. Another strange trick is that, while a sound may be audible at distances of two and four miles during a fog, it fails to strike the ear at three miles. It is as if the sound struck the water at a range of two miles, bounded high into the air, and again fell upon the water at four miles, giving a second leap to hit the water again farther on, in much the same way as a thin flat stone, when thrown horizontally into the water, will hop, skip, and jump over the surface. This trick renders the task of the lighthouse engineer additionally exasperating and taxes his ingenuity to the utmost, as it appears to baffle completely any attempt towards its elimination.

Recently another ingenious and novel system has been perfected by Messrs. D. and C. Stevenson. This is an acetylene gun which acts automatically. Hitherto an unattended fog-signal—except the bell-buoy tolled by the movement of the waves, which is far from satisfactory, or the whistling buoy, which is operated upon the same lines and is equally ineffective except at very short range—has found little favour. The objections to the bell and whistle buoys are the faintness of the sounds, which may be drowned by the noises produced on the ship herself; while, if the wind is blowing away from the vessel, she may pass within a few feet of the signal, yet outside its range. Thus it will be recognized that the fog-gun serves to fill a very important gap in connection with the warning of seafarers during thick weather.

As is well known, even a small charge of acetylene, when fired, will produce a loud report, and this characteristic of the gas induced Messrs. Stevenson to apply it to a fog-signal. They have developed the automatic acetylene system of lighting to a very high degree around the coasts of Scotland, and there are now more than twenty lights of this class, mostly unattended, in operation, some of which have been established for many years. These lights have proved highly satisfactory. There has never been an accident, a freedom which is due to the fact that Moye's system is used, wherein the possibilities of mishap are surmounted very effectively. Accordingly, the engineers saw no reason why a similar system should not be adapted to the emission of sound instead of light signals, or, if desired, of both simultaneously. Their experiments have been crowned with complete success, and, as the gun uses no more gas than would be consumed if a flashing light system were used, the cost of operation is very low.

The general features of the acetylene fog-gun may be observed from the illustration (facing p. 64). The acetylene, dissolved in acetone, is contained under pressure in a cylinder, and thence passes through a reducing valve to an annular space, where it is ignited by an electric spark. A trumpet is attached to the firing chamber, so that the sound becomes intensified. If desired, the explosion can be effected at the burner, so that, in addition to a sound-signal, a flashing light is given.

The applications vary according to the circumstances. Suppose there is an unlighted bell-buoy at the bar of a port. Here the procedure is to install a gun and light combined, so that the flash of the explosion may give visual and the report audible warning. Or, should there be a lighted buoy already in position, its effectiveness may be enhanced by adding the gun, the detonation alone being employed for warning purposes. The size of the cylinder containing the dissolved acetylene may be varied, so that renewal need only be carried out once in one, two, or more months, according to conditions. If the increasing traffic around a certain rock demand that the latter should be marked, a combined sound and light apparatus can be installed. It may be that the head of a pier which is accessible only at certain times, or a beacon which can be reached only at rare intervals, may require improved facilities. In this case the gun can be set up and a cable laid to a convenient spot which may be approached at all times by an attendant. Then the latter, by the movement of a switch, can bring the gun instantly into action upon the alarm of fog, and it will keep firing at the set intervals until, the fog lifting, the gun is switched off.

In some cases, where the apparatus is set upon a lonely rock, a submarine cable may be laid between the marked point and the control-station. The cable is not a very costly addition. There are many lights where wages have to be paid merely for a man to bring the fog-signalling bell machinery into action. In such cases a fog-gun can be installed and the annual cost of maintenance decreased enormously, thereby enabling the outlay on the gun to be recouped within a very short time; while the light may be improved by using the flashes, so that the warning can be rendered more distinctive.

The invention is also applicable to lightships, many of which are manned by four men or more at a large cost per annum. In the majority of cases an unattended Stevenson lightship—such as described in another chapter, six of which are in use around the coasts of Scotland, and which give, not only a first-class light, but, by the aid of the fog-signal gun, can be made to give an excellent fog-signal as well—offers a means of reducing the heavy maintenance charges arising in connection with a manned light-vessel. In many instances existing lightships can be converted to the automatic system and completed by the gun. Each case must, of course, be decided upon its merits as regards the time the gun and light are required to work upon a single charge of acetylene, but there are no insuperable obstacles to its utilization.

Of course, in an isolated station lying perhaps some miles off the mainland, it may be necessary to keep the gun going night and day in fog and in clear weather alike. In this case, naturally, the great number of explosions involves considerable expense; but the inventors are carrying out experiments with a view to switching the gun on and off, as required, from a distant point by means of wireless telegraphy, so as to effect a saving in the expenditure of acetylene when there is no need on account of fine weather to keep the gun going. Still, it must not be supposed that the detonations even during clear weather are altogether abortive, inasmuch as a sound-signal at sea, where the atmosphere has a long-distance-carrying capacity as a rule, in conjunction with a light, draws double attention to a danger spot. Under such circumstances the waste of acetylene gas during periods of clear weather is more apparent than real.

The contest against the elements is still being waged, and slowly but surely engineering science is improving its position, and is hopeful of rendering audible signals as completely effective as those of a visual character.

CHAPTER V

THE EDDYSTONE LIGHTHOUSE

It is doubtful whether the name of any lighthouse is so familiar throughout the English-speaking world as the "Eddystone." Certainly no other "pillar of fire by night, of cloud by day," can offer so romantic a story of dogged engineering perseverance, of heartrending disappointments, disaster, blasted hopes, and brilliant success.

Standing out in the English Channel, about sixty miles east of the Lizard, is a straggling ridge of rocks which stretches for hundreds of yards across the marine thoroughfare, and also obstructs the western approach to Plymouth Harbour. But at a point some nine and a half miles south of Rame Head, on the mainland, the reef rises somewhat abruptly to the surface, so that at low-water two or three ugly granite knots are bared, which tell only too poignantly the complete destruction they could wreak upon a vessel which had the temerity or the ill luck to scrape over them at high-tide. Even in the calmest weather the sea curls and eddies viciously around these stones; hence the name "Eddystones" is derived.

From the days when trading vessels first used the English Channel the reef has been a spot of evil fame. How many ships escaped the perils and dangers of the seven seas only to come to grief on this ridge within sight of home, or how many lives have been lost upon it, will never be known. Only the more staggering holocausts, such as the wreck of the *Winchelsea*, stand out prominently in the annals of history, but these serve to emphasize the terrible character of the menace offered. The port of Plymouth, as may be supposed, suffered with especial severity.

As British overseas traffic expanded, the idea of indicating the spot for the benefit of vessels was discussed. The first practical suggestion was put forward about the year 1664, but thirty-two years elapsed before any attempt was made to reduce theory to practice. Then an eccentric English country gentleman, Henry Winstanley, who dabbled in mechanical engineering upon unorthodox lines, came forward and offered to build a lighthouse upon the terrible rock. Those who knew this ambitious amateur were dubious of his success, and wondered what manifestation his eccentricity would assume on this occasion. Nor was their scepticism entirely misplaced. Winstanley raised the most fantastic lighthouse which has ever been known, and which would have been more at home in a Chinese cemetery than in the English Channel. It was wrought in wood and most lavishly embellished with carvings and gilding.

Four years were occupied in its construction, and the tower was anchored to the rock by means of long, heavy irons. The light, merely a flicker, flashed out from this tower in 1699 and for the first time the proximity of the Eddystones was indicated all round the horizon by night. Winstanley's critics were rather free in expressing their opinion that the tower would come down with the first sou'-wester, but the eccentric builder was so intensely proud of his achievement as to venture the statement that it would resist the fiercest gale that ever blew, and, when such did occur, he hoped that he might be in the tower at the time.

Fate gratified his wish, for while he was on the rock in the year 1703 one of the most terrible tempests that ever have assailed the coasts of Britain gripped the structure, tore it up by the roots, and hurled it into the Channel, where it was battered to pieces, its designer and five keepers going down with the wreck. When the inhabitants of Plymouth, having vainly scanned the horizon for a sign of the tower on the following morning, put off to the rock to investigate, they found only the bent and twisted iron rods by which the tower had been held in position projecting mournfully into the air from the rock-face.

Shortly after the demolition of the tower, the reef, as if enraged at having been denied a number of victims owing to the existence of the warning light, trapped the *Winchelsea* as she was swinging up Channel, and smashed her to atoms, with enormous loss of life.

Although the first attempt to conquer the Eddystone had terminated so disastrously, it was not long before another effort was made to mark the reef. The builder this time was a Cornish labourer's son, John Rudyerd, who had established himself in business on Ludgate Hill as a silk-mercer. In his youth he had studied civil engineering, but his friends had small opinion of his abilities in this craft. However, he attacked the problem boldly, and, although his tower was a plain, business-looking structure, it would have been impossible to conceive a design capable of meeting the peculiar requirements of the situation more efficiently. It was a cone, wrought in timber, built upon a stone and wood foundation anchored to the rock, and of great weight and strength. The top of the cone was cut off to permit the lantern to be set in position. The result was that externally the tower resembled the trunk of an oak-tree, and appeared to be just about as strong. It offered the minimum of resistance to the waves, which, tumbling upon the ledge, rose and curled around the tapering form without starting a timber.

Rudyerd, indeed, may be considered to be the father of the science of modern lighthouse designing, because the lines that he evolved have never been superseded for exposed positions even in these days of advanced engineering science, greater constructional facilities, and improved materials. Rudyerd's ingenuity and skill received a triumphant vindication when the American engineers set out to build the Minot's Ledge and Spectacle Reef lighthouses, inasmuch as these men followed slavishly in the lines he laid down, and their achievements are numbered among the great lighthouses of the world to-day.

Rudyerd built his tower with infinite care, although he was harassed in his operations by the depredations of French privateers, who haunted this part of the British coast. On one occasion the whole of the men were surprised while at their work, and were borne off in triumph as prisoners of war to France. Louis XIV., however, heard of the capture, and the privateers, instead of being honoured for the catch, as they anticipated, were strongly reprimanded and compelled to release their captures. "Their work is for the benefit of all nations. I am at war with England, not with humanity," was the Sovereign's comment; and by way of compensation the prisoners were loaded with presents and reconveyed to the rock, to resume their toil.

For forty years Rudyerd's structure defied the elements, and probably would have been standing to this day had it not possessed one weak point. It was built of wood instead of stone. Consequently, when a fire broke out in the lantern on December 4, 1755, the flames, fanned by the breeze, rapidly made their way downwards. The keepers were impotent and sought what refuge they could find under projecting crags below, as the lead which had been employed in construction melted into drops and rained down on all sides, so that the unfortunate men were exposed to another and more alarming danger. In fact, one man, while watching the progress of the fire, was drenched with a shower of molten metal, some of which, he declared, had entered his open mouth and had penetrated into his stomach. When rescued he was writhing in fearful agony, but his story was received with incredulity, his comrades believing that the experience had turned his brain and that this was merely one of his delusions. When the man died, a post-mortem examination was made, and the doctors discovered ample corroboration of the man's story in the form of a lump of lead weighing some seven ounces!

No time was lost in erecting another tower on the rock, for now it was more imperative than ever that the reef should be lighted adequately. The third engineer was John Smeaton, who first landed on the rock to make the surveys on April 5, 1756. He was able to stay there for only two and a quarter hours before the rising tide drove him off, but in that brief period he had completed the work necessary to the preparation of his design. Wood had succumbed to the attacks of tempest and of fire in turn. He would use a material which would defy both—Portland stone. He also introduced a slight change in the design for such structures, and one which has been universally copied, producing the graceful form of lighthouse with which everyone is so familiar. Instead of causing the sides to slope upwards in the straight lines of a cone, such as Rudyerd adopted, Smeaton preferred a slightly concave curve, so that the tower was given a waist at about half its height. He also selected the oak-tree as his guide, but one having an extensive spread of branches, wherein will be found a shape in the trunk, so far as the broad lines are concerned, which coincides with the form of Smeaton's lighthouse. He chose a foundation where the rock shelved gradually to its highest point, and dropped vertically into the water upon the opposite side. The face of the rock was roughly trimmed to permit the foundation-stones of the tower to be laid. The base of the building was perfectly solid to the entrance level, and each stone was dovetailed securely into its neighbour.

From the entrance, which was about 15 feet above high-water, a central well, some 5 feet in diameter, containing a staircase, led to the storeroom, nearly 30 feet above high-water. Above this was a second storeroom, a living-room as the third floor, and the bedroom beneath the lantern. The light was placed about 72 feet above high-water, and comprised a candelabra having two rings, one smaller than, and placed within, the other, but raised about a foot above its level, the two being held firmly in position by means of chains suspended from the roof and secured to the floor. The rings were adapted to receive twenty-four lights, each candle weighing about $2\frac{3}{4}$ ounces. Even candle manufacture was in its infancy in those days, and periodically the keepers had to enter the lantern to snuff the wicks. In order to keep the watchers of the lights on the alert, Smeaton installed a clock of the grandfather pattern in the tower,

Photo, Paul, Penzance.

THE EDDYSTONE, THE MOST FAMOUS LIGHTHOUSE OF ENGLAND.

To the right is the stump of Smeaton's historic tower.

Photo, Paul, Penzance.

A THRILLING EXPERIENCE.

Landing upon the Eddystone by the crane rope during a rough sea.

and fitted it with a gong, which struck every half-hour to apprise the men of these duties. This clock is now one of the most interesting relics in the museum at Trinity House.

The first stone of the tower was laid on a Sunday in June, 1757, as the date on the block indicates; and although work had to be pursued fitfully and for only a few hours at a time between the tides, in the early stages, Smeaton seized every opportunity offered by the wind and sea to push the task forward. For four years the men slaved upon the rock, and, although the mechanical handling appliances of those days were primitive, the tower was completed without a single mishap. The solidity of the structure, and its lines, which, as the engineer stated, would offer the minimum of resistance to the Atlantic rollers, but at the same time would insure the utmost stability, aroused widespread admiration, for it was felt that the engineer had triumphed over Nature at last. Many people expressed a desire to see how the tower would weather such a storm as carried away Winstanley's freakish building, especially as, in a roaring sou'-wester, the waves hurled themselves upon the ledge to wreathe and curl upwards to a point far above the dome, blotting the light from sight. The supreme test came in 1762, when the lighthouse was subjected to a battering and pounding far heavier than any that it had previously known. But the tower emerged from this ordeal unscathed, and Smeaton's work was accepted as invulnerable.

The lighthouse had been standing for 120 years, when ominous reports were received by the Trinity Brethren concerning the stability of the tower. The keepers stated that during severe storms the building shook alarmingly. A minute inspection of the structure was made, and it was found that, although the work of Smeaton's masons was above reproach, time and weather had left their mark. The tower was becoming decrepit. The binding cement had decayed, and the air imprisoned and compressed within the interstices by the waves was disintegrating the structure slowly but surely. While there was no occasion to apprehend a sudden collapse, still it was considered advisable to take precautionary measures in time. Unfortunately, it was not feasible to strengthen Smeaton's tower so adequately as to give it a new lease of life, while lighthouse engineering had made rapid strides in certain details since it was completed. Another factor to be considered was the desire for a more elevated light, capable of throwing its rays to a greater distance.

Under these circumstances it was decided to build a new tower on another convenient ledge, forming part of the main reef, about 120 feet distant. Sir James Douglass, the Engineer-in-Chief to Trinity House, completed the designs and personally superintended their execution. The Smeaton lines were taken as a basis, with one important exception. Instead of the curve commencing at the foundations, the latter comprised a perfect cylindrical monolith of masonry 22 feet in height by 44 feet in diameter. From this base the tower springs to a height which brings the focal plane 130 feet above the highest spring-tides. The top of the base is 30 inches above high-water, and the tower's diameter at this point being less than that of its plinth, the set-off forms an excellent landing-stage when the weather permits.

The site selected for the Douglass tower being lower than that chosen by Smeaton, the initial work was more exacting, as the duration of the working period was reduced. The rock, being gneiss, was extremely tough, and the preliminary quarrying operations for the foundation-stones which had to be sunk into the rock were tedious and difficult, especially as the working area was limited. Each stone was dovetailed, not only to its neighbour on either side, but below and above as well. The foundation-stones were dovetailed into the reef, and were secured still further by the aid of two bolts, each 1½ inches in diameter, which were passed through the stone and sunk deeply into the rock below. The exposed position of the reef enabled work to be continued only fitfully during the calmest weather, for often when wind and sea were quiet the rock was inaccessible owing to the swell. Upon the approach of bad weather everything was made fast under the direct supervision of the engineer—a man who took no chances.

From the set-off the tower is solid to a height of 25½ feet, except for two fresh-water tanks sunk in the floor of the entrance-room, which hold 4,700 gallons. At this point the walls are no less than 8½ feet thick, and the heavy teak door is protected by an outer door of gun-metal, weighing a ton, both of which are closed during rough weather.

The tower has eight floors, exclusive of the entrance; there are two oilrooms, one above the other, holding 4,300 gallons of oil, above which is a coal and store room, followed by a second storeroom. Outside the tower at this level is a crane, by which supplies are hoisted, and which also facilitates the landing and embarkation of the keepers, who are swung through the air in a stirrup attached to the crane rope. Then in turn come the living-room, the "low-light" room, bedroom, service-room, and finally the lantern. For the erection of the tower, 2,171 blocks of granite, which were previously fitted temporarily in their respective positions on shore, and none of which weighed less than 2 tons, were used. When the work was commenced, the engineer estimated that the task would occupy five years, but on May 18, 1882, the lamp was lighted by the Duke of Edinburgh, the Master of Trinity House at the time, the enterprise having occupied only four years. Some idea may thus be obtained of the energy with which the labour was pressed forward, once the most trying sections were overcome.

Whereas the former lights on this rock had been of the fixed type, a distinctive double flash was now introduced. The optical apparatus is of the biform dioptric type, emitting a beam of some 300,000 candle-power intensity, which is visible for seventeen miles. In addition to this measure of warning, two powerful Argand burners, with reflectors, were set up in the low-light room for the purpose of throwing a fixed ray from a point 40 feet below the main flashing beam, to mark a dangerous reef lying 3½ miles to the north-west, known as Hand Deeps.

When the new tower was completed and brought into service, the Smeaton building was demolished. This task was carried out with extreme care, inasmuch as the citizens of Plymouth had requested that the historic Eddystone structure might be re-erected on Plymouth Hoe, on the spot occupied by the existing Trinity House landmark. The authorities agreed to this proposal, and the ownership of the Smeaton tower was forthwith transferred to the people of Plymouth. But demolition was carried out only to the level of Smeaton's lower storeroom. The staircase, well and entrance were filled up with masonry, the top was bevelled off, and in the centre of the stump an iron pole was planted. While the Plymouth Hoe relic is but one half of the tower, its re-erection was completed faithfully, and, moreover, carries the original candelabra which the famous engineer devised.

Not only is the Douglass tower a beautiful example of lighthouse engineering, but it was relatively cheap. The engineer, when he prepared the designs, estimated that an outlay of £78,000, or $390,000, would be incurred. As a matter of fact, the building cost only £59,255, or $296,275, and a saving of £18,000, or $90,000, in a work of this magnitude is no mean achievement. All things considered, the Eddystone is one of the cheapest sea-rock lights which has ever been consummated.

CHAPTER VI

SOME FAMOUS LIGHTS OF ENGLAND

The captain of the lordly liner, as he swings down Channel or approaches the English coast from the broad Atlantic, maintains a vigilant watch until the light or the slender proportions of the lonely outpost rising apparently from the ocean's depths off the south-west corner of the Scilly Islands, become visible. This is the Bishop Rock, the western sentinel of the English Channel, mounting guard over as wicked a stretch of sea as may be found anywhere between the two Poles, where the maritime traffic is densest and where wrecks, unfortunately, are only too frequent; for the toll levied by the sea off the Cornish coast is fearful.

Among these islands was planted one of the first beacons erected off the British coasts. At the outset it was merely a wood bonfire, then a brazier, and finally a lighthouse, which crowned St. Agnes's height, to guide the mariner on his way. But to-day the St. Agnes light is no more than a memory. Two or three years ago the keepers quenched the light in the misty grey of the dawn for the last time. The vigil which had been maintained over shipping uninterruptedly through some 230 years was ended. On a neighbouring point a superior modern light had been planted which took up the sacred duty. Although established in 1680, the St. Agnes was not the oldest light in England. This distinction belongs to the North Foreland light on the East Kentish coast, which was set going as far back as 1636. This warning was shed from a tower of limber, lath, and plaster, built by Sir John Meldrum, but it fell a victim to fire forty-seven years later. The light was reconstructed promptly, and to-day throws a red and white gleam of 35,000 candle-power, which may be picked up twenty miles away.

The south-western extremity of England, however, is far more to be dreaded than the south-eastern. Here Nature mixed land and water in an inextricable maze during her moulding process. Deep, tortuous, wide channels separate rugged granite islets, while long, ugly ridges creep stealthily out to sea beneath the pall of water, ready to trap the unsuspecting vessel which ventures too closely. If one were to take a map of this part of the country, were to dig one leg of a compass into the Lizard Head, stretching the other so as to reach the Eddystone light, and then were to describe a circle, the enclosed space would contain more famous sea-rock lights than a similar area on any other part of the globe. Within its circumference there would be the Eddystone, Bishop Rock, Wolf, and Longships, each of which lifts its cupola above a wave-swept ledge of rocks.

The need for an adequate indication of the Scillies was felt long before the Eddystone gained its ill fame. These scattered masses of granite, numbering about 140 in all, break up the expanse of the Atlantic about twenty miles south-west of the Cornish mainland. Now, the maritime traffic flowing in and out of the English Channel is divided into two broad classes—the coastal and the oversea trade respectively. The former is able to creep through the dangerous channel separating the Scillies from the mainland, but the latter has to make a détour to the south. One fringe of the broken cluster is as dangerous as the other, so that both streams of trade demand protection.

On the south side the knots dot the sea in all directions. They are mere black specks, many only revealing themselves at lowest tides ; others do not betray their existence even then. The outermost ledge is the Bishop Rock, where disasters have been fearful and numerous. One of the most terrible catastrophes on record happened here, when three vessels of Sir Cloudesley Shovel's fleet went to pieces in the year 1707, and dragged 2,000 men down with them, including the Admiral himself. In more recent times, some two or three years ago, the Atlantic transport liner *Minnehaha* dragged her lumbering body over the selfsame attenu-

Photo, Paul, Penzance.

THE "BISHOP," THE WESTERN OUTPOST OF ENGLAND.

This tower marks a treacherous reef, rising from the depths of the Atlantic off the Scilly Islands. Its slim proportions are familiar to Transatlantic passengers.

Photo, Paul, Penzance.

THE WOLF ROCK LIGHTHOUSE.

One of the famous lights of England. Owing to the rocks being exposed to the full fury of the Atlantic, its erection was attended with prodigious difficulty.

ated rampart, and was badly damaged before she could be rescued. As may be supposed, in days gone by the awful character of the coast brought prosperity to the inhabitants of Cornwall, who reaped rich harvests from the inhuman practice of wrecking, in which horrible work the Scilly Islanders were easily pre-eminent and more successful, since they held the outer lines upon which the majority of ships came to grief.

In the forties of last century it was decided that this graveyard should be marked, but there was one great difficulty. This was the exposure of the low-lying rock to some 4,000 miles of open Atlantic, where the rollers rise and fall with a force that turns the waters for miles around into a seething maelstrom of foam and surf. The aspect presented at this spot during a stiff south-westerly or westerly gale is terrifying in the extreme, and it is not surprising that approaching vessels stand so far off that the tower is often barely discernible against the background of cloud and banks of mist caused by the spray hurled into the air from the breakers smashing on the rocks.

When it was proposed to build a lighthouse upon a crag in the heart of this vortex, many people who knew the neighbourhood shook their heads doubtfully. The ledge was so small, the force of the elements so powerful, that it appeared to be tempting Fate unduly to attempt the erection of a slim stalk of stonework thereon. Some records of the wind pressure exerted during the heaviest tempests were taken, and they showed that the pressure of the wind at times exceeded 7,000 pounds per square foot. It was decided to provide a structure which should offer the minimum of resistance to the waves. This assumed the form of the iron screw-pile tower so common in American waters. The legs were cast-iron tubes sunk into the solid granite, braced and stayed by means of wrought-iron rods. The engineers maintained that the waves would be able to roll unrestrainedly among the piles, instead of being obstructed, so that the skeleton building would escape the heavy buffetings which solid masonry would experience.

But engineering science proved woefully frail when pitted against the unharnessed forces of Nature. A heavy gale sprang up one night ; the waves rose and fell upon the stilts, broke them up like reeds, and carried away the whole of the superstructure. The following low-tide revealed only a few short lengths of broken and bent tubes, around which the waves bubbled and hissed as if in triumph at their victory. Thus ended the first attempt to provide the Bishop Rock with a lighthouse.

The engineer, though defeated, was not dismayed. As a skeleton structure was impotent, he would erect a massive masonry tower which not all the force of the waves could avail to demolish. Although the reef is about 150 feet in length by 52 feet in width, the engineer, James Walker, was not afforded much space upon which to place his creation. He reconnoitred the ridge, and finally chose a small lump just sufficiently large upon which to effect a foothold. The Smeaton type of tower was his model, and the surface of the rock was trimmed to receive the first blocks. This was the greatest difficulty. Unless the sea were as smooth as a millpond, he was helpless, as the lowest blocks had to be laid a foot beneath low-water mark. A heavy cofferdam was erected around the site, and the water within was pumped out, so that the masons might be able to toil upon a dry rock-face.

The exposed, isolated character of the spot rendered the housing of the workmen a problem in itself. They could not be accommodated on the site ; a temporary dwelling on piles for their accommodation could not be established, as it would come down with the first gale, and housing on a tender was equally impracticable. There was a small uninhabited islet within convenient distance of the reef, and on this the living-quarters and workshops were erected, the men being transported to and fro whenever the conditions were suitable. Traces of this bygone industrial activity still remain on the island, but the sea-fowl have once more claimed it exclusively as their home. The working spells were brief, as well as being somewhat few and far between, while the base was being prepared. The granite was brought to the island depot, fashioned into shape, and then sent to the Bishop for erection. Granite was used exclusively, and in 1878, after seven years' arduous labour, the tower, 120 feet in height, capped by a powerful light, was completed : the dreaded Bishop Rock was conquered at last.

When it was first commissioned, four men were deputed to watch this light, three being on the rock, and the fourth man on leave at St. Mary's. The duty was for three months continuous, one man being relieved every month if possible ; but, as a matter of fact, the spell on the rock often was increased, owing to the weather rendering it impossible to exchange the men. The character of their duty, under the terrible assaults of the sea, played havoc with the constitutions and nerves of the lighthouse-keepers. They became taciturn, and inevitably fell victims to neurasthenia, owing to their long periods of isolation. Accordingly the authorities gradually relaxed the spell of duty, until now it comprises a month on the rock, followed by a fortnight ashore, while six men, instead of four, are appointed to the station. The Bishop light demands watchers of iron constitution and prolonged experience of the rigours of imprisonment upon a lonely rock. The men appear to suffer most from the fear that one day the seas will regain the upper hand and carry the slender-looking shaft of masonry away. When the Atlantic is roused to fury, the din created by the waves smashing against the tower and reef is so deafening that the keepers can only converse by signs.

The attacks which this tower has to withstand are fearful. When the equinoxes are raging, it is no uncommon circumstance for the waves to roll up the side of the tower and hurl themselves clean over the lantern. The enormous force of the water was brought home very startlingly to the attendants of the light one night, when a more than usually wicked breaker slid up the curved round face and wrenched the fog-bell, weighing 550 pounds, from its fastenings on the lantern gallery. The ponderous piece of metal was dashed on to the reef and smashed to fragments. A small piece was recovered after the gale, and is now preserved in the Trinity House museum as an interesting memento of the night when the Atlantic almost got the upper hand. The nerves of the men are tried severely, also, by memories of the terrible marine disasters which have happened on or near the ridge, such as that of the German packet *Schiller*, which went down in 1875 with the loss of 331 lives.

It is not surprising that the ceaseless attacks of the waves should have left their traces at last. The light had been burning for about twenty years, when tremors and quakings, similar to those observed in connection with Smeaton's Eddystone tower, were reported to the authorities. Sir James Douglass visited the rock, and made a minute inspection. It was apparent that the lighthouse demanded extensive overhauling and strengthening if it were to be preserved. In fact, this was the only feasible course of action, as there was not another suitable spot whereon a new structure could be raised. The Eddystone had been completed, and as the same tackle was available, the protective work was undertaken at once. In conjunction with this enterprise, the engineer also advocated an increase in the height of the tower.

His plans met with approval, and an ingenious means of strengthening the existing building was evolved. Virtually it comprised the erection of a new tower around the old shaft, and connected to the latter, so as to form one homogeneous structure. In order to strengthen the foundations, massive blocks of masonry were sunk into the rock, cemented, and held in position by heavy bolts. From the masons' point of view, the task of overhauling was more exciting and dangerous than that which had attended the erection of the original tower; for the men had to toil on narrow, swinging platforms, cutting notches in the face of every stone in the existing structure to receive dovetails on the blocks of the new outer shell. Thus the latter were dovetailed to adjacent blocks on five out of their six faces. A massive chain was slung round the upper part of the tower, from which life-lines hung down to the men working below. A man was stationed as a lookout. When he saw a breaker approaching he gave a signal ; each man clutched his life-rope tenaciously and retained his foothold as best he could on his perilous perch while the water swept over him. Often the men were submerged by a rushing wave, and when the water subsided shook themselves like dogs emerging from the water. But the provision of the life-ropes prevented serious injury and loss of life, although the masons at times were considerably knocked about.

The tower has been given an enormous, massive, cylindrical base, while the shaft is solid to the entrance level, except for the usual water-tanks. The attachment of the outer shell reinforced it remarkably, the walls at the entrance being increased to a thickness of 8 feet. The addition of the four extra floors elevated the light by a further 40 feet, the focal plane now being 163 feet above high-water. The light, of 622,500 candle-power, visible for eighteen miles, is a white group-flash, there being two flashes, each of four seconds' duration, with an intervening eclipse of five seconds, while the groups are separated by intervals of forty-seven seconds.

Off the northern shores of the Scillies, standing in the strait which provides a short-cut around the toe of England, is another magnificent tower. This is the Wolf Rock lighthouse, marking the reef of that name, which lies eight miles off Land's End in the fairway of the coastal traffic. The cluster of rocks from which it rises is just as dangerous as that to the south, and is exposed likewise to the full fury of the south-westerly gales coming in from the Atlantic. It was one of the most attractive spots to the old Cornish wreckers, for ships which lost their way during the fogs which hang about this coast invariably blundered into the reef, to be smashed to pieces within a very short time.

This spot was not so greatly feared by the seafarer when heavy gales prevailed. There was a hollow rock on the ridge, into which the waves were driven. In so doing they compressed the air within the space, which, as it escaped, produced a long, distinctive wail, recalling the cry of the wolf. It was this natural phenomenon which gave the rock its name. The harder the wind blew, and the higher the waves rose, the louder was the reverberating bellow, and, as it could be heard distinctly above the music of the storm, the navigator was able to steer clear of the formidable obstruction. On the other hand, during periods of heavy fog, when the waves were usually quiet, there was scarcely any perceptible sound.

The Wolf Rock would be growling to this day had it not been for the inhuman action of the Cornish plunderers. They detested the weird noise as cordially as the mariner blessed it. It robbed them of so many rich hauls that at last they decided to silence the rock for ever. They filled the cavity with large boulders, which were carried out in boats from the mainland and dumped overboard. Then the Cornishmen met with a spell of enhanced prosperity from the increased number of wrecks which occurred.

When the exigencies of commerce demanded that the reef should be guarded, a most fantastic device was prepared. An attempt was made to restore artificially the natural siren. A fabric wrought in copper in the form of a huge wolf with distended jaws was contrived, the designers averring that the air would rush in and produce a distinctive whistle. This grotesque danger-signal never reached its destination. It would have been absolutely useless even had it been placed over the rock, as the first lively sea would have carried it away, while the noise produced, if any, would have been inaudible more than a few feet away.

The Trinity Brethren at last took the matter up, but their investigations caused them to doubt the possibility of building a lighthouse on such a forbidding spot. They did the next best thing. They drove a thick oak joist into the rock, and attached a coloured sphere to its upper extremity. This constituted a valuable landmark by day, but was useless at night. But its life was brief. The first storm which swept

Photo, Paul, Penzance.

THE LONGSHIPS LIGHT.

In the background is the forbidding iron-bound Cornish coast, where wrecks unfortunately are frequent.

Photo, Paul, Penzance.

THE GODREVY LIGHT, SCILLY ISLANDS.

It marks a forbidding clump of rocks, landing on which is always exciting.

the reef after the erection of the beacon tore it up by the roots. It was replaced by a heavy mast of wrought-iron, which suffered a similar fate, as did also a third iron pole 9 inches in diameter. At last a low conical stump was built upon the ridge, with the staff and sphere projecting from its centre. This defied wind and wave successfully for many years. Its permanency impressed the builders of the Bishop Rock light, who came to the conclusion that, as the small conical tower held hard and fast, a masonry tower could be given just as firm a hold.

When the engineer approached the reef to make his surveys, he found the water boiling and bubbling madly, and it was some time before he could get a foothold. He completed his examination, and then found, to his dismay, that the boat could not approach to take him off. He could not stay where he was, as the tide, which was rising, would engulf the reef within a short time, so he resorted to a bold expedient. He had taken the precaution to bring a life-line with him, so that he was in touch with the boat. He looped this round his waist securely, and then, telling the men to pull as hard as they could, he plunged into the water. In this manner he was dragged through the furious surf and pulled into the boat, thoroughly drenched, but otherwise none the worse for his adventure.

The work was begun in 1862, when the masons were despatched to the rock to prepare the face for the reception of the bottom masonry blocks. The tedious and exceptionally dangerous character of the work was emphasized very forcibly upon those engaged in the task. It was seldom that the water was sufficiently placid to enable a landing to be made. Then, as the working spell was very brief, being restricted to low-tide, the men could pause only for a few minutes at a time, and even during these were menaced by the breakers. During the first working season only eighty-three hours of labour were possible—a fact which conveys a graphic idea of the exposed character of the site, its difficulty of access, and the short time available for work between the tides.

While excavations were under way, the preparation of a landing-stage was taken in hand. As only small blocks of stone could be used, naturally it occupied a considerable time. It was, however, essential, in order to permit the erection of a derrick by which the heavy blocks for the tower could be lifted from the construction boat to the rock. On the rock-face itself the masons toiled strenuously, chipping, scraping, and paring away all the faulty pieces of gneiss, so that a firm, solid foundation was secured, into which the bottom course of stones was dovetailed and anchored.

Owing to the frequency with which the rock was swept by the seas, special precautions had to be adopted to insure the safety of the workmen. Iron dogs were driven into the rock at frequent points, to which ropes were fastened and allowed to trail across the rock, each mason being urged to keep one of these life-lines always within arm's length. As an additional precaution he was compelled to wear a lifebelt, which, although it hampered free movement somewhat, yet gave the wearer, if he lost his foothold or were thrown into the water, a chance of keeping afloat until the lifeboat standing by was able to reach him. A Cornish fisherman, who was familiar with the seas on this part of the coast, and who could judge a breaking wave from a distance, acted as a lookout. When he saw a comber about to creep over the rock, he gave a signal, when the workmen clutched their life-lines, and, with feet firmly planted and the ropes drawn taut, or throwing themselves prostrate, with heads pointed to the advancing wave, allowed the breaker to roll over them and expend its violence harmlessly. Time after time the masons were buried beneath huge tumbling hills of water. Work under such conditions was decidedly irksome, and progress was very appreciably retarded, but the safety of the workmen was, of course, the pre-eminent consideration. Curiously enough, these men who face the perils, privations, and exciting incessant dangers, incidental to lighthouse building, are extremely superstitious. If an undertaking such as the Wolf were attended by a disaster and loss of life in its initial stages, the completion of the task might be seriously jeopardized. The rock would be regarded as a "hoo-doo," and would be shunned like a fever-stricken city. Therefore the engineer will go to any lengths to secure, so far as is humanly possible, the preservation of the lives and limbs of those in his employ. This is the chief reason why the erection of these wonderful towers has been attended by so few accidents or fatalities, while the men fitted for the task are so few that the engineer cannot afford to disturb their peace of mind.

The Wolf tower follows the generally accepted lines, and is solid at the base. It is wrought throughout of granite, the stones being joggled together. One ingenious measure was adopted in connection with the lower courses in order to prevent the action of the waves from breaking up the cement in the exposed joints and setting up disintegration. The upper surface of each stone is given a wide rabbet, and the stone above fits into the recess so that the horizontal joint between the two is covered by the outer fillet, thereby protecting it completely. This practice was followed throughout all the lower courses to a height of 39 feet, and the security thus obtained is reflected by the strength of the tower to-day after half a century's wear.

Work proceeded so slowly in the early stages, owing to the abnormal conditions, that by the end of 1864 only thirty-seven stones in the second course of masonry were laid. In the meantime, however, the landing-stage had been practically completed, and the erection of the crane enabled the blocks for the tower to be transferred to the rock with greater ease and rapidity. The tower, 135 feet in height, was completed on July 19, 1869, while the light was brought into service early in the following year. Eight years were expended upon the enterprise, and during this period 296 landings were effected upon the rock and 1,814 hours of labour were consummated. This is equal to about 101 working days of ten hours each, or, on the average, less than one hour every day of the years occupied in the undertaking. The lantern throws a powerful white light, which in clear weather may be seen from twenty to twenty-five miles away. The cost of the enterprise was £62,726, or $313,630—nearly twice that of the first Bishop Rock light.

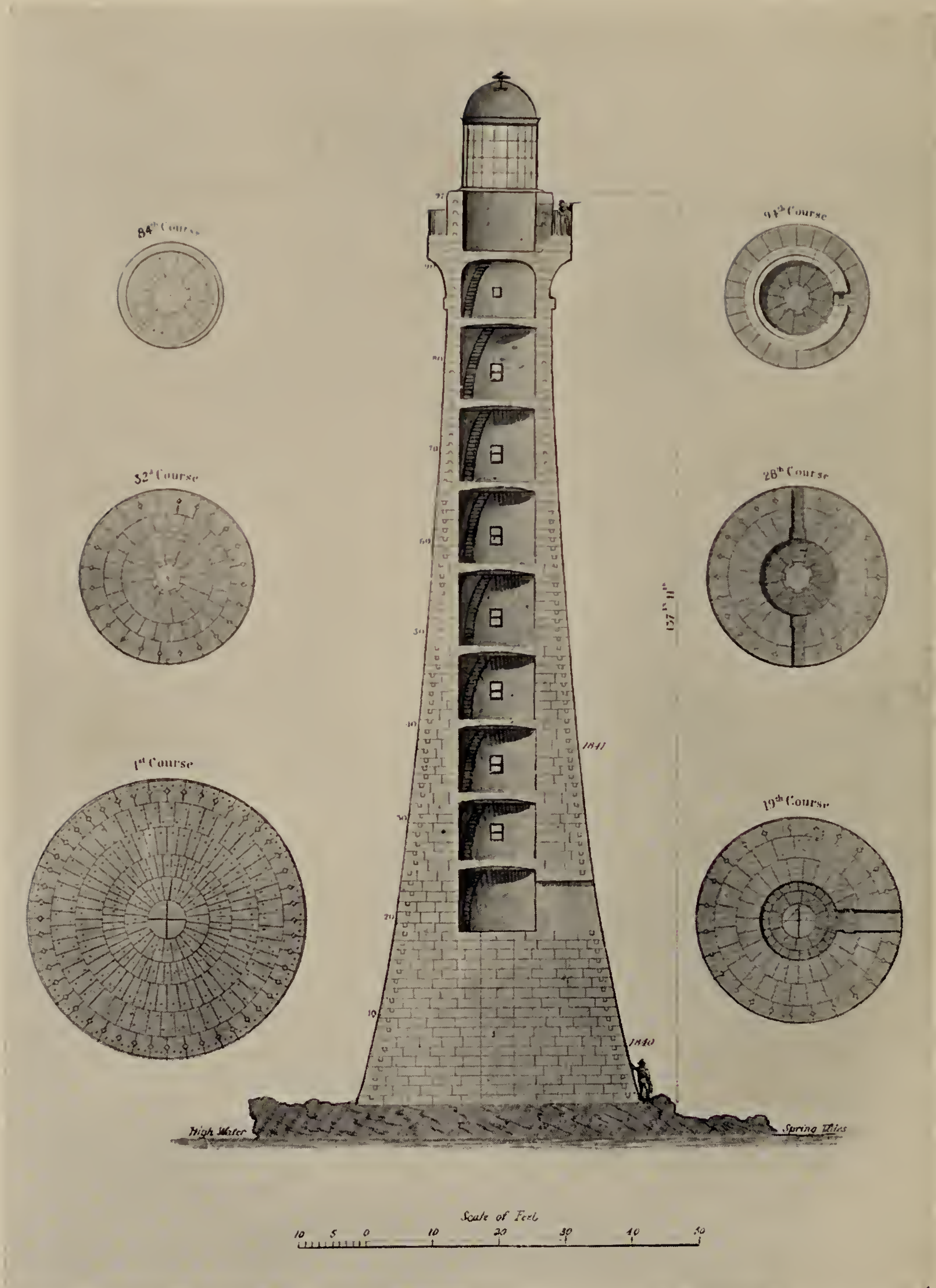
Another gaunt structure rears itself from a reef a few miles to the north-west of the Wolf, and a short distance off the Land's End. This is the Longships light. The name itself suggests a light-vessel, and a stranger is surprised to learn that it is an imposing building, worthy of comparison with the two other structures already described which guard the Scillies. Although it is within a short distance of the mainland, its exposed situation rendered its construction as exasperatingly difficult as that of both the Bishop and Wolf lights. A few miles farther north another powerful light indicates the "Kingdom of Heaven," as the black hump of Lundy Island, rising out of the Bristol Channel, is colloquially called, from the name of its clerical owner.

On the opposite side and due north of this bight, the Pembrokeshire coast breaks off abruptly at St. David's Head, only to reappear out at sea in some twenty little rugged islets known as The Smalls. They occur some twenty-one miles off the mainland, and for years they played havoc with the shipping plying between North of England ports and the Bristol Channel. These rocks—for they are little else—were the private property of a Liverpool gentleman, who became so distracted by the frequency of disaster that, in 1773, he decided to crown them with a beacon. He selected a musical instrument manufacturer named Whiteside as his engineer, and this amateur mechanic, after an inspection, decided to place the warning light on a tiny crag which projected about 5 feet above high-water. It is somewhat strange that the adequate safeguarding of two devastating parts of the south-western coast of England should have been placed in the hands of men who were not professional engineers. Rudyerd, the silk-mercer, was responsible for the second Eddystone, and here was an instrument-maker taking over one of the most difficult enterprises it was possible to find. Yet both these amateur engineers inscribed their names ineffaceably upon two of the most evil spots around the coasts of the British Islands.

By courtesy of Messrs. D. and C. Stevenson.

THE CHICKEN ROCK LIGHTHOUSE, OFF THE ISLE OF MAN.

It marks a dangerous reef. The revolving light of 143,000 candle-power is visible for sixteen miles. Although the lantern is 143 feet above the water, the waves frequently engulf it.



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HOW THE SKERRYVORE IS BUILT.

In the centre, a vertical section. At sides, transverse sections at different masonry courses, showing method of laying the stones.

Rudyerd gave us the true conical design, which has never been superseded for strength and stability ; while Whiteside evolved a skeleton tower which braved the most tempestuous seas for some eighty years. In the first instance the latter carried out his work in iron, thinking that metal would prove irresistible, but within a short time he replaced it with heavy legs of oak. The frail-looking structure was submitted to storms of almost seismic violence, but it withstood them all for over half a century, when a peculiarly vicious wave, as it rolled between the supports, suddenly flew upwards, driving the floor of the keepers' quarters into the roof. It was an exceptional accident, which no engineer could have foreseen. When the Trinity House Brethren took over the light, their chief engineer, Mr. James Walker, looked upon the erection as such a fine piece of work that the damage was repaired, and the Whiteside light gleamed for a further twenty years before it gave place to the present graceful stone building.

It was a grim episode at this light which brought about the practice of appointing three men at least to a sea light-station. When first completed, The Smalls was provided with only two keepers, and on one occasion one of the two died. His companion refrained from committing the body to the sea, lest he might be suspected of foul-play, so he constructed a rough shell, in which he placed the body of his dead chum, and stood the grisly burden on end beside his flag of distress on the gallery outside the lantern. As the spell of duty in those days was four months, it was some time before the relief came out. Then they discovered a shattered human wreck tending the lights, who had never neglected his duty under the onerous and weird conditions, but who nevertheless had become broken down and aged under the terrible ordeal. After this experience three men instead of two were placed on duty at all such exposed and inaccessible lights. It may be recalled that Alphonse Daudet tells a similar creepy story which was related to him by a light-keeper on the rugged Corsican coast, and which he narrates in the "Phares des Sanguinaires." A similar experience is also associated with Rudyerd's Eddystone light.

Off the North Welsh coast there are the famous lights of the South Stack and the Skerries, the latter rising out of the water on a dangerous cluster of rocks off Carmel Head. The Isle of Man also possesses a magnificent specimen of lighthouse engineering in the Chicken Rock light, the work of the brothers Stevenson, which, although in the Irish Sea, comes within the jurisdiction of the Commissioners of Northern Lights. This tower stands on a reef which is submerged by 6 feet of water even at high neap-tides. When a gale is raging and the spring-tides are at their highest, the waves frequently engulf the lantern, although it is perched 143 feet above the water. The light is of 143,000 candle-power, of the revolving type, and visible for sixteen miles in clear weather.

Entering the English Channel from the Scillies, the voyager observes the powerful Lizard light gleaming like two brilliant white stars from a prominent elevated point on the cliff. Formerly three lights were shown, but two were found to meet the necessities of the situation adequately. The steamship lane lies across the chord of the arc formed by the coastline between the Lizard and Start Point, leaving the Eddystone to the north. The next important light is the Needles, at the entrance to the Solent. A few miles farther on the brilliant spoke-light flashes of St. Catherine's, described in another chapter, compel attention. No other light after this is seen until Beachy Head is approached. Another dreary stretch brings the vessel abeam the nose of Kentish coast known as Dungeness, a particularly notorious danger spot. Here there is a continual struggle between the engineers and the sea. While the waves gnaw into the coastline at other neighbouring places, here they surrender their capture, so that the headland is persistently creeping farther and farther out to sea. It is lighted, and has been guarded for years, but the tower is left at a constantly increasing distance from the water's edge. The light has been moved once or twice, so as to fulfil its purpose to the best advantage, but the engineer will be kept on the alert until the currents change their courses and refrain from piling up further drift at this point. This light, coming as it does at the entrance to the bottle-neck of the English Channel, is of prime importance to navigation, because vessels, after they have rounded the South Foreland, make a bee-line for this headland.

Since the eastern coast of England is flanked by sand-banks and shoals, the lighthouse is not in powerful evidence, the aids to navigation consisting chiefly of light-vessels, which are distributed liberally so as to patrol completely a treacherous stretch of shoals. Northwards the sandy, low-lying wastes give way to towering cliffs, amongst which Flamborough Head and its light are conspicuous. At the far northern limit of the operations of Trinity House comes the Longstones, mounting guard over the terrible Farne Islands and their rocky outposts. Who has not heard of the heroism of Grace Darling, the light-keeper's daughter, and the thrilling rescue, in the teeth of a hurricane, of the exhausted survivors of the *Forfarshire?*

Complaints have been made often regarding the paucity of powerful lights around the coast of England, but the criticism scarcely is deserved. All the prominent and most dangerous spots are lighted adequately, and, as may be recognized, the provision of these lights has proved an exacting and costly enterprise. What England may lack in numbers in this particular field of engineering is compensated for by the daring nature of the works completed, which are regarded throughout the world as marvellous achievements.

CHAPTER VII

THE BELL ROCK AND SKERRYVORE LIGHTS

At first sight it seems somewhat remarkable—some might feel disposed to challenge the assertion—that so small a country as Scotland should stand pre-eminent among the nations of the world as being that possessed of the greatest number of imposing sea-rock lights. But such is the case. Moreover, North Britain offers some of the finest and most impressive specimens of the lighthouse builder's resource and skill to be found in any part of the globe.

When the responsibility for lighting the Scottish coasts was handed over to the Commissioners for Northern Lighthouses, one of their first tasks was the adequate illumination of the wave-swept Inchcape or Bell Rock, which lies some twelve miles off the Scottish mainland in the busy portal of the Firth of Tay. At that time this sinister menace to navigation was not marked in any way whatever, and apparently had remained in this unprotected condition ever since the notorious pirate, Ralph the Rover, cut away the buoy-bell which had been placed upon it by the Abbot of Aberbrothock, as narrated in Southey's famous ballad.

The rock, or rather reef—inasmuch as it measures 2,000 feet from end to end, and lies athwart the fairway—is submerged completely to a depth of 16 feet at high spring-tides, while at lowest water only some 4 feet of its crest are laid bare here and there. This is not all. The ledge is the summit of a dangerous, slowly-rising submarine hillock, where, for a distance of about 100 yards on either side, the lead sounds only 3 fathoms. Wrecks were so numerous and terrible at this spot that the protection of the seafaring community became imperative, and the newly-appointed guardians of the Scottish coast lost no time in justifying the trust reposed in them, but erected a first-class light. The Eddystone had been conquered, and, although the conditions were dissimilar and the enterprise bolder, no tangible reason against its imitation was advanced.

The engineer John Rennie was entrusted with the work, while Robert Stevenson was appointed as his assistant. The rock was surveyed, and a tower similar in its broad lines to that evolved by Smeaton for the Eddystone was elaborated, and the authority for its construction given in the year 1806.

Work upon the rock in the earliest stages was confined to the calmest days of the summer season, when the tides were lowest, the water was smoothest, and the wind in its calmest mood. Under such conditions the men were able to stay on the site for about five hours. The engineer hoped against hope that the elements would be kind to him, and that he would be able to complete the preliminary work upon the rock in one season.

The constructional plans were prepared carefully, so that advantage might be taken of every promising opportunity. One distinct drawback was the necessity to establish a depot some distance from the erecting site. Those were the days before steam navigation, and the capricious sailing craft offered the only means of maintaining communication between rock and shore, and for the conveyance of men and material to and fro. The year 1807 was devoted to the construction of vessels for the work, and to the establishment of workshops with machinery and other facilities at Arbroath, the nearest suitable point on the mainland to the rock. A temporary beacon was placed on the reef, while adjacent to the site selected for the tower a smith's forge was made fast, so as to withstand the dragging motion of the waves when the rock was submerged. The men were housed on the *Smeaton*, which during the spells of work on the rock rode at anchor a short distance away in deep water. The arrangements stipulated that three boats, which were employed to bring the men from the vessel to the rock, should always be moored at the landing-place, so that, in the event of the weather changing for the worse, the masons, forced to cease work suddenly, might regain the *Smeaton* safely in one trip, the three boats being able to convey thirty men, which constituted the average complement on the rock.

While the preparations were proceeding ashore, a little body of workers toiled, whenever possible, at clearing the face of the rock and carrying out the requisite excavation work. While this was in progress a disaster was averted very narrowly, which would have jeopardized the completion of the tower, owing to the superstitious natures of the men engaged. On September 2, 1807, the *Smeaton*, as usual, had brought out some thirty masons, had landed them safely on the rock, and was riding at anchor.

Suddenly the wind freshened, and the engineer on the rock grew apprehensive of the *Smeaton* dragging her cables. A party at once put off from the rock in one of the three boats and regained the ship, but were scarcely aboard when the cables parted, and the vessel, caught by the wind and tide, made off. Before the men regained control of her she had drifted some three miles to leeward. Meantime on the rock the situation was growing serious. Only Mr. Stevenson, who was supervising operations on the spot, and the landing-master were aware of its gravity. The masons were so busy hewing, boring and chiselling, that they had not noticed the *Smeaton's* drift. But the engineer, observing the flowing of the tide, realized that the rock must be submerged before the ship could be brought up again. He racked his brains to find some means of getting his gang of men off safely in the nick of time, but it was a searching problem to solve with only two boats, which, at the utmost, could carry twenty-four persons. To make matters worse, one of those mists which are so peculiar to the Scottish coast began to settle down, blotting everything from sight.

The water rose higher. The men toiling on the lowest levels receded higher and higher before the advancing tide, though still too deeply occupied in their labours to bestow a thought upon the *Smeaton*. At last the smith's forge was quenched, and this was the general signal to the men to prepare to leave the rock. Tools were collected, and the party strode towards the landing-stage to enter the boats. Conceive their consternation when they saw that one boat was missing! When they glanced over the water the *Smeaton* was not riding in her usual place—in fact, was nowhere to be seen! One and all gathered around the engineer to learn the reason for this remarkable breach in the arrangements for their safety, and yet all were too dumbfounded to question or protest. As for the luckless engineer, he was at his wits' end and could not offer a word of explanation to the inquiring looks that besieged him. One and all, as the water lapped their feet, realized the hopelessness of the position. Suddenly, when they were beginning to despair, one of the men described the phantom form of a vessel making for the rock. "A boat!" he shouted in exultation. Sure enough the shadow matured into the familiar form of the Tay pilot-boat, the master of which, observing the workmen on the rock, the rising tide, and the absence of the *Smeaton*, had realized that something must have gone wrong, and approached the rock to make inquiries. He came up at the critical moment. The men were drenched, and, their feelings having been strung to a high pitch with anxiety, they nearly collapsed at the arrival of this unexpected assistance. The pilot-boat, after taking off the men, awaited the return of the *Smeaton*, which took them on board about midnight.

This narrow escape so terrified the men that on the following day the engineer found only eight of his staff of thirty-two, who were willing to venture upon the rock again. When this gang returned in the evening, their safety appeared to restore courage to their companions, so that next day all expressed their readiness to resume their tasks.

The fitful character of the work did not leave its mark so distinctly as might be supposed. Whenever there was a chance, the men worked with an amazing will and zeal; and although the first stone of the tower was not laid until July 10, 1808, three courses of masonry were completed when the undertaking was suspended at the end of November for the winter. The succeeding season's toil saw the addition of about 27 feet more of the tower, which was finally completed by the close of 1810. The building was 120 feet in height, and the light was shown for the first time on February 1, 1811.

In view of the difficulties which had to be surmounted, this "ruddy gem of changeful light," as it is described by Sir Walter Scott, was not particularly costly. By the time it was brought into commission, £61,330, or $306,650, had been expended. In 1902, after nearly a century's service, the tower was provided with a new light-room, so as to bring it into conformity with modern practice.

While the Bell Rock tower stands as a monument to the engineering ability of Robert Stevenson, the Skerryvore, on the western coast, is a striking tribute to the genius of his son, Alan. For forty years or more previous to 1844 one ship at least had been caught and shattered every year on this tumbled mass of gneiss. From the navigator's point of view, the danger of this spot lay chiefly in the fact that it was so widely scattered. The ridge runs like a broken backbone for a distance of some eight miles in a west-south-westerly direction, and it is flanked on each side by isolated rocks which jut from a badly-broken sea-bed. The whole mass lies some distance out to sea, being ten miles south-west of Tyree and twenty-four miles west of Iona. In rough weather the whole of the rocks are covered, and the waves, beating heavily on the mass, convert the scene into one of indescribable tumult.

The Commissioners of Northern Lights acknowledged the urgent need of a light upon this ridge, but it was realized that its erection would represent the most daring feat of lighthouse engineering that had been attempted up to this time. There was only one point where a tower could be placed, and this was so exposed that the safe handling of the men and materials constituted a grave responsibility. The rock has to withstand the full impetus of the Atlantic waves, gathered in their 3,000 miles' roll, and investigations revealed the fact that they bear down upon the Skerryvore with a force equal to some 3 tons per square foot. It was apparent that any masonry tower must be of prodigious strength to resist such a battering, while at the same time a lofty stack was imperative, because the light not only would have to mount guard over the rock upon which it stood, but also over a vast stretch of dangerous water on either side.

After he had completed the Bell Rock light, Robert Stevenson attacked the problem of the Skerryvore. In order to realize the magnitude of the undertaking, some of the Commissioners accompanied the engineer, but the experience of pulling out into the open Atlantic on a day when it was slightly ruffled somewhat shook their determination to investigate the reef from close quarters. Sir Walter Scott was a member of the party, and he has described the journey very graphically. Before they had gone far the Commissioners on board expressed their willingness to leave the matter entirely in the hands of their engineer. With grim Scottish humour, however, Robert Stevenson insisted that the rock should be gained, so that the Commissioners might be able to grasp the problem at first hand.

But after all nothing was done. The difficulties surrounding the work were only too apparent to the officials. They agreed that the expense must be prodigious and that the risks to the workmen would be grave.

In 1834 a second expedition was despatched to the reef under Alan Stevenson, who had accompanied his father on the previous occasion, and who now occupied the engineering chair. He surveyed the reef thoroughly, traversing the dangerous channels around the isolated humps, of which no less than 130 were counted, at great risk to himself and his companions. However, he achieved his object. He discovered the best site for the tower and returned home to prepare his plans.

His proposals, for those days, certainly were startling. He decided to follow generally the principles of design, which had been laid down by his father in regard to the Bell Rock. But he planned something bigger and more daring. He maintained that a tower 130 feet high, with a base diameter of 42 feet, tapering in a curve to 16 feet at the top, was absolutely necessary. It was the loftiest and weightiest work of its character that had ever been contemplated up to this time, while the peculiar situation of the reef demanded pioneering work in all directions.

The confidence of the Commissioners in the ability of their engineer was so complete that he received the official sanction to begin, and in 1838 the undertaking was commenced. The engineer immediately formulated his plans of campaign for a stiff struggle with Nature. One of the greatest difficulties was the necessity to transport men, supplies and material over a long distance, as the Scottish coast in this vicinity is wild and sparsely populated. He established his base on the neighbouring island of Tyree, where barracks for the workmen, and yards for the preparation of the material, were erected, while another colony was established on the Isle of Mull for the quarrying of the granite. A tiny pier or jetty had to be built at this point to facilitate the shipment of the stone, and at Tyree a small harbour had to be completed to receive the vessel which was built specially for transportation purposes between the base and the rock.

Another preliminary was the provision of accommodation for the masons upon the reef. The Atlantic swell, which rendered landing on the ridge precarious and hazardous, did not permit the men to be housed upon a floating home, as had been the practice in the early days of the Bell Rock tower. In order to permit the work to go forward as uninterruptedly as the sea would permit, a peculiar barrack was erected. It was a house on stilts, the legs being sunk firmly into the rock, with the living-quarters perched some 40 feet up in the air. The skeleton type of structure was selected because it did not impede the natural movement of the waves. It was an ingenious idea, and fulfilled the purpose of its designer admirably, while the men became

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THE SKERRYVORE, SCOTLAND'S MOST FAMOUS LIGHTHOUSE.

The erection of this tower upon a straggling low-lying reef 24 miles off Iona, and exposed to the full fury of the Atlantic, ranks as one of the world's engineering wonders.

BARRA HEAD LIGHTHOUSE, SCOTLAND.

The tower is 60 feet in height, but owing to its position on the cliffs, the white occulting light is 683 feet above high water, and is visible 33 miles.

By permission of the Lighthouse Literature Mission.

THE HOMES OF THE KEEPERS OF THE SKERRYVORE AND DHU-HEARTACH LIGHTS.

On the Island of Tiree, Argyllshire, 10 miles away.

accustomed to their strange home after a time. For two years it withstood the seas without incident, and the engineer and men came to regard the eyrie as safe as a house on shore. But one night the little colony received a shock. The angry Atlantic got one or two of its trip-hammer blows well home, and smashed the structure to fragments. Fortunately, at the time it was untenanted.

The workmen, who were on shore waiting to go out to the rock to resume their toil, were downcast at this unexpected disaster, but the engineer was not at all ruffled. He promptly sent to Glasgow for further material, and lost no time in rebuilding the quaint barrack upon new and stronger lines. This erection defied the waves successfully until its demolition after the Skerryvore was finished.

Residence in this tower was eerie. The men climbed the ladder and entered a small room, which served the purposes of kitchen, dining-room, and parlour. It was barely 12 feet across—quarters somewhat cramped for thirty men. When a storm was raging, the waves, as they combed over the rock, shook the legs violently and scurried under the floor in seething foam. Now and again a roller, rising higher than its fellows, broke upon the rock and sent a mass of water against the flooring to hammer at the door. Above the living-room were the sleeping-quarters, high and dry, save when a shower of spray fell upon the roof and walls like heavy hail, and occasionally percolated the joints of the woodwork. The men, however, were not perturbed. Sleeping, even under such conditions, was far preferable to doubtful rest in a bunk upon an attendant vessel, rolling and pitching with the motion of the sea. They had had a surfeit of such experience during the first season's work, while the barrack was under erection.

Yet the men could not grumble. The engineer responsible for the work shared their privations and discomforts, for Alan Stevenson clung to the rock night and day while work was in progress, and he has given a very vivid impression of life in this quaint home on legs. He relates how he "spent many a weary day and night—at those times when the sea prevented anyone going down to the rock—anxiously looking for supplies from the shore, and earnestly looking for a change of weather favourable for prosecuting the works. For miles around nothing could be seen but white foaming breakers, and nothing heard but howling winds and lashing waves. At such seasons much of our time was spent in bed, for there alone we had effectual shelter from the winds and spray, which searched every cranny in the walls of the barrack. Our slumbers, too, were at times fearfully interrupted by the sudden pouring of the sea over the roof, the rocking of the house on its pillars, and the spurting of water through the seams of the doors and windows—symptoms which, to one suddenly aroused from sound sleep, recalled the appalling fate of the former barrack, which had been engulfed in the foam not 20 yards from our dwelling, and for a moment seemed to summon us to a similar fate."

The work upon the rock was tedious and exasperating in the extreme. The gneiss was of maddening hardness and obstinacy—" four times as tough as Aberdeen granite " was the general opinion. The Atlantic, pounding the rock continuously through the centuries, had faced it smoother than could any mason with his tools, yet had not left it sufficiently sound to receive the foundations. In the external layer, which the masons laboured strenuously to remove with their puny tools, there were cracks and crevices here and there. The stubborn rock played havoc with the finest chisels and drills, and clearing had to be effected for the most part by the aid of gunpowder. This powerful agent, however, could only be used sparingly and with extreme skill, so that the rock-face might not be shivered or shattered too severely. Moreover, the men ran extreme risks, for the rock splintered like glass, and the flying chips were capable of doing as much damage, when thus impelled, as a bullet.

While the foundations were being prepared, and until the barrack was constructed, the men ran other terrible risks every morning and night in landing upon and leaving the polished surface of the reef. Five months during the summer was the working season, but even then many days and weeks were often lost owing to the swell being too great to permit the rowing-boat to come alongside. The engineer relates that the work was "a good lesson in the school of patience," because the delays were frequent and galling, while every storm which got up and expended its rage upon the reef left its mark indelibly among the engineer's stock-in-trade. Cranes and other material were swept away as if they were corks; lashings, no matter how strong, were snapped like pack-threads. Time after time the tender lying alongside had to weigh anchor hurriedly, and make a spirited run to its haven at Tyree.

When the barrack was erected, the situation was eased somewhat, but then the hours became long. Operations being confined to the summer months, the average working day was from four in the morning until nine in the evening —seventeen hours—with intervals for meals; but the men were not averse to the prolonged daily toil, inasmuch as cessation brought no welcome relaxations, but rather encouraged broodings over their isolated position, whereas occupation served to keep the mind engaged. Twice the men had severe frights during the night. On each occasion a violent storm sprang up after they had gone to bed, and one or two ugly breakers, getting their blows home, shook the eyrie with the force of an earthquake. Every man leaped out of his bunk, and one or two of the more timid, in their fright, hurried down the ladder and spent the remaining spell of darkness shivering and quaking on the completed trunk of the lighthouse, deeming it to be safer than the crazy-looking structure which served as their home.

Two years were occupied upon the foundations, the first stone being laid by the Duke of Argyll on July 7, 1840. This eminent personage evinced a deep interest in the work and the difficulties which had to be overcome, and as proprietor of the island of Tyree extended to the Commissioners free permission to quarry any granite they required from any part of his estate.

For a height of some 21 feet from the foundation level the tower is a solid trunk of masonry. Then come the entrance and water-tanks, followed by nine floors, comprising successively coal-store, workshop, storeroom, kitchen, two bedrooms, library, oil-store, and light-room, the whole occupying a height of 130 feet, crowned by the lantern. As a specimen of lighthouse engineering, the Skerryvore has become famous throughout the world. The stones forming the solid courses at the bottom are attached to one another so firmly and ingeniously as to secure the maximum of strength and solidity, the result being that nothing short of an earthquake could overthrow the stalk of masonry.

The erection of the superstructure was by no means free from danger and excitement. The working space both on the tower itself and around the base was severely cramped. The men at the latter point had to keep a vigilant eye upon those working above, since, despite the most elaborate precautions, falls of tools and other heavy bodies were by no means infrequent. Notwithstanding its perilous character, the undertaking was free from accident and fatality, and, although the men were compelled by force of circumstances to depend mostly upon salt foodstuffs, the little colony suffered very slightly from the ravages of dysentery.

Probably the worst experience was when the men on the rock were weather-bound for seven weeks during one season. The weather broke suddenly. Heavy seas and adverse winds raged so furiously that the steamboat dared not put out of its haven, but remained there with steam up, patiently waiting for a lull in the storm, during which they might succour the unfortunate men on the reef. The latter passed a dreary, pitiable time. Their provisions sank to a very low level, they ran short of fuel, their sodden clothing was worn to rags, and, what was far worse from their point of view, their tobacco became exhausted. The average working man will tolerate extreme discomfort and privation so long as the friendship of his pipe remains, but the denial of this companion comes as the last straw.

The lantern is of special design, and is one of the most powerful around the Scottish coasts. It is of the revolving class, reaching its brightest state once every minute, and may be seen from the deck of a vessel eighteen miles away Six years were occupied in the completion of the work, and, as may be imagined, the final touches were welcomed with thankfulness by all those who had been concerned in the enterprise. The tower contains 4,308 tons of granite, and the total cost was £86,977, or $434,885, rendering it one of the costliest in the world. This sum, however, included the purchase of the steam-vessel which now attends the lighthouse, and the construction of the little harbour at Hynish.

The lighthouse-keepers live on the island of Tyree, where are provided substantial, spacious, single-floor, masonry dwellings with gardens attached. This is practically a small colony in itself, inasmuch as the accommodation includes, not only that for the keepers of the Skerryvore, but for the guardians of the Dhu-Heartach light as well.

CHAPTER VIII

THE LONELY LIGHTS OF SCOTLAND

Barren ruggedness, ragged reefs, and towering cliffs form an apt description of the north and west coasts of Scotland, and he is a prudent navigator who acknowledges the respect which these shores demand, by giving them a wide berth. The Norwegian coast is serrated, the island of Newfoundland may be likened to the battered edge of a saw, but Scotland is unique in its formation. The coastline is torn and tattered by bays and firths, with scattered outlying ramparts. The captain of a "tramp" who has sailed the seven seas once confessed to me that no stretch of coastline ever gave him the shivers so badly as the stretch of shore between Duncansby Head and the Mull of Kintyre.

Certainly a ship "going north about" is menaced every mile of her way between these two points unless she takes a very circuitous course. If the weather conditions are favourable and daylight prevails, the North of Britain may be rounded through the narrow strait washing the mainland and the Orkney Islands, but the Pentland Firth is not an attractive short-cut. The ships that run between Scandinavian ports and North America naturally follow this route, as it is several hundred miles shorter than that via the North Sea and English Channel; but they keep a sharp eye on the weather and are extremely cautious. When the Pentland Firth is uninviting, they may either choose the path between the Orkneys and the Shetlands, or, to eliminate every element of risk, may stand well out to sea, and round the most northern stretches of the Shetlands. These are lonely seas, comparatively speaking, and yet are well lighted. Although a wicked rock lies in the centre of the eastern entrance to the Pentland channel, it is indicated by the

Pentland Skerries light. When the mariner in his wisdom pushes still farther north, he falls within the glare of the rays thrown from the beacon near Muckle Flugga. This is the northernmost point of the British Islands, and it is truly forbidding. The rock lies three-quarters of a mile off the Shetland Islands, and is a huge fang, sheering to a height of 196 feet above high-water. On the side facing north it rears up so abruptly that it appears to lean over, while on the opposite side it is almost as steep.

The majority of lighthouses have been called into existence by the claims of commerce purely and simply. But it was not so with the North Unst lighthouse, as the beacon crowning this pinnacle is called. War was responsible for its creation, though probably sooner or later the requirements of peace would have brought about a similar result. While the armies of France and Britain were fighting the Russians in the Crimea, the British fleet was hovering about these waters, watching the mouth of the Baltic, so as to frustrate any attempts on the part of the Russian fleet to dash around the northern coast of Scotland. In those days these lonely seas were badly lighted, and the Admiralty realized only too well the many perils to which the warships were exposed while cruising about the pitiless coasts of the Orkneys and Shetlands. Accordingly, the department called upon the Commissioners of Northern Lighthouses to mark Muckle Flugga. Time was everything, and the engineers were urged to bring a temporary light into operation with the least delay.

The engineers hurriedly evolved a tower which would meet the Government needs. It was thought that the extreme height of the rock would lend itself to the erection of a building which, while possible of early completion, would be adequate for subsequent purposes. The materials for the light, together with a lantern, and a second building for the storage of the oil and other requisites, were shipped northward from Glasgow. Simultaneously the engineers, with another small gang of men who had already reached the rock, pushed on with the preliminary preparations, so that when the constructional vessel arrived erection might go ahead straightforwardly and rapidly.

The engineers tried the rock from all sides to find a safe landing. This was no light matter, owing to the steepness of the slope even upon the easiest face of the pinnacle. The attempt represented a mild form of mountaineering, for the sea had battered away the projection of the lower-lying levels, and the men found it trying to effect a foothold, even in stepping from the boat on to the rock. They had to climb hand over hand up the precipice, with life-lines round their waists, taking advantage of every narrow ledge. With infinite labour they gained the summit, and then they found that there was just sufficient space, and no more, upon which to plant the lighthouse buildings.

The top was cleared quickly, and then the advance party set to work to improve the landing-place on the south side of the rock for the reception of the building materials. A small site was prepared with great difficulty, as the tough rock offered a stern resistance to the chisels, drills, and wedges; while in addition the men had to cut steps in the flank of the rock to facilitate the ascent to the site.

On September 14, 1854, the constructional vessel *Pharos* hove in sight, and, the weather being favourable, the landing of the material was hurried forward. The men had to become pack-animals for the time, carrying the loads on their backs. In this manner they tramped laboriously up and down the cliff-face with material and stores of all descriptions. The heavier and bulkier parts were hauled up by rope and tackle, a few feet at a time, and this task was quite as exacting. In all, 120 tons were conveyed to the top of the crag. Construction was hastened just as feverishly, and on October 11, 1854, twenty-six days after the *Pharos* anchored off Muckle Flugga, the North Unst light shone out for the first time. This is probably one of the most brilliant exploits that has ever been consummated in connection with lighthouse engineering, the merit of which is additionally impressive from the fact that almost everything had to be accomplished by manual effort.

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THE DHU-HEARTACH LIGHTHOUSE.

To the left is the lower part of the temporary structure in which the builders lived while erection was in progress.

THE NORTH UNST, BRITAIN'S MOST NORTHERLY LIGHT.

The tower is perched on the top of a precipitous crag, the light being 260 feet above the sea. Despite this height, the waves often dash over the lantern.

While the light was admittedly of a temporary character, the importance of the outpost had been appreciated, and it was determined to erect a permanent light upon the rock for the guidance of those who compass the North of Scotland in order to pass from and to the North Atlantic. It was decided to commence the permanent masonry building the following year, and a gang of men volunteered to stay behind on the rock throughout the winter to complete all the essential preparations for the foundations. Accommodation was available for this staff in a substantial iron shelter, in which they made themselves comfortable for the winter.

But it is during this season that the winds from the north, lashing the sea to fury, create huge rollers which thunder upon the base of the pinnacle to crawl up its perpendicular face in the form of broken water and spray. The men standing on the brink often watched these rollers, but never for a moment thought that one would be able to leap to a height of nearly 200 feet and sweep over the rock. The December gales dispelled this illusion very convincingly. One morning the workmen, while breakfasting in their warm shelter, received a big surprise. A terrific blow struck the door, which flew open as if hit by a cannon-ball. It was followed instantly by a three-foot wall of water. The broken wave rushed round the apartment, seething and foaming, and then out again. The workmen were dumbfounded, but had scarcely recovered from the shock when another roll of water came crashing in and gave the apartment another thorough flushing out. One of the Scottish workmen vouchsafed the remark that the man responsible for cleaning the floors that day would be spared his job, but he was silenced when, a few seconds later, another angry sheet of water dropped on the roof of the building and threatened to smash it in.

The closing month of that year was particularly boisterous. Time after time when the sea rose, the lighthouse tower was drenched in water. One might think it impossible that a wave could get up sufficient impetus to mount a height of 200 feet ; but this experience offered conclusive testimony to the contrary and to the immense power of the waves when they have an uninterrupted run over several hundred miles of open ocean.

In a way, the terrifying experience of these marooned workmen was invaluable. They reported the bare facts to the engineers upon the first opportunity, and this intelligence brought about a revision in the designs for the permanent masonry structure.

The present North Unst lighthouse is a massive masonry building, standing in the centre of the small flat space on the top of the pinnacle, with heavy masonry walls bounding it on all sides. The tower is 64 feet in height, while the red and white light may be seen from a distance of twenty-one miles in clear weather. That the winter storms of 1854 were by no means exceptional has been proved up to the hilt on several occasions since. When the nor'-wester is roused thoroughly, the breaking waves curl up the cliff and rush over the lantern. Such a climb of 260 feet conveys a compelling notion of the force of the sea. The weight of the water thrown into the air has threatened to overthrow the massive boundary walls, while now and again the invader leaves tangible evidences of its power by smashing the windows of the lantern. Upon one occasion it burst open the heavy door, which weighs the best part of a ton.

The light-station is served by four keepers, two on duty simultaneously, their homes being on the island of Unst, four miles away. For the conveyance of water, fuel, provisions, and other requirements, from the landing-stage to the lighthouse 200 feet above, an inclined railway has been provided on the easier slope, so that the men are no longer called upon to pack their provisions, like mules, from the water-level up a steep cliff, as was formerly required.

Rounding these island dangers, the navigator picks up the light of Cape Wrath, glimmering from a height of 370 feet above the water-level and standing at the western corner of the rectangular head of the Scottish mainland. Going south, he has two passages available—the inner, which extends through the Minches and inside the Hebrides;

or the outer, which lies beyond the latter rampart. In making the outer passage he comes within range of the light shining from the summit of a lonely group of rocks standing some twenty-two miles out to sea off the Isle of Lewis. These are the Flannen Islands, or Seven Hunters, one of many similar lonely Scottish stations. The tower is mounted upon the crown of one of the highest points, and the white group-flashing light is visible over a radius of twenty-four miles. Farther south the seafarer picks up and drops the Monach Islands light, likewise lying out in the Atlantic, some ten miles from the nearest land. Finally, rounding Barra Head, the most southerly point of the reef lying off Barra Island, the light from which is cast 580 feet above the water owing to the height of the cliff, the vessel slips into a huge indentation, where isolated rocks peep above the Atlantic, one of the most dangerous of which is indicated by the Skerryvore lighthouse.

I have described the Skerryvore light in the previous chapter ; but nineteen and a half miles to the south-east of the latter is another reef, just as exposed, which is as perilous in every respect. Indeed, it may be said to constitute a greater menace to the navigation of these waters, since it lies in the cross-roads of the entrance to the Irish Channel, the Firth of the Clyde, and the Minches. A powerful light mounts guard on the Rhins of Islay, twenty-seven miles due south, but between the latter and Skerryvore there are forty-three miles of coast, as dangerous as the mariner could wish to avoid, with this rock looming up almost halfway.

This peril is the Dhu-Heartach, lying out to sea in deep water, fourteen miles from the nearest point of the mainland. The physical configuration of the sea-bed at this point is somewhat similar to that prevailing at Skerryvore. The Ross of Mull tumbles abruptly into the Atlantic, to reappear out to sea in the form of the Torrin Rocks, which run for a distance of four and a half miles in the direction of Dhu-Heartach. Then the reef comes to a sudden stop, to be seen once more, nine miles farther out, in the rounded hump of Dhu-Heartach, this being practically the outermost point of the ridge. Being so isolated and projecting so suddenly from deep water, this ledge claimed many victims among the vessels frequenting these unlighted waters. The Commissioners of Northern Lighthouses were assailed for not marking the danger spot in some form or other. The authorities, however, were fully alive to the need of such protection, but it was not until 1867 that they were able to proceed with the erection of a lighthouse.

The situation is peculiar, and the engineers, Messrs. D. and T. Stevenson, were faced with a somewhat perplexing problem recalling those which had arisen in conjunction with the Skerryvore, not far distant. Indeed, the Dhu-Heartach undertaking might very well be described as a repetition of those struggles, with a few more difficulties of a different character thrown in. The rock itself in reality is a series of islets, or hummocks, surrounding the main hump, which is 240 feet in length by 130 feet in breadth, the highest point of the rounded top being 35 feet above high-water at ordinary spring-tides. On all sides the lead marks very deep water, the result being that in times of storm and tempest the rollers of the Atlantic, having a "fetch" of some 3,000 miles or more, thunder upon it with terrific force, the broken water leaping high into the air. It is very seldom that the rock can be approached even in a small boat and with a calm sea, as the hump is invariably encircled in a scarf of ugly surf. The swell strikes the western face of the rock, is divided, flows round the northern and southern ends of the obstruction, and reunites on the eastern side. Consequently the rock is nearly always a centre of disturbance.

The distance of the rock from the mainland complicated the issue very materially. A suitable site had to be prepared on shore as a base, where the stones could be prepared for shipment, while a special steam-tender was necessary to run to and fro. The handling of the workmen had to be carried out upon the lines which were adopted at Skerryvore—namely, the erection of a barrack upon a skeleton framework on the rock, where the men might be left safely for days or weeks at a time. The shore station selected was at Earraid, on the neighbouring island of Mull, because it was the nearest strategical point to the work, and because ample supplies of first-class granite were available in the immediate vicinity, the proprietor, the Duke of Argyll, as in the previous instance, facilitating the work as far as possible.

The authority to commence operations was given on March 11, 1867, and this year was devoted to completing preparations, so that in the following season work might be started in earnest and carried on throughout the summer at high pressure. The first task was the erection of the barrack on the rock. The workmen got ashore for the first time on June 25, 1867, and, although landing at all times was trying and perilous, attempts often having to be abandoned owing to the swell, the engineer succeeded in landing twenty-seven times up to September 3, when work had to be suspended until the following year. Despite the shortness of the season, the men made appreciable headway. The iron framework of the barrack was completed to the first tier, while a good beginning was made upon the rock-face in connection with the foundations for the lighthouse. When the autumnal gales approached, everything in connection with the barrack was left secure, the builders being anxious to ascertain how it would weather the winter gales and the force and weight of the waves which bore down upon it.

The engineers finally decided upon a tower 107½ feet in height. After trying various curves for the outline, they came to the decision that a parabolic frustum would afford the most serviceable design, as well as providing the maximum of strength. A diameter of 36 feet was chosen for the base, tapering gradually and gracefully to one of 16 feet at the top, with the entrance 32 feet above the base, to which point the cone was to be solid.

The arrangements were that work should be resumed in the early spring of 1868, so as to secure full advantage of the favourable easterly winds. Accordingly, when the special steam-tender arrived on April 14, she was loaded up with necessaries and men, ready to proceed to the site directly the wind should veer round to the desired point of the compass. But with aggravating persistency it clung to the west and south-west until the end of June, so that many valuable weeks were unfortunately lost. Time after time, when there was a lull in the weather, the steamer put out from Earraid, the engineers determined to make a dash for the rock, and as many times they were foiled, as the men could not be got through the surf. One day, however, an hour and a half was snatched on the rock, and, although no work could be done in that time, yet the interval was sufficient to enable the engineers to take a look round and to see how their handiwork had withstood the heavy gales of the previous winter. There was only one marked evidence of the Atlantic's wrath. One section of the iron ring connecting the heads of the legs of the barrack at a height of 30 feet had been carried away.

On June 29 the wind moderated sufficiently to enable the men to be landed, but the climatic conditions remained adverse. The wind refused to swing round to the east; a westerly swell was the luck day after day. The engineers had to dodge the ocean as best they could, and some idea of the handicap under which they laboured may be gathered from the fact that only four landings were made during the sixty-one days of May and June. July enabled the greatest number of landings to be effected—thirteen; while during August and September the men only gained the rock on twenty-one occasions, making a total of thirty-eight landings in the course of 153 days.

During this interrupted season, however, the barrack was completed. It was a massive structure, and resembled a huge iron barrel secured endwise upon an intricate arrangement of stilts which were heavily stayed and tied together by diagonals and cross-members. In the two previous instances where a similar arrangement had been adopted the temporary dwelling had been wrought in wood, but on this occasion the engineers decided to adopt iron, as they concluded that a wooden structure would not fare well

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THE NORTH UNST LIGHT.

The first light was built in twenty-six days during the Crimean War at the British Government's urgent request.

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LANDING WATER AT THE NORTH UNST.

Showing tramway connecting with tower, 200 feet above.

By permission of the Lighthouse Literature Mission.

THE FLANNEN ISLANDS LIGHT STATION.

One of Scotland's lonely beacons. It marks a group of islets 15 miles off the Hebrides. In 1900 the three keepers mysteriously disappeared, and their fate remains unsolved to this day.

against the heavy seas. This was a fortunate decision, because, as subsequent experience proved, a wooden barrack would have received very short shrift from the Atlantic breakers; in fact, probably it would have gone down with the first sou'-wester. The iron barrack, as the workmen narrated, was pounded and battered by the waves most unmercifully; but although it suffered at times, quivering and shaking under the terrific impacts, it weathered all the onslaughts.

One interesting incident serves to illustrate the perils to which the workmen were exposed. A date had been set down when all the men were to be brought off the rock for the season, as the approach of the equinox rendered further toil extremely doubtful, and there was no intention of unduly imperilling them. The engineer's resident representative, Mr. Alexander Brebner, went out to the rock on August 20, the day fixed for the suspension of operations, to inspect the progress that had been made and to have a last look round. At the time of his arrival the weather was beautifully calm, and held out every promise of remaining settled for several days. As the season had been so adverse, he decided, on his own responsibility, to delay the cessation of toil, so, with the thirteen men, he remained on the rock, determined to make up leeway somewhat while the weather held out.

But the resident paid the penalty for his disobedience. The little party retired that night with the stars shining brilliantly overhead from a cloudless sky, and with the sea like a mirror. In the middle of the night one and all were roused suddenly from their slumbers. The wind was roaring, and the breakers were hammering upon the rock, while the foam and surf rushed violently between the legs of the barracks. When the men looked out they were confronted with a terrifying spectacle. The night was black as pitch, but the sea white as a snow-covered plain, from the crests of the rollers and the surf playing on and around the rocks. A furious gale had sprung up with the characteristic suddenness of the Atlantic, and was already raging. The next morning no one dared to venture outside the iron home, while the gale, instead of abating, appeared to be increasing in fury. For five days the men were held fast, and at times their fears got the better of them. This was particularly the case when, now and again, a more than ugly wave got up, rolled over the rock, and crashed with full force against the barrack. The building shook and trembled fearfully, but its legs were driven too deeply into the rock for it to be overturned, while the cross-bracing was too intricate for the legs to be snapped off. Again and again the men were plunged into darkness, as a wall of water rushed right over the drum, notwithstanding that the roof was 77 feet above high-water.

Their fears rose almost to frenzy when a breaker, leaping the rock, drove full tilt against the floor of the barrack. In this upward rush of 55 feet the building suffered. The men's entrance to the home was by means of a heavy hatch, or trapdoor, which was bolted securely upon the inside. This particular comber burst in the hatch as if it were no thicker than the wood of a matchbox, flooding the whole compartment.

Meantime the engineer-in-chief at Edinburgh had heard of the incident. He had given strict instructions that the men should be brought off on August 20, and when the intelligence was communicated to him that his order had been disobeyed, and that his men were in serious straits, he became distracted. He knew only too well how the waves bombard Dhu-Heartach. Mr. David Stevenson related to me how his father paced the offices during the day, and his own home at night, unable to drown his thoughts in work or sleep. His worry was intensified as the true character of the gale came to his ears. He had planned everything with such care that neither life nor limb of a single workman need be jeopardized, and here he was confronted with the possibility of losing fourteen men at one stroke! The iron barrack, although staunchly constructed, was just as likely as not to succumb to the full brunt of a very vicious sou'-wester, so there was every excuse for his anxiety. He gave orders that the steam-tender was to stand by with steam raised, so as to make a dash for the rock upon the first opportunity. No one had a moment's peace until at last the news came through that the steam-tender had been out to the rock, and with much difficulty had got hold of the fourteen men and brought them ashore, somewhat scared and bearing evidences of their experience, but unharmed. Mr. Stevenson told me that he could not quite say which was worse—the distracted wanderings of his father, or the expression of his pent-up feelings when he met the unfortunate resident a few days later, who was taken severely to task for his flagrant breach of orders, whereby the lives of the workmen had been imperilled so unnecessarily.

The year 1869 was kinder to the engineers, and great headway was made. The men were able to make their first landing on the rock as early as March 25, and it was accessible up to October 29, when all forces withdrew from the scene for the winter. During this period sixty landings were effected, while heavy supplies of masonry and other materials were shipped to the site. The masons took up their permanent residence in the barrack on April 26, and did not leave it until September 3, while they were able to squeeze in 113 days of toil, with a welcome rest from their labours on Sundays. The excavations for the foundations were completed speedily, and on June 24 the erection of the tower was commenced. The stones were brought ready for setting in position, and were laid so rapidly that by the end of the month two courses were completed and the third had been well advanced. Then came a temporary setback. A blusterous summer gale sprang up, and the sea, after assaulting the rock for two days, succeeded in leaving its mark. The crane and other tackle at the landing-stage were washed away, while fourteen stones laid in the third course were uprooted, of which eleven were seen no more. The water in this case had to leap upwards for 35½ feet, while the stones which it carried away weighed 2 tons apiece, and were firmly joggled, so that the wrench which displaced them must have been terrific indeed.

If a summer gale could wreak such damage, what was the dreaded equinox likely to achieve ? The engineers were so much impressed that they thereupon made assurance doubly sure by effecting a modification of the original plans. When the work was commenced, it was intended to take the solid part of the tower up to a height of 52 feet 10 inches above high-water. The effects of this summer gale induced them to continue the solid section a further 11½ feet, so that the entrance level is 64 feet 4 inches above high-water mark. The result is that the solid base of the Dhu-Heartach tower weighs no less than 1,840 tons—more than one-half the total weight of the structure—and is executed throughout in massive blocks of grey granite.

The tower contains six floors above the entrance hall, these, on ascending the spiral staircase, being as follows: oil-store, kitchen, provision-store, bedroom, dry-room, and light-room. The masonry part of the work was completed by the end of the season of 1871, and the first-order dioptric, fixed, white light was exhibited on November 1, 1872. The focal plane, being 145 feet above the water-level, has a range of eighteen nautical miles. The total cost of the work was £76,084, or $380,420, of which sum the shore station was responsible for £10,300, or $51,500.

The ocean made an attempt to defeat the workmanship and skill of the engineers in the very winter following the opening of the lighthouse. On the lee side of the tower there is a copper lightning-conductor, 1 inch thick by 1½ inches wide, which is let into a channel cut in the stonework, so that it comes flush with the face of the building. This conductor is fixed at intervals of 5 feet in a substantial manner. The winter storms of 1872 tore some 10 feet out of this channel near the base of the structure, and wrenched the screws from their sockets; while at the kitchen window level, which is 92 feet above high-water, the rod was similarly disturbed for some distance. It will be seen that the waves which assail Dhu-Heartach are by no means to be despised.

CHAPTER IX

THE FASTNET, THE OUTPOST OF EUROPE

FOUR and a half miles out to sea, separated from Cape Clear, the most south-westerly point of Ireland, by a treacherous channel, rises the jagged, formidable shape of the Fastnet. To mariners the rock, with its brilliant shaft of light by night, has developed into more than a mere beacon. It is the first and last light of the Old World on the eastward and westward passages across the Atlantic. All passing vessels are "spoken" from this point to London, New York, and elsewhere.

It was in the early fifties of the past century that the engineer conceived the idea of planting a light upon this lonely crag. Maritime interests had agitated for a beacon for many years previously, since, although a warning gleam was thrown from the station on Cape Clear, this ray often was invisible, or partially obscured, owing to the wreaths of cloud and mist which draped the summit of the headland. The builder was Mr. George Halpin, engineer to the Port of Dublin Corporation, which was responsible at that time for the illumination of the shores of Ireland.

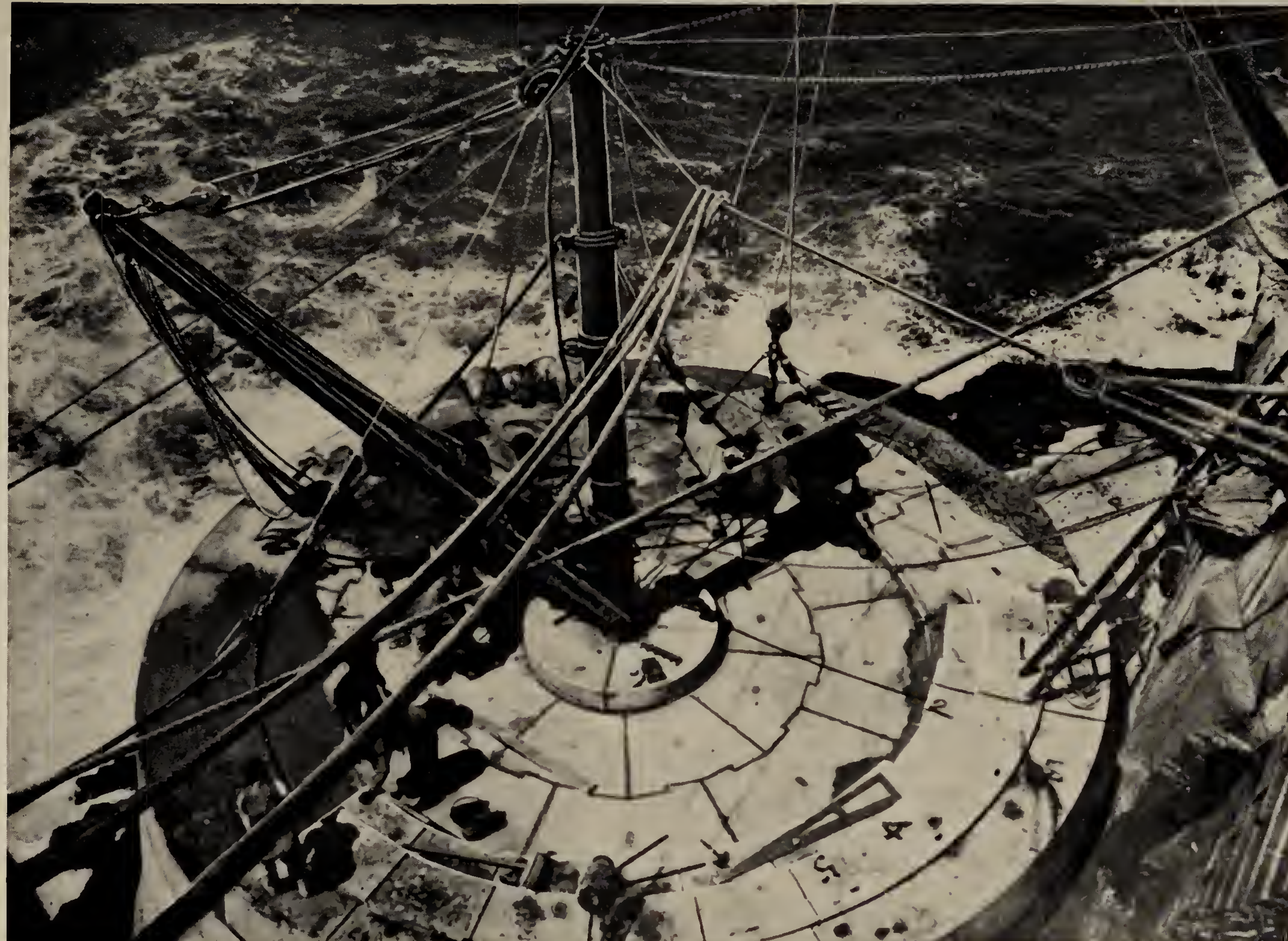
His task was not to be despised. The Fastnet itself is merely a pinnacle, rising precipitously to a height of about 100 feet above low-water, but it is the centre of many dangers. It is flanked on all sides by needle-points and ridges; the currents run strongly, and the tides are wicked, rendering approach uncertain even in the smoothest weather.

The indefatigable engineer attacked his task boldly. He chose the highest point of the rock as the site for his tower, which was a cast-iron cylindrical building, 91 feet in height. The lantern was equipped with a revolving apparatus which threw a flash of 38,000 candle-power for fifteen seconds once every two minutes from an elevation of 148 feet, rotation being obtained through a belt and a weight-driven clock. Its erection was a tedious undertaking; although a start was made in 1848, it was not until January 1, 1854, that the light first cast its welcome rays over the wastes of the Atlantic, by which time £20,000, or $100,000, had been spent upon the undertaking.

For ten years Halpin's work successfully defied the elements, although at times the keepers grew somewhat apprehensive concerning its stability. Time after time, during heavy gales, it seemed as if it must succumb to the storm. The waves curled up the cliff and struck the tower with staggering force, causing it to tremble like a leaf. On one occasion a cup of coffee standing upon the table was thrown to the floor. While the shaft defied the most severe poundings, the cliff itself gave way, and large masses of rock on which the tower stood were carried away. One huge chunk, weighing some 3 tons, was detached, and, as it slipped down, was picked up by the next incoming wave, to be hurled with terrific force against the tower, but without inflicting any marked damage. On another occasion a cask containing 60 gallons of fresh water, which the keepers had made fast to the railing of the gallery surrounding the lantern, 133 feet above the water, was wrenched free by a wave which dashed over the rock, and was swept away as if it were an empty tin. The keepers' anxiety under these circumstances may be understood.

At last, in April, 1865, the consulting engineer to the Corporation visited the lighthouse in company with Mr. George Stevenson, the famous Scottish lighthouse builder, to examine the rock thoroughly. The latter suggested certain recommendations to insure the stability of the tower; but when the sanction of the Brethren of Trinity House was sought, they deferred a decision until their own engineer had visited the works, although they appreciated Mr. Stevenson's advice.

Some of the recommendations advanced by Mr. Stevenson were followed subsequently, and this reluctant recognition



From the "Scientific American."

BUILDING THE FASTNET ROCK LIGHTHOUSE.

Looking down from the top of the rock upon the men setting one of the solid masonry courses.

BUILDING THE FASTNET TOWER.

Showing derrick for setting the stones into position.

The "Scientific American."

ERECTING THE FASTNET LANTERN.

This illustration gives a striking idea of its height.

of his knowledge brought its reward. The authorities—now the Commissioners of Irish Lights—had a fright in 1881. The storms of that winter were among the heaviest that have ever assailed the British Islands. The Calf Rock light, which was a similar tower to the Fastnet, and which had been strengthened upon identical lines, came to grief. The tower was broken off at the point where the reinforcement ceased. This disaster naturally aroused many misgivings concerning the luck of the Fastnet. Had it shared a similar fate during the same gale? To their intense relief, the Commissioners found that it had issued from the conflict with no more injuries than a few broken panes of glass.

The tower withstood the attacks of wind and wave successfully until 1891, when the Commissioners came to the conclusion that it was time the Fastnet light was improved, to meet the requirements of the busier mercantile traffic passing the point. Accordingly, Mr. William Douglass, the engineer to the Commissioners, recommended a new tower, fitted with the latest form of illumination, so as to bring it into line with the other leading lights of the world. He advocated a tower of masonry with the focal plane at an elevation of 159 feet; the shaft, 147 feet high, springing from a position 6 inches below high-water, with a diameter at the base of 42 feet. The cost of the light was estimated at £70,000 or $350,000.

One cannot help admiring the daring of the engineer, since he declined to be assisted by the rock summit in his purpose. Instead he preferred the ledge of a chasm on the hardest part of the rock below high-tide, and directly exposed to the full force of the sea. He maintained that such a tower, planted on this shelf, would receive the force of the heaviest seas before they rose to their full height; also by building the base of the tower in the form of steps, as in the case of a breakwater, an excellent buffer would be offered to the rollers.

The new design came at an opportune moment. Another inspection of the existing tower by Mr. C. W. Scott, the present engineer-in-chief to the Commissioners, revealed a parlous state of affairs. Halpin's building was on the verge of collapse. Many of the plates in the upper stories had worked loose under the poundings inflicted by the seas, and in many instances the bolts holding the fabric together were sheared. Repairs had to be made hastily to enable the old tower to hold out until the new lighthouse was erected.

Before the work was commenced, the designer, as a result of further investigation, decided to increase the diameter of his tower to 52 feet at the base. The lowest courses did not comprise complete rings of masonry, but were anchored at the points where the circle was broken into the face of the cliff, so as to form an integral part thereof, as it were. The depth of this partial ringwork is 26 feet, at which level the first complete ring of masonry was laid. Thenceforward the tower is solid throughout its thickness for a further height of 30 feet, except for a central circular space forming the water-tank, which holds 3,250 gallons of water. From this point the masonry structure rises gracefully to a height of 88⅛ feet to the lantern gallery. The lighthouse is divided into eight floors, affording living-rooms for the keepers, storerooms for oil, fog-signals, provisions, coal, etc.

The lighthouse, the landing-stage, and other appurtenances, are executed in Cornish granite throughout. The blocks were fashioned from picked stone of fine, close, hard grain, and ranged up to 4 and 5 tons in weight. The method of construction followed the approved lines of to-day, in which each stone is dovetailed into its neighbour, above, below, and on either side. As the stones were cut and fitted in the Cornish quarries, they were set up and fitted course by course. Then, when they had met the approbation of the engineer deputed for this duty, they were numbered and given other identification marks, so that upon reaching the base at Rock Island, upon the Irish mainland, within easy reach of the Fastnet, they could be despatched in rotation to the site, to be set in position.

It was in August, 1896, that the first little squad of labourers landed on the Fastnet, under the superintendence of James Kavanagh, a first-class all-round mason—one of those men who occupy a unique position when emergency calls. He was just the type of foreman that the task demanded, careful, daring, a hard worker, zealous, dauntless. Once he had landed on the rock to prepare the foundations, he seldom left it; and, what is more, every stone constituting the tower was well and truly laid by his own hand. It was indeed unfortunate that Kavanagh, after his momentous round of toil was over, should be stricken down with apoplexy, to which he succumbed, after virtually years of imprisonment upon an ill-famed rock, facing discomforts and privations of all descriptions, and seizing every opportunity to drive the task forward. It was as if Nature, baffled in her efforts to circumvent the work of human ingenuity, had taken revenge upon the man who had laboured mightily to complete her subjection.

Kavanagh took with him upon the rock a small boiler and steam-winch, which he set up without delay, to land both workmen and necessaries. He lost no time in cutting away at the toe of the cliff, to admit the first partial ring of stones. It was a ding-dong battle between the masons and the sea for the first few rounds. The men toiled heroically with their chisels between the coming of the rollers, with one eye on the water and the other on a handy life-line, which they grabbed when the Atlantic endeavoured to steal a march upon them. On some days splendid progress was made; on others the masons never drove the chisels once into the rock-face.

Landing was an exciting experience in itself. The tender, naturally, could not draw right in, owing to the swell and other dangers. She stood off a little way, and there anchored. When men were coming to or going from the rock, the rope was run out from the derrick. To this was attached a kind of double stirrup, not unlike a child's swing. The men took up their position, two at a time, on these stirrups, standing face to face. At the command, "Lower away!" or "Heave ho!" the derrick winch commenced to grunt and rattle, and the men were whisked into mid-air, clutching tightly to their frail, cramped hold, and steadied in their aerial journey by another rope extending to the rowing-boat below. It was an exciting trip while it lasted, and at first glimpse appeared to be dangerous, so much so that on one or two occasions the courage of raw hands broke down at the last moment, and they hesitated to trust themselves to such a flimsy-looking vehicle.

Bringing the stones ashore was even more difficult. It was imperative that the edges and corners of the blocks should be protected from blows which might chip and scar them, thereby impairing their true fit, and possibly allowing the sea to get a purchase in its efforts to destroy. Accordingly, the blocks were packed in skeleton crates, with substantial wooden battens completely protecting the vital parts. It was impossible to swing them singly direct through the air from steamer to rock, and it was inadvisable to transfer them first to a rowing-boat; so an ingenious alternative method was perfected. The tender was brought as near the rock as possible, and the derrick boom was swung out, so that a hook carried at the end of the rope could be attached to the stone, which rested on rollers upon the tender's deck leading to an open doorway in the taffrail. When the rope was secured, the word was given to haul in the derrick rope slowly and gently. This brought the stone gradually to the vessel's side, when it was permitted to fall into the water where it could suffer no injury. The derrick rope meanwhile was wound in, and the stone, still submerged, at last brought to rest against the side of the tower.

A vertical series of wooden battens had been attached to the outside of the building, so as to form a slide up which the blocks could be hauled to the required level. Of course, as the tower increased in height, the latter part of the operation had to be varied, owing to the concave curve of the structure. Then the stone had to complete its final stage through the air, being steadied in its ascent by a rope held below to prevent it swinging and coming to grief against the completed part of the shaft. In this manner 2,074 stones, representing a dead-weight of 4,633 tons, were landed and set in position.

Work was painfully slow and tedious at times, owing to adverse weather. Although the men on the rock were condemned inevitably to periods of idleness, they were made as comfortable as conditions would permit, so as to remove any longing on their part to return to the mainland for a change. This was a necessary precaution. Although the men might leave the rock in perfectly calm weather, the Atlantic is so fickle that an interval of two or three hours was quite sufficient to permit the wind to freshen, and the swell to grow restive, to such a degree as to render a return to the rock impossible for several days. Owing to the cramped nature of the quarters on the rock, elaborate care had to be exercised to protect the men from the ravages of disease. The toilers had to board themselves, and the authorities demanded that each man should maintain a fortnight's reserve supply of provisions upon the rock to tide him over a spell of bad weather. This rule was enforced very rigidly, any infringement of it being attended with instant dismissal. For emergency purposes the Commissioners maintained a small stock of salt beef, pork, tinned meats, tea, sugar, milk, biscuits, and so forth, on the rock, from which the men could replenish their larders. The foreman acted as a kind of medical officer of health, as well as fulfilling his other duties. He was supplied with a ship's medicine-chest, plenty of bandages, liniment, and antiseptics, in case of accident. At five o'clock every morning the men were compelled to tumble out of their bunks, to indulge in a thorough wash, to turn their bedding into the air when the weather was agreeable, and to wash out their quarters. The strictest supervision was maintained over matters pertaining to sanitation, and, thanks to these elaborate precautions, cases of sickness were very few.

Extreme care was observed in the building operations, so that no workman might be exposed to any unnecessary risks, although the task at times bristled with unavoidable perils. As a matter of fact, the whole enterprise was attended by only three accidents on the rock. One man was cutting a tram-rail, when a piece of steel flew into one eye, completely blinding it. Another suffered a similar calamity from a chip of stone while quarrying. The third man met misfortune while at work at the windlass of the derrick. As a breaker rolled in, his companion dropped his handle, with the result that the other workman was knocked down and had one leg broken. There was a true Hibernian flavour about this last-named accident, in keeping with the setting in which it occurred. The man was incapacitated for some months, and then brought an action for compensation, claiming that he had been rendered unfit for any further manual labour. The sympathetic court solaced him with an award of £350, or $1,750. The amazement and disgust of the engineer may be imagined when, three months after the action, he suddenly espied the supposedly totally incapacitated workman assisting in the transference of coal from a barge to the tender!

As the tower grew above the existing building, which it was to exceed in height, it obscured the light thrown from the latter in a certain direction. At this juncture, accordingly, a temporary scaffolding was erected upon the summit of the new shaft, on which were rigged two ordinary lightship lights, and these were kept going until the new lantern was completed. The last stone was set on June 3, 1903, after some four years' labour.

During the winter everything was brought virtually to a standstill, owing to the succession of gales, but the men on the rock never missed an opportunity to advance the undertaking. Kavanagh, the foreman, absolutely refused to go ashore so long as any work could be completed. Often he remained on the Fastnet the whole year round, and never was away for more than two months in the year, when work was impossible. Other workmen, when they had lived down the first feelings of loneliness, became imbued with the same spirit, and appeared loth to forsake the scene

By courtesy of the "Scientific American."

THE FASTNET, THE OUTPOST OF EUROPE.

On the top of the rock is the first light, opened in 1854. At the side is the present noble tower, completed in 1906. The flashing beam of 750,000 candle-power has a range of 20 miles.

By courtesy of Messrs. Chance Bros. & Co., Ltd.

THE LANTERN OF THE FASTNET ROCK LIGHTHOUSE.

It consists of two tiers each of four panels of 920 millimetres focal distance.

of their labours even for a day or two. When the men settled down to their toil, it was very seldom that a wish was expressed to be taken ashore more than once in three months.

The lantern was undertaken directly the stonework was completed. The landing of this apparatus was an exciting task, for, the season being advanced, it was decided to run unusual risks, lest the rock should become unapproachable. It was accomplished successfully, and the various parts were stored on the rock in what was considered a safe place. The weather looked fine and gave no signs of breaking; yet two hours after all had been inspected and secured for the night a terrific gale sprang up, and the rock was enveloped in water, which dashed right over it. The waves caught some of the lantern apparatus and smashed it; other parts were carried away and never seen again. This was an unexpected catastrophe. The remaining damaged parts of the apparatus were sent back to Birmingham to be overhauled and the missing portions replaced.

As there was no possibility of being able to complete the lantern that winter, and the authorities did not like to entrust the marking of the rock solely to the temporary lightship lights—the lantern of the Halpin tower had been taken down meanwhile—it was thereupon decided to erect the dismantled old lamp in the new tower for the time being.

The next summer the new apparatus was got on to the rock and erected safely. The light is of the dioptric type, derived from a series of incandescent burners, giving a total power of 1,200 candles. This part of the installation is the invention of the chief engineer to the Commissioners, Mr. C. W. Scott, and it has proved to be one of the most perfect and economical devices of this type yet submitted to practical operations. The oil is vaporized by being passed through a spraying device under pressure, similar to the forced carburation in automobile practice, and the gas is fed to the Bunsen burners. The lenses, together with their revolving apparatus, weigh 13,440 pounds, and rotate upon a bed of mercury under the fall of a weight of 290 pounds, which descends 40 feet per hour, this being sufficient to secure three complete revolutions per minute. In case the incandescent gas installation should break down from any cause, a four-wick oil-burner is held in reserve, and can be brought into action instantly. The power of the rays thrown from the 1,200 candle-power burners is intensified by the lenses to some 750,000 candle-power, of extremely white brilliancy, recalling the beam thrown by an electric searchlight. The flash, of three-twenty-fifths of a second's duration, recurs every five seconds, and on a clear night the light is readily distinguishable from a distance of twenty miles, while its reflection in the sky may be observed from a considerably greater distance.

The erection of this lighthouse was not without one humorous incident. While the lantern apparatus was being set in position, a plumber was sent to the rock. He spent one day and night there, a period that proved to be more than enough for him. The murmuring of the waves lost all their musical glamour for him when he was imprisoned on a wild, isolated, wind-and-wave-swept eyrie. He did not get a wink of sleep, and was scared nearly out of his wits. When morning broke, and the men were turned out of their bunks, the plumber expressed his fixed determination to return to the shore at once. His companions laughed at his fears, ridiculed his anxieties, coaxed and upbraided him in turn. It was of no avail. He would not do another stroke of work. Realizing the hopelessness of such a workman, the engineer in charge signalled the mainland for assistance. The steamer could not put out, but the lifeboat, not understanding the import of such an unusual call, made the dangerous pull to the rock, to ascertain what was the matter. When they found that it was to take off a scared workman, their feelings may be imagined. The demoralized plumber was bundled into the lifeboat and rowed back to shore. The blood did not return to his face, nor did he collect his scattered wits, until he planted his two feet firmly on the mainland, when he very vehemently and picturesquely expressed his determination never to accept a job in such a forsaken place again.

The old tower was reduced to the level of its solid base, and converted into an oil-store. The finishing touches were applied to the new tower, and on June 27, 1906, the scintillating and penetrating ray of the present Fastnet was shown for the first time. It is a magnificent light, and, being the latest expression of British lighthouse engineering upon a large scale, compels more than passing interest. The light is fully in keeping with the importance of the spot it marks, and the £84,000, or $420,000, which it cost has been laid out to excellent purpose. The light and fog-signal station is tended by six keepers, four being on the rock simultaneously, and two ashore. The latter constitute the relief, which is made twice a month if the weather permits, the service being one month on the rock, followed by a fortnight on shore. One keeper has day duty, maintaining a lookout for fog and to signal passing ships; two are on duty at night, the one having charge of the light and its operation, while his comrade devotes his attention to signalling ships and watching the weather. When a mist creeps over the light, the fourth keeper is called up to manipulate the explosive fog-signal. The lighthouse, being an important landfall, is a signalling-station for Lloyd's, and is also fitted with wireless telegraphy, wherewith the movements of outgoing and incoming vessels are reported to the mainland for notification to all parts of the world.

CHAPTER X

LIGHTHOUSES BUILT ON SAND

While the greater number of the most famous sea-lights have been erected upon the solid foundation offered by rock, in one or two instances notable works have been consummated upon sand. The two most remarkable achievements in this particular field of enterprise are the Rothersand lighthouse, off the coast of Germany, in the North Sea, and the Fourteen Foot Bank, in Delaware Bay, U.S.A.

The Rothersand light became necessary owing to the expansion of the German mercantile marine and the development of the ports of the Weser and Elbe. The estuary of the Weser River is hemmed in by shoals and sandbanks, similar to those found at the entrance to Liverpool, London, and New York, rendering navigation extremely hazardous under the most favourable circumstances. Bremerhaven, on the Weser, had been selected as the home port for the North German Lloyd Atlantic liners, but it was threatened with abandonment unless the entrance to the waterway should undergo improvement. It was of no avail to dredge a deep channel through the treacherous ridges of sand, if the general proximity of the shoal were left unmarked. Consequently, in order to secure the interests of Bremerhaven, it was decided by the three border States—Prussia, Oldenburg, and Bremen—to provide a powerful light at this danger-point. The financial problem was solved by the agreement to levy a special tax upon all vessels entering the Weser, to defray the cost of providing the safeguard.

The undertaking was somewhat formidable. The shoal, being of soft sand, was liable to erosion and movement, owing to fluctuating and changing currents. Then, again, the proposed site, some thirty miles from Bremerhaven and about halfway between that port and the island of Heligoland, was exposed to the assaults of the North Sea, where even slight breezes ruffle the water considerably. From the soundings and observations that were made, it was evident that the foundations would have to be carried down to a great depth, and that ordinary systems of construction were quite impracticable. At this juncture the Society Harkort of Duisburg, which had accumulated great experience in subaqueous work, was approached and asked if it would undertake the enterprise at its own risk. This was tantamount to a "no cure, no pay" proposal. If they succeeded, they would be rewarded for their labours; if they failed, they would have to face a heavy loss.

This firm, after careful deliberation, allowed that the work could be accomplished, but in one way only. This was to construct a huge caisson—practically a gigantic barrel of steel—on shore, to launch and tow it to the site, and there to lower it until it rested on the bottom. Then, by a removal of the sand from beneath this caisson, it could be sunk to a great depth, and, the interior being filled with concrete, a huge artificial core of rock would be created, capable of supporting a tower. This system is employed extensively in connection with bridge-building operations, and the firm entertained no doubts concerning its feasibility at Rothersand. The society accordingly prepared its designs, and advanced an estimate for the cost of the work.

At this juncture an unexpected competitor appeared on the scene. One of the engineers engaged in the preparation of the Harkort designs severed his connection with that firm, and, securing the collaboration of two engineering colleagues, established a rival concern, which tendered for the contract. They would follow the same lines, but would complete it for £22,750, or $113,750, instead of £24,025, or $120,125, asked by the Duisburg firm. The lower price was accepted, the more readily since it included the foundations, whereas the Society Harkort set these down as an extra. Naturally, the society was somewhat chagrined at this turn of events, after all the trouble and care it had taken to discover the most satisfactory solution of the problem, but subsequently it had good reason not to regret its loss.

The new engineers set to work and during the winter of 1880-81 constructed a huge caisson, which was launched and on May 22 of the latter year started down the Weser in charge of tugs. Then came a whole string of accidents. One night the unwieldy fabric got adrift and drove its nose into a sandbank, where it settled down with the tide. The towing cables were attached once more, and after a great struggle the structure was extricated on the next high-tide, and resumed its journey. Reaching the site without further incident, it was lowered by admitting the water within the barrel. But this task being accomplished somewhat crudely, the water rushed in with such force that the caisson commenced to spin round like a top, as well as bobbing up and down like an angler's float. It threatened to topple over and founder every moment, but, luckily keeping upright, finally touched bottom. Lowering was completed. Night having approached, workmen made themselves comfortable on the caisson, while the constructional steamer stood off and cast its anchor.

The men on the caisson, however, experienced one of the most sensational nights in their lives. As the tide rose, they found their novel home to be behaving somewhat curiously. It moved, and then heeled over. This was an alarming state of affairs, especially as the list gradually became worse and worse. They shouted frantically for help, but, a heavy fog having descended upon the shoal, their cries were absorbed by the white pall. At last the caisson careened over to such a degree that the men could not keep their feet, while the depressed edge was in danger of being submerged. The men crawled to the opposite or elevated side, and held on for their lives, expecting every moment that the structure would give a heave and roll over. It was a terribly anxious time for them, and at last, when the constructional steamer came alongside in the morning, they scuttled down the ropes from their perilous perch to the deck below, thankful for having escaped, as they thought, a certain watery grave.

The engineers spared no effort to save their work. They were harassed at every tide because the water rose above the depressed edge and flooded the interior. With all speed the wall at this point was increased in height, so as to prevent inundation. Then, stormy weather having cut away the sand under the elevated side, the structure gradually righted itself. When it had regained its vertical position, it was found that no serious damage had been done, but rather that the engineers had profited, inasmuch as the caisson had buried itself some 16 feet into the sand.

Winter was approaching, and so the engineers crowded on every man and effort possible, in order to get the structure sunk to the requisite level before work would have to be abandoned for the season. They departed from the engineer's axiom, "Make haste slowly," and paid the penalty. When the bad weather broke, compelling the return of all the workmen to shore, the fabric was left insecure. The lower part had been given its filling of concrete, but above a certain level the fabric depended only upon the iron shell of the cylinder. It was stiffened as much as possible with cross-timbers and bracing, but the elements soon made short work of this puny defence. The North Sea, in common with the other large stretches of water throughout the world, was swept by terrible storms that winter, and one morning, when the sea was scanned from shore through glasses, strange to say the caisson was nowhere to be seen. All sorts of rumours were circulated to account for its disappearance, among others being a sensational theory that the caisson, having reached swampy ground while being sunk, had simply dropped suddenly into the submarine quagmire, and had been swallowed up completely. But the divers, when they could get out to the site and could venture into the ocean depths, returned to the surface with a very different story. The waves had snapped off the top of the caisson at the upper level of the concrete within, and had carried it away. Thus ended summarily the first attempt to build a lighthouse upon the red sand at the entrance to the River Weser.

The project, however, was not abandoned. The Society Harkort was approached once more, and requested to undertake the work upon its own terms. The invitation was accepted, but the firm, realizing the abnormal risks incidental to the enterprise, revised their price, so as to provide for contingencies. It demanded a sum of £42,650, or $213,250, in return for which it undertook to supply a fully-equipped lighthouse less the illuminating apparatus. The terms were accepted, but the responsible authorities, having suffered a heavy loss from the first failure, decided to protect themselves against a similar disaster, so exacted a bond for £12,000, or $60,000, to be returned when the work should be completed and accepted by the Government. The Society Harkort, on its part, reserved the right to withdraw from the undertaking in the event of the caisson sharing the fate which overtook the first structure.

The contracts were signed in September, 1882, and the task was commenced. The first disaster was a blessing in disguise, for the new engineers were able to turn the mistakes of their predecessors to advantage. They designed a caisson of oval shape, with pointed ends, measuring 46 feet in length by 36 feet wide. It was an elaborate, staunch structure, towering to a height of 60¾ feet when launched. At a height of 8 feet from the bottom edge was a massive flooring built of iron. The space below constituted the area in which the men were to work upon the sea-bed, excavating the sand under compressed air, while the lower rim was a cutting edge, so as to facilitate the sinking of the mass as the sand was removed. The upper part of the caisson was divided into four floors, each of which was set aside for a specific purpose. The lowest was the concrete-mixing chamber ; that above carried the machinery and boilers ; the third floor formed the living-quarters for the men who worked and slept on the structure ; while the top floor formed a deck, and carried two powerful cranes whereby the material was lifted from the boats which drew

Photo by permission of the North German Lloyd S.S. Co.

THE ROTHERSAND LIGHTHOUSE.

This magnificent light marks a dangerous shoal in the estuary of the Weser. The masonry tower is built upon a massive concrete caisson driven deeply into the sand.

THE FOURTEEN-FOOT BANK LIGHTHOUSE, BUILT ON SAND.

The erection of this structure constitutes a brilliant achievement in United States lighthouse engineering.

alongside. Of course, when the caisson had been lowered into the water and was eating its way deeper and deeper into the sand, these platforms had to be moved higher and higher from time to time, as the base of the tun became filled with concrete, the outer walls of the fabric being increased to keep the top well above high-water mark.

When the caisson was completed on shore and sent into the water, it was an impressive-looking monster. The shell itself weighed 245½ tons, and with the various accessories aboard the weight was brought up to some 335 tons. It then had to be loaded down to the required depth for towing, for which purpose ballast in the form of pig-iron, concrete, and bricks, to the extent of another 245 tons, was stowed aboard, while delicate precautions were taken to maintain stability. The combined efforts of 120 men, working day and night for 127 days, were required to erect this caisson, and on April 1, 1883, it was ready for its transportation to the site.

The towing operation was extremely difficult, and the voyage out was full of exciting incident. It was possible to advance only on the ebb-tide, and the towing cables, 5 inches in diameter, were specially manufactured for the operation. Two of the most powerful tugs owned by the North German Lloyd Steamship Company were requisitioned, three other steamers engaged in the conveyance of requirements between tower and shore accompanying the procession. Although the engineers were ready, the weather, with aggravating persistence, refused to clear sufficiently to produce the smooth sea and calm demanded for the safe journey of the ungainly craft. Day after day slipped by, with eighty men on the alert, and with fires banked and steam raised on the vessels, ready to weigh anchor at the first favourable moment. Fifty-five days passed before the weather bureau recommended that the conditions were suitable. Under the foregoing circumstances the expense of this delay may be realized.

Directly the intimation was conveyed that the tow could be attempted, there was a scene of indescribable activity and bustle in the Bremerhaven dock, where the caisson was moored. Full steam was raised on the tugs, and at half-past three in the morning of May 26 the mighty steel barrel moved out of the dock. The towing ropes were hitched on, and very slowly the "Colossus," as the caisson was named, moved down the harbour, accompanied by the whole fleet of nine vessels engaged in construction work, so that the procession was imposing. It dropped down the river without incident, when, the tide turning, anchor was cast, and all was made fast until another advance could be made at four o'clock in the afternoon. But the rising tide was stronger than had been anticipated, and trouble was soon encountered. The caisson, pressed by the current, dragged and strained at the two tugs by which she was being towed, causing them to slip their anchors. It was an anxious moment. The two vessels could not hold the "Colossus"; in fact, they were being towed backwards by it. Hurriedly another tug was called up, and helped in the effort; but although the three steamers put on full steam ahead, they failed to keep the mass in check. Another tug was signalled, and then, under the combined effort of 350 horse-power, driving for all it was worth against the current, the four vessels mastered the swing of the scurrying water, and had the "Colossus" under control.

A little later the procession continued on its way to the North Sea, but when the boats came up with the Hoheweg lighthouse further disquieting news was received. The keepers signalled that the barometer was falling, and that a thunderstorm was hurrying across the North Sea from England. Anchors were thrown out hurriedly, and everything made snug and tight for the approaching storm. It burst with fearful severity. The waves got up, the wind blew with fiendish velocity in terrifying gusts, and the rain tumbled down in sheets. The engineers were on tenterhooks the whole hour and a half the storm raged, as they foresaw lively times if the unmanageable hulk broke loose. But the "Colossus" rode the gale as quietly as if moored to a wharf in dock. The storm, however, upset all calculations for the day. There was no possibility of getting the caisson out and sunk before nightfall, so the engineers prepared to pass the night at anchor, and to start off again with the dawn. The weather, ruffled by the thunderstorm, refused to settle down until a further day and night had been wasted. Then, at 7.30 in the morning, on a favourable tide, anchors were weighed, and, steaming hard through a broken sea, the tugs conveyed the caisson on its journey. At last the procession reached the buoy marking the site. The caisson was brought to rest, the water was admitted gently through the valves, and slowly, steadily, and vertically, the shell sank lower and lower, until a scarcely perceptible shock conveyed the intimation that it had touched bottom.

The most anxious part of the task was consummated with complete success: the caisson had been got to the site and sunk. Then the task of burying it deeply and irremovably in the sand was hurried forward. Workmen descended into the space beneath the bottom floor and the sea-bed. Under compressed air they excavated the sand within the area to permit the cutting edge to sink lower and lower. The sand, as removed, was lifted to the top of the "Colossus" and discharged overboard. Meanwhile the concrete-mixing machine got busy, and the stone heart of the tun was fashioned rapidly. Under this increasing weight the sinking operation was assisted very appreciably. By the middle of October the work had been advanced to such a stage that the total weight of the structure had been increased to over 3,350 tons, and the top deck of the caisson, which had grown in height by the attaching of successive rings of plates, was about 99 feet above the cutting edge, which had buried itself to a depth of 51 feet below low-water. Then work had to be abandoned, as the autumnal gales sprang up. The whole of the staff, with the exception of two men, who mounted guard over the work, were taken back to Bremerhaven. The gales increased in fury, culminating in a tempest similar to that which had destroyed the first caisson. Remembering the fate of that enterprise under such fearful pounding from wind and wave, the Harkort engineers naturally were somewhat anxious concerning the welfare of their handiwork under identical conditions. But the new creation was overwhelmingly strong where its predecessor was weak, although the seas, baffled in their efforts to upset the caisson, did not fail to leave their mark by knocking the superstructure and scaffolding about somewhat, as well as carrying away a few weighty pieces of the top hamper.

Work was resumed in February, 1884, and continued more or less regularly until November. Interruptions were of frequent occurrence, so that only about one-quarter of the time available could be turned to useful account. The structure which had been towed out of Bremerhaven a year previously had disappeared from sight, the rim of the barrel built on dry land being about 4 feet below water ; but, of course, as the work proceeded and the caisson sank, its walls were extended upwards, as already explained. When the structure had been sunk to its designed depth, the steel shell was 107½ feet in height, from the cutting edge to the top projecting above the water, and nearly 40 feet of its height was buried in the Rothersand. To sink it to this level required the removal of 3,000 cubic yards of sand from beneath the bottom floor of the structure ; while 49,100 tons of material were brought out from Bremerhaven and built into the steel shell to render it a solid elliptical mass, with the exception of a short central hollow space which has a narrow conduit connection with the outer sea, and which, fitted with a float, acts as a tide-gauge which may be read in the lighthouse. From this massive concrete pedestal rises the tower proper, which at the base is circular, with a diameter of 33¾ feet. This base rises in the form of a graceful concave curve to a height of 26 feet, and is solid except for two water-tanks. At the entrance level the tower is 23 feet in diameter. Above this are disposed four floors, comprising the cellar, storeroom, kitchen, and living-quarters for the men, crowned by the lantern, the gallery of which is 80½ feet above low-water.

The external appearance of this interesting lighthouse is somewhat different from the general conception of such a building. Instead of being merely a circular top and lantern, there are three semicircular turret-like projections on the dwelling-room and lantern levels, which serve for directing and warning lights as well as for a lookout station.

The fickle character of the North Sea where it rolls over the Rothersand is reflected by an experience which befell the Harkort engineer and the superintendent of erection for the authorities, who wished to complete his duty of inspection. The finishing touches were being applied, a squad of twelve workmen being in the tower to continue the work during the winter. The early December day was fair and the sea smooth, as well as giving every indication of remaining quiescent for some hours. The superintendent had arranged to spend his Christmas holidays with some friends, and desired to complete his duty in good time, so that his sojourn might be free from care. The two started off in the steamer, and landed without effort. But while they were engaged in their work of inspection the wind and sea freshened, so that a boat could not be sent from the steamer to take them off. It was an amusing situation which was keenly enjoyed at Bremerhaven ; but all would be right on the morrow, said everyone. But the next day the weather was worse, and continued so for day after day. When a fortnight had passed without it being possible to succour the weather-bound engineers, amusement gave way to anxiety, more especially as a signal was flying from the tower which conveyed the unwelcome intelligence that one of the workmen had fallen ill. The feelings of the superintendent may be imagined. He had visions of spending his Yuletide in a draughty, half-finished lighthouse tower, where comfort was conspicuous by its absence, and where seasonal fare such as he had been anticipating keenly was unknown. But on December 21 the constructional engineers, having grown impatient with the weather, sent out one of their boats, with instructions to bring everyone ashore at all hazards. The waves were running high and the wind was gusty, but the steamer anchored as near the lighthouse as she dared, and by means of her boats, which were in momentary danger of being swamped, brought off the two engineers as well as all the workmen except two. The latter remained behind as a guard, and, being given a good stock of seasonal provisions and other necessities, were left in their splendid isolation. The superintendent, after all, was able to enjoy his Christmas holidays.

The succeeding spring brought a resumption of toil, and by September the tower was completed except for the illuminating apparatus. One feature was observed during construction and had to receive attention. The free swing of the currents and tides, being obstructed by the tower, had commenced heavy erosion, big hollows being scooped out of the soft sea-bed around the caisson. As it was quite possible that in the course of time this scouring might imperil the safety of the building, protective works had to be undertaken. These were of an elaborate character, and comprised the sinking of mattresses, fashioned from brushwood, around the foundations, upon which were dumped boatloads of broken stone. This mattress had to be nearly 50 feet in width, and in some places about 15 feet in thickness. For this protective work alone some 176,550 cubic feet of brushwood, and 600 tons of block-stone to hold it down, were used. These measures, however, effectually overcame the danger of erosion.

On November 1, 1885, the light was shown for the first time, and the greatest peril at the entrance to the Weser was indicated far and wide by night and day. It was a magnificent achievement, carried through in the face of enormous difficulties, sensational incidents innumerable, and upon a foundation of disaster. The lighthouse is as firm as if it were anchored upon a solid granite rock, instead of having its roots thrust deep into treacherous shifting sand, and constitutes an imperishable monument to German engineering ability ; while, all things considered, the cost was low, being only £43,400, or $217,000, in all. The light is electric, the power being supplied from a station on shore, and fed to the lighthouse through a submarine cable ; the keepers are also in submarine telegraphic communication with the mainland.

When the United States set out to build a similar structure in the spacious Delaware Bay, they were confronted with a prospect just as forbidding, and a task in every way as difficult, as that offered in connection with the Rothersand. There is a dangerous shoal about twenty miles off the land, where the Atlantic beats with furious rage, and where vessels were apt to stick hard and fast. It was described as " Fourteen Foot Bank " by mariners, from the depth of the water flowing over the shoal, and this colloquialism has provided the name for the present guardian light. The open situation did not augur favourably for the completion of a lighthouse at this spot, but the American engineers were resolved to make the attempt. Accordingly, plans were prepared for a construction upon the caisson principle, which was the only method promising success.

The preliminary step was the fabrication of a caisson. The first part was more like a raft with sides. It was about 40 feet square, 5 feet thick, and with walls 7 feet deep. It was built of timber, the staves being 12 inches square, and upside down—that is, with the floor uppermost—on a building-slip, as if it were a ship, and was launched into the water upon similar lines. The sides and top were lined, so as to secure water-tightness. In the centre there was a circular space 5 feet in diameter to form the air-shaft.

As the structure was built upside down, the rim was brought to the lowermost position, and this formed the cutting edge, which was to be sunk into the sand. On this floating platform a circular iron cylinder was erected. This tube was 35 feet in diameter, and was built up in plates, 6 feet in width by 1½ inches thick. When three rings of iron were set up the cylinder was 18 feet in height. In order to sink it to a depth of 15½ feet into the water for towing purposes, it was charged with a layer of concrete, 9 inches in thickness, to serve as ballast, and in this condition the caisson weighed 400 tons.

This huge barrel was built at Lewes, Delaware, and when it was launched two powerful steam-tugs set out to drag it to the shoal, twenty miles away. As the tide rises and falls a matter of 6 feet in these waters, and the currents are somewhat wicked, the engineers displayed no undue haste. They waited for the first favourable opportunity, and seized it. But it took the two tugs some six hours to reach the site ; an average speed of about three and a half miles per hour cannot be construed into fast travelling.

When the mighty caisson had been warped and nudged dead into position over the desired spot, water was admitted. With a gurgling and hissing the hulk sank slowly into the sea. At last a slight jolt, which quivered through the mass, signified that the structure was resting on the bottom. The engineers gave a sigh of relief, but the next instant changed it to a cry of dismay. The caisson began to heel over to one side. Was it going to capsize ? That was the absorbing fear. It canted more and more, until at last it had a list of 12 degrees. *It had not sunk vertically !* There was less than 16 inches of water between the sea-level and the rim when the caisson first jarred against the sand, and if it careened over too far the water certainly would rush in, roll the whole tub over, and tumble it hither and thither over the sea-bed. The engineers watched that caisson as closely as a cat watches a mouse-hole. Presently it eased up, and then, as the tide rose some six hours later, it began to right itself. The engineers were relieved once more. The danger was over. But their self-satisfaction was soon upset as the tide began to ebb, because again the cylinder gradually fell over on its side. The cause of this strange behaviour flashed upon them. The surface of the sandbank was not level ! The mass in sinking had touched bottom on the highest point of the shoal, and was trying to find its own level.

Without any further delay, the engineers decided upon an ingenious means of correcting this erratic and dangerous action. The tugs were despatched hurriedly to Lewes to bring out cargoes of broken stone, which had been delivered for the preparation of the concrete. While the steamers pursued their errand, the engineers fashioned large pockets on the elevated section of the structure, into which the stone upon its arrival was placed. Gradually but surely the caisson not only was corrected, but the weighted end was induced to settle into the sand, until the opposite free edge in its turn was resting upon the shoal.

In this manner all danger of further canting now was removed. As the rim had been brought perilously near the water-level, and there was a possibility of flooding from a rough sea, the walls of the caisson were extended vertically with all haste; meanwhile two additional rings of iron were placed in position, and the top was brought about 20 feet above the water. While this work was in progress the structure gradually bit farther and farther into the sand, until at last it secured a firm hold.

At the earliest possible moment the air-compressors were set to work, and air was driven into the space between the cutting edge and the roof, in which the men were to work. This space was 40 feet square and 7 feet deep. The greater pressure of the air drove the water out from this space, and the men were able to enter through the air-lock and to work upon a dry surface, isolated from the surrounding sea by the fence formed by the cutting edge.

The men toiled in eight-hour shifts continuously, removing the sand within the space and sending it upwards to be discharged overboard. As the area was excavated, the cutting edge sank deeper and deeper, so that the structure became more and more firmly embedded. There was apprehension that the obstruction offered by the caisson to the movement of the currents might set up undermining around the cylinder, as in the case of the Rothersand ; but the engineers arrested any tendency in this direction by dumping large pieces of stone overboard around the tub. Some 6,000 tons of stone were used for this purpose, so that the caisson has an impregnable protection.

As the structure sank lower and lower, owing to the excavation, concrete was dumped around the air-tube above the floor of the space in which the men were labouring, while successive rings of iron were added to the top of the cylinder. The men worked with great gusto in their novel situation, and, the task being prosecuted uninterruptedly throughout the day and night, the cylinder sank from 12 to 24 inches during the twenty-four hours. This labour was maintained until the cutting edge of the caisson was 33 feet below the surface of the shoal, when the engineers called halt. They considered that the task had been continued to a sufficient depth to secure the requisite rigidity for their lighthouse. The men left the working chamber, which was then tightly underrammed with sand, so as to form a solid foundation, while the air-shaft was filled up with rammed sand and sealed with a thick plug of concrete. The wall of the iron cylinder had been intermittently increased in height by the addition of successive rings of plates, until the rim was 70 feet above the cutting-edge and projected about 30 feet above the water at low-tide. From the bottom to a height of 40 feet it is virtually a solid mass of concrete, protected by a skin of iron 1½ inches thick. Further concrete was added, bringing the solid section to within 10 feet of the rim, so that the concrete heart is about 53 feet in height and 35 feet in diameter. It is a solid circular rock sunk into the sand, and as firm and free from vibration as a granite core.

Upon this foundation a house for the light-keepers, crowned by a tower, was erected, the focal plane being 59 feet above mean high-water. It is fitted with a light of the fourth order, visible for thirteen miles.

One of the most important features in connection with the Fourteen Foot Bank light was its small cost, which was below the estimate, especially when it is compared with the German work. The United States Government appropriated a sum of £35,000, or $175,000, for the undertaking, but the total expenditure was less than £25,000, or $125,000, so that a sum of £10,000, or $50,000, was handed back to the Treasury—a most unusual event in connection with Government contracts. The lighthouse was finished and brought into service in 1886.

The success of this novel enterprise prompted the authorities to essay a more daring project—the erection of a lighthouse upon the caisson principle on the Outer Diamond Shoal, off Cape Hatteras, North Carolina. But the storms encountered off this inhospitable coast have proved too overpowering for the engineer. Numerous attempts have been made, but disaster has been their invariable fate. The Diamond Shoal refuses to be indicated by anything except a lightship.

CHAPTER XI

SOME LIGHT PATROLS OF THE FRENCH COAST

In the matter of safeguarding its shores the French nation has displayed considerable enterprise, and its engineers have added some magnificent contributions to this field of engineering. The maintenance and welfare of these aids to navigation is placed in the hands of the Service des Phares, which is controlled by the Department of Bridges and Roads. The French scheme is the disposition of the lights along the shore in such a way that their ranges overlap on either side, so that, as one passes along the coast, before one ray is dropped the next is picked up. Electricity is employed extensively as the illuminant, so that the lights are of great power and twinkle like brilliant white stars on a clear night.

While the majority of these guides are erected on the mainland, others rise from islands lying off the coast, which, by their position in deep water, render navigation hazardous. The finest expressions of French lighthouse engineering are to be found along the rugged islet-dotted coast of the huge indentation in which lie the Channel Islands—the cruel coast of Brittany. It was off the western extremity of Brittany, which thrusts itself well out into the Atlantic Ocean, forming the point generally known as Ushant, that the *Drummond Castle* lost her way, to pull up with a fatal crash against one of the jagged reefs stretching to seaward. While this wreck was but one of many in these troubled waters, it sent a thrill round the world, owing to the terrible loss of life with which it was accompanied.

It is not surprising, therefore, that the French Government has endeavoured to remove the evil notoriety which this coast has reaped, and to render it as safe as the other stretches lying to the north and south. The conditions, however, are against the engineer, as the nose of the mainland projects well into the ocean, and receives the full brunt of its attacks when gales rage, so that a foothold is precarious.

When the question of lighting this inhospitable stretch of coast arose, the French authorities debated whether it would not be easier, cheaper, and more satisfactory, to place the lighthouses on the mainland at a sufficient altitude, and to fit them with adequately powerful lights to indicate the outlying reefs. The general opinion was in favour of such a practice. So when Léonce Reynaud proposed to mark the Heaux de Bréhat with a magnificent tower, there was considerable opposition. The critics maintained that it was a flagrant temptation of Fate to attempt the conquest of such an evil wave-swept rock, the head of which was barely visible above high-water, and was of such small dimensions that work would be possible for only a few hours daily and then by no more than a mere handful of men.

The engineer was confident that he could surmount all difficulties in construction, and that he would be able to erect a tower which would defy wind and wave, so he gained the day and received the requisite sanction to proceed with his undertaking. He had surveyed the rock and its surroundings thoroughly; had discovered the velocity of the currents, and their varying directions under all conditions of weather. They tore along at about nine and a half miles an hour, and this speed was augmented considerably in rough weather. He selected the site for the lighthouse about nine miles from the Isle of Bréhat, where landing would have to be made at low-water, owing to the water rushing first from the island to the rock, and then in the opposite direction, according to the movements of the tides.

The Isle of Bréhat was made the base for operations. It is freely indented, and one of the coves was found to form an excellent little harbour. A rough stone jetty was run out for a length of 170 feet, and while one fleet of boats was retained to convey material from the island to the rock, another was kept to bring supplies to the island for preparation, and the support of the men, whose quarters were established at this depot. Sixty men were employed on the work. They dressed the granite stones and prepared the woodwork as it arrived in the raw condition, ample workshops being provided for these purposes.

The face of the rock was cleaned off during the brief intervals when it was bared by the sea, and rough stones and masonry were laid in concrete and continued solidly to a point 13 feet above high-water. Around this confined platform quarters were built for the handful of men who stayed on the rock during the periods of calm weather, as too much time was lost in travelling to and from the island, while there were risks of landing being interrupted by the swell. A temporary light was also placed in position while constructional work was proceeding, to warn navigation. The facilities also included a small forge for the fashioning upon the spot of the iron dogs and bolts whereby the stones were clamped together, and this proved highly convenient, except for one thing : when the water was somewhat rough and playful, the waves, striking the rock, flew into the air, soused the forge, and extinguished the fire.

The preparations of the foundations proved exceedingly tedious. The rock is a very hard black porphyry, but the surface was so scarred with fissures and deep cracks that the whole of the upper surface had to be cleaned off, so as to remove all rotten and splintered rock in order to secure a firm, solid foundation. Then a circle 38 feet in diameter was marked off, and masons cut away all the rock around this line to a depth of about 20 inches and of sufficient width to take the stones—a trench, as it were. This work had to be executed during the short period of low-water, and a special schedule was prepared to insure the men concentrating the whole of their energies upon the task when opportunity offered. As the ebbing tide began to bare the space, the workmen were called, and they followed the receding water, never leaving the spot for meals, but toiling

Photo by permission of the Lighthouse Literature Mission.

THE HEAUX DE BRÉHAT LIGHT.

A striking tower built by Léonce Reynaud off the exposed Brittany coast. It is 159 feet high and took six years to complete.

FITTING THE LANTERN OF LA JUMENT LIGHT.

continuously until the returning tide drove them off. As a rule the men were sufficiently fleet to get clear untouched, although they delayed their retreat until the very last moment; but at other times the sea was a trifle quicker, and the men received an unexpected douche from a scurrying wave.

When this trench had been cleared out and the face levelled, the outer ring of stones was laid and secured firmly in position. The inner space of the rock was left in its roughly trimmed condition, and was then buried beneath cement and rock to the level of the outer ring of stones, forming a platform ready to receive the mass of the tower. The outer ring was the main consideration, and the work had to be finished in such a manner that a tight joint was made with the rock, to resist the penetration of the water. When the men were compelled to lay down their tools for the coming tide, they hastily applied a thick covering of quick-drying cement to the work completed, thereby protecting it against the disintegrating and percolating action of the sea.

Ere the work had started thoroughly, the engineer was faced with a trouble which he had not anticipated. The men were left to attend to their own desires in the way of provisions. This haphazard arrangement had the inevitable sequel. Some of the men were stricken down with scurvy, and the disease promised to secure a firm hold, when the engineer stepped in with a firm hand. He established a canteen, the contractor of which was compelled to maintain a supply of varied provisions for six months at least, lest the little colony should become isolated by rough weather. A regular varied bill of fare was imposed upon the workmen, who were compelled to purchase their requirements from the canteen. By this firm and timely action the disease was stamped out. The engineer also enforced other stringent regulations in the interests of health. The men were compelled to bathe once a week, and had to turn their sleeping-blankets into the open air every day; while the quarters had to be washed out and the walls given a dressing of limewash at frequent intervals.

When the visitor approaches the tower for the first time, he cannot fail to be impressed by its unusual design. It appears as if a former tower of great diameter had been decapitated, and another more slender building placed upon its butt. This is due to the ingenious idea adopted by Reynaud. The lower part of the tower rises like the trunk of a tree from the base, which is a solid plinth, to a height of 39 feet above highest spring-tides. At the top this lower tower is 28 feet in diameter, as compared with 38 feet at the base. Here the butt is levelled off, and from its surface rises the lighthouse proper, in the form of a slightly tapering cone, leaving a narrow gallery around the superimposed structure to serve as a "set-off" and landing or entrance platform.

In carrying out his work, Reynaud followed a principle quite divergent from the prevailing practice in lighthouse construction. He did not attach every stone irremovably to its neighbours, but merely made fast the masonry at varying points, where the mass of water might be expected to expend the greater part of its violence. The method he adopted is very simple. Keystones are introduced at selected points in each course, and these are driven up and held tight by granite plugs and wedges. The principle was assailed at the time as being deficient in strength, but no apprehensions ever have arisen concerning the safety of the tower, so that the engineer's daring ingenuity has been completely justified.

Considering the isolation of the rock and its wind-swept position, it was built in a very short time. The whole of the year 1834 was devoted to the survey of the rock, close observations of the prevailing meteorological conditions, and the preparation of the design. The succeeding year was confined to the establishment of the workmen's quarters, the cutting of the annular trench in the rock, and the setting of the masonry course. The erection of the superstructure occupied nearly four years, the work being completed and the light exhibited in 1859, according to the inscription. The tower is 159 feet in height, and the light has a range of eighteen miles.

Since the Heaux de Bréhat was conquered so successfully, French lighthouse engineering skill has been manifested actively around the ill-famed Brittany coast, which now is robbed of the greater part of its dangers. Reynaud's work, however, did not bring complete safety to the waters from which it lifts its imposing form. Four miles off the self-same island is the plateau of Horaine. This is a chain of rocks, the greatest peril of which is that at high-tide nothing whatever of them is seen, and their existence is betrayed only by the agitated and broken waves rushing over them with fearful force. As the tide falls the water becomes more tormented, and is torn into flying foam, until, when it has almost ebbed, these jagged fangs may be seen projecting above the surf. Bearing in mind these terrible characteristics, it is not surprising that time after time vessels which had been driven out of their course by tempestuous weather, or had got lost in a dense fog, blundered into this death-trap and were lost.

The French Government was sorely puzzled as to how to overcome this danger. The engineers fought the elements valiantly for forty years in an effort to crown Horaine with a beacon, but time after time they were defeated. Landing on the reef is highly dangerous. The rocks are surrounded by surging, eddying currents, running at anything from six miles upwards per hour, while the slightest ruffle of wind is quite sufficient to stir up the water so as to fling it swirling over the rocks even at lowest tide. Once or twice, when a period of abnormal calm prevailed, the engineers struggled on to the rock and hurriedly built a substantial masonry beacon, but its life was always brief. The first two or three gales which pounded and roared over the chain invariably scattered the handiwork of man in all directions.

Then another expedient was attempted. A party landed upon the ridge, drove a hole into the solid rock, and there set a vertical iron girder 4 inches in thickness, trusting that it would hold fast and indicate the reef sufficiently during the day. But its life was short. A gale came along and snapped the post in twain, leaving a twisted, bent stump, some 36 inches long, remaining on the rock.

In 1890 another bold effort to subjugate the ridge was made. An hexagonal structure was designed, and it was determined to plant this on the rock by hook or by crook, and so firmly as to resist the most powerful hammerings to which it could be subjected by the waves. Six holes were bored into the rock surface to form the corners of the hexagon. But before commencing the work proper it was decided to insert an iron post, 6½ inches thick, into one of the holes, and to leave it to see what would happen. Time after time it was inspected, and was found to be safe and sound. Two years had slipped by, practically, since the post was planted, and it was still intact. The engineers thought they had triumphed, and were preparing their plans, when the news came that a heavy storm, which had swept the coast, had broken the pillar off flush with the rock.

This necessitated another change in the designs and the plan of campaign. After further discussion it was decided to proceed right away with a masonry tower, although the engineers were prepared for a mighty tussle. The surveys showed that, as the rock upon which the building was to be erected was covered by 10 feet of water during the highest spring-tides, work upon the foundations would be confined to the lowest neap-tides, when about 4 feet of the rock were exposed. But the tide sinks to the very low level desired infrequently—about four days in every month. Even then work would be possible for only about an hour per day—four hours per month! The prospect certainly was far from being attractive, especially as even to accomplish this meed of toil the calmest weather and smoothest sea were imperative, and it was scarcely to be expected that everything would be in favour of the engineers at one and the same time.

Another adverse feature was only too apparent. If unpropitious weather prevailed just after an hour or two's work had been completed, the chances were a thousand to one

PREPARING THE FOUNDATIONS OF THE JUMENT LIGHT.

This illustration conveys an idea of the difficulties encountered in connection with this work.

THE JUMENT LIGHT RECENTLY ERECTED OFF USHANT.

This beacon was built with a legacy left by M. Potron, a distinguished French traveller, in the interests of humanity.

that it would be swept away. But this was a contingency which had to be faced. The engineer could only do the utmost humanly possible to secure his work, and then must trust to luck.

With infinite difficulty a small corps of daring workmen and appliances of the simplest description, together with materials, were got out to the rock upon the first favourable day when there was a very low tide. An outer wall of bricks was built piecemeal, and the space within was filled with concrete. This stood, and so the engineer secured a level plinth upon which to place his tower. He selected an octagonal building, the angles of which touch the circumference of a circle 20 feet in diameter described on the rock. It was to be 50 feet in height, bringing the warning light about 40 feet above high-water. The beacon was to be a concrete monolithic structure at least for the greater part of its height, as the light was to be of the unattended class. Accordingly, the mould was formed by setting a cast-iron post, 18 inches in height, at each corner of the octagon, this support being anchored into the solid rock beneath. These posts contained grooves to admit sliding wooden uprights, which were to be firmly wedged, these joists being inclined to take the angle, or batter, proposed for the tower. Heavy transverse pieces of timber were laid between these posts, forming a capacious octagonal box, into which the concrete was poured. As the filling process behind the wooden wall advanced, angle pieces of steel were superimposed and bolted up.

The security of the structure occupied the sole attention of the engineer. When work had to cease, and the boat put off with the workmen after a spell of toil, the engineer would watch the rising tide and the waves sweeping over his structure, until at last it disappeared from sight. As the tide fell he followed the receding waters just as eagerly, and gave a sigh of relief when he saw that the tower was still withstanding the blind forces of Nature. In the early stages an effort to protect the work, when the men had to retreat before the rising tide, was made by covering it with a heavy piece of sailcloth, lashed down and weighted in position with huge masses of pig-iron. This served its purpose for a time, but finally the sea got the upper hand, tore the canvas from its lashings, and carried it away, together with the whole of its weights. Then a wooden protective device was employed, and this likewise held out until a particularly unfriendly September gale smashed it to matchwood, as well as damaging the concrete slightly here and there.

The men took their tools and materials with them on every visit, and, as the tower rose, the working spells between the tides became longer and longer, until, when a point above high-water was reached, work was continued throughout the day whenever the rock was approachable. A small wooden platform was erected on one side, on which the concrete was mixed, while on the other there was a little shelf with a small cistern, which was filled with water from the boats below, through the agency of a pump. A jury derrick was rigged up to lift the material and men to the working level. As the tower rose in height, the wooden mould had to be dismembered and re-erected upon the new level, this operation being repeated no less than forty times until the desired height was gained. Work was exasperatingly slow and intermittent, while it had to be suspended entirely for about six or seven months, as no one dared to venture near the rock in winter. Taken on the whole, it was one of the most anxious and difficult pieces of the work of this character which the French Government has ever undertaken, while the working area was so confined that less than a dozen men could toil simultaneously without getting in one another's way.

Recently the Brittany coast has been further protected by another magnificent beacon, the Jument lighthouse, off Ushant. This awful spot has long been marked by a very powerful electric light at Creach, which may be seen over twenty miles away, and, together with its fellow on the opposite end of the island, may be said to guide the crowded shipping around this promontory very effectively. But foggy weather reduces the mariner to helplessness, as the sea for two miles round the island is studded with reefs, ridges and rocky humps of a very formidable character, so that vessels have to keep well beyond this zone. When the light is obscured, safe travelling is possible only by going very slowly and making liberal use of the lead, while the captain must keep a sharp eye upon the rapid currents which set inshore if he would not be thrown upon the rocks he is seeking sedulously to avoid.

The French Government, with its characteristic thoroughness, determined to secure the complete indication of the Ushant and all its dangers by a carefully-conceived and comprehensive chain of lights distributed over the dangerous area. The urgency of such a scheme is obvious when it is remembered that it is computed that 24,000 vessels of all classes pass Ushant in the course of the year. At the same time the sea's harvest of vessels and lives off this rocky shore every year is appallingly heavy. The only handicap to the immediate completion of the Government's humane project is the extreme difficulty of the work and its prodigious cost.

Fortunately, through the extreme generosity of a French traveller—M. Potron—it was rendered possible to commence the scheme. Upon his death, and according to the terms of his will, dated January 9, 1904, this gentleman left 400,000 francs—£16,000, or $80,000—for the erection of a lighthouse of the latest type and with the most powerful lighting apparatus off the coast washed by the open Atlantic, and even suggested that a site off Ushant would be found the most beneficial to humanity. After consultation between his executor, residuary legatee, and the Government, a rock known as La Jument, off the south of the Ile d'Ouessant (Ushant) was selected for the site of his monument. The lighthouse engineers advocated a tower 118 feet in height, with a light of the latest type and a modern fog-signalling apparatus. This proposal was accepted, and was sanctioned on November 18, 1904, by the parties concerned.

Headquarters were established in the Bay of Lampaul, on

Ushant Island, which immediately faces the site, and by the end of 1904 the preparations were well advanced. A steamboat, a launch and a lifeboat were secured, the first-named for the purpose of maintaining communication with the mainland and to bring in supplies, together with suitable craft for transporting material and provisions to the rock. The situation of the ledge and its exposure to the worst weather rendered approach very difficult. The danger spot itself is completely covered at high-tide, and only projects 4 feet at low-water. So far as the foundations were concerned, work was only possible for a few hours at a time. During the closing months of 1904 seventeen landings were made and fifty-two hours in all spent upon the rock, while in the succeeding year the men landed fifty-nine times, to put in an aggregate of 206½ hours.

The current rushes round the reef with a velocity of some ten miles per hour, varying its direction according to the movements of the tides. Investigation proved the existence of a small space of water on one side where the boats could approach and moor safely in an eddy. The men were brought out in the steamer, which also towed the launch and the lifeboat. The latter was kept in readiness alongside the rock while the men were at work, in case of emergency. A sharp eye had to be kept upon the weather while the handful of men laboured hastily preparing the face of the rock, and at the first signs of a threatening sky or increased movement in the swell the steamer blew its siren, the men scrambled aboard, and were hurried back to the island.

The year 1906 was one of bad weather, rendering frequent approach impossible. During this season the men landed only thirty-nine times and toiled for 152 hours, while the sum of their achievement was the least throughout the whole seven years which the tower occupied in its erection. The building is solid for about 30 feet above the rock, and in 1908 the construction of the tower proper was commenced. The base is circular, with a diameter of 33¾ feet; but the tower itself is of octagonal form, with a diameter at the base of 28 feet, tapering slightly to the top.

One notable feature in connection with the work was the utilization of electricity for the operation of the derrick, which was driven by a petrol motor coupled thereto. This was supplemented in times of pressure with another derrick, driven by current generated on the steamer, from which a cable trailed to the rock. Altogether 4,180 tons of masonry were transported to the rock and set in position. During the seven years the work was in progress, from the first landing to the final withdrawal of the workmen, 449 landings were made and 2,937 hours of work put in. The largest annual aggregate of labour was in 1911, when 70 landings were made and 400 hours turned to useful purpose. The tower, which is of imposing appearance, has six floors for the convenience of the keeper, stores, etc. The apartment immediately beneath the lantern contains the fog-signalling apparatus, which comprises a siren driven by air which is compressed for the purpose by means of a fourteen horse-power petrol motor. The signal is as follows : Three blasts of one and a half seconds' duration with intervening intervals of one and a half seconds, followed by a silent period of fifty-two and a half seconds, one cycle thus being emitted every minute. The light, which is thrown from an elevation of 110½ feet above high-water, throws groups of three red flashes at intervals of fifteen seconds, and has a maximum range of twenty miles in very clear weather.

In accordance with the terms of the donor's will, the light is named after the rock upon which it stands, and therefore is known as the Jument of Ushant lighthouse. The benefactor's second wish is also respected in the inscription wrought in the solid granite, which translated runs : "This lighthouse was built with the legacy of Charles Eugène Potron, traveller, and member of the Geographical Society of Paris." The sum set aside by this benefactor of humanity, however, did not defray the entire cost of the lighthouse. As a matter of fact, the total outlay on the undertaking was more than twice the sum left for the purpose, totalling 850,000 francs—£34,000, or $170,000. The Government decided that the munificence of its citizen offered the opportunity to carry out the first instalment of the scheme it had in view upon the most complete lines—hence the heavy disbursement. Nevertheless the origin of the Jument lighthouse is almost unprecedented in the annals of lighthouse engineering, and it probably ranks as the first important light which has been built in accordance with the terms, and with funds, left by a will.

CHAPTER XII

THE GUARDIAN LIGHTS OF CANADA'S COAST

THE phenomenal commercial expansion of the Dominion of Canada, which has brought about an amazing development in the maritime traffic with that country on both its seaboards, naturally has been responsible for the display of striking activity in the provision of aids to navigation. Both the Atlantic and Pacific coastlines bristle with dangers of a most terrible nature ; the innumerable islands and precipitous flanks of rock recall the wild ruggedness of the western coast of Scotland or the forbidding Atlantic shoreline of France and Spain.

When the ships of Britain first traded with Canadian shores, shipwrecks and ocean tragedies were numerous ; there is no escape for a ship which is caught on those pitiless coasts. The early settlers, therefore, did not hesitate to provide ways and means of guiding navigators to safety. Their first lights were primitive, comprising bonfires fed with wood, of which ample supplies abounded, pitched on prominent headlands ; and these flickering rays, when not obscured by smoke and fog, served to speed the ship safely on her way.

The British pioneers, naturally, did not hesitate to improve upon these uncertain crude methods of warning, in course of time, by the erection of more substantial lights. These for the most part comprised timber-frame dwellings, used by the family entrusted with the maintenance of the light, from the roof of which a wooden tower extended, similar in design to the buildings favoured for a similar purpose in the United States. Many lights of this class are still doing faithful service to-day, and although one might anticipate the destruction of such a beacon from fire, yet, owing to the unremitting care displayed by the families associated with the upkeep thereof, this awful fiend has not been responsible for the temporary extinction of many lights in the country's history.

One of the oldest, if not the first light to be established, was that on Sambro Island, to indicate the entrance into Halifax Harbour, Nova Scotia. This signpost of the sea was set up in 1758, and fulfilled its purpose for 148 years, when it was reconstructed and fitted with the most up-to-date appliances. The white flash now bursts forth, at an elevation of 140 feet above mean high-water, from the top of a white octagonal stone and concrete tower, and is visible from a distance of seventeen miles. When it is blotted out by fog, a powerful signal is given once every ten minutes by a cotton-powder charge. Mariners, however, are cautioned against attempting to make Sambro in fog, as the shore is wild and cruel. This explosive signal is emitted rather to communicate a timely warning to vessels which have lost their way.

The two most dangerous spots in the approach to Canada, however, lie off the mainland. One is the irregular triangular island of Newfoundland; the other is a low-lying stretch of sand known as Sable Island. Both are amongst the most ill-famed graveyards in the North Atlantic, where hundreds of ships have gone to their doom. Even to-day, although both are well protected by lights, wrecks are by no means uncommon. Sable Island is stalked by the ghosts of scores of seafarers who have been the victims of some ghastly ocean tragedy upon its banks.

The island of Newfoundland lies in the jaw of the River St. Lawrence, with two narrow passages leading between the Gulf behind and the broad Atlantic. Both straits offer dangers to navigation, although in this respect that of Belle Ile, whereby the northern corner of the island is rounded, is the worse offender. Yet the most dangerous corner of the island is, not where the waterways are hemmed in, but that tongue which thrusts itself far out to sea, to terminate in the bluff headland of Cape Race. This shore-line is as serrated as a fine saw, being a succession of indenta-

Photo by permission of Lieut.-Col. W. P. Anderson.

THE CAPE RACE LIGHTHOUSE, NEWFOUNDLAND.

One of the finest and most powerful beacons in the world. It is filled with the hyperradiant apparatus, and the ray is of 1,100,000 candle-power.

By permission of the Lighthouse Literature Mission.

CANN ISLAND LIGHTHOUSE ON THE EAST COAST OF NEWFOUNDLAND.

This is a typical example of a wooden frame building. The tower projects from the roof of the home of the lighthouse-keeper and his family.

tions and steep promontories, with submerged reefs running far out to sea. To the south lies that great submerged tableland, invariably curtained in fog, where mighty icebergs that have come down from the north pound and grate themselves to pieces, which throughout the shipping world is regarded with dread—the Grand Banks. This south-eastward corner of the island, by being thrust so far outwards, brings the rocky headlands into the path of the vessels plying between Europe, Canada, and New York.

The shortest route between the Old and New World extends across the northern half of the Banks, with a slight swing southwards to avoid Cape Race. So far as the great liners are concerned, they are spared this peril, inasmuch as their prescribed lanes give the cruel coast a wide berth; but all other shipping has either to swing round the headland to enter the Gulf of St. Lawrence, or strike farther north and pass through the Strait of Belle Ile. The latter route, however, is available for only five months in the year; the greater volume of the traffic skirts the southern shores of the island.

Under these circumstances Cape Race is to the western side of the Atlantic what the Fastnet and Bishop Rocks are to the eastern boundaries of this ocean. Even if the wild character of the coast were not sufficient justification for a light, the currents experienced off these shores, which are of high velocity and violently broken up by the indentations and protuberances, would demand the provision of a beacon. Over one hundred vessels of all descriptions have been smashed to pieces in the vicinity of Cape Race alone. The Allan liner *Anglo-Saxon* crashed into the cliffs and went down in 1864 with 290 souls. In this instance the death-roll would have been far heavier had it not been for the pluck and grit of the lighthouse-keepers, who, observing the wreck, hurried to the water's edge, lowered themselves with ropes from the heights above, and, stumbling, groping, and feeling their way through the darkness, at imminent risk to their own limbs and lives, rescued 130 of the luckless passengers and crew from the wreck, who were huddled on a ledge under the cliffs, hungry, shivering with cold, and too exhausted to assist themselves. The light-keepers and men from the telegraph-station had to lift these helpless survivors one by one to the top of the precipice, a task demanding herculean effort, patience, and intrepidity, and to lead and help them to the lighthouse, where they were tended until a steamer, answering the telegraphic call for help, came round from St. John's and took the hapless people off.

In 1901 the *Assyrian* ran ashore in calm weather, and was too firmly jammed on a reef to extricate herself. A week later another fine vessel and cargo worth £80,000, or $400,000, was battered to pulp by the waves, the lighthouse-keepers once more, at great risk to themselves, putting out and rescuing those on board in the nick of time. Ere the excitement of this wreck had died down, a French emigrant steamer, the *Lusitania*, ran full-tilt on to a reef, and but for the timely aid rendered by the lighthouse-keepers and the fisherfolk 550 people would have been drowned. More fearful catastrophes have been enacted within hail of the lights at Cape Race and Cape Ray, hard by to the west, and more millions sterling of cargo and ship have been shattered and lost here than upon any other corresponding stretch of coast in the world. The most noticeable point in connection with these disasters is the large number of big boats which have ended their careers abruptly off this spot, although the rocks have claimed a big share of small fry as well.

The first beacon was placed on the headland in 1856. It was a cylindrical tower, built up of cast-iron plates, erected near the edge of the cliff, which is 87 feet high. The tower itself being 38 feet in height, the focal plane of the beam was at an elevation of 125 feet above the sea. It was erected jointly by the British and Newfoundland Government authorities, although the maintenance thereof was entrusted to Great Britain. In return for the provision of this warning, a tax of one-sixteenth of a penny, or an eighth of a cent, per ton, was collected in England from vessels passing the light. The beacon was not particularly powerful, the ray being only of some 6,000 candle-power.

Some years ago the lighthouse was handed over to the Canadian Government to be included in its service, together with the balance of the fund which had accrued from the levy of the special tax. This sum represented £20,579, or $102,895. The Canadian Government abolished the light-due, and the surplus funds were absorbed into the general revenue of the country.

The new owners, realizing the importance of the light, subsequently decided to provide a new beacon of greater power to meet the demands of shipping, which had increased amazingly. In 1907 this structure was completed. It is a cylindrical tower, carried out in reinforced concrete, 100 feet in height, surmounted by a lantern of the first order with hyperradial apparatus. This is the largest type of optical apparatus in use at the present time, and the ray of light produced by an incandescent oil-burner and mantle is of 1,100,000 candle-power, shed from an elevation of 195 feet above the water. The warning flash of a quarter of a second every seven and a half seconds is visible from a distance of nineteen miles. In addition, the fog-signalling apparatus was brought up to date. The steam-whistle, which had sufficed up to the date of reconstruction, was replaced by a diaphone of the greatest power installed up to that time. This is set up about 250 feet south of the lighthouse, with which it is connected by a covered passage. The air required to emit the warning blast, lasting three and a half seconds once in every half-minute, is compressed by the aid of steam. By day the lighthouse is readily distinguishable from its red and white vertical stripes, red lantern, and white dwelling with red roof, in which the keepers have their quarters. To-day the station ranks as one of the finest in the world, complying in every respect with the requisitions for one of a first-class character.

Sable Island is perhaps an even more evil spot in the North Atlantic than the ill-famed Newfoundland coast. It is a bleak, inhospitable, crescent-shaped collection of sand-dunes, eighty-five miles due east of Nova Scotia and lying right in the steamship tracks. A more uninviting stretch of dry land could not be conceived. Little grows here beyond a special kind of brush, which appears to flourish in sea-swept billows of sand. But the obstacle is formidable, being twenty-two miles in length by a mile in width at its broadest part. This does not constitute the extent of its dangers—far from it. The island is slowly but surely being swallowed up by the restless, hissing sea, with the result that, when one stands on the almost indistinguishable line where sea meets land, an aspect of white ruffs of foam curl in all directions as far as the eye can see, where the surf is thundering over the shoals. I have related the toll that this island of the dead has exacted from shipping,* and now confine myself to describing the means that have been provided to warn the mariner off its bars. The Canadian Government maintains two lighthouses, at the western and eastern extremities respectively, and those entrusted with their safe-keeping have as lonely an existence as may be conceived. The welcome face of a stranger never brightens their lives, except when the relief-boat draws in as far as it dares in the calmest weather, or when some luckless wretches are snatched from a vessel which has fallen into the toils of the sand and is doomed. The sea-birds and seals are their sole companions on this lonely outpost.

The necessity of indicating this death-trap to the mariner was realized at the end of the seventeenth century, but it was not until 1802 that a forward step was taken to ease the plight of those who were thrown upon its shores. Then the province of Nova Scotia voted a sum of £400 or $2,000, per annum, for the maintenance of a fully-equipped life-saving station. This sum was too slender to fulfil the purposes conceived, but in 1827 the Imperial Government, recognizing the humane character of the enterprise, voted a similar appropriation, which is paid regularly, or was up to a few years ago, towards its support. When the Dominion of Canada became an accomplished fact in 1867, by the confederation of the provinces, the matter was taken up wholeheartedly, and since that date enormous sums have been

* "The Steamship Conquest of the World," chapter xxi., p. 299.

Photo by courtesy of Lieut.-Col. W. P. Anderson.

THE LIGHT AT THE SOUTHERN END OF BELLE ILE.

This Canadian beacon throws its rays from a height of 470 feet. In foggy weather the headland often is obscured by fog, so an auxiliary light has been provided 346 feet below.

Photo by courtesy of Lieut.-Col. W. P. Anderson.

THE NORTH BELLE ILE LIGHTHOUSE.

The warning flash, thrown from a height of 137 feet, can be seen from a distance of 17 miles.

expended upon the island for the protection of shipping and the mitigation of the sufferings of those cast upon its inhospitable shores. At the present time three life-saving stations and six relief stations, equipped with the best modern apparatuses, are maintained, connected by telephone and equipped with a staff of about twenty men. When the gales are raging and the island is encircled in a broad band of maddened spray stretching to the horizon, these men are out patrolling the shore, ready to man the lifeboat upon the first signals of distress. The life of these lonely workers now is lightened very appreciably, as the island is fitted with a wireless station, wherewith the men are able to talk through space with the mainland and with passing vessels.

The west end light has passed through many vicissitudes, and the keepers have experienced innumerable thrills. At this point the ocean is devouring the island rapidly. In 1873 the tower was raised in what was considered a safe position. It was placed some distance from the water's edge on a favourable knoll, and thought to be immune from the gnawing of the sea for many years to come. But Nature disposed otherwise. The awful winter of 1881 played havoc with the island. One mighty gale carried away a solid chunk 70 feet wide by nearly 1,400 feet long. When the summer came, and an inspection was made, fears were entertained concerning the safety of the lighthouse. The keepers had observed violent tremblings, for the tower vibrated considerably under the smashing blows of the waves. Nothing could be done that summer, and it was hoped that the succeeding winter would be milder, to enable plans to be prepared for the construction of a new tower in a safer position. The keepers, however, were urged to keep a sharp eye on developments, and to be prepared for any emergency. The winter of 1882 proved to be worse than that of the previous year, and the island suffered more than ever. The keepers and their isolated comrades viewed the advance of the waves with ill-disguised alarm. Would the island around the light hold out until the spring ? That was the uppermost thought. Every gale brought the waves nearer, and at last it was recognized that one good gale would finish matters. So the men prepared for the emergency. The demolition of the tower commenced, a race between the waters and human labour. The men worked well and had just got the superstructure away, when there was a creak, a groan, and a crash! The foundations, which had been undermined, disappeared into the Atlantic. In less than ten years the hungry ocean had carried a mile of Sable Island away.

In 1888 the present magnificent lighthouse was brought into service. It is a ferro-concrete tower of octagonal shape rising from a massive plinth of the same form, and is provided with four equidistantly-spaced wing buttresses to hold the structure more rigid in rough weather. The building is set on a knoll rising 20 feet above the water, and about 2,100 yards east of the extremity of the western dry spit of land, so that the Atlantic will have to gnaw a considerable distance before it will render the position of this light untenable. The tower is 97 feet in height, bringing the white ray 118 feet above the level of the sea. The light is of the group revolving type, thrown once every three minutes. The warning is made up of three flashes, with an eclipse of thirty seconds between each flash, followed by darkness for ninety seconds, and may be seen sixteen miles away. While the beacon mounts guard over the main end of the island on one side, there is a dangerous submerged bar which runs north-westwards and westwards for seventeen miles. The light at the east end, which was erected in 1873, is likewise carried on an octagonal tower 81 feet high, but, being set upon a more commanding position, the beam is elevated to 123 feet. It is erected five miles south-westwards of the extreme tip of the island, and gives a white flash at intervals of three seconds, followed by an eclipse of fifteen seconds; it may be picked up seventeen miles away. Similarly, this light mounts guard over a submerged sand-bar, which extends eastwards for at least fourteen miles.

During the late summer and autumn the majority of the vessels plying between ports on the St. Lawrence and Europe take the shorter route round the northern corner of New-

By kind permission of Lieut.-Col. W. P. Anderson.

A MAGNIFICENT CANADIAN LIGHT ON THE PACIFIC COAST.

An octagonal tower, 127 feet high, built of ferro-concrete.

By permission of the Lighthouse Literature Mission.

THE WEST END GUARDIAN OF SABLE ISLAND, THE GRAVEYARD OF THE ATLANTIC.

This tower replaces the structure demolished by the waves.

By permission of the Lighthouse Literature Mission.

ST. ESPRIT ISLAND LIGHT, NOVA SCOTIA.

Its white revolving light is visible for 14 miles.

THE GULL ISLAND LIGHT, NEWFOUNDLAND.

A very lonely beacon, visible for 27 miles.

foundland through the Straits of Belle Ile. This is a highly dangerous passage, inasmuch as the narrow streak of water, seventy miles in length, with a maximum width of eleven miles, separating the frowning coasts of Newfoundland and Labrador, is strewn with menaces, the most formidable of which is Belle Ile, which lies right in the centre of the entrance from the ocean. The island is really a lofty hump of rock, twenty-one miles in circumference, with the shores for the most part dropping precipitously into the water. It is an extremely lonely spot, and, naturally, is feared by the mariner. His apprehensions, however, have been considerably relieved, because the channel is brilliantly lighted by several powerful lights visible from twelve to twenty-eight miles, while another is being established.

The beacons are distributed along the shores of Newfoundland, Belle Ile, and Labrador, one powerful light being placed on Cape Bauld, the northernmost point of Newfoundland, and another on Cape Norman, another promontory to the west. These two lights are visible from twenty and sixteen miles respectively, while on the opposite side of the strait is Amour Point light, guarding the south-east side of Forteau Bay on the Labrador shore, which has a range of eighteen miles. Cape Bauld is the most important mainland beacon, inasmuch as it indicates the entrance to the Belle Ile Straits. Belle Ile is well protected at its two extreme tips, the principal light being at the southern end. The necessity of guiding ships between the island and Newfoundland was recognized half a century ago, for this light was erected in 1858. It is perched on the summit of the cliff, 400 feet above the sea, the occulting light of ten seconds' duration and five seconds' eclipse being thrown from an altitude of 470 feet, rendering it distinguishable twenty-eight miles away. Unfortunately, however, the extreme elevation of the light often causes it to be enshrouded in impenetrable banks of clouds, which drape the headland ; so in 1880 an auxiliary light was established, 346 feet below the upper light. This beam is similar in character to the one above, and, from its elevation of 124 feet above the water, it may be picked up from seventeen miles out. Consequently, in foggy weather the lower light may be seen when the upper beacon is obscured. This is one of the most important points on the coast, being a marine telegraph, signal, and ice-report station, while it is also fitted with wireless telegraphy. An interesting feature in connection with this light is that it was kept going for three generations by one family, the Coltons, whose name is legendary in Quebec, and some of whom were born and died on Belle Ile.

The second light, on the northern extremity of the island, to indicate the northern entrance into the straits, is of recent date, having been brought into operation in 1905. It is a tower of iron, encased in a white octagonal reinforced concrete covering capped with a red polygonal-shaped lantern throwing a flash of half a second once every eleven seconds from a height of 137 feet, visible from a distance of seventeen miles.

Fogs and mists are two great perils peculiar to this northern waterway, so the splendid lighting arrangements are supported by excellent and powerful fog-signals. The northern light has a diaphone giving a blare lasting three and a half seconds every minute, while the southern station has a siren giving a double tone. First there is a low note of two and a half seconds followed by silence for two and a half seconds; then a high note of two and a half seconds and a silent interval of 112½ seconds. This signal is emitted from a point midway between the upper and lower lights, the air for the blast being compressed by water-power. Another humane provision is the depot at the southern station, which is kept stocked with food supplies for the benefit of shipwrecked mariners. In 1898 a freighter carrying a deck-load of 400 oxen went ashore beneath this light and became a hopeless wreck. The crew, realizing the impossibility of saving the animals, fired the ship, so that the animals were suffocated and bruised, thereby sparing the inhabitants of the island a deadly risk, and solving the difficult problem which otherwise would have arisen, had the brutes been drowned in the ordinary way and their decom-

THE BATISCAN FRONT RANGE LIGHTHOUSE, RIVER ST. LAWRENCE.

ISLE ST. THÉRÈSE UPPER RANGE BACK LIGHTHOUSE, RIVER ST. LAWRENCE.

By courtesy of Lieut.-Col. W. P. Anderson.

UPPER TRAVERSE LIGHTHOUSE IN THE RIVER ST. LAWRENCE.

By courtesy of Lieut.-Col. W. P. Anderson.

AN "ICE SHOVE" UPON THE BACK RANGE LIGHT IN LAKE ST. PETER.

This photo gives a striking idea of the trouble experienced with ice in Canadian waters.

posing carcasses cast up on the beach. In the following year the Dominion liner *Scotsman* crashed on to the rocks near the same spot, and likewise became a total loss, with a death-roll of nine. By dint of great effort the survivors scrambled ashore, and had a weary trudge of nine miles over a broken, rock-strewn wilderness to gain the lighthouse station and assistance, arriving in a famished and exhausted condition, to be tended by the light-keepers and their families.

Belle Ile is a lonely station in the fullest sense of the word, although the keepers are better off now than they were a few years ago. The straits are busy in the summer, being crowded with shipping, but with the coming of November all life disappears, and the liners do not return until the following May or June. The rock is cut off from the mainland by the masses of ice which pile up in the estuary, together with the crowds of icebergs which come down from Greenland. For six months the guardians of the light are isolated from the world at large, although they have a slender link of communication in the submarine cable. But the storms and stress of winter often rupture this line, and, as the wireless installation is closed down when navigation ceases, the keepers and their families settle down to a silent, weary vigil, knowing nothing of the rest of the world, and all but forgotten by civilization, because an interruption in the cable cannot be repaired until the ice disappears.

Even when the Gulf of the St. Lawrence is entered, the navigator is not free from peril. The waterway is littered with rocks and islands. Among these are Coffin Island and Anticosti, the latter being the private property of M. Henri Ménier, the French chocolate magnate. For many years the St. Lawrence was a byword to navigation, and wrecks were numerous. It was shunned by navigators and abhorred by underwriters. Even to this day the latter regard it askance, and the insurance rates are high upon vessels trading in these waters. Through the efforts of the Department of Marine and Fisheries, the Dominion Government is removing this stigma from their great marine avenue, and their engineer-in-chief, Lieutenant-Colonel William P. Anderson, to whom I am indebted for much information concerning the guardians of the Canadian coasts, has displayed commendable enterprise and ingenuity in combating the natural odds pitted against human endeavour to render the coasts of the country more friendly to navigation.

In the St. Lawrence the great foe is ice. Its onslaughts are terrific, and none but the strongest works has a chance to survive the enormous pressure exerted when the ice is on the run after the break of winter. As is well known, for some five months in the year the river is frozen so thick and solid that it will support a train. Naturally, when this armour collapses, and the floes are hurled seawards by the current, they concentrate their destructive energies upon any obstacles in their way, piling up in huge masses weighing thousands of tons. It is no uncommon circumstance for the floes to pack in a jagged heap 50 feet high, while all the time there is a continual push against the obstruction.

Under these circumstances extreme ingenuity has to be displayed in the erection of the fixed lights. The floating lights, such as buoys, escape this peril, as they are picked up when navigation ceases, to be housed in quarters on dry land, and replaced when the river is open once more. Yet it is not only the ice in itself which causes trouble. The level of the river rises when the ice is running, and this pressure alone is enormous, while the scouring action about the foundations is terrific. The type of structure adopted varies with the situation and character of the light. The beacons for the aid of navigation, in common with the practice upon American waterways, are divided into groups or ranges, and the captain picks out his channel by keeping these lights and marks in various lines. Maybe four or five lights have to be brought into line, and accordingly the height of the unit of each range varies from its fellow. Thus, the front light will be low, that behind a little higher, and so on, until the last light in the group, or "back light" of the range, as it is called, is a lofty structure.

In some places the light is placed in mid-stream, and perhaps mounted upon a massive, high, steel caisson, resting upon a concrete foundation, thereby proving immovable to the most powerful of ice-shoves. Or a large pier carried out in ferro-concrete and pyramidal in shape is used. In the case of the back light there is a skeleton tower, which structure is employed to gain the necessary height. This is carried upon a high, huge, solid plinth of concrete, even if built against the bank. The frazil ice dams the channel, causing the water to rise, and unless the foregoing precautions were adopted widespread damage would result. All the lights between the gulf and Montreal have to be protected in this manner, so that it will be seen that the adequate lighting of this waterway bristles with engineering difficulties of no light character, and is expensive.

The Canadian Government also is responsible, to a certain extent, for the lighting of the Great Lakes, which is described in another chapter, where similar difficulties prevail. It has also a long stretch of the most rugged part of the Pacific coast to patrol, aggregating about 600 miles between Victoria and Vancouver to the Portland Canal, where Canadian meets Alaskan territory. This is a wicked coast, broken and battered, as well as flanked by an outer barrier of islands, recalling the Scandinavian Peninsula in its general topographical characteristics. During the past few years the necessity of lighting this seaboard adequately has become more pronounced, owing to the creation of the new port of Prince Rupert, a few miles below Alaskan territory, where the Grand Trunk Pacific reaches down to the western sea, and the growing sea-borne traffic with Alaska. The fact that a large portion of this navigation is maintained through the inside passages, bristling with sharp turns, narrow defiles, and jagged headlands, which for the most part are wrapped generally in fog, renders the lighting problem more intricate. Probably the most important light, and certainly the loftiest on the Pacific seacoast north of the Equator, is that on the summit of Triangle Island, British Columbia. It was built in 1910, and although the lantern itself is only 46 feet in height, the elevation of the headland brings the white group-flashing light of 1,000,000 candle-power 700 feet above the sea, giving it a range of thirty-four miles. Four flashes are emitted during each ten seconds, each flash lasting 0·28 second with intervening eclipses each of 1·28 seconds, with an eclipse between each group of 5·94 seconds.

Lieutenant-Colonel Anderson has introduced a new type of reinforced concrete lighthouse with flying buttresses. The latter are not required for strength, but are utilized to give greater stiffness to the tower, as a column 100 feet or more in height, no matter how strongly it may be built, must vibrate and swing in high winds. Yet it is desirable to keep the lantern as steady as possible, and this is achieved much more completely upon the above principle. The engineer-in-chief of the lighthouse authority of the Canadian Government considers this method of construction to be the last word in lighthouse building, and has completed some notable works upon these lines. Perhaps the most important is the Estevan Point light, on the west coast of Vancouver, at a place known as Hole-in-the-Wall. The tower, of octagonal, tapering form, is 127 feet in height, and throws a white group-flashing light, comprising three flashes each of 9·3 seconds with two eclipses, each of 1·37 seconds, and a final eclipse of 6·36 seconds between each group, seventeen miles out to sea. The surroundings of this station are most romantic. Landing anywhere in its vicinity is extremely difficult and dangerous, and the engineer had to select a point about two miles distant for this purpose. From this place a road and tramway have been laid through a grand primeval forest, such as is to be found only upon Vancouver Island, wherein roams a drove of magnificent wild cattle.

While the Canadian coast cannot point to any lighthouse work comparing with the Eddystone, Skerryvore, or Heaux de Bréhat, yet its most powerful beacons are of a commanding character, representing as they do the latest and best in connection with coast lighting. There is an enormous stretch of difficult shore to patrol, along which has to be guided an immense volume of valuable shipping. In addition to the attended lights, the Government has been extremely enterprising in the adoption of unattended beacons (described in another chapter), miles of lonely, inhospitable shore being guarded in this way. Although the development in this direction is of comparatively recent date, the protection of maritime trade is being carried out in accordance with a comprehensive policy, so that within a few years the coasts of the Dominion will be rendered as safe to the shipping of the world as human ingenuity can contrive.

CHAPTER XIII

THE MINOT'S LEDGE LIGHT

LOVERS of Longfellow will recall the poet's song to the lighthouse, but how many of his admirers know to what beacon these stirring lines refer? When they were penned the author had in his mind's eye an example of the engineer's handiwork which ranks as one of the finest sea-rock lights in existence, worthy of comparison with the most famous of similar structures scattered throughout the waters washing the Old World.

This is the far-famed Minot's Ledge light, warning the seafarer making to and from Boston Bay of the terrible peril which lurks beneath the waves on the southern side of the entrance to this busy indentation. "Like the great giant Christopher it stands," a powerful monument to engineering genius, dogged perseverance against overwhelming odds, and a grim, bitter contest lasting five weary years between the implacable elements and human endeavour. The Minot Ledge is one of those jagged reefs which thrust themselves far out into the sea, studded with pinnacles and chisel-like edges, which never, or very seldom, protrude above the waves. Ship after ship fouled this danger spot, either to be sunk or to be so badly crippled that it barely could contrive to crawl to safety.

The prosperity of Boston was threatened by this peril to shipping, and therefore it is not surprising that a resolution was passed to devise some ways and means of indicating its presence to those who go down to the sea in ships. The solution was offered in a skeleton structure fashioned from iron, which was designed by Captain W. H. Swift, of the United States Topographical Engineers. He searched the reef through and through to ascertain the point where the beacon should be placed so as to prove of the greatest value. This in itself was no simple matter, inasmuch as Minot's Ledge is but one of a great area of wicked crags, which collectively are known as the Cohasset Rocks, and which straggle over the sea-bed in all directions. After the position had been reconnoitred thoroughly, and sounding and levels had been taken, the engineer decided that the most seaward rock of the group, known as the Outer Minot, would be the most strategical position, and accordingly he planned to erect his beacon thereon.

It was a daring proposal, because the reef at the point selected only exposes some 25 feet of its mass above the falling tide, and then the highest point of the rock scarcely thrusts itself $3\frac{1}{2}$ feet into the air. It was realized that the periods of working between the tides would inevitably be very brief, while even then, owing to the open position of the ridge, a landing would only be possible in very smooth weather, and the men would have to suffer exposure to the fury of the waves as they dashed over the ledge.

Captain Swift decided upon a skeleton iron structure, not only because it would be quicker to erect and would cost less, but because it would offer the least resistance to the waves, which would be free to expend their energy among the stilts. The task was taken in hand at the first favourable opportunity, and, the system lending itself to rapid construction, marked progress was made every time the workmen succeeded in getting on the ledge. The lantern and keepers' quarters were supported upon nine piles, 60 feet above the rock. The legs were so disposed that eight described the circumference of a circle, while the ninth constituted the axis.

This tower was completed in 1848, and for the first time the navigator making these treacherous waters received a powerful warning to keep clear of Minot's Ledge. For three years the beacon survived the battering of wind and wave, but its welcome beam was last seen on the night of April 16, 1851. In the spring of that year a gale of terrific fury beat upon the Massachusetts coast. The wind freshened on April 13; the next day it rose to its full force, and did not abate for four days. The good people of Boston grew apprehensive concerning the plight of the two keepers of the lonely Minot's light, but, however willing they might have been to have put out to the beacon, they were absolutely impotent before the ferocity of the elements. Time after time the light vanished from sight as it was enveloped in an angry curling mountain of water. On April 17 the doleful tolling of the lighthouse bell was heard, but the light was never seen again. The structure had slipped completely from sight, together with its faithful keepers, swallowed by the hungry Atlantic. Evidently the wail of the bell was a last plea for assistance, because no doubt the lighthouse had bowed to the storm and was tottering when the tolling rang out. But the call brought no help; it was the funeral knell of the guardians of the beacon. When the sea went down a boat pushed off to the ledge, and all that was seen were a few bent piles. Captain Swift had done his work well. The waves could not tear his beacon up by the roots, so had snapped off the piles like carrots, and had carried away the lantern.

This sensational disaster, after a brief existence of three years, did not augur well for the permanence of a light upon this precarious ledge. The Outer Minot appeared to be determined to continue its plunder of ships, cargoes, and lives, untrammelled. Accordingly, for three years no effort was made to bring about its subjugation.

In 1855 General Barnard, one of the most illustrious engineers which the United States has ever produced, brought forward the plans for a structure which he thought would resist the most formidable attacks of wind and wave. He took Rudyerd's famous Eddystone tower as his pattern. This was perhaps the strongest design that could be carried out against the sea, having one weak point only—it was built of wood. General Barnard contemplated a similar structure for Minot's Ledge, but in masonry.

The Lighthouse Board, which had recently been inaugurated to control the lighthouses around the coasts of the

THE MINOT'S LEDGE LIGHT.

Marking the rock off Boston Harbour, it is one of the greatest works completed by the lighthouse builders of the United States. It forms the theme of Longfellow's well-known poem.

TENDER LANDING BUILDING MATERIAL UPON THE TILLAMOOK ROCK.

A derrick has been provided to facilitate these operations, while a stairway leads from the landing point to the lighthouse.

country, examined the idea minutely, and submitted the design to the most expert criticism and discussion, but all were so impressed with its outstanding features that they decided to support it whole-heartedly. A minute survey of the rock was prepared, and the plans were straight away perfected for the preparation of the masonry on shore. So carefully was this work carried out, that, with the exception of a few blocks of masonry constituting the foundations, which had to be prepared on the site, and some slight variations in the method of construction, the original ideas were fulfilled.

Work was commenced in 1855, the building operations being placed in the hands of B. S. Alexander, at that time Lieutenant of Engineers, and the successful completion of the work was due in a very great measure to his ability and ingenuity, because the whole undertaking was placed in his hands and he had to overcome difficulties at every turn as they arose.

The builder was handicapped in every way. First there was the brief period in which operations could be carried out upon the site, the working season extending only from April 1 to September 15 in each year. This is not to say that the masons were able to toil upon the rock continuously every day during this interval—far from it. In order to get the foundations laid there were three essentials—a perfectly smooth sea, a dead calm, and low spring-tides. Needless to say, it was on very rare occasions indeed that these three requirements were in harmony. As a matter of fact, they could occur only about six times during every lunar month—three times during full moon, and three at the change. Even then, either the wind or the sea intervened to nullify the benefits arising from the lowest tides. So much so that, although work commenced at daybreak on Sunday, July 1, 1855, only 130 working hours were possible upon the rock before labours ceased for the season in the middle of the following September.

On gaining the rock, Lieutenant Alexander decided to make use of the holes which had been driven into the granitic mass by Captain Swift to receive the piles of the previous structure. The twisted and broken pieces of iron were withdrawn and the holes cleaned out. Simultaneously the upper surface of the rock was pared and trimmed by the aid of chisels, which was no easy task, because at times the masons were compelled to manipulate their tools as best they could in two or three feet of water. This preparation of the rock to receive the base constituted one of the most notable features of the work. In the greater number of other outstanding achievements upon sea-rocks the surface of the latter has been above the waves at lowest spring-tides, whereas in this case a great part of the foundation work was continuously submerged.

This preparation of the rock-face necessitated the final trimming and shaping upon the site of many of the masonry blocks forming the root of the tower. They could not possibly be prepared ashore to bring about the tight fit which was imperative. Accordingly, all but the bottom faces of the blocks were prepared in the depot on the mainland, and they were then shipped to the ledge for final paring and trimming.

The attachment of the bottom courses to the rock-face was carried out very ingeniously. Bags of sand were brought on to the rock and laid around the spot upon which a particular block of stone was to be laid. The sacks, being filled with sand, were pliable, so that, when deposited, they adapted themselves to the contour of the ledge, and prevented the water making its way in under the rampart. The water within this small dam was then removed, sponges being used in the final emptying task, so as to suck out the salt sea from the cracks and crevices, leaving the surface on which the block of stone was to be laid quite dry. A film of cement was then trowelled upon the rock surface, and upon this was laid a sheet of muslin. The inclusion of the muslin was a wise precaution, because while the work was in progress a wandering wave was liable to curl over the rock, swamping the small dried space, when, but for the presence of the muslin, the cement would have been carried away. At the same time the cement was able to penetrate the meshes of the muslin when the stone was deposited, so as to grip the surface of the latter and to hold it tightly in position.

Under such abnormal conditions of working the masons had many exciting moments. No matter how smooth was the sea, several renegade waves would plunge over the ledge. The masons had to be prepared for these unwelcome visitors, and precautions had to be introduced to prevent them being washed off their slender foothold. A substantial iron staging was erected over the working area on the rock, to facilitate the handling of the building material. A number of ropes were attached to this staging, the free ends of which dangled beside the workmen. These were the life-lines, one being provided for each man. A lookout was posted, who, when he saw a wave approaching and bent upon sweeping the rock, gave a shrill signal. Instantly each workman dropped his tools, clutched his life-line tightly, threw himself prostrate on the rock, and allowed the wave to pass over him. The situation certainly was uncomfortable, and the men often toiled in soddened clothes, but an involuntary bath was preferable to the loss of a life or to broken limbs.

Work advanced so slowly that during the first two years, which were devoted to the excavation of the pit and the preparations of the rock-face, only 287 hours' work were accomplished. In the third year this task was completed, and four stones laid in a further 130 hours 21 minutes. By the end of the working season of 1859 twenty-six courses were finished, so that, while the volume of work fulfilled in 1,102 hours 21 minutes, and spread over five years, certainly was not imposing, it was remarkable under the circumstances.

The stones for the foundations were sent from shore with the indication −3′ 5″, −2′ 9″, −1′ 3″, and so on, indicating that these stones were prepared for positions 3 feet 5 inches, 2 feet 9 inches, and so on, below zero. And the zero mark was 21 inches below water! Above the zero mark the stones were prefixed by a "plus" sign.

The shaft is purely conical, and solid except for a central well extending from the foundations up to the level of the entrance. The successive courses of stones were secured to one another, and each stone was attached to its neighbour in the ring by the aid of heavy iron dogs, so that the lower part of the shaft forms a practically solid homogenous mass. What are known as continuous "dowels" were sunk through each course of masonry into the holes in the solid rock prepared by Captain Swift for his skeleton light, this further attachment of the mass to the ledge being continued until the twelfth course was gained. Thus additional security is obtained by anchoring the tower firmly to the reef.

The solid portion of the building is 40 feet in height from the level of the first complete ring of stones, and the tower is 80 feet high to the lantern gallery. The over-all height to the top of the lantern cupola is 102¾ feet, while the focal plane is 84½ feet above mean high-water. The first stone was laid on July 9, 1857, while the masons completed their duties on June 29, 1860, so that five years were occupied upon the work. In erection 3,514 tons of rough and 2,367 tons of hammered stone, in addition to 1,079 numbered stones, were used, and the total cost, including the light-keepers' houses on the mainland, was £60,000, or $300,000, so that it ranks among the more costly lights which have been provided for the seafarer's benefit.

On November 15, 1860, nine and a half years after the destruction of the first beacon, the light was once more thrown from Minot's Ledge for the benefit of passing ships. The light is of the second order, visible fourteen and three-quarter miles out to sea, and is of the flashing type, signalling "143" every thirty seconds thus—one flash followed by three seconds' darkness, four flashes with three seconds' eclipse, and three flashes with an interval of fifteen seconds' darkness.

The tower has been subjected to repeated prodigious assaults, the north-east gales in particular thundering upon this reef with tremendous fury, but it has withstood all attacks with complete success.

CHAPTER XIV

THE TILLAMOOK ROCK LIGHT-STATION

WHILE the Northern Pacific Ocean is the loneliest stretch of salt water in the world, yet it possesses one or two busy corners. Prominent among the latter is that where it washes the shores of the United States around the entrance to the mighty Columbia River. The estuary is wide, and, although navigation is handicapped by a bar, it is well protected. But coming up from the south there is a stretch of terribly forbidding coastline, with the cliffs at places towering 1,500 feet or more into the air and dropping sheer into the water. Rock-slides are of frequent occurrence, and the beach is littered with heavy falls from above. Here and there protuberances rise from the sea, formed of rock sufficiently dense and hard to withstand more effectively the process of erosion, only to constitute fearful menaces to navigation. Often the mainland is completely obscured, either by streaks of mist or heavy clouds of smoke produced by forest fires, which in the dry season rage with great violence. A ship caught within the toils of this stern coast has no possible chance of escape, while the crew would find it difficult to get ashore, inasmuch as at places there is not a single landing-place within a distance of twenty miles.

Owing to the coast being frequently blotted from view, and to the fact that this stretch of sea is swept by furious storms, the plight of the mariner making to or from the Columbia River became exceedingly precarious. The worst tragedy of these waters was enacted on the dark and stormy night of January 3, 1881, when the sailing-ship *Lupata* lost her way and went to pieces on the rocks off Tillamook Head.

Under these circumstances it is not surprising that an outcry arose for protection along this lonely reach of Oregon's jagged shoreline. The authorities responded to the agitation by the promise to erect a lighthouse, once they should have decided the site, which was the really perplexing question. In the first instance it was thought that its location upon the mainland would suffice, but a survey betrayed the futility of such a choice. The light would be too elevated to be of any service; for the greater part of its time it would be rendered invisible by land fogs. Then, again, it would mean cutting a road for a distance of twenty miles through heavy, undulating country and primeval forest to gain the point, as the verdant sea of green timber extends to the very brink of the cliffs.

After prolonged consideration, it was decided to erect the light upon the Tillamook Rock. This is a hard mass of basalt, rising boldly from the water to a height of 120 feet, which, when viewed from one side, presented the appearance of a clenched fist. It stands about a mile off the mainland, twenty miles south of the Columbia River mouth, and drops plumb into the sea, where the lead gives readings ranging from 96 to 240 feet. The whole area of the rock is less than one acre, and it is split almost in two; another isolated knot of basalt, upon which the seas break heavily when a storm is raging, rears its shaggy head into the air near by at low-tide. The only possible landing-point is on the east side, where there is a beach sloping upwards sharply from the water to the crest. When the ocean is roused the sight certainly is terrifying. The waves fall with shivering force upon the base of the rock, to rush up its ragged sides and sweep right over its crest in a dense curtain of angrily frothing water and whipping spray.

Despite its fearsome character, this rock constituted the most serviceable situation for a light, for the reason that, being a mile from the shore, it was free from land fogs and clouds. The decision of the authorities depended upon three factors only—that a landing could be made, the rock occupied, and the requisite building materials unloaded. The introduction of such a saving clause was politic, because at first it seemed as if the rock would defy the gaining of a foothold. The ghastly failure attending the survey, as described in a previous chapter, brought public opinion into dead opposition to the project, and many fearsome stories were circulated sedulously up and down the coast and among the towns fringing the Columbia River concerning the perils, hardships, and terrible death-roll, which would attend any attempt to place a beacon on this rock.

After the disaster the authorities pressed forward the enterprise with greater vigour than ever, so as to get work well under way before public opinion would be able to make its influence felt upon the unsophisticated minds of workmen required to carry out the undertaking. A daring, determined, and energetic leader was secured in Mr. A. Ballantyne, and he was deputed to rally a force of eight or more highly skilled quarrymen with whom to proceed to Astoria, where the land headquarters were to be established. He was informed that upon arrival at this point he would find everything in readiness for his immediate departure to the rock, with all essentials to enable him to commence work at once and to provide quarters for the workmen, who would be compelled to suffer isolation and a certain amount of discomfort for weeks at a time. It was impossible to take more than a handful of men at first, owing to the difficulty of landing provisions.

Mr. Ballantyne started off with his small picked force, reached Astoria on September 24, 1879, and there suffered his first check. The autumn gales had sprung up, rendering approach to the rock absolutely hopeless. There was no alternative; he must wait until the weather moderated. As this might be a question of a few hours, days, or perhaps a week or two, the chief grew anxious concerning his force. If the men, having nothing to do, wandered idly about the town, making acquaintance with all and sundry and listening to gossip, then they could not fail to be impressed with the extraordinary stories concerning dangers, hardships, perils, and adventures; would conclude that the Tillamook was a "hoodoo" rock; and would desert him promptly. To guard against this contingency, the quarrymen were hurried off and temporarily housed in the old light-keeper's dwelling at the Cape Disappointment light, some miles away on the northern portal of the estuary, where they were safe from pernicious influences.

After twenty-six days of enforced idleness the squad was picked up by a revenue cutter, which steamed to the rock, and made fast to a buoy that had been laid previously for mooring the vessels deputed to transport building materials and other requirements. With extreme difficulty four men were got on the rock, together with a supply of hammers, drills, iron ring-bolts, a stove, provisions, supplies, and an abundance of canvas, with which the advance staff were to erect temporary shelters and to make themselves as comfortable as they could. While the work was in progress the wind freshened, the swell rose, and the boat had to retire hurriedly before the remainder of the force could be landed; but five days later they were transferred to the rock, together with further provisions and supplies, as well as a derrick.

The little party soon received a taste of what life would be in this lonely spot. Three days after the second landing, and before they had shaken down to their strange surroundings, a gale sprang up. Heavy seas pounded the rock, and the waves, mounting its vertical face, threw themselves over its crest, drenching the workmen and their sleeping blankets. It was a startling episode, but it became so frequent that the quarrymen became inured to their fate, and were not perturbed in any way, except when the Pacific was roused to exceptional fury.

When the first four men gained the rock it was seen that the landing of material, especially the heavier incidentals, would constitute the greatest difficulty. Then an ingenious idea was advanced. Why not rig a heavy rope between the mast of the vessel and the top of the rock, draw it taut, and devise a traveller to run to and fro? It was a practical suggestion and was adopted forthwith. With much difficulty a 4½-inch rope was towed from the vessel—to the mast of which one end was secured—to the rock, and grabbed

THE TILLAMOOK ROCK LIGHT STATION FROM THE SOUTH.

Rising from the sea one mile off the Oregon Coast, it was for years a terrible danger spot. The light of 160,000 candle-power, 132 feet above high water, is visible for 18 miles.

THE CONQUEST OF THE TILLAMOOK.

The top of the crag was blasted off to provide a level space for the lighthouse.

THE TERRIBLE TILLAMOOK ROCK.

Showing how the menace rises abruptly from the sea on one side.

by those in occupation. This end was anchored firmly, and constituted the track. Then a large single block was rigged to this main line in such a way that it could move freely to and fro along the cable. This block was provided with a heavy hook on which the weights could be slung. Other blocks were fixed on the vessel and on the rock, while an endless line, passing through these blocks at each end, and attached to the shank of the hook on the travelling block, enabled the traveller to be pulled freely and easily in either direction.

Both men and supplies were transferred from ship to shore by this primitive, albeit ingenious, system. The men were carried in a novel device, described as a "breeches-buoy," such as is used with the rocket life-saving apparatus, but of very crude design improvised on the spot. It was contrived from an ordinary circular rubber life-preserver, to which a pair of trousers cut short at the knees were lashed tightly. This was suspended from the block-hook by means of three short lengths of rope. The trip through the air certainly was novel, and not free from excitement ; indeed, there was just sufficient spice of adventure about it to appeal to the rough-and-ready, intrepid spirits who constituted the forces of the lighthouse engineer. Also, owing to the primitive character of the apparatus, there was just the chance that something would go wrong when the man was between ship and rock. The breeches were provided to hold the man in a safe position while in the air, to guard against a loss of balance and tipping out ; while should anything give way, and the man make an unexpected plunge into the water, the life-preserver would keep him afloat until a boat could draw alongside to rescue him.

There was another factor which had to be taken into consideration, and which certainly contributed to the novelty of the trip. As the boat responded to the action of the waves the rope alternately drew tight and sagged. When she rolled towards the rock the cable was slackened, and the man generally had a ducking ; the next moment, when the vessel rolled in the opposite direction, he was whisked unceremoniously and suddenly into the air. It was like being suspended at the end of a piece of elastic. The men for the most part enjoyed the fun of the journey, and considered it a new and exhilarating "divarshun." Among themselves the effort was to travel in either direction so as to escape a cold douche on the journey. When the water was rough, speculation took the form of guessing how many dips into the water would be made before either terminus was gained.

This novel landing method provoked one amusing incident. The supply-boat came out to the rock one day bringing a new raw hand. The cableway was rigged up, and the workman prepared for his ride to the rock. But the man was somewhat corpulent, and could not be thrust through the preserver. This was an unexpected *contretemps*, and it seemed as if the superintendent would have to let his recruit return. But Ballantyne did not worry over trifles, neither did he relish the idea of losing a hand after having him brought so far, so he put forward a somewhat daring proposal. He told the captain of the steamer to lash the workman to the top of the buoy, and they would pull him ashore all right. The labourer was scared out of his wits at this suggestion, and resented being handled as if he were a balk of timber. Why, even the perishable articles were unloaded in casks to protect them from the wet. He expressed his determination to see them to perdition before he would make a trip through the air under such conditions. Ballantyne was somewhat crestfallen at the cold reception of his brilliant idea, so told the captain to take the workman back to Astoria, and to ransack the place to discover a buoy which would be big enough to fit him.

Two days later the vessel returned with the larger buoy and also the corpulent quarryman. His second glimpse of the primitive travelling frightened him worse than ever, and he point blank refused to budge. In order to reassure the raw hand, Ballantyne hauled the buoy ashore, and, jumping into it, made a journey, to illustrate that the system was perfectly safe, and that one need not even get wet. But Ballantyne's demonstration was rather unfortunate. The cable was slack, and the ship rolled heavily. Result: the superintendent was dragged through the water for nearly the whole distance, and at times nothing of him could be seen. When he landed on the boat, half-winded and drenched to the skin, the quarryman was scared more than ever, and announced his intention to return to Astoria. Ballantyne cajoled, coaxed, argued, and stormed, in turn, but to no avail. Then another idea came to his fertile mind. If the man would not travel via the breeches-buoy, why not send him ashore in a bos'n's chair? This was rigged up satisfactorily, and therein the workman consented to go ashore, though not without the display of considerable trepidation and anxiety to keep out of the water. They got him on the rock safely, and without so much as wetting the soles of his feet. The quarryman by his resolute opposition set up a record. He was the first man to land dry on the Tillamook.

Subsequently this novel and, so far as it went, efficient method of "quick transit" was superseded when the men on the rock got their big derrick to work. The long arm of this appliance leaned over the water far enough to pick up the goods direct from the deck of the vessel moored off the rock. This system was quicker, and enabled the goods to be got ashore unsoiled.

The first men to land found the rock in the occupation of sea-lions, who swarmed its scaly sides in huge numbers, even making their way to the crest to bask in the sunshine. These tenants at first resented the white man's invasion, and were somewhat troublesome; but at last they recognized that their eviction was certain, so suddenly deserted in a body to another equally wild spot farther south.

The first task was the preparation of the site for the building. The fist-like overhanging crest was attacked to prepare a foundation, thereby reducing the height from 120 to 91 feet. The rock surface was scarred and riven in a fantastic manner, owing to the scouring action of the waves eroding the soft portions leaving the hard rock behind in the form of needles, scales, and ugly crevices. The outer part of the rock, moreover, was found to be of an unreliable character, being more or less rotten, while the core, on the other hand, was intensely hard, and promised an excellent foundation for the beacon. The superfluous mass was removed by blasting, this being carried out with extreme care and in small sections at a time. The largest blasts did not remove more than 130 cubic yards, or tons, of débris at one time. This slow blasting, by handfuls as it were, was necessary so as not to shatter or impair the solidity of the heart of the rock, which was to support the buildings.

Drilling and blasting were carried out in the face of great difficulties. Rain, rough seas, spray, and heavy winds, combined to thwart the little band of workers toiling strenuously in solemn loneliness upon this bleak crag. Often days would pass without any tangible impression being made upon the surface. The drilling holes would be swamped, and unless care was observed the powder charges ran the risk of being damped and rendered impotent or uncertain in firing. In the attack upon the crest the workmen distributed themselves around the crown. On the precipitous side, as there was not a friendly ledge on which to secure a foothold to work the drills, bolts were driven into the rock-face, from which staging was suspended by ropes, and on this swinging, crazy foothold the men drove their tools with salt fleece whirling round them.

Until the men were able to erect more or less permanent quarters, their plight at times was pitiable. The canvas was cut up and an **A**-tent was rigged up. It was a cramped home, measuring 16 feet long by 6 feet wide, while the ridge pole was only 4½ feet above the ground. This domicile just held the ten men in their sleeping-blankets. Naturally, they had to crawl rather than walk about, and, as the shelter served as a dining-room as well, the little band had to tolerate many discomforts. When the wind howled round the rock, causing the canvas to flap violently and threatening to carry it away at every turn, when the sea swarmed over the rock, and when the heavy rains to which this coast is subject poured down pitilessly, the men never knew what it was to have dry clothing or bedding. Cooking was carried on in the open, and the kitchen arrangements had to be shifted from time to time, according to the direction of the wind, so that the fire was brought on the lee side of the shelter.

The workers were exposed to danger on all sides incessantly, but fortunately in their chief, Ballantyne, they had one of those men who appear to be made for such contingencies; who was alert, ready for any emergency, nursed his staff sedulously, and whose buoyant spirits dispelled all feelings of gloom, loneliness, or homesickness. The little band toiled hard and long through the rough autumnal weather, and the arrival of stern winter did not bring any cessation in their labours. They fought the rock grimly and ignored hardship. Certainly, they were cheered by the arrival of the boats with supplies, but occasionally a fortnight or more would pass without a call being made at the rock, and often, when a boat did come up and prepare to land material, it had to slip its anchor hastily to make a frantic run for safety before the rising swell and the gathering storm.

Early in January Nature concentrated her forces, as if bent upon a supreme effort to shake the determination and courage of the little army striving so valiantly upon the rock. On the night of New Year's Day the clouds assumed an ominous appearance, and accordingly the workmen were not surprised to meet a stormy and rainy reception when they made their way to their duties the following morning. The weather grew worse on the third day, the spray enveloping the rock and drenching the men, while the wind blew so fiercely that they could scarcely keep their feet. During the next two days it increased in force, while the sea grew angrier. On the 6th the elements were raging in torment, and in the afternoon Ballantyne, taking stock of the meteorological signs, came to the conclusion that the party "were in for it." A hurricane, or possibly a tornado, was looming. The tools were being swung with infinite difficulty, when suddenly came the signal "Stop work!" Ballantyne urged them to set to at once to lash everything securely. At six o'clock in the evening the hurricane burst, and the workmen witnessed a sight such as they had never seen before. The whole coast was in the grip of a tornado, of which the Tillamook Rock was the vortex, whereon the elements concentrated their destructive forces. The huge rollers assumed an uglier appearance than ever; the broken water rushed up the steep sides into the air, where it was caught by the whirling wind and dashed on the tiny camp. It was impossible to escape that savage attack, as it was driven home from all sides simultaneously. The men took to their permanent quarters in silence and very gloomy. By midnight the roof was being peppered with huge masses of rock, which, detached by the waves, were caught up and thrown clean over the rock. Ballantyne urged the men to stay in their bunks, to keep up their spirits, and to seek a little rest.

But sleep was impossible. The quarrymen were scared out of their wits, and there was every cause for their dismay. It seemed as if the very rock itself must succumb to the savage onslaught. The din was deafening; the rock shivered and trembled as the breakers hurled themselves upon it.

It had just turned two. Suddenly one and all sat up in terror. There was a fearful crash—a rending and splitting, which was heard plainly above the weird howling of the hurricane. The men tumbled out of their bunks panic-stricken, and were about to stampede from their shelter to seek refuge upon a higher ledge. But Ballantyne's pluck asserted itself. He, too, had been scared by the awful noise, but he collected his scattered wits more quickly than did his comrades. He grasped the situation, and with iron nerve commanded all the men to stick tightly where they were. An ugly rush seemed imminent, but he stood with his back to the door, and in plain English dared the men to leave their cover. Any man who attempted to fight his way to the upper refuge would be swept overboard by the wind and sea.

FAMOUS UNITED STATES LIGHTHOUSES OF TWO CENTURIES.

The rear tower was built on Cape Henry in 1789, with stones shipped from Great Britain. Owing to the sand thrown up by the sea, another light had to be provided nearer the water, and was completed in 1879. The old light is retained as an historic building.

THE RACE ROCK LIGHT.

It marks a dangerous reef in Long Island Sound. where, owing to the swift currents, construction of the foundations proved very difficult.

The quarrymen were not cowards, and Ballantyne's action steadied them. Then the foreman announced his intention to go out to see what had happened. He grabbed a storm-lantern and opened the door. Instantly he was hurled back by the wind and sea, which appeared to be submerging the rock. For two hours he stood waiting an opportunity to slip out against the hurricane. At last he succeeded, and in the intense darkness endeavoured to grope his way over the rock. He had been gone only a few minutes when he staggered back, battered, shaken, and almost exhausted. He could not make headway against the gale. So the men sat down and silently waited the approach of dawn. Then they found that the rushing waves had fallen upon the building in which all their supplies were stored, had smashed it to atoms, and had destroyed and carried away nearly all the provisions, the freshwater tank, and other articles, although the requisites for work were left untouched. It was the break-up of this storehouse which had woke them from their slumbers and had provoked the panic.

For ten days the gale raged, being more furious on some days than others. When it decreased in fury the men were able to settle to their work for an hour or two, but progress was painfully slow ; on other days not a tool could be picked up. On the 18th the revenue cutter came out from Astoria to ascertain how the men had weathered the tornado, and the signal for coal and provisions was answered immediately by the lowering of a surf-boat. The sailors had a stiff pull to reach the rock, found that the men still had a scanty supply of hard bread, coffee, and bacon—this was all—and, taking off the letters, promised to send supplies immediately. The construction ship also came up ; the captain sent ashore all the provisions he could spare, and undertook to return at once with a full supply. But another ten days passed before the sea went down enough to permit these to be landed, together with five more men.

Nature appeared to capitulate after this terrible assault, and work proceeded rapidly. The crest of the rock was removed and levelled off, to form an excellent platform for the reception of the beacon and other buildings. An inclined tramway was excavated out of the rock-face, communicating with the landing-stage, to facilitate the haulage of the light-keepers' necessities, and then the arrangements for the completion of the building were hurried forward.

When the public saw that the work was being accomplished without loss to life or limb, and that the plucky little party of toilers weathered the gales, an intense interest was manifested in the undertaking. The foreman was provided with an international code of signals, and passing vessels, as an act of courtesy and in recognition of the work that was being done to further their safety, always stood towards the rock to render assistance in case it was required. The workmen appreciated this feeling, and on two occasions, during dense fog, intimated to captains who had lost their way, and were groping blindly round the rock, that they were venturing into dangerous waters. The warning was primitive but effective. It comprised the explosion of giant-powder cartridges over the sea in the direction whence the ships' sirens sounded. In both instances the navigators heard the signals in the nick of time, and were able to steer clear.

The lighthouse itself comprises a group of buildings for the keepers, from which rises a square tower 48 feet in height, bringing the light 132 feet above mean high-water. The dwelling is built of stone, measures 48 feet by 45 feet, and is one story in height. In addition there is an extension for housing the powerful siren and its machinery. The building contains adequate living-quarters, together with storage rooms and a kitchen. As this light is particularly lonely, four keepers are stationed on the rock, and their rooms each have a clear length of 12 feet by 10 feet wide. Also, as the rock is so difficult to approach, and relief may suffer extreme delay from adverse weather, sufficient provisions are stored to insure full rations for six months.

The light is of the first order, of 160,000 candle-power, and is visible at a distance of eighteen miles in clear weather.

It is a brilliant white flashing beam, occurring once every five seconds, the flash being of two seconds, followed by an eclipse of three seconds. The fog-siren is likewise of the first order, driven by steam-engines. This plant is in duplicate, and the signal is given every forty-five seconds, the blast being of five seconds, followed by silence for forty seconds.

The conquest of the Tillamook Rock has been one of the most difficult tasks that the United States Lighthouse Board ever has accomplished. The little band of quarrymen who braved danger, hardship, and privation, effected occupation of the rock on October 21, 1879, and the light was exhibited for the first time on January 21, 1881, the total time occupied in the task being 575 days. It has robbed the dreaded Oregon coast of one of its worst perils, and the money which was devoted to the provision of this stalwart guardian—£24,698, or $123,493—was indeed expended to good purpose.

CHAPTER XV

THE COAST LIGHTS OF THE UNITED STATES

Few nations have such a varied coastline to guard as the United States. On the Atlantic seaboard the northern shore is a shaggy bold rampart of lofty cliff, hard and pitiless. Farther south the rock gradually gives way to sandy dunes, which the hungry sea is continually gnawing away here and piling up somewhere else. Then, as the tropics are entered, the sand in turn gives way to coral reefs, every whit as formidable as rock and as treacherous as sand, where the hurricane reigns supreme and makes its presence felt only too frequently. Across the continent a similar variation, though not perhaps so intense, is observable on the Pacific side. The coast range runs parallel with the shore, and consequently cliff and precipice are common, owing to the lateral spurs of the range coming to an abrupt termination where land and water meet.

The result is that no one type of beacon is possible of adoption as a standard for the whole coastline. The class of structure has to be modified to meet local conditions, but the battle between destruction and preservation is none the less bitter and continuous. When ships began to trade with the Atlantic seaboard of the United States, the erection of warning lights became imperative. This duty was fulfilled in the early days by local enterprise, and the first lighthouse on the continent was built on Little Brewster Island, at the entrance to Boston Harbour. It was completed about 1716, was a conical masonry tower, and its cost, which is interesting as being set out to the uttermost farthing —£2,285 17s. 8½d. — betrays the scrupulous commercial integrity of the first financiers of the United States. The light was maintained by the levy of a due of one penny per ton on all incoming and outgoing vessels, except those engaged in coastal traffic, and was collected by the same authority which subsequently got into trouble in the endeavour to collect the tax on tea. This pioneer light is still in service, although in 1783 it was rebuilt. The light, of the second order, is 102 feet above mean high-water, and gives a white flash every thirty seconds, which is visible from a distance of sixteen miles; the fog-signal is a first-class siren, giving a blast of five seconds, followed by silence for ten seconds, with a succeeding blast of five seconds and silence for forty seconds.

The excellent example thus set by the good people of Boston was followed by other States and individual authorities along the coast. This system of local and arbitrary control was by no means satisfactory, so in 1789 the Federal Government took over the control of the lighthouse service, and entrusted its safe-keeping to the Secretary of the Treasury. There were only eight lights to watch when the cession was effected, but the growth of the country soon increased the duties of the department. Accordingly, a decree was passed in 1817 whereby the control was transferred from the Secretary of the Treasury to the fifth auditor of the same department, Mr. Stephen Pleasanton, who became known as the General Superintendent of Lights. He assumed the new office in 1820, taking over fifty-five lights, so that during the thirty years the aids to navigation had been under the jurisdiction of the Secretary of the Treasury forty-seven new stations had been established.

The new official held the post for thirty-two years, and prosecuted his work so diligently and systematically that by 1852 the service had grown to 325 lighthouses, lightships, buoys, and other guides. The lighthouses were maintained under contract, the contractor for each light undertaking for a fixed annual sum to keep his charge in a perfect state of repair, to supply all illuminant, wicks, chimneys, and stores, that were required, as well as making one visit to the lighthouse in the course of the year. Subsequently it became necessary to award the contracts for terms of five years.

As time progressed, and the duties of the Superintendent became more onerous, certain individuals took exception to the idea of such an important service being entrusted to the charge of one man, vested with wide discretionary powers. Accordingly, complaints were formulated liberally, and the superintendent became the butt of venomous attack. The outcome of this agitation was the formation of a committee, two members of which were sent upon a mission of inspection to Great Britain and France, the lighthouse services of which were stated to be far superior to that of the United States, and more efficiently controlled. The result of this investigation was the inauguration of an official department known as the Lighthouse Board, constituted of capable engineers. In 1852 this authority took over the administration of the light service, which has remained under its control ever since. In order to secure the utmost efficiency, the coasts were divided into districts, each of which is presided over by an accomplished officer of the United States Corps of Engineers, who is held directly responsible to the Board at Washington for the lights in his area. So admirably was the new authority constituted that it has never failed to give the utmost satisfaction, and the result is that to-day the Lighthouse Board of the United States is comparable with contemporary authorities in the Old World.

In the early days the majority of the lights were placed on the mainland, and as a rule comprised wooden towers, projecting from the roof of the keepers' dwelling, similar in character to some of the older lights to be found on the coasts of Newfoundland and New Brunswick in Canada. These buildings were cheap to construct, as they were carried out upon the timber-frame principle ; but they possessed many disadvantages. The greatest objection arose from the attachment of the tower to the roof frames of the house. Being exposed to the full fury of the tempest, the tower in time would become loosened, and the roof itself distorted, so that the inmates had to suffer the inconvenience of water penetrating into their rooms. Even the

THE CARQUINEZ STRAIT LIGHT.

An imposing station on the north side of the entrance to the Strait.

A CHURCH AS A LIGHTHOUSE.

A fixed white light, thrown from the tower of St. Philip's Church, and visible for 18 miles, forms the rear light of the main channel range in Charleston Harbour, South Carolina.

few masonry towers which were erected were of the most primitive description, and soon fell victims to the ravages of the weather.

Accordingly, when the lighthouse administration was placed upon an efficient footing, the first task was the complete overhaul, and reconstruction where necessary, of many of the existing lights. Of the eight beacons which were taken over by the Federal Government in 1789, six have been rebuilt. The only two exceptions are the Sandy Hook light — a stone tower 88 feet high — and Cape Henlopen, at the entrance to Delaware Bay, both of which were built in 1764. Naturally, their illuminating apparatus has been remodelled from time to time, in accordance with the advances in this field of lighthouse engineering, but that is the only change which has been effected.

One lighthouse on the Atlantic coast of the United States possesses a pathetic and romantic interest. It indicates the treacherous shores around Cape Henry, and mounts sentinel on the headland at the southerly side of the entrance to Chesapeake Bay, Virginia. The stranger on the passing ship, as he scans the dreary bench of sand rising from the water's edge at this point, has his attention arrested by two gaunt towers. The foremost is almost lapped by the water ; the other is some distance to the rear, and upon a higher level. "Two lights, and for what ?" is a natural exclamation. But only one tower—that nearer the waves —throws its glare by night. Its companion behind has passed its cycle of utility long since, but it has not been demolished because of its unique history. It was built in 1789 with bricks and stones brought from England. In shape it is a tapering octagonal cone, and when first erected the waves almost washed its base. But the sea, which eats away the rock and soft soil at some parts, casts this débris ashore here, so that Cape Henry is slowly but surely thrusting its dismal tongue of sand farther and farther into the Atlantic. The old tower fulfilled faithful service until the seventies, when, being considered too far from the water, it was superseded by the shaft rising from the sand-dunes below. After a century's service the old light was extinguished, to permit the fixed white light of the first order in the new tower to take its place.

The new building, completed in 1881, is likewise octagonal in section, gradually tapering from the base to the lantern gallery. It is built upon what is described as the "double-shell principle," there being two iron cylinders, one within the other. It is 152 feet in height, and the powerful white beam has a range of twenty miles, while a red beam is cast from one side to mark a dangerous shoal. As a powerful flashing white light of a similar character is shed from a tower on Cape Charles opposite, the mariner has a well-illumined entrance into Chesapeake Bay.

Ice was one of the great difficulties against which the American lighthouse builders had to contend, and they laboured valiantly to mitigate this evil. It caused more damage to their works than wind and wave of the most terrifying violence. The upper reaches of the great rivers are encased with thick ice throughout the winter. When the spring comes round, this brittle armour is broken up, and, caught by the current, is swept toward the ocean, the floes jostling and crashing among one another. When the slightest obstruction is offered to their free movement, the pieces mount one another, forming large hummocks, and the pressure thus imposed is terrific. The "ice-shove," when it assumes large proportions, is quite capable of wreaking widespread damage.

When the screw-pile lighthouses came into vogue, this danger was advanced as one of the greatest objections to the adoption of this idea. It was pointed out that the ice would pack around the slender legs, and either snap them, or would bring about such severe distortion as to imperil the safety of the superstructure. When Major Hartman Bache undertook the erection of the Brandywine Shoal light in Delaware Bay, he determined to frustrate the effects of this peril. The light, being eight miles from the ocean, was right in the path of the ice-shoves of the Potomac, so the nine iron legs upon which the beacon is supported—

eight in a circle and one central—are protected by what is known as an "ice-breaker." This is a pier of thirty iron piles, which likewise are screwed into the sea-bed. Each pile is 23 feet long by 5 inches in diameter, and they are connected at their heads, and at a point just above low-water, by what are known as "spider-web braces." The result is that, when a shock is inflicted upon one pile, it is communicated throughout the entire breaker. This system has proved entirely successful, and has protected the lighthouse within completely. The main building, although subjected to heavy attacks by the piled ice, has never been damaged thereby, although subsequently it became necessary to strengthen the ice-breaker, because the onslaughts of several winters had left their mark.

Off the coast of Florida, and in the waters of the Gulf of Mexico, this type of lighthouse is very strongly in evidence, as it was found to be the most suitable for the coral sea-bed. The most notable structure of this class is the Fowey Rocks light, which rises, a flame-crowned skeleton, from the extreme northern point of the Florida reefs. It is in an exposed position, where inclement weather is often experienced. At this point there is not more than 3 feet of water, and the spot is as bad as a mariner could wish to avoid, for no ship could hope to escape destruction once it became entangled in these submerged toils.

The building of this light presented many perplexing difficulties, the greatest of which was offered by the weather. The structure is an octagonal pyramid, with the keepers' quarters on a lower deck, communication with the lantern being afforded by a winding staircase encircling a vertical cylinder. The light is 110¼ feet above high-water, of the fixed type, with red sectors guarding dangerous shoals in the vicinity, while the white beams can be picked up some eleven miles away.

The integral parts of this building were prepared by three different contractors, were fitted together, and the building set up temporarily, on the mainland, so as to facilitate erection at the site. The work was started in 1876, the first move being the provision of a platform about 80 feet square and 12 feet above low-water, from which to conduct operations. The lower piles were driven about 10 feet into the live coral reef. Extreme care was observed during this operation, the pile after every stroke of the driver being tested with a plumb-line, to make sure that it was being sent home absolutely vertically. If it diverged, however slightly, from the perpendicular, the error was corrected immediately. When the piles had been driven to the requisite depth, the tops were levelled to the height of the most deeply driven pile; then the horizontal members were placed in position, followed by the diagonal bracing.

This task occupied some two months, and then a spell of bad weather broke over the coast, interspersed with brief intervals of smooth seas and calms. As the land depot was four miles away, this involved frequent journeys to and fro for the workmen, who had to be brought off the work upon the slightest sign of rough weather. To eliminate the interruptions arising from this procedure, tents were despatched to the site and pitched on the wooden platform, so that the men might reside there. At times their situation was alarming; the heavy seas rushed and tumbled among the piles beneath the crazy perch, and the men were always on tenterhooks lest a hurricane, such as is experienced often in this region, should bear down upon them and carry the whole colony away. When work was in progress, they did not realize their lonely, perilous position so much, since their minds were otherwise occupied; but it was the enforced periods of idleness, often lasting several days on end, which made them grow despondent, as they were virtually imprisoned, and there was very little space in which to obtain exercise. The material was brought out in lighters towed by a steam-launch, on which steam was kept up day and night, because the material had to be sent out at any moment when the conditions were favourable. Again, this "standing by" was imperative, in case a sudden call for assistance should be given by the little isolated community when faced with disaster during a storm. When the men

THE BONITA POINT LIGHTHOUSE OFF THE CALIFORNIAN COAST.

While the tower is only 21 feet in height, its position on a lofty cliff gives the light of 27,000 candle-power a range of 17 miles.

POINT PINOS LIGHT STATION, CALIFORNIA.

This mariners' friend has been tended by a woman for the past 30 years.

got the keepers' quarters completed, their minds became easier, as they were now in possession of a more stable camp. The superstructure advanced at a rapid rate, and the light was shown for the first time on June 15, 1878.

Toil of a different character was associated with the building of the Race Rock lighthouse, eight miles from New London, Connecticut. This peril is a submerged ledge off Fisher's Island Sound, and is of formidable magnitude, since the ledge is at the mouth of the race, where the waters, according to the tide, sweep along with great velocity and force, while in heavy weather the waves get up high and thunder with awful power. The main ledge bristles with ugly sharp spurs, some of which rise above the main cluster, known as Race Rock, which is about 3 feet below mean low-water. The situation of this lurking danger called for the erection of an efficient beacon, though not demanding a light of the calibre of Minot's Ledge, because even in rough weather the water does not mount in the form of thick curtains of spray. A smaller and different type of light, therefore, was considered to be adequate for the purpose.

Even then, however, erection was not an easy matter by any means. The velocity of the water and the submerged character of the reef demanded the aid of divers to prepare the ledge-face and to complete the foundations. The rock was levelled as much as possible by the aid of small broken stone and riprap. On this a heavy circular stepped plinth of solid mass-concrete was laid. This foundation is 9 feet in thickness, and is disposed in four concentric layers, the lowermost of which is 60 feet in diameter by 3 feet in thickness. The concrete was laid in huge hoops of iron, of the desired height and diameter for the respective layers, to prevent the mass from spreading. When this task was completed, there was a level platform, as solid as the rock itself, and projecting 8 inches above mean low-water. On this a conical stone pier was built to a height of 30 feet, by 57 feet in diameter at the base. The top was crowned with a projecting coping 55 feet in diameter. The outer face of this pier is composed of massive blocks of stone backed with concrete ; while in its heart are the spaces for cisterns and cellars. From one side of this pier stretches a short jetty, to form a landing-place.

The lighthouse comprises a granite dwelling of two floors for the accommodation of the keepers, from the centre of the front of which rises a granite tower, square at the base, but round at the top, to carry the lantern, the light of which, of the fourth order, is 67 feet above mean high-water. The warning is an alternate flash of red and white, with a ten seconds' dark interval. For the protection of the base of the pier, the ledge on all sides is covered with a thick layer of boulders. The work was commenced in 1872, but, owing to its difficult character, occupied six years. The Race Rock lost its terrors for all time when the beam flashed out on the night of New Year's Day, 1879.

On the Pacific seaboard, while the American lighthouse engineers have not been so active in regard to engineering work of an impressive nature, owing to the more slender proportions of the maritime traffic, they have accomplished some notable triumphs. The Tillamook Rock light, described in the previous chapter, is the most important, and is to the Pacific seaboard of the country what the Minot's Ledge light is to the Atlantic coast. The majority of the lights on the Pacific are stationed on the mainland, or contiguous thereto. These beacons are of more modern construction than those on the Atlantic shore, and in some instances are very powerful. Pride of place in this respect is shared between Point Arena and Cape Mendocino. The former, perched on the cliff-shore of California, has a flashing group of two flashes of $\frac{3}{8}$ second in five seconds, with eclipses of $1\frac{1}{8}$ and $4\frac{1}{8}$ seconds respectively, thrown by its light of 1,000,000 candle-power over the water for a radius of eighteen miles from a height of 155 feet. Cape Mendocino light, on the same coastline, has the further distinction of being the most elevated light on the United States Pacific coast, the 340,000 candle-power beam being thrown for ten seconds once every thirty seconds from an elevation of

THE FARALLON ROCK AND LIGHT.

The light of 110,000 candle-power is placed on the highest peak of the rock, 358 feet above the sea.

THE FARALLON LIGHTHOUSE OFF SAN FRANCISCO.

Owing to the height of the rock, a tower 29 feet high was adequate to carry the lantern and its equipment.

THE PUNTA GORDA LIGHT STATION, CALIFORNIA.

One of the latest built by the United States. Commodious and handsome buildings are provided for the wardens of this light.

422 feet. Although the tower itself is only 20 feet in height, the cliff sheers up for 402 feet. Consequently the flash may be detected from twenty-eight miles out to sea in clear weather.

On the other hand, the Point Cabrillo light, a few miles south, whose flashing ray is of 650,000 candle-power, is picked up from a distance of only fourteen miles, because the light is but 84 feet above mean high-water. The Farallon beacon, comprising a tower 29 feet high planted on the highest point of Farallon Island, off San Francisco, comes a good second in point of elevation, as the 110,000 candle-power flash, occurring for ten seconds once in every minute, is projected from an altitude of 358 feet, and can be discerned twenty-six miles away. For many years the Point Reyes light held the distinction of being the loftiest beacon, since its flash of 160,000 candle-power once every five seconds is shed from an elevation of 294 feet, but is now relegated to third place in this respect. Taken on the whole, the lights scattered along the rugged, lonely Pacific seaboard are far more powerful than their contemporaries guarding busier shipping on the eastern coast of the country; but whereas the latter are placed somewhat close together, the former are spaced far apart.

There are some points which, while being so extremely perilous to the mariner as to demand the provision of a lighthouse, yet cannot be guarded at present. The peculiarity of their situations and their physical characteristics completely defy the ingenuity, skill, and resource, of the engineer. Cape Hatteras, perhaps, is the most forcible illustration of this defeat of science by Nature. The sea-bed for miles off this point is littered with the most treacherous sandbanks, beside which the Goodwins of Britain appear insignificant. Every seafarer knows the Diamond Shoals, and gives them a wider berth than any other danger spot in the seven seas. For some seven and a half miles out to sea from the prominent headland, the Atlantic, according to its mood, bubbles, boils, or rolls calmly, over shoals and serried rows of submerged banks. The currents are wild and frantic ; the storms which rage off this point are difficult to equal in any other part of the world ; and the number of ships which have gone to pieces or have been abandoned to their fate in these inhospitable stretches of sea is incalculable

Time after time the engineers have sought to subjugate this danger, but without avail. The sea-bed is so soft and absorbing that a firm foundation for a tower defies discovery. One brilliant attempt was made to sink a caisson, similar to that employed for the famous Rothersand light in the River Weser. The mammoth structure was built, and with extreme difficulty was towed out to the selected site. But the seas roared against this attempt to deprive them of their prey. They bore down upon the caisson and smashed it to fragments, causing the engineers to retire from the scene thoroughly discomfited. When a huge mass, weighing several hundred tons, could be broken up by the maddened seas so easily, of what avail were the knowledge and effort of man? The Diamond Shoals still resist conquest. The only means of warning ships of their presence is a lightship moored well out beyond the pale of their sucking embrace.

At the present time the United States Lighthouse Board mounts guard over 17,695 miles of coastline. This aggregate embraces, not only the two seaboards of the North American continent, but sections of the Great Lakes, the Philippines, Alaska, Hawaiian Islands, and the American Samoan Islands, the total detailed coast or channel line being no less than 48,881 miles. In order to guide the mariner on his way through waters over which the Stars and Stripes wave, no less than 12,150 lights of all descriptions are required, demanding the services of an army of 5,582 men and women ; while the cost of maintenance exceeds £1,200,000, or $6,000,000, per annum. Seeing that the country levies no tolls for services rendered in this connection, the shipping community, and humanity in general, owe a deep debt of gratitude to a powerful nation.

The United States share with Great Britain, Austria, Belgium, Spain, France, Italy, the Netherlands, and Sweden, the expense of maintaining a lighthouse which is situate on the property of none of them. This is a kind of no man's, and yet it is every man's, light. The beacon is not located in an out-of-the-way part of the world, such as the Arctic Sea, as might be supposed, but mounts guard over one of the busiest marine thoroughfares of the globe—the western entrance to the Mediterranean. This unique light is that of Cape Spartel, on the Moroccan coast. While it was built at the expense of Morocco, the responsibility for its maintenance was assumed by the foregoing Powers, in accordance with the convention of March 12, 1867, which has remained in force since. There is no other light upon the seven seas which has so many Powers concerned in its welfare and maintenance.

CHAPTER XVI

THE LAMP-POSTS OF THE GREAT LAKES OF NORTH AMERICA

On the North American continent the efficient lighting of the coasts washed by two salt oceans is only one, although the most important, concern of the United States and Canadian Governments. In addition each has a long stretch of rugged, tortuous shore hemming in those capacious depressions draining a vast tract of country, and known generally as the Great Lakes. These unsalted seas are rightly named, seeing that they constitute the largest sheets of fresh water on the inhabited globe.

The responsibility of safeguarding the navigator as he makes his way across these wastes is shared equally by the two countries which they divide, with one exception. This is Lake Michigan, which lies entirely within the United States. The narrow necks of water which link these lakes into one long chain likewise are lighted by the two nations. For some years the Lower Detroit River, connecting Lakes Erie and St. Clair, was maintained for the most part by the United States, but the practice was not satisfactory; so, as the result of a conference between the two Governments, Canada assumed charge of the aids in certain specified portions of the navigable channel lying entirely in Canadian waters. The result of this new arrangement has been the better patrolling of the waterway.

The water-borne commerce on these lakes, although possible for only half the year, is tremendous, while navigation is extremely difficult and beset with innumerable dangers.* The different means whereby a ship is handled

* For a full description of the marine traffic on the Great Lakes, see "The Steamship Conquest of the World," chapter ix., p. 119.

and maintained on its course upon the salt-water ocean are not completely applicable in this case. The greater number of the boats are freighters and engaged in the transport of ore, which, from its metallic character, is apt to disturb the compass, rendering it somewhat unreliable. Nor is the lead of much avail in thick weather, as the lake-bed varies suddenly from comparative shallowness to great depths. Navigation on these lakes has been likened to coastal traffic, only with land on both sides of the mariner, and the intervals when the ship is out of sight of the shoreline are comparatively brief. Accordingly, the captain picks his way rather by the aid of landmarks, and the vessels are fitted with a bowsprit, to give the master a point whereby to judge his direction. But landmarks, however conspicuous and trustworthy they may be by day and in clear weather, are useless at night and in fog, to which latter visitation, by the way, these waters are extremely susceptible.

Steamship traffic cannot be carried on with financial success by daylight and in fair weather only, so it became necessary to distribute beacons around the indented shores. This procedure was rendered additionally necessary owing to the formidable character of many of the dangers besetting navigation, in the form of shoals, projecting ridges, and submerged reefs, quite as terrifying to the master of a fresh-water ship as similar dangers on an ocean-swept coast.

At the same time, however, one would not expect to find examples of lighthouse engineering comparable with the great sea-rock lights rearing above the ocean, such as the Minot's Ledge, Dhu-Heartach, or Bishop's Rock. On the other hand, the uninitiated might conclude that buoys and small lights, such as indicate the entrance to harbours, would fulfil requirements. So they would but for two or three adverse factors. These lakes are ravaged at times by storms of great violence, which burst with startling suddenness. Fogs also are of frequent occurrence, especially in the spring and autumn, often descending and lifting instantly like a thick blanket of cloud. But the most implacable enemy is the ice. The engineer can design a tower which will withstand the most savage onslaughts of wind and wave with comparative ease, at, relatively speaking, little expense ; but the ice introduces another factor which scarcely can be calculated. The whole of these lakes are frozen over during the winter to such a thickness as to defy all efforts to cut a channel, becoming, in fact, as solid as terra firma.

In the spring this armour cracks and breaks up like glass shattered with a hammer. It then becomes the sport of the currents, which in many places sweep and swirl with enormous force round the headlands and spits projecting into the lake. This action sets the ice moving in stately majesty, but crushing everything that rears in its way, or piling and breaking against the obstruction. Ice-shoves, ice-jams, and ice-runs, are the three forces against which the engineer has to contend, and at places his efforts are so puny as to be useless. The ice, if it collects across one of the outlets so as to form a massive dam reaching to the lake-bed, immediately causes the level of the lake to rise ; and when at last the barrage breaks, then the water is released in a mad rush.

Lighthouse building on the Great Lakes demands the highest skill, incalculable ingenuity, and the soundest of design and workmanship. Consequently, some of the guardian lights distributed around these shores, such as Spectacle Reef, the Rock of Ages, Colchester, and Red Rock lighthouses, are striking evidences of the engineer's handiwork. Of course, where the land presses in on either hand, transforming the waterway into a kind of canal, or where the shore is free from submerged obstructions, the type of lighthouse on either shore follows the wooden frame dwelling with a low tower, as it is completely adequate for the purpose.

The one erection, however, which commands the greatest attention is the Spectacle Reef light, which has been called the Eddystone, or Minot's Ledge, of the Lakes. In its way

By permission of the Lighthouse Literature Mission.

A LIGHTHOUSE ON THE GREAT LAKES IN THE GRIP OF WINTER.

This tower marks the Racine Reef in 20 feet of water near the entrance to Racine Harbour on the west coast of Lake Michigan.

By courtesy of Lieut.-Col. W. P. Anderson.

BUILDING THE BARRE À BOULARD LIGHT IN THE RIVER ST. LAWRENCE.

Owing to the severity of the ice piling in this waterway, the structures have to be provided with massive foundations.

it was quite as bold an undertaking as either of these far-famed works, and in some respects was far more difficult to carry out, although the builder was spared the capriciousness and extreme restlessness of tidal waters. Spectacle Reef lighthouse rears its tapering head from a particularly dangerous reef in an awkward corner of Lake Huron, where commences the Strait of Mackinac, leading to Lake Michigan. The spot is dangerous, because it is covered by about 7 feet of water; awkward, because it occurs about ten and a half miles off the nearest land, which is Bois Blanc Island. The reef in reality comprises two shoals, which lie in such relation to one another as to suggest a pair of spectacles—hence the name. As it is exposed to 170 miles of open sea on one side, when these waters are roused the rollers hammer on the reef with terrible violence, while at times the currents skirl by at a velocity of two or three miles per hour, and the ice in its movement grinds, piles, and grates itself upon the reef in impotent fury. When this ice is forced forward with the push exerted by the currents, the pressure is tremendous and the force well-nigh irresistible.

When the lighthouse was projected, it was realized that it would have to be of massive proportions and provided with adequate measures to protect it from the assault and battering of the ice. The task was undertaken by General O. M. Poe, who was engineer-in-chief to General Sherman on his historic march to the sea. This engineer decided to take the Minot's Ledge monolithic structure as his model, seeing that the latter had withstood the savage onslaughts of the Atlantic. Fortunately, the foundations were of an excellent character, the reef being formed of hard limestone.

The engineer selected as the site for the tower a point where the ridge is submerged by 11 feet of water. Seeing that the base was to be laid under water, obviously it seemed to be an operation for divers; but General Poe prepared a superior means of getting the subaqueous foundations laid. He built a cofferdam around the site, and, as the work would have to be protected from the winter ice, he built another cofferdam, entirely for protective purposes, outside the former. The nearest point on the mainland where he could establish a depot was Scammon's Harbour, some sixteen miles away, and here everything in connection with the work was prepared and shipped to the site ready for placing in position.

The protective work comprised a wooden pier, built up of timbers 12 inches square, 24 feet in height. This structure was divided into a series of vertical compartments on all four sides, leaving a clear internal space 48 feet square. The outer compartments or pockets were filled with stone, to secure solidity and stability. Landing facilities were provided on this pier, together with quarters for the men engaged in the construction work.

In the inner space, containing 48 square feet of still water, the cofferdam, in which the subaqueous work was to be carried out, was lowered. This structure was cylindrical in form. It was built up of staves, banded with heavy hoops of iron, so that in reality it resembled a huge barrel 36 feet across. It was fashioned at the site, being built while suspended directly over the spot on which it was to be lowered. When the tub was finished, loosely twisted oakum, 1½ inches thick, was nailed all round the lower edge, while a flap of heavy canvas was secured to the outside bottom rim in such a way as to leave 36 inches dangling free. The exact circular shape of the cofferdam was insured by liberal cross-bracing from a central vertical post, which constituted the axis of the barrel, corresponding to the vertical axis of the tower. While this work was in progress, the face of the rock was cleared of loose boulders, and then the cofferdam was lowered bodily with extreme care, so that it descended with unerring accuracy perpendicularly into the water, to come to rest over the desired spot. As the surface of the reef was very uneven, the cofferdam stopped when it reached the highest projection under its edge. Then each stave of the barrel was driven downwards until it came to rest upon the sea-bed, and, as the oakum rope was forced down likewise, this served to act as caulking. The outer flap of canvas, when the cofferdam was driven right home, spread out on all sides, and lay upon the surface of the reef.

Pumps capable of discharging 5,000 gallons per minute then were set to work, removing the water from within the cofferdam. The oakum rope seal prevented the water regaining the internal space under the bottom edge of the tub, while the canvas assisted in securing absolute water-tightness, because the outer water-pressure forced it into all the nooks and crevices.

By these means the workmen were given an absolutely dry space in which to carry out their erecting work. The face of the reef was cleaned and levelled off, and the first layer of stones was laid. These were first fitted temporarily upon a false platform on shore, so that when they reached the site they could be set at once without finicking. The bottom layer is 32 feet in diameter, and the tower is solid to a height of 34 feet above the rock. The stones are each 2 feet in thickness, and are secured to one another on all sides with wrought-iron bolts, 24 inches long by 2½ inches in diameter ; while the tower is anchored to the rock by cement and bolts 3 feet long, driven through the bottom course into the real rock beneath, entering the latter to a depth of 21 inches. Liquid cement was driven into the holes so as to fill up all the remaining interstices, and this now has become as hard as the stone itself.

The exterior of the tower is the frustum of a cone, and at 80 feet above the base is 18 feet in diameter. The total height of the masonry is 93 feet, and the focal plane is brought 97¼ feet above the rock, or 86¼ feet above the water-level. The tower is provided with five rooms, each 14 feet in diameter, while the entrance is 23 feet above the water. The undertaking was commenced in May, 1870, and the light was shown first in June, 1874. As work had been confined to the summer months, and a fortnight every spring was devoted to preparations, as well as an equal period in the autumn to making all fast to withstand the rigours of winter, the total working period was only some twenty months.

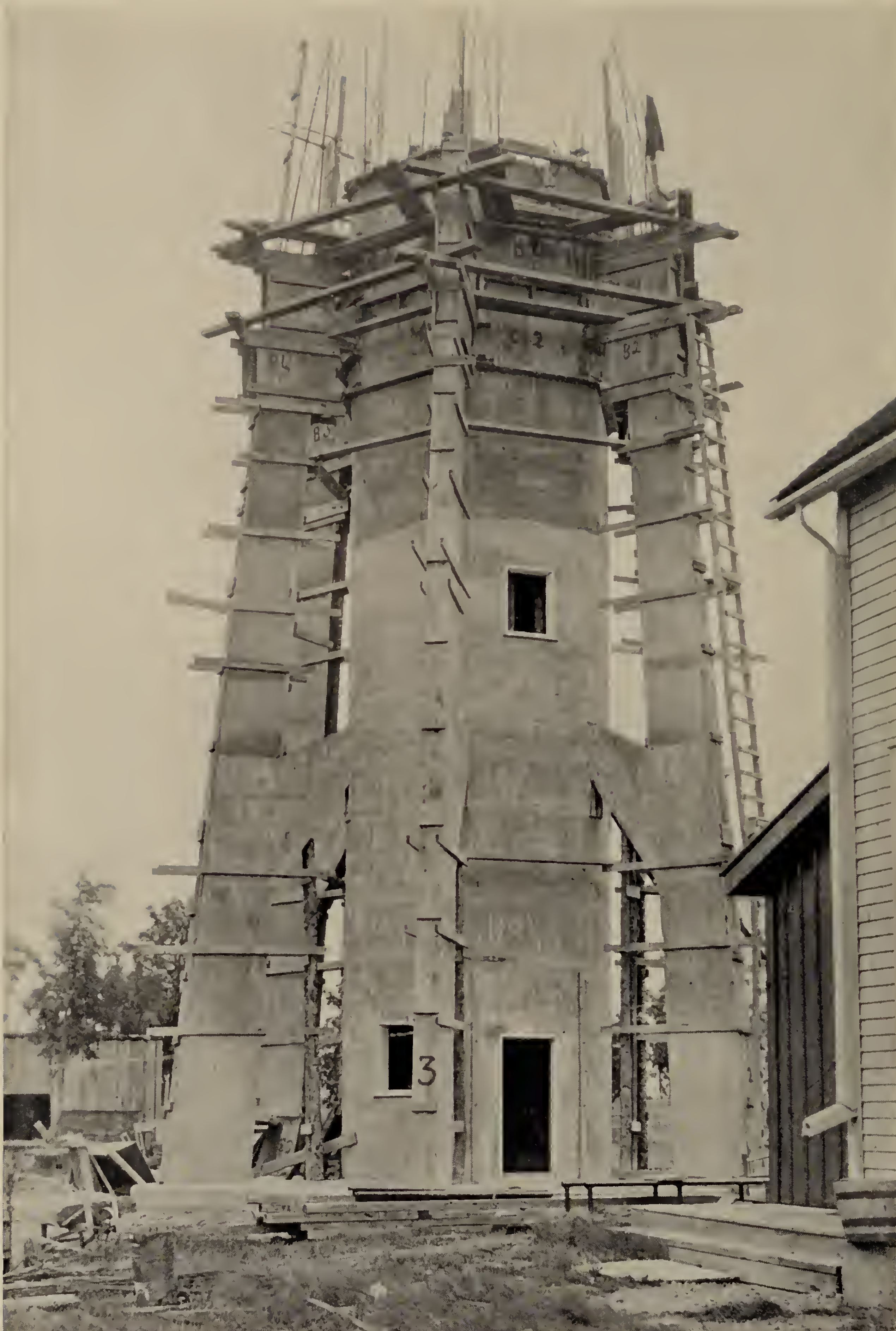
The protection against the ice has proved its value completely. The ice as it moves becomes crushed against the defence, and then has its advance impeded by the shoal upon which it grinds and packs, to form in itself a barrier and ice-breaker against other approaching ice-fields. This structure was soon submitted to a stern test to prove its efficacy. In the spring of 1875, when the keepers returned to the lighthouse—the light, in common with all other beacons guarding the Great Lakes, is shut down during the winter, when navigation is closed—they found the tower unapproachable. The ice-shove had jammed, packed, and been frozen into a solid berg to a height of 30 feet, of which the tower itself formed the core. The doorway was buried to a depth of 7 feet, and the keepers had to carve their way with pickaxes to the entrance.

Owing to the success of the design for the Spectacle Reef lighthouse, which ranks as a striking engineering achievement, it was adopted for the Stannard's Rock tower. This ledge rises from the water 28 feet from shore, and the plant and tackle which were employed in connection with the first-named structure were utilized in this undertaking. The tower is 191 feet in height, and the light can be seen for about twenty miles. During the past two or three years the United States Government has erected two other noble lighthouses in Lakes Superior and Michigan. The first warns all and sundry off a rock having three ugly pinnacles projecting above the water, and known as the "Rock of Ages." This danger stands right in the steamship tracks between Port Arthur and Duluth, off the western end of Isle Royale. The engineers selected one of the pinnacles as the base for the tower, decapitating the projection to 12 inches above mean low-water, so as to secure a sufficiently large and level plinth. On this bed a cylindrical foundation pier, of massive proportions and strength so as to withstand the ice action, was planted, to support a lofty tower in reinforced concrete. The building has seven floors, one being set aside for housing the two twenty-four horse-power oil-engines which are used to drive the air-compressors for

By courtesy of Lieut.-Col. W. P. Anderson.

COLCHESTER REEF LIGHTHOUSE, LAKE ERIE.

An isolated station maintained by the Canadian Government. It is a fixed light, visible throughout a circle of 16 miles radius.



THE LATEST DEVELOPMENT IN LIGHTHOUSE ENGINEERING.

Building the hexagonal tower on Caribou Island, Lake Superior, upon the lines evolved by Lieut.-Col. W. P. Anderson, the chief engineer to the Canadian Lighthouse Department.

the fog-siren. The light is 125 feet above water-level, and gives a double flash at ten-second intervals, which can be picked up twenty-one miles away. This tower was erected in a very short time, the work, commenced in May, 1907, being completed, except for the installation of the permanent lens, thirteen months later. The optical apparatus was fixed and the light shown first on September 15, 1910.

The second light has been placed on White Shoal, at the north end of Lake Michigan, and supersedes a lightship which fulfilled all requirements for many years. The shoal is exceptionally dangerous, and the crowded character of the shipping demanded the installation of a more powerful light and fog-signal. The structure is a striking piece of work, comprising a steel cylindrical tower, or shell, lined on the inside with brick and faced externally with terra-cotta—an unusual material for lighthouse construction. The superstructure is built upon a massive concrete pier, about 70 feet square, rising 20 feet above water-level, this being borne in turn upon a heavy stone-filled timber crib laid on a block-stone foundation, the whole being protected thoroughly with riprap. The lantern is of the second flashing order, with the focal plane 125 feet above the lake-level, and the 65,000 candle-power ray is visible twenty-five miles away. The tower is fitted with a duplicate plant of twenty-four horse-power oil-engines and air-compressors, operating an eight-inch whistle ; and there is also an electrically-operated submarine bell, the power for which is generated by an independent oil-engine, the bell being operated from the engine-room. This station is equipped also with a compressed-air water-supply system and a motor-boat.

Owing to the peculiar prevailing conditions, the provision of adequate beacons upon the Great Lakes is highly expensive. Up to the year 1883 more money had been devoted to the lighting of the shoreline of Lake Michigan than to the illumination of any ocean or gulf in any other State in the country. The total expenditure up to the above year exceeded £470,000, or $2,350,000. The Spectacle Reef light was considered cheap at £75,000, or $375,000; and the Stannard Rock lighthouse, owing to the plant and other facilities being available from the foregoing work, cost £60,000, or $300,000. By the time the "Rock of Ages" tower threw its light, £27,649, or $138,245, had been sunk; and the White Shoals lighthouse absorbed £50,000, or $250,000.

The Canadian Government, too, has completed some notable works upon the Great Lakes during recent years. In Lake Erie, in the fairway of passing traffic, is a ledge known as Colchester Reef, on the south-east edge of which a lighthouse, one of the most isolated in Canadian waters, has been placed. The circular stone pier is built in 14 feet of water, and the lighthouse, comprising a two-story dwelling and tower, supports the beacon 60 feet above the lake. The light is a fixed white, of the third dioptric order, visible throughout a circle of fourteen miles radius.

At the entrance to Parry Sound, on a convenient site offered by the solid granite mass of Red Rock, a new lighthouse was constructed in 1911. This was the third beacon placed at this point, the two previous lights dating from 1870 and 1881 respectively. It is a particularly bad spot, since the waters of Georgian Bay have a free run, so that the rock experiences the full hammering of the sea. The beacon comprises a reinforced concrete building, nearly elliptical in section, supported upon a heavy stone foundation, which is encased in steel, and which is 12 feet high. The tower has a height of 57 feet, bringing the occulting flash of twelve seconds, with an eclipse of four seconds, 60 feet above the water. This station is also equipped with a powerful diaphone. The keepers of this light experience exciting times, as in a furious gale, such as the lakes only can produce, the waves frequently crash over the building.

Another fine light in the stretch of these waters under Canadian jurisdiction is found about halfway across Lake Superior, where Caribou Island thrusts its scrub-clothed hump above the water, almost directly in the path of the vessels running between Sault Ste. Marie and Sarnia. This magnificent structure, placed on a small islet lying off the main island, is built in ferro-concrete, in accordance with Lieutenant-Colonel Anderson's latest ideas, and was opened for service in 1912. It is of hexagonal shape, with six flying buttresses, and the focal plane is brought 99 feet above the water-level, so that the white flash of half a second may be seen all round from a distance of fifteen miles.

The steamship lanes across the Great Lakes are now well lighted. Canada alone maintains over 460 lights of all descriptions throughout its waters between the eastern extremity of Lake Ontario and the head of Lake Superior at Port Arthur. The United States authorities watch over 694 attended and unattended aids to navigation in the same seas, of which total 152 are scattered around the coast-line of Lake Michigan. The mariner in these fresh-water oceans, consequently, has a round thousand lights to guide him on his way, and the number is being steadily increased to keep pace with the growth of the traffic, so that these seas may become regarded as the safest and best protected in the world.

CHAPTER XVII

THE MOST POWERFUL ELECTRIC LIGHTHOUSES OF THE WORLD

In a previous chapter I have mentioned that, although oil is the most popular form of illuminant in lighthouse engineering, electricity is maintained to be preferable, but labours under one heavy disadvantage which militates against its more general adoption. It is expensive to install and to maintain. Under these circumstances the system has been restricted to lights of the most important character, preferably landfalls or beacons indicating the entrance to a harbour. Thus, we have the Lizard at the entrance to the English Channel ; St. Catherine's on the Isle of Wight ; the Rothersand at the entrance to the Weser ; the Heligoland flaring over the island of that name ; the Isle of May at the entrance to the Firth of Forth ; Cape Héve near Havre ; and the Navesink light on the highlands of the New Jersey coast, to guide the mariner into New York harbour.

The first attempt to apply electricity to lighthouse illumination was made in the year 1859, by the Trinity Brethren, on the strong recommendations of Professor Faraday, who was then scientific adviser to the British lighthouse authorities. The South Foreland light was selected for the experiments, and the magneto-electric machine invented by Professor Holmes, who subsequently perfected the siren, was used.

The installation was built with extreme care, as the imperative necessity of reliability, owing to the peculiar nature of the application, was recognized very fully. The large wheels made eighty-five revolutions per minute, and at this speed produced a very steady light. On a clear night, owing to the elevation of the cliff the light was visible for over twenty-seven miles, and could be descried readily from the upper galleries of the lighthouses on the opposite French shore. In order to determine the relative value of electric lighting in comparison with the other methods of illumination then in vogue, another light emitted by an oil-lamp, with reflectors characteristic of the period, was burned simultaneously from a point below the top light, so that passing mariners were able to compare the two systems of illumination under identical conditions.

The French lighthouse authorities were not dilatory in adopting the new idea, and electricity was installed in the Cape Héve lighthouse in 1863. The light was brilliant for those times, being approximately of 60,000 candle-power. The French investigators then embarked upon an elaborate series of experiments, and in 1881 an electric light of about 1,270,000 candle-power was established at the Planier lighthouse, near Marseilles. The investigations culminated in the great achievement of M. Bourdelles, who, while engineer-in-chief of the Service des Phares, designed a new electric installation for the Cape Héve light, of 25,000,000 candle-power.

Meantime British engineers had not been idle. In 1871 Messrs. Stevenson, the engineers-in-chief to the Commissioners of Northern Lighthouses, advocated strongly the establishment of an electric light upon the Scottish coast; but it was not until 1883 that the Board of Trade sanctioned the sum necessary to complete such an enterprise, and suggested that the innovation should be made at the Isle of May lighthouse, as being the most important on the East Scottish coast.

This is one of the historic light-stations of Scotland. Lying in the Firth of Forth, five miles off the Fifeshire shore, the islet obstructs a busy marine thoroughfare. For 276 years a light has gleamed from its summit, the change from the coal fire to Argand lamps with reflectors having been made by Thomas Smith, the first engineer to the Commissioners of Northern Lighthouses, when this body assumed its control in 1816. Twenty years later it was converted to the dioptric system, with a first-order fixed light apparatus having a four-wick burner. This arrangement was in service for half a century, when it was converted to electricity in conjunction with a dioptric condensing apparatus.

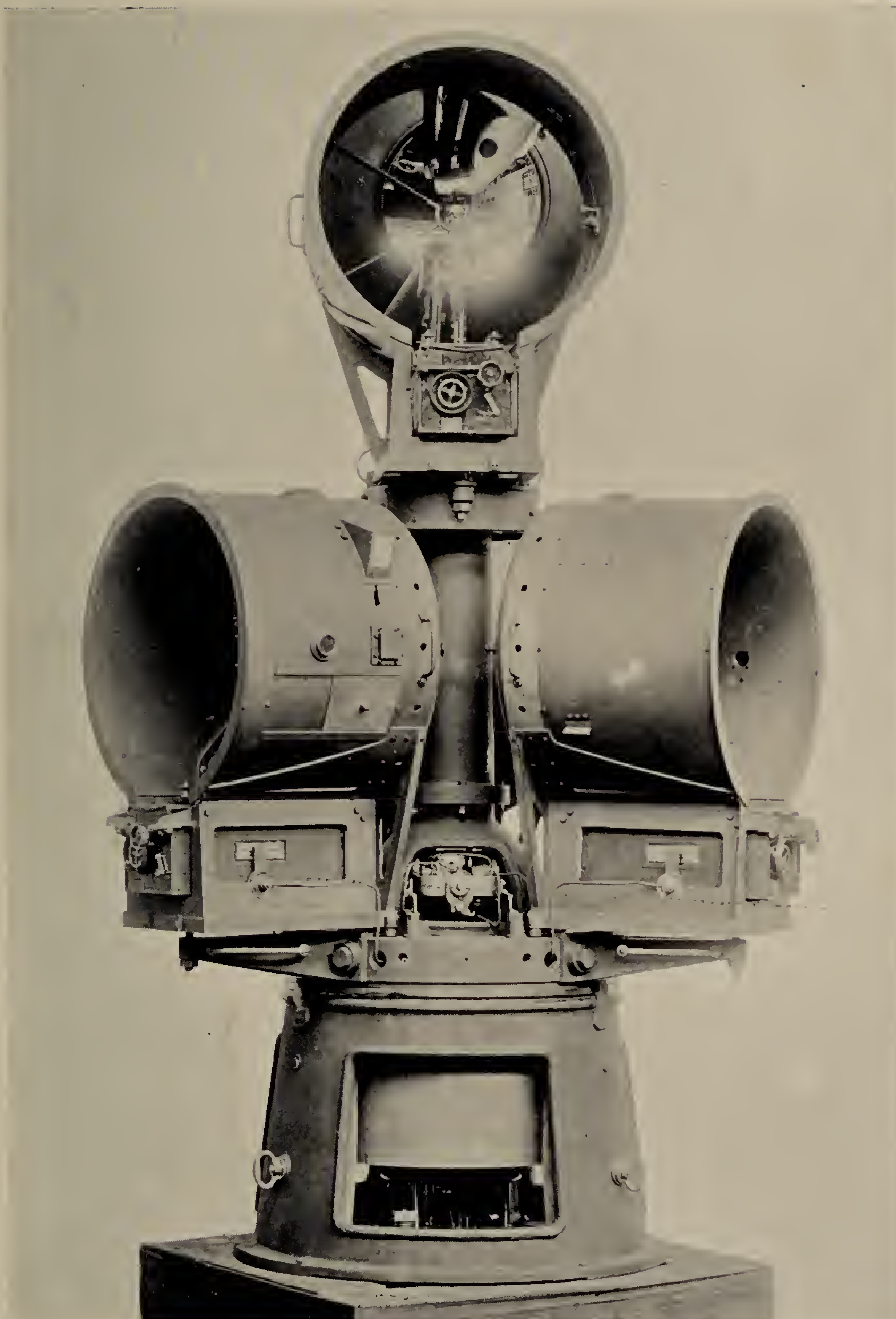
The electric installation was designed throughout by Messrs. Stevenson, and it possesses many ingenious and novel features to this day, while it was the pioneer of modern electric lighting systems as applied to lighthouse engineering. Although marked improvements have been effected in electrical engineering and science since its completion, it still ranks as one of, if not the, most powerful electric lighthouses in the world. The beacon is a prominent edifice on the summit of the island. The building is somewhat pretentious, rather resembling a battlemented castle than a warning for the mariner, the optical apparatus being housed in a square turret rising above the main part of the building. When electric illumination was adopted, the existing accommodation for three keepers was found insufficient, while a generating-station was necessary. Instead of extending the old building to accommodate the additional facilities, a second station was built at a low-lying point near the sea-level. This contains the engine and generating house, together with quarters for three more keepers and their families. This decision was made because at this point, 810 feet away and 175 feet below the lighthouse, there is a small fresh-water loch whence water is available for the boilers and condensers, while a marked saving in the cost of handling fuel as well as of the haulage of the building materials and machinery was feasible. The current is led from the power-house to the lighthouse by means of overhead copper conductors.

Some difficulty was experienced in securing electrical apparatus suited to the searching exigencies of lighthouse engineering, and the designers made one stipulation, which at first appeared to baffle fulfilment. This was the placing of the positive carbon below, instead of above, so as to enable the strongest light to be thrown upwards, to be dealt with by the upper part of the dioptric apparatus, whereby it could be used more effectively. One firm struggled with this problem for many months, and then was compelled to admit defeat, as time for further experimenting was unavailable, since the lighthouse was almost completed. Accordingly, the designing engineers had to revise their plans, and had to acquire alternate-current De Meriten machines, which, although more expensive and less powerful than those originally intended, yet were, and are still, wonderfully steady in working, while they had previously proved highly efficient for lighthouse service. Two generators of this description were secured, and they constituted the largest that had been made up to this period, each plant weighing about 4½ tons. Each machine has sixty permanent magnets, disposed in five sets of twelve each, while each magnet is made up of eight steel plates. The armature makes 600 revolutions per minute, and develops an average current of 220 ampères.

The installation is so designed that one-, two-, three-, or four-fifths, or the whole, of the current can be sent from each unit to the distributor for transmission to the lantern, or the two machines may be coupled and the full current from both utilized. The current is conveyed to the lantern through copper rods 1 inch in diameter, and this was the first occasion on which such conductors were utilized for lighthouse work. There are three lamps of a modified Serrin-Berjot type, one being in service, and the other two held in reserve. By means of a by-pass, or shunt, a large percentage of the current is sent direct to the lower carbon, only a sufficient amount to regulate the carbons being sent through the lamp. The carbons used are about 1½ inches in diameter, though two-inch carbons can be employed when both machines are running, and the rate of consumption is 1¼ inches, or, including waste, 2 inches, per hour. The power of the arc thus obtained with the current fed from one generator is between 12,000 and 16,000 candles. In the event of the electric installation breaking down, a three-wick paraffin oil lamp is kept in reserve, ready for instant service, and it can be brought into use within three minutes.

The dioptric apparatus, designed by Messrs. Stevenson, and manufactured by Messrs. Chance Brothers and Co. of Birmingham, is of a novel character, inasmuch as the condensing principle has been carried to a pronounced degree. The light characteristic is four brilliant flashes in quick succession every thirty seconds. The lenticular apparatus also includes the ingenious idea advocated by Mr. Thomas Stevenson, an earlier engineer-in-chief to the Northern Commissioners and perhaps the greatest authority on lighthouse optical engineering, whereby the light may be dipped during a fog. Thus, in clear weather the strongest part of the ray may be directed to the horizon, while in thick weather it can be brought to bear upon a point, say, four or five miles away. The flashes are produced by a revolving cage of straight vertical prisms, which enclose the fixed-light apparatus. This cage makes one complete revolution every minute, the rotary movement being secured through a train of wheels and a weight, which has a fall of 60 feet in a tube extending vertically through the centre of the tower, the mechanism being wound up once an hour by manual effort.

The beam of light obtained by the aid of electricity is of intense brilliancy and penetration. Its equivalent in candle-power is somewhat difficult to determine, because the methods of calculation are somewhat arbitrary and misleading. By their own method of calculation, the engineers responsible for the installation rate it at 3,000,000 candle-power with one generator in use, and 6,000,000 candle-power when both are going. This is from 300 to 600 times as intense as the oil light which was superseded. By another method of calculation the beam is of 26,000,000 candle-power, while another principle of rating brings it to upwards of 50,000,000 candle-power. In clear weather the light has a range of twenty-two miles, being indistinguishable at a greater distance, owing to the curvature of the earth ; but the flashes of light illuminating the clouds overhead may be picked up forty or fifty miles away. The total cost of



By permission of Messrs. Siemens Bros. & Co., Ltd.

THE ELECTRIC SEARCHLIGHTS OF THE HELIGOLAND LIGHTHOUSE.

On the lower level are three projectors spaced 120 degrees apart. Above is a fourth searchlight revolving three times as rapidly as those below.

By permission of Messrs. Siemens Bros. & Co., Ltd.

THE HELIGOLAND LIGHTHOUSE.

One of the most powerful electric beacons in the world. Its maximum candle-power is 43,000,000.

electrifying the Isle of May light was £15,835, or $79,175; while the annual cost of maintenance is over £1,000, or $5,000.

The most famous English electric lighthouse is that of St. Catherine's, in the Isle of Wight. This point, like the Isle of May, has been a beacon for centuries. Its creation for this work even antedates its northern contemporary, because in the fourteenth century a chantry was built by a benevolent knight on the highest point of St. Catherine's Downs, who furthermore provided an endowment for a priest "who should chant Masses and maintain a burning light at night for the safety of mariners." But this protection fell into desuetude.

The station, however, was revived upon the old site in 1785, but it had to be abandoned, because it was found to be built at too high an elevation. It was so often enveloped in fog as to be useless, or at least unreliable, to the seafarer. A new tower, accordingly, was erected at a lower level, and brought into service in 1840, the warning rays being thrown from a height of 134 feet above the water. Oil was used with a burner of six rings, the light being officially known as a "fixed oil light of the first class," while the beam was diffused over an arc of 240 degrees. In the middle eighties the Brethren of Trinity House decided to bring it up to date, and selected electricity as the illuminant, at the same time changing the light from the fixed to the revolving class, with a five-second flash once every thirty seconds.

The installation is not widely dissimilar from that used at the Isle of May. It comprises two De Meriten dynamos in duplicate, while the lamps are of the modified Serrin-Berjot type, using carbons, not of circular section, but with fluted sides. This shape was introduced by Sir James Douglass, who contended that the former type did not produce the requisite candle-like steadiness of the flame so essential to lighthouse illumination. The dioptric apparatus was of the sixteen panel type, so that the rays were thrown out in sixteen brilliantly white horizontal spokes. To one approaching the lighthouse at night-time, the effect in the sky was somewhat curious. It recalled a huge and illuminated cart wheel or Catherine wheel, lying flat on its side, throwing its rays to all points of the compass in a steadily moving circle. This practice had been borrowed from the French, who went so far as to introduce a twenty-four panel system, and, as in France, the St. Catherine's light, when first brought into service, was not a complete success. The French considered that, by distributing the light through as many panels as possible, the question of bringing the flashes into action at short intervals would be facilitated, ignoring the fact that by so doing the intensity of each ray was impoverished. In other words, with the twenty-four panel light each panel only received and threw out one-twenty-fourth part of the volume of light emitted by the arc. Similarly, in the St. Catherine's light only one-sixteenth part of the light produced was thrown through each panel. A few years ago the optical system was replaced by an apparatus having fewer panels. The light thrown from the Isle of Wight pharos, with its beam exceeding 5,000,000 candle-power, represents a marked advance upon the oil light which it displaced, and certainly it ranks as the most brilliant light in the English Channel.

A few years ago another magnificent light was brought into service in the North Sea by the installation of electricity in the lighthouse of Heligoland. With characteristic Teuton thoroughness, the Germans discussed the question of the illuminant for this beacon in all its bearings, and resolved to introduce the most powerful light possible. This decision was influenced by the dangerous character of the waters washing the island, as it is flanked on all sides by highly perilous ridges and sandbanks, which must become accentuated owing to the heavy sea-erosion that prevails.

The German authorities investigated the various electrical installations that had been laid down for lighthouse work, with a view to discovering the most suitable system, the advantages and defects of existing electric lights, and how the drawbacks might be overcome most successfully. Meantime the famous Siemens firm discovered a means of grinding glass mirrors into parabolic form, and this discovery was accepted as the solution to the problem.

In this type of mirror the back is silvered. The metallic polished surface is protected completely from mechanical injury and from all possibility of tarnishing. The inventors claim that mirrors so prepared are able to compete successfully with lenses and totally reflecting prisms—in fact, it was maintained that the silvered glass parabolic mirror possessed the advantages of greater reflecting power and enhanced accuracy, with less divergence of the beam of light.

Owing to the perfection of the lenses and prisms system of lighthouse optics, the introduction of arc lights in conjunction with parabolic mirrors was received with considerable hesitation. In order to dispel these doubts, the abovementioned firm forthwith embarked upon an elaborate series of comparative tests at Nuremberg to ascertain the relative value of the two systems, and as a result of these experiments they concluded that quite as good an effect is obtainable with the arc and parabolic mirror as with the best examples of any other method.

Accordingly, the authorities decided to install the system in the Heligoland lighthouse. They stipulated that the intensity of the beam of light should be at least 30,000,000 candle-power, with a maximum current of 100 ampères. The duration of the flash was to be one-tenth of a second, followed by eclipses of five seconds' duration.

The electrical engineering firm entrusted with the contract fulfilled these conditions by mounting three searchlights spaced 120 degrees apart upon a rotating platform. That is to say, each light is projected outwards from a point equal to a third of the circumference of a circle. The mirror diameter was settled at 75 centimetres (29½ inches) and the focal length at 250 millimetres (10 inches), the current being taken at 34 ampères when the table made four revolutions per minute.

Subsequently a fourth searchlight was introduced into the apparatus, for the purpose of practical experiments and observations concerning the duration of the light-flash. This fourth unit was mounted above the three searchlights, but in the axis itself. It is so disposed that its flash comes midway between any of the two below, and it is arranged to rotate three times as quickly as the main group of lights. Accordingly, the duration of the flash thrown from the fourth searchlight is only one-third of the flash thrown by the others—that is, one-thirtieth of a second. This lamp is provided with all the necessary mechanism for keeping it in steady rotation at the increased speed, and for drawing current from its feed-cable.

Before the installation was placed in the lighthouse at Heligoland, it was submitted to searching tests at the Nuremberg works of the builders. These trials proved that with a current of only 26 ampères the average intensity was as high as 34,000,000 candle-power, with a maximum of nearly 40,000,000 candle-power ; while with 34 ampères the average intensity rose to approximately 40,000,000, with a maximum of nearly 43,000,000 candle-power. Accordingly, the terms of the contract were fulfilled completely.

The searchlights throw their rays from a massive conical tower, the focal plane of which is 272 feet above sea-level. In average weather the rays are visible at a distance of twenty-three nautical miles, and under the most advantageous weather conditions visibility is limited only by the curvature of the earth, although on a clear night the light is seen from Büsun, which is about thirty-five miles away. The Heligoland electric light ranks as a remarkable development in the application of electricity to lighthouse illumination, but it never has been duplicated. The cost of maintenance — about £1,400, or $8,000, per annum — is an insuperable handicap.

On the other hand, the Hornum electric light, which is the most modern of its type in Germany, is more economical, although by no means so powerful. The tower is of cast-steel, and carries two electric lights ; while about half a mile distant is a second tower, which throws a third electric light. In the main tower, on the ground floor, is installed the electric generating plant (in duplicate), together with all accessories, such as switchboards, etc. The floor above is devoted to housing 100 accumulators, which are charged during the day. This task can be completed by one generating set in about six hours. A single charge is sufficient to keep the three lights going for ten or eleven hours, and the lights are controlled by a simple throw-over switch. By this arrangement the cost of the maintenance of the light is reduced very appreciably, as only one keeper is on duty at a time, the station being equipped with two men, who have proved adequate for the purpose.

Above the accumulator-room is the storeroom and a general workshop, followed by a bedroom and above that the service-room. As only one keeper is on duty at a time, he is provided with ample devices whereby he can summon his comrade in times of emergency; the generating machinery is also controllable from this floor. From the service-room the lower light-room is entered. This is a secondary or back light in the range, the front light being in the tower half a mile away. Each of these two light-rooms is fitted with two 150 candle-power incandescent electric lights, but only one is burned in each set at a time: the second is a reserve. Should the light in action fail from any cause, although the keeper is warned of the occurrence, he does not have to stir a finger to bring the reserve light into service. The short-circuit produced by the accident to the light automatically revolves the table upon which the lamps are mounted, swings the reserve light into focus, and then sets it going.

Above the secondary light in the main tower is the principal beacon, comprising a brilliant rapidly-flashing light, the characteristic of which is groups of two flashes alternating with four flashes, the cycle being completed once in thirty seconds. The optical apparatus has been devised especially for the "differential arc-light," as it is called, with a reflecting lens having a focal distance of

250 millimetres (10 inches), the lens itself being 1,180 millimetres (approximately 47 inches) in diameter. In front of the lens is placed a disperser, having a diameter of 1,200 millimetres (48 inches) whereby the ray of light is dispersed through an arc of 10½ degrees. Before the disperser is the means for producing the characteristic flash. This comprises a blind, or shutter, which is opened and closed by mechanism adjusted to requirements ; while the rotating mechanism, instead of being weight-driven, is actuated by an electric motor.

The "differential arc," which is utilized in this installation, is considered by German engineers to be the best system that has yet been devised for the exacting purposes of lighthouse engineering, and the description has arisen from the disposition of the carbons. While the positive carbon is held horizontally, the negative carbon is placed at an angle of 70 degrees thereto, and only the crater of the positive carbon is considered for the lighting effect, this being placed in the focus of the apparatus. The positive carbon is $\frac{3}{5}$ inch, and the negative carbon $\frac{2}{5}$ inch, in diameter, although both have a common length of 19 inches, which is sufficient for nine hours' service. The beam emitted is of some 5,000,000 candle-power. This is one of the cheapest electric stations at present in operation, the annual running charges averaging less than £300, or $1,500.

CHAPTER XVIII

SOME LIGHTHOUSES IN AUSTRALIAN WATERS

Although the waters washing the Australian continent are not so thickly intersected with steamship lanes, and the mercantile traffic is not so dense there as in the seas of the Northern Hemisphere, yet, owing to the activity in emigration from Great Britain, as well as to the increasing prosperity of the various rising industries under the Southern Cross, they are becoming more crowded with each succeeding year. The efficient lighting of the coasts is an inevitable corollary of this expansion. Lighthouse engineering, however, is unavoidably expensive, especially when sea-rocks demand indication.

From time to time severe strictures are passed by European shipping interests upon the apparent lack of coastal lights in Australasian waters, and the various Government departments concerned with this responsibility are often accused of parsimony and neglect. Unfortunately, the greater number of these critics are apt to consider the situation through European glasses; to take the countries of the Old World and the United States as a basis for their arguments, and to ignore local conditions. It has taken a century or more for Europe and the United States to develop their respective organizations, and in the majority of instances there are ample funds from which expenses in this direction may be met, especially when passing shipping is mulcted a small sum in light-dues for the purpose. When the shipping is heavy, these levies are certain to represent in the aggregate a large sum every year.

From time to time New Zealand has been roundly assailed for its apparent negligence in the extension of its lighthouse system. It maintains thirty-four lighthouses and beacons, which represent a capital outlay of over £200,000, or \$1,000,000. The total maintenance charges average about £16,500, or \$82,000, per annum, while the dues collected from shipping for the maintenance of these aids to navigation approximate £38,000, or \$190,000, per annum. The balance is not amazing, and certainly is not sufficient to warrant heavy expenditure towards new lights, as the installation of such warnings nowadays is highly expensive if they are to conform with modern requirements. If the demands of the critics were met, and a comprehensive scheme, such as is advised, were taken in hand, the shipowner would have to pay to meet the deficiency on the revenue account, and this individual complains that he is overtaxed already.

Those Australian States which possess what may be described as a normal coastline—that is, one fairly free from solitary rocks rising from the sea some distance from land—are fortunate, since the sea-rock light is notoriously costly. On the other hand, lights placed on the mainland, even of the most powerful type, may be completed for a small outlay, relatively speaking.

Such a fortunate condition exists in connection with New South Wales. Here and there off the mainland are small reefs and ridges, but, taken on the whole, all these danger spots are adequately covered, so that the State has not been faced with searching problems of a technical or financial character in this connection. The State boasts only two "rock" lighthouses, and these obstructions are large enough to be called "islands." The one is South Solitary Island, off the coast north of Sydney; the other is Montague Island, to the south of the port. On the other hand, the mainland is very well patrolled, some thirty lights being scattered between Point Danger and Cape Howe, the respective northern and southern sea-limits of the country.

Although the light-keepers upon the rocks may consider themselves somewhat isolated, yet their plight is enviable as compared with that of some of their comrades in other parts of the world. At Montague Island the three keepers and their families are housed in comfortable cottages in close proximity to their ward, and they mantain a small farm, including a horse, goats, well-stocked gardens, and so forth. The keepers on South Solitary Island used to be able to vary the monotony of their daily or nightly round by indulgence in exciting sport. This assumed the form of rabbit trapping and hunting, as the island was overrun with these animals. One form of game must have become somewhat nauseating in time upon the menu of the keepers, but this diversion is now a thing of the past. A mysterious disease appeared among the rabbits, and its ravages were so devastating that within a short time Montague Island knew them no more.

The lighthouses of New South Wales deserve distinction in one direction. As specimens of architecture they are magnificent pieces of work, so that what the towers lack in romance they make up in attractiveness. The most imposing is the Macquarie tower, or Sydney lighthouse, mounting guard over the harbour. The first beacon was erected upon this site as far back as 1816, thereby rendering it the first lighthouse in the State, and it was fitted with an oil light, while one or two of the English lights were still open coal fires. In 1883 it was decided to modernize the lighting apparatus, so that a more powerful beam might be thrown. Electricity was the illuminant selected, the machinery for the generation of the requisite current being designed for installation in the original tower. But three-quarters of a century's exposure to the elements had rendered this building somewhat too weak to carry the requisite heavy lenses and machinery, so a new tower was projected. The old light was kept going while its successor sprang up alongside ; when the latter was completed, the oil light in the famous old tower was extinguished for ever and the building demolished.

The new lighthouse is a fine structure. At the foot of the tower is a spacious, well-lighted, and artistic one-floor building housing the electrical machinery as well as the office. The domiciles for the keepers and the engineers are placed on either side of the spreading lawn surrounding the station.

The most southerly light upon the New South Wales coastline is that at Green Cape, a few miles north of Cape Howe. As at the other stations, three keepers are maintained, being accommodated, with their families, in roomy cottages; while a small patch of land is turned to agricultural advantage, cows, horses, etc., being maintained by the men. The most easterly light on the Australian continent is at Cape Byron. This light is perched on a dangerous cliff, which drops almost vertically into the water 371 feet below; but it is within touch of civilization, a winding road having been cut down the flank of the promontory on the land side into the neighbouring town of Byron Bay, so that the tradesmen's carts are able to make their rounds up the cliff to satisfy the varied wants of the wardens of the light. One of the loneliest lights is that on Norah Head—Bungaree Norah it is called—and this is also the latest light erected by the State, as it dates from 1903. Although somewhat out of the way, it is not to be compared with some of the isolated British, Canadian, and United States lights, being, in fact, no more inaccessible or lonely than most localities in the Australian Bush.

Sugar-Loaf Point is one of the most serious danger spots along the shoreline, but is now well guarded with a fine lighthouse planted on its summit, the welcome rays of which are visible for many miles out to sea. The light-keepers here had a surprising discovery one morning in 1910. The *Satara* fouled the point and was wrecked, though fortunately her passengers were succoured by passing steamers. On this vessel at the time of the disaster there was a staghound, and although, when the rescues were effected, search for the animal was made high and low on the wreck, no signs of it could be seen. It was given up as lost. Some days later the lighthouse-keepers ventured to the beach below to have a look round, and to their astonishment a staghound come bounding towards them, yelping with joy at the sight of a human face. For a dog to be in such a lonely spot was a strange circumstance, but at last it was surmised to be the animal which was missed on the *Satara*.

THREE STRIKING GUARDIANS OF THE SHORE OF NEW SOUTH WALES.

1. Green Cape Lighthouse. 2. The sentinel of Sugar Loaf Point, or Seal Rocks. 3. "Bungaree Norah" station, one of the loneliest on the coast.

THE CAPE BYRON LIGHTHOUSE, NEW SOUTH WALES.

THE MACQUARIE LIGHTHOUSE, SOUTH HEAD OF SYDNEY HARBOUR, NEW SOUTH WALES.

The original tower, erected in 1816, was the first lighthouse built in the State. In 1882 it made way for the present magnificent station.

Apparently the animal clung to the crippled craft for some time, and then, realizing that the ship was abandoned, dived overboard and swam ashore. It fraternized with the keepers, and for some time kept them company at the station.

One of the worst wrecks which have happened upon the shores of New South Wales was that of the steamer *Ly-ce-moon*. By some inexplicable means the ship got out of her course on a fine Sunday night, and came to grief off Green Cape. The lighthouse-keepers at once hurried to the rescue, the hapless passengers, as they were got ashore, being tended at the station until they were removed to their homes. The lighthouse-keepers worked tremendously hard, but they were not entirely successful. Although by herculean effort they brought a large number of people to safety, there is a small fenced enclosure in the Bush behind the station where lie the remains of some fifty persons who lost their lives in the wreck, and whose bodies were washed ashore.

While New South Wales has a comparatively easy length of coastline to protect, the neighbouring colony of New Zealand, on the other hand, has a wild, forbidding, and extensive stretch of shore. Up to the present the Government has concentrated its energies upon the illumination of the busiest reaches of water, and has planted prominent outposts at the respective extreme tips of the twin islands. During the financial year ending March 31, 1912, sixteen wrecks occurred in these seas, of which six were total losses. The most ill-famed corner appears to be the large sweeping indentation at the southern end of North Island, lying between Cape Egmont and Wellington, particularly in the vicinity of Wanganui, since this stretch of coast claimed five victims. Cook's Strait, which is dangerous to navigators, is well protected, however, the most prominent beacon being that on Stephens Island, its group-flashes, occurring every thirty seconds, being particularly powerful, and having a range of thirty-two miles.

The Marine Department maintains thirty-two coastal lights, of which twenty-two are on the mainland, and ten situate on islands off the coast. They are of a varied description, ranging from powerful lights of the first order to beacons dependent upon dissolved acetylene, stored in cylinders of sufficient capacity to keep the light gleaming for sixty days continuously. Some of the places in which the warning lights are placed are exceedingly lonely and inaccessible, so that the perfection of the unattended light has solved a complex problem, and has enabled many terrible stretches of forbidding coast to be well indicated.

The first tower to be brought into service in New Zealand was that on Pencarrow Head, to indicate the entrance to the inlet in which Wellington nestles. It shed its rays for the first time on New Year's Day, 1859. It is an iron structure, from the top of which a fixed white light may be picked up by a vessel twenty-seven miles off the coast. The iron had to be prepared and shaped in England, as there was no foundry in the islands at that time capable of executing the work. The building was shipped to New Zealand in sections and erected. To-day, owing to the growth of the iron industry, the country can supply all its own needs in this field without difficulty, but in all cases the lanterns, mechanism, and lenses, have to be acquired in Europe.

As may be imagined, with such a rugged coastline as New Zealand possesses, some of the stations are terribly lonely and difficult of access, owing to the treacherous nature of the waters over which they mount guard. With the exception of the Brothers light, which is situated on an exposed rock in Cook's Strait, three keepers are maintained at each island lighthouse—one as relief—and at the more isolated mainland lights. Those of the latter stations which are within easy reach of civilization have only two keepers. The Brothers light, which is New Zealand's most lonely station, has four keepers, three on the rock at one time, while the fourth is ashore. The spell of service on the rock is three months, followed by one month's leave. The wives and families of the men reside at Wellington. The

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PAINTING THE TROUBRIDGE LIGHTHOUSE, SOUTH AUSTRALIA.

Keeping the building in repair is one of the lighthouse keepers' duties. This is especially urgent in the case of an iron structure This tower is 78 feet high, the light being visible for 15 miles.

By permission of the Lighthouse Literature Mission.

GREEN POINT LIGHTHOUSE, NATAL.

A well-known South African warning with a range of 23 miles.

THE PACIFIC OUTPOST OF THE UNITED STATES.

The *San Francisco* Lightship throws a flashing electric beam of 700 candle-power and is fitted also with the submarine bell.

authorities, however, do not condemn the light-keeper to one station throughout his whole term of service. He undergoes frequent transference, so that all may have a turn at good and bad stations. The duration of the stay at each light averages about three years, so that there is very little possibility of these patient, long-suffering stalwarts being condemned to such a period of loneliness as to provoke taciturnity and melancholia.

The keeper of the lighthouse light in New Zealand is as well provided for as his colleague in any other part of the world. When he enters the service, he is placed on probation as assistant keeper for six months, at an annual salary of £90, or $450. Emerging from this ordeal satisfactorily, he finds his salary increased at once to £100, or $500, per annum, rising by increments of £10 every two years, until it reaches £130, or $650, per annum. It remains at this figure until he is promoted to the position of head-keeper, which post brings an annual wage of £140, or $700, rising by biennial increments of £10 to a maximum annual remuneration of £180, or $900. In addition to the foregoing scale, a keeper receives an extra annual station allowance of £10 in the case of third-class stations, which are those on lonely rocks and islands, and £5 in the case of stations which are not isolated or difficult of access. All keepers in the service live rent-free, and are supplied with coal and oil, together with the free use of sufficient land, if available, to prepare gardens, as well as grazing for two or three cows and a few sheep, etc.; while their stores and provisions are carried without charge by the Government steamer *Hinemoa*. This vessel is retained solely for attending upon the lighthouses and buoys, and visits every light, save in exceptionally rough weather, once in three months.

At all the isolated and rock stations landing is a hazardous task, even under the most favourable conditions. The swell and currents breaking upon the rocks render it impossible for freight and men to be landed direct from the steamer to the rock. Consequently all the work has to be carried out by means of surf-boats, and heavy drenchings from breaking waves, and exciting moments, are unavoidable. At times the task assumes exceptional difficulty, and is attended with fatal mishaps. On June 2, 1899, the *Hinemoa* stood in towards the East Cape, the most easterly promontory on the islands, on the southern arm enclosing the Bay of Plenty. The sea looked wicked, but the relieving ship decided to go ahead with its work. All went well until a heavy roller suddenly came in and caught one of the boats at a disadvantage. The craft was capsized before the crew realized their position, and the chief officer, with three of his men, was drowned. Such is one of the penalties which have been exacted by the relentless sea, while courageous men have been engaged in the risky occupation of keeping the coast lights shining for the guidance of seafarers.

The New Zealand shores have been the scenes of some heartrending catastrophes. The steamship *Tararua*, of 563 tons register, was making her way from Dunedin to the Bluff, when she crashed on to the reef which juts seaward from Waipapapa Point. There was no light to warn the ship—hence the accident. The vessel, battered by sledgehammer seas, broke up very rapidly, and 130 passengers lost their lives. If the point had been guarded, no accident would have happened. Now a second-order dioptric flashing light of ten seconds guards the reef, and may be seen from a distance of thirteen and a half miles. Another calamity was the loss of the *Huddart Parker* liner on a danger spot known as the Three Kings Rock. The fearsome character of this peril has been recognized for many years past, but, as it is to be marked by a light suited to the locality, it is hoped that its evil harvest will come to an end. Yet at the same time it must be pointed out that the provision of a light does not always prevent a wreck even in the clearest weather, owing to the weakness of human nature. This was proved by the steamship *Triumph*, of 1,797 tons register. She left Auckland on the night of November 29, 1883, picked up the Tiri-Tiri Island light—this fixed star can be seen from a distance of twenty-four miles—and yet within two hours of her sailing was wrecked almost under the lighthouse. In this instance gross negligence was only too palpable, and the court of inquiry, after its investigation of the wreck, signified its opinion of the carelessness displayed by suspending the certificate of the master for three years, and that of the chief officer for six months.

Apart from Cook's Strait, the narrow passage between the two islands, the extreme points of the country are well guarded, the towers for the most part being located upon the prominent headlands. The southern extremity of the South Island is a dangerous coast to navigate, since going east, after the Puysegur Point ten seconds flashing light is dropped at a distance of nineteen miles from the headland, the vessel's course is set to traverse Foveaux Strait, between the mainland and Stewart Island. In the centre of the neck of water is an ominous rock, Centre Island, which, however, is well guarded by a first-order catadioptric fixed light, shining from a wooden tower, the range of which extends for twenty-two and a half miles, with red arcs marking the inshore dangers. Overlapping this beacon's field of patrol is a light mounted on Dog Island, revolving once in thirty seconds, and visible for eighteen miles, which in turn meets the Waipapapa light. Thus the approach to Invercargill is well indicated, and, with the east coast promontories all protected, the possibility of a repetition of the *Tararua* disaster is rendered remote.

On the extreme northern tip of the sister isle, the headland known as Cape Maria Van Diemen carries a first-order dioptric light, revolving once a minute, illuminating a circle of sea having a radius of twenty-four and a half miles. The adjacent headland at the opposite corner of this spit, North Cape, has not been protected hitherto; but this deficiency is now being remedied by the erection of a second-order, incandescent, group-flashing white light, giving three flashes in quick succession every half-minute. The brilliant illumination of this part of the coast is imperative, inasmuch as shipping bound for and from Auckland has to bear round this heavily indented and rock-strewn coast. The entrance to Auckland harbour in particular is disconcerting, but the navigator is assisted by the friendly guardians placed on Cape Brett, Moko Hinou, and Tiri-Tiri, which have ranges of thirty and a half, twenty-six, and twenty-four miles, respectively. The task of the mariner, however, is to be further simplified by the erection of another powerful light on Chicken Island, in the Hauraki Gulf, which will overlap the Moko Hinou and Tiri-Tiri lights. When this light and that at North Cape are placed in commission, the sea between Cape Maria Van Diemen and Auckland will be very well lighted, and will offer the ship's master few causes for complaint. Two other points are being equipped, Castle Point and Cape Terawhiti, the former with a second-order, incandescent, group-flashing white light, flashing at intervals of forty-five seconds, with periods of darkness lasting eight seconds between each group.

While the majority of the New Zealand coastal lights are attended, certain beacons, from their exposed position, come in the category of unattended lights, as described elsewhere. These burn acetylene gas, and are replaced with fresh supplies of dissolved acetylene every three months by the *Hinemoa*. Simultaneously with the provision of additional beacons the existing lights are being overhauled and fitted with modern apparatus, rendering them more reliable, economical, and of greater power. When the service was established, the Doty burner, using paraffin-oil, was adopted; but the perfection of the incandescent oil system, and its many advantages over that in vogue, have influenced the Government towards its adoption. The transformation will be completed as soon as practicable, the work being in active progress, as maintenance expenses are reduced appreciably thereby, because kerosene, a cheaper oil, is used in lieu of paraffin, while, furthermore, less oil is burned under the incandescent system.

Before many years have passed, the coasts of New Zealand will be as adequately protected as is humanly possible by a complete chain of coastal lights, which is being forged as rapidly as the circumstances permit. The Government has revised its light-dues in order to meet the increased expenditure in connection with the lighthouse service. Vessels arriving from outside the Dominion have to pay oversea light-dues at the first port of call, and coastal dues at all other New Zealand ports which they touch; while vessels arriving from the Chatham, Auckland, Campbell, Antipodes, and Bounty Islands also have to contribute to the funds.

CHAPTER XIX

THE SIGNPOSTS OF THE SANDBANKS

ALTHOUGH by dint of great effort and the expenditure of considerable ingenuity the lighthouse engineer has succeeded in erecting a permanent masonry tower upon a foundation no more substantial than quicksand, yet the general method of indicating these menaces is by the aid of a lightship. In this way the estuaries leading to the great ports of the world, which are littered with ridges, humps, and mounds, of mud and sand brought down by the river or thrown up by the sea, are guarded very completely. There is the Nore lightship at the entrance to the Thames, the Bar and North-West lightships off the mouth of the Mersey, Fire Island near the portal to New York, and so on. Similarly, the whereabouts of huge stretches of sand lying off a coast, which either defy detection altogether or only partially expose themselves at low-water, and which constitute certain death-traps, are shown. The most striking illustrations of this application are supplied by the Goodwin Sands, the submerged sandy plateau lying off the east coast of England, and by the serried rows of ridges running seven and a half miles out to sea from Cape Hatteras, the ill-famed headland of North Carolina.

The utilization of the lightship, however, is not restricted by any means to marking shoals and sandbanks. Here and there are clusters of rocks obstructing the ocean highway, which from their extremely exposed character would offer the engineer a searching and expensive problem to solve, and which, accordingly, are protected by a floating light. But, taken on the whole, the lightship is used very sparingly. If it is at all possible to provide a permanent structure, even at an apparently prohibitive cost, upon a danger spot, this practice is followed in preference to the mooring of a light-vessel thereto. A masonry tower is stationary in its resistance to the assaults of the wildest tempest, but the lightship swings like a cork at the free end of a chain. At times it drags its anchors, and thereby unconsciously shifts its position, so that it may throw its light from some distance beyond the actual area of danger. Again, a lightship, athough not costly in the first instance, is somewhat expensive to maintain. It cannot withstand the poundings of the waves and the force of the wind for long without developing some signs of weakness. It may ride over its reef or shoal for several years, but depreciation is sure to set in, so that at last it becomes too decrepit to be trusted. Moreover, the number of men required to man a lightship exceeds the force necessary to maintain a lighthouse.

Lightships follow much the same general shape and construction the whole world over. There is very little opportunity to depart from well-tried lines ; the experience of a century and more has indicated conclusively the form of hull, as regards both material and shape, best adapted to the peculiar work which has to be fulfilled. The modern lightship is essentially a British idea, the first floating beacon of this description having been built and placed in the mouth of the Thames as far back as 1713. From this small beginning, which virtually was an experiment, has grown the large fleet of light-vessels scattered all over the globe.

The craft is sturdily built, and, although of clumsy appearance, is capable of withstanding the onslaughts of the fiercest gales. Internally it is made as snug as possible, but the opportunities in this direction are not very extensive, as the beacon is built primarily to protect ships and lives against accident, and comfort is necessarily made subordinate to reliability, durability, and serviceability.

A mere hulk would be the most apt description as applied to the average lightship. It is intended to cling to one spot through thick and thin, and not to move about. In the majority of instances the vessel is without any propelling or sailing accessories. If it should happen to break its leashes,

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it then becomes the sport of the waves, as helpless as a derelict, until its signals of distress are espied and it is picked up by a passing vessel. Although every precaution is adopted to preserve the lightship from this mishap, when the waves become exceptionally heavy and violent the strongest chains are apt to snap under the sawing and tugging of the vessel. In one or two instances lively times have been experienced by the handful of men on board, especially off the wicked stretches of the American seaboard which is exposed to the attack of hurricane and cyclone.

In her helplessness, the light-vessel depends upon the friendly aid of any craft. The rescuer may be the alert tender, which, having received intimation that the floating beacon has got adrift, raises steam in all haste, hurries out, scours the seas for the wanderer, recovers and rechains her to the danger spot below. Or it may be that a passing steamer sights the breakaway, retrieves and restores her to the allotted position, making her temporarily secure, and reporting her condition when passing or entering a port.

The lightship may be identified easily. There is nothing inspiring about her lines. Her ugly hull, built for strength and not beauty, is painted red, black, or white, according to the colour practice of the country to which she belongs, while on her sides in huge letters, stretching almost from water-line to taffrail, is the name of her station, "Nore," "Seven Stones," "Norderney," "Ruytingen," "Fire Island," or whatever it may be. Nor is this the sole means of identification. From afar the mariner learns her character and business by a huge skeleton sphere, a triangular cage, or some other device, carried at the top of the mast or masts. At night a lantern, entirely surrounding the mast, and large enough to enable a person to stand upright within to trim the lamps, throws its warning glare from an elevation about halfway between the deck and the mast-top with the intensity of 12,000 or more candles. Oil is the illuminant most generally employed for the purpose, although in one or two instances electric light is used.

The specific purpose of the lightship, as already men-

Photo. Paul, Penzance.

THE "SEVEN-STONES" LIGHTSHIP.

This vessel, probably occupying the most exposed position around England, marks a terrible danger spot off the Cornish coas

THE "SAN FRANCISCO" LIGHTSHIP.

This vessel, riding in 18 fathoms, marks the entrance to the Golden Gate and San Francisco Bay.

tioned, is to warn passing vessels. But the French Government, when they made an elaborate investigation of their lightship service with a view to its modernization and elaboration, discovered that at times the floating signpost fulfils another and unofficial duty. The entrance to St. Malo Harbour is flanked by an uneven group of rocks lying about midway between the French coast and the island of Jersey. Though a terrible spot for mariners, it is one of incalculable value to the sturdy French and Jersey fishermen, as in the waters around these barriers rich hauls may be made with the net ; indeed, the fishing industry here affords employment for several score of persons. The French Government contemplated the withdrawal of the lightship marking the Minquiers, as these rocks are called, and the substitution in its stead of a number of powerful automatic buoys which would indicate the exact position of the most conspicuous dangers, whereas the lightship only indicated their general whereabouts, compelling mariners to calculate their distances from the peril, which, by the way, was no easy matter owing to the short range of the beacon.

Before making a decision, the Commission interviewed the French fishermen to ascertain their views upon the subject. To their intense surprise, a suggestion which they thought would be received with unmixed approval was condemned unequivocally. There was not a single fisherman who could be found to support the buoy system. The unanimity of the objection aroused suspicions, and further investigation was made to probe the cause of this unveiled hostility. The answer was found without effort. The fishermen pushed off in their boats every night to the grounds, but they did not spend the whole of their time throwing and hauling their nets. When their luck was in, or they were satisfied with the catch, one and all pulled for the lightship. There was not another café within a dozen miles, and fishing is thirsty work. So the lightship was converted into a nocturnal hostelry. The keepers charged the glasses, and the captains courageous sipped and quaffed to a whistling accompaniment, finally indulging in terpsichorean acts on the lightship's decks, to give vent to their exuberant spirits. They did not care whether the light overhead were throwing its yellow beams over the waters or not. They made merry, and kept up the orgy until the approaching dawn or the watch showed that it was high time to pull for the shore with their catches. It was a fortunate circumstance for these happy-go-lucky spirits that the beacon was not regarded by mariners as of much utility at night, owing to the feebleness of its light. If seafarers failed to pick up the Minquiers's shimmering star, they attributed the obscurity to the haze. That was all.

This revelation, needless to say, clinched the Commission's decision. To-day four unattended gas-buoys mount vigil over these rocks, and the rollicking days on the floating *café chantant* are known no more.

The average crew for a lightship numbers some seven men under a captain and mate, who take it in turns to have charge of the vessel, the second official being responsible during the former's spell of leave on shore. The crew is not a man too many, owing to the several and varied duties to be performed, especially when the storm-fiend is roused or fog pays a visit. The arrival of the latter demands the fog-horn's mournful dirge to penetrate the dense white curtain. Some of the vessels possess a hooter, the unmusical wail of which in its discordance is almost sufficient to put false teeth on edge, because a blast runs through the whole chromatic gamut with variations which would startle a disciple of Tschaikowsky or Wagner. But discordance in this instance is of incalculable value. The ear of the captain of a passing vessel is unconsciously arrested ; he can distinguish the sound readily, and by noting its character can identify the particular light-vessel from which it proceeds, although he cannot get a glimpse of her form.

The southern coasts of England, owing to the density of the maritime traffic, especially on both sides of the bottle-neck formed by the Straits of Dover, are well patrolled by this form of warning which supplements the lighthouses. Those guarding the dreaded Goodwin Sands perhaps are the most important. The crew of a vessel in these waters is busy throughout the day and night even in calm, clear weather, and the feeling of isolation is not so pronounced, since the continuous sight of traffic dispels despondency. The Nore light is another station which encounters very few minutes of rest throughout the complete revolution of the clock hands; especially is this the case when fog settles down, rendering the Thames inapproachable, so that incoming craft have to line up in long queues, ready to dash forward directly the pall lifts sufficiently for them to see 100 yards ahead.

There have been some exciting incidents among the lights strung around the south-eastern toe of England. The vessel outside Dover harbour appears to be particularly unlucky, or to exercise such a peculiar magnetism upon passing vessels that they must needs embrace her. This is the peril that a lightship crew dreads more than any other. Certainly it seems a sorry trick of Fortune that occasionally the workers in the cause of humanity should be compelled to fight desperately for their lives from a blow inflicted by the very interests they strive might and main to protect. The Dover light was sent to the bottom twice within a very short time, and in each instance the men were rescued only in the nick of time. On another occasion a relief lightship was being towed to a station on the east coast, the acting vessel being much in need of overhaul and repair. The tug laboured through the North Sea with her charge, and just before daybreak sighted the twinkling light which was her goal. She eased up, meaning to stand by with her charge until the beacon's round of vigilance should be over, and the light extinguished before the gathering dawn. Her crew saw the light grow dimmer, until it was no longer of sufficient power to penetrate the whitening haze. With the sun just creeping over the horizon the tug weighed anchor, and, heralding her approach vociferously on the siren, steamed slowly towards the danger spot. To the surprise of the captain, there came no answering blare. When he thought he was alongside the light-vessel he stopped, and the haze lifted. But there was no sign of the light-vessel; she had vanished completely. The captain of the tug and the master of the relief-boat wondered what had happened, but without more ado the relief-ship was moored in position, and the tug returned home empty-handed. There the crew heard one of those grim stories sometimes related in the service. The light-keepers had sighted the tug with the relief-vessel, and were anticipating keenly their return to civilization, when there was a crash! A cliff of steel reared above them like a knife-edge; a vessel had blundered into them, cutting their home in two. The next moment they were shot pell-mell into the water as their craft sank beneath their feet.

On a calm day, when the lightship is riding quietly at anchor, and the members of the crew, maybe, are beguiling the tedium by fishing, a passer-by on a liner is apt to consider the life one of quietness and enjoyment, albeit monotonous. But contrast this placidity with the hours of storm. Then the ungainly vessel writhes and twists, saws and rasps at the chains which hold her prisoner. At one moment, with bow uplifted, she is on the crest of a spray-enveloped roller; the next instant she drives her dipping nose into the hissing white and green valley, meanwhile lurching and staggering wildly as she ships a sea, first on this side and then on that.

The plight of the lighthouse-keeper in a gale is unenviable, but it is far and away preferable to that of the lightship crew under similar circumstances. The tower may bow slightly like a tree before the storm, and the waves may cause it to shiver at times, but that is the only movement. On the lightship the crew appear to be tossed, rolled, and spun, in all directions simultaneously. The deck becomes untenable, but the men in the performance of their duties have to grope and crawl from point to point, holding on grimly with both hands when an angry sea douches them. The spherical ball overhead gyrates in an amazing manner, as if it were a pendulum bob boxing the compass. The crew have a stiff struggle, to keep everything below safe and sound, while the waves, as they come aboard, thump on the deck as if determined to smash it to splinters, and to drive the whole fabric to the bottom. To be so unlucky as to be run down by a passing craft under such conditions is certain death, as there is no hope of rescue in such maddened seas.

The crew of an English ship emerged badly battered from one heavy gale. Two or three rollers got aboard, and drove their blows well home, pulverizing the lifeboat on deck, and tearing up stretches of the bulwarks by the roots. The crew were flung about like shuttlecocks. One of the hands was making his way cautiously along the deck, trying to maintain equilibrium upon an alarming incline, when a breaker struck him from behind. He grabbed the ratlins to secure himself, but his hand was wrenched away, and he was flung against the mast, where the wave left him. He was half stunned by the concussion, but a comrade, realizing his plight, dashed forward while the vessel rolled over in the other direction, grabbed the prostrate form by the collar of its coat, and dragged it into the companion-way. The man's face was disfigured, and when bathed it was found to have been cut, or rather burst, open from the eye to the chin by the force of the blow.

Bad weather tends to make the crew despondent at times, inasmuch as its persistency holds them prisoners, so that they cannot get ashore when the relief day comes round. During some seasons of the year a delay of ten or twelve days is not uncommon, owing to the weather, but the men on the relief tender are so used to hard knocks and rough seas that they do not wait for an absolute calm to achieve their purpose. Heavy risks are incurred often in order to lighten the lives of those who guard the deep by bringing them ashore as near to the scheduled date as possible.

Another ship that has to mount guard over a dangerous corner of the coast of England is that which indicates the cluster of rocks lying between Land's End and the Scilly Isles, about sixteen miles off the mainland. For the most part the reef is submerged, but as the water goes down seven ugly scattered pinnacles thrust themselves into the air. They are terrible fangs with which to rip out the bottom of a steamer, and they have accomplished their fell work only too often. The number of the projections has given its name to the graveyard, which is known far and wide as the Seven Stones, though the mariner refers to them simply as The Stones.

It would be difficult to say offhand which has claimed the greater number of victims from the mercantile marine—the sucking, glue-like sands of the Goodwins, or the splitting granite teeth of the Seven Stones ; they run a close race for ill-fame. The latter lie right in the path of vessels rounding the western toe of England, and the sea-bed on all sides of them is littered with the shivered timbers of wooden sailing-ships, the splintered iron and steel of steamers, and the bones of scores of unfortunate passengers and crews. Although a light of 12,000 candle-power strives to warn the seafarer, now and again there is a miscalculation, and the intimation is conveyed to the mainland : "Ship and all hands lost."

It was in 1841, owing to the frequency and severity of the disasters at this spot, that Trinity House decided to guard it with a lightship. A lighthouse would be preferable, but there is such small foothold for the engineer, and the position is so fearfully exposed, that the erection of a masonry tower would prove a costly and tedious enterprise. So the only feasible alternative was adopted, and the vessel is kept abreast of modern developments in this phase of coast lighting. Lying as it does in a somewhat narrow channel, yet open to the full roll of the terrible westerly gales, it meets the Atlantic thundering through this constricted passage with awe-inspiring violence. It has often suffered greatly from the fury of the sea. Once a wave tumbled aboard, crashed a man against the pump, knocked him half senseless ; picked up the lifeboat and threw it against the deck-house, and in so doing caught another member of the crew, mauling his thigh badly in passing. Two out of the seven men forming the crew were thus put *hors de combat* by a single wave. The taut little vessel rides in 40 fathoms of water, about one and a half miles eastward of the danger spot, as even a lightship must not be moored too closely to a ridge, or she herself would incur the risk of being pounded to fragments.

The French lighthouse service has a magnificent lightship in the *Ruytingen*, which rides in 60 feet of water over a treacherous sandbank outside Dunkirk. It is a steel vessel about 100 feet in length, and displaces in loaded condition about 387 tons. It is held in position by massive umbrella-like anchors, weighing some 2 tons, which, burying themselves in the ground, refuse to drag even under the most fearful tugs and jerks imposed by a gale, while the chains which hold the ship in leash are able to give her a run of approximately 1,000 feet.

The German coast is as dangerous to approach, owing to the shoals and banks, as the eastern shores of England, and one or two magnificent lightships have been built and stationed over the most notorious danger areas, among which may be mentioned the *Norderney* and *Eider* vessels. The latter is about 133 feet in length by 24 feet wide, and is fitted with three masts. It throws a fixed white light, which may be seen on all sides from eight to eleven miles away. This boat is fitted with every modern device to increase its warning powers and service, including wireless telegraphy and the submarine bell.

These two latter inventions have improved the serviceability of the lightship to a vast degree, inasmuch as the ocean liners and many freighters are equipped with both these useful handmaids to navigation. The tolling of the bell under water may be heard for several miles, and conveys intimation of the approach to danger in foggy weather, when the siren or other fog-signal is somewhat precarious.

The *Norderney* lightship is probably one of the finest craft in operation upon the seven seas. Before it was designed the German engineers carried out a thorough inspection of all the most modern lightships in service in Europe, and from the results of their investigations contrived this magnificent aid to navigation. The vessel is about 150 feet in length, and is built of steel. The light is shown from a lantern fitted with a third-order pendular lens carried at the top of a hollow steel mast. The illuminant used is Pintsch's oil-gas, with incandescent mantle, the fuel being stored in reservoirs stowed in the hold of the ship; fresh supplies are brought out by the tender at periodical intervals. Weight-driven clockwork mechanism is employed to revolve the lantern. The light is one of the most powerful in European waters, 50,000 candle-power being emitted with an incandescent gas mantle having a diameter of 30 millimetres ($1\frac{1}{4}$ inches).

The vessel is also equipped with 200 horse-power oil-engines, driving an air-compressor for the operation of the fog-siren, the air being stored in reservoirs in the hold and maintained at the working pressure, so that the signal may be brought into service at a moment's notice. The vessel is also furnished with a Pintsch submarine bell, driven by compressed air. When not required, this bell is housed amidships on the spar-deck, and when the occasion arises for its service it is lowered into the water through an open tube built in the ship for this purpose. This important light-vessel carries a full complement of thirteen men, including the captain, mate, and engineer. The arrangement is, one-third of the crew on shore-leave at a time; but this does not apply to the winter months, when the full number has to remain on board, owing to the duties being more arduous and continuous during that season of the year.

"Fire Island!" What a thrill the sound of this name sends through the floating town approaching the New World from Europe. Its effect is magical among the emigrants who scan the horizon eagerly for the first glimpse of this outpost of the new home, in which all their hopes are centred. The sullen red hull of this flush-deck, schooner-rigged steam-vessel, with her two masts, and name painted in huge white letters on her flanks, rides in 96 feet of water, nine and three-eighth miles south of Fire Island lighthouse. A few miles beyond is a similar craft marking the Nantucket Shoals, whence incoming and outgoing vessels are reported, while

By permission of the Lighthouse Literature Mission.

THE " NORDERNEY " LIGHTSHIP.

One of the finest in the world.

THE "FIRE ISLAND" LIGHTSHIP, THE ATLANTIC OUTPOST OF THE UNITED STATES.

This vessel rides in 96 feet of water, $9\frac{3}{4}$ miles south of the Fire Island Lighthouse.

the end of the chain is "No. 87," marking the Ambrose Channel off the entrance to New York.

But the light-vessel controlled by the United States which occupies the most responsible and perilous post is the *Diamond Shoal*, off Cape Hatteras. It throws its warning rays from a spot about four and five-eighth miles beyond the most seaward point of this terrible ocean graveyard, and is thirteen and five-eighth miles distant from Cape Hatteras light on the mainland. A long way from the actual danger spot, you say, but the little squad of men who have to maintain the light through storm and calm will tell you that the situation, in 180 feet of water, is quite as near as is pleasant when there is the ever-present danger of anchors being dragged, or of the craft breaking adrift under the force of the cyclonic disturbances which ravage this sinister coast. Even in calm weather the relief-boat has many anxious moments, owing to the swell and currents, while storms rise with startling suddenness. While the exchange of men is being made and stores are being transferred, a keen lookout is kept by the relief-boat hands so as to be ready to cut and run for the open sea the moment the clouds begin to collect ominously. In these latitudes the weather is placid one minute; the next the elements are writhing in fury.

Probably this is the most dangerous station on the whole seaboard, and if any heavy trouble is caused by the tempest, the *Diamond Shoal* inevitably bears grim evidence of the conflict. The skill of the engineers is taxed sorely to devise ways and means of keeping the vessel in the position she is designed to occupy, but moorings and anchors must be of great weight and strength to stand up against a wind blowing eighty miles an hour, with the waves running "mountains high" and repeatedly sweeping the vessel from stem to stern. After every battle a careful look round has to be made to determine how far the vessel has shifted. Being steam-driven, this craft is not condemned to absolute helplessness when her moorings snap. The crew get her under control and keep her head pointed in the desired direction, so as to mitigate the battering of the wind and waves, and not moving more than is essential for safety. Subsequently the vessel crawls back to her position, the bearings are taken, and she is anchored firmly once more.

One hurricane swept Cape Hatteras, and the lightship received its full energy. The boat strained and groaned at her chains. Suddenly they snapped. No steam could hold the boat against the assault. She was picked up, thrown about like an empty box, and carried inshore, luckily missing the ridges of sand. Had she plumped into one, it would have gripped her tightly while the waves pounded her to fragments. The crew were helpless and could only wonder what the end would be, as they saw the rugged coastline approach nearer and nearer. When they thought all was over and that their fate was sealed, a big incoming wave snatched the lightship, hurried her along on its bosom, and dropped her on the beach, practically uninjured, and safe from further attack.

When the crew surveyed their position, they found themselves faced with a difficult proposition. The ship was safe and sound, but on the wrong side of the shoals, and the question was how to lift her over those greedy ridges. There was only one method. That was to dig a pit around her on the beach, let in the water so that she could float, and then to cut a wide deep trench out to sea so as to regain deep water. It was feasible, and was attempted. While the pond on the beach was being dug, a powerful dredger came up, and ploughed its way through the shoals from deep water to the stranded light-vessel. When the craft was once more afloat, the dredger carved its way back again, the light-vessel being taken through the narrow, shallow ditch thus provided, which was closed up by the running sand as the two boats crept slowly forward, until at last the shoals were negotiated. The ship was taken to headquarters, the relief-vessel, which is always kept ready for an emergency, having taken up her position on the station immediately the hurricane had blown itself out.

Under these circumstances it will be realized that the maintenance of the *Diamond Shoal* light is by no means a sinecure. When these adversities are aggravated by the relief-boat being unable to fulfil its scheduled duty, when week after week slips by without the men receiving the welcome spell ashore, while they are suffering privations and experiencing the nerve-shattering pangs of isolation and monotony, it is not surprising that despondency shows signs of getting the upper hand among the crew. Melancholia is the malady which is feared most on a light-vessel such as this, and the men have to pull themselves together to resist its insidious grip. Probably at times there is half an inclination to desert the light, but fortunately there is little fear of this temptation succeeding. The axiom "Never abandon the light" is too deeply rooted; besides, the men are safer where they are, although it appears a crazy refuge in rough weather.

Prolonged imprisonment on the *Diamond Shoal* precipitated one mutiny. The crew on duty were awaiting the arrival of the reserve vessel to take them home; but the weather disposed otherwise. With that inexplicable persistence, the wind got round to a rough quarter and kept there tenaciously, never moderating for a few hours, but just blowing, blowing, blowing, getting up a nasty sea which made the lightship reel and tumble, while at intervals a comber came aboard to flush the decks.

In the course of ten days or so the crew began to fret and fume at the obstinacy of the elements; when a month slipped by without bringing any welcome relief, the mate and the engineer incurred the captain's dire displeasure by fraternizing and playing cards with the crew, thereby creating a breach of discipline and etiquette. The offenders, somewhat overwrought by their continued incarceration, ignored the captain's reprimand. This arrant disobedience played upon his nerves, which similarly were strung up. It did not require a very big spark to start a conflagration of tempers. The mate and engineer brooded over the captain's remarks, and at last they waited upon him, forcibly ventilated their opinions concerning his lack of civility and of endeavours to make one and all comfortable under the trying circumstances, and expressed their determination to tolerate his overbearing manner no longer. This was the last straw from the captain's point of view. Drawing his revolver, he growled that he was master of the lightship, and that they would have to do as he told them. There was a tussle, but the firearm was wrenched away from the master's hands as being a somewhat too dangerous tool for a man in his overstrung condition. The crew naturally sided with the officers, and the captain was kept under surveillance until the relief-vessel came up some weeks later.

The moment the crew stepped on dry land, every man, with the exception of the mate, deserted the ship, thoroughly satiated with the uncertainty pertaining to watching the Diamond Shoals. They indulged in a hearty carousal, and were arrested. And the captain, who also was not averse to enjoyment on shore, having lodged the charge of mutiny, followed their example. An inquiry was held, and the sequel is interesting. The captain, having deserted his ship upon reaching port, was dismissed from the service ; the mate, who had provoked the captain, not only was acquitted of the grave charge, but was promoted to the command of the light-vessel, because there was one outstanding feature in his favour which negatived everything else—he had stuck to his post.

Life on a lightship, although somewhat strenuous, has its interludes. In fine weather the men have considerable time on their hands, and while away the hours in various occupations. Fretwork, mat-making, carpentering, and other hobbies, are followed with keen enjoyment. Owing to the light attracting flocks of birds during the migratory seasons, the men often effect valuable captures on the deck, rare songsters and other specimens falling exhausted into their hands. Cages are contrived, and the silence of the living-quarters is relieved by the piping and trilling of the birds when once they have shaken down to their captivity. Meteorological work, which is practised in some cases, relieves the round of toil, while contributions to science are made by investigating the depths of the sea and its bed with small trawls and other devices, so as to secure data concerning life in the deep, the vagaries of currents, submarine temperatures, and so forth.

The lightship, however, is both a safeguard and a menace. When she is riding quietly at the end of her chains she is an incalculable boon to the passing mariner, but after a gale the navigator and the light-keepers are suspicious. The boat may, and indeed probably has, dragged her anchors somewhat. Now, the seafarer on his chart has the precise position which the lightship should occupy. Consequently, if she has shifted and he is unaware of the error, his calculations will lead him astray. After a tempest the master of a lightship endeavours to ascertain if his craft has moved, and if he can he takes his bearings at once. If this is impossible, or if he entertains any doubt in his mind, he flies a signal, which warns the navigator that the lightship has moved. Unless the vessel is able to regain her station under her own steam, she communicates with the shore at once, and a boat is sent out to reset her. Every time the relief is effected the officer in charge takes the bearings, so that the lightship may be truly in the position she is intended to assume, and able to effect her humane work satisfactorily.

The evolution of the most efficient illuminating apparatus for the lightship has been a most perplexing problem to the lighthouse engineer. What is applicable for the masonry tower is not necessarily adapted to its floating contemporary, since the conditions are so dissimilar. The United States service has adopted electric lighting on all its steam-driven vessels, the current being easily obtainable in this instance. On the whole, however, oil is the most popular form of illuminant, the burners—there are several lamps arranged in a ring round the mast—being fitted with two circular wicks, one within the other; while behind the lamp an ordinary parabolic reflector is placed in order to increase the intensity of the light produced. These reflectors are disposed in such a manner around the mast that the concentrated beam of light from one lamp just overlaps the rays which are projected similarly from the lamp placed on either side, the result being that a fixed white light of equal luminosity throughout the circle is projected. But, unlike the illuminant in the lighthouse, the light is not stationary in its vertical plane; it is swung from side to side and up and down in rhythm with the movement of the vessel. Under these circumstances, at one moment the light would project a short ray owing to the declination of the beam in relation to the line of the water, thereby bringing it below the horizon, while the next moment, when the ship lurched in the opposite direction, the ray of light would be thrown into the air and above the horizon. The problem is to keep the light at one steady angle, irrespective of the motion of the vessel, and this end is achieved by hanging each reflector upon gimbals, so that the rolling practically is counteracted, the reflectors maintaining a constant vertical position.

Some lights are of the flashing type, and in this instance the reflectors are disposed in groups. Here the gimbals, carrying the reflectors, are mounted upon the framework which revolves around the mast by clockwork mechanism, and are so arranged as to give any type of distinguishing flash that may be desired. In the most approved types of modern lightships, however, the dioptric apparatus is incorporated, means having been discovered to avoid breakage from the rolling motion of the ship, while the risk of throwing the beam above or below the horizon according to the rolling of the boat is overcome. In this case the lamps and reflectors are disposed on a turntable in the lantern, with the dioptric apparatus mounted very carefully so as to secure a true balance upon gimbals. The apparatus for revolving the light is erected in a deck-house, the weight actuating the mechanism being permitted to rise and fall in a special tube extending from the bottom of the ship to the deck. The rotary action thus produced is transmitted from the deck to the lantern above by means of a vertical shaft and pinion. While ordinary lamps are installed as a rule in the lanterns, Messrs. Chance Brothers and Co., the Birmingham lighthouse illuminating engineers, have succeeded in adapting their incandescent oil-vapour system, which has proved so eminently successful in lighthouses, to light-vessels, with a very decided increase in the candle-power, and marked economy in oil consumption and cost of upkeep.

CHAPTER XX

A FLAMING SENTINEL OF THE MALACCA STRAITS

With the development of commerce between Europe, China, and Japan, following the awakening of the East, it became imperative to render the seas approaching these countries far safer to navigation. If one consults the atlas, and follows the routes taken by the great liners from Britain and the Continent to the Orient, he will see a rampart forming the boundary between the Indian Ocean and the South China Sea. This is the East Indian Archipelago, and it bristles with dangers of all descriptions to the mercantile traffic flowing to and fro. After leaving India, the steamships turn their noses towards Singapore, at the extremity of the Malay Peninsula ; but this busy port is shut in on the south by the attenuated rocky chain of islands forming the Dutch East Indies, of which Sumatra and Java are the most important.

The steamship lane lies between Sumatra and the Asian mainland, and is known as the Straits of Malacca. It is a fearsome neck of water, studded with islands and sandbanks, some visible above high-water, others revealed only by the falling tide ; while still more never see daylight at all, yet owing to their shallow position are none the less perilous.

In order to foster the growth of the sea-traffic with China, these unattractive waters demanded full illumination, while the rock-girt shores of China and Japan were similarly in need of protective outposts. Japan was particularly enterprising in this forward movement. The country was emerging from the state of suspended civilization in which it had reposed so calmly for centuries. The rising forces were not slow to realize that unless they safeguarded steamship traffic their ports would wait in vain for the ships from Europe. In fact, the mercantile interests of the Western world bluntly stated that unless this course were followed their ships would not come to trade.

Japan at that time had not capable men at home for the purpose of completing the first part of a comprehensive coast-lighting scheme, and it was acknowledged that years must elapse before the country would be able to walk alone in this field. Accordingly they sought Britain's assistance. The Stevenson family, as narrated already, elaborated a comprehensive scheme, which was accepted. The structures were prepared in Britain, sent out piecemeal to Japan together with a force of competent men, and erected at the desired points.

Upon this foundation the Japanese built up their excellent lighthouse service. The Eastern pupil, in his own estimation, became as competent as the Scottish teachers. At all events, Japan has since completed all works of this description at home and unaided. China followed suit, but in this instance it was due to British initiative purely and simply. The British Inspector-General of the Imperial Maritime Customs took up the question. He appointed an engineer-in-chief, to whom the construction and repair of the lights were entrusted. The chief engineer was provided with a coast inspector, upon whom devolved the responsibility for the personnel and the maintenance of the stations, he in turn being assisted in his exacting and, at that time, difficult work by a corps of zealous officers.

Although the countries concerned and the shipping companies of Europe appreciated this forward policy, one class of individuals resented this introduction of Western ideas into Oriental life. This was the population who lived by wrecking and piracy. They recognized the fact only too well, that, if brilliant beacons were to be permitted to be erected freely throughout these troublous seas, their despicable but remunerative calling would cease. Their solution of the problem assumed a characteristic Chinese and Malay form ; they endeavoured to wreak their revenge upon the lights. Now and again there were sharp tussles between the engineering staffs and these high-water brigands, but firearms well handled by the white men invariably got the better of the argument. Pirates caught in the attempt to tamper with the lights received very short shrift. One engineer who had seen service in these waters related to me that in the early days the amount of lead expended in protecting a light from these marauders exceeded the quantity of this metal used in the tower itself.

The Malacca Straits, from their exceedingly dangerous nature, constituted a happy hunting-ground for these gentlemen, and the lighting of these waters was effected as soon as possible. Among the innumerable menaces abounding, a shoal some sixteen miles west of the coastline was particularly harassing to mariners. It became known as One Fathom Bank, and the shallowest part was only about 18 feet below the surface at high-water. When these waters were guarded first, a lightship did duty; but the position is so open, and is so exposed to the full fury of the monsoon, that she frequently dragged her anchors, so that the warning became somewhat uncertain.

Accordingly, it was decided to supersede the floating light by a permanent structure, and a lighthouse on stilts, similar to those familiar to American waters, was erected in 1874, and emitted a white flash once a minute. Although this ironwork structure was pounded mercilessly by the seas, it withstood all assaults completely, and was only superseded eventually owing to the ever-increasing exigencies of commerce, which demanded a more powerful and elevated light.

The present tower was commenced in 1907. The engineers appreciated the fact that they were being called upon to carry out an undertaking in an especially trying position. The bank is well out to sea, and when the monsoon is in full blast waves 8 feet in height thunder upon the shoal, their ferocity varying according to the state of the tide, which rises and falls a matter of 14 feet. The difficulties attending the building of the Rothersand and Fourteen Foot Bank lighthouses under closely similar conditions were not forgotten, and the prospect of building a huge caisson on the mainland, and then towing it to the site to be sunk, was by no means attractive, even if the fullest avail were taken of the spells of calmest weather.

Therefore an alternative method of construction, possessing the qualities of being simpler, quicker, and less expensive, which was advanced by a well-known firm of engineers in Singapore, Messrs. Hargreaves, Riley and Co., upon the designs of Mr. O. P. Thomas, received the closest consideration. This scheme proposed a lighthouse constructed on piles, with the focal plane 92½ feet above water-level, wrought in ferro-concrete.

The project was somewhat novel and daring, because, although this constructive principle had been adopted previously for stations upon the mainland, it had never been utilized in connection with exposed sea-lights. The system recommended was that known as the Hennebique, which had been employed extensively for buildings, bridges, sea-defences, and other works. The proposal was investigated thoroughly by the Hon. A. Murray, M.Inst.C.E., the Colonial Engineer and Surveyor-General for the Straits Settlements, and, as it met with his full approval, the work was handed over to the Singapore engineers to fulfil upon the lines advanced.

The structure comprises the main building, including the living-quarters, supported upon piles disposed in two rings, an inner and an outer, about a central pile, the whole being well braced together. The shape is octagonal in plan. From the roof of the living-quarters, to which point the outer piles are carried vertically from the sea-bed, these members rise with an inward rake, forming an octagonal pyramid, with the lantern and its room below forming the apex.

The underwater work was the most difficult, owing to the situation and the climatic conditions. Seeing that the nearest land is sixteen miles distant, it was impossible to carry the men to and from the scene of their labours every day when the weather permitted. A base was established on the coast for the preparation of materials and as a point for shipping all requirements to the site, but the men were accommodated with special facilities upon the spot. Here a temporary staging was built on piles, on which platform a large hut was erected to provide quarters for the men, as well as a workshop.

The piles forming the main support to the building were made $50\frac{1}{2}$ feet long, and hollow. The concrete, composed of broken granite and Portland cement, encased a steel skeleton, consisting of four longitudinal round steel rods, $1\frac{3}{4}$ inches in diameter, laid at the corners, and laced together with steel wire $\frac{3}{16}$ inch thick. Eight of these piles were made 18 inches square, while nine were 24 inches square, and each was fitted with a pointed end to facilitate driving into the sea-bed.

As these piles were prepared on shore, their transference to the site was a pretty problem in itself. Ordinary methods of transport were impracticable. The engineer overcame the difficulty in an ingenious manner. He built up a raft of barrels, twenty-six of which were lashed together in two rows, between which the pile was laid flat and evenly. The raft was built upon peculiar lines, so as to facilitate the unshipping of the pile when it reached its destination. It was divided into four sections, each of which could be detached without disturbing the other three parts. The raft and its pile were towed out to sea by a steamer, and when the work was gained the raft was cast off, to be floated under the staging and to the exact point where it was to be set up. A chain sling was lowered from the platform and attached to the head of the pile, and the lashings to the first section of the raft were released, thus permitting the strapped barrels concerned to float away and to be recovered. The pile was then slowly and carefully hoisted at the head, the second part of the raft being released when the pile had gained a certain height. This procedure was repeated until finally, when the last part of the raft was freed, the pile hung free, as vertically true as a plumb-line, with the pointed foot resting on the sand. In order to send it truly into the sea-bed, heavy timber guides were set up, and as the pile descended it was frequently tested with the plummet, to see that it was sinking in an absolutely perpendicular manner.

The piles were sunk into the soft sea-bed by means of water-jets, which, playing about the foot of the pile, burrowed a hole into which it could move downwards. A depth of 15 feet had been considered necessary to secure the desired rigidity, and as a rule the pile could be driven to this depth in about four hours. When the pile-driving commenced, however, it was found that the sandbank had undergone a marked change since the surveys were made. Erosion had been very active owing to the currents having been checked by the obstructions which the legs of the staging offered. Under these circumstances a novel experiment was made upon the site. One of the piles was lengthened by 14½ feet, to be driven to its limits, just to ascertain how far it would go into the sand. This in itself was a somewhat daring undertaking, seeing that the tiny colony on the staging did not possess the facilities which were available on shore for the work. However, it was accomplished satisfactorily, and when the pile was sunk it was found to descend another 13½ feet, where it touched hard rock. This discovery brought about a modification in the plans. As a solid foundation could be gained at a depth of 28½ feet, and as the piles could be lengthened successfully upon the site, it was decided to extend all the piles to a complete length of 64½ feet, and to drive them down to the hard bottom. When the piles were all lowered, they were subjected to four blows from a "monkey" weighing 2½ tons, dropped from a height of 4 feet. But these four final blows only drove the piles from ¼ to ⅞ inch farther into the sea-bed, whereas, according to the specification, a margin of 1 inch was allowed for this test.

The diameter of the tower at the base is 40 feet, and heavy bracing is introduced at a point 4 feet below high-water to hold the fabric together, and to supply the requisite strength and rigidity. At a height of 21 feet above this main

COMPLETING THE ONE FATHOM BANK LIGHTHOUSE IN THE MALACCA STRAITS.

The keepers live on the lower floors. The upper floor beneath the lantern is the service room.

THE ONE FATHOM BANK LIGHTHOUSE, MALACCA STRAITS, IN COURSE OF ERECTION.

It is built throughout of ferro-concrete, and is supported on piles driven into the sand. At the left are the quarters provided for the lighthouse builders who lived on the spot.

bracing is the floor of the superstructure, comprising an octagonal two-floor building, surrounded by an overhanging gallery, built on the cantilever principle, 5 feet in width, which forms the landing platform. The two floors have a total height of 24 feet, and constitute the keepers' home. The roof is flat, in order to facilitate the collection and conduct of rain-water into two ferro-concrete cisterns, each holding 1,000 gallons. The lower floor is devoted to housing stores, oil, etc., while the upper story forms the living-quarters. The roof is caused to overhang a distance of 4 feet on all sides, thereby providing a flat surface 44 feet across. From this point the eight main columns of the building slope inwards, until, at a height of 30 feet, they have a diameter of 18½ feet, where the lantern is introduced. The lower part of the latter constitutes the service-room, and leads directly to the lantern above. Access to the different levels is afforded by means of a teak-wood staircase, while that leading from the entrance floor to the water for landing purposes is hinged, so that it may be accommodated to the condition of the tide.

The lantern, which weighs 17½ tons, is of the modern type, and is more powerful than that of the 1874 light, which it displaced. The white light is thrown in groups of flashes every fifteen seconds, and the warning is visible from the deck of a vessel some fifteen miles away. The central pier, which carries a great proportion of the total weight of the tower, and which extends continuously from the bed-rock foundation to the lantern-room, is solid to the roof of the living-quarters. Above this point it is hollow, having a bore of 12 inches, and in this space the weight actuating the revolving mechanism of the light moves up and down.

Although the idea was novel at the time, the complete success of the work justified the recommendations of the designers as to the suitability of this form of construction for open-sea lighthouses. In this instance the enterprise not only was completed for a less sum than would have been required for a corresponding lighthouse erected in masonry upon orthodox lines, but the structure is lighter, was more rapidly built, and is thoroughly hygienic. The complete weight of the whole tower is less than 1,000 tons; and from the setting of the first pile to the lighting of the lamps only fourteen months elapsed, notwithstanding the fact that work was interrupted and hindered frequently by inclement weather. Any doubts that were entertained concerning the ability of the structure to resist the attacks of the wind and seas encountered in these latitudes was dispelled during erection, because the monsoons which broke during the period of erection were abnormally heavy, and submitted the fabric to exceptional strains and stresses, which it withstood with complete success.

Another fine light which has been provided for the benefit of the navigator in these Eastern seas is that on Gap Rock. This is a rugged, lofty eminence, rising from the sea, thirty-two miles south of Hong-Kong. Being exposed on all sides, it is difficult to approach, while at the same time it lies in the path of vessels. A few years ago the Hong-Kong Government decided to conquer this islet, and to deprive it of its perils to shipping. With great effort a landing was effected, and one of the pinnacles was decapitated and levelled off, to form a spacious platform for landing. The light itself rises from the highest point of the rock, and its rays are visible through a circle of twenty miles radius. The Gap Rock light is also a signal-station, being in telegraphic communication with Hong-Kong.

Although the days of human hostility to the lighthouse in Eastern waters have passed, the engineer is confronted by an enemy which is in every way as destructive. This is the white ant. The ravages of this insect are so relentless and complete where wood is concerned that timber towers are quite impracticable. Moreover, this material has to be used only sparingly for fittings, even in masonry and iron buildings.

A curious experience with this insidious and implacable foe was related to me by a lighthouse engineer. He was engaged in the erection of a new beacon at a remote point on the coast. The lenses and lantern apparatus, as usual, had been ordered in England, and were despatched to the East carefully packed in substantial tin-lined cases. In order to secure the utmost protection during transit, each metallic and lenticular part was wrapped in tow. Care also was bestowed upon the sealing of the tin case, since the propensity of the ant to discover the smallest pin-hole so as to reach the interior was emphasized upon the packers. Accordingly the seams were doubly soldered.

In due course the cases with their precious contents reached the site of erection, but unfortunately the season was so far advanced that the engineer concluded he could not complete the erection of the lantern before the monsoon broke. As the contents of the cases were preserved by the tin armour from climatic attacks, he stored the cases securely, and with his workmen left the place until favourable weather returned.

Some weeks later the chief and his toilers reappeared upon the scene. All preparations for setting the optical apparatus were completed. Imagine the dismay of the engineer when, on opening the case containing the most important parts of the lantern, he found that it had been raided by white ants. They had driven their tracks spirally through the tow, which evidently they had enjoyed, and although this was of little consequence, the formic acid had played sad havoc with the bright surfaces of the spindles. In lighthouse engineering the surfaces of these parts must be as bright and as clean as a mirror to insure smooth, steady working. But now these spindles were as pitted and marked as a victim to smallpox. It was a maddening contretemps, since the only way to restore the vital bright surfaces was to turn them in the lathe. Such a tool was not available within a hundred or more miles. Erection had to be delayed, however, until this treatment was effected.

Seeing that the tin case was soldered up with such infinite care, the question arises, How did the ants get into it? To the engineer it seemed an inscrutable puzzle, but he subjected the case to a minute examination. Finally he solved the problem. At one corner he found that a nail, while being driven during the process of nailing up the heavy outer wooden case at the English factory, had turned slightly, so that its point had punctured the inner metal case. The ants, too, had discovered this minute breach, and through it had swarmed to the attack upon the interior.

CHAPTER XXI

UNATTENDED LIGHTHOUSES

DURING the past fifty years engineering science as applied to lighthouses has made remarkable advances. This has been due largely to the indefatigable perseverance and ceaseless labour of the chemist in regard to illumination. This wonder-worker has given us acetylene, has evolved means whereby oil-gas may be compressed to a pressure of several atmospheres with safety, and has discovered other gases obtainable by inexpensive and simple means. The engineer has not hesitated to profit from these developments, and has devised highly ingenious apparatuses whereby these illuminating mediums may be stored and used, so as to dispense with the human element almost entirely ; in fact, in these instances the latter factor has been reduced to such a degree that it is only called upon to perform certain perfunctory operations, such as the recharging of the storage vessels at long intervals—three, six, or twelve months, according to circumstances.

This combination has provided the lighthouse engineer with a new, powerful, and efficient means of overcoming abnormal difficulties. Many a rock, reef, or stretch of uninhabited coastline has demanded indication, but has defied such protection from motives of cost, inaccessibility, or searching problems concerning the accommodation and relief of the keepers. As I have shown in the course of this volume, the erection of a first-class lighthouse is a costly undertaking, and the shipping interests, which in the case of Great Britain and a few other countries are called upon to pay the bill, naturally demur, unless the rock or other obstacle is situate in the centre of the marine thoroughfare, or the approach to a pitiless coast is extremely hazardous, when the erection of the tower becomes absolutely imperative. If one were to add up the costs of all the great lights scattered throughout the seven seas, it would be found that several millions sterling had been sunk in this humane effort, and yet, relatively speaking, but a small area of danger in the aggregate is safeguarded.

Then the human factor demands consideration. A colony of four or six men scarcely could be found willing to suffer isolation from the world at large and to be deprived of intercourse with their fellow-beings in the interests of shipping, say, through the Straits of Magellan, around Cape Horn, among the icy fastnesses of the Northern Labrador coast, or in Hudson Bay. Life in the lighthouses which guard the busy steamship lanes is monotonous and nerve-shattering enough, but to maroon men in such remote places as those mentioned above would be to promote a wholesale rush of inmates for the lunatic asylums.

This is where the chemist and the engineer in collaboration have triumphed. By their joint efforts it is now possible to supply the most inhospitable shore with a belt of lights equal in every respect to those mounting sentinel over the more densely populated reaches of coast in the civilized parts of the globe. The unattended lighthouse is a modern development born of necessity, which has proved highly serviceable, effective, and reliable. The passenger, as he lolls against the taffrail of the steamer ploughing her way carefully through the lane 375 miles long separating the mainland of South America from Tierra del Fuego, and watches the faithful star twinkling upon the top of a frowning cliff and urging the mariner to keep clear, may cherish a feeling of pity for the man who has to keep that beam shining. But his commiseration is misplaced. No human hands touch that beacon, perhaps, for six months or more at a time. It is a triumph of automatic operation. The same applies to the wicked shores of New Zealand, the uninviting northern stretches of the Gulf of Bothnia, the iron-bound coasts of Norway and Sweden, and many another unattractive mainland and island.

THE PLATTE FOUGÈRE LIGHTHOUSE UNDER CONSTRUCTION.

This automatic light marks a dangerous reef, off the Guernsey coast, which is familiar to readers of Victor Hugo's "Toilers of the Sea."

THE PLATTE FOUGÈRE LIGHTHOUSE.

This beacon, designed by Messrs. D. and C. Stevenson, probably is the finest unattended lighthouse in existence. On the top of the tower is the automatically controlled acetylene light.

All the great maritime nations possess several of these silent, faithful lights, which, although upon their introduction they were regarded with a certain amount of suspicion, owing to the urgent necessity of a light never failing in its duty for the guidance of the seafarer, yet have been proved by the convincing lesson of experience to be as reliable in every respect as the light which is tended by human hands.

So far as Great Britain is concerned, the unattended light has been brought to a high stage of efficiency and utility by the efforts of Messrs. David and Charles Stevenson, while in other parts of the world the apparatus and methods perfected by Mr. Gustaf Dalén of Stockholm are used extensively.

The most interesting example of the Stevenson unattended lighthouse is provided in the English Channel, indicating the entrance to the strait which leads to the Guernsey capital of St. Peter Port. This was one of the first of its character to be erected, but the type is now being adopted widely owing to the success of this initial undertaking. The Channel Islands have achieved an unsavoury reputation in marine annals, as they form a graveyard of the Channel; they have claimed their victims, during recent years at any rate, mostly from the ranks of the heavy cross-Channel traffic.

The Russell Channel, leading to St. Peter Port from the north, is exceedingly dangerous, the sea being littered with granite rocks both submerged and exposed, of which the Grande Braye, Barsier, and Platte Fougère, form the outer rampart. Readers of Victor Hugo may gather some realistic idea of the perilous nature of these waters by perusing "The Toilers of the Sea," in which these rocks figure very prominently, particularly the Platte Fougère. The menace of this corner of the channel is accentuated by the velocity of the tidal currents which swing and swirl round the reefs, together with the extreme range of the tides, which averages about 30 feet. Formerly, in thick weather, vessels found it almost impossible to pick up the Russell, and often a captain, by the rip and crash of metal being torn, to his dismay learned that he had swung too far to the westward.

The companies engaged in this traffic repeatedly petitioned the authorities to mark the entrance to the strait by some adequate means. A light was not required so keenly as a sound-signal, because in clear weather navigation was tolerably safe. The proposal was discussed time after time, but no solution appeared to be forthcoming. To erect a lighthouse on the outer fringe of the barrier would have entailed prodigious expenditure, which the island authorities could ill afford, even if such a scheme were practicable.

The question was taken up boldly by General Campbell during his occupation of the post of Governor-General of the Island of Guernsey, and he pressed forward the scheme vigorously in a resolute determination to bring about a diminution in the number of maritime disasters at this point. He approached Messrs. David and Charles Stevenson, who had considerable experience of similar conditions around the Scottish coasts, and they, after an elaborate survey of the site, recommended the erection of a light and fog-signal station upon the Platte Fougère, which should be controlled from the land a mile distant. They agreed that the erection of a tower similar to those generally planted on sea-rocks would be a formidable undertaking and enormously expensive, owing to the conditions prevailing, but the station they suggested was quite practicable, and would serve the purposes equally well.

Instead of a massive, gracefully-curving tower, measuring some 40 feet in diameter at the base, these engineers suggested a building of irregular octagonal shape, measuring 14½ and 17 feet across the faces, 80 feet in height, and carried out in ferro-concrete. They advocated its erection upon the Platte Fougère, because there the fog-signal would be brought into the most serviceable position for shipping. A narrow or thin building was advised, to offer the minimum of surface to the waves, which break very heavily on these ridges. The wisdom of this design has been revealed very convincingly since the tower has been in service. The seas fall on either side, divide and rush round the building, so that it does not experience the full brunt of

SETTING THE COMPRESSED-AIR RESERVOIR AT FORT DOYLE.

The Platte Fougère automatic light is supplemented by a land station on the island of Guernsey a mile away.

THE FORT DOYLE SIREN.

This installation on the island is maintained so as to take the place of the automatic lighthouse a mile out to sea, in the remote event of the latter breaking down.

their heavy, smashing blows. As the engineers pointed out, "It is better to avoid heavy sea pressures, where feasible, in preference to courting them."

Still, the Platte Fougère was not an ideal rock from the engineers' point of view, although it is a solid knot of granite. Its head is visible only at low-water spring-tides, while it is difficult to approach, even in the smoothest weather, owing to the tides and currents. Much of the foundation work had to be carried out under water. The season was unavoidably limited, as the days when both the wind and the sea are calm in this part of the channel are very few and far between.

The tower is solid for a height of 46 feet above the rock, and the base is formed of Portland cement placed in iron moulds, with iron bars driven into the solid rock to anchor the concrete firmly. On the side to which the building is exposed to the heaviest seas, massive beams of rolled steel are driven into the rock, so as to impart additional strength to the part of the tower where the greatest strains are likely to be set up.

On the entrance level is a compartment containing an electric motor and air-compressor, while on the floor immediately above is a duplicate installation. The siren projects through the top of the tower, the trumpet being so turned as to throw the sounds in a horizontal direction over the water. On the top of the tower is a small automatic acetylene gas plant and light, such as the engineers have employed so successfully in their unattended Scottish light-stations, two air-receivers, and a water-tank. A new type of burner is used, and a clockwork mechanism is incorporated to extinguish the light at dawn and to ignite it at dusk, with a special arrangement to allow for the short summer nights and the long periods of darkness during the winter.

As mentioned above, the station is controlled electrically from a point on shore. In deciding the latter, it was necessary to discover the most favourable landing-place for the submarine cable in relation to its route, and Doyle Fort was selected as meeting all requirements in this direction. Here a two-floor dwelling has been erected for the keepers, together with an adjoining engine-house, which measures 32 feet in length by 20 feet wide. The tower being a mile distant, the designers had to meet the possibility of the machinery therein breaking down. Accordingly, at the shore station there is an auxiliary fog-siren and air-compressing plant, which is brought into use when the sea apparatus is deranged.

The machinery includes two oil-engines which drive three-phase alternators, and an air-compressor for working the land siren when required. One of the greatest difficulties arose in connection with the submarine cable which connects the land-station with the sea-tower. Owing to the broken, rocky nature of the sea-bed, the viciousness of the currents, and the heavy seas, the cable had to be of exceptional strength ; indeed, it had to be made specially for the purpose. It is a double-sheathed, steel-armoured cable of the heaviest " rock " type, being 11 inches in circumference, and weighing 45 tons per nautical mile. As the current used is three-phase, there are three conductors, which weigh 1,100 pounds per mile, protected by a thick layer of gutta-percha averaging 450 pounds per mile. In the centre of the core are two other wires for switching and telephone purposes respectively. The laying of the cable was a peculiar and exacting task in itself ; 6,504 feet had to be paid out. But by waiting for a very calm day and slack water this task was achieved without mishap. In the tower there is a simple switch operated by an electro-magnet, whereby the motor-driven air-compressors are thrown in and out of action. The two compressors are used alternately, so as to keep them in thorough working order ; and as they have to be left sometimes for months without being examined, special attention has been devoted to their lubrication.

A visit to this lighthouse is a somewhat curious experience. Climbing the ladder and entering the building, one finds it apparently abandoned. Not a sound beyond the murmuring of the waves playing about the rocks below disturbs a silence which is uncannily tense. Suddenly there is an almost imperceptible click. The keeper at the light-station has

By courtesy of Messrs. D. and C. Stevenson.

AN UNATTENDED BEACON LIGHT PLACED UPON A WILD PART OF THE SCOTTISH COAST.

These lights will run for several months without any human attention, and, by means of ingenious mechanism, light and extinguish themselves automatically.

THE GASFETEN LIGHT: A LONELY BEACON IN SWEDISH WATERS.

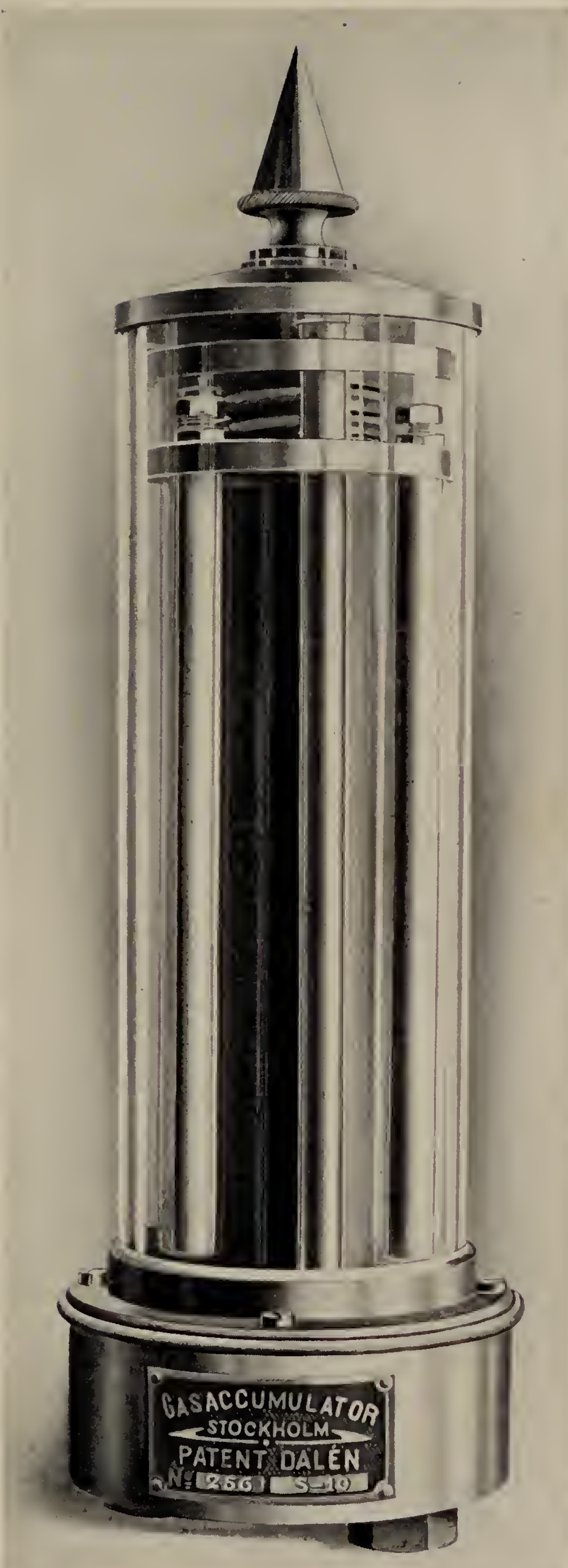
This was the first tower to be fitted with the Dalén "sun-valve" in conjunction with the Dalén flasher. Several automatic lights of this type are used to show the way through the Panama Canal.

moved his switch, and simultaneously that in the tower has closed. The electric motors instantly commence to revolve, with a low grunt at first, but rising quickly to a loud humming as they settle down to their stride, driving the air-compressors. Then comes the ear-splitting, deep-toned roar from the siren overhead, attended by the whirr of machinery in motion. The humming of the motors and the compressors dies down, and in a few seconds absolute stillness prevails once more. The sensation is decidedly eerie. It seems impossible that a silence so intense as to be felt should be interrupted by a click—the result of a slight movement by an unseen hand a mile away—which gives forth such a nerve-shattering din as to convey the idea that Bedlam had been let loose. At the land-station the experience is similarly weird. The keeper moves his switch which brings the tower machinery into action. Presently there is the sharp tinkle of an electric bell. This notifies the keeper that the blast on the tower has been given, but conclusive evidence of this fact does not arrive until five seconds later, when the baying of the siren comes rolling over the water.

A complete check is kept upon the isolated station out at sea. If the electric bell does not ring out at the appointed period, to notify the keeper that the siren has emitted its warning note, he knows that something is amiss. The land-station is brought into service without delay, the intimation to the mariner to stand clear being thrown from Doyle Fort once every ninety seconds. The men on shore take it in turns to mount watch for fog both day and night, and their vigil is checked. There is an electric alarm, which maintains silence only so long as the man on duty fulfils his appointed task and records this fact upon his mechanical register at scheduled intervals. Should he fail to perform this function, there is a frenzied clanging by the alarm-bell, which summons the second keeper to duty.

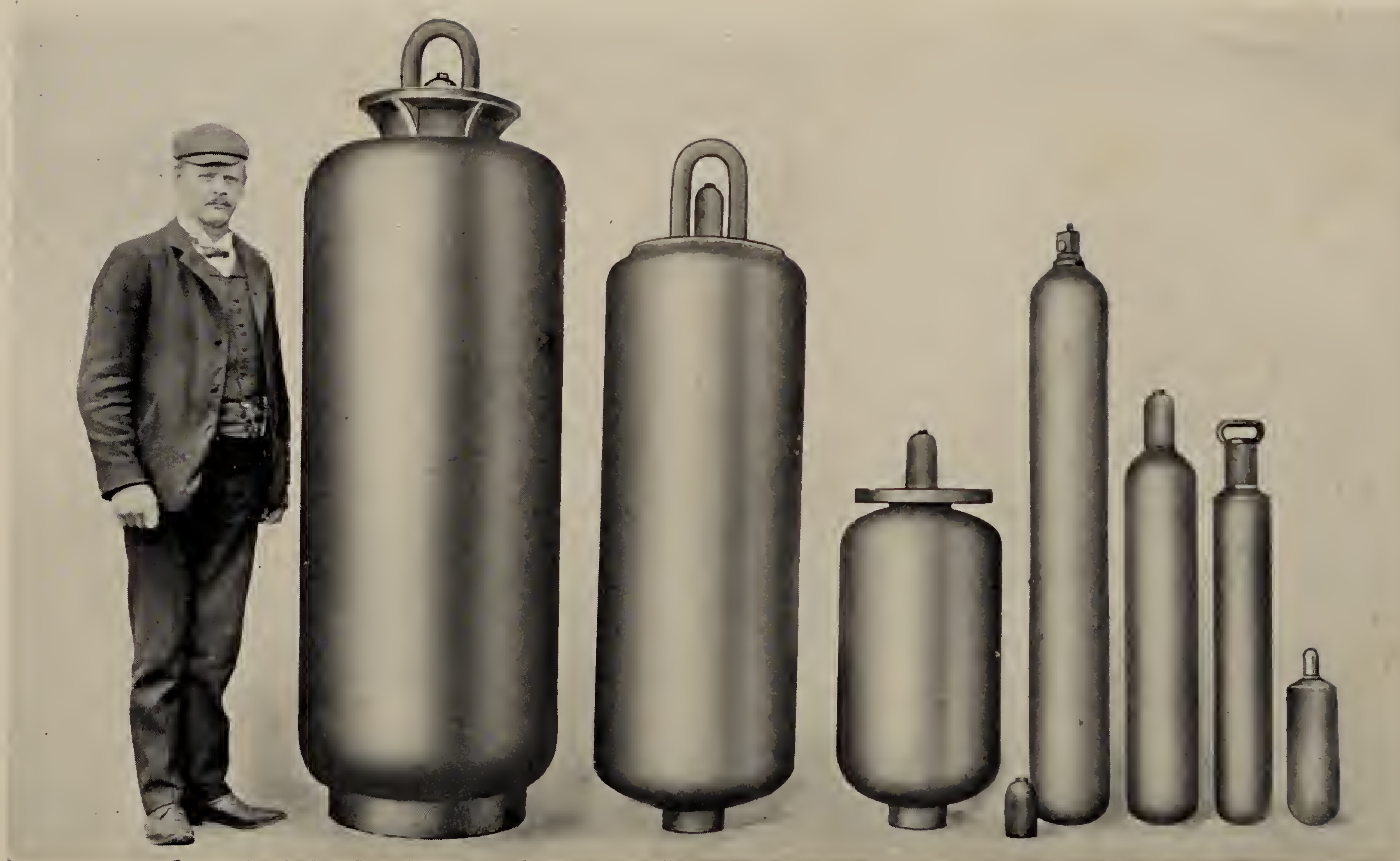
Apparently, the weakest point in the installation is the submarine cable, but the engineers entertain no apprehensions on this score. It is too stoutly made and too heavily armoured to rupture very readily. Experience has proved its efficiency and reliability, while a long life is anticipated for it. The Platte Fougère unattended lighthouse has opened up new possibilities for protecting wild coasts. It has proved conclusively that there is no difficulty in maintaining such a station and controlling it from a distance so long as automatic apparatus which has proved its worth is employed. This practical application should serve to solve many peculiar problems. No longer can the bogie of expense be put forward as an argument against safeguarding a notoriously evil length of shoreline or isolated rock, even if the latter is exposed to the heaviest seas known. The Guernsey installation was completed for £8,500, or $42,500, and is as serviceable as the ordinary type of tower, which in this instance would have cost at least £60,000, or $300,000, to build and equip. From the maintenance point of view it is equally convincing and economical, inasmuch as only two keepers are required in the place of the four who otherwise would have been necessary.

The system which has been devised by Mr. Gustaf Dalén of Stockholm, and which is exploited by the Gas Accumulator Company of the Swedish capital, operates with dissolved acetylene. The first light in Scandinavian waters to be brought into action upon the "Aga" principle, as it is called, was installed in the Gasfeten tower, an exceedingly isolated beacon which offered every means of testing it thoroughly. The idea follows the broad lines of that adopted in connection with lightships, and, the Gasfeten experiments proving completely successful, it has been adopted extensively since, not only by the Swedish authorities for the lighting of lonely waters in the Baltic Sea and Gulf of Bothnia, but by various other Powers. The Straits of Magellan are protected in this way, and when one recalls the sparse population which dwells upon the banks of this short-cut between the Atlantic and Pacific Oceans, and bears in mind the fact that the lights have to be left to their own automatic action for some months on end, then one may realize the perfection and reliability of the invention. The failure of a light in such treacherous waters would be



THE DALÉN "SUN-VALVE," THE MOST WONDERFUL INVENTION OF MODERN LIGHTHOUSE ENGINEERING.

Depending upon the action of daylight alone, it automatically ignites and extinguishes the light at dusk and dawn respectively.



THE GAS ACCUMULATORS EMPLOYED IN THE DALÉN AUTOMATIC SYSTEM.

The size of the storage cylinder varies according to the work, character, and position of the beacon.

notified speedily to the authorities responsible for the illumination of this sea-lane, but no such complaints appear to have been received from passing vessels. These lonely lights for the most part are of a very simple character, a result due to local conditions. As a rule they are planted on lofty eminences—not at too high an elevation, as thereby they might be rendered useless by headland fogs—at a height varying between 150 and 250 feet. The base of the tower forms a space for the accommodation of the gas-accumulators, wherein the illuminating medium is stored under pressure, surmounted by the lantern which carries the requisite optical apparatus, and the flasher whereby the characteristic visual warning is given.

Although adoption of the flasher enabled the consumption of gas to be reduced very appreciably, there was one noticeable drawback: the light had to burn both night and day, unless clockwork mechanism were introduced to extinguish the light at sunrise and to ignite it at twilight. Some authorities, however, do not place trust in clockwork mechanism. Certainly it is liable to fail at a critical moment, and in the case of an isolated light, several hundred miles from the nearest base, this would be a serious calamity, intimation of the fact not being available until several weeks after the disability had been observed.

In order to overcome the fallibility of clockwork, and to insure a still further marked decrease in the consumption of gas, Mr. Gustaf Dalén devoted his energies to the perfection of a device which should achieve the self-same end, but be operated by Nature herself. His efforts were crowned with complete success by the invention of the "light-valve," but which has become more widely known as the "sun-valve."

This device is based upon a well-known principle. If two objects, fashioned from the same metal, and identical in every respect except that one is made light-absorbing and the other light-reflecting, are exposed to daylight, while the former will expand, the latter will remain unaffected. This result is due to the fact that the one which absorbs light transforms it into energy. The acting part of the "sun-valve" therefore is a light-absorber. It consists of a central rod, the surface of which is coated with lampblack, so that its light-absorbing qualities are enhanced as much as possible. The lower part of this rod is connected to a small lever, which opens and shuts an orifice through which the gas passes to the flasher in the lantern above. Around this central black copper rod are three other copper rods, disposed equidistantly. They resemble the former in every respect except that they have no light-absorbing qualities, but they are given polished gold surfaces, so that their light-reflecting properties are raised to the maximum.

This sun-valve is exposed. At the break of dawn, under the gathering intensity of daylight, the central black rod absorbs the luminosity, the amount of which is increased by the light thrown from the gold-burnished outer rods, and, converting it into energy, expands longitudinally. In so doing it forces the lever at the base downwards, closing the opening through which the gas flows to the flasher. In a short while, when the day has broken fairly and there is no further need for the beacon's services, the gas-feed is cut off entirely, only the pilot burner remaining alight, the gas-supply to this not being affected by the sun-valve. In order to bring the greatest possible pressure upon the lever, the blackened rod is so arranged that it can expand only in one direction—namely, downwards.

Upon the approach of evening, owing to the daylight becoming weaker, the blackened rod contracts, and, the pressure upon the lever being released, the gas commences to flow once more to the burner. It is a small stream at first, but as the darkness gathers, and the shrinking continues, the valve opens wider and wider, until at last, when night has settled down and the copper central rod has fully contracted, the gas-valve is opened to its fullest extent, permitting the greatest pressure of gas to flow to the burner, so that the beacon throws its most brilliant light. This automatic action continues infallibly every dawn and dusk, and is the simplest and at the same time most reliable means of economizing gas during the day that has yet been devised.

There is another feature of this system which must not be overlooked. Suppose, for some reason or other, that the sea becomes shrouded in suffused light, such as might arise from the obscurig of the sun by an overhanging bank of fog or smoke, the beacon comes automatically into service, as the cutting off of the daylight must bring about a contraction of the blackened copper rod controlling the valve.

The central rod can be adjusted to any degree of sensitiveness, by means of a screw, while protection of the vital parts is insured by enclosure within a heavy glass cylinder. The first apparatus of this character was tested by the Swedish authorities in 1907, and proved so successful that it is now in service at all the exposed unattended lighthouses in Swedish and Finnish waters; while it has been adopted, also, very extensively by the United States, more particularly for the lighting of the lonely stretches of the Alaskan coastline and of the Panama Canal.

Of course, the saving of gas which is rendered possible by the use of the sun-valve varies according to the season of the year. During the winter, when the nights are long, the saving may not be very marked, but in the summer, when darkness does not last more than four or five hours, the economy is very noticeable. According to the experience of the Swedish authorities, the average saving of gas during the year varies from 35 to 40 per cent., as compared with similar lights not fitted with this device.

But there is another factor which is influenced to a very appreciable degree by the utilization of the sun-valve. By cutting off the light when it is not required, the capacity of —*i.e.*, the duration of service upon—one charge is lengthened, and this in the case of an isolated light is a very important consideration. In fact, with the "Aga" system wherein the sun-valve is combined with the flasher, it is possible for the light to work a round twelve months without the least control or necessity for intermediate inspection, and at as low an annual charge as £2 15s., or about $14.

One of the latest unattended installations which have been carried out upon these lines is the Lagerholmen lighthouse, marking a dangerous rock in the Baltic Sea. It is a cylindrical tower, with the focal plane 56 feet 4 inches above sea-level, and the flashing light, with sun-valve control, has a range of eighteen miles. The geographical range, however, is only thirteen miles, owing to the comparatively low height of the tower.

An interesting and ingenious automatic unattended light has also been established in an isolated part of the Bristol Channel. It was designed by Sir Thomas Matthews, the engineer to the Brethren of Trinity House. This is purely and simply a clockwork-controlled apparatus in which extreme care has been taken to eliminate the disadvantages incidental to such mechanism. This type of light was designed to fulfil three conditions—to give a flashing light; to light up and go out at the proper times; and to require attention only at long intervals. Acetylene is the illuminant used, the gas being stored in a reservoir under high pressure. The gas as it emerges from the supply cylinder is expanded, so that the pressure at the burner does not exceed 2 pounds per square inch.

The outstanding feature of this apparatus is that the clockwork control cutting off and turning on the gas does not require to be wound by hand, but is actuated by the mechanism which revolves the lenses, through a simple set of gearing. The gas as it issues from the reservoir passes into one of two cylinders. Each of these is provided with an inlet and an exhaust valve, while the upper end is closed with a lid of leather, covering the top like the vellum of a drum. To each leather cover is attached a circular piece of metal, smaller than the leather diaphragm, and from this in turn extends a vertical rod, the upper end of which is connected to one end of a centrally pivoted rocking arm. When the gas enters one cylinder, naturally in expanding it forces the leather lid upwards, and with it the vertical rod. This elevates the corresponding end of the rocking arm, and simultaneously drives down the rod attached to

THE LAGERHOLMEN LIGHTHOUSE.

It marks a lonely dangerous rock in the Baltic Sea, and operates upon the Aga unattended automatic system, with Dalén flasher and "sun-valve."

AN UNATTENDED BEACON LIGHTING THE STRAITS OF MAGELLAN.

This warning, fitted with Dalén flasher and sun-valve, is visited once in six months.

AN AUTOMATIC LIGHT-BOAT.

This novel warning was constructed for installation at the mouth of a Swedish river owing to the extreme velocity of the current. Such a boat may be left unvisited for a year if desired.

the opposite end of the beam, which in turn drives down the leather lid of the second cylinder, and forces out any gas that may be therein. The apparatus consequently is something like a double pump, owing to the rocking arm having a seesaw motion. This reciprocating action serves to wind up the clock, and also to revolve the lenses through spurs and pinions. The mechanism, however, is controlled completely by the clock whereby the light is started, inasmuch as without this the apparatus cannot be set in motion. There are two dials, one of which is divided into twenty-four divisions, corresponding to the hours of the day, and the other into twelve divisions, representing the twelve months of the year. The clocks work together, and the time of lighting up is advanced or retarded, according to the time of the year, through the clock train wheels.

The apparatus is very compact, highly ingenious, and has proved efficient in service. Although this is the first application of the idea for rotating the lenses by the gas which feeds the burners, so far as England is concerned, it has been employed under similar circumstances in Germany with conspicuous success, in combination with the Pintsch oil-gas apparatuses, but it lacks the simplicity and reliability of the sun-valve.

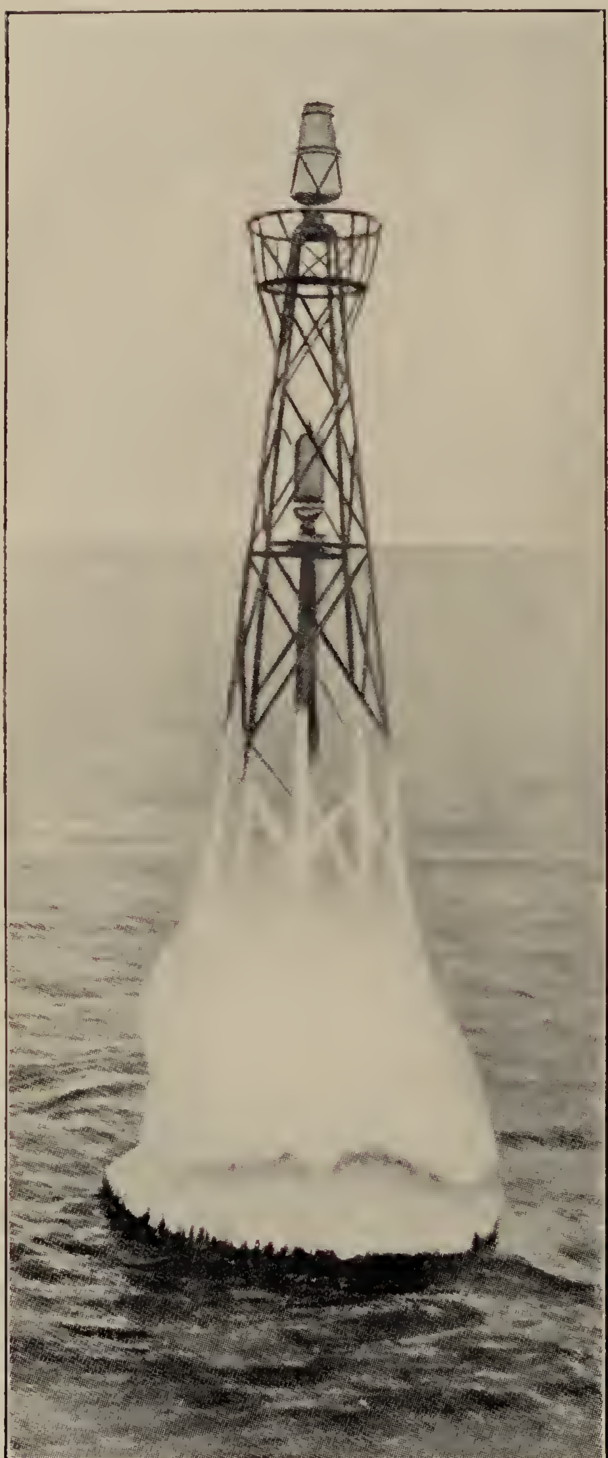
A different system, which has been adopted widely throughout the East and in Australian waters, is the Wigham petroleum beacon. This system possesses many notable features, the most important being that well-refined petroleum oil is employed. In many parts of the world carbide of calcium is not readily obtainable, and, moreover, is somewhat expensive, whereas, on the other hand, oil is comparatively cheap and available in unlimited quantities. The principle of working is somewhat novel. The wick is not burned in the manner generally followed in regard to lamps—viz., at the end, which within a short time becomes carbonized and brings a marked diminution of the illuminating power—but it is moved so that the same part is not exposed continuously to the action of the heat arising from combustion. It is caused to travel horizontally over a small roller, in a specially-constructed burner, combustion taking place, therefore, on its flat side. It is moved slowly and continuously over this roller, so that it cannot burn through, and in this manner the flame, being constantly emitted from a fresh surface, is of uniform intensity.

The lamp comprises three main parts. There is the lantern, with the lens and the projecting panes of plate-glass, in the focus of which the burner is fixed. Then there is the burning-oil reservoir, which feeds the wick as it moves towards the burner. This reservoir is circular in shape, somewhat shallow, and serves as a deck on which the lantern is built up. The third part is the float cylinder, made of copper, which is attached to the underside of the oil reservoir. This cylinder is filled with oil, which is kept quite distinct from the burning oil, and thereon floats a weighted copper drum, to which one end of the wick is secured by means of a hook. At the lower end of this cylinder is a micrometer valve, which when opened permits the oil to drip away at a certain speed. This causes the float to fall with the oil in the cylinder, and to drag the wick over the burner roller and down the float cylinder after it, so that a fresh surface of the wick is presented continuously for combustion. The lamps themselves may be divided into two broad classes—the single-wick and the three-wick respectively. The latter obviously emits the more brilliant light, and is the type which is coming into more extensive use at the present time. In the latest type a duplex burner is employed, and this has been found to give a very powerful light with a comparatively low oil consumption.

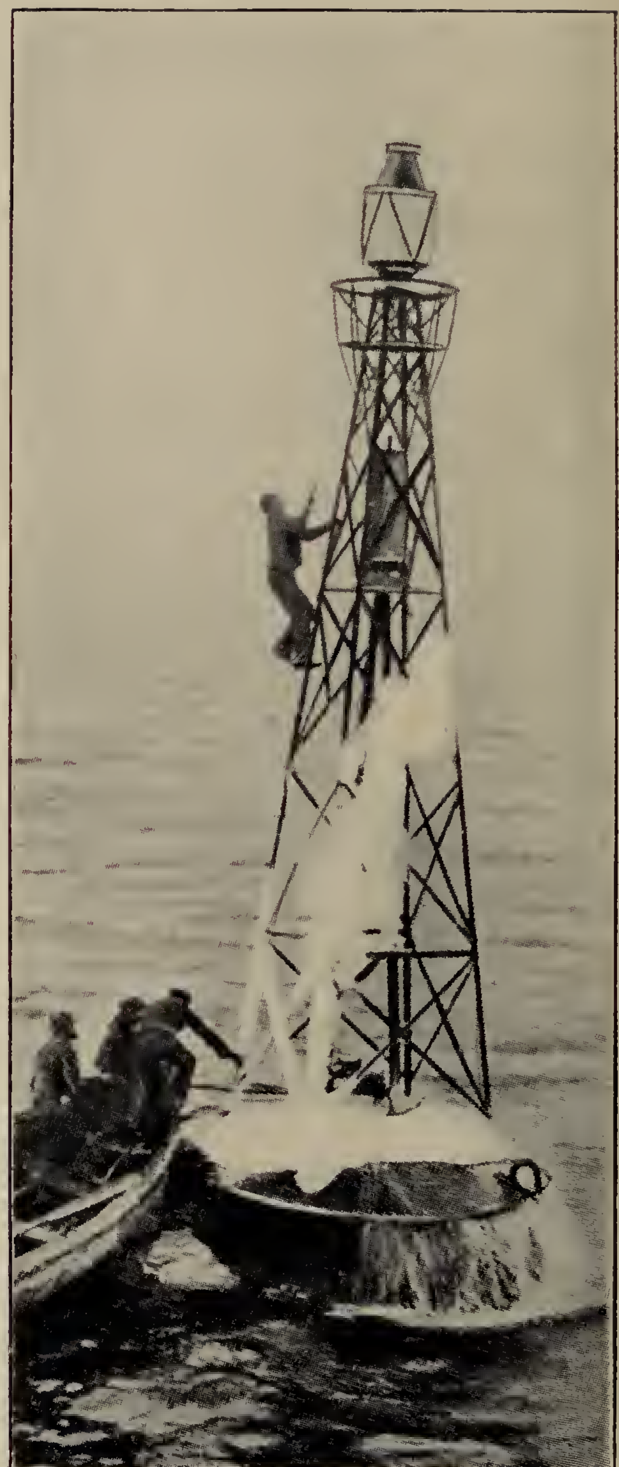
The light is generally carried at the top of a lattice-work steel tower. A support of this character can be taken to pieces, packed within small compass, and transported without difficulty, while erection is simplified and facilitated. Seeing that a large number of these beacons have been erected on headlands along the wildest stretches of the African continent and the loneliest coasts of Australia,

THE WIGHAM THIRTY-ONE DAY UNATTENDED PETROLEUM LIGHT.

The type at left shows the lamp carried upon a cast-iron pillar; while on the right it is mounted upon a lattice tower.



WILLSON GAS AND WHISTLING FLOATING LIGHT OFF EGG ISLAND, NOVA SCOTIA.



THE WILLSON "OUTER AUTOMATIC," HALIFAX, NOVA SCOTIA.

where the methods of transport are restricted to coolies or mules, this method of packing is distinctly advantageous. The lamp is secured to the top of the tower, with the float cylinder of the lamp depending from the centre. In this arrangement, as a rule, a small tank is provided into which a drain-pipe empties the oil dropping from the drip-valve. In this way the oil may be drawn off, filtered, and used again in the float cylinder. In some instances the lamp is mounted upon a cast-iron column, in which case the float cylinder and the oil-drip tank are placed within the tube, access thereto being obtained through a door.

The length of service on one charge varies according to the situation of the light. If in a very exposed and inaccessible place, it may be required to burn for two or three months without attention. Taken on the average, however, a monthly charge has been found to offer the greatest advantages. But in some places the longer interval is unavoidable. For instance, the Wigham light which is mounted upon the extremity of the Manora breakwater at Karachi cannot be approached for three months at a time during the monsoon. Under these circumstances a one-hundred-day service is imperative.

The lenses are of the dioptric order, consisting of six elements built up into a strong gun-metal framework. The internal diameter naturally varies with the size and number of the wicks, and ranges from 10 inches for a $1\frac{1}{8}$-inch single wick, to 15 inches in the case of a $1\frac{5}{8}$-inch three-wick lamp. In the larger sizes a curved plate-glass pane is fitted outside the lens as a protection from the action of the weather. These storm-panes are set in copper doors, so that the glasses may be easily cleaned and polished when the lamp is being retrimmed.

The maintenance charges are guided by the local market values of materials and labour, the item of repairs and renewals being practically negligible. So far as oil consumption per month is concerned, this fluctuates according to the type of lamp used, ranging from $1\frac{1}{5}$ pints per twenty-four hours, or 4·8 gallons per month, in the case of a $1\frac{1}{8}$-inch single-wick burner, to $2\frac{1}{4}$ pints per twenty-four hours, or $8\frac{3}{4}$ gallons of oil per month, in the case of the latest $1\frac{5}{8}$-inch duplex-wick burner. American petroleum-oil, of a specific gravity of about 0·795, gives the best results and the brightest and clearest flame. Russian and other heavier oils generally used in lighthouses are unsuitable. In view of the world-wide operations of the Standard Oil Company, however, no difficulty is experienced in procuring adequate supplies of this oil anywhere between the two Poles.

The oil used in the float cylinder, as mentioned previously, is quite distinct from the burning oil, and is used only to support the float to which the wick is attached. As the oil escapes through the drip-valve, it may be allowed to run to waste, or, what is far preferable, it may be caught, filtered, and used again for this purpose, to bring about a reduction in the cost of upkeep. The float cylinder of a thirty-one-day light, irrespective of the number of wicks, requires the same quantity of oil for the float cylinder—$9\frac{1}{2}$ gallons.

The advantages of the unattended, automatic light have been appreciated by the various maritime Powers, and their application is being developed rapidly. They are inexpensive in first cost, and their maintenance charges are very low. In Sweden a second-order light, consuming 6 cubic feet of acetylene gas per hour, throwing a fixed white light of 4,000 candle-power, and visible for seventeen miles in clear weather, costs about £15, or $75, per annum; while the smaller lights, with a 300-millimetre lens and a 12-inch burner emitting 360 candle-power, may be run for £2, or $10, per annum, the low cost in this instance being attributable to use of the Dalén flasher and sun-valve.

The cost of the acetylene gas averages $\frac{3}{4}$d., or $1\frac{1}{2}$ cents, per cubic foot, a result attributable to the fact that Scandinavia is the world's largest producer of carbide of calcium.

The Wigham petroleum system has proved similarly economical and reliable, and has been installed in some of the wildest corners of the globe. The Congested Districts Board for Ireland have established a number of these beacons on the rugged west coast to assist the fishermen in making their harbours at night. Many are placed in very exposed positions on headlands, where they are frequently swept by the full force of the Atlantic gales. The Austrian Government has adopted the principle for lighting the dangerous coasts of the Adriatic near Trieste, while the shoreline of Jamaica is safeguarded by more than sixteen lights of this type. Many of these lights suffered severely from the effects of the earthquake which overwhelmed the island a few years ago, but others withstood all the shocks successfully. In this instance, had expensive and massive lighthouses of the usual type been erected, the loss would have been considerable, in view of the severity of this seismic disturbance and the widespread destruction which was wrought. These lights play a very prominent part in the guarding of the southern ocean, the Australian shores being protected by over sixty such beacons, many of which are established in very exposed and isolated positions off the mainland.

While the day is still far distant when expensive graceful towers, carrying immensely powerful lights, will be no longer constructed, the perfection and utility of the unattended light, in one or other of its many forms, are assisting tangibly in the solution of the problem of lighting busy shorelines adequately and inexpensively. Structures costing tens of thousands sterling in future will be restricted to important places, especially in connection with sea-rocks, such as landfalls, or to those some distance from the land, where a fog-signal station must be maintained, unless the example of the Platte Fougère land-controlled station becomes adopted.

CHAPTER XXII

FLOATING LIGHTHOUSES

HAND in hand with the development of the unattended light for service on land positions has proceeded the adaptation of the floating light. This may be described briefly as an enlarged edition of the lighted buoy, which is such a conspicuous feature of our harbours and estuaries. Yet it is more than a buoy. It can fulfil all the purposes of a light-vessel, both as regards the emission of a ray of light or a distinctive sound, so that both audible and visual warning are given simultaneously. These lights likewise are automatic in their action, and, when set going, require no further attention for some time. Nine months or more are often permitted to pass without human hands touching them, and they have solved some very abstruse problems in connection with coast lighting.

For instance, there is probably no such lonely stretch of coastline as that of British Columbia and Alaska. There is only one large port north of Vancouver—Prince Rupert—and this rising hive of maritime activity is 550 miles distant. The coast is as wild as that of Norway, which, indeed, it resembles very closely, bristling as it does with fjords and islands, with rugged cliffs rising abruptly from the water to a height of several hundred feet. Navigation at night is extremely hazardous, as the path leads by devious ways through deep channels intersecting the outer barriers of islands, where fogs hang low and thickly. The captain has to pick his way carefully, determining his course by timing the period between the blast of his siren and its echo, as it is thrown from headland to headland. As the passenger traffic developed, the masters of the vessels entrusted with so many human lives felt the increased responsibility keenly, and agitated for more adequate protection. The erection of lighthouses, even of the most economical type, would have entailed huge expenditure by both the United States and Canadian Governments, while the question of maintenance would have bristled with searching problems.

Accordingly, it was decided to adopt the floating automatic system, which had proved eminently satisfactory in other parts of the world. In this manner a highly successful and inexpensive solution of the difficulty was found. These buoys have been installed at all the most treacherous points leading to sounds and canals, as the lochs are called, and have been found in every way equal to the simplest type of attended lighthouse. The southern coast of Nova Scotia has been protected in a similar manner, a chain of automatic lights, spaced ten miles apart, having been completed, so that this wild, rugged shore is patrolled very efficiently at the present moment. Other countries have not been dilatory in adopting the same methods. Consequently, to-day the automatic floating lighthouse is one of the handiest, most efficient and reliable devices for assisting navigation that the lighthouse engineer has at his command.

The lights assume different forms, this factor being influenced by position, specific duty, and local conditions. Similarly, the character of the illuminant employed also varies, acetylene, compressed oil-gas, petroleum, and electricity, being utilized, according to circumstances. On the whole, however, acetylene gas appears to be the most favoured illuminating medium, inasmuch as the preparation of the carbide of calcium has undergone such marked improvement.

When Mr. Thomas L. Willson discovered the cheap process for the manufacture of carbide of calcium upon a commercial scale, and the new industry became placed upon a firm footing, it was only natural that the inventor should realize the possibilities of applying the new illuminant to the assistance of navigation. Acetylene gas gives a brilliant clear light of intense whiteness, which is capable of penetrating a great distance. Accordingly, he set to work to devise a buoy lighted by this gas, and able to carry sufficient storage of calcium carbide to burn for weeks or months without attention. When he had completed the first apparatus of this character, he handed it over to the Marine Department of the Canadian Government for submission to any test that they might consider expedient, in order to ascertain the limits of its application. The buoy was set in position and watched carefully. Periodically it was examined to ascertain whether overhauling and cleaning were necessary, as well as the behaviour of the light under all conditions of weather. Captains of vessels passing the beacon were requested to pronounce their opinions upon the quality of the light, and their remarks concerning its range, facility with which it might be picked up, reliability, and so forth, were carefully marshalled and digested by the authorities. Precisely what the officials thought of the invention is reflected most convincingly by the fact that to-day over 300 lights working upon this principle are stationed in Canadian waters, both upon the storm-bound ocean coasts and upon the wind-swept shores of the Great Lakes and waterways.

The Willson buoys are absolutely automatic in their operation. All the impurities in the gas are removed by passing it through a special purifier, so that the burner cannot become clogged or the light impoverished. A charge of 1,300 to 1,500 pounds of carbide is carried within the apparatus, and the gas is generated *under low pressure*. The lantern is fitted with a Fresnel lens, so that the light is condensed into an intensely powerful and penetrating horizontal beam. One prominent feature is that the candle-power of acetylene gas is seven times as high as that of compressed oil-gas, while the reservoir of a given size will contain this equivalent of more light. The candle-power of these floating lights obviously varies, the largest size being capable of emitting a beam of 1,000 candle-power, this flame being the maximum that the lens will stand without breaking.

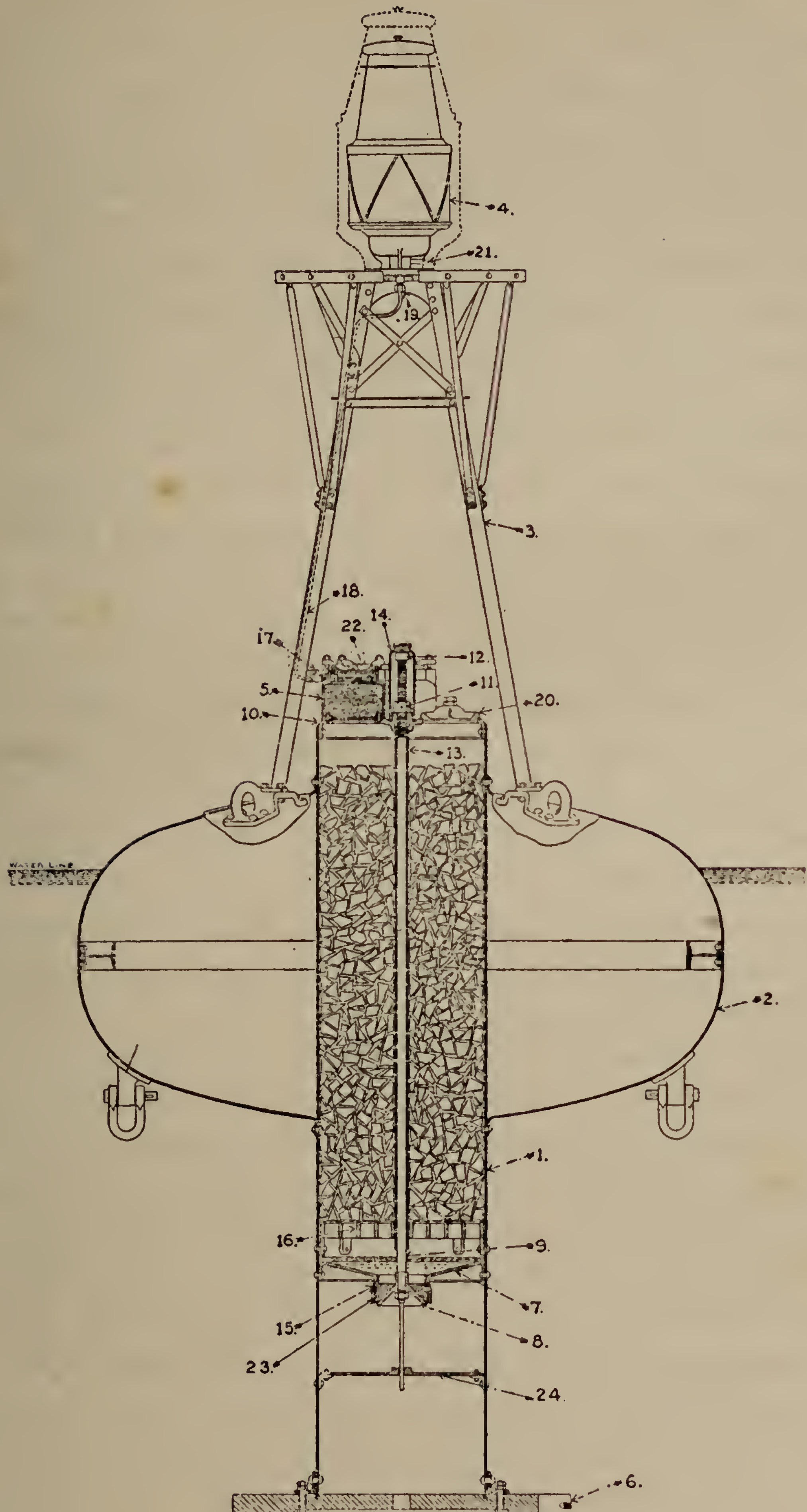


FIG. 16.—SECTIONAL ELEVATION OF THE WILLSON AUTOMATIC FLOATING LIGHT. (See next page.)

The construction and the principle of operation are exceedingly simple, as may be gathered from reference to Fig. 16. The beacon comprises a gas generator tube of steel (1), which is supported by the steel float chamber (2), on the upper side of which is placed the support (3) carrying the lantern (4). Stability is insured by means of the counterweight (6) attached to the lower end of the generator tube. A few feet from the bottom of the latter is a diaphragm (7), fitted centrally with a conically-seated valve (8) which is mounted on a stem (9). This extends through the centre of the generator and its head (10). The upper end of the valve stem carries a hexagonal nut (11), while the stem itself at this point has a keyway cut into it. A spline is fitted into the generator head to engage the keyway, and when the nut (11) is turned to close or to open the valve, the stem itself cannot move with it, except in two directions only—up or down. The nut itself cannot be turned too far, in which event it might drop the stem and valve, as there is a stop-collar (12). Leakage of gas is prevented by a cap (14), which is screwed into the generator head and sealed with a rubber washer. This cap is sufficiently long to permit the valve stem to be raised or lowered so as to adjust the movement of the valve. The stem of the valve is protected from the carbide by enclosure within a tube (13), which works through a guide bar (24) bolted to the side of the generator tube. A grid (23) is fitted in the centre of the diaphragm (7) and surrounding the valve (8), so as to prevent small pieces of carbide, which may pass through the grate (16), from falling into the water, and thereby being wasted. The steel grate upon which the carbide rests is attached to the inside of the generator, a short distance above the diaphragm. The grid (23) also acts as a valve seat, and is provided with a rubber packing (15), which is held in a groove in the seat, and projects a sufficient distance to make a good joint with the valve (8) when it is closed, even if the valve happen to be foul.

The carbide of calcium, in the form of large crystals measuring about 8 by 4 inches, is placed in the generator tube when the beacon is immersed in the water, the valve (8) being opened and the valve-cap (14) screwed down. In the centre of the counterweight (6) is an orifice through which the water enters from the outside, and passes through the open valve, to come into contact with the carbide resting upon the grate. Gas is generated instantly, to ascend through the carbide into the purifying chamber (5), where all deleterious matter is removed, the gas escaping thence through the small aperture (17) and pipe (18) to the lantern, to which the supply-pipe is connected by the aid of the coupling (19).

Of course, at times gas is liable to be generated more rapidly than it can be consumed. What happens? The apparatus is not provided with facilities to receive the surplus gas. Being unable to escape upwards through the generator tube, it collects at the bottom, and as the pressure increases it gradually forces the water away from the carbide, so that generation ceases, and is not resumed until the surplus gas has been absorbed, when the water once more is able to come into contact with the carbide. Thus it will be seen that the gas generation is controlled automatically, and that it is almost impossible for the gas pressure within the plant to reach a disruptive degree, owing to the fact that when it exceeds a certain limit it has a free vent from the bottom of the device, where the water normally is permitted to enter to carry out its designed purpose.

This invention has been utilized for a wide variety of purposes, from the lighting of harbours, navigable channels, rivers, bays, and so forth, to that of exposed coasts. The automatic beacon, properly so called, has a tower, which brings the focal plane to an elevation varying between 50 and 100 feet, this tower being built of lattice steelwork attached to the top half of the buoy, with a day mark surrounding the lantern gallery, access to which is secured by an iron ladder. This type of light carries a sufficient storage of carbide in a single charge to keep the light burning continuously for about forty weeks. In this instance the only modification from that already described is that the water for the production of the gas is admitted into the top instead of to the bottom of the generator. When an excess of gas occurs, the pressure thereof drives the water away from the carbide until the surplus has been consumed. Another type, somewhat smaller, carrying a charge sufficient for nearly six months, has proved highly successful as a coastal light, some thirty beacons of this class being stationed along the shore of British Columbia. The only trouble experienced therewith in these waters has been due to frost, which, solidifying the water around the buoy, has interrupted the designed functions.

But probably the most complete and useful type of Willson acetylene gas beacon is that in which the Courtenay whistling device is incorporated, so that in thick weather audible warning of the danger may be extended. In this instance the floating chamber which supports the superstructure carrying the light and also the generator tube, is fitted with two further tubes which project from the base like huge legs. These tubes are open at the bottom, but are closed at the top except for a connection with a valve-casing, which is fitted with a ball-valve, and upon which a powerful whistle is bolted. Now, if the buoy is lowered and anchored in absolutely still water, the water will rise to the same level within the tubes as it is outside; but when the buoy is lifted upon the crest of a wave, the level of the water falls, so that the air space within the tubes is increased. Air enters this augmented space through the ball-check inlet valve in the valve-casing. When the beacon falls, naturally the water endeavours to maintain its level within the tubes, and therefore the air which was admitted into the space becomes compressed, to be expelled through the only possible vent—the whistle—thereby producing a very powerful blast. Thirty of these combined light and whistling buoys have been strung along the rugged Nova Scotia coast, and have proved highly popular, that outside Halifax harbour being known colloquially among seafarers as the "Outer Automatic."

Another acetylene system, but working upon a better principle, has been perfected in Sweden, and, indeed, now has been adopted universally, owing to its many excellent features. This is the "Aga" light, which is the invention of Mr. Gustaf Dalén,* and which has been brought to a high stage of commercial success by the Gas Accumulator Company of Stockholm. I have pointed out the one objection to the Willson acetylene automatic light—namely, its uselessness when the surrounding water becomes frozen. While this drawback does not affect its sphere of utility to a noticeable degree in Canadian waters, it acts somewhat adversely in other seas where similar conditions prevail, but where the navigable channels are kept open by ice-breakers, such as, for instance, in the Baltic Sea. Mr. Dalén recognized this weak point in any system wherein contact with water is responsible for the generation of the gas, and accordingly sought for a superior method. Fortunately, the perfection of a new means of handling acetylene, by French inventors, offered the complete solution of the problem in a practical way. The principle of this lies in the use of dissolved acetylene, which is perfectly safe from explosion, and can be handled with the greatest facility. The gas can be stored in cylinders similar to those used for containing oxygen and hydrogen under pressure, gases which are easier to transport than carbide of calcium, and, what is far more important, climatic conditions do not exercise the slightest influence upon it.

Dissolved acetylene may be stored within the cylinder, or accumulator, as it is called, to a pressure of at least ten atmospheres, and at this pressure it contains 100 times its own volume of acetylene gas. The accumulators may be made of any desired size, this factor being governed by considerations of transport and application, as well as of the consumption of the burner.

The perfection of the dissolved acetylene process came as a great boon to the Swedish lighting authorities, inas-

* The humane labours of Mr. Dalén received recognition by the award of the Nobel Peace Prize in 1912.

much as they have probably the most difficult stretch of coastline in the world to protect. At the same time, owing to the wild, exposed character of many of the points which demanded lighting, a perfect, economical, and reliable automatic system was in urgent demand. Acetylene was an obvious illuminant, since, while the country is deficient in the essential resources for the preparation of other fuels, carbide of calcium is very cheap, Sweden, in fact, being the largest producer of this commodity. The Swedish Board of Pilotage experimented with acetylene lighting for six or seven years, submitting every known acetylene lighting system to searching practical trials, but failed to be sufficiently convinced on the vital question of reliability. Freezing-up was the most pronounced shortcoming, but when dissolved acetylene appeared as a commercial product this disadvantage was removed completely, and acetylene was adopted.

Yet dissolved acetylene, though completely successful, possessed one drawback. It was expensive as compared with oil-gas. Accordingly, there was great scope for a means of economizing the consumption of the fuel without interfering with its lighting value and efficiency. At the same time a superior flashing system was desired. The methods which were in vogue to this end were satisfactory so far as they went, but they involved a considerable useless consumption of gas.

This is where Mr. Gustaf Dalén completed one of his greatest achievements. He perfected a flashing apparatus wherein the gas passes to the burner in intermittent puffs, to be ignited by a small invisible pilot light. The device was tested and proved so successful that it was adopted throughout the service. In Swedish waters to-day there are 127 aids to navigation operating upon this system, of which five are lightships. The success of the invention in the land of its origin attracted other nations to its possibilities. At the present moment over 700 lights, scattered throughout the world, are working upon this principle.

THE "SVINBĀDAN," UNATTENDED LIGHTSHIP IN SWEDISH WATERS.

It works upon the Dalén system with flasher, giving a flash of 0·3 second duration, followed by darkness for 2·7 seconds.

THE "KALKGRUNDET," SWEDEN'S LATEST AUTOMATIC LIGHTSHIP.

The Dalén flasher is used, and this undoubtedly is the finest vessel of its type in the world.

If a beacon throws a fixed light, unless it is of extreme power, it is liable to be confused with a ship's mast-light, a fact which was found to be one of the greatest objections to the fixed white light of the acetylene aid to navigation. On the other hand, a flashing warning must be of such a character that it cannot be mistaken for the twinkling of a brilliant star, or of a light which has nothing to do with navigation. This is where the "Aga" flasher emphasizes its value. It throws a short, powerful gleam at brief intervals. The mariner cannot possibly confuse or misconstrue it ; the regularity of the flash arrests his immediate attention, and its purport may be divined instantly. The apparatus is simple and highly effective, while it has the advantage that the periods of light and darkness can be altered in relation to one another, or grouped, as desired.

From the maintenance point of view, however, the invention is of far greater significance. As the gas is consumed only during the light periods, which are very brief in comparison with the eclipse, the economy effected is very appreciable. When the apparatus was first brought within the range of practical application, many authorities, which had become wedded to the oil-gas lighting system, wherein the light flashes are of long duration in comparison with the dark periods, maintained that the Dalén flash was too short to be of any value. They disregarded the fact that the power of the acetylene-gas flash is about seven times as intense as that of the oil-gas light. For instance, when the United States acquired the first Aga light in the autumn of 1908, the authorities demanded either a characteristic signal comprising ten seconds of light followed by five seconds of darkness, or flashes and eclipses of equal duration—five seconds.

There was a prejudice against short, powerful, and oft-repeating flashes, mainly because their advantages were misunderstood. Practical experience, however, demonstrated the fact that the period of light might be reduced very considerably, and, as a result of prolonged investigations, the Swedish Board of Pilotage adopted a characteristic comprising 0·3 second light followed by darkness for 2·7 seconds. This has become known since as the "one-tenth flash," owing to the luminous interval occupying one-tenth of the combined period of light and darkness. It will be seen that, as a result of this arrangement, twenty flashes are thrown per minute.

As the flame is lighted for only one-tenth of the signal period, it will be seen that the saving of gas amounts to 90 per cent., as compared with the light which is burning constantly. Accordingly, the gas charge will last ten times as long with the flashing apparatus; consequently, the accumulator need have only one-tenth of the capacity of that for a similar beacon which burns constantly. The economy really is not quite 90 per cent., as a certain volume of gas is consumed by the pilot flame, which ignites the charge of gas issuing from the flasher burner. This, however, is an insignificant item, inasmuch as the quantity of gas burned by the pilot light does not exceed one-third of a cubic foot per twenty-four hours.

Not only has this highly ingenious system been adapted to varying types of buoys, similar in design and range of action to those described in connection with the Willson apparatus, wherein the light may be left unattended for as long as twelve months, according to the capacity of the accumulator, but it has also been applied to "light-boats" and light-vessels. The "light-boat" is a hybrid, being a combination of the buoy and the lightship, and was devised to meet special conditions. Thus, the "Gerholmen" light-boat stationed in the mouth of a Swedish river, where the current runs exceedingly strongly, resembles a small boat with a water-tight deck. From the centre of this rises a steel tripod, at the top of which the lantern is placed. The gas accumulators are stored within the hull, and are of sufficient capacity to maintain the light for a round twelvemonth without attention, as the flashing apparatus is incorporated.

The Aga light has come to be regarded as one of the greatest developments in lighthouse engineering, and has been adopted extensively throughout the world in connection with either floating or fixed aids to navigation. The United States have decided to adopt the system exclusively henceforth, until a further progressive step is achieved, and several floating lights of this type have been acquired already to guard wild and lonely stretches of the coastline.

Here and there attempts have been made to apply electricity to inaccessible lights. The most interesting endeavour in this direction was in connection with the lighting of the Gedney Channel from the open Atlantic to New York harbour. This formerly constituted the only available highway for the big liners, and it is exceedingly tortuous and treacherous—so much so that vessels arriving off Sandy Hook in waning daylight invariably anchored and awaited the dawn before resuming the journey. The great difficulty in connection with Gedney's Channel was the distance of the main lights on shore, the direct range at one part being over thirteen miles. Consequently the land lights were of little utility to the pilot.

The authorities decided to convert the channel into an electric-lighted waterway. Buoys were laid down on either side of the thoroughfare. They were of the spar type, resembling decapitated masts projecting from the water, and were held in position by mushroom anchors, weighing 4,000 pounds, or nearly 2 tons, apiece. Each buoy was crowned with a 100 candle-power incandescent electric lamp, encased within a special globe having a diameter of 5 inches. An electric cable was laid on either side of this street and connected with each buoy. The first section was completed in 1888, the electric gleams being shed for the first time on November 7 of that year. The system appeared to give such complete satisfaction that it was extended. Altogether six and a quarter miles of cable were laid down, which in itself was no easy feat, while prodigious difficulties were experienced in its maintenance, owing to the severity of the currents and the treacherous character of the sea-bed. The lights were controlled from a central point ashore, and the idea of being able to switch on and off a chain of aids to navigation by a simple movement presented many attractive features. Although navigation appreciated this improvement, the Great White Waterway did not prove a complete success. It did not possess that vital element of complete reliability which is so essential to navigation.

Compressed oil-gas has been employed extensively for unattended floating lights, but it possesses so many shortcomings that it is being superseded on all sides by acetylene, with the exception of one or two countries which appear to be inseparably wedded to this princple. It is expensive both to install and to maintain, while the "radius of action" —otherwise, the period during which it may be left without human attention—is unavoidably brief. For temporary purposes, such as the indication of a submerged wreck, it is efficient, while it is also serviceable for accessible positions, but it is not regarded as being a satisfactory system for places which human hands cannot reach for months at a time.

Crude petroleum in conjunction with the Wigham long-burning petroleum lamp, wherein the flame is produced from a moving wick, has been adopted widely. Lights installed upon this principle may be left for ninety-three days at a time without anxiety. In many instances the Wigham light is mounted upon steel boats ; in other cases it is attached to floating wooden structures. The British Admiralty in particular is partial to this type of light, and it must be confessed that it has proved highly serviceable and reliable.

I have described already the general principles and features of this system. When it is applied to a floating beacon, and it is desired to save the oil dropping from the drip valve, a tank is fixed to the deck of the floating structure, and connected by a flexible pipe to the coupling at the bottom of the float cylinder. A universal joint is attached to the connection on the top of the tank to prevent the pipe being twisted by the swinging and swaying motion of the lamp on the gimbals. When the lamp is inspected, the oil may be pumped out of the tank, strained, and used time after time in the float cylinder.

One of the most interesting of this type of floating boat-lights is to be seen in Queenstown harbour. The hull is 30 feet in length, and has a beam of 11 feet. On this, within a conical structure measuring 7½ feet high and 6½ feet in diameter at the deck, is mounted the lantern. Although the lamp is exposed to drenching seas and heavy storms, it has never yet failed, a fact which conclusively points to its efficiency. It rides well, and the lamp is kept much drier than the lights on ordinary buoys, according to the observations of the engineer responsible for its maintenance. In this case the focus of the light is brought 12 feet above the level of the sea.

Probably the most compelling illustration of the utility of the automatic beacon is offered by the unattended light-ship. The Otter Rock vessel is one of the most interesting examples of this development. It was designed by Messrs. D. and C. Stevenson, and comprises a substantial steel hull, the deck of which is covered so that the interior is absolutely water-tight. The craft is provided with a central and heavy bilge keels, so as to reduce rolling to the minimum. Two heavy steel bulkheads divide the craft into three water-tight compartments, in the centre of which two large welded-steel gas tanks are stowed. These are of sufficient capacity to feed the light for several months without replenishment. The light is mounted upon a steel tower placed amidships, which brings the focal plane 25 feet above the water. The gas is fed from the tanks to the lantern through the tower, a valve reducing the pressure, while a ladder enables the attendants to climb to the lantern gallery to adjust the burner and flame, and to clean the lenses, upon the occasion of their periodical visits.

The gas cylinders are charged from the supply-ship through flexible hoses, the gas being compressed to about 180 pounds per square inch. The light is of sufficient power and elevation to be seen from a distance of some twelve miles. The beacon gives not only a visual, but also an audible warning. On the deck of the boat a bell is mounted, this being rung not only by the motion of the ship, in the manner of a bell-buoy, but also by the gas on its passage from the tanks to the lantern, the bell being fitted with two clappers for this purpose. The gas in passing from the tank enters a receptacle having a flexible diaphragm, which, as it becomes filled with gas, is naturally pressed outwards. On this is mounted a central metal piece, which is connected to a rod and lever. As the diaphragm is forced outwards, it moves the rod and actuates the lever, which, when the diaphragm falls, return to their normal positions. Attached to this mechanical arrangement is the bell-clapper, which alternately is lifted and dropped upon the dome of the bell, thereby causing it to ring. After the gas has performed its duty in raising the clapper lever and rod, it passes to the lantern to be consumed. Thus, while the light gleams brightly and steadily, the bell rings with unerring regularity —about three times per minute—day and night for months on a single charge ; both must continue in operation until the supply of gas is expended. The success of this interesting and novel lightship has been responsible for similar installations in other similarly wild and exposed positions where approach is uncertain and often impossible for weeks at a time.

One misadventure befell the Otter Rock light-vessel, which is moored in an open position over the rock of that name near Islay, although it was not the fault of either the system or the designing engineers. There was a flaw in one of the shackles, and while the ship was sawing and tugging at her anchors during a heavy gale the flaw asserted itself, the shackle broke, and the lightship got away. She was recovered with some difficulty, after having drifted about twenty miles. She was found stove in, having embraced the rocks during her wayward journey, but otherwise was unharmed. She was towed into port, repaired, and then taken back to her station, where she was secured more firmly than ever, while her chains were closely inspected to make assurance doubly sure. No repetition of the accident has occurred since, and the Otter Rock lightship, tethered firmly to the rock, rides gales and calms, throwing her welcome

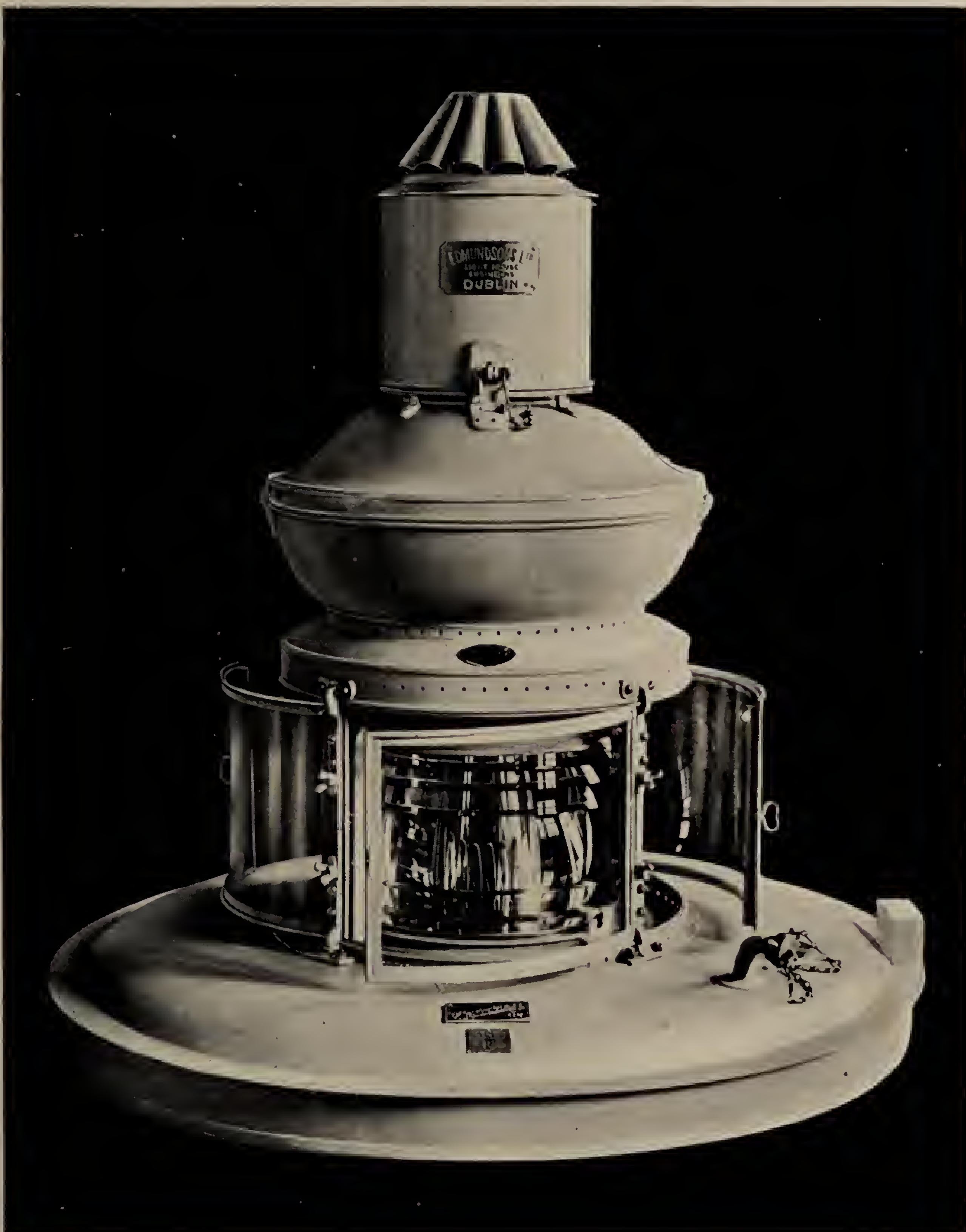


Photo by permission of Messrs. Edmondsons Ltd., Dublin.

THE LANTERN USED IN THE WIGHAM AUTOMATIC PETROLEUM BEACON.

The circular shallow reservoir contains the burning-oil, which feeds the wick as it moves towards the burner, and also acts as a deck on which the lantern is built. In this ingenious system the flame is not produced at the end of the wick as in the ordinary lamp, but from the flat side of the wick, which is moved continuously in a horizontal direction over a small roller. By this means a light of uniform intensity is obtained, as carbonization cannot occur.

By permission of Messrs. Edmondsons Ltd., Dublin.

THE "6-BAR" FLOATING AUTOMATIC WIGHAM LIGHT IN PORTSMOUTH HARBOUR.

This beacon, burning crude petroleum, burns for thirty days on a single oil charge.

rays and droning her musical warning the whole year round as steadily and efficiently as if she had a crew aboard.

A similar lightship was built for the Trinity House authorities from the designs of their engineer, Sir Thomas Matthews, for service on the English coast. This boat, built of steel, measures 65 feet in length, by 18½ feet beam and 10½ feet depth, with the lantern carried at the point of an open steel pyramidal structure, rising sufficiently high above the boat's deck amidships to bring the focal plane 26 feet above the level of the water, thereby giving it a visible range of some ten miles. The boat is provided with two holds, in which the gas reservoirs are placed, the total gas capacity being about 1,500 cubic feet—enough to keep the light burning for one hundred days.

This light is of the revolving type, and the rotation of the apparatus is accomplished very ingeniously. Before the gas passes to the burner, it drives a tiny three-cylinder engine, the crank-shaft of which is connected to the revolving apparatus through gearing. The speed of the turntable is kept constant by the aid of a governor, and the apparatus works so smoothly and perfectly that there is not the slightest divergence from the rate at which the apparatus is set. As the gas emerges from the engine, it passes to the burner to be consumed. By means of a novel apparatus, should anything befall the little motor or the rotating mechanism, the light does not drop out of service. In that event the gas flows directly to the burner, the only difference being that a fixed instead of a revolving light is emitted.

When the Scandinavian liner *Norge*, while on her way to the United States in July, 1904, fouled the terrible Rockall and lost 750 of her passengers, the outcry about the absence of all means of indicating this spot to the navigator vibrated round the world. Yet it was a useless agitation. Rockall is a no-man's land ; no nation has planted its flag upon its cone of granite ; no Power cares whether it continues its harvest of human lives or otherwise. The various countries appear to think that it is too much off the map to be worthy of a moment's thought ; its existence is brought home only by a holocaust.

After this heartrending disaster, Messrs. D. and C. Stevenson adumbrated a promising means of indicating this awful graveyard to the seafarer. They suggested that two automatic unattended lightships should be constructed, and that one should relieve the other every six months. The project was eminently practicable, but every country seemed to shirk responsibility in the expense of its adoption. But Rockall is a unique danger spot ; in no other part of the known world does such a formidable isolated peak of granite rise from the ocean depths, for it is in mid-Atlantic, 160 miles west of St. Kilda, and 290 miles off the Scottish mainland. It may be away from the great steamship lanes of the Atlantic, yet a vast volume of shipping passes within sight of its curious formation. Seeing that the foremost maritime Powers defray between them the cost of maintaining the light off Cape Spartel, surely the dictates of humanity are sufficiently pressing to secure the indication of this islet. The maintenance of an unattended automatic beacon, such as Messrs. Stevenson advocated, would not impose a severe strain upon the treasuries of the leading Powers of the world, whose interests are associated intimately with the North Atlantic.

The perfection of the unattended lightship, working automatically, has provided the lighthouse engineer with a powerful weapon for marking the most exposed and out-of-the-way danger spots. When the new development is carried to its uttermost lengths, no graveyard of the ocean, no matter how remote and inaccessible, need be without means of warning shipping of its whereabouts.

CHAPTER XXIII

THE LIGHT-KEEPER AND HIS LIFE

THE life of the guardian of a blazing signpost of the coast is much the same the whole world over. It is unavoidably monotonous under the best conditions. Each succeeding day and night brings a similar round of toil, with very little variation. There are the same duties to be performed in strict accordance with routine, and under normal circumstances there are many idle hours which have to be whiled away as best one can. On the mainland, especially in the South of England, France, Germany, and the United States, the loneliness and monotony are not felt so keenly by the wardens of the light, as in many instances they are in close proximity to ports and towns, where a little welcome relaxation may be obtained during the rest spells; while in the summer evenings, if the lights should be only a few miles away from civilization, visitors are frequent. Again, the keepers as a rule live with their families in cosy solid buildings, and, having a stretch of garden flanking their homes, can expend their hours of leisure to advantage.

On the isolated, lonely rock, however, the conditions are vastly different. The average person, when regarding on a calm day the tall slim outlines of a tower rising from the water, is apt to regard the life of those responsible for keeping the light going as one enveloped in romance and peace, far removed from the trials and worries of the maelstrom of civilization. But twenty-four hours on one of these beacons completely dispel all romantic impression. The gilt of fascination wears away quickly, and the visitor recognizes only too forcibly the terrible desolation of it all, and admires the little band of men who watch vigilantly over the deep for the guidance of those who go down to the sea in ships.

The keepers of such stations are marooned as completely as any castaway on a barren island. In many instances they cannot even signal to the shore. If anything should go wrong, they must wait until a ship comes in sight, to communicate their tidings by flag signals. If the call is urgent, say for illness, and the passing boat carries a doctor, she will heave to, and, if conditions permit, will launch a boat to carry the medical man to the rock to administer aid. If it is a matter of life or death, the ship will take the man off.

As may be imagined, upon a sea-rock, owing to the slender proportions of the tower, the quarters are inevitably very cramped, with no facilities for the men to stretch their limbs. The manner in which space is economized in the small circular apartments is astonishing. The essential furniture is built to the wall, and liberal cupboard space is provided, the governing consideration being to provide the men with as much open space as the restricted circumstances will permit. The only exercise that the men can obtain in the open air is upon the narrow shelf forming the landing platform, or the narrow gallery around the lantern. In the majority of circumstances it is less than that provided for the benefit of a prisoner in an exercise yard.

The lamp is lighted at dusk, and, unless it is a fixed white light, the clockwork driving the occulting and revolving mechanism has to be wound up. Seeing that this entails the lifting of a ton or so up the vertical cylinder in which the weight travels, this is no mean task in itself.

Unremitting vigilance has to be maintained while the lamp is burning. It demands attention from time to time, while, should anything serious go wrong, the attendant must bring the reserve lamp into service without a moment's loss of time and without interruption of the ray.

"The light must not go out!" That is the inflexible rule of all attended lights between the two Poles. Even if it failed only for a minute, the circumstance would not escape observation. Some vessel would detect the breakdown; it would be recorded in the captain's log-book. When he touched the first port, intimation would be sent to the organization responsible for the beacon, setting forth the fact that on such and such a night, at a certain hour, this light was not showing in accordance with the official light list, or was giving a warning different from that laid down for the guidance of the seafarer. An inquiry would be instituted immediately to ascertain the reason, and the light-keeper probably would find himself in an awkward position, although months might have elapsed since the incident.

There is nothing haphazard about the control of lights. The circumstances are too serious to permit the slightest deviation from hard-and-fast regulations. The passing mariner is entirely dependent upon these blazing guardians, maybe from a distance of fifteen miles or more. He has his chart wherewith he is able to steer his way, but he must have certain marks to guide him at night, so that he may be sure of his course and position. Accordingly, every lighthouse possesses some individual characteristic in regard to its light. As explained elsewhere, it may be a group flash, an occulting flash of a distinctive nature, a revolving light which completes a revolution once in a certain period of time, or a fixed blaze.

Fortunately, the men watching over the lights appreciate the gravity of their responsibility, and are reliable to an heroic degree. Each is a man picked for the duty, who is not appalled by loneliness, and is of unimpeachable precision. Of course, accidents will happen, but dereliction of duty is criminal, because it may bring about loss of life. Carelessness on the part of a light-keeper precipitated the loss of the steamer *Victoria* when crossing the English Channel from Newhaven to Dieppe on April 12, 1887. The French coast, as it was being approached, became shrouded by the inexorable fog-fiend. The captain lost his way, although he knew, from the time he had been steaming, that he must be perilously near the French shore. He listened for the droning of the fog-siren mounted on Pointe d'Ailly, but in vain. He sent to the engine-room to ascertain the number of revolutions the engines had made, and this convinced him that he must be close inshore, despite the silence of the fog-signal. Thinking that he might have strayed some distance east of Dieppe, he brought his vessel round, and then crawled slowly ahead. But he had scarcely settled into his forward stride when there was a crash—a terrible splitting and crunching. The vessel had kept a true course, and now had hit the very rocks which the captain had sought to avoid. The passengers, being ready to land, were got into the boats and pushed through the dense curtain for land, but some thirty passengers and crew were never seen again.

The subsequent inquiry revealed an amazing breach of duty on the part of those in charge of the light-station. The head lighthouse-keeper, off duty at the time, was asleep in bed, but his wife awoke him as she observed the fog settling upon the water. He dressed hurriedly, and rushed to see what his companion was doing. This official had failed lamentably in his duties. Instead of starting the boiler fires to raise the steam to work the siren upon the first signs of the approaching enemy, as he should have done, he had delayed the duty. The result was that an hour was wasted, and during this interval the unfortunate captain took his ship upon the rocks. To make matters worse, the keepers did not perceive the wreck until some two hours after the disaster, although they admitted that they heard the cries of people an hour and a half previously, but never suspected the cause of the turmoil.

The man on watch during the night maintains a keen lookout. The faintest signs of a gathering mist are sufficient to cause him to wake his assistant to manipulate the fog-signal, even if the precaution proves to be unnecessary. "It is better to be safe than sorry," is the lighthouse-keeper's motto ; so he runs no risks.

When the gathering brightness of the dawn enables the form of the tower to be identified from a distance of several miles, the light is extinguished. Heavy curtains are drawn across the windows, not only to protect the lenses from the sun, but also to give a characteristic colour to the lantern.

Thus, by daylight a lantern may appear to be a dull red or an intense black. To give a brilliant light by night and be a prominent landmark by day forms the dual duty of the guardian of the coast.

When the lantern has cooled, the keepers coming on the day shift have to clean the lamps and put them in order for service the following evening. Everything has to be overhauled and got ready for use at a moment's notice. The oil reservoirs have to be examined and charged, and the panes of glass, with which the lantern is glazed, cleaned and brightened. The reflectors have to be polished, for they must be kept in a constant state of mirror-like brilliancy. All brasswork has to be cleaned and polished until it gleams like burnished gold, while the rooms must be washed and kept in the pink of condition, free from the smallest specks of dust.

The necessity for extreme cleanliness and spotlessness is emphasized in every lighthouse. The inspector has a highly-trained, quick eye for detecting carelessness, and he has one instinct developed peculiarly—the discovery of dust. He draws his fingers over everything, and squints quizzically at an object from all angles. Woe betide the keeper if the slightest trace of dirt is detected. Then the inspector closes the other eye, and the keeper receives a squint which does not augur well for his future. A few sharp, pointed remarks are rasped out, and it is not long before the relief-boat comes out with another man.

The engineers and other representatives of authority are remorseless. A man is judged from apparently trifling details. If he permits a door-knob to become sullied, he is just as likely to overlook the polishing of the lenses, or to perform some other vital task in a perfunctory manner.

One of the Stevensons achieved a peculiar notoriety among the Scottish keepers for his unbending attitude in this connection. He had a scent for dust and untidiness developed as keenly as that of a mouse for cheese. When his boat came alongside a light, and the keeper stepped forward to extend a helping hand, the eyes of the engineer scanned him searchingly. If the man's appearance were not immaculate, trouble loomed ahead. This engineer maintained that if a man were indifferent to his own appearance, and permitted dust to collect upon his own clothes, he could not be trusted to maintain the delicate apparatus of a lighthouse in apple-pie order ! What was more to the point, the engineer generally was correct in his deductions. He spared no effort to place the most responsible lights in the hands of men above suspicion in regard to cleanliness. Although, as this martinet confessed, nothing pained him more than to have words with any of his keepers, cleanliness had to be maintained.

When the keeper has completed his routine duties, he is at liberty to spend his leisure according to his inclinations. As a rule the men turn these periods to advantage. Reading is a popular recreation, and the authorities maintain a circulating library, the books being changed with every relief. But the men could accept twice as much literature as is available at present. Here a word should be said concerning the Lighthouse Literature Mission and its work, which is international. The idea was conceived by Mr. Samuel H. Strain, and the work is conducted from Belfast, Ireland. The most conspicuous feature of this organization is that every penny received is turned to good and useful purpose in connection with the object. The founder conducts it without monetary reward, so that the item of "operating" charges does not swamp the greater proportion of receipts, as is the case with so many so-called missions in other fields. There are few organizations which are so deserving of financial support, because this mission brings welcome relaxation to a hard-worked community whose vigil secures the safety of those who travel on the sea. The labours of Mr. Strain are highly appreciated by those who keep watch and ward in seagirt prisons, and the mission deserves far stauncher support from the philanthropic than it receives at present. Sympathizers with the loneliness of the lighthouse-keeper are prone to think that these men are in dire need of spiritual pabulum, and are apt to send literature of

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THE PUMPS WHEREBY THE OIL IS LIFTED FROM THE LOWEST FLOOR TO THE LANTERN-ROOM.

By permission of the "Syren and Shipping."

COMBINED KITCHEN AND LIVING-ROOM IN THE LIGHTHOUSE.

an emphatic goody-goody nature. But the keeper of the light is as human as the clerk in the city. He is so accustomed to the company of Nature, and has cultivated such a deep respect for the Master of the Universe during his spells of duty, that he welcomes a diversion therefrom in his hours of leisure. A humorous paper is more welcome than a tract on the evils of drink.

When the weather is favourable the men seek a little relaxation in fishing, but here again they have to suffer considerable denial, as the tackle invariably becomes inextricably entangled with the rocks, so that the losses exceed the prizes. In the United States the greater number of the keepers maintain a garden well stocked with vegetables and flowers. The tending of these charges carries the minds of the men from their work completely, and for the opportunity to practise this hobby they are indebted to the kindness of the Government, which supplies seeds free of charge.

It is when the gale is raging tumultuously that the men in the tower are compelled to realize their position. The waves pound the rock and building so ceaselessly and relentlessly that the latter trembles and shakes like a leaf. At times the din is so deafening that the men cannot converse ; they are compelled to communicate with each other by signs. The waves pick up stones and hurl them with terrific force against the lantern. Occasionally the elements triumph in their assault, and the missiles shatter the glass. To step out on the gallery in the teeth of a blizzard to clear the snow away demands no little courage. As the man emerges upon the narrow platform, he is engulfed in the swirling flakes, and often is pinned against the masonry so tightly by the wind that he cannot move a limb ; at other times he is swept almost off his feet. While engaged in his freezing task, he also runs the risk of being drenched by a rising comber.

The men on the lonely, exposed Tillamook Rock, off the Oregon coast, have had more than one occasion to respect the storm-fiend. One night, while a fearful gale was raging, a huge mass of rock was torn away from the islet, snatched by the waves, and thrown high into the air. It fell with terrific force upon the dome of the lantern, splintering the roof and smashing the light, so that no welcome rays could be thrown from the tower again that night. The keepers at once set to work with the fog-signal, and during the hours of darkness worked like slaves, blaring out a warning by sound which they were unable to give visually.

Fortunately, such an experience as befell the keepers of the American Thimble Shoal light is very rare. This beacon marks the shoal of that name, and is, or rather was, a screw-pile iron lighthouse, marking 11 feet of water at the entrance to Chesapeake Bay, Virginia, U.S.A. On December 27, 1909, the keepers were immersed in their tasks, when there was a terrible crash followed by a dismal rending and splitting. The building shivered from top to bottom. The keepers were thrown off their feet, and when they regained their wits they found that the schooner *Malcolm Baxter Junior*, while being towed by a tug, had blundered into them, and had carried a considerable portion of the building away. The impact upset the light; the scattered oil burst into flame, and within a few minutes the lighthouse was blazing like a gigantic bonfire. The keepers stuck to their posts, and endeavoured frantically to extinguish the outbreak, but their efforts were too puny to make any impression. At last, when a foothold was no longer possible with safety, and under extreme pressure, they abandoned their charge. When the flames had completed their destructive work the lighthouse presented a sorry sight, being a mass of broken and twisted ironwork. A wooden tower was erected with all despatch, and a fog-signal was installed, so that the men could carry on their duties while the reconstruction of the station was hurried forward.

The keepers turn their hands to strange occupations. Fretwork, wood-carving, poker-work, and similar hobbies, are practised freely. A few devote their leisure to intellectual improvement to fit them for other walks in life. The keeper of Windward Point, Guantanamo Bay, Cuba, devoted his energies to studying, and obtaining diplomas in, mechano-therapy and suggestive therapeutics, as well as becoming proficient in Esperanto. The keepers of two other American lights set themselves to the mastery of jurisprudence, and in due course resigned their positions and rented offices in the city, where in the course of a few years they built up very remunerative legal practices. As a rule the lighthouse-keeper is an expert handy-man, as he is compelled to complete a whole list of duties in addition to maintaining the lights. In the summer the metal and wooden lights have to be given a coat of paint, while plumbing and other displays of skill in metal have to be carried out, even if only temporarily.

The calling is exceedingly healthy, which accounts for the immunity from illness which these men enjoy. Also, as a rule, the land-lights are set amidst wild romantic surroundings. Some years ago a number of American families, in the search for a quiet, health-restoring rest, were in the habit of spending their vacations at lighthouses, to the financial profit of the keepers. Eventually, however, the authorities, fearing that the keeper might be distracted from his duties, issued a summary order forbidding this practice, much to the disgust of the men, and "attractive lighthouse apartments" became a thing of the past. In Great Britain an order was issued that "no ale or other intoxicating liquor be allowed to be sold in any lighthouse." The precise reason for this strange ordinance is not quite clear, but it is significant to note that it came into force immediately after the disastrous fire at the Leasowe lighthouse, on the Wirral shore.

The lighthouse invariably is an object of attraction among the general public, but this interest seldom goes to the length narrated by a keeper of one of the West Indian lights. One night two of the men at this particular station decided to hunt for red crabs on the beach below. They started off with a hurricane lamp, but were astonished, when they gained the foreshore, to see a large sloop hard and fast on the reef, although the night was beautifully clear and the light was burning brilliantly. With much effort the keepers got out their dory, put off to the wreck, and endeavoured to get the sloop out of her uncomfortable position, but, finding her too well fixed, took off the passengers. The survivors were housed in the keepers' quarters until next morning, when they were succoured. The head-keeper asked the captain how he managed to get into such a position, and to his surprise learned that, as the passengers were anxious to obtain a clear close view of the light, the master had stood inshore, not knowing that the reef over which vigil was mounted ran out far into the water. That navigator paid dearly for his attempt to satisfy curiosity. His sloop broke up, since she was impaled too firmly to be salvaged.

It is not often that the utter loneliness and monotony of the daily round unhinges a keeper's mind, but this awful fate overtook the warden of a somewhat isolated American light. The man had served with Admiral Dewey off Manila, and upon his return home the Government placed him in charge of a station as an occupation for the evening of his life, and as a recompense for faithful service. He settled down with his wife and family, but the isolation soon began to affect his brain. For days he would absent himself from the light, which would soon have failed had it not been for the unswerving devotion of his wife and the assistance of one of two friends living in the locality. They spared no effort to keep the beacon burning, lest the authorities might hear about the keeper's strange behaviour, and deprive him of his charge, and, incidentally, of his livelihood. In due course the incident did reach the authorities, and, not knowing what was the matter with the man, they took action accordingly. As the keeper entered the station after one of his inexplicable expeditions of a fortnight's duration, he was arrested for desertion. He was examined promptly by two doctors, who found him hopelessly insane, and was incarcerated in an asylum, where in the course of a few days he became a raving lunatic.

Often the keepers, although only condemned to imprisonment for a certain period at a time, have to tolerate a longer stay, owing to the relief-boat being unable to approach them. In some instances the delay may run into five weeks or more. During the winter the relief of the Eddystone, Longships, Wolf, Fastnet, Skerryvore, and Dhu-Heartach lights is always a matter of extreme uncertainty. Although the men have to provide themselves with supplies, a reserve is maintained at the station by the authorities for such emergencies. Even some of the land stations are not approachable readily. There is the Punta Gorda light-station on the Californian coast, the situation of which is wild and forbidding. There is a landing about eight miles above the station, but it is extremely precarious. Still, unless a certain element of risk is accepted in coming ashore here, it is necessary to face a tramp or stage journey of nearly fifty miles across country in order to gain the lighthouse.

The lighthouses in the Red Sea are, perhaps, among the most unenviable and trying in the world. This stretch of water, lying between two blistered coasts of sand, is no more or less than an oven, where even the strongest constitution finds it difficult to hold out for long. Moreover, the absence of civilization, owing to the extreme aridity of the country, renders the life exceptionally depressing. In the summer the heat is wellnigh intolerable. The thermometer hovers between 95° and 110° F. in the shade throughout the twenty-four hours, so that night brings no relief to the oppressiveness.

At some of the stations the men seek a little diversion, and incidentally add occasionally to their pocket-money, by shark-catching, which is a tolerably profitable pursuit, since these waters are thickly infested with this fish. The jawbone and backbone invariably find ready purchasers, the former being mounted as a curiosity, while the backbone forms a novel and serviceable walking-stick.

One method of trapping these monsters which affords keen delight was related to me. The requirements are an electric battery, some rope, a few feet of electric wire, a cartridge, and an empty box, with a chunk or two of bad meat. The cartridge is fitted with an electric primer, the wire of which stretches to the battery. This cartridge is buried in a hunk of meat, the whole being dangled from a box—an empty cask is better—which serves as a float, while a rope is stretched from the box to the shore, with the electric wire spirally wound round it. A short length of chain is preferable, if available, to attach the bait to the float, but a short piece of rope will do. This novel line is thrown into the water, and the man keeps his eye on the float, with one finger on the battery. The hungry shark, espying the tempting morsel, makes a grab and swallows it, but the chain prevents him tearing away with it. The pull causes the float to disappear, the man's finger presses the button, and the trick is done. There is an explosion, and pieces of shark and showers of water fly into the air. The incident is all over too quickly for the fish to marvel about the strange indigestibility of the tainted meat he grabbed so greedily. The men enjoy this sport hugely when it can be followed, as they regard the shark with intense detestation.

Despite the vigilance of the various Powers, slave-running is still a lucrative business on these forbidding coasts. Now and again a forced labourer gets away from his taskmaster, and comes panting into the lighthouse territory. This is sanctuary to the hapless wretch, and although the keepers invariably receive a call from the runaway's master, he meets with scant courtesy, while his demand for the surrender of the fugitive is answered by a point-blank refusal. The slave-driver may storm, threaten, and abuse, to his heart's content, and, as he is generally a past-master in Arabian invective, the keepers have to listen to a pretty tune. But the slave is kept in the lighthouse until the relief-tender makes its periodical call, when he is taken back to Suez and liberated.

Fortunately, owing to the extreme care that is manifested by the authorities, mishaps at a lighthouse are few and far between. The men are supplied with rules and regulations which are drawn up with an eye for every possible emergency. Yet accidents will happen, due in the majority of

By permission of the "Syren and Shipping."

KEEPER CLEANING THE LAMP AFTER IT HAS COOLED DOWN.

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A LIGHTHOUSE BEDROOM.

Owing to the limited space the furniture is reduced to the minimum, the bunks being built against the wall.

instances to familiarity bred of contempt. The majority of these calamities occur in connection with the explosive fog-signalling apparatus, although every device is adopted to safeguard the men. At one of the Scottish stations a keeper was manipulating the fog-signal, but, flying in the face of instructions, he caused the charge to explode prematurely. The man escaped injury, but the detonation shattered several panes of glass in the lantern.

One of the keepers of the Rathlin light, on Altacarry Head, was not so fortunate. The White Star Canadian liner *Megantic* was rounding the corner of Ireland to enter the last lap of the homeward journey one Saturday evening, when the captain's attention was arrested by a signal of distress flying from the lighthouse. The interpretation of the signal revealed the fact that a doctor was wanted, so, easing up the ship, he lowered a boat, and the doctor was sent away to the island. Upon landing he found one of the men in dire straits. He had been cleaning the fog-gun, when a charge, which had been left in the weapon inadvertently upon the last occasion it was used, exploded. The man's arm had been wrenched off, and he was burned terribly. It was a stroke of luck that the liner hove in sight at the moment she did. There was no chance of extending succour to the injured man on the spot, and he would have died before a doctor could have been summoned by boat from Ballycastle, nine miles away. The surgeon bound up the man's injuries, lowered him into his boat, and, on regaining the liner, placed him in the hospital, where he was tended until the vessel's arrival in Liverpool, where he was landed and placed in hospital.

More remarkable was the accident which happened at the Flannen Islands light-station in 1900; it remains an unsolved mystery to this day. This is one of Scotland's lonely lights, mounting guard over a group of islets fifteen miles off the Hebrides. On December 26 the relief-tender approached the station on her usual fortnightly visit, but, to the amazement of those on board, no signs of the keepers or the usual signals were to be seen, while the lantern was not dressed in its daylight garb. The crew landed hurriedly, wondering what was amiss. They found the lighthouse absolutely deserted ; not a sign of any of the three keepers was to be seen or heard. They examined the log, and found that the light had not been burning for some days, the last entry being made about 4 a.m. nearly a week previously. The rock was searched, but yielded no clue to the mystery of the complete disappearance of the men. The light had not been abandoned ; it had simply burned itself out. It was a fortunate circumstance that very little shipping frequents these seas during the winter, or there would have been one or two marine disasters, as the islands are often wrapped in fog.

It is surmised that one of the men ventured outside on to a rocky ledge in the early hours of the morning. According to the log, a vicious storm was raging at the time, and probably in the darkness the man was swept off his feet and carried into the sea. The second keeper on duty, marvelling at the non-return of his assistant, evidently had roused his other companion, and the two had instituted a search in the storm, only in turn to be caught by a wave and carried away.

In Great Britain, since 1860, men only have been employed by the Trinity House Brethren for the maintenance of the lights, but in the United States women still are engaged in this duty. Some of the British lights have been controlled by one family through two or three generations. It was only a few years ago that a Darling retired from the vigil on the Longstones of Farne Islands, the scene of Grace Darling's heroism, while for a century and a half one family kept the South Foreland light faithfully. The Casquets light off Alderney, in the Channel Islands, was maintained by one family, some of the children spending the whole of their lives on the rock, son succeeding father at the post of duty.

On the American coast, however, women are more extensively employed. Seeing that many of the lights are burned in a low tower projecting from the dwelling-house, this circumstance may be readily understood, as the duties beyond the maintenance of the light are not exacting. One of the most notable instances, however, is the Point Pino light at the entrance to Monterey Bay, on the Californian coast, the guardianship of which has been in feminine hands for the past thirty years. For something approaching half a century a woman maintained the Michigan City harbour light on the Great Lake of that name. Indeed, the associations were so deep-rooted and long that the beacon became popularly known as "Miss Colfax's light," after the name of its keeper. Even when she attained the age of eighty years she was as active and attentive to her charge as on the day, in 1861, when she first assumed responsibility for its safe-keeping.

In those times there was a beacon established on the end of the wooden pier, which railed off an area of the restless lake for the purposes of the inland port. Those were strenuous days. Her home was on shore, and every night and morning she tramped the long arm of woodwork to light and extinguish the lamp. Lard-oil was used, and during the winter the food for the lamp had to be heated to bring it into a fluid condition before she set out from home. It was no easy matter struggling along on a blusterous, gusty evening, with a pail of hot oil in one hand and a lamp in the other, over a narrow plank. Often, when a gale was raging, progress was so slow that by the time the beacon was reached the oil had cooled and congealed, rendering it a difficult matter to induce the lamp to burn. Once set going, however, it was safe for the night, as the heat radiated from the burner kept the lard melted. In addition to this lamp, there was another light in the tower projecting from the roof of her house, which had to be maintained, and this, being the main light, was the more important of the two.

In 1886 the pier tower was taken out of her hands for ever. A furious gale, such as is peculiar to these inland seas, and which cannot be rivalled on the ocean for fury, was raging. At dusk she started on her usual journey. Time after time she was wellnigh swept off her feet, so that she staggered rather than walked, for the spray and sand flecking her face nearly blinded her. When she gained the tower she paused, and observed that it was trembling violently. Undismayed, she ascended, lit the light, and tramped back to the shore. Scarcely had she gained the mainland, when, glancing seawards, she saw the light sway from side to side for a second or two, and then make a dive into the water. A few moments later a crash reverberated above the noise of the storm: the decrepit pier had succumbed at last. Hers was a lucky escape, but she hurried home, and sat by the main light gleaming from her roof all that night, apprehensive that some vessel might endeavour to make the harbour and come to grief. When the pier was rebuilt, a new beacon was placed on its extremity, but its upkeep was taken over by the harbour authorities, leaving only the shore light in the trusty woman's keeping, the wicks of which for over forty years were trimmed and lit at dusk, and extinguished with the dawn, with her own hands.

During the migratory season of the birds extraordinary sights are witnessed around the light at night. The brilliant glare attracts enormous flocks, which flit to and fro. As the monster flaming spoke swings round, the birds, evidently blinded by the glare, dash with such fury against the glass panes of the lantern as to flutter to the floor of the gallery with broken necks and wings, while large numbers, dazed or killed, fall into the water. The birds are of all species, and at times may be picked up by the basketful. Then the light-keepers are able to secure a welcome change in their dietary. Moths, too, often hover in clouds round the light, and are of such variety that an hour on the gallery would bring infinite delight and rich harvests to the youthful entomologist who has to be content to hunt around electric lamps in quiet streets at night.

While the lamp is burning, time cannot drag, owing to the multitude of details which compel the keeper's constant attention. The official log has to be kept posted with a host of facts, such as temperature, barometric readings, weather conditions as they vary from hour to hour, behaviour of the lamps, etc.; while, when the lighthouse is a marine signal-station as well, passing ships have to be signalled and reported. The spell of labour varies from four to five hours or more. Obviously, the task is more exacting and arduous in the winter than in summer. During the former season the lamps have to be lighted as early as 3.15 p.m., and are not extinguished until eight o'clock the next morning. In the summer, on the other hand, the lamps may be required for less than six hours or so. In northern latitudes where the daylight is continuous owing to the midnight sun, the light scarcely seems necessary. Yet it is kept burning during the scheduled hours of darkness.

Thus, night in and night out the whole year round, a comparatively small band of faithful toilers keeps alert vigil over the dangers of the deep, for the benefit of those who "go down to the sea in ships, and do their business in great waters." The safety of thousands of human lives and of millions sterling of merchandise is vested in their keeping. The resources of the shipbuilder, the staunchness of the ship, the skill and knowledge of the captain—all would count for nothing were it not for the persistent, steady glare of the fixed, the twinkling of the occulting, or the rhythmic, monotonous turning spokes of the revolving light, thrown over the waste of waters from the lighthouse and the lightship.

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