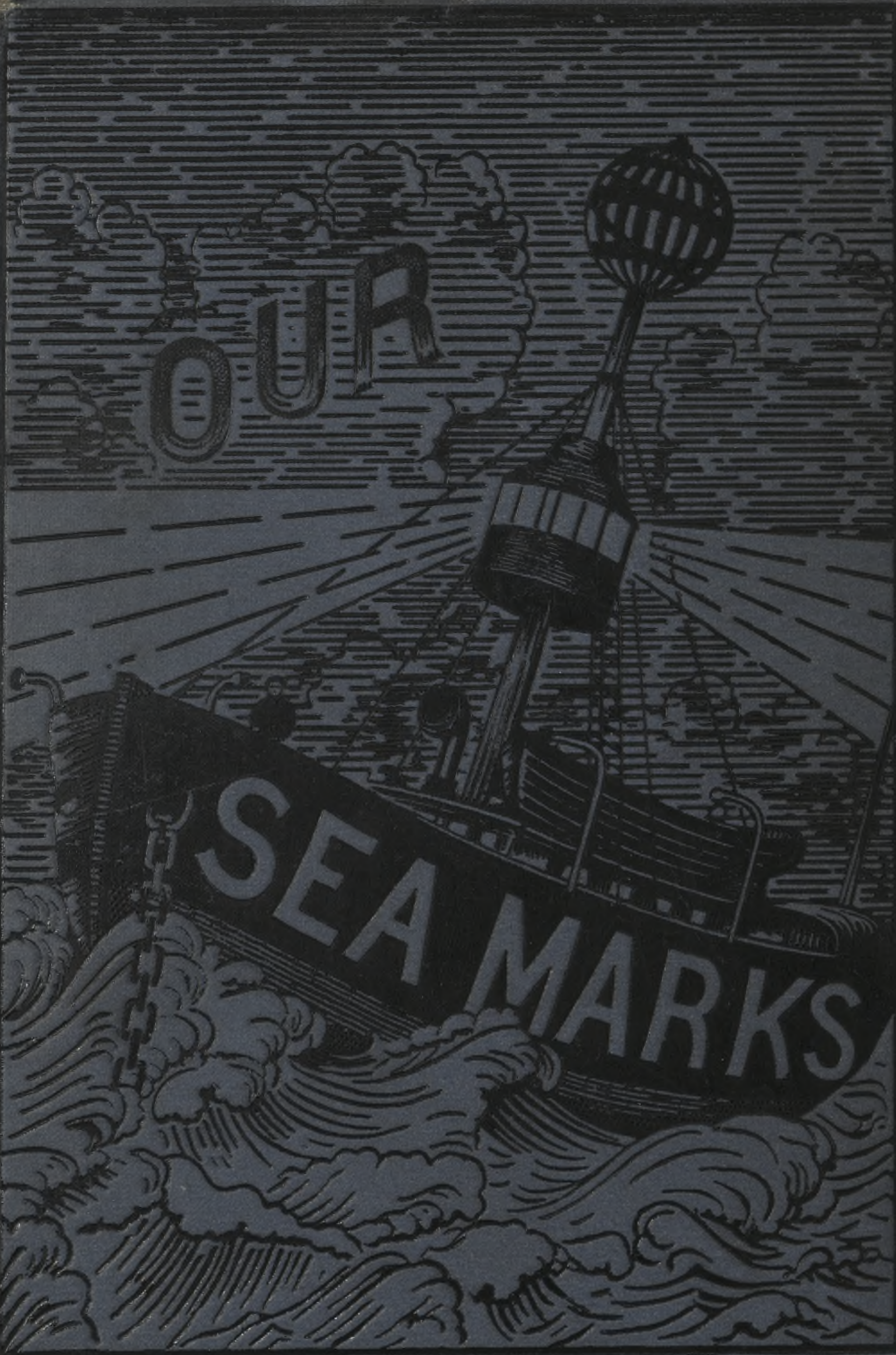
OUR
SEA MARKS

SEAMARKS.

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OUR SEAMARKS;

A PLAIN ACCOUNT OF THE

LIGHTHOUSES, LIGHTSHIPS, BEACONS, BUOYS, AND
FOG-SIGNALS MAINTAINED ON OUR COASTS
FOR THE GUIDANCE OF MARINERS:

BY

E. PRICE EDWARDS.

WITH NUMEROUS ILLUSTRATIONS.

LONDON:
LONGMANS, GREEN, AND CO.
1884.

PREFACE.

OUR insular position and extensive coast line, affording facilities for an ever-expanding maritime commerce carried on by thousands of vessels voyaging to and from our ports and harbours, make the subject of our Seamarks one of international importance, but of especial interest to the British nation.

I have therefore ventured to offer to the public this little book, prepared at the suggestion of my kind and honoured friend Professor TYNDALL, containing, as I believe, a simple, accurate, and non-technical description of Lighthouses and other kinds of seamarks, derived from knowledge gained during a long period of service under the venerable and honourable Corporation of the Trinity House.

My grateful acknowledgments are due to sundry gentlemen who have kindly furnished me with information upon certain details. To Mr. JOHN A. OWEN, of the Engineer's Department at the Trinity House, my warm thanks are due for the excellence of the diagrams and drawings which illustrate the text.

E. P. E.

SUTTON, SURREY:
May 1884.

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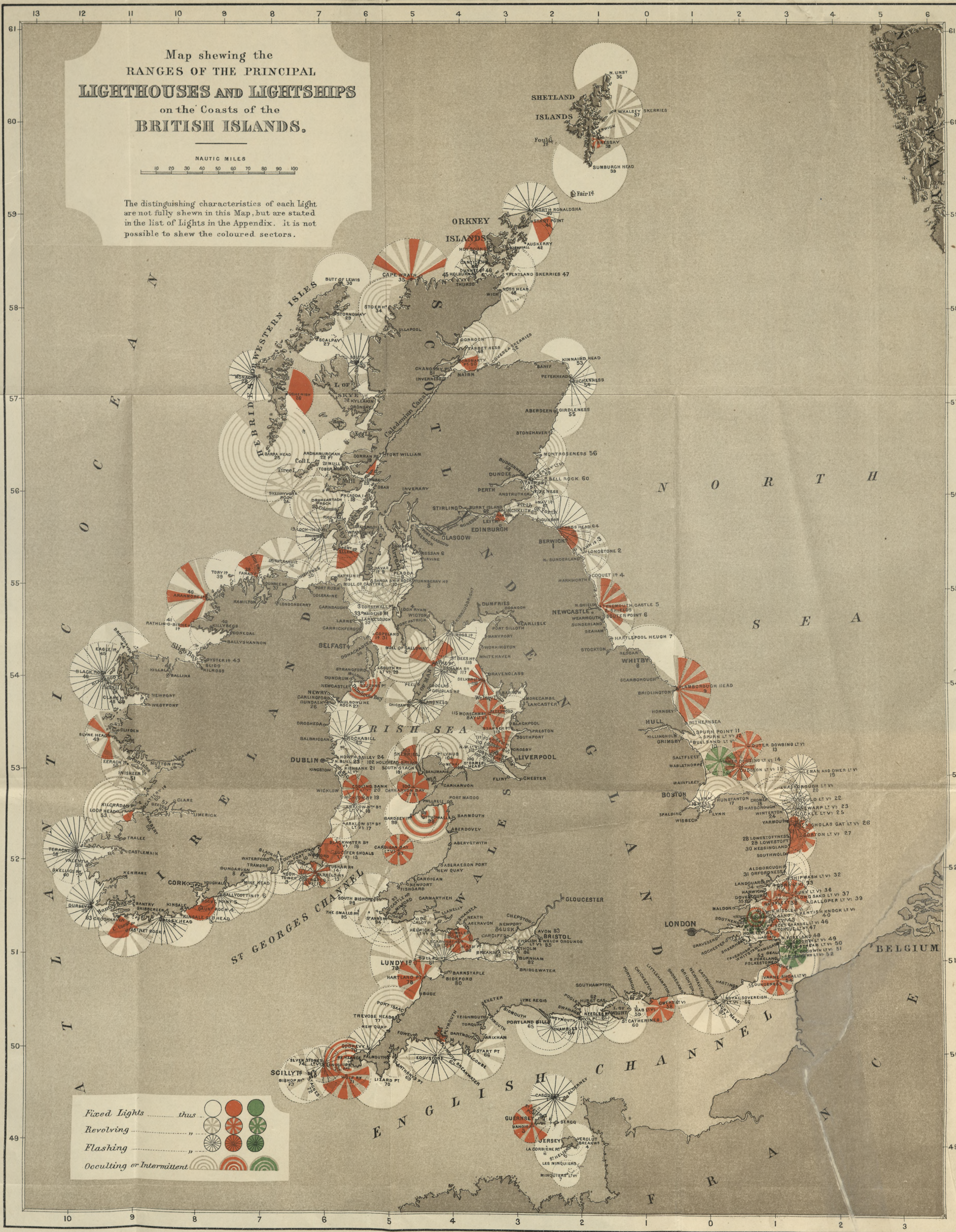

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OUR SEAMARKS.

CHAPTER I.

INTRODUCTORY.

UNDER the influence of frost, heat, rain, floods, rivers, tides, currents, and the fierce action of tempest-tossed waters, the configuration of our coast line is ever slowly but surely changing, and while in one place the land is worn gradually away, in another little by little it is added to. The hardest rock on our iron-bound coasts, as well as the friable soil of our soft and sandy shores, yields sooner or later to the erosive action, although naturally the former holds out much longer against the attack. As a result of this general disintegration and crumbling away of the shores, it is obvious that the adjacent sea receives continually a vast quantity of rocky and earthy matter—matter which may remain in a state of suspension so long as the movement of the water is sufficiently rapid and strong to carry it along and prevent it falling to the bottom as sediment. Again, great rivers having a rapid flow bear with their hurrying waters large quantities of detritus obtained from the land through which they have taken their course, but when the stream mingles with the broad waters of the ocean its rapid flow ceases, and the suspended matter falls on the bed of the sea. Sometimes the strength of the stream is sufficient to carry the suspended matter to great distances from the coast, where it may become subject to the influence of tides and ocean currents. Impelled by the action of these forces, the shingle, sand, or mud may travel in different directions, and ultimately be deposited far from the shore; or the set of the tide may be so strong as still to prevent it from being deposited on the sea-bed, and it may at last even be carried back to another part of the coast by the flowing tide and left in ridges on the shore as the tide recedes. Again, in stormy weather, when huge waves break upon a soft shore, the water becomes charged with sand or mud, which also may be carried out with the ebbing tide until it reaches a less turbulent region, where it sinks.

Such deposits as these have always been going on near the coast, and in time have formed submarine banks of shingle, sand, or mud, on which many a ship has laid bare her bones, and many a valuable life has been cast away.

Not only is the gradual formation of new shoals always going on near our coasts, but those already formed are exposed to influences which make them liable to continual change; the scouring effect of a rapid tideway or current in a narrow channel eats into and undermines the banks on either side, washing away to other parts great quantities of the shingle, sand, or mud of which the banks are composed, in time altering their shape, and by consequence changing the form of the channels between them through which vessels are navigated.

But equally as treacherous as the sandbanks and mud shoals are the rocky ribs of earth which do not shift or change within the experience of a generation, and, in spite of the action of the waves, tides, and currents, remain to all appearances steadfast and immovable. In most cases rocks near the coast may be regarded as the ragged remnants of the shores of ancient days. They are either scattered about here and there in the sea not far from land, or they may be the projecting points of long low submerged reefs jutting out to sea from a rock-bound coast. Occasionally isolated rocks are to be found in the deep water of mid-ocean, but in such cases they are the summits of rocky mountains springing up from broad bases in the ocean plains.

Ever since man has attempted to voyage across the sea these rocks and shoals in the vicinity of land have seriously threatened his safety, and too often have proved the cause of disastrous shipwrecks; indeed a much greater number of shipping casualties occur near shore than in mid-ocean. Consequently from the earliest times efforts have been made to assist mariners to reach their ports in safety by

Sands at Mouth of the Thames.

pointing out where these dangers are situated, and how they may be avoided.

The principal shoals and sandbanks around the British coasts are those formed at the mouths of the rivers Thames, Mersey, Humber, Tees, and Severn, and those established by the action of tides and currents off the Eastern counties of England, known generally as the Yarmouth Sands, the notorious Goodwins, and the extensive sandbanks off the East coast of Ireland. These sands are usually intersected by deep-water channels, which, when the sands are covered at high water, are indistinguishable in the open expanse. Reefs and rocks are more frequent round the iron-bound coast of Scotland and on the West coasts of England and Ireland, although there are here and there on other parts of the English coast sundry dangerous rocks and reefs which have proved fatal to many ships and their crews.

It is by means of seamarks that the positions of these dangers are pointed out and the safe channels marked ; they also serve the purposes of direction-posts, indicating the sea-lanes and roads available for maritime traffic, marking turning-points, showing the mariner the way to the haven where he would be, and telling him on what part of the coast he is. On approaching land from over sea, the mariner calculates where he ought to be, but his reckoning may be wrong, or his vessel may have been so driven by winds, tides, or currents that he really is in doubt as to where he is. If nothing has occurred to disturb his reckoning he knows what part of the coast he ought to see first, and looks eagerly for some seamark by which he is able to confirm his calculations. But if he should have lost his reckoning and land should be reported, he then keenly scans the coast-line until he sees some object by which he can identify the locality and so learn how to continue his voyage in safety.

In these days, when sea traffic is so enormous, when thousands of vessels come to and sail from our ports, when the darkness of night is no hindrance to sea voyaging, and, regardless of the opposing influences of wind and tide, gigantic steamers are continually hurrying across the ocean to and from all parts of the globe, freighted with human lives or valuable commodities, it is very evident that the necessity for effectual seamarks on all coasts for use both by day and by night is most urgent.

In the case of our country it is specially important. Not only are we as a maritime nation bound to afford facilities for our own vessels to go from and return to our shores, but it is our great interest to induce foreigners to visit us, and by instituting friendly relations with other countries to develop our own commerce and assist in that general intercommunication among nations which is the enemy of war and the promoter of the general good of the world. Inhospitable shores, like inhospitable people, do not encourage visitors, but if the friendly hand of assistance 'holding a lantern o'er the restless surge' be extended across the perilous waters which surround us, our neighbours and even strangers afar off will find the welcome an inducement to pay us frequent visits.

The seamarks employed on our coasts may be classed as follows :—

1. Lighthouses.
2. Light vessels.
3. Buoys and unlighted beacons.
4. Fog-signals.

It is proposed in the following pages to deal with each of these different kinds of seamarks, to describe what they are, and how they are made useful for marking dangers or for guiding purposes.

CHAPTER II.

LIGHTHOUSES.

THE term 'lighthouse' in itself obviously supplies a general explanation of what it signifies, but the purpose of a lighthouse is not fully revealed in its name. It may be gathered that it is a house specially adapted for showing a light, but it must also be understood that the light is intended to assist the seaman at night, while the house or tower serves as a landmark to help him by day.

Out in the open sea the lights of heaven guide the mariner on his way. The flaming sun by day, the moon and the trembling stars by night, are the blessed lights by whose aid he makes his voyage across the great deep. But near land these heavenly luminaries are insufficient guides, and when darkness envelops both land and sea the seaman wants some earthly lights to show him where and how the land lies, and to enable him to navigate his vessel safely among the sandbanks and rocks to which reference has already been made.

The practice of the ancients in regard to setting up light-towers is wrapped in some obscurity. Here and there in the works of old writers may be found brief references to the aid rendered to mariners by beacon-fires at night and landmarks by day, and ingenious commentators have found a number of possible references to seamarks in connection with noteworthy pillars and other structures set up near the sea ; but no verified details are forthcoming as to the special purpose of any such reputed beacon. The only indisputable fact which one gathers from the references to such matters by early writers is that navigation in their time being in a very crude condition, the necessity for guiding and warning signals had not made itself specially manifest. There is no trace of anything like systematic exhibition of lights at night, and if such means were resorted to it is extremely difficult to find any trustworthy record of them. Having regard to the consequent uncertainty of knowledge concerning the history of lighthouses in the very early period, the author conceives it will be better to present to his readers a plain and practical explanation of why seamarks are necessary, and how the desired object is achieved by the arrangements in operation at the present time. Leaving to antiquaries and others interested in such matters the historical account and determination of the purposes of such structures as the Pharos of Alexandria, the Colossus of Rhodes, Cæsar's Altar at Dover, together with sundry other alleged beacon-towers in different parts of Europe, it is intended in this little work to deal with those periods and places which are within the grasp of actual knowledge.

During the reigns of King Henry VIII. and Queen Elizabeth, British commerce and shipping grew considerably, and it became necessary that something should be done to assist mariners in approaching and leaving our shores.

In the year 1536, Henry VIII. granted a charter to a maritime society known as the Trinity House of Newcastle-upon-Tyne, incorporating them and giving them certain privileges. One provision of this charter is that they 'may found, build, make, and frame of stone, lime, and sand, by the best ways and means which they know or can, two towers, one, to wit, in the northern part of the Shelys [Shields], at the entrance of the port of the said town, and the other upon a hill there fit and convenient for signals, meets, and bounds, for the safe and secure custody of the town and port aforesaid, and also of our subjects and others being in our alliance coming to the said town and port' . . . and that . . . 'for the maintenance of the said towers and port aforesaid, with a perpetual light to be nightly maintained,' they may receive certain tolls, &c.

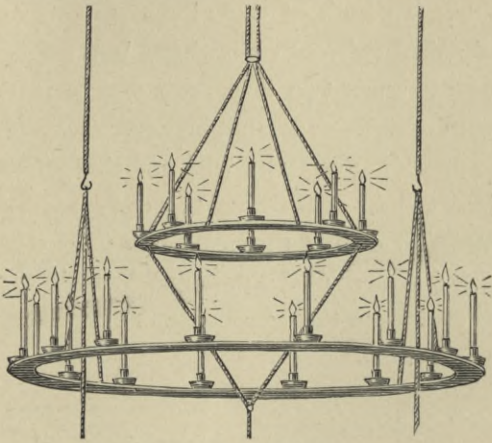
Again, by the Act of 8 Elizabeth (1566), the matter seems to have been more generally dealt with, the preamble stating that, 'Forasmuch as by the destroying and taking away of certain steeples, woods, and other marks standing upon the main shores adjoining to the sea coasts of this realm of England and Wales, being as beacons and marks of ancient time accustomed for seafaring men, to save and keep them and the ships in their charge from sundry dangers thereto incident, divers ships with their goods and merchandises in sailing from foreign parts towards this realm of England and Wales, and specially to the port and river of Thames, have by the lack of such marks of late years been miscarried, perished and lost in the sea, to the great detriment and hurt of the common weal and the perishing of no small number of people,' &c.

Here we have the earliest official references to seamarks on our coasts, but the nature of the allusions shows that at the periods in question the use of coast-lights was but little known in this country. Mariners had navigated their vessels to and from our shores chiefly by the aid of such seamarks as nature had provided in the distinctive features of the coast-line, or by churches, castles, clumps of large trees, or other prominent objects visible from the sea ; and although there are references by various authors to the existence of small sea-lights, it does not appear that the subject became one of national importance until the period now referred to, and certainly such lights as are alluded to were shown for merely local purposes, such as the guidance of fishing craft into harbour, and not for the general advantage of passing ships.

Dungeness Fire-Tower.

The beginning of the following (the seventeenth) century saw several towers set up on salient points of our coasts for the purpose of showing lights therefrom to assist navigation, and gradually the number was increased. Of the structures so set up there are still some few remains, but the buildings have in most cases been modernised. They were simple, massive towers, built on prominent headlands, and huge fires of wood or coal were kindled on the tops. Under the name of fire-towers, structures of this kind had been in existence in the Mediterranean for a long period antecedent; but they were used only at the entrances of ports and harbours to guide ships in. The use of such blazing beacons was gradually extended as the years rolled on, and as mariners found an increased need for them. We may be sure that such beacon-fires were not kept up without continual watchfulness and labour. There must necessarily have been much uncertainty in regard to their efficiency; at one moment vigorously blazing, then a mass of red-hot coal—again, with a supply of fresh fuel, giving off clouds of thick smoke and no light, and with a strong wind, heavy rain, or a snow-storm, in danger of being altogether extinguished. These fluctuations would render such a light so uncertain that when a mariner most wanted its aid it might not be visible to him. Think too, of the enormous consumption of fuel, the labour of conveying it to the top of the tower and of feeding the fire, and the exposure to heat and weather to which the attendant must have been subject. But, in addition to all this, the light would be weak, not able to send its rays any distance out to sea and much of its light would be sent up into the sky, where only its reflection from the clouds could be of service to the mariner.

It is by the light of modern knowledge that we are enabled to criticise the crude and imperfect system of those days ; the present arrangements, as will be seen, offering so striking a contrast as compared with those of the early period. For nearly two hundred years these bonfires blazed with burning wood or coal ; the only improvements being that some of the fires were closed in with bars and made to present a bright side to the sea, while the landward side was screened, and subsequently in a few cases the coal fires were enclosed with glazed lanterns. It has also been said that a flat plate of brass on the landward side of a coal fire was used as a reflector ; but on this point no details are obtainable. Candles were used in some lighthouses at an early period ; in Rudyerd's tower on the Eddystone, and subsequently in Smeaton's, the light was maintained with twenty-four candles 'whereof five made two pounds.' There must have been much inconvenience in the use of the candles of those days, for we find they were frequently discarded in favour of coal fires, and more recently of oil. But whether wood, coal, candles, or oil were the illuminating agent, uncertainty and very limited efficiency marked the system, and the lights could only be serviceable to mariners creeping anxiously close in along the coast. This may be taken as the condition of things during the whole of the seventeenth and nearly to the end of the eighteenth century. It is true that the number of lighthouses increased round the coasts; but their smoky, ill-burning flames were felt to be very defective and insufficient for guiding purposes at any distance. In those days navigation was, in a



Smeaton's Chandelier.

general way, carried on slowly and cautiously; night voyaging when near land was rarely practised, so the want of brilliant and powerful lights was probably not keenly felt. To reach the days when wood, coals, and candles became things of the past, and the results of scientific knowledge began to be utilised for the improvement of coast lights, we must advance to the beginning of the present century. The invention of the argand burner in the latter part of the last century enabled a very remarkable improvement in lighthouse illumination to be introduced ; and again in the early part of the present century the construction of lenticular apparatus on the principle of Fresnel's celebrated invention offered another means of greatly improving the lights. To both of these improvements we shall make detailed reference elsewhere, but we mention them now to mark two important epochs in the development of lighthouse illumination.

The preceding remarks will probably afford sufficient information concerning the early condition of lighthouses to enable the reader to understand the objects and growth of the system. We will therefore proceed at once to the consideration of lighthouses as they are now.

CHAPTER III.

LIGHT-TOWERS OF THE PRESENT DAY.

In these days light-towers are vastly different from those of olden times, and may be found at short intervals all round our coasts, whereas the blazing beacons of old were separated by great distances. The towers now in use may be divided into three classes—viz. those erected upon the mainland or upon islands, those set up upon sandbanks, and those built upon rocks out in the sea.

Light-towers on the mainland are usually solid-looking structures, designed to withstand the influences of weather, of a sufficient height to command a good range to seaward and also to show as distinctive marks for the use of navigators in the daytime. Formerly the interior of such towers formed the living apartments of the keepers; but the practice of giving the men such 'cabin'd, cribbed, and confined' accommodation is not now adopted where other arrangements can be made, and usually the tower lifts its head from the midst of a cluster of neat dwellings or cottages, where every provision is made for the comfort of the keepers, their wives and families. The tower is surmounted by the lantern, a large circular chamber, glazed all round, which will be described hereafter. A noticeable feature about many of these lighthouses is their wild, isolated, and almost inaccessible situation. The necessity of marking some prominent point of land, or of indicating to passing ships dangers in the vicinity, often entails the selection of a lighthouse site in a very desolate place, miles from any town or even village. This naturally adds to the difficulty and cost of erecting the lighthouse, and involves much expense and trouble for the conveyance of oil, coals, &c. when it is established. Indeed, so wild and exposed are the situations of some lighthouses on the mainland that it is a matter of wonder how the materials were carried to the localities. At Spurn Point, on the north shore of the Humber entrance, there are two lighthouses and a coastguard station. The light-keepers and coastguard men with their wives and families form a little community on the sea-washed shingly promontory many miles from the nearest village. Dungeness, on the Kentish coast, another shingly point to which additions are constantly being made by the action of the sea, is also a settlement of lighthouse keepers and coastguard men, a considerable distance from Lydd,

NORTH FORELAND LIGHTHOUSE.

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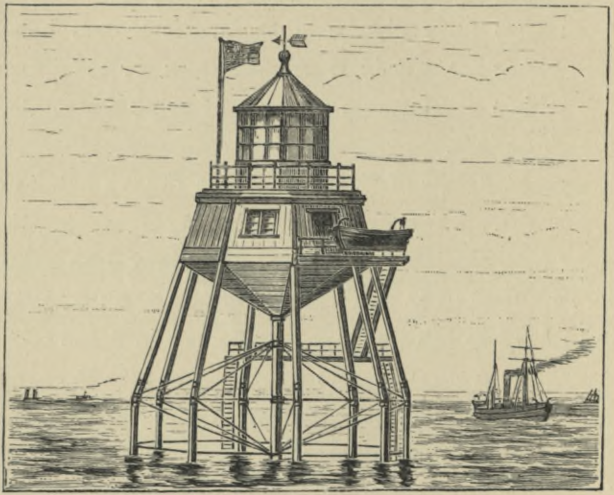
the nearest town. Hartland Point, and Bull Point, North Devon, have lighthouses entirely secluded from society. On the Scotch and Irish coasts there are many stations of the character above referred to, where the keepers are unable to send their children to school, or to attend any place of worship. On the other hand, some lighthouses are situated very agreeably to those who have charge of them, the towers being built either actually in a seaside town or village, or else within comfortable vicinity of some frequented watering-place.

Another class of lighthouses are those erected on sandbanks. These are slender-looking structures, the lower part consisting of six or eight long iron cylinders grouped so as to form a hexagon or an octagon, and joined to piles screwed or forced in some other manner to a considerable depth down into the sand, the piles and cylinders being braced together by strong iron ties. Upon a skeleton structure of this kind is built the lighthouse, consisting of living rooms for the keepers surmounted by the lantern, while underneath the tide ebbs and flows, and the waves pass harmlessly through the framework. No resistance being offered to the waves, the lighthouse is not battered by heavy seas, and stands firmly although built upon sand. The internal arrangements of such a lighthouse are not very commodious, space is much confined, and the rooms are necessarily few ; but nevertheless the keepers are able to make themselves snug and comfortable. The sands off the coast of Essex formed by the outflow of the river Thames are guarded by four of these pile lighthouses, whereby the navigation of the North Channel leading into the Thames is



Maplin Screw Pile Lighthouse.

much assisted. These lighthouses are known as the Chapman, Mucking, Maplin, and Gunfleet, each name having reference to the shoal which the structure is intended to mark. The Mucking Lighthouse stands upon a shoal of sand and mud, and is built upon hollow piles—that is to say, eight cast-iron pipes, each the rooms are necessarily few; but nevertheless the keepers are able to make themselves snug and comfortable. The sands off the coast of Essex formed by the outflow of the river Thames are guarded by four of these pile lighthouses, whereby the navigation of the North Channel leading into the Thames is

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HARTLAND POINT LIGHTHOUSE.

See page 10.

HARTLAND POINT LIGHTHOUSE.

See page 19.

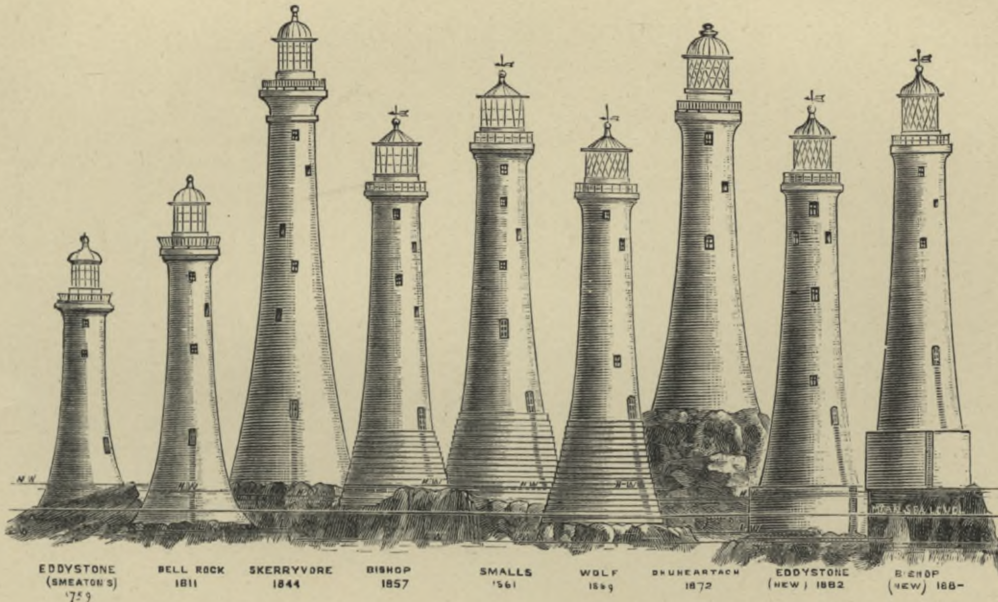
eighteen inches in diameter, placed so as to form an octagon, are worked into the shoal as far as they can be forced, and upon the foundation thus formed the skeleton structure which has to support the living rooms and lantern is erected. The other three lighthouses have foundations upon what are known as screw piles. In these cases the piles are of solid wrought iron, five inches in diameter, and attached to the foot of each pile is a wide flat screw having about one turn and a quarter, four feet in diameter, and finished off at the bottom with a sort of drill. By means of the screw the piles are worked down more easily into the sand, and the broad flanges of the screw add considerably to the strength of the foundation and the stability of the building. The Maplin screw-pile lighthouse has now stood for thirty-eight years, and the other structures referred to for upwards of twenty-eight years. It might seem that such a house built upon sand is not likely to have an existence so enduring as one founded on a rock ; but it is to be borne in mind that these iron framework structures are not placed in such exposed positions as towers designed and constructed to withstand the full force of the mighty rollers of the Atlantic, which often come swelling along the ocean's surface with the momentum of probably many hundred tons of water.

The lighthouses built on rocks out at sea are structures which excite the wonder of all who see them, about which many books have been written, and which are justly regarded as monuments of the highest engineering skill. Exposed to the fierce rage of tempests, with mighty waves often weighted with many tons of water dashing and breaking against, at times going completely over them, these towers bear witness to a marvellous triumph by man over the forces of nature. Round our coasts there are now many of these wonderful structures which remain steadfast through the most severe storms, while their light shines through the boisterous atmosphere across the angry waters, reaching the anxious sight of the mariner, and, in spite of the conflicting elements, giving him comforting assistance at the moment when it is most needed.

The history of the building of such lighthouses is full of interest. The descriptive accounts of these works are records of personal risks, exposure, and endurance of the staff employed ; of continual battling with opposing natural forces ; of long and arduous spells of work in favourable seasons ; of successes and disappointments ; of ingenious adaptations to meet exceptional difficulties, and of skilful and clear-sighted engineering ability.

Without entering into technical engineering details, it may be observed that in the construction of these towers the chief elements taken into consideration are (1) form, (2) weight, and (3) rigidity, or the method of joining stone blocks one to the other. As regards form (1), it has been supposed that lighthouse engineers have been in some degree influenced by Nature's handiwork as shown in the trunk of a large oak tree; but Mr. Alan Stevenson, in his 'Treatise on Lighthouses,' has effectively shown that, as regards stability, there is no real analogy between a lighthouse tower and the trunk of a tree. Technically speaking, the form generally adopted is that of a number of horizontal conic sections or *frusta* with varying diameters, placed one upon another in such a manner that the vertical outline of the tower forms a curve convex to its axis, commencing at the radius of the base and ending at the radius of the top, the curve being made to approach parallelism with the axis towards the top. In more popular language it may be said that, starting with a large circular base, the tower gradually becomes narrower upwards to about three-quarters of its height, after which it is continued the same size up to the top. In some cases the upper part has a gently swelling curve outwards up to a cornice at the top, designed to throw off the waves when running up the tower, and to prevent the water striking the lantern. With this form a low centre of gravity is obtained, and great strength is imparted to the lower part of the tower, where the maximum force of the waves is expended. The force of inertia produced by the weight (2) of the material of construction is a most important element in connection with the stability of a rock lighthouse tower. A sheer weight of over 3,000 tons is not likely to be easily moved, and this weight of stone has been exceeded in several instances; indeed the new Eddystone tower contains over 4,000 tons of masonry. To insure rigidity (3), and to prevent the loosening of any of the stone blocks, it is necessary that the structure should be practically monolithic—in other words, like a solid piece of stone carved out of the quarry. With this object the stones are joined to each other by dovetailed joints and by metal bolts at the sides and at the top and bottom, so that no single stone can be moved without disturbing all its neighbours. The lowest course is fixed on to the rock itself in a similar manner, and thus rock and tower are, so to speak, all of a piece.

There are many other considerations in connection with the building of these rock towers which lighthouse engineers have to take into account, but the points above indicated may be regarded as the most important. There are questions concerning the means of landing on the rock and of access to the tower,



COMPARATIVE ELEVATIONS ABOVE MEAN SEA LEVEL OF PRINCIPAL BRITISH ROCK LIGHTHOUSES.

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the internal space to be provided, the thickness of the walls, the flooring of the several rooms, ventilation of the living rooms and lantern, the storm shutters for the windows, accommodation for storing oil, coals, water, provisions, &c., and many other details which alter with every lighthouse, and have been modified by the respective engineers to suit different necessities.

The building of these light-towers has been in nearly every case attended with great difficulty and risk. The names of Smeaton, Stevenson, Walker, Douglass, and Halpin are all well known in connection with such works ; but perhaps few people have an accurate idea of the great personal risk and inconvenience to which these engineers have subjected themselves in order to encourage their men, and to urge on the works with the greatest speed at every available opportunity.

The relative elevations of the chief rock lighthouses on our coasts are shown in the drawing. The following details of each structure will probably be of interest.

The Eddystone, in the English Channel, situated about 14 miles SSW. from Plymouth. The present lighthouse is the fourth tower erected on this dangerous reef. The first was Winstanley's wooden building, commenced in 1696 and finally completed in

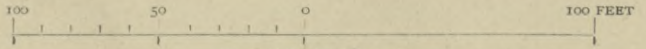
1699; it stood for five years, and was swept away in the terrible storm of November 26, 1703. The second was Rudyerd's tower of wood and stone, commenced in 1706 and completed in 1709, which stood until December 1755, when it was completely destroyed by fire. The third was the famous stone structure set up by John Smeaton, commenced in 1756 and finished in 1759. This tower stood for 122 years, and would no doubt have endured much longer had it not been for the giving way of the rock on which it was built, thus necessitating the erection of another tower on an adjacent peak of the reef. The fourth lighthouse (that now standing) was commenced in July 1878 and finished in the spring of 1882. This noble building was designed by Sir James N. Douglass, and the work executed under his immediate directions.

From the bottom of the lowest or foundation course to the centre of the vane at the top of the lantern, the height is rather more than 170 feet, and the light is about 135 feet above high water.

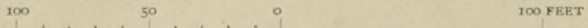
The drawing shows the internal arrangements, which, it may be remarked, are more commodious than those of any rock lighthouse hitherto erected. The tower consists of 2,171 stones, containing 63,020 cubic feet, or 4,668 tons of masonry. Smeaton's tower was only 96 feet from foundation to the highest point, and contained only 988 tons of stone. The total cost

NOTE.

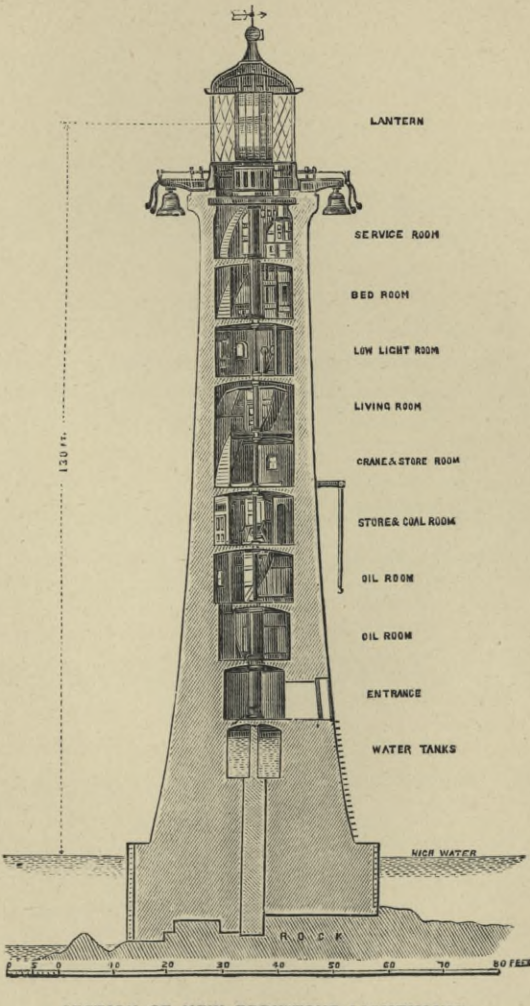
Owing to a mistake, the last two towers in this plate (viz. the New Eddystone and the New Bishop) have been drawn to a smaller scale than the others, and show therefore an insufficient elevation. They should be about sixteen feet higher than they are here represented. The two scales below will afford a means of comparison.



General Scale of Drawing.



Scale of last two Lighthouses.
viz. New Eddystone and New Bishop.



SECTION OF NEW EDDYSTONE LIGHTHOUSE.

To face page 26.

of Smeaton's tower is understood to have amounted to 40,000*l.*, that of the present larger and more commodious structure to 61,500*l.*

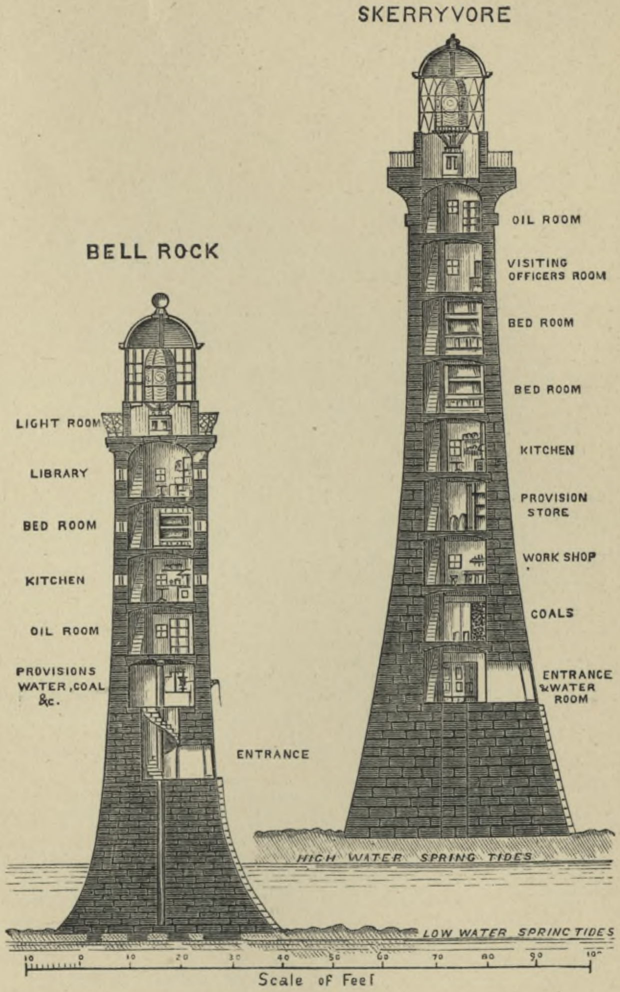
The Bell Rock is situated on the northern side of the entrance of the Firth of Forth, about 14 miles from land. The tower on this dangerous reef was commenced in 1807 and completed in 1811, under the personal direction of Mr. Robert Stevenson, the work being of a most arduous character. The exposed situation of this rock, and it being uncovered only at low water, caused the operations to be somewhat prolonged. The total height of the structure from foundation to ball on top of lantern is about 117 feet, but the light is shown from an elevation of 93 feet above high water. The drawing shows the internal arrangements. The cubical contents of the materials used in the erection of this tower were about 28,530 feet, the total weight of which was 2,076 tons, and the cost of the whole work amounted to 61,331*l.* It was this lighthouse which was visited in 1814 by Sir (then Mr.) Walter Scott, on which occasion he wrote the following lines in the album kept at the tower :—

Pharos loquitur.

Far in the bosom of the deep
O'er these wild shelves my watch I keep,
A ruddy gem of changeful light
Bound on the dusky brow of night :
The seaman bids my lustre hail,
And scorns to strike his tim'rous sail.

The Skerryvore is the principal peak of a most dangerous reef situated about 11 miles WSW. of the Island of Tyree, the nearest land, while it is about 50 miles from the main coast of Scotland. The tower on this rock was commenced by Mr. Alan Stevenson in 1838, and completed in 1844. At an early stage of the operations Mr. Stevenson erected a strong wooden barrack on the rock, but it was carried away in a storm. Another was built, in which the working party lived for intervals of many weeks at a time. The work-yard for preparing the stones, &c. was at Hynish, on Tyree Island. The Skerryvore Lighthouse is of considerable elevation, being 158 feet from foundation course to top of the lantern, the light being shown at a height of 150 feet above high water. The cubical measurement of the stone part of the tower is 58,580 feet, representing about 4,300 tons weight of masonry. The total cost of this great work amounted to 90,268*l.*

The Wolf Rock is situated about 9 miles SSW. of the Land's End, and for a long time was a terror to navigators. It is covered at high water, and at times a terrific sea falls upon it, being exposed to the full force of the Atlantic. In the year 1860, Mr. James Walker, then the Trinity House engineer, prepared a design for a lighthouse on this rock, Mr. (now Sir) James N. Douglass being appointed the resident



SECTIONS OF BELL ROCK AND SKERRYVORE LIGHTHOUSES.

To face page 28.

engineer. The work was commenced in 1862 and not completed until 1869, the lengthened period being due to the fact that, in the early stages of the building, landings on the rock were difficult, comparatively rare, and of short duration. The total height of the lighthouse from foundation to the centre of the ball is

North Unst.

138 feet, but the light is shown at a height of 110 feet above high water. The tower contains 44,506 cubic feet of granite, weighing about 3,296 tons. The total cost of building amounted to 62,726*l.*

The North Unst tower, on the north coast of Shetland, is the most northern lighthouse of Great Britain, and is remarkable for the wildness of its situation, as may be seen from the sketch. The top of the rock affords just sufficient space for the necessary buildings. The tower is 50 feet high, and contains three living rooms beside the light-room. Its base is surrounded by storehouses. The rock itself is 200 feet above the sea ; but at times the waves reach even that height, and dash themselves with considerable violence against the outbuildings. The transport of materials to the top of the rock was necessarily a very arduous undertaking, and the permanent structure was completed in 1858, the work having occupied about four years. The total cost of this lighthouse was 32,478*l.*

The Dhuheartach Rock, off the west coast of Scotland, about 14 miles from Iona, the nearest land, is marked by a noble lighthouse. The tower, designed by the Messrs. Stevenson, was commenced in 1867, and completed in 1872. The masonry of this tower rises to a height of 107 feet, but owing to the height of the rock the light is shown at an elevation of 145 feet above high water. The total cost of this structure amounted to 65,784*l.*

The Chickens Rock Lighthouse, just off the Calf of Man, on the south coast of the Isle of Man. This tower was begun in 1869 and finished in 1872, under the immediate direction of the Messrs. Stevenson, engineers to the Commissioners of Northern Lights.

The tower is 123 feet high, and the light is shown from about the same elevation. The cost of building was 64,559*l.*

On the *Bishop Rock*, off Scilly, about 6 miles W. from the Island of St. Agnes, stands an imposing lighthouse. The tower was originally designed by Mr. James Walker, built by Mr. Nicholas Douglass, the father of the present Sir James Douglass, and completed in 1857, at a cost of 39,560*l.* This is an exceedingly exposed position. Of late years it has been observed that some very ominous cracks had established themselves in this tower, and in consequence extensive repairing works have been undertaken. The main feature of these works is the encircling of the present tower with a new granite casing, and increasing the height of the lighthouse by 35 feet. A new cylindrical base, similar to that at the Eddystone, is being added, from the top of which the new stone jacket will average 3½ feet in thickness, as far up as the commencement of the new masonry required for the increased elevation of the light. Bearing in mind that the light must continue to be shown throughout the progress of the works, and that the situation is a fearfully exposed one, it will be plain that the undertaking is fully as difficult and hazardous as building a new lighthouse. The works are now progressing under the direction of Sir James Douglass, his son, Mr. W. T. Douglass, being the resident engineer for carrying out the work. The second sketch of the Bishop tower, shown in the illustration facing page 25, will indicate generally the nature of the alterations.

The Smalls Rock, off St. David's Head, South Wales, is crowned with a remarkable tower, built in 1861 to replace a wooden structure which had stood for many years on the rock.

The Longships Rock, off the Land's End, has also a noble tower upon it, completed in 1873, which replaced a still older one established in 1795.

The Needles Rock, at the western extremity of the Isle of Wight, and *the Hanois Rock*, off Guernsey, are both marked by granite towers set up within the last five-and-twenty years.

The lighthouse on *the Haulboline Rock*, at the entrance of Carlingford Lough, Ireland, is a remarkable and beautiful structure, built from the designs of Mr. George Halpin, and first lighted in 1823. Though not so much exposed as many other sea-beaten rocks, the work of building the tower was attended with much difficulty and risk.

The Fastnet Rock, about 4¼ miles SW. from Cape Clear, is also marked by a fine tower built from the designs of Mr. George Halpin. The erection of this building occupied six years, from 1848 to 1854. The rock is of considerable area, affording accommodation for comfortable dwellings for the keepers. The tower is of cast iron, lined with brickwork.

The tower on *the Tuskar Rock*, on the east coast, should also be specially mentioned as a noteworthy specimen of an Irish rock lighthouse.

The foregoing may be regarded as typical examples of rock lighthouses on our coasts, but they bear only a small proportion to the number of lighthouses on the mainland.

In all these lighthouses the keepers have to reside in the towers, and accommodation has to be provided for them, as well as for storing their provisions, oil for the light, coals, water, and other necessaries. In treating of the general service of the lighthouses, a description will be given of the arrangements in force for the periodical relief of the men, and for supplying the station with stores, &c.

CHAPTER IV.

LIGHTHOUSE ILLUMINATION.

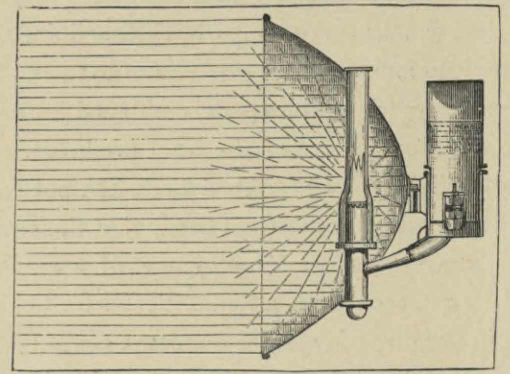
FOLLOWING upon the subject of lighthouse towers the nature of the lights exhibited from their summits naturally suggests itself for consideration.

From wood to coal, from coal to candles, from candles to oil, were the transitions through which, as we have seen, lighthouse illumination passed in years gone by. Numerous projects have from time to time been put forward in connection with the sources of light for lighthouses, and trials have been made with the lime or oxyhydrogen light, the Bude light, the Voltaic light, and sundry other tentative applications of scientific discoveries; but they have all failed to meet the practical needs of the lighthouse service in a sure and satisfactory manner. Gas and electricity have, however, been more successfully applied, and are in several places being made available, while so much has been done in regard to the combustion of oil that remarkable results have been obtained. In the development of the various systems of lighthouse illumination now in operation, science and practical experience of the wants of the mariner have gone hand in hand, and advancement is still being made.

OIL.—Oil is the source of light employed at the large majority of stations on the British coasts. Previously to 1846 the animal oil obtained from the sperm whale was used in lighthouses. This oil was very costly, and attention being called to the economy which would result from the use of the vegetable oil expressed from the seeds of the rape and other cruciferous plants, the change was made from the animal to the vegetable oil with satisfactory results. Of late years, however, mineral oils, under the names of paraffin and petroleum, have become serious rivals to rape, otherwise colza oil. The reader is probably aware that paraffin is obtained by the distillation of bituminous shale and cannel coal, while petroleum in a crude liquid state is obtained from the earth in various parts of the world, and has also to be subjected to the process of distillation. All the mineral oils sold for domestic purposes under various names, such as kerosine, crystal oil, petroline, astral oil, &c., are either paraffin or petroleum slightly modified in the refining process. Some of the preparations, such as benzoline, are unquestionably dangerous. For a long period a strong prejudice existed against these mineral oils by reason of their tendency to give off inflammable vapour at a low temperature, but by the careful elimination of the more volatile portions of these oils that danger has been so reduced as to enable them to be employed in lighthouses and elsewhere with safety, although long since they have been thus rendered safe the prejudice has continued to operate against them. The temperature at which a mineral oil gives off inflammable vapour is known as its flashing point, and so long as this flashing point is above 125° F. there is little danger to be apprehended. With ordinary care an oil having a flashing point above 100° is quite safe for domestic purposes. In reference to the burning of these oils, a few simple observations may perhaps be acceptable. It should be first realised that when oil of any kind is burned, the actual liquid is not ignited. By the action of heat the liquid is converted into vapour or gas, and the application of flame to this vapour will cause it to burn. In the case of mineral oils, if this vapour be mixed with atmospheric air in a free state, and flame be applied to it, the combustion will take place very rapidly, and assume the character of an explosion, in a similar manner to the explosion of ordinary coal gas. But in no case will the vapour ignite unless a flame be applied to it; it will neither explode nor inflame spontaneously. From the foregoing it will be plain that if a mineral oil, be it paraffin, petroleum, crystal oil, &c., does not give off combustible vapour until heated to 125° F., there is not much danger in handling it. In burning mineral oil in an ordinary domestic lamp, a cotton woven wick is used as a vehicle for bringing the oil up to the top of the burner, where it is to be converted into inflammable gas. The lower part of the wick is in the oil in the reservoir, two, three, or four inches below the top of the burner, and by what is known as capillary action, the oil being of a volatile nature, creeps up the wick. Imagine then the wick saturated up to the top ; apply a light to that part of it which rises above the edge of the burner, and the heat of the flame will convert the oil at that point into vapour, and will ignite it ; the lighted vapour will then continue the manufacture of more vapour or gas, and the oil so converted into vapour will continue to be replaced by capillary action, the lamp continuing to burn as long as oil remains to be drawn up. In the act of burning—the vapour combines chemically with the oxygen of the atmosphere, and, as oxygen is the chief supporter of combustion, it follows that the more effectively oxygen is supplied to the flame the more perfect and vigorous will be the burning of the vapour. This is the ruling principle in the construction of all oil lamps. One great difference between colza and mineral oil is that it requires much greater heat to produce inflammable vapour from the former than from the latter; consequently the conditions of burning the two kinds of oil are somewhat different. Colza oil must be forced close up to the burning point, so that it just flows over the edge of the top of the burner; there is therefore not so much scope for capillary action, indeed the wick is completely enveloped in oil forced up from the cistern. Colza is not so easily lighted as paraffin, but when once the former is lighted the principles of supplying the flame with oxygen are much the same as with paraffin, only with the latter oil the combustion is very vigorous, and may be supplied more freely with air. But one great advantage paraffin has over colza is that it is considerably less than half the price, and at the same time is equally effective so far as illuminating power is concerned. Consequently it has in many lighthouses superseded colza. The latter oil, however, continues to be largely employed at rock lighthouses where space is limited, and where there is not convenience for storing paraffin in a building separate from the tower and dwelling rooms, as is done at shore stations where paraffin is used. A supply of oil sufficient for fifteen months' consumption is sent to every station once a year, the supply in some cases amounting to over 3,000 gallons, and is stored in capacious iron cisterns. Very careful precautions are taken to ensure that the oil, whether colza or paraffin, shall be of the highest quality. A sample from every delivery by the contracting oil merchant is, before it is accepted, subjected to the most rigorous tests, and if it fail to equal the standard is rejected. Moreover, the cotton wicks employed in the burning of these oils are specially manufactured, and are required to be of the very finest quality.

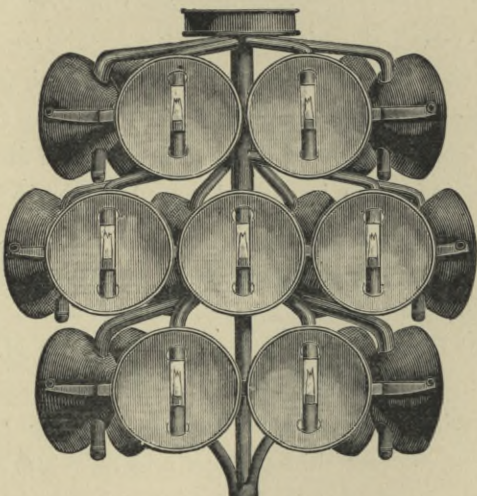
We must now pass on to consider the important subject of oil burners or lamps, but before doing so it is necessary to make a passing reference to two different systems, catoptric and dioptric, employed for making the most effective use of the light produced. Each system will be fully described hereafter, but for our present purpose it is sufficient to say that the catoptric system necessitates the employment of a number of small lamps, each with a metallic reflector behind it, while in the dioptric system one large central lamp is used, having three, four, or six concentric wicks.

The small lamps are constructed on the well-known Argand principle, each lamp having a single concentric wick working on a cylindrical tube open at both ends, the wick rising slightly above the top of the cylinder, and when lighted yielding a ring of flame. By means of the cylindrical tube a current of air is caused to impinge upon the internal surface of the ring of flame, the oxygen in which makes the combustion of the oil vapour more vigorous, while a current of air is also caused to impinge upon the external surface of the flame. The glass chimney serves to protect the flame from irregular puffs and draughts of air. Some improvements made by Sir James Douglass have resulted in these lamps being rendered available for burning either colza or paraffin, and in yielding a splendid light with either. The lamps having been



Argand Burner with Reflector.

originally designed to burn colza, the alterations consisted in an arrangement for lowering the level of the oil when burning paraffin, in altering the tips of the wick case, in inserting a conical button point downwards in the centre of the burner, whereby the current of air ascending the tube is thrown into the heart of the flame, causing it to bulge out a little, and in slightly changing the position of the outside brass jacket, so that air is more largely supplied to the external surface of the flame. Associated with each lamp is a reflector of twelve or twenty-one inches diameter across the mouth, for the purpose of reflecting forward all the backward rays of light which would otherwise be lost. The burner has to be accurately

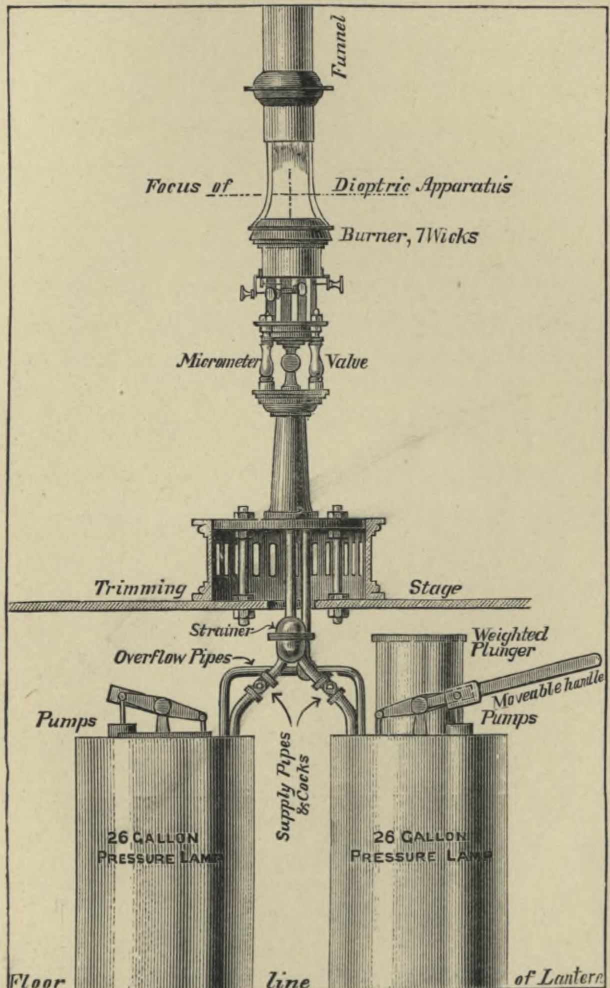


Seven Lamps and Reflectors on a Face.

adjusted so that the flame is exactly in the focus of the reflector—that is to say, it must be so placed that all the backward rays are caught and reflected forward in such a manner that they go out to sea with the direct rays from the front part of the flame (*see* Diagram, page 40). The reflector is made of copper, the inner surface being coated with pure silver, which is capable of receiving a very high polish ; the proportion of the two metals is six ounces of silver to sixteen ounces of copper. The catoptric system in lighthouses is applied mostly to revolving lights. The lighting apparatus consists of an iron framework mounted on a spindle. The framework has three or four vertical faces, on each of which are fixed a certain number of lamps, three, five, seven, or ten. The drawing (page 41) represents one face with seven lamps. On the whole framework being made to rotate, each face with its group of lamps is carried round successively, and it can easily be imagined that as each group comes round the combined rays of seven lamps throw a splendid beam of light on the sea. The magnificent lights at Cromer on the East coast, Beachy Head on the South coast, and St. Agnes, Scilly, are catoptric, each having three faces, with ten lamps and reflectors on a face, making thirty lamps and reflectors at each station. As the flame of each lamp has to be maintained at a height of one inch and a half, there is naturally great heat developed in the lantern by the burning of these thirty lamps, and it is therefore considered prudent to continue to use colza in preference to paraffin oil at these stations. This system is, however, gradually being superseded, and no fixed lights of any importance are now on the catoptric principle ;

indeed it has been thought that, before many more years have passed away, lamps and reflectors in lighthouses will be things of the past; but Sir James Douglass has lately brought into use some two and three-wicked argand burners of great power, which may perhaps resuscitate the waning reputation of lamps and reflectors.

The single lamp used for dioptric lights is placed in the middle of the lantern, and the burner is supplied with oil either on the hydrostatic principle or by means of pressure—that is to say, there is either a cistern fixed somewhere near the lamp, but at a higher level than the burner, from which the oil flows to the burning point by the natural action of gravitation; or by the automatic action of a weighted plunger, adjusted to the amount of pressure required, the oil is forced up to the wicks from a reservoir placed underneath the burner. The latter is the method in general use at most lighthouses in the United Kingdom, and, although it involves the winding or pumping up of the weight rather often, it is generally regarded as being the most efficient system. The burner can be made available for using animal, vegetable, or mineral oil, and equal results as regards illuminating power can be obtained from them all; therefore, in respect of the supply of oil for all lighthouses other than rock stations, the question of expense is the ruling consideration. The wicks employed are concentric (*i.e.* ring within ring), and the number employed varies from one to six according to the power of light required. In many lighthouses four wicks have been used for a long period, yielding a very serviceable flame ; but of late years, since the introduction of the five and six-wick burners, a great number of lighthouses have been fitted with such burners. The value of a light given by a six-wick burner is said to be equal to that of 722 sperm candles, while the four-wick burner yields a light equal to that obtained from 328 sperm candles. By some important improvements recently made by Sir James Douglass in connection with the compression of the flame, a seven-wick burner has been brought into action, the intensity of the six-wick burner has been considerably raised, and a proportionate increase will be obtained from four and three-wick burners, to which Sir James Douglass's improvements have been applied. One of the great advantages claimed for the larger-ringed burners is that when the weather is clear some of the inner rings of flame can be turned down, thus effecting an economy in the consumption of oil, the full power of all the wicks being reserved for those occasions when the atmosphere is thick with rain, snow, mist, haze, or fog. The diameter of the flame of the six-wick lamp at



DOUGLASS SEVEN-WICK OIL BURNER.

To face page 44.

its broadest part near the top of the burner is 5 inches, but it is narrowed in the upper part to 3½ inches by the glass chimney. The height of flame usually maintained is about six inches. It is evident that such a body of flame must develop considerable heat, and the keepers have to exercise the greatest care to prevent frequent breakage of the glass cylinders. When burning colza, the wicks are raised about a quarter of an inch above the top of the burner, and the oil is caused to overflow slightly ; but in burning paraffin the wicks are raised about one-sixteenth part of an inch above the top of the burner, and the level of the oil is about an inch and a quarter below.

The four-wick burner is still employed at many stations in England, but the use of six or seven wicks is being gradually extended. In Scotland a five-wicked burner is largely employed. At some light-houses, where a powerful light is not required, three-wick and two-wick lamps are sufficient.

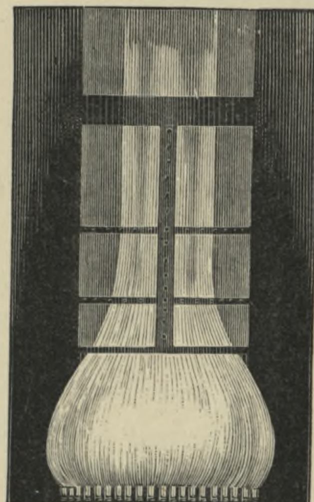
The consumption of oil, whether colza or paraffin, for a four-wick lamp is about 1,100 gallons a year. In consequence of the large lamps being sometimes burned at full and sometimes at half power, it is not possible to say accurately what the annual consumption of such a lamp should be, but it may be stated that the six-wick burner consumes about 1,750 gallons per annum.

The advantages of oil lamps for lighthouse illumination are manifold. Oil can be conveniently transported and safely stored ; and the certainty and simplicity of its action are great recommendations. The lamps are easily manipulated by the keepers, and if paraffin be used it is the cheapest kind of illumination available. At present oil is the only illuminating agent which can be used at a rock lighthouse. At the Eddystone two six-wick burners, one placed about six feet above the other, aie employed, one light only being used for clear weather, and two lights when the atmosphere is misty or foggy.

CHAPTER V.

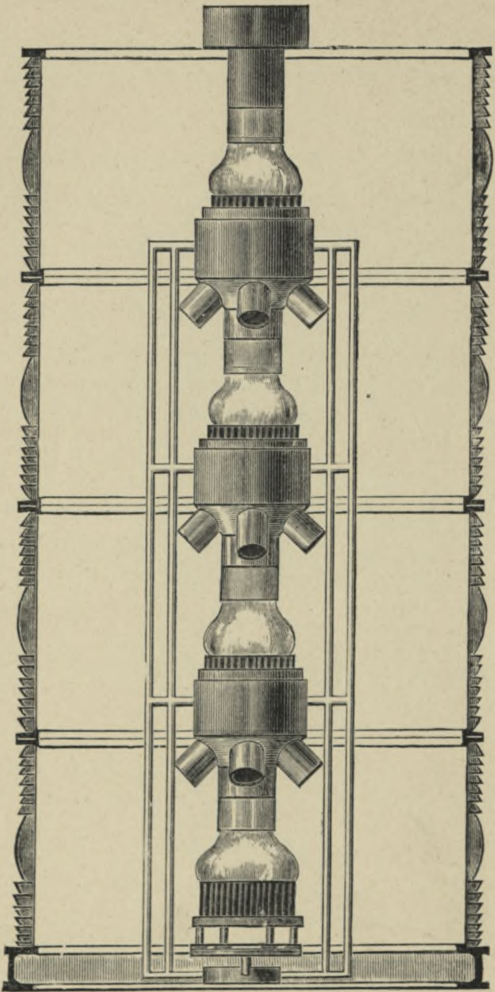
LIGHTHOUSE ILLUMINATION—*continued.*

GAS.—Seeing the results achieved by gas as an illuminator of our streets and houses, it is not surprising that efforts should have been made to apply it for lighthouse purposes; but, notwithstanding its apparent suitability, its employment has been by no means so general as might have been expected. Prejudice and the fear engendered by ignorance had first to be overcome; then practical difficulties with respect to its application had to be surmounted. Plenty of suggestions and projects have been forthcoming, but not until the year 1865 did any practically serviceable plan for the use of gas in lighthouses make its appearance. At that period Mr. J. R. Wigham, of Dublin, inaugurated the gas system for lighthouses by the introduction of his patent gas-burner at the Howth Bailey Lighthouse, near Dublin. The burner in its complete form consists of five concentric rings of gas jets, the innermost ring having 28, the next 48, the next 68, the next 88, and the outermost one 108 jets, the diameters of each ring being respectively 4, 6½, 8½, 9½, and 11 inches. It is stated that the light from 28 jets equals in candle power that from the four-wick oil lamp, and that the 48-jet burner is more than equal to the six-wick oil-burner; while the light from 68, 88, or 108 jets is far



Wigham Gas-Burner.

above that of the six-wick oil lamp. The object of introducing these higher powers of illumination is to enable the light to contend with the intermediate conditions of the atmosphere between clear weather and thick fog; the latter condition continues to be fatal to the efficiency of the most powerful light yet



QUADRIFORM GAS-BURNER.

To face page 49.

known. The facility of increasing the size and power of the gas flame to meet different conditions of the atmosphere is a strong recommendation. A very advantageous development of the gas system consists in the introduction of biform, triform, and quadriform lights—that is to say, two, three, or four burners placed vertically over each other, with a distance of 3 or 4 feet between them, by which a column of light of great power is obtained. By Mr. Wigham's plan the products of combustion of the lower burners are intercepted and carried outwards, while a supply of pure air is conveyed to each flame by cylindrical openings brought through the flues. This air is sucked in by the draught, and is much heated by its contact with the casing of the nearly red-hot flues, as is also the gas, the pipes for which pass through the hot chamber. The illuminating power of the upper flames is materially increased by this arrangement. Each flame is controlled by a mica chimney which does not descend so far as to enclose the flame, but leaves naked the thickest and most intense portion. These chimneys have different end-pieces to suit the different sizes of the flames of the various powers. Surrounding each light is an arrangement of lenses (the principle of which will be explained in another chapter), and the rays passing through each tier of lenses issue from the lantern in the form of a powerful columnar beam.

It is claimed by the advocates of the gas system that this great pillar of light is more effective in thick weather than the most intense single point of light. On the other hand, it is asserted that much of the light produced by the triform and quadriform arrangements is practically wasted so far as the seaman is concerned; that it is diffused in the sky and does not reach the horizon at all; but, again, the gas advocates say that this 'ex-focal' light is of the greatest value to the mariner when the actual beam is rendered invisible; for by its illumination of the sky and glare in the turbid atmosphere, its locality is made known at times when a powerful condensed beam with a small angle of divergence would yield no such evidence of its whereabouts. These disputed points, however, are about to be decided by practical trial at South Foreland, near Dover; the experiments having been commenced while this work is in the press. But it is unquestionable that a really splendid light is obtained from gas as now applied in lighthouses, and that it possesses some special advantages which add to its practical value. Dr. Tyndall's opinion is that 'It may be beaten in point of cheapness by mineral oil, but in point of handiness, distinctiveness, and power of variability to meet the changes of the weather, it will maintain its superiority over all oils.' As a matter of fact, it has been adapted to meet the requirements of fixed, intermittent, revolving, and group flashing lights, with success in every case. There are, however, some difficulties in the way of the more general use of gas, and it is obvious that it cannot be employed for rock lighthouses. The gas has to be manufactured at the station, gas-works, retort-house, gas-holder, and other buildings have to be erected. Expensive cannel coal is used for making the gas, the retorts being heated by a cheaper kind of coal, or by the tar produced. The ordinary operation of gas-making has to be gone through each day, probably more attention being paid to the purifying process than is devoted to it in the manufacture of gas for large towns. The consumption of gas per night of eight hours, with a single 48-jet burner, is about 1,000 cubic feet, and the total cost per 1,000 feet is stated to be about 10*s*. The increased cost of lighthouse gas as compared with city gas is of course due to the fact that the gas produced on a small scale is always more costly than that made on a large scale; and further that gas made of superior cannel coal is of about 35 candle-power, while city gas seldom gives over 16 candles.

As compared with oil, it is clear that gas is equally effective as an illuminant for lighthouses on the mainland; but it has not yet been demonstrated that it is cheaper; consequently its extension is not rapid. There may be a great future for gas as a lighthouse illuminant, especially if the process of manufacture be simplified, the price of gas coal reduced, or an efficient means of safely transporting and storing large quantities of gas discovered. Oil will then have to look to its laurels.

As regards its great rival, electricity, of which we are about to speak, there is some difference of opinion as to the relative merits of electric and gas lights in a misty or foggy atmosphere. It is strongly asserted on one side that the electric light has a greater power than any other luminary of penetrating fog, while the opponents of that theory affirm that in foggy weather the electric beam is more readily quenched than the beam from a gas or oil light. It is not a question of intensity or actual candle power that is here involved, for in this respect there is no doubt whatever as to the superiority of the electric light, but it is a question connected with the colour of the lights. It is well known that red and orange rays are not so soon absorbed in their passage through a thick atmosphere as are violet rays, and it is asserted that in gas and oil lights the red rays are proportionally more abundant than in the electric light, in which there is an equality of all the rays. This of course is an exceedingly important point in connection with lighthouse illumination. In clear weather the four-wick oil lamp is quite able to send its rays with good effect to the horizon, but, as previously pointed out, it is for periods when the transparency of the atmosphere is more or less obscured (a condition which in our latitude may be regarded as the rule rather than the exception) that these powerful lights are wanted. If it should be proved that the electric light succumbs sooner than the gas or oil light to the obscuring influence of fog, it would detract seriously from its value as a lighthouse illuminant. This is a question which will doubtless be definitely solved in the coming experiments. Meanwhile gas will continue to hold its own as far as it has gone, and it is to be hoped will be developed into further utility. The stations now lighted with gas in the United Kingdom are—Haisbro', two lighthouses on the coast of Norfolk; Howth Bailey, Dublin Bay; Wicklow Head, east coast of Ireland; Hook Tower, entrance to Waterford Harbour; Mine Head, near Dungarvan, co. Waterford; Galley Head, south coast of Ireland, co. Cork; St. John's Point, north-east coast of Ireland, co. Down; Rockabill, east coast of Ireland, co. Dublin; and two other stations in Ireland, viz. Mew Island and Tory Island, are about to be converted to gas establishments.

ELECTRICITY.—It does not appear to be generally known that as far back as 1857 trials were made in this country with the electric light for the illumination of lighthouses. At that time Professor F. H. Holmes had, after much persevering effort, succeeded in turning to practical account Faraday's grand discovery of electric induction in a coil of copper wire. The generation of electric currents by the voltaic battery had long previously been known as capable of producing light and heat; but the enormous expense attendant upon the production of light by this method was for fifty years an effectual bar to its application for practical purposes. Faraday's discovery in 1831, and Holmes's mechanical realisation of it in 1857, enabled the electric current to be utilised for light-giving purposes.

Holmes's apparatus was termed a magneto-electric machine, and, after some careful experiments with it at the South Foreland lighthouse in 1858, the results obtained from this most ingenious piece of mechanism, in Faraday's own words, 'practically established the fitness and sufficiency of the magneto-electric light for lighthouse purposes, so far as its nature and management are concerned.' Without going into details it will be sufficient to state that, after burning experimentally at South Foreland during 1857, 1858, and 1859, it was agreed to employ the new illuminator in place of the oil light at the dangerous point of Dungeness on the Kentish Coast. Some difficulties had still to be overcome, and it was not until February 1, 1862, that the electric light shone from the Dungeness tower.[1] The early experience of this light was far from encouraging. There were many difficulties to contend against and many failures of the light, the stand-by oil lamps having to be frequently resorted to. Much of this irregularity was doubtless due to imperfections in the apparatus, but a portion was attributable to the want of knowledge on the part of the lighthouse keepers, to whom the system was novel and unfamiliar. But nevertheless the trial was persisted in until the failures became less frequent, and the light was maintained with comparative regularity.

In 1867, Holmes's attention was called to an improved machine made by the Alliance Company of Paris, two of which were in use at the lighthouses at Cape la Hève in France. The new machine was unquestionably a marked improvement on those constructed by Holmes for Dungeness; and, as it was then in contemplation to show the electric light from a new lighthouse at Souter Point, Durham, Holmes made two new machines, embodying all the improvements of the Alliance Company's patent. These machines, after being shown at the Paris Exhibition of 1867, were in due course sent to Souter Point. Since

[1] On December 26, 1863, the south lighthouse at Cape La Hève, in France, was lighted experimentally by means of electricity, nearly two years after its permanent adoption in this country.

January 1871 this point has been crowned with the electric light, much to the satisfaction of mariners entering the Tyne or navigating up and down the NE. coast.

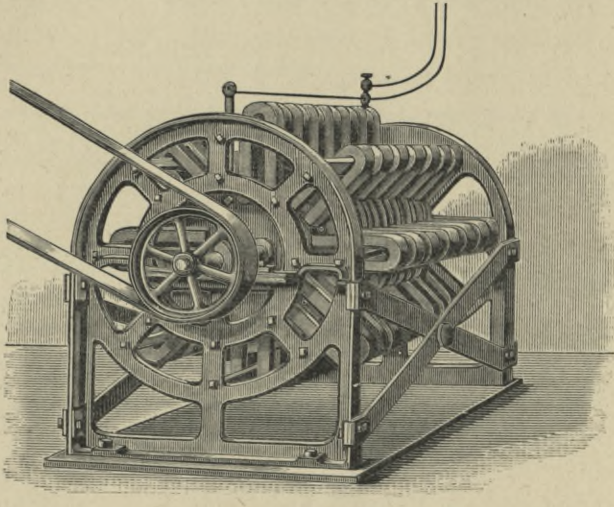
The extension of the electric system was carried further in 1872, when it was established permanently at the two lighthouses at the South Foreland. Holmes's improved machines, similar to those at Souter Point, were employed.

In 1874 the electric light at Dungeness was discontinued, the old oil illuminant being resumed. The reason for this apparently retrograde step was that Dungeness is very low, and the continual growing out of the point had set back the lighthouse so far from the actual ness which it was intended to indicate, that to the mariner navigating in its vicinity the light appeared to be but slightly, if at all, elevated above his own level; the full glare of the electric light at a low elevation was found to be dazzling and bewildering, so much so that it was impossible to judge accurately of the ship's distance from the shore, and most difficult for those on board a vessel approaching the point to see the lights of any vessel which might be between them and the shore. When the question arose of renewing the illuminating apparatus at Dungeness, the electric machinery there being regarded as obsolete, it was decided to put a small oil light on the extreme point, and revert to oil with the addition of an improved arrangement for exhibiting the light for the old tower ; it being understood that the electric system was to be extended to the important station of Lizard Point on the coast of Cornwall.

An important discovery, made simultaneously by Dr. Siemens and Sir Charles Wheatstone, that induced electricity could be generated in great force without the use of permanent magnets, brought about the construction of what are known as dynamo-electric machines. In some exhaustive comparative trials carried out at South Foreland in 1876–77, the dynamo machines constructed by Messrs. Siemens were found to yield superior illuminating results as compared with any of the magneto-electric machines previously constructed. The question as regards the application of electricity to the lighthouses at Lizard Point being then under consideration, it was resolved to exhibit the electric light from the two towers at that station, the light to be produced by Siemens' machines.

This completes the historical statement concerning the application of the electric light in the lighthouses of this country up to the present time, but it is understood that it is in contemplation to proceed further with the system.

The general nature of the machinery employed and the arrangements in operation for exhibiting the electric light at lighthouses may be briefly and popularly described as follows. The first thing required is motive power. At Souter Point and South Foreland steam engines are used ; at Lizard caloric or hot air engines are employed. The engines are necessary for



Magneto-Electric Machine.

driving the machines by which the electric currents are generated. Magneto-electric machines are constructed on the principle ot Faraday's discovery that an electric current is induced in a coil of copper wire when it passes the poles of a permanent magnet. Accordingly the magneto-electric machine consists of two parts—viz. magnets and coils of wire, or helices, as they are called, the helices being so arranged that they can be made to rapidly pass the poles of the magnets. Each magnet is made up of six superposed plates, and is curved in the usual horse-shoe shape. Each coil of wire is wound round a cylinder or bobbin of soft iron, the wire being insulated. The magneto-electric machine as formerly used at Souter Point and South Foreland consists of seven parallel series of fixed magnets, so arranged that the poles of the eight magnets in each series converge toward but are not attached to a central axis or shaft. These circular frames of magnets are fixed at equal distances from one another, and between them are six small rotating discs mounted on the central shaft, each carrying sixteen coils of wire or helices, which, on the shaft being rotated by the steam engine, pass the poles of the fixed magnets. Electric currents are thus induced in the coils, strengthened as each succeeding helix passes, and one revolution of the rotating wheel causes the sixteen helices to pass the poles of eight magnets. Imagine then the six wheels revolving at a speed of 400 revolutions a minute, and some idea will be obtained of the force exerted by the whole machine when working in the production of electricity. By this process alternating currents of positive and negative electricity are generated in the coils and are taken off from the axle of the rotating wheels and transmitted where required by conducting wires. Having thus obtained the electric current, the next thing is to cause it to yield the desired light. The conducting wires are carried up to the lighthouse lantern, and to their ends are fixed carbon pencils. If the ends of the wire were joined together, the circuit would be completed, and the currents would flow through without making any display of electric force, but the carbon points are brought close to each other, and the passage of the current from one point to the other is opposed by a small interval of air. In the effort of overcoming this opposition great heat is developed, which makes itself apparent in the incandescence of the carbon points ; and the consequent flow of incandescent matter from one carbon terminal to the other acts as a bridge across which the current passes. The proper distance between the carbon points is maintained by a regulator, also known as the lamp, which automatically moves the carbons towards each other as fast as they are


Incandescent Carbon Points.

consumed. The foregoing has been treated in a very elementary manner, but text-books on the subject are now so numerous and so widely read that a more detailed reference to the principles of electrical science is hardly necessary.

At the Lizard, as has been stated, dynamo-electric machines, in which the electricity is developed more by means of dynamic force than by permanent magnetism, are employed. By the interaction of the coil and of the latent magnetism in soft iron, it was discovered that currents of extraordinary power could be produced without the aid of permanent magnets. The development of this discovery was much aided by the improved armature of Messrs. Siemens, in which coils of wire are wound longitudinally round a cylinder of iron, the cylinder being caused to revolve near the poles of electro-magnets, around which coils are also wound. The very feeble current so induced in the coils of the armature is made to traverse also the coils of the electro-magnets, whereby their magnetic intensity is increased, and they react on the armature. In this way the current and magnetism go on mutually reinforcing each other until a very strong current is accumulated, which is taken off by conducting wires to the lamp. These machines are much more economical in original cost and in working; they are less complicated in construction, occupy smaller space, and are not subject to deterioration by the weakening of magnets, to which magneto-electric machines with permanent magnets are said to be liable. They have hitherto yielded more powerful light than the magneto-electric machines. Operated by hot air engines, the machines of Messrs. Siemens have been employed at the Lizard since 1878.

The electric light is very beautiful as a lighthouse illuminant; there is nothing can compare with its magnificent effects on a dark night. But opinions are still divided as to its real value at all times. Mariners have not yet fully learned how to accommodate themselves to its dazzling brilliancy, and complain at times of its bewildering influence; moreover, they are not yet fully assured as to its superior efficiency in thick weather; but, on the other hand, who can be more glad than the weather-tossed seaman at sighting its glorious light or luminous glare at its extremest range? But whatever may be the ultimate practical judgment of those who are most concerned, it will be generally agreed that no light has ever equalled it for distinctiveness of character or beauty of appearance, and that the chief complaint which can be made against it is that under ordinary circumstances it is, if anything, too good for the purpose.

If the electric system in the end prove successful for lighthouses, we may expect as the progressive movement goes on that by improvements and economies this source of lighting will be rendered more and more serviceable, until the time arrives for our lighthouses to be supplied with boxes of accumulated electrical energy, to be kept in store and made use of as required ; machinery being wanted only at some great central factory, where fuel can be cheaply obtained, and where communication with all parts of the country is easy.

CHAPTER VI.

LIGHTHOUSE ILLUMINATION—*continued.*

HAVING dealt with the various illuminating agents employed in lighthouses, the next points which suggest themselves for consideration are the means adopted for making the best use of the light produced; for concentrating its rays, so that they may be sent out to sea in the form of a beam, and for making use of those which under ordinary conditions would be projected in directions where light was not required for the purpose in view. It will readily be understood that the light from the flame of a lamp distributes itself in all directions; it goes straight upward and downward, and all round. But to the sailor at sea lighthouse rays sent up to the sky are of comparatively little use, except possibly in certain conditions of weather; and those falling down on the lantern floor or ground in the immediate vicinity of the lamp are altogether unserviceable to him. It was one of the chief defects of the blazing beacon of old that the greater part of its light went up to the sky, and comparatively little on the sea; and this defect was admitted to be a serious one. Moreover, the light from a lighthouse on the edge of the mainland is not required to shine over the land at the back; all which goes in that direction is wasted. As the employment of lighthouses was more generally extended on our coasts, these defects showed themselves with prominence, and efforts were made to remedy them to some extent. The open blazing fires were closed in with bars towards the sea, and some efforts were made to reflect back the landward light from a coal fire. But it was not until a more perfect means of producing the light itself was brought into use that any really effectual method of collecting and diffusing the rays for the especial benefit of the navigator was inaugurated. The invention of the Argand lamp, by means of which oil could be burned in a more perfect manner than had ever before been achieved, marked an important stage in the progress of lighthouse illumination; previously to the advent of this lamp, oil was used only with a thick solid wick, which when burned yielded a poor and smoky flame. In Argand's lamp a compact ring of flame is produced. His method made the combustion of the oil-vapour much more perfect than any previously known method, and did away with the smoke. The plan of supplying the wick with oil from a cistern connected with the lamp, but placed above the level of the burner, was known at the time of Argand's invention, and was applied by him to his lamp. But this improvement, great as it was, did not by itself provide a remedy for the defects before referred to. Something more was wanted to utilise to greater advantage the flame of the lamp, and the want was ultimately supplied by the application of the principle of reflection. As before indicated, there are evidences that the application of this principle was attempted with coal fires ; but it is certain that the use of argand lamps facilitated the employment of reflectors in combination with them ; and thus was established what is known as the catoptric system of lighting.

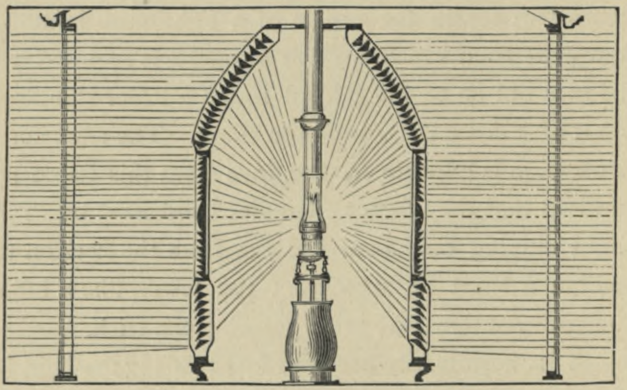
Without going into technicalities or mathematical calculations, the system may be generally and popularly described as follows :—The object is to intercept as many as possible of the rays proceeding in directions where the light is not wanted, and to send them in certain other directions, so as to strengthen the beam shining over the sea surface, and intended to meet the eye of the mariner. In the catoptric system of lighthouse illumination a number of lamps (argand) are employed, and fixed behind the burner of each lamp is a metallic cup-shaped reflector, with its reflecting surface very highly polished, the oil cistern for feeding the lamp being at the back of the reflector.

Many of the rays from the burner proceed directly on to the sea, where the light is wanted ; but very many fall upon the polished inner surface of the reflector, and are thence reflected forward into the beam formed by the direct rays, thus greatly reinforcing it (*see* Diagram, page 40). The form of the reflector is that of a parabola, which is the most effective shape for reflecting forward in a parallel beam all the rays proceeding from the burner which strike its surface. The burner is carefully adjusted so that the flame shall be exactly in the focus of the reflector ; if it were not accurately placed, many of the rays would be reflected off in lines different from those of the direct rays from the flame itself. Let it then be imagined that one lamp with its associated reflector sends out a strong concentrated beam of light, with just sufficient lateral divergence—*i.e.* the tendency of its rays to spread out —to cause the whole beam to spread out a very little as it advances ; it will be obvious that with a cluster or group of such lamps arranged on a framework in a vertical plane, as has been previously described (page 41), at a short distance all their beams will coalesce into one large beam, which will be visible to the sailor as one powerful light ; and, in the case of a revolving light with three or more groups of lamps, each group in its turn and at its appointed interval will carry round a powerful condensed beam, sweeping the area of sea which it is intended to illuminate. Although yielding a splendid beam, the number of lamps necessary entails the consumption of a large quantity of oil, and causes the development of great heat; besides which, the trimming and cleaning of the lamps, the polishing of the reflectors, and the constant care requisite to ensure the proper burning of each lamp, combine to render the system cumbrous and troublesome as compared with more modern apparatus. Neither gas nor electricity have yet been employed in connection with reflectors in lighthouses; but possibly the time may come when the electric spark will be made serviceable in the focus of a reflector.

We may now briefly consider the other method for employing rays of light in the most economical and serviceable manner—viz. the dioptric system. It has been shown that with reflectors this object is attained by reflecting forward the rays thrown on to a highly polished surface. In the dioptric method, all the rays emitted by one large flame are intercepted by glass lenses or prisms at a short distance from the flame, and are bent or refracted, so that they issue from the lighthouse lantern in a compact beam.

It has been previously indicated that the chief difference between the catoptric and dioptric systems is that the former has many lamps, while the latter has one only. This one lamp for dioptric lights was described in a preceding chapter, and consists of a number of concentric rings of lighted wicks forming one large flame, situated in the centre of the lantern. The size of the flame varies with the number of wicks employed; two or three wicks are used for small lights, four, five, or six wicks for the more important lights. Imagine the splendid flame of, say, a six-wick lamp burning in the centre of a lighthouse lantern, the light from which, we will suppose, is required to be sent out on to the sea all round a tower standing on a rock some miles from the shore. The next consideration is how are all the rays from this flame so utilised that they form an annular condensed beam of light shining only over the sea from the horizon to within a short distance from the tower, like a huge umbrella of light, the tower forming the stick.

This is ordinarily achieved by enclosing the light in what may be described as a glass hive, the diameter of which varies from two to six feet according to the importance of the light. The internal surface of this glass hive intercepts nearly all the rays proceeding from the lamp. The hive is composed of three parts—the dome, the central belt, and the lower belt. The dome and the lower belt are composed of circular rows of totally reflecting prisms, so fixed as to catch the rays proceeding obliquely upwards or downwards from the central lamp. The property of each prism is such that a ray falling upon one of its sides is refracted through the substance of the glass at an angle on to another side, from whence it is totally reflected out through the third side in an altered direction from that in which it entered the prism. The adjustment of prisms has to be carried out with mathematical



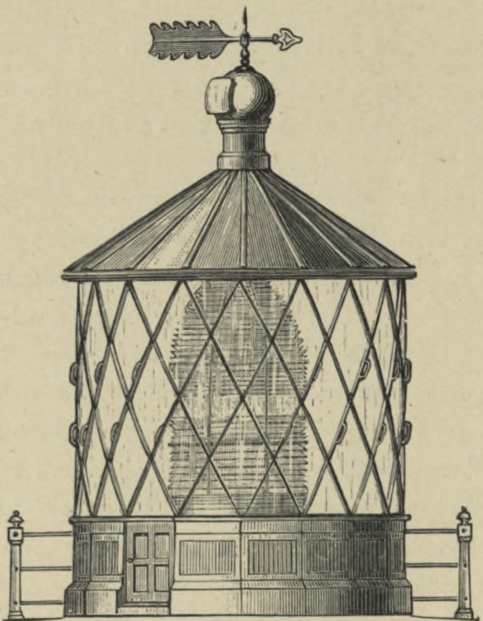
Dioptric Apparatus.

accuracy, in order that all the rays from the luminous centre may be caught, and by refraction and reflection sent out in parallel lines, although some few of the rays striking directly upward or downward necessarily escape. The central belt is composed of lenses which gather up all the rays falling upon their inner surfaces, and bend them so that they issue from the other side in parallel lines ; and as the parallelism of those issuing from the dome and lower belt is by the adjustment of the prisms made to coincide with the parallelism of the central rays, the whole of the rays combine to form a powerful beam of light streaming from the entire apparatus, striking the sea at a short distance from the tower and, in clear weather, stretching over the waters as far as the horizon. This arrangement is suitable for a fixed light; but for a revolving light the hive is divided into vertical panels or segments, of which the divisions of an orange will give an approximate idea, in each of which a section of the incident rays is condensed so as to yield a separate beam. Between the vertical panels or segments divisions occur through which no light passes. On the hive being made to revolve, the beams from the different panels, separated by intervals of darkness, successively come round like the spokes of a wheel, and the mariner sees the waxing and waning flashes of a revolving light. A further elaboration of the system is that of group flashes, for which the vertical panel as above described is further subdivided and is cut up into two or more smaller panels, each yielding a beam or flash, short intervals of darkness separating the flashes. By this means two, three, or four comparatively quick flashes are made to strike the sea in the same period as that in which the simple revolving light showed its one longer waxing and waning flash. This method is found to possess great distinctiveness, an element in lighthouse illumination which will be hereafter dealt with. In the case of a light not required to show all round, but intended merely to illuminate a certain seaward arc, the form of the hive is incomplete, and the greater part of the rearward rays from the lamp, which under ordinary circumstances would be wasted, are by an appropriate arrangement of prisms or mirrors reflected back, so that they pass through the lenses or prisms out to the sea with the whole beam. In some instances this rearward light has been most ingeniously utilised in another way. At the back of the lamp a dioptric mirror is so adjusted as to reflect the rays falling upon it vertically downward through an opening in the floor on to another reflector, placed so as to re-reflect them out to sea through a lower window. By this plan a most useful lower light is now obtained at some stations, the back light being reflected downwards and caused to issue from a window in the tower twenty feet below the actual light. This plan is in operation at the electric light station at Souter Point, Durham, and at the oil station at Bull Point, North Devon.

Another highly ingenious adaptation of the reflecting principle (to which further reference will be made in the chapter on beacons) is that by which a beam of light is projected from a shore lighthouse on to an arrangement of prisms fixed on a structure built upon an outlying rock, the prisms being so adjusted that they receive a portion of the beam from the shore light and diffuse it in a more widely diverging beam in the direction required, the appearance to the mariner being that of an actual light burning on the beacon.

In the foregoing remarks we have endeavoured to describe concisely and without technicalities the chief points in connexion with the catoptric and dioptric systems of lighting; but for the mechanical details and mathematical formulæ connected with the adjustment of the reflecting and refracting media we must refer the reader to Mr. Alan Stevenson's treatise on 'Lighthouses,' Mr. Thomas Stevenson's book on 'Lighthouse Construction and Illumination,' and to various papers on different branches of the subject read by Sir James Douglass, Mr. James T. Chance, and Dr. Hopkinson at the Institution of Civil Engineers.

Having thus described the apparatus employed for economising the light, it remains to consider briefly the protecting lantern which encloses it. The shape of the lantern is usually cylindrical, corresponding in a general way with the form of the tower, and surmounted with a dome or conical roof, finished off at the summit with a wind vane or a ball. The glazing of the lantern has to be of stout plate glass of the best quality, having to withstand at times a considerable force of wind and even the driving



Lantern.

against it of small shingle ; at night, too, birds, attracted by the light, dash themselves wildly against the glass, falling stunned or dead on the floor of the external gallery which surrounds each lantern. The thickness of the glass usually employed is a little over a quarter of an inch. In former times the framing of all lighthouse lanterns was vertical, and a considerable quantity of light was intercepted by the upright astragals or standards. The framing of Scotch lighthouses is diagonal, glazed with flat plate glass in diamond-shaped panes. In English and Irish lighthouses the framing of the lantern is helical or spiral, and the panes of glass are slightly curved outwards to accord with the curve of the cylinder and to enable the rays to fall radially upon the inner surface. The curving of the glass is also an element of strength. This lantern is the design of Sir James Douglass. Effective ventilation is most essential in a lighthouse lantern. Great heat is at times generated by the burning lamp or lamps, and the panes are apt to be obscured by the condensation of aqueous vapour when the warm moist air comes in contact with the colder surface of the glass. To obviate this as far as possible ventilators are placed in the iron panels of the lower part of the lantern, and a supply of fresh air is also admitted through ventilating windows in the watch-room underneath the lantern, which passes upwards through the grating of the lantern floor. By this arrangement a constant stream of cold air flows upward, close to the glass, finding an outlet at the top of the roof through the outside ball, which is pierced with holes for the purpose ; and the flame itself, which requires an ample supply of fresh air to support vigorous combustion, is also adequately recruited. The method above described is found to be fairly effective in preventing condensation, but it is not at all times sufficient for the purpose. A special arrangement of a double roof, the lower one not joined at the sides to the structure, is adopted to assist in the upward flow of air. Some important improvements in lighthouse ventilation have recently been perfected by Sir James Douglass, but they have as yet been applied only to the experimental lighthouses at South Foreland.

CHAPTER VII.

LIGHTHOUSE ILLUMINATION—*continued.*

IT is well known in a general way that the object of a lighthouse is to show a light at night, and popular knowledge on the subject seldom goes much further than this. The seaman, however, requires to make himself much more fully acquainted with the purposes of lighthouses, and if we consider what his wants are in this respect we shall be able to form some ideas concerning the functions and value of such seamarks.

Numerous lighthouses are placed at short intervals all round our coasts. From the lighthouse chart of the British Islands (*see* frontispiece), in which the arc illuminated by each lighthouse is shown, it may be seen that the circles or segments of circles of light nearly everywhere overlap, thus forming a belt of illuminated sea all round our shores. Let us suppose the mariner coming from foreign parts to this country, and at night-time striking into this illuminated belt at one place or another, one or more of the coast lights being visible to him. If he is a careful navigator, he probably knows where he ought to be by his reckoning and soundings, and when he sees the lights he is probably able to recognise them and so is confirmed as to his position. But, on the other hand, he may have been driven by various influences far out of his reckoning, and if he should strike then into the belt of light—*i.e.* if some coast lights should become visible to him—it is of the utmost importance he should quickly find out on what part of the coast he has arrived, and for doing this at night-time he is mainly dependent on being able to identify the light or lights he sees. In the daytime the shape and colour of the lighthouse tower and cottages, and the positions of other prominent objects on the coast, in conjunction with the soundings he obtains with his lead, enable him with certainty to say where he is.

It will therefore be quite evident that the lights shining at night along a stretch of coast line must differ one from another, that no two lights exactly alike should be placed near to one another unless they are quite close and intended to be used together. The necessity for distinctiveness has given rise to the employment of different well-marked peculiarities in lights, simple in character, such as may be easily and immediately recognised by the navigator when the lights come into view. The system, if it may be so called, now in operation, is one which has grown with the growth of our shipping trade, has been developed as new necessities arose, and is still capable of adaptation to altered conditions. It is understood by all nautical men, affords a ready means of identifying the lights, and is generally agreed to be sufficient for the purposes in view.

There are two generic distinctions, under one or other of which the majority of the different characteristics of light may be grouped—viz. (*a*) light which is fixed, *i.e.* which shows continuously ; (*b*) light which does not show continuously, but is broken by periods of darkness.

With fixed lights, variations are made by putting two lights close together, either side by side or one above the other, or by use of coloured glass ; for example, one distinction may be a single fixed white, another a single fixed red, another double fixed, *i.e.* two lights, either both white, or one red, the other white, and further obvious combinations will suggest themselves. Again, the peculiar appearance of the electric light is in itself a distinctive feature for a fixed light.

With lights that are not fixed the varieties are very numerous. Every one knows the character of the revolving light, which, as has been previously explained, consists of a number of beams separated by dark intervals, the beams travelling round successively, each periodically illuminating the sea. The effect produced, as observed by the mariner, is that of waxing and waning, the beam faintly appearing at first, gradually swelling into its full strength, and then slowly receding until it is lost sight of. This kind of light may be varied by altering the length of the dark intervals between the beams; for example, with a half-minute revolving light a beam comes round every half-minute, and with a one-minute revolving light the beam is seen every minute, and so on. Another modification of this kind of light is produced by the addition of coloured beams, which may be made to show alternately with the white beams, or the proportions may be varied by showing two coloured beams to one white cne, or *vice versâ*; here again differences in the length of the dark periods may be also made available for further distinctions.

Flashing lights constitute another class by means of which additional distinctions are obtained. The flashes of such lights differ from the waxing and waning beams of a revolving light in being shorter in duration, more sudden in their appearance and disappearance, and more frequent in occurrence. There is not much scope for differentiating these lights by time periods merely, half a minute being the longest interval of darkness which it is considered should separate the flashes, and this would be regarded as a very slow flashing light; for quick flashing lights dark intervals of five or at most ten seconds are employed. The intervention of coloured flashes is occasionally adopted for giving special characters to flashing lights, and, when the coloured are of equal power with the uncoloured flashes, is very effective, on account of the coloured and white flashes being brought suddenly into direct contrast. But the most important method of producing easily recognised differences in flashing lights is one of comparatively recent introduction, to which reference has already been made—viz. the group flashing system. Two, three, or four flashes are made to appear in quick succession, forming a group of flashes, each group being followed by a dark period of sufficient length to distinguish it from the very short intervals separating the flashes. The advantages of this method for distinctive purposes are numerous; the time distinctions can be brought into play, variations in the number of flashes in a group are available, and further distinctions may be made by the use of coloured flashes entirely, or alternately with white flashes. The most satisfactory results have already been obtained by this method, and its capabilities have not been nearly developed to their full extent, so that there remains for use when required a store of distinctive characteristics which have never yet been applied.

Hitherto we have dealt with lights the characteristic features of which have to do with the actual light itself—that is to say, the seaman has to note the peculiarities which the light itself exhibits. In the case of fixed lights he has to observe any special appearance about them ; in the case of revolving or flashing lights he has to regard the nature and number of the beams or flashes, and how often they appear. But with what are known as occulting lights this order of things is reversed, and the mariner has to observe the number and periods of the eclipses instead of noting the number and periods of flashes or beams. The light burns continuously, but eclipses or occultations are produced by the automatic and periodic interposition and withdrawal of a screen in front of the light, or by the dropping and lifting at stated times of a metal cylinder which surrounds the lamp chimney. The effect of these sudden obscurations and reappearances of the light is very striking, and, if seamen can learn to concentrate their observing powers on the eclipses, it will open a wide field for the extension of distinctive features for lighthouses. But it is obvious that, accustomed as mariners have been for so long a period to count the flashes of light, there is some risk of their getting at times a little confused. Let us suppose, for instance, that in a certain light three occultations occur every half-minute, it is clear that between the occultations there will occur two short intervals of light, which the mariner will be prone to read as two flashes in quick succession, instead of three eclipses or occultations ; so his ideas of the character of the light may possibly become somewhat 'mixed.' But, assuming sailors to be capable of observing either flashes or eclipses as may be necessary, there can be no doubt that the occulting method is exceedingly well adapted for giving effective distinctions. There have been of late years some ardent advocates of an elaborate and complex system of lighthouse distinctions which it has been suggested ought to be substituted for the arrangements now in force. The proposed scheme was based upon the alleged necessity of making every lighthouse indicate itself more plainly than it does at present. This object was to be achieved by making all existing lights either flashing or occulting, and by means of combinations of long and short flashes, or occultations, each light was to be continually signalising a letter which should be appropriated to it, in accordance with the dot-dash system of the Morse telegraphic code. The futility of this proposition has been exposed again and again. Such a plan as that advocated would require from the mariner additional knowledge and more trained powers of observation ; it would entail much additional watching on his part, and would occupy more time in determining the individuality of a light. At the most twenty-six distinctions only could be produced by the use, as proposed, of the Morse alphabet, so that the same character of light would have to be repeated at comparatively short distances. On the other hand, by the system now in operation, two lights of the same character are seldom placed within a hundred miles of each other; the characteristics named, with one or two exceptions, are familiar to all seamen; and as every light proclaims itself at once, its individuality can be fixed without the necessity of distinguishing between and counting dots and dashes of light, of determining what letter is indicated by any combination of such symbols, and then finding out to what lighthouse such letter is appropriated. Furthermore, the system now in operation has a large reserve of varying characteristics, and sailors are generally familiar with the distinctions employed.

The use of coloured lights for lighthouses deserves a few remarks. Red and green are the only tints made available, the latter very sparingly. As a great loss of power takes place after the passage of light through red or green glass, the use of colour is not so frequent as might be supposed. In passing through green glass light suffers even more than when passing through red glass, but in the case of the latter, where it is necessary to place the red beams on an equality as regards power with the white ones, the ratio of the areas of the red and white panels has to be as 21 to 9, in order to ensure an equal range for both beams—that is to say, rather more than twice as much light must be employed for the red beam as is used for the white beam to make them both equal in power. Green light is not used as a main feature in any lighthouse. But there is an important service performed by coloured lights, reference to which must not be omitted. It will be understood that the main light is intended to do what may be called distant work; it lifts its head high, reaches out across the waters as far as the horizon, and, we may fancy, strives to look over and beyond the earth's curve, so as to catch the eye of any far-off struggling mariner who may need its guiding light. Having then this important duty to fulfil, there is some difficulty in making it applicable for giving special warnings and guides as regards the neighbourhood close at hand. Accordingly it is the practice at many places to throw from the lighthouse a subsidiary light of a special character, intended more particularly to mark any rocks or shoals in the immediate neighbourhood. On seeing this special light sailors know that they are in danger, and by its bearing are assisted in shaping a course of safety. Neither long ranges nor powerful lights are required in these cases, and there is consequently less objection to the employment of coloured light. The portions of the main light appropriated for this purpose are generally given a special character by means of colour, and are called sectors, the object being practically achieved by simply causing the light going out in the direction of the dangers requiring to be indicated to pass through a vertical strip of coloured glass. Red is the colour mostly employed, but it is plain that any kind of sector differing from the character of the main light will be applicable. A remarkable exemplification of this method is in operation at the Coquet Island Lighthouse, off the coast of Northumberland. The surrounding sea is divided into eight irregular areas, each area being marked in a distinct manner; the main or seaward area being of course the largest, having an illuminated arc of 180°, the other areas being very much smaller in extent. The diversity of characteristics is aided by a lower light in the same tower twenty-eight feet below the main light.

The sailing directions and charts for the various parts of the coast instruct the mariner how to make use of the lights as guiding or warning marks after he has identified them. In conjunction with compass bearings he knows that when he sees two lights in line—that is, one exactly behind the other—he will be on the line leading him through a certain channel.

He can also ascertain his distance from the land by taking two bearings of a light, and he also knows that if he keeps a certain light on a certain line of bearing, having previously assured himself of his distance from land, he can safely keep his course for a certain period, until by other conjunctions he is informed when to alter his course and get the light on another bearing, &c. These are details which it is the business of a mariner to be thoroughly familiar with, and are merely roughly indicated here with the object of conveying to non-professional readers a general idea concerning the manner in which lights are made practically serviceable.

CHAPTER VIII.

THE LIGHTHOUSE SERVICE.

HAVING given a general account of the methods and mechanical appliances for maintaining the illumination of lighthouses, the next point which suggests itself for consideration is in connection with the human element of the service. We have not yet arrived at the period when the lights around our shores can be simultaneously and automatically lit up or extinguished by electric agency set in operation at a central depot; nor is it possible at present to leave the lights to take care of themselves between sunset and sunrise like so many lamp-posts. It is quite conceivable that the former state of things indicated may sooner or later come into operation, and human service thereby be reduced to a minimum, but for the present the lights must be lit, watched, and put out by men employed specially to perform such duties. It will be evident that great responsibility rests upon these lighthouse-keepers, for negligence on their part may be attended with disastrous consequences. A light not visible where it ought to be, expected and anxiously looked for in vain by a storm-tossed mariner, not quite sure where he is, and only waiting for the appearance of the light to enable him to fix his position and to shape his course in safety, may be the cause of his vessel going ashore, or at least of seriously misleading him. And it is the lighthouse-keeper upon whom he is mainly dependent for keeping the lights burning. One of the first necessities which manifests itself for such a service is discipline. Carefully drawn-up rules and regulations must be observed scrupulously, and punishment must immediately follow any negligence or flagrant misconduct. The men in the lighthouse service are subject to this wholesome disciplinary system, and frequent supervision of the authorities from headquarters, or the local officials, keeps them watchful and careful. So completely is the practice of inspection carried out that it is not uncommon for official visits to be paid to the lighthouses on shore at midnight, the officials obtaining admittance by a master key; or from the steam-vessels of the authorities cruising about at night the appearance of the lights from rock lighthouses is carefully noted, and, when possible, a boat is sent off with an official, who lands on the rock and inspects the establishment. Moreover, the coastguard all round the coast are instructed to report any falling off or extinction of the lights within their sight ; and further, the masters of passing vessels are always on the look-out, and seldom fail to report any apparent negligence or irregularity in regard to them. This vigilant supervision is unquestionably the prime cause of the general efficiency and trustworthiness of our coast lights.

But there are other causes which conduce greatly to the satisfactory performance of their duties by the men—viz. that they are trained up in the service, and are not sent to do permanent duty at any station until they have proved themselves competent to undertake the management of the elaborate apparatus entrusted to their charge. Further, they are in every way well cared for, well paid, and made as comfortable as the circumstances of their employment will permit. No man is admitted into the service above the age of twenty-eight, and for the first year or two he has to educate himself in the details of the different kinds of lamps, the method of obtaining and keeping up a full-sized flame, the trimming of the wicks, and the management of the air supply to ensure the most satisfactory results as to burning ; also how properly to clean and keep in order all the parts of the apparatus. He also has to make himself acquainted with the use of tools in carpentry and plumber's work, and with the general management of the steam-engine.

Besides receiving instruction at the central depot, he is sent from place to place to do temporary duty at different lighthouses, so that he may learn practically what he is required to do. During this period he is known as a supernumerary assistant-keeper, until the time arrives when he is pronounced efficient, and he is promoted to be an assistant-keeper. In this capacity he has to serve for many years, and at different places, in due course reaching the position of principal, provided his conduct has been such as to merit promotion. It will readily be understood that service at an isolated rock station is not so agreeable as at a lighthouse on the mainland, but all keepers have to take their turn at rock towers, while the veterans of the service are generally lodged in the more comfortable shore stations.

To a rock lighthouse there are attached four keepers, three always at the lighthouse and one on shore. The regulation in force is that each keeper has to remain on duty at the lighthouse for two consecutive months, then he has a month on shore, and by the occasional employment of a supernumerary keeper it is so arranged that every month one of the keepers goes ashore and one returns to duty at the lighthouse. At a land station such a method of relief is unnecessary, as each keeper has a comfortable cottage to live in with his family, which for a time, at any rate, constitutes his home. The necessity for three men being at a rock lighthouse has been more than once demonstrated. A number of stories are told about the keepers at rock lighthouses, but they are not all true; and where there is some basis of truth it is often heightened and coloured by romance to satisfy the popular appetite for the marvellous. But life at such stations is not without its anxieties and remarkable features. The keepers are continually in the presence of the ocean with its varying moods, and are at times involuntary witnesses of the fiercest strife between winds and waves; powerless to aid, they may at times have to behold the dread consequences of the elemental strife—to see a helpless ship breaking her bones on the cruel rocks, or hear through the storm the dying shrieks of drowning human beings. Again, they may feel their tower at times tremble with the shock of huge waves hurling themselves against the comparatively slender column of masonry, not seldom going completely over the top of the lantern. They cannot tell whether sooner or later the tower may not yield, and they, with the whole structure, be dashed to destruction. There may also be cause for anxiety now and again when bad weather prevents the relief vessel from approaching sufficiently near for communication. The man whose turn has come round for going ashore is of course looking out with eager eyes for the arrival of the vessel at the appointed time, but this is clearly a case of 'L'homme propose et Dieu dispose;' the keeper has to wait the good pleasure of the elements. A reserve stock of water and provisions is kept for use in such emergencies, and when bad weather prevails for a month or more the stock is apt to run low, and to cause some disquietude; but no serious misadventure of this kind has ever happened. Otherwise the life is quiet and unexciting, at times monotonous. Space is naturally very limited, walking exercise being confined mostly to the gallery outside the lantern. At some places the men can get down on the rocks at low water and catch a few fish, or occasionally a seal. The authorities give them a good deal to do to occupy their time; weather reports and daily journals have to be filled up, daily expenditure of oil, glass chimneys, or other stores, must be recorded, and everything in the establishment must be kept scrupulously clean. A look-out during the daytime has to be kept for the appearance of any of the vessels which attend on the lighthouses, in which event the flag has to be hoisted, and any communications made by signal which may be necessary. At some stations systematic meteorological observations are made; while when fog comes on a bell or other sound-producer has to be set in motion and kept going as long as the fog lasts. These numerous duties, combined with the necessary operations of eating and drinking, are sufficient to fill up the day ; but when sunset arrives the main purpose of their attendance has to be looked to, the lights are lit, and by an equitable division of time each keeper takes his fair share of the night watch. It is not difficult to believe that the seclusion and novelty of the situation might be agreeable for a short time, but not so for a permanence. As a matter of fact, however, there are men who after being some time at a rock station become quite attached to it, and do not wish to leave it for one of the shore stations. It is fortunate that there are men who develop such tastes.

It is very seldom, indeed, that a rock lighthouse has proved a refuge for shipwrecked men. There are obvious difficulties in the way of its being made available for such a purpose. The sea breaking upon the rock on which the tower stands is generally so turbulent as to render it an impossibility for a human being to retain hold or footing for an instant, while the ladder of ascent to the doorway is of necessity terribly exposed and cannot be protected in any way.

It has been stated that four keepers are attached to an isolated rock station, but in the case of a lighthouse within signal distance of dwellings on the shore three only are considered necessary, each of whom has one month ashore and two months' duty at the lighthouse, so that two men only are at the station together. At iron screw-pile lighthouses erected on sandbanks, the habitable accommodation is exceedingly cramped, much more so than in a stone tower. There is barely room for two men, and, as such lighthouses are generally close to the track of navigation, any urgent necessity can be readily signalled to passing vessels ; consequently two men out of the three attached to the station remain on duty, while the third is on shore. As at rock towers, the men go ashore in rotation after two months' duty at the station. The number of keepers at other lighthouses is regulated by the number and nature of the lights to be attended to, but a shore station where there is only one light has two keepers only, who perform continuous duty without relief.

At shore stations things are naturally much more comfortable than at rock or pile lighthouses. Each keeper has a well-furnished cottage, with garden and piggery. The large majority are married men, and their cottages are their homes. At many places there are, however, certain drawbacks in connection with the difficulty of obtaining school education for children, the absence of opportunities of attending a place of worship, and the difficulty of procuring medical attendance. These inconveniences arise from the necessarily isolated situations of the lighthouses, they being often perched on the summits of wild headlands far from towns or even villages, difficult of access, and in some cases communication having to be made by sea. But the watchful authorities do not lose sight of such matters as these, and facilities are afforded for the performance of special religious services at some of the stations, while changes are made from time to time so as to avoid a keeper with a family of young children being detained for a lengthened period at a very remote or inaccessible lighthouse. Wherever it is practicable, a medical man residing in the vicinity is regularly appointed to attend on the keepers, but in some instances this is simply impossible. All lighthouses, however, both shore and rock stations, are furnished with a medicine chest, with full directions as to how and when the drugs, &c., are to be employed, the scale of medicines, &c., being in accordance with that required by the Board of Trade to be kept on board British merchant-ships in pursuance of the provisions of the Merchant Shipping Act.

An electric light station necessitates the employment of elaborate machinery; consequently a skilled engineer is placed in charge of such an establishment. He has a number of assistant-keepers under him who have to stoke the fires and attend to the engines, electric machines, &c., besides taking their night watches in the lantern in turn. The pay of the keepers at an electric establishment is higher than that at an oil station, in consideration of the additional labour entailed, and the additional knowledge with which the men have to possess themselves in regard to the motor engines and the machines for generating electricity. The engineer in charge supervises the working of the whole place, and sees that his assistants do their duty properly.

At a station where gas is used as the illuminating agent there are also different conditions of service existing. Gas has to be made at the station, an operation requiring special knowledge and additional labour.

With many of the lighthouses some sound-producing apparatus is associated, intended to be made available when fog obscures the light. Here again in most cases the keepers have to be sufficiently acquainted with the machinery to be able to set the instrument in operation and to keep it going. Of fog-signals generally we shall speak in another chapter, but we allude to them now in connection with the duties of a lighthouse-keeper.

Taking the service as a whole, it would appear that the men are happy and contented; that the few inconveniences and risks connected with their vocation are balanced by advantages which are not to be found in more ordinary employments. A principal keeper is paid about *72l.* a year, being also supplied with uniform clothing, a comfortably furnished house, fuel and lights, besides all the necessary appliances and stores for cleaning, sweeping, &c. He is assisted to insure his life, so that in the event of his death there is a small provision for his family, and when he himself is enfeebled by age, so that active service becomes a burden to him, he can retire on a pension to spend the rest of his days in peace. An assistant-keeper's pay is, of course, not so high as a principal's, but the advantages in other respects are equal.

The following extract from the 'Regulations for the Lighthouse Service' in this country will appropriately end this branch of the general subject, and will give a plain indication of the spirit by which the makers of the Regulations are influenced in their supervision and direction of this most important service:—

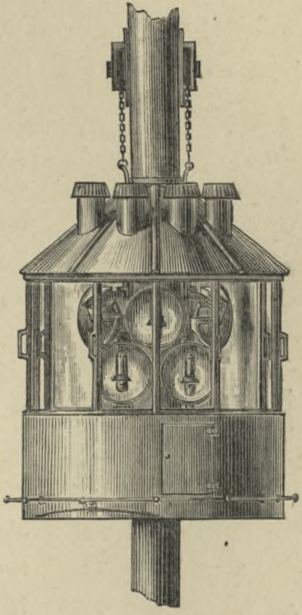
'The keepers, both principal and assistant, are enjoined never to allow any interests, whether private or otherwise, to interfere with the discharge of their public duties, the importance of which to the safety of navigation cannot be overrated; and they are cautioned that their retention or promotion in the service depends upon their strict obedience to orders, and upon their adherence to the rules laid down for their guidance; on the exercise of constant habits of cleanliness and good order in their own persons and that of their families, as well as in every part of the lighthouse establishment and premises; and they are warned that any breach of good conduct, temperance, or morality, or the use of bad language, will render them liable to instant dismissal or other punishment, or, on the part of any of their families, to their exclusion from the Corporation's premises.'

CHAPTER IX.

LIGHTSHIPS.

We have seen that the seas adjacent to our coasts are interspersed with dangerous and sometimes extensive shoals, and that on account of those obstacles navigation is rendered difficult and often perilous. Even at so great a distance as thirty miles from land these treacherous shoals waylay the mariner, the deep-water passages between them, through which the tides run with great velocity, being frequently very narrow. At low water many of these banks become visible, but before and after high water they are most frequently submerged ; and though the open area of sea may appear to be smooth and inviting, underneath lurk the sandbanks, very little below the surface, which would be fatal to any vessel attempting to pass over them, especially in bad weather. It is obviously impossible that lighthouses on the mainland can in all cases be made serviceable in directing vessels how to thread their way through the intricacies of narrow channels running in all directions, and distant perhaps fifteen, twenty, or thirty miles from the coast. Something more is necessary to aid the mariner when he approaches the belt of sea immediately surrounding our islands ; directions must be more definite, and the marks brought closer to the points or dangers required to be indicated. To meet these requirements, lightships or floating lights were established. It was not until lighthouses had been in existence for a considerable period that the idea of mooring floating lights in certain positions was carried into effect. The first lightship was placed at the Nore, at the entrance of the Thames, in 1731, for the benefit of vessels entering and leaving the port of London. On the requisition of the colliers voyaging up and down, and at the general desire of the shipping trade of the East coast, another floating light was placed in 1736 to mark the Dudgeon Shoal off the coast of Lincolnshire, at the entrance of the Wash, so that with easterly winds vessels could, by keeping outside the lightship, avoid getting embayed. In those days the vessels employed as lightships were sloops, each with two lanterns fixed horizontally on a crossyard on the mast. Many years elapsed before the system was extended ; but in 1788, the question of marking the Owers Shoal, off the South coast, being under discussion, it was resolved to place a floating light there ; and vessels bound to Portsmouth, Southampton, and the Isle of Wight have been and now are greatly assisted by it. After that, in 1790, a floating light was placed close to the Newarp Sand, off the Norfolk coast, which was followed in 1795 by one moored to the NE. of the Goodwin Sands. From this vessel three lights in a triangle were first exhibited. Three years later, the Sunk lightship was placed on the extremity of the Sand of that name, situated at the entrance of the north channel into the Thames. At the beginning of the present century the Galloper Sand at the Thames entrance and the Gull stream, between the Goodwins and the mainland, were marked by floating lights. On coming to our own times, we find there are nearly fifty lightships now in position for guiding and warning purposes around the English coasts, ten to indicate the shoals and channels adjacent to the shores of Ireland, but none at all employed on the Scotch seaboard. The reason for the absence of lightships around Scotland is because its coasts are rocky and not friable; very few sand or mud shoals are formed in the adjacent waters, and lighthouses on the salient points of the mainland or on the isolated rocks are sufficient for the purposes required, the water being nearly always of good depth close to the shore.

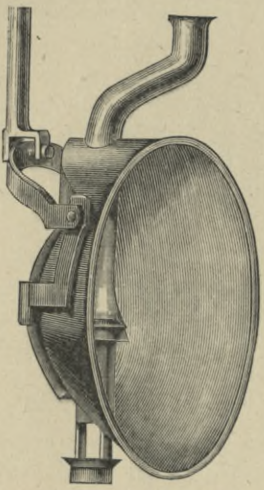
English light-vessels are always painted red, those off the Irish coast black, with the name in large white letters on both sides. Another distinguishing characteristic by day is that at the masthead a large wooden globe, diamond or other shape, is carried. Encircling the mast is the lantern, which is lowered on to the deck in the daytime, but hoisted up the mast when lighted. If two lights are shown from a light-vessel, she has two masts and two lanterns.



Lantern around Mast.

The lights exhibited from lightships, and the method by which the vessels are moored so that they remain at their stations and ride securely through the most tempestuous weather, are the chief considerations in connection with this branch of 'Our Seamarks.'

The lantern encircling the mast contains a number of argand lamps and reflectors. If the character of the light is fixed, the lamps are adjusted so that they send out a constant band of light all round ; if revolving, a certain number of lamps and reflectors (three, five, or seven) are arranged on a face, three or more of such faces being fitted in a framework, as already described in connection with the catoptric system for ighthouses (page 41). By clockwork mechanism very carefully regulated, the whole framework is made to revolve, each face bringing round its own combined beam at regular intervals as appointed. But no doubt the question will occur to many, How can an elaborate arrangement of lamps, glasses, and reflectors be kept in position in a ship, whose lurches must be sufficient to displace any such arrangement? The answer is that every lamp, with its associated cistern and reflector, is hung on a gimbal, so that it has free play in all directions; and when the vessel rolls or pitches, the lamp, by its own gravity, maintains an approximately constant vertical position. It is, of course, of the highest importance that the lamps should be properly hung, otherwise there would be endless breakage of the glass chimneys, spilling of the oil, and extinction of


Argand Lamp and Reflector on Gimbal.

the lights. The number of the lamps employed on board different lightships varies from nine to as many as twenty-four. Rape or colza oil only is used—mineral oil not being yet regarded as sufficiently safe for the trying conditions under which the lights are maintained. On an average, it may be said that one lamp consumes about thirty-six gallons of oil in a year, or, say, three-quarters of a pint per night, taking an average of all the nights in the years: the total expenditure for the different lightships therefore varies according to the number of lamps employed.

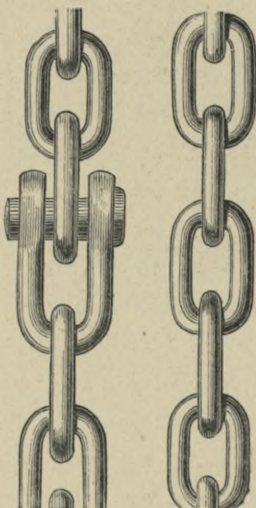
The argand lamp already referred to as used in some few lighthouses is in all respects similar to that employed for lightships; it is therefore needless to again explain it. The reflectors are also similar in construction, but on board lightships the smaller-sized reflectors—*i.e.* those twelve inches in diameter across the mouth—are at present more generally in use, although they are being superseded by the 21-inch reflectors, the employment of which, by providing a larger divergence of the light, enables a less number of lamps to be used, the result obtained in illumination being equal to that yielded by a larger number of lamps with the small reflectors. Some further improvements in connection with these lamps have recently been made by Sir James Douglass, the engineer to the Trinity House, which considerably increase their illuminating power, two and three wicks having been introduced. Every precaution is taken to ensure perfect ventilation in the lanterns, so that the heated air escapes freely and fresh air is equably supplied without irregular draughts or puffs, which interfere very much with the proper burning of the lamps.

In connection with the maintenance of the lights it is very seldom that anything goes wrong. Accidents will happen at times, in spite of the greatest care, such, for instance, as an occasional breakage of glass chimneys, or the clockwork machinery getting out of order, or a pane of lantern glass breaking by birds flying against it, &c. But such things are seldom due to culpable negligence on the part of those in charge.

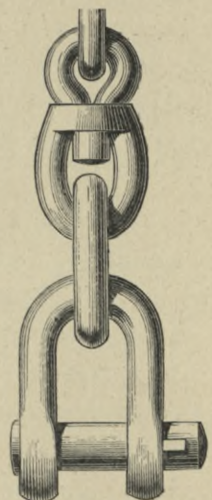
It is of course necessary that lightships should be easily identified at night-time, and with that object various characteristics are applied to the lights so as to distinguish them from each other, and also from any neighbouring lighthouses. In a former chapter we have indicated the nature of the distinctions now in general use for lighthouses, and of these many are applicable for lightships, such, for instance, as single or double fixed lights; revolving lights with varying intervals of darkness between the beams, or with coloured beams alternating with white, or with coloured beams altogether. The system of showing a group of flashes following each other in quick succession at certain intervals has also recently been successfully applied in connection with the arrangements of lamps and reflectors on board lightships. This system affords abundance of variety without the use of colour, it being possible to diversify the lights by changing the number of flashes in a group, and by varying the intervals of darkness between the groups. The lightships of the Royal Sovereign near Beachy Head, the NE. Goodwin, the Seven Stones off Scilly, and others are distinguished by this method, and seamen speak of their effectiveness in the highest terms, and are able to recognise them with facility.

The next point we have to consider is the method of mooring the lightships, so as to ensure their remaining at their stations and riding with safety in tempestuous weather. This is obviously as important a matter as the maintenance of the light itself. When lightships were first placed as seamarks, there were frequent instances of their breaking adrift, whereby a certain mistrust of them was engendered, which probably operated to retard their more general adoption. Of late years, however, the perfection of the manufacture of mooring chains, the experience of many years as regards the behaviour of lightships in bad weather, and the consequent knowledge of the best method of handling the vessels, have combined to prevent the recurrence of such disasters, the fact being that for more than twenty years no instance of one of our lightships breaking adrift has occurred.

The links of the mooring cable now in use are made of iron $1\frac{1}{2}$ inch diameter. The chains are manufactured with the greatest care, and before being accepted for service the iron of each link is required

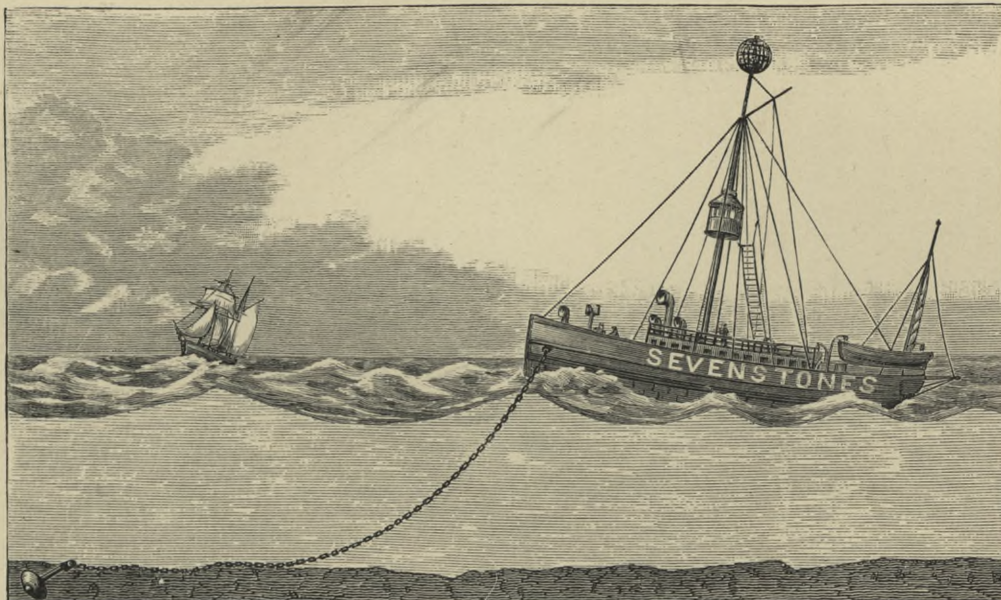


Link of Mooring Cable.



Swivel.

to bear a tensile strain of 23 tons per square inch of original area, and subsequently three four-foot lengths cut from any cable selected indiscriminately are further tested for the welding, when the ultimate breaking stress must not be less than 16 tons per square inch of each side of the link. These tests are

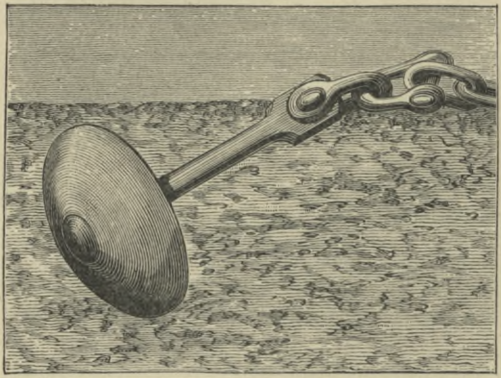


SEVENSTONES LIGHTSHIP, SHOWING MOORINGS.

To face page 108.

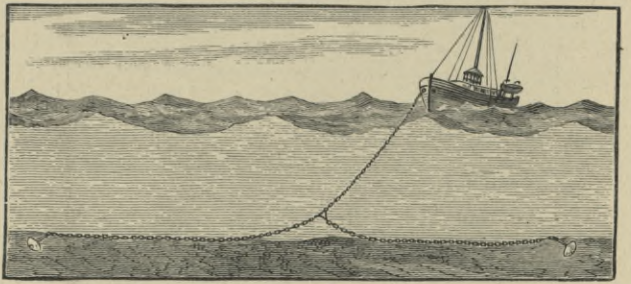
most rigorously carried out, and any chain not coming up to the requirements is at once rejected, and has to be replaced by the contractor.

The chains are made in fifteen-fathom lengths, with a swivel, to prevent kinking, in the centre of every alternate length, and are joined by shackles, all of which have to undergo a breaking stress as severe as the



Mushroom Anchor and Chain.

links of the cable. From 210 to 315 fathoms of such chain cable are supplied to every lightship, that at the Seven Stones, which is moored in 40 fathoms of water, having 315 fathoms of cable. Ordinarily, this cable is directly connected with a mushroom or Martin's anchor lying on the sea-bed and weighing two tons, and the lightship so moored swings round as the tide changes. Another method of mooring is with two mushroom anchors connected by a length of 2-inch ground chain which lies along the sea-bottom, a mushroom being at each end. In the centre of this length of chain are a ring and swivel, to which is attached a $1\frac{1}{2}$-inch chain which leads up into the vessel, and by which she rides. This plan of ground moorings is employed in places where the channel to be indicated is very narrow, or where the vessel



Ground Moorings.

has but little room to swing round with the tide. The veering cable can be hove short so that the vessel swings in a very small area. In addition to the mooring cables and anchors above referred to, every lightship is supplied with two bower anchors for use in case of emergency, and an additional length of 150 fathoms of $1\frac{1}{2}$-inch chain. But although it is of the utmost importance that every precaution be taken to obtain the very best quality of materials, yet it is chiefly by the skilful management of the mooring cable that a lightship is enabled to ride out the fiercest storms in safety. With a smooth sea, a short cable is sufficient, but when the waves run high it is necessary to pay out a long scope of chain, so that the ship may ride over the highest crests and plunge down into the lowest depth of the trough of the sea. It is also necessary to have a very great deal more cable out than is actually required to enable the vessel to surmount the highest waves; she must never be allowed to go to the end of her tether and pull directly upon her mushroom; as the vessel rises she takes as much chain as she requires, but still must leave a considerable quantity on the sea-bed. This surplus cable, by its own weight, acts as a spring, and entirely prevents any direct jerking or straining at the mushroom. The experience of years has educated the officers of our lightships to regulate the scope of cable paid out to the necessities of the occasion. The constant rise and fall of the cable and the swinging round of the vessel with the tide are at times the cause of strange entanglements, and it is by no means an uncommon duty for one of the steamers of the service to go out to 'clear the moorings' of a lightship. In this connection it may be pointed out that herein lies the chief obstacle to connecting lightships with the shore by means of submarine telegraphic cables. The crucial point is to get the telegraphic cable away from the lightship without risk of its being fouled and probably broken by the mooring chains with their varying and ponderous movements. The possibility of doing this has not yet been practically demonstrated, but the public, not being generally aware of the nature of the difficulties which prevent electric communication being established, and seeing only that in cases of shipwreck such a means of conveying intelligence might have been serviceable, have been somewhat clamorous for its being forthwith carried into effect. It is much to be hoped that the experiment now being made by the Trinity House will bring the desired object within the range of practicability, and that before many years are passed all lightships will be enabled to communicate with the shore by means of submarine electric cables.

In the event of success being attained in this respect, possibilities hardly thought of now will then present themselves. Even the light itself may ultimately be produced by electricity, conveyed from the shore by submarine cables; and it is more than probable that the public usefulness of lightships will be capable of great development, if between them and the mainland telegraphic communication is satisfactorily established. At present the means of calling assistance consists of signal flags or guns by day, and rockets by night. The flags in most cases cannot be made out from the shore, but a passing vessel may read the signal and carry the intelligence to the nearest port. Guns are rather more effective than the flags ; the flash of the former is often visible when flags cannot be made out at all ; distance frequently prevents their being heard, although when firing commences from one lightship it is taken up by any neighbouring lightship where it may be heard, and thus the chance of the signal being answered is increased. An effort has been made to utilise carrier pigeons for conveying messages from the vessels to the shore, and it is no doubt possible, by judicious breeding, severe training, persistent care and watchfulness, to make them useful under certain conditions. But to successfully develop such a plan would be work for an enthusiast who would *con amore* devote the whole of his time to the undertaking. And even if an efficient service of messenger birds were established, they would only be available in fair weather when least likely to be wanted, for they will not fly at night-time, in fog or falling snow, and when a gale is blowing the strongest bird is liable to be carried away to leeward.

From lengthened experience it has been found that wood is the most suitable material for the hull of a lightship. A wooden vessel will ride at her station for seven years before requiring to be overhauled, cleaned, and painted; with iron ships, on the other hand, the bottoms foul very quickly, and they have to be brought in for cleaning, &c., every three years. Furthermore, iron ships are cold and uncomfortable for the crew, and in the event of a collision are likely to be more seriously damaged than wooden hulls. The form of a lightship is adapted to her vocation, viz. to remain in one place. Her lines are not fine, nor are her bows sharp. She is very strongly built, and although a landsman might find her a most uncomfortable craft, yet in every respect she is a first-rate seaboat.

The crew attached to such a vessel numbers eleven all told—the master, mate, three lamplighters, and six seamen. Of these, seven only are on board the vessel. The master and mate have alternate months afloat and ashore: the others have each two months afloat and one month ashore. While on shore the men have certain duties allotted to them at the district depot. Every lightship is visited once a month by the attendant steamer, which takes out those who have had their month ashore, and brings back those whose turn it is to be relieved from sea duty. The visit is known as the monthly relief, and it is then that the lightship is furnished with stores, water, and provisions sufficient to last considerably beyond the time when the next month's relief would be due. This precaution is taken in case the weather should be so bad as to prevent communication with the lightship, a state of things which happens more often than is agreeable to the men waiting to go ashore. This monthly visit is not the only call that is made on the lightship people. Other steamers of the lighthouse service, with some of the authorities on board, are frequently running about from place to place, and they visit the lightships at unlooked-for times. Passing ships often give them a friendly hail, and sometimes send them a bundle of newspapers, a boon which the lightship men appreciate highly. Occasionally they are able to do a little business with the fishing boats, but at some stations they are able to catch a good deal of fish for themselves. Now and then a shipwrecked crew has to be received and entertained, which is naturally a very important event on board. Occasionally, and indeed much more frequently than might be supposed, a lightship is run into by a careless navigator, or a too smart captain who likes close shaving. This is a most serious matter for those on board the lightship, which is not under any sort of command as regards motion. Some years ago the Tongue lightship at the entrance of the

Thames was run into by one of the steamers which trade regularly into and out of the river, and was cut down to the water's edge so that she sank almost immediately, the master and crew being saved with difficulty.

In a general way it can easily be understood that life on board a lightship is monotonous and wearisome, but every effort is made to occupy and divert the minds of those on board. Their daily duties are clearly defined and have to be scrupulously carried out; books in plenty are always on board, there being a circulating library in connection with the service; the men are most of them ingenious in some kind of work, such as shoe-making, toy-making, veneering, &c., with which they occupy themselves on board. What they have to contend with is the depressing influence of the vessel being stationary, of her never going on, but remaining moored to one spot, a plaything for the waves, with the same endless, monotonous waste of waters everywhere around. There is little poetry in the sea from their point of view. But notwithstanding all this there are fortunately plenty of men willing to join the service, and avail themselves of its advantages: good pay, uniform clothes, pension when old and unfit for service, and the prospect of rising from the grade of seaman to be master of a lightship, are inducements which attract many; and with the strict discipline which is maintained, and the watchful supervision which is always exercised over the service, the vessels are efficiently manned, and the lights unfailingly shown at night, to the great benefit of navigation near our shores.

CHAPTER X.

BEACONS AND BUOYS.

BEACONS and buoys are a very important branch of 'our seamarks,' and contribute greatly to the value and efficiency of our coast-marking arrangements. They are exceedingly numerous, and are invaluable to master mariners and pilots as guiding marks by day through narrow channels, and as warning marks for isolated dangers, but being as a rule unilluminated, they are not so serviceable at night-time.

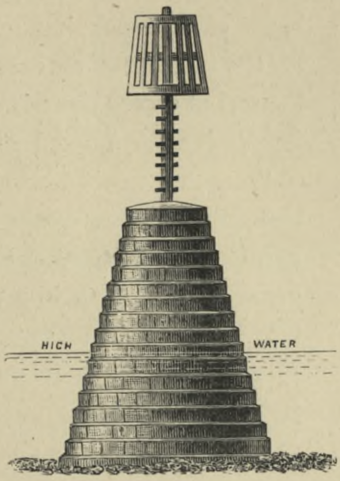
The term 'beacon' as distinct from a lighthouse may possibly seem anomalous to those for whom the word still retains its ancient and more comprehensive meaning. In olden times the term beacon was always associated with flaming bonfires on high points of land, with signal lights and seamarks of all kinds,—and doubtless this general signification is so understood by many at the present day. But in connection with 'our seamarks' the term must be defined more exactly to take its proper place and to receive the amount of consideration due to its importance. It is the custom with those who have to do with lighthouse affairs to use the term in a much more restricted sense than that in which it was formerly used, and to apply it only to those unlighted pillars and other structures set up on rocks or sandbanks, or on the low outstretching points of land in the estuaries and broad parts of great

River Thames Reaches.

rivers and elsewhere, which at certain times of the tide are hidden from the mariner's sight. In the long tortuous reaches of the Thames they are of great service. With the high spring tides nearly all the outstretching points of land at the bends of the river are submerged.

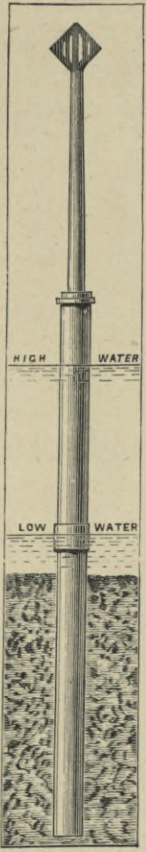
At the end of nearly every such point a beacon of some kind is placed, and although the point itself is hidden the head of a tall mast, pillar, perch, framework, cylinder, or other structure on the extreme point, shows above water, and warns the navigator that by keeping outside of that head he will be safe. The writer was once witness of a casualty occasioned by the master or pilot of a powerful screw steamer not seeing one of the Thames beacons. The vessel was proceeding down the river at half speed on the top of a high tide in a thick misty rain drizzle. The beacon which stood on one of the points, although showing above water, was not seen by those on board, probably owing to the state of the atmosphere, and inadvertently the vessel was steered inside the beacon. The result was that she ran her nose forcibly into the submerged bank, and, notwithstanding the exertion of four tugs, which after a time came to her assistance, remained wedged in until the next tide. Luckily there was no danger of her being battered and knocked about by furious waves, or the result would have been much more serious.

There are probably about 250 recognised beacons on the British coasts, each serving some special purpose, and of these 250 there are various kinds. Many are simple structures of masonry on land, doing duty by day as prominent objects for leading through certain channels, for the avoidance of special dangers, and for guidance in entering harbours, anchorage grounds, &c. The majority of these have been specially erected for the purposes which they serve, but others are monuments erected for commemorative purposes at one time or other, which, being found serviceable by the



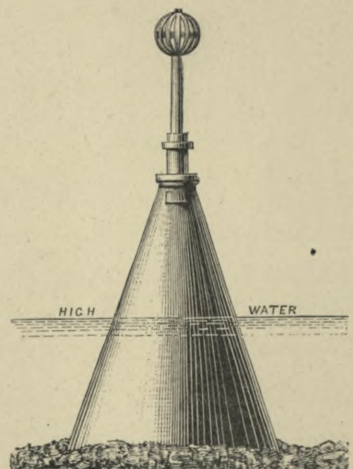
Stone Beacon.

mariner, have been appropriated to his use, and have been repaired and maintained for his benefit. Others are iron framework or cylindrical structures: then there are masts, poles, or perches with stays, the mast being made of iron or wood. Fishermen's beacons may be seen in plenty on the sea-coast, and are of a very simple character. But every beacon set up has some special characteristic, so that mariners may recognise it, being usually surmounted with a characteristic head, in the form of a globe, diamond, cross, triangle, &c. &c., and wherever a spot requiring to be marked is neither large enough nor important enough for the erection of an expensive lighthouse, but where there is some sort of foundation for a fixed structure, one of these beacons is erected. The iron beacon which now marks the Shingles Sand off Margate was erected some years ago: it is an iron cylinder two feet six inches in diameter and 48 feet long. It was taken out in two pieces, and at low water when the sand was nearly dry one half of the cylinder was set on the sand. A man then went inside, and in this very limited space had to dig out the sand, which was hoisted up in buckets. As the sand was taken from the inside the cylinder gradually sank, aided by a little battering on the outside, until it was fifteen feet down; the



Shingles Beacon.

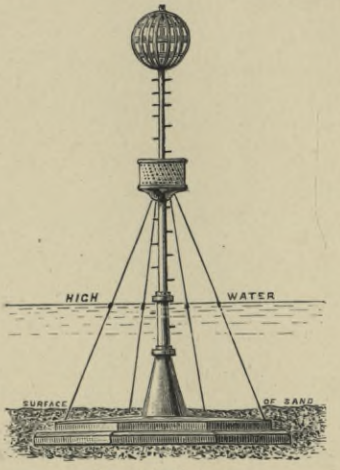
other half was then fastened on and the operation continued until the cylinder was twenty-five feet deep in the sand. The inside was then filled up with shingle mixed with cement, which, with the water that made its way up from the bottom, formed a hard concrete ; a mast was then fixed in the concrete, the upper part protruding about 20



Wolf Rock Beacon.

feet above the top of the cylinder, and at the head of the mast was fixed a diamond-shaped frame. Other iron beacons of a somewhat similar kind have since been erected on the sandbanks at the Thames entrance.

Before the lighthouse was built on the Wolf Rock off the Land's End there was a beacon on the rock to mark it at high tide. It was a simple cone of masonry with a mast and globe at the top, and it is said to have cost more than 10,000*l.* to place it there. Occasionally beacons in exposed situations are carried away by the force of the waves. On the Goodwin Sands there stood for about thirty years a warning



Goodwin Beacon.

and refuge beacon which was washed away in 1877. This consisted of an iron mast, with ladder steps leading up to the refuge cage considerably above high-water mark, and capable of holding several persons.

As a general rule, beacons such as those of which we are now treating are not lighted up at night, but it has been mentioned that some beacons in Scotland are remarkable exceptions. At the entrance of the anchorage in Stornoway Bay, Isle of Lewis, Hebrides, is Arnish Rock, 530 feet distant from the island of Lewis, forming a dangerous obstruction in the narrow channel leading into the anchorage. Upon this danger a conical beacon of cast iron is placed, on its summit a lantern is fixed, and from it a useful light is diffused indicating not only the position of the rock but also the channel leading to the anchorage. The interesting feature connected with this light is that in the lantern there is no burning lamp, no light-producing agent at work; moreover, no one goes near it night after night, and yet every evening a light shines from the beacon. The effect is produced in the following manner. On the adjacent Isle of Lewis there is a lighthouse, and from a lower window in the tower a condensed beam of light is projected on to a mirror in the lantern on the top of the beacon, so placed as to reflect the rays on to an arrangement of prisms; by the action of the prisms the reflected rays are made to converge to a focus outside the lantern, from which point they again diverge in the required direction. The effect produced is that of an actual lamp burning in the lantern, and it is found by fishermen and others to be of the greatest service in entering the harbour.

It is called an apparent light, and is an economical method of lighting a dangerous rock and of providing an efficient guide into the anchorage. A lighthouse built on the rock itself would be attended with very great expense, but the plan now adopted answers the purpose as well as if a lighthouse were there. The range of the light is not great, but it is sufficient. This method is also in operation at Grangemouth in the river Forth, and at Ayr in the Firth of Clyde.

One of the best features of beacons is that when once put up securely they cost almost nothing for their keep. To maintain in efficient working order lighthouses, lightships, buoys, or fog signals requires a great deal of personal attendance and the annual outlay of a considerable sum of money, but, beyond the cost of an occasional inspection and coat of paint, the beacons are not a very expensive item in the total charges for keeping up 'our seamarks.'

We will now pass to the consideration of 'our buoys,' those uneasy, restless bodies which are encountered here, there, and everywhere by the mariner when prosecuting his voyages. Motion is an inseparable characteristic of a buoy's existence. The unceasingly agitated surface of the sea imparts its perpetual motion to the buoy, which rolls and plunges with the most furious waves, dances playfully with the sunlit ripples, or gently rocks in slumber on the bosom of a sleepy undulating ocean. But under all these varying influences it does not alter its position, it coquettes with the waves and joins them in their sport, but nevertheless remains firm to its trust. Whatever the particular mission of any buoy may be, it appears to be always rising and curtseying before the eyes of the sailor as much as to say, 'Look at me; you know why I am here, so be careful.'

Probably there are close upon 1,000 buoys round the coasts of the United Kingdom. This number does not include warping and mooring buoys, which are not regarded as being entitled to rank amongst 'our seamarks.' We are dealing with those jolly fellows who in their bright-coloured coats tumble and dip themselves far out in the salt green sea. Each buoy has a special duty to perform, each one has to tell the mariner something which it is important he should know. Pilots rely mainly on their assistance in conducting ships through narrow channels; and the masters of coasting vessels could not pursue their voyages in safety without them. Seeing that so much dependence is placed on the buoys by mariners, it is obvious that every precaution should be taken to ensure their not being driven from their positions by wind or waves, tides or currents. Science and mechanical skill have done much in the adaptation of the shape and construction of buoys to enable them to withstand the sea's violence, and in the provision of mooring chains of sufficient strength to keep them in their places.

It is also obvious that every facility should be given to the mariner to enable him to distinguish between one buoy and another, or between one set of buoys and another. But it has been regarded as a perplexing element in the navigation of the channels adjacent to our coasts and leading to our great ports, that a general uniform system of employing buoys for marking out the channels is not in existence. At one port the mariner may find the buoys placed according to certain principles, while at another he may find them laid according to rules exactly the reverse.

Let us then consider the general question of distinctiveness. The chief elements of distinction for buoys are form, size, and colour, but these distinctions may be supplemented by the addition of a shape (globe, diamond, triangle, &c.) at the top of the mast fixed in the head of the buoy. In the early days of our seamarks, buoys in the shape of casks were generally used—probably the actual casks themselves, well bunged up, were made available. The more elaborate forms of buoy now used appear to be mostly developments of the original tub. It is not easy to follow the various changes which have been made from time to time in the shapes and sizes of buoys used on our coasts. The smallest buoys now in use are about four feet in length, but the employment of such small objects is being discontinued. The largest buoys which have been constructed have been as much as twenty feet long, but the difficulty of handling these monsters has led to their withdrawal, and the sizes now found to be most practicably serviceable range from six to thirteen feet in length.

The shapes of buoys around our coasts are various, and the distinctive appellations of the different kinds have been frequently changed. The descriptive title of a buoy should certainly indicate the appearance which it would present to those who have to depend upon the information it conveys. But unfortunately the nomenclature of the various forms of buoys has been somewhat unsettled ; their descriptive names are found to vary at different places ; and a further cause of ambiguity is the introduction of new forms of buoys, with the descriptive names of which mariners do not readily become familiar in the absence of any special description of their peculiar features. The terms nun, can, conical, convex, spiral, drum, cylinder, spherical, spar, mast, and cask have been and are still employed as descriptive titles of buoys, but few there are even among sailors who could accurately state what constitute the characteristics of each. But, in addition to variability of nomenclature, buoys of the same shape are employed to give the mariner exactly opposite indications at different places.

Again, the intimations conveyed by the colours of buoys vary at different places, and the nomenclature of the colouring arrangements is not always so definite as it might be. Red, black, green, or white, as whole colours, are of course plain enough, but with parti-coloured buoys a slight diversity of expression in referring to the disposition of the different colours is apt to lead to some confusion. Buoys painted in alternate bands of red and white, or black and white, are sometimes described as painted in rings, belts, or horizontal stripes; chequered buoys are occasionally referred to as being painted in squares, &c.

For many years efforts have been made to bring about uniformity as regards the use of buoys on our coasts. The Admiralty, Board of Trade, and Trinity House agreed upon a system which has for a long time been acted upon as regards the buoys under their management and control, but, there being no law to regulate the usage of other bodies, it has followed that some authorities prefer to adhere to their own methods, and the result is that different systems prevail at different places.

In view of the necessity for a general agreement on the subject, a conference of representatives of the various British authorities concerned has been held, under the presidency of H.R.H. the Duke of Edinburgh, Master of the Trinity House, and it has been resolved to propose for general adoption a uniform system of buoyage, as follows :—

'UNIFORM SYSTEM OF BUOYAGE.

'1. The mariner when approaching the coast must determine his position on the chart, and must note the direction of the main stream of flood tide.

'2. The term starboard-hand shall denote that side which would be on the right hand of the mariner either going with the main stream of flood, or entering a harbour, river, or estuary from seaward ; the term port-hand shall denote the left hand of the mariner under the same circumstances.

'3. Buoys showing the pointed top of a cone above water shall be called Conical, and shall always be starboard-hand buoys, as above defined.

'4. Buoys showing a flat top above water shall be called Can, and shall always be port-hand buoys, as above defined.

'5. Buoys showing a domed top above water shall be called Spherical, and shall mark the ends of middle grounds.

'6. Buoys having a tall central structure on a broad base shall be called Pillar buoys, and, like other special buoys, such as Bell buoys, Gas buoys, Automatic Sounding buoys, &c., shall be placed to mark special positions either on the coast or in the approaches to harbours, &c.

'7. Buoys showing only a mast above water shall be called Spar buoys.

'8. Starboard-hand buoys shall always be painted in one colour only.

'8. Port-hand buoys shall be painted of another characteristic colour, either single or particolour.

'10. Spherical buoys at the ends of middle grounds shall always be distinguished by horizontal stripes of white colour.

'11. Surmounting beacons, such as staff and globe, &c., shall always be painted of one dark colour.

'12. Staff and globe shall only be used on starboard-hand buoys, staff and cage on port-hand, diamonds at the outer ends of middle grounds, and triangles at the inner ends.

'13. Buoys on the same side of a channel, estuary, or tideway may be distinguished from each other by names, numbers, or letters, and where necessary by a staff surmounted with the appropriate beacon.

'14. Buoys intended for moorings, &c., may be of shape or colour according to the discretion of the authority within whose jurisdiction they are laid, but for marking submarine telegraph cables the colour shall be green, with the word "Telegraph" painted thereon in white letters.

'*Buoying and Marking of Wrecks.*

'15. Wreck buoys in the open sea or in the approaches to a harbour or estuary shall be coloured green, with the word "Wreck" painted in white letters on them.

'16. When possible the buoy shall be laid near to the side of the wreck next to mid-channel.

'17. When a wreck-marking vessel is used it shall, if possible, have its top sides coloured green, with the word "Wreck" in white letters thereon, and shall exhibit—*By day:* Three balls on a yard twenty feet above the sea, two placed vertically at one end, and one at the other, the single ball being on the side nearest to the wreck. *By night:* Three white fixed lights similarly arranged, but not the ordinary riding light.

'18. In narrow waters, or in rivers, harbours, &c., under the jurisdiction of local authorities, the same rules may be adopted, or, at discretion, varied as follows:—When a wreck-marking vessel is used she shall carry a crossyard on a mast, with two balls by day placed horizontally not less than six nor more than twelve feet apart, and two lights by night similarly placed. When a barge or open boat only is used, a flag or ball may be shown in the daytime.

'19. The position in which the marking vessel is placed with reference to the wreck shall be at the discretion of the local authority having jurisdiction.'

Mariners generally will probably fully endorse the recommendations of the Conference as regards the adoption of the shape of the buoy and not its colour as the distinguishing characteristic in marking our numerous navigable channels. It is undoubtedly true that the systems which have hitherto been and are now in operation have been long understood by pilots and mariners, but it is also true that the knowledge of their variations and complexities has only been arrived at by study and lengthened experience, and is only kept up by continual and strained watchfulness. Whatever tends to make distinctions more intelligible, more easy to grasp, is a direct gain to those who have to make use of such distinctions—more especially at times when the person responsible for the safe navigation of a ship has to exercise special vigilance in other directions, besides that of looking out for the characteristics of seamarks. The proposal of the Conference to make shape always the leading feature of a buoy is a large step towards simplifying the buoyage system, and consequently of facilitating navigation through our channels. Colour must necessarily be an uncertain element as the distinguishing medium for objects continually washed by salt water, and subject to the varying lights and refractive influences of the atmosphere suspended above the sea surface. But its use as a subsidiary means of variation will no doubt be still continued with advantage, when once the limiting sides of a channel have been marked by buoys of different shapes.

It is also very satisfactory to observe that the nomenclature of buoys is to be simplified, and that practically three shapes only are to be recognised for general use. The definitions of the terms conical, can, and spherical as applied to buoys are most valuable. It seems really too good to be true that, although buoys may vary in size, yet the large majority of them will be conical, can, or spherical in shape. Pillar and spar buoys will each have their special functions, but they will be in a small minority in the school of buoys around our coasts.

And now a few words as to the construction of the buoys and mode of keeping them in their places.

Exposed to the angry buffetings of the waves, and to the risk of being run down or struck by steamers at night, it is necessary that the buoys be constructed as strongly as possible. In olden times the material used was wood, but in this iron age wood is only employed for wreck, spar, and mooring buoys, all the more important kinds being made of iron. Wooden buoys are made with staves bound together with iron hoops. The plates for iron buoys are three-eighths of an inch thick, and are strongly riveted together. The internal space of an iron buoy is divided by bulkheads into watertight compartments, so if a hole be knocked in one part of the buoy the remaining compartments will keep it afloat. A compartment at the bottom is filled with water for ballasting purposes, which assists the buoy to ride properly. Important questions as to the stability of buoys and their riding qualities have to be considered in connection with their construction, having regard to tidal and wave action in urging them from the perpendicular.

A buoy should be of such a shape and so weighted as to retain under ordinary circumstances as much as possible an upright position, and must have sufficient floating stability to withstand its liability to be carried under or to loll on one side by the action of strong tides or currents.

Each buoy is held in position by a mooring chain attached to a flat iron sinker. The chain varies from five-eighths of an inch to one inch and a quarter diameter of iron, according to the size and weight of the buoy to be moored. The sinker varies also in weight from ten to thirty hundred-weight, according to the size of buoy and the depth of water in which it is placed. As a rule, a length of chain equal to three times the depth of water is given to each buoy, so that in rough weather the buoy may have ample scope for riding on the top of the waves, and sudden jerks or wrenches on a taut cable may be prevented. But, notwithstanding all these precautions, a buoy does now and then break from its

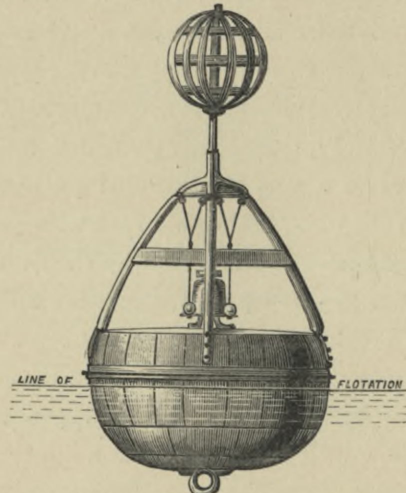
Buoy Chain and Sinker.

moorings ; a vessel runs it down, or the cable gets worn on the bottom, and it goes dancing off wherever the wind and tide may carry it. Buoys which have strayed from our waters have been picked up on the shores of Norway, Denmark, Belgium, and France ; some have never been seen or heard of again, and are probably at the bottom of the sea or may be wedged up in the ice at the North Pole. Everything is done, however, with a view to prevent such accidents. The officers of the various authorities, particularly those of the three General Lighthouse Boards, are constantly inspecting the buoys. As soon as a buoy is observed to be dingy or rusty it is painted afresh ; if it rides in a suspicious manner it is taken in for overhaul, its place being in the meantime occupied by its duplicate ; if the sand which it marks alters in shape, the buoy is moved ; or if a new shoal appears, new buoys are placed as soon as possible to mark it. Periodically the moorings of every buoy are examined, and if needful are changed.

In addition to the distinguishing shape of a buoy which helps to indicate the relative position of the danger to be avoided or the channel to be adhered to, a further individuality must be conferred on each buoy by giving it a name. This name, which generally has reference to the danger to be marked, is painted in large white letters on a plate and affixed to the buoy.

Various proposals have been made at different times for increasing the usefulness of buoys. It has been proposed to connect them with electric wires all round the coast, and to light them all simultaneously with the electric light. Matters, however, are not yet sufficiently ripe for so startling an innovation as this, but a great advance in the direction of the illumination of buoys has been made by the introduction of a gas-lighted buoy. M. Julius Pintsch, of Germany, has brought out a plan for making gas in an economical way from various kinds of fatty refuse, and of compressing the gas so made into a very small compass. Using the body of the buoy as a receptacle for this compressed gas, a pipe connects the gas chamber with a burner enclosed in a small strongly made lantern at the top of the buoy, and thus, at about eight or ten feet above the water level, a light is produced and maintained successfully. The gas is admitted at an even pressure to the pipe supplying the burner by an ingenious automatic regulator, the invention of M. Pintsch. It is plain that the confined gas must exert a very considerable pressure on the walls of its chamber, and would rush with great force through any available outlet, but by the action of the regulator the gas can pass through the tube only at a very low pressure, just sufficient to keep a fair light always burning. It thus depends upon the amount of compression to which the confined gas has been subjected how long it will maintain a light. As soon as the pressure of the gas inside the buoy comes down to fifteen pounds on the square inch, equilibrium is established between it and the external atmosphere, the gas no longer ascends to the burner, and the light goes out. One gas buoy in the river Thames has been burning for five and six months continuously, day and night, and has been found very serviceable by pilots ; the pressure at which the gas was stored in the buoy being equal to that of ten atmospheres, or 150 pounds on the square inch.

Up to the present time the efforts to make luminous paint available for the illumination of buoys have not succeeded well. The fluorescent light emitted by the paint is not intense enough to be of service a



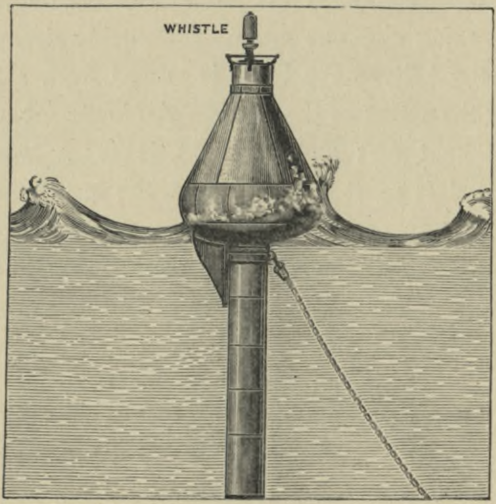
Bell Buoy.

long way off, and although an object so painted might become visible at a very short distance sooner than one not so painted, and to that extent might be useful, yet at the longer ranges, when it would be really serviceable to make out a buoy, it fails to give any definite assistance.

The application of sound for warning purposes at night and in foggy weather is made available in two kinds of buoys—viz. the bell buoy and the automatic whistling buoy.

For the former the buoy is made rather larger and heavier. The bell, about three cwt., is fixed in an iron framework above the platform of the buoy, and four hanging clappers around the outside alternately strike the bell as the buoy is moved from side to side by the action of the waves. An incessant tolling is thus kept up; and at night, in foggy weather, the signal is most useful to mark the turning-points at the entrances to important ports and at other places where the navigation is intricate, or to mark isolated dangers. The number of bell buoys round the British coast is considerable.

The other kind of sounding buoy is the automatic signal buoy, devised by Mr. J. M. Courtenay, of New York, by which a powerful whistle fixed at the top of the buoy is sounded automatically by the action of the sea. The apparatus consists of a buoy, twelve feet in diameter, with a tube of thirty-three inches in diameter and thirty-two feet in length passing vertically through the centre, and descending below the bottom of the buoy to a depth of about twenty feet, the object of this length of tube being to reach a depth where the water is not subject to wave agitation. The bottom of the tube is open, and freely admits a column of water, which is maintained at a constant level, and is not affected by the external superficial wave motion. The buoy, however, with a broad rounded bottom, moves with the surface undulations of the water, and of course carries the tube up and down with it, thus



Courtenay Buoy.

establishing a piston and cylinder movement, the column of water in the tube forming a piston, and the tube itself being a moving cylinder, the weight of the buoy and the tube exercising a considerable pressure. By means of the motive power so established, air, which is admitted by stop-valves into that part of the tube which is above the level of the water, is compressed and forced through a pipe two inches and a half in diameter, communicating with and sounding the whistle at the top.

This instrument has been successfully employed in various parts of the world, and is regarded by many as superior to the best kind of bell buoy. The inventor claims for it 'that in thick or foggy weather, on the passage of any wave or undulation which will cause the instrument to rise and fall six inches or more, it will emit a sound that can be heard distinctly from five to seven miles.' As regards the distance of audibility this statement must be accepted with reserve; inventors and patentees are as a rule sanguine persons. Several of these buoys have been placed for practical trial on our coasts; and on the coasts of the United States, France, Germany, &c., they have been in successful operation for about two years.

CHAPTER XI.

COAST FOG-SIGNALS.

It will be observed that the various seamarks which have been dealt with are those which appeal to the sense of sight only. All signals intended for human purposes are of course dependent upon human perceptions for their comprehension. Sight, as we have seen, is made available.

But the necessity for conveying information to the mariner is found to exist at times when sight is unavailing, and the sense of hearing has naturally suggested itself as the perception which should be appealed to.

The effective employment of sound signals appears to be chiefly dependent upon two factors—the facilities offered by the atmosphere as a vehicle of sound, and the human capacity for hearing and distinguishing sounds of different characters. It will perhaps be convenient to regard these two points first, and afterwards to deal with the application of sound signalling for coast-marking purposes, and the different kinds of instruments used to produce the sounds.

Without entering upon a lengthened explanation of the general laws governing the propagation of sound, it is desirable to discuss briefly various considerations relating to sound transmission, which have a direct bearing upon the subject of coast fog-signals.

It is evident that there are various influences which may be supposed, in one way or another, to affect the transmission of sound. Wind has always been known as a most powerful agent in intercepting and even diverting it. Fog, snow, and rain have also been regarded by many as serious obstructions, while it has long been popularly considered that a bright, warm, sunshiny day, with little or no wind, was exceptionally favourable for the travelling of sound. These views, it may be said, have grown up as the result of general expectation rather than of scientific observation ; but the development of signalling by means of sound has necessitated a more exact enquiry than has hitherto been made, into the general subject of sound transmission, and the result has been that some of the old theories have been considerably shaken, if not overthrown, while new ones have been set up.

In the years 1873 and 1874 an investigation was carried out, at the instance of the Trinity House, with the object of obtaining some definite information as to the relative merits of sound-producing instruments, and also of ascertaining how the propagation of sound was affected by different meteorological phenomena. Professor Tyndall, as the scientific adviser of the Trinity House, conducted the investigation, aided by a committee of the Elder Brethren, and some officers of the Corporation. The experiments were extended over a lengthened period, observations being made in all conditions of weather, and repeated over and over again, in order to eliminate error; and the information gained thereby is of the highest interest and importance.

The conclusions arrived at are stated at length in the third edition of Dr. Tyndall's book on 'Sound,' but may be popularly summarized as follows:—That neither rain, hail, snow, or fog has any sensible power to obstruct sound. From this it is most satisfactory to know that, at those times when a sound signal might especially be of service, the sound is not likely to be obstructed in its passage. That the real obstructors of sound are—first, the wind, and, secondly, what Dr. Tyndall has named acoustic clouds. These clouds have nothing to do with ordinary clouds, fogs, or haze, and may arise from air currents differently heated, or from air currents differently saturated with vapour, and they often exist on days when the atmosphere is visually in a very transparent condition. The sound, intercepted by these acoustic clouds, is wasted by repeated reflections. In short, it is now established that a bright clear day is not necessarily the best for hearing distant sounds, and that on a day of dense fog it is more than probable that no obstruction is offered to the passage of sounds.

Experiments of an elaborate nature, in respect to the propagation of sound in the atmosphere, have also been made under the auspices of the United States Lighthouse Board, with results mainly corroborating those obtained in the Trinity House trials. In one respect, however, the late Professor Henry, who was at the time chairman of the United States Lighthouse Board, differed from Dr. Tyndall—viz. in regard to the theory of acoustic clouds, and their resultant aerial echoes.

Professor Henry's explanation of the obstruction of sound in clear weather, and the echoes, is founded upon the asserted existence of upper and lower currents of air, the tilting up of the sound wave, and the reflection of the sound from the surface of the sea, or the crests of the waves. From the last explanation Professor Henry seems to have receded before his death. Into the details of this purely scientific controversy it is not necessary to enter; but it may be stated, as a matter of fact, that the observations at the

South Foreland, and the explanations given of them by Professor Tyndall, have been, one and all, illustrated and confirmed by strict experiment.

One other point may appropriately be alluded to here—viz. regarding the nature of the sound which is most readily propagated through the air, and which, therefore, is most effective for signalling purposes. It appears that what Mr. Alexander Beazeley (who very ably treated this subject of coast fog-signals some years ago) has termed 'effective sound range' is made up of two elements—viz. intensity and pitch. It is tolerably well established that initial intensity is the first thing needful, and initial intensity depends upon the actual force employed in creating the sound waves. With suitable apparatus, and an effective application of very high power, there is little doubt that sounds of overpowering loudness may be produced. But the effective range of sound appears to be also controlled by its musical pitch. The short waves of a very shrill or high-pitched sound may appear extremely powerful and effective to observers in the immediate vicinity, but their energy seems to be quickly dissipated, and the sound fails to be appreciated effectively at a distance. Again, the long undulations of a very low-pitched sound do not apparently reach great distances. It may be that this kind of movement is more readily acted upon by opposing influences, such as reflection or diversion. But, for practical purposes, it seems that the pitch best adapted for signalling lies about the middle of the scale of sound. With sound, as with light, there are wave motions above the highest pitch intelligible to the human ear, and below the lowest sound audible, and it may be that, the nearer sounds approach the limits of human apprehension, so they tend to become less appreciable. In addition to this, it has been found that the atmosphere exercises a selective influence, and within certain limits will, under some conditions, favour the transmission of the shorter waves, or high-pitched note ; while, at another time, it may be found that the longer waves of a low-pitched note have the advantage.

Speaking generally, the range of sound seems to be attended with much uncertainty. It is popularly supposed that if a sound, at any time, is heard ten or fifteen miles, it must necessarily be an exceedingly powerful sound. Now, this does not follow as a matter of course. The variability of the atmosphere will throw out any calculation made upon such an hypothesis. In the experiments at South Foreland, in calm, clear weather, one of the instruments was, on a certain day, heard at a distance of 16½ miles, but on another day, with apparently identical weather, the same instrument was heard at only 2½ miles' distance. Obviously, it is no satisfactory test of a good signal that on one occasion it had a great range; sounds comparatively small and weak have at times been audible at long distances. The true test of a sound signal appears to be that it shall, under all conditions of weather, be uniformly effective at a short distance, say two miles.

With the development of signalling by means of sound it does not appear that the human capacity for hearing and distinguishing sounds of different kinds has received the consideration which it merits. Let it be granted that there are instruments capable of producing sounds of great power; let it also be granted that the signals appear to be distinctive and easy of comprehension; it will still be found that very many people in the world are incapable of availing themselves of such signals, either by reason of whole or partial deafness, or inability to appreciate differences in sounds. Now, the question almost naturally asserts itself, Cannot something be done to assist the ear, or, at any rate, the perception of sounds in the air? This seems to be the complementary side of the general question, to which but little attention has been given. In regard to visibility, by means of telescopes and binocular glasses a distant object can be brought more plainly into view. But nothing of any real value has been done to assist the hearing. The old-fashioned ear-trumpet for deaf people is little, if at all, improved. Some years ago, an effort was made in this direction by a gentleman from Glasgow, who devised what he termed a phonoscope. This instrument consisted of a sort of metal helmet for the head, with an opening like the bent cowl of a chimney, which could be directed towards any point required. This cowl was supposed to act as a sort of ingatherer of sounds, which were conveyed to the ears by two small tubes, each terminating in a button, intended to go just inside the ear. The faults of this apparatus were, first, its cumbrousness, and, secondly, the remarkable way in which all the ordinary small noises around were collected and magnified into large ones, which, combined with other sounds hitherto unheard, created a general uproar in the ears. The object this gentleman had in view deserved greater success than it obtained. He wished to assist the mariner in picking up and locating a distant sound; and, although his apparatus acted so well that it picked up noises of all kinds, and somewhat bewildered the sense of audition, yet if any one were to accomplish successfully what this gentleman so perseveringly attempted, a very great public benefit would be brought about. What is especially wanted is not an improved ear-trumpet for deaf persons, but, rather, an instrument intended to aid people with fair hearing, or to render obscure sounds more easily perceptible. The late

Professor Henry, of Washington, in carrying out his experiments, devised what he termed an artificial ear, by which the relative power of different sounds could be determined at short distances. This instrument consisted of an arrangement by which sand, on a stretched membrane, assumed certain definite forms, or was more or less agitated, in response to different sounds. As a phonometer, at short distances, this instrument appears to have been fairly effective, but it does not meet the want which appears to exist. With the growing use of sound for various purposes, there is scope for inventive genius to produce a phonoscope, which shall be capable of assisting the healthy listening ear in a manner analogous to that by which a telescope aids the healthy seeing eye.

By far the most important development of sound signals is in connection with the lighthouse and coast-marking service. The most powerful lights are unavailing at night if enshrouded with fog, and, by day, buoys, beacons, and other marks and signs of the sea are then rendered useless. The necessity for sound signals to do duty at such times for the obscured lights and hidden seamarks has brought about the development of a system of coast fog-signals, in which development, so far as the English coast is concerned, the Corporation of Trinity House, aided by Professor Tyndall, and Sir James Douglass, the Trinity House engineer, and others, have had a large share. The Commissioners for Lighthouses in Scotland and Ireland, aided by their respective engineers, have also taken vigorous measures for guarding their coasts with fog-signals when necessary. It is proper, however, to observe that the lighthouse authorities in the United States took up the matter practically before it engaged much consideration in this country, owing to the east coast of America being in an exceptional degree liable to the visitation of fog, by which the coasting traffic was seriously inconvenienced ; and the necessity arose for something to be done whereby the difficulty might be obviated. The ready genius of the country was not long in coming to conclusions, and although some kinds of sound signals, such as bells, gongs, &c., were employed in Europe, the Americans first brought into use Brobdignagian trumpets, whistles, &c.

We will now pass on to consider the different kinds of instruments employed in connection with coast fog-signals.

Bells.—From the earliest times bells have been employed to convey intimations by means of sound. Their chief uses in olden times have been summed up in the following :—

> Laudo Deum verum, plebem voco, congrego clerum,
> Defunctos ploro, pestem fugo, festa decoro.

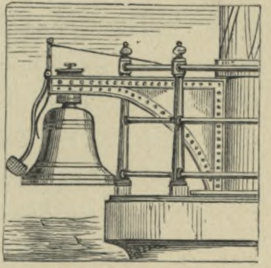
In these days churches have not a monopoly in regard to the use of bells. The town-crier, the muffin-seller, the railway-porter, and many others signalise themselves by the ringing of bells, and in some of these cases it would be an addition to the public comfort if they were suppressed.

The present regulations for preventing collisions at sea require that, in fog, mist, or falling snow, 'a steamship and a sailing-ship, when not under way, shall, at intervals of not more than two minutes, ring the bell.' These regulations are international, but the Turkish Government have objected to the use of bells as fog-signals on board Turkish vessels, on the ground that it is against their religion to use bells on board ship ; and, therefore, in all cases where the regulations require a bell to be used, a drum will be substituted on board Turkish vessels.

As warning signals, bells have been employed from a very early date. It is impossible to say when or where the first bell was put up to assist mariners ; but we may quote the oft-narrated tradition, handed down by an old writer, respecting the Bell Rock :—

'By east of the Isle of May, twelve miles from all land, in the German Ocean, lies a great hidden rock, called Inch Cape, very dangerous for navigators because it overflowed every tide. It is reported in old times upon the saide rock there was a bell, fixed upon a tree or timber, which rang continually, being moved by the sea, giving notice to the saylers of the danger. This bell, or clocke, was put there and maintained by the Abbot of Aberbrothock; and, being taken down by a sea-pirate, a yeare thereafter he perished upon the same rock, with ship and goodes, in the righteous judgment of God.'

The story, it is true, is only supported by tradition, but it serves to show that the notion of marking a hidden danger by a sounding bell was certainly in existence—if not practically applied—at a very early period. It was practically applied at Poolbeg, in Ireland, in 1811, and at the Bell Rock, in Scotland, in 1812; and before the year 1860 bells were established, to be sounded in foggy weather, at sundry other lighthouses on the coasts of Great Britain and Ireland, and of France, the United States, and other countries, many of which continue to be sounded at the present day. The bells now in use vary in weight from 3 cwt. to 45 cwt., and are generally struck by means of clockwork. In no case does the bell itself move, the hammer or clapper alone being actuated by machinery. It is well known that


Lighthouse Bell.

the sound of a bell is curiously fluctuating. In the open country or at sea, the sound of church bells may be heard rising and falling, the peal at one time swelling out as if close at hand—at another fading into the thinnest sound, as if retreating far, far away. These effects are familiar to most people, and in themselves are really beautiful, but they come into play injuriously when the sound is wanted to be evenly distributed over a certain area. The truth probably is, that the vibrations from the largest bell are not of sufficient intensity to yield a sound capable of overcoming opposing influences, even of a slight nature. The sound produced in the immediate vicinity of the bell seems, no doubt, exceedingly powerful, the greatest energy of vibration being there exerted ; but at moderately long distances this apparent energy is dissipated, and the bell ceases to be of use. It will be easily understood that little dependence can be placed upon bells as trustworthy sound signals for long distances. The effective sound range of the largest bell is at all times very doubtful : the wind may carry it to a distance even of ten or twelve miles, but against the wind it may be inaudible at less than a quarter of a mile.

The use of bells on floating buoys has been referred to in the chapter on Buoys and Beacons.

Gongs.—The next kind of sound-producer we have to notice is the gong. This instrument has been appropriated for use on board the light vessels round the coasts, owing, probably, to its peculiarly distinctive sound. The gongs used in the Trinity House service are about two feet in diameter, Chinese make, and cost about 4*l.* each. They are struck with a stick with a padded head, the strokes being very short, and delivered in quick succession, so as to bring up the gong into a vigorous state of vibration. The sound is undoubtedly distinctive and serviceable at very short distances, but, like the sound of a bell, is soon dissipated after leaving the immediate vicinity of the instrument. Passing vessels may approach nearer to a light ship than to a rocky coast marked by a lighthouse, therefore a sound with only a short range may oftentimes be of great service. In many lightships, however, the gong as a fog-signal is now superseded by instruments of very much greater power.

Gong.

Guns and Explosive Signals.—Guns are used for various purposes in connection with signalling. 'The minute gun at sea' indicates that a vessel is in distress, and that assistance is required. This is one of the authorised distress signals. On board H.M.

ships, guns have been employed for signalling in foggy weather, in accordance with an arranged code, and for salutes and other announcements they are used at military depots and elsewhere. But they are also used as warning signals on headlands and dangerous points on a coast, to assist the mariner in foggy weather. The necessity for distinctiveness in the use of sound-signals, and the loudness of the report yielded by the discharge of cannon, led to the adoption of this form of sound-producer.

There is no doubt that these gun signals have been of the greatest value. Many and many a time the warning gun has been heard by the bewildered seaman in time to enable him to alter his course, and probably save his vessel. Formerly the fog-signal guns were fired every fifteen minutes, but recently the interval has been altered to ten minutes. It would be difficult for two men to clean, load, and fire for a lengthened period—say even twelve hours—with less intervals than ten minutes between each discharge.

The piece of ordnance ordinarily employed was the old long eighteen-pounder, with a 3-lb. charge of powder, but in the Trinity House experiments at the South Foreland it was found that a short gun, the 24-lb. howitzer, gave a better sound than the long eighteen-pounder, and since then the shorter gun has been employed.

In 1874–76 some experiments were made at Woolwich Arsenal, with the view of reducing the labour of firing, so as to enable two men to fire at more frequent intervals, and also to produce, if possible, a more effective report than had been obtained by discharges from guns of ordinary pattern. Colonel Eardley Maitland, of the Royal Gun Factories, Woolwich Arsenal, devised a form of gun, breechloading, with six-chambers, similar in some respects to a revolver, and with a parabolic mouth-piece fitted to the muzzle. The experiments gave promise that this fog-signal gun would prove a success, and ultimately it was conveyed to the North Stack, near Holyhead, in order that it might have a practical trial. To reach the station it was necessary to cross very bad mountain roads, and the gun received a severe jolting, and probably jarring, for it broke down shortly after being used. No further attempt was subsequently made to repair the damaged gun, nor to manufacture another, owing to the attention of the Trinity House being then diverted to gun-cotton as an explosive sound-producer. It should also be mentioned that in the trials at Woolwich one experiment was devoted

Experimental Gun.

to testing the comparative advantages of the various kinds of service powder for noise-making purposes. The powders tested were (1) F. G. (fine grain); (2) L. G. (large grain); (3) R. L. G. (rifle large grain); and (4) P. (pebble). In point of effectiveness in sound-producing, the result of the trial placed the powders exactly in the order named; the fine grain, or most rapidly burning powder, giving indisputably the loudest sound, while the report of the slowly

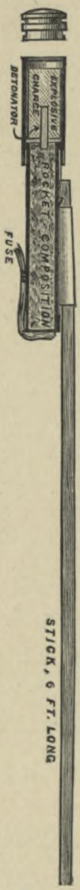
Sizes of Powder.

burning pebble-powder was the weakest of all. The 80- and 100-ton guns, fired with charges of 300 and 400 lbs. of pebble-powder, do not make anything like so terrible a noise as the enormous charge would lead one to expect. The sound seems to lack intensity, and in comparison with the sharp smack of the detonation of gun-cotton, or of a much smaller charge of the most rapidly burning powder, appears to be more of a prolonged and somewhat soft roar.

While upon the subject of guns, a reference should be made to the very ingenious invention of the gas gun by Mr. J. R. Wigham, of Dublin, the advantages claimed for which are that, where a supply of gas is available, the apparatus is very easily applied, and that the gun can be loaded and fired at a considerable distance from the point of explosion. The gun consists merely of a tube about eighteen inches bore and twelve feet long, placed at the point where the signal is required to be made, and connected with a gas main or gas-holder by iron piping. The gun is loaded with an explosive mixture of gas and atmospheric air, by turning on a cock simply, and fired by a light applied by percussion or otherwise to the shore end of the tube, the explosion taking place at the mouth of the gun almost immediately. Mr. Wigham states that a gas gun may be fixed at the water's edge, or on a rock in the sea, at half a mile from the loading and firing station. The idea, which is certainly one of originality, was conceived by Mr. Wigham when he was engaged in connection with the application of gas to the lighthouse at Howth Bailey, and his experiments at that station have met with a very encouraging amount of success, but the system is not yet in practical operation as a fog-signal.

In 1874 some experiments were made at the Royal Arsenal, with the object of ascertaining the value of the sound produced by the explosion of varying quantities of gun-cotton. The explosion of gun-cotton takes place so instantaneously that an exceedingly sudden and sharp blow is given to the surrounding air, whereby a sound wave of great initial intensity is generated. A number of comparative trials were made at Woolwich and elsewhere, in which the superiority of gun-cotton over gunpowder was incontestably demonstrated. It was found that charges of gun-cotton, however fired, yielded reports louder at all ranges than equal charges of gunpowder; and further experiments proved that the detonation of half a pound of gun-cotton gave a result at least equal to that produced by the firing of a 3-lb. charge of gunpowder. During these experiments the various charges of gun-cotton had been merely suspended from a horizontal bar, or in the focus of a large parabolic reflector, and fired by means of electricity. To explode gun-cotton it is necessary to employ a detonator, consisting of a small cylindrical copper case, resembling an elongated percussion cap, containing a certain quantity of fulminate of mercury. This detonator is inserted in the heart of the portion of gun-cotton to be exploded, and an attachment is then made with one wire, connected with a small electric machine, and with another attached to a conducting plate embedded in the earth. On turning the handle of the machine, a current is induced sufficiently strong to generate a spark at the connection of the wires with the detonator, which, coming in contact with the fulminate of mercury, immediately explodes it, and instantaneously the explosion is communicated to the gun-cotton. If gun-cotton in a wet state is used, it is necessary to have a small plug or primer of dry gun-cotton, into which the detonator is inserted. Four processes then take place—viz.: 1. Generation of electric spark. 2. Ignition of detonator. 3. Communication of explosion to dry primer. 4. Communication of explosion of dry primer to the wet portion. The entire operation is, however, perceptible to the human sense as one explosion only. It will be readily understood that to discharge gun-cotton in this way would entail some little expenditure of time and trouble, and might prove inconvenient if required to be repeated every ten minutes for many hours during fog.

But, it being clearly demonstrated that the explosion of gun-cotton gave a very effective sound, a project emanated from the Trinity House for making a rocket serviceable for carrying a charge of gun-cotton up to a certain height, and then causing it to explode. This project was, with the aid of Mr. Brock, the well-known pyrotechnist, and subsequently the officers of the Woolwich Arsenal, after numerous experiments, made a practical success; and now, at five stations on our coasts, we have sound-rockets, either substituted for guns previously used, or established *de novo* for signalling in foggy weather.



Sound Rocket.

The following description of the rocket now used is given in the instructions issued to the fog-signal attendant at Flamborough Head, where sound-rockets have been in use since January 1878. The explosive used is a slight modification of gun-cotton, called tonite, which is said to be cheaper than gun-cotton, and as effective for producing a loud report.

Description of Rockets.—For purposes of safety, the rocket is supplied, and is to be kept, in three parts, viz.:—

1. The Rocket.—This is a case charged with the ordinary rocket composition, and is intended merely to carry up the explosive charge to the required height and then to ignite the detonator which is to explode the tonite.

2. The Detonator.—This is an enlarged percussion cap, filled with fulminate. Its duty is to cause an explosion to take place in the heart of the tonite charge, whereby the charge is exploded. The

detonator is ignited by the burning of the rocket composition.

3. The Tonite Cartridge.—This is the explosive which produces the report, and which, with the detonator placed inside it, is to be fitted in the head of the rocket, when immediately required for use.

The fitting together of the three parts can be accomplished in less than a minute; the rocket is then lighted by applying an ordinary fusee to a piece of Bickford fuse, communicating with the rocket composition. The whole operation occupies less than two minutes. The cost of the rocket is about 1*s.* 4*d.*, whereas each discharge of the gun costs 2*s.*

Another advantage gained by the introduction of the sound-rocket is of a very practical nature. It frequently happens that the sound of a signal intended to be heard at a certain distance over an arc of say 180 degrees to seaward, is obstructed, or deflected, by intervening obstacles, so as to cause certain parts of the arc to be immersed in sound shadow, into which the sound penetrates with very feeble effect, and often not at all. This difficulty the rocket has surmounted most successfully.

The explosive charge is carried up to the height of about 600 feet, and is there caused to explode in free air. From the height at which the explosion takes place, the direct sound is sent downwards into places which would be completely hidden from the level at which a gun could be fired, and which would seldom be reached by the sound of its discharge. At Flamborough Head, the gun was placed on the extreme edge of the point, the cliffs being about 100 feet high. But in Bridlington Bay, a very short distance to the south-westward, the gun was invisible at the sea level, on account of intervening faces and edges of the cliffs. A practical trial of the rocket *versus* the gun at this station clearly showed the value of the former. One man walked along the edge of the cliff, keeping the gun in sight, and several observers were below on the rocks at the foot of the cliff, it being low water at the time. It had been arranged that, upon intimation from the observers below, the man above should signal to the people at the gun station to fire, first a rocket, then a gun. At a quarter of a mile from the point, with a light wind against the sound, the first experiment was made. The rocket gave a loud and sharp report, the gun a dull heavy thud. At half a mile the rocket was very loud, the gun very faint. At $1\frac{1}{4}$ mile the rocket was loud and distinct, the gun heard only by two observers, and then only with the most strained attention. The fact of the explosion of the rocket having been visible and audible on each occasion shows that it was clear of the obstructions which intercepted the sound of the gun, and hid its discharge from sight.

The sound-rocket is now in use at Flamborough Head, at Lundy Island, the Smalls and South Bishop Rocks in St. George's Channel, at Heligoland, and at the Tuskar Rock, on the south-east coast of Ireland. The system offers the means of placing an effective fog-signal at a rock lighthouse station, where limited space and accommodation would prevent the establishment of a gun, or sound signal requiring furnace and machinery.

At two stations explosive charges are fired without the aid of the rocket. The charge with the detonator inside is connected by the necessary wires with a small electric machine specially made for the purpose; it is then suspended from the end of a long arm which is thrust out a good distance from the building or side of the ship. On a current being generated by the machine the induced spark fires the detonator and causes the charge to explode. This method is now in operation at the Longships Rock lighthouse off the Cornish coast and on board the Breaksea light-vessel in the Bristol Channel.

The development of explosive coast fog-signals has not gone beyond this point. Gun-cotton and cotton powder (or tonite) may be handled and stored with quite as much safety as gunpowder; in fact they are really less dangerous; and it has not yet been shown that other explosive compounds, such as dynamite, lithofracteur, blasting gelatine, or any other nitro-glycerine mixture can be made practicably serviceable. Some freeze at a temperature a little above 40° Fahr., and others do not lend themselves to safe manipulation and to storing for lengthened periods.

WHISTLES.—The next instrument employed which claims notice is the whistle. In connection with coast fog-signals, whistles, whether operated by steam or compressed air, do not appear to have found so much favour in this country as in the United States and Canada; indeed, with the exception of one station in the Clyde, where two small whistles, sounding different notes, are in operation, there are no fog-signal whistles on our coasts. In the United States they have been employed at various points since the year 1851. The first was set up by Mr. C. L. Daboll at Beaver Tail Point. In Canada, also, whistles have been in use for some time, the type adopted being that invented by Mr. Robert Foulis, of St. John's, N.B., and known as the Vernon-Smith whistle. Steam whistles are simple enough in their arrangements, requiring only a boiler for generating steam, and a simple

Whistle.

mechanical arrangement for opening a valve for the periodic passage of the steam to sound the whistle. For air whistles it is necessary to have some motive power to compress air, and also some mechanical arrangement to regulate the admission of the compressed air to sound the whistle.

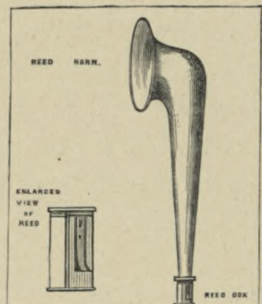
In the Trinity House experiments of 1873–74 it was shown that the sound of the most powerful whistles, whether blown with steam or air, was generally inferior to the sound yielded by other instruments, and consequently, no steps have been taken to extend their use in this country. Various reports have been circulated as to the great distance at which whistles have been heard on the American and Canadian coasts, but in the very careful trials, made with both American and Canadian whistles, at the South Foreland, in 1873, no such results as those claimed were obtained.

The sounding of a whistle is caused by the vibration of the column of air contained within the bell or dome, the vibration being set up by the impact of a current of steam, or air, at a high pressure. It is probable that the metal of the bell is likewise set in vibration, and gives to the sound its timbre or quality; but it is to be noted that the energy so excited expends its chief force in the immediate vicinity of its source, and may be, therefore, regarded as to some extent wasted.

The sound of the whistle, moreover, is diffused equally on all sides. Probably these characteristics, to some extent, explain the impotency of the sound to penetrate to great distances. Difference in pitch is obtained by altering the distance between the steam orifice and the lower rim of the dome; when brought close to each other—say within half an inch—the sound produced is very shrill, and it becomes deeper as the space between the rim and the steam or air orifice is increased.

The most recent adaptation of the whistle as a fog-signal is shown in the automatic signal buoy, which has been described elsewhere.

HORNS.—The next instrument to which reference should be made is the horn or trumpet, in which air or steam pressure is employed to set in vibration a metallic reed, or tongue, the vibrations being communicated to air inside the trumpet.

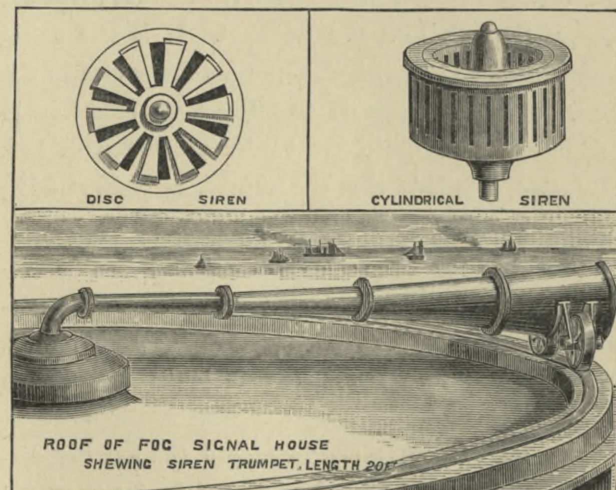


Reed Horn.

Mr. C. L. Daboll, of the United States, to whom reference has been previously made, introduced, in 1851, an instrument of this kind to the notice of the United States Lighthouse Board, and a trial was made at Beaver Tail Point, Rhode Island.

This instrument was sounded with air condensed by two air-pumps, worked by a horse, the compressed air being stored in a receiver, and the trumpet sounded at a pressure of about 40 lbs. to the square inch. Ultimately Mr. Daboll employed Ericcsen's caloric engine as the motive power for condensing the air, with an automatic arrangement for regulating the blasts; and in 1862 he introduced his improved signal to the notice of the Trinity House Corporation, who gave it a practical trial at Dungeness. The results being very satisfactory, the Corporation placed other instruments of the same kind at several places round the coast, and one was fitted up on board the Newarp lightship. The experiments at South Foreland showed such instruments to be, under some conditions, fairly efficient, but they suffered from several disadvantages, which may have led to their disuse of late years. Allusion has been made to the probability that with whistles some of the initial power is wasted by the metal of the dome, or bell, being set in vibration; this occurs to a greater extent with the huge brass trumpets which have generally been associated with reeds. The trumpet acts chiefly in concentrating the sound into a beam, thus causing it to be projected through the air with greater force in any required direction. With a brass trumpet, the molecules of the metal are also set in vibration, and sound waves appear to be generated from all parts of the external surface of the trumpet, so that, although a very loud sound may be produced in the immediate neighbourhood of the instrument, it is open to doubt whether that sound is transmitted with force to any great distance, its strength being, so to speak, dissipated in the space close to its source. The local noise occasioned by the vibration of the trumpet would be intolerable for any length of time. In addition to the objection to the trumpet being made of brass, the necessity which exists for tuning the reed in unison with the fundamental note of the trumpet is a source of much inconvenience. At the present time there are very few reed instruments with brass trumpets in operation, many of those originally established having been superseded by the siren, an instrument which will be referred to presently. In connection with the development of reed horns, very much is due to Professor F. H. Holmes, whose energy in connection with the electric light is well known. Under his immediate superintendence and advice two reed horns, sounded directly by steam, were fitted on board two light-vessels sent out to China, and have worked very satisfactorily.

SIRENS.—We now come to the instrument which has been authoritatively described as 'beyond question the most powerful fog-signal which has hitherto been tried in England.' In 1872 a Committee from the Trinity House, who went to the United States, witnessed the performance of an apparatus known as the Siren, and patented by Messrs. Brown, of Progress Works, New York, and for the experiments at the South Foreland in 1874 one of these instruments was sent over to be tried.



Siren Fog-signal.

The instrument sent from America could be sounded either with steam or compressed air, made to pass through a fixed flat disc, fitted into the throat of a long cast-iron trumpet, connected with the steam or air-pipe. This disc has twelve radial slits, and behind it is a rotating disc, with twelve similar slits, the rotation being effected by separate mechanism. Imagine, then, a pressure of steam or air to be coming through the steam pipe : with one disc fixed, and the other rotating, it will be understood that the slits in each frequently coincide—in fact, the twelve slits in one revolution coincide twelve times, and at each coincidence a puff of steam or air, at great pressure, escapes through into the trumpet. It is the rapid succession of these puffs which forms the sound of the siren. The disc is caused to make 2,400 rotations in a minute, and, as there are twelve coincidences in a revolution, it follows that the number of puffs passing through in a minute would be $2,400 \times 12 = 28,800$.

It can readily be understood that a sound of surpassing power is thus generated, and, as the vibrations produced are not taken up by the cast-iron trumpet, the sound issues from the mouth in a condensed beam of great intensity.

It is not of importance to record the longest distances at which the siren has been heard, the sound range under different atmospherical conditions being so exceedingly variable, but in regard to its superiority over other instruments it may be said that, under meteorological conditions unfavourable to the transmission of sound, the voice of the siren had a greater range than that of any other sound-producer ;

and that, when local noises—such as those of wind in the ears, rattling of rigging, breaking waves, shore surf, paddle-wheels, and the working of engines—have to be contended with, according to Dr. Tyndall, 'its density, quality, pitch, and penetration render it dominant over such noises after all other signal sounds have succumbed.' It is obvious that this power to overcome obstructive influences is the true test of the value of a sound signal, and it is not surprising that the experience of the siren at the South Foreland should have led to the extensive adoption of this form of fog-signal on the coasts of Great Britain. Since 1874, no less than twenty-two sirens have been placed at the most salient lighthouse stations on our coast, and sixteen on board lightships, moored in positions where a guiding signal is of the greatest service to the passing navigation. It should be stated that, in the experiments of 1874, steam alone was used for sounding the siren ; but the instruments now in operation on our coasts are sounded with air compressed by means of caloric engines of greatly improved design and construction, examples of which are in exclusive use at the Lizard, both for the electric lights and the fog-signal. Steam is not available at many lighthouse stations, owing to a scarcity of fresh water, and the caloric engine, which also rotates the siren disc, is regarded as safer and more economical in working than a high-pressure steam boiler, and is independent of water supply. In America, Canada, and some other countries, steam has been employed with considerable success.

At Howth Bailey, a gas engine is employed as a motor for compressing air for the siren now in operation there. This arrangement is due to Mr. J. Wigham, of Dublin, and is said to work very efficiently.

The adoption of the siren as the most efficient sound signal for use in foggy weather, may be regarded as an important epoch in the history of the development of the use of sound signals. Improvements have been made by Sir Jas. N. Douglass, engineer to the Trinity House; and Mr. Slight, superintendent of the Trinity House workshops, has invented an improved arrangement by which, instead of flat discs being used, the siren consists of two concentric cylinders, with slits in both, one inside the other, the outer one being fixed, and the inner one revolving, with the smallest possible clearance between them. The advantages of this arrangement are, that the suddenness of letting on or taking off the pressure is much increased, whereby the successive blows upon the air are rendered much sharper, and the sound intensity augmented. It is also considered an improvement mechanically, by somewhat lessening the friction. Professor F. H. Holmes has succeeded in rendering the rotation of this siren cylinder automatic, with perfect control over the speed and consequent pitch; an apparatus of this kind has been fitted to most of the fog-signal instruments now in operation on board the lightships.

Messrs. Sautter, Lemonnier, & Co., of Paris, have more recently introduced a double-siren, in which two sirens, having different numbers of orifices in their respective cylinders, produce simultaneously two notes in the trumpet, and by this means the power of the instrument is more than doubled, and a characteristic feature is given to the sound.

It now remains to offer a few general remarks upon the subject.

It is obvious that, with the increasing use of sound signals, there is an increasing necessity for differentiating them. Something must be done to prevent one from being mistaken for the other: in fact, it is necessary that every signal should have its own characteristic. This essential element, as regards coast fog-signals, has by no means been overlooked, and, as each lighthouse is made to proclaim its own individuality, so every fog-signal established on our coast has been made to particularly indicate itself by some distinguishing feature. One great reason why explosive reports, whether from guns or rockets, are made use of, is because their sound is so entirely different from that of the blast of siren, reed-horn, or whistle. Indeed, the three latter strongly resemble each other, and can only be distinguished by trained ears. It has also been found useless to attempt to get differential signals by means of pitch of the note alone. To employ a high note at one station and a low note at another would, in the present condition of the musical cultivation of mariners generally, be more likely to lead to confusion and disaster ; but it is possible to obtain an effective distinction by sounding a high and a low note in direct contrast. This has been recognised by the Trinity House, and now the necessary distinctions for siren fog-signals are obtained by employing combinations of high and low notes, the mechanism of the siren being adapted for producing the required sounds. It has been frequently proposed to introduce long and short blasts ; but here, again, experience has shown that many difficulties and risks would attend such an arrangement, and might result in conveying wrong information to the mariner, and lead him into danger. Formerly it was thought best to trust to the distinctions which could be obtained by varying the number of blasts, and the length of the silent interval. This is a system which seemed intelligible to the most ordinary understanding, and accordingly on this basis the characteristics of sound signals were founded.

But the adoption of the high and low note system has changed all this, and mariners need not now confuse themselves with lengths of intervals, nor with the perplexing attempts to distinguish between long and short sounds.

It is not easy to see how the system of long and short sounds could be brought into satisfactory operation. Such distinctions are extremely pretty and simple upon paper, but they assume a vastly different aspect to an anxious and perhaps not over-intelligent master mariner, on board his vessel, say in the Downs, in a thick fog. All around he hears horns and whistles blowing, and he simply does his best to keep clear of those vessels which by the sounds appear to be nearest. Of what use to him would be combinations of long and short sounds? Would he, in his bewildered state, care to try to distinguish between them? It is more than probable that he would have neither the time nor the inclination to do so, and it must not be forgotten that, in making provisions of this kind, it is not the skilled, clear-headed, highly educated Royal Naval or merchant captains who have to be considered, so much as the thousands of experienced, weather-beaten master mariners in command of small foreign-going and coasting vessels, who know well how to navigate their vessels under trying circumstances, but whose minds are not adapted for comprehending any system requiring accurate and attentive observation, to which is tacked on the necessity of finding out the meaning after the observation is made.

As regards the present development of our coast fog-signals, there is every reason for congratulation.

This new branch of coast marking has so far been brought up to a very effective condition; no efforts have been spared to cope with the seaman's greatest enemy, fog. By the aid of sound signals the mariner is now enabled to continue his voyage with comparative safety, even when his vessel is enshrouded with a thick pall impenetrable by the keenest vision; and there is little doubt that those who have their business in the great waters are ready gratefully to acknowledge the humane spirit which has prompted the development of these signals, as well as the practical benefit which they derive from them.

APPENDIX.

LIST OF THE PRINCIPAL COAST LIGHTS OF THE BRITISH ISLANDS.

CORRECTED TO MARCH 1884.

(The numbers correspond with those on the Chart in the Frontispiece.)

ENGLAND.

From Berwick, coastwise, to St. Bees.

No.	Name	Light	Visible in clear weather
			Miles
1	Berwick Pier—2 lights in same tower	High,—white, fixed . . .	12
		Low,—red	8
2	Longstone . . .	White, revolving, half-minute interval	15
3	Farn Island—2 lights .	High,—white, revolving, half-minute interval . . .	15
		Low,—white, fixed . . .	12
4	Coquet Island—2 lights in same tower	White, fixed, with red sectors .	14
5	Tynemouth Castle . .	Red,—revolving, one minute interval	18
6	Souter Point—2 lights .	Electric: high,—white, revolving, half-minute interval . .	20
		Low,—white, fixed, with red sectors	
7	Hartlepool Heugh . .	White, fixed	15
8	Whitby—2 lights . .	White, fixed	23
9	Flamborough Head .	White and red revolving—twice white, once red, half-minute interval	21

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
10	Bull Sand light vessel .	White,—fixed	8
11	Spurn Point—2 lights .	High,—white, occulting every half minute with red sector .	15
		Low,—white, fixed . . .	12
12	Spurn light vessel . .	White,—revolving, one minute interval	10
13	Outer Dowsing light vessel	Red, revolving, half-minute interval	10
14	Inner Dowsing light vessel	Green, revolving, 20 seconds intervals	10
15	Dudgeon light vessel .	White and red alternately, flashing, half-minute interval .	10
16	Lynn Well light vessel .	White, flashing, 10 seconds interval	10
17	Hunstanton . . .	White, occulting half-minute interval	16
18	Cromer	White, revolving, one minute interval	23
19	Leman and Ower light vessel	White, flashing 2 flashes every half-minute	10
20	Haisborough light vessel.	Two fixed, white lights, placed horizontally	10
21	Haisborough—2 lights .	Gas : white, fixed, high . .	17
		,, ,, low . .	15
22	Would light vessel . .	White, flashing 5 seconds interval	10
23	Newarp light vessel .	White, group flashing, 3 flashes in a group, every minute . .	10
24	Winterton . . .	White, fixed	14
25	Cockle light vessel . .	White, revolving, one minute interval	10
26	St. Nicholas Gat light vessel, 2 lights	White, fixed	10
		Red, flashing, 10 seconds interval,	4
27	Corton light vessel . .	Red, revolving, 20 seconds interval	10
28	Lowestoftness . .	Red, with white sector, occulting half-minute . . .	11
29	Lowestoft High . .	White, revolving, half-minute interval, red sector fixed . .	16
30	Kessingland . . .	Red, fixed.	9
31	Orfordness—2 lights .	White, fixed, with red sector, high	17
		low	14

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
32	Shipwash light vessel .	White, group flashing, 3 flashes in a group, half minute interval	10
33	Cork light vessel . .	White, revolving, half-minute interval	10
34	Landguard Point . .	Red and white sectors, fixed .	10
35	Dovercourt, Harwich—2 lights	White, fixed, high . . .	11
		,, low . . .	9½
36	Sunk light vessel . .	Red and white, revolving, 45 seconds interval . . .	10
37	Longsand light vessel .	White, revolving, half-minute .	10
38	Gunfleet . . .	Red, revolving, half-minute interval	11
39	Galloper light vessel .	Two fixed white lights, placed horizontally	10
40	Kentish Knock light vessel	White, revolving, one minute interval	10
41	Swin Middle light vessel	White, revolving, half-minute interval	10
42	Maplin sand . . .	Red, occulting, with white sectors, half-minute interval . .	10
43	Mouse light vessel . .	Green, revolving, 20 seconds interval	10
44	Girdler light vessel . .	White, revolving, half-minute interval	10
45	Nore light vessel . .	White, revolving, half-minute interval	10
46	Prince's Channel light vessel	Red, revolving, 20 seconds interval	10
47	Tongue light vessel .	Two fixed lights of unequal heights—high, white . .	10
		low, red . . .	7
48	North Foreland . .	White, occulting, half-minute .	19
49	Goodwin light vessel (No. Sand)	White, group flashing, 3 flashes every minute	10
50	Gull Stream light vessel .	White, revolving, 20 seconds interval	10
51	East Goodwin light vessel	Green, revolving, 15 seconds interval	10
52	South Sand Head light vessel	White, fixed	10
53	South Foreland—2 lights	Electric, white, fixed, high .	26
		,, ,, low	23

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
54	Varne Shoal light vessel .	Red, revolving, 20 seconds interval	10
55	Dungeness—2 lights .	High,—white, fixed . . . Low,—white, flashing, 5 s. interval	15
56	Royal Sovereign light vessel	White, group flashing, 3 flashes every minute	10
57	Beachy Head . . .	White, revolving; bright 15 seconds, eclipsed 1 minute 45 seconds	23
58	Owers light vessel . .	White and red, revolving, twice white, once red, half-minute interval	10
59	Nab light vessel—2 lights	White, fixed, 18 yards apart .	8 / 6
60	St. Catherine's, Isle of Wight	White, fixed	17
61	Needles Rock, Isle of Wight	White, occulting, half-minute interval, with red and green sectors, red	14 / 9
62	Hurst—2 lights . .	White, fixed	13 / 10
63	Anvil Point . . .	White, flashing, 10 seconds interval	18
64	Shambles light vessel .	White, group flashing, 2 flashes every half-minute . . .	10
65	Portland Bill—2 lights .	White, fixed	21 / 18
66	Start Point . . .	White, revolving, one minute interval; white, fixed, in same tower	20
67	Plymouth Breakwater .	White to seaward, red over anchorage, occulting, half-minute interval; white, fixed, in same tower . . .	9
68	Eddystone—2 lights .	White, group flashing, two flashes every half-minute; white, fixed, in same tower . . .	17½
69	Falmouth, St. Anthony's Point	White, revolving, 20 seconds interval; white, fixed, in same tower	13
70	Lizard—2 lights, east and west	White, fixed (electric) . .	21

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
71	Wolf Rock . . .	White and red alternately, revolving, half-minute interval . .	16
72	St. Agnes, Scilly . .	White, revolving, half-minute interval	17
73	Bishop Rock, Scilly .	White, fixed	16
74	Seven Stones light vessel.	White, group flashing, 3 flashes every minute	11
75	Longship's Rock, Land's End	White and red, with short occultation every minute; red towards the land . . .	16
76	Godrevy—2 lights . .	White, flashing, 10 seconds . Red, fixed, in same tower	15
77	Trevose Head. . .	White, occulting, three occultations every minute . . .	20
78	Hartland Point . .	White and red, revolving, half-minute interval . . .	17
79	Lundy Island—2 lights .	Upper, white, revolving, 2 minutes interval . . . Lower, white, fixed	30
80	Bideford—2 lights . .	White, fixed	14 / 11
81	Bull Point . . .	White, group flashing, 3 flashes every half-minute . . . Red, fixed, in same tower	18
82	Burnham—2 lights . .	High, white, intermittent, 3½ minutes visible, half-minute dark	15
		Low, white and red, fixed . .	9
83	Avon	White, with red and green sectors, occulting half-minute	13
84	Usk	Red, white, and green sectors, fixed	11
85	English and Welsh Grounds light vessel	White, revolving, one minute interval	10
86	Flatholm . . .	White, with red sector, occulting half-minute	18
87	Breaksea light vessel .	White, revolving, 15 seconds interval	10
88	Nash—2 lights . .	White, fixed, with red sector .	19 / 17
9	Scarweather light vessel .	Red, revolving, 20 seconds interval	10
90	Mumbles Head . .	White, fixed	15

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
91	Helwick light vessel .	White, revolving, one minute interval	10
92	Caldy Island . . .	White, fixed, with red sector .	20
93	Great Castle Head—2 lights	White, fixed	{15 / 13
94	St. Ann's Head, Milford —2 lights	White, fixed	{20 / 18
95	Smalls Rock . . .	White, fixed, with red sector .	17
96	South Bishop . . .	White, revolving, 20 seconds interval	18
97	Cardigan Bay light vessel	Red, revolving, half-minute interval	10
98	St. Tudwall . . .	Red and white sectors, occulting, bright 8 seconds, eclipsed 2 seconds . . . . . Red, fixed, in same tower . .	19
99	Bardsey	White, fixed	17
100	Carnarvon Bay light vessel	White and red, revolving, 20 seconds interval; twice white, once red	10
101	South Stack . . .	White, revolving, one minute interval	20
102	Holyhead Breakwater .	Red, flashing, 7½ seconds interval	13
103	Skerries—2 lights . .	White, fixed . . . . Red sector from lower window	16
104	Point Lynus . . .	White, occulting, 8 seconds visible, 2 seconds dark . .	16
105	Menai	Red, fixed.	12
106	Great Orme's Head .	White, fixed, with red sector .	24
107	Rock	White, flashing, half-minute .	8
108	Hoylake—2 lights . .	White, fixed	{13 / 11
109	Leasowe. . . .	White, fixed	15
110	Crosby light ship . .	White, fixed	8
111	Formby light ship . .	Red, revolving	11
112	N.W. light ship . .	White, flashing, half minute .	11
113	Stanner Point, Ribble .	White, occulting, 3½ minutes bright, half-minute dark. .	12
114	Fleetwood—2 lights .	White, fixed	{13 / 9
115	Morecambe Bay light vessel	Red, revolving, half-minute interval	10

ENGLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
116	Selker light vessel . .	Red and white, flashing, one white one red, every half-minute	10
117	Bahama Bank light vessel	White, flashing, 2 flashes every half-minute	10
118	St. Bees	White, fixed	25

ISLE OF MAN.

No.	Name	Light	Visible in clear weather
			Miles
	Douglas Head . .	White, fixed	14
	Langness . . .	White, flashing, every 5 seconds.	14
	Chicken Rock . .	White, revolving, half-minute interval	16
	Ayre Point . . .	White and red alternately, revolving, one minute interval . .	16

SCOTLAND.

From Solway Firth, coastwise, to St. Abb's Head.

No.	Name	Light	Visible in clear weather
			Miles
1	Little Ross Island . .	White, flashing every 5 seconds .	18
2	Mull of Galloway . .	White, intermittent, half-minute visible, quarter minute dark .	25
3	Corsewall . . .	White and red alternately, revolving, one minute interval . .	16
4	Loch Ryan . . .	White, fixed	12
5	Turnberry Head . .	White, flashing every 12 seconds	15
6	Ardrossan Breakwater .	White, occulting, 2 seconds visible, 2 seconds dark . .	10

SCOTLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
7	Cumbrae Island . .	White, fixed	16
8	Pladda, Arran—2 lights	White, fixed	{17 / 14
9	Davar Island . . .	White, revolving half-minute interval	17
10	Sanda, Ship Rock . .	White, occulting, about 8 seconds visible, 16 seconds dark . .	18
11	Mull of Cantyre . .	White, fixed	24
12	Port Ellen . . .	Red, fixed	12
13	Loch-in-Dail . . .	White, fixed, with red sectors .	12
14	Rhinns of Islay . .	White, flashing every 5 seconds .	18
15	MacArthur Head, Islay .	White, fixed, with red sector .	17
16	Rhu Vaal, or Rudha Inhail, Islay	Whi e, fixed, with red sector .	18
17	Skeir Maoile or Iron Rock, Jura	White, revolving, half-minute interval	14
18	Phladda Island . .	White, fixed, with red sector .	11
19	Corran Point, Loch Eil .	Red, fixed, with white sector .	11
20	Lismore . . .	White, fixed	16
21	Mull Sound . . .	Red, green and white sectors, fixed	12
22	Ardnamurchan . .	White, fixed	18
23	Dhuheartach Rocks .	White, fixed, with occulting sector	18
24	Skerryvore Rock . .	White, revolving, one minute interval	18
25	Barra Head, Hebrides .	White, intermittent, half-minute visible, half-minute dark .	33
26	Ushenish, Hebrides .	Red, fixed	18
27	Scalpay, Glass Island, Hebrides	White, fixed	17
28	Monach, Hebrides . .	White, flashing, 10 seconds interval	18
29	Stornoway, Hebrides .	White, revolving, half-minute interval	13
30	Butt of Lewis, Hebrides.	White, fixed	19
31	Oronsay . . .	White, fixed	13
32	Kyleakin, Loch Alsh .	White, fixed, with red sector .	12
33	South Rona . . .	White, flashing every 12 seconds	21
34	Stoer Head . . .	White, intermittent, one minute visible, half-minute dark .	20
35	Cape Wrath . . .	Red and white alternately, revolving, one minute interval . .	27
36	North Unst, Shetland .	White, fixed, with red sector .	21

SCOTLAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
37	Whalsey Skerries, Shetland	White, revolving, one minute interval	18
38	Bressay, Shetland . .	Red and white alternately, revolving, one minute interval . .	6
39	Sumburgh Head, Shetland	White fixed	24
40	North Ronaldsha . .	White, flashing every 10 seconds	18
41	Start Point, Ronaldsha .	Red, fixed	14
42	Auskerry, Stronsa . .	White, fixed	16
43	Hoy Sound—2 lights .	High, red, fixed, with white sectors	15
		Low, white, fixed . . .	12
44	Cantick Head, Hoy Island, Orkney	White, revolving, one minute interval	16
45	Holburn Head, Thurso Bay	White, flashing every 10 seconds, with red sector . . .	14
46	Dunnet Head. . .	White, fixed	24
47	Pentland Skerries — 2 lights	White, fixed	19 / 18
48	Noss Head . . .	White, revolving, half-minute interval, with red sector . .	18
49	Tarbetness . . .	White, intermittent, 2½ minutes bright, ½ minute dark . .	18
50	Cromarty . . .	Red, fixed	13
51	Chanonry Point . .	White, fixed	11
52	Covesea Skerries . .	White, revolving, one minute interval, with red sectors .	18
53	Kinnaird Head . .	White with red sectors, fixed .	17
54	Buchanness . . .	White, flashing every 5 seconds .	17
55	Girdleness—2 lights in same tower	White, fixed	19 / 16
56	Montroseness . . .	White, occulting . . .	17
57	Tay Port, or Port on Craig—2 lights	White, fixed	12 / 10
58	Buddonness, Frith of Tay—2 lights	White, fixed	16 / 13
59	Albertay light vessel .	White, flashing 10 seconds .	8
60	Bell Rock . . .	White and red alternately, revolving, one minute interval . .	15
61	May Island—2 lights .	White, fixed	21 / 15
62	Burnt Island . . .	Red, fixed	8
63	Inchkeith . . .	White, revolving, one minute interval	21
64	St. Abb's Head . .	White, flashing every 10 seconds	21

IRELAND.

From Fastnet (extreme S.W. point), round coastwise, by W., N., E., and S.

No.	Name	Light	Visible in clear weather
			Miles
1	Fastnet Rock . .	White, revolving, one minute interval	18
2	Galley Head . . .	Gas; white, flashing, 6 or 7 flashes in quick succession every min.	19
3	Kinsale Old Head . .	White fixed, with red sector .	21
4	Daunt Rock light veseel .	Red, fixed	10
5	Roche Point—2 lights .	White, occulting, 15 seconds visible, 5 seconds dark . .	10
		White, fixed, in same tower .	8
6	Ballycottin Island . .	White, flashing every 10 seconds	18
7	Mine Head . . .	Gas: white, intermittent, 50 sec. visible, 10 seconds dark . .	21
8	Dungarvan . . .	White, fixed, with red and green sectors	10
9	Hook Tower, Waterford	Gas: white, fixed . . .	16
10	Duncannon Fort—3 lights	One white, fixed, with red sector; 2 white, fixed, in same tower .	10
11	Black Head . . .	White, fixed	16
12	Coningbeg (Saltees) light vessel	White, group flashing, 3 flashes every minute	10
13	Barrels Rock light vessel	Red, flashing every half-minute .	10
14	Tuskar Rock . . .	White and red, revolving, one minute interval, twice white once red	15 10
15	Lucifer Shoals light vessel	Red, fixed	8
16	Blackwater Bank light vessel	White, fixed	10
17	Arklow, South Bank light vessel	White, revolving, half-minute interval	10
18	Arklow, North Bank light vessel	White, flashing one minute .	10
19	Wicklow Head . .	Gas; white, intermittent, 10 seconds bright, 3 seconds dark	16
20	Codling Bank light vessel	Red, revolving, 20 seconds interval	9
21	Kish Bank light vessel .	White, revolving, one minute interval	10
22	Poolbeg. . . .	White, fixed	12
23	North Bull . . .	White, occulting, 14 seconds .	19
24	Howth Bailey . .	Gas, white, fixed . . .	15

IRELAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
25	Rockabill . . .	Gas ; white, flashing every 12 seconds, with red sectors .	18
26	Dundalk . . .	White, flashing every 15 seconds, with red sectors . . .	9
27	Haulboline Rock, Carlingford—2 lights	White, fixed	15
28	Dundrum Bay, St. John's Point	Gas, half red, intermittent, 45 seconds visible, 15 seconds dark	12
29	South Rock, light vessel	White, revolving, $1\frac{1}{2}$ minutes in-interval	10
30	Donaghadee . . .	Red, fixed, with white sectors .	12
31	Copeland Island . .	White, fixed	16
32	Larne Lough . . .	White, fixed, with red sectors .	11
33	Maiden's Rock—2 lights, north and south	White, fixed	14 13
34	Rathlin Island—2 lights .	White, intermittent, 50 seconds bright, 10 seconds dark . .	21
		White, fixed, with red sector	
35	Inishowen—2 lights .	East, white, fixed . . .	13
		West, white, fixed, with red sectors	15
36	Inishtrahull . . .	White, revolving, half-minute interval	18
37	Dunree Head, Lough Swilly	White, fixed	13
38	Fanad Point, Lough Swilly	Red, fixed (white, towards Harbour)	14
39	Tory Island . . .	White, fixed	16
40	Aranmore Island—2 lights	Alternate, red and white, revolving, 20 seconds interval . .	25
		Red, fixed, in same tower	
41	Rathlin O'Beirne . .	White, fixed, with red sector .	16
42	Killybegs—2 lights .	White, fixed	14 12
43	Sligo Bay, Oyster Island	White, fixed	11
44	Broadhaven . . .	White, fixed	15
45	Eagle Island—2 lights .	White, fixed	20
46	Black Rock . . .	White, flashing every half-minute	22
47	Blacksod Point . .	White, fixed, with red sectors .	10
48	Clare Island . . .	White, fixed	27
49	Slyne Head—2 lights .	White and red, revolving, twice white once red, 2 minutes interval	15
		White, fixed	14

IRELAND—*continued.*

No.	Name	Light	Visible in clear weather
			Miles
50	Eeragh Island, Galway Bay	White, revolving, one minute interval	16
51	Inisheer Isl., Galway Bay	White, fixed, with red sector .	15
52	Mutton Island, Galway .	White, fixed	10
53	Loop Head . . .	White, intermittent, 20 seconds visible, 4 seconds dark . .	22
54	Kilcradan . . .	Red and white, fixed . . .	16
55	Scattery Island . .	White, fixed, with red sector .	10
56	Tarbert	White, fixed	13
57	Beeves Rock . . .	White, fixed, with red sector .	10
58	Tearaght Island . .	White, flashing, 2 flashes every minute	22
59	Valentia . . .	White, fixed	12
60	Skelligs Rock . .	White, fixed	18
61	Dursey Head . . .	White, flashing every 15 seconds	16
62	Bantry Bay . . .	White, fixed	12
63	Crookhaven . . .	Red, fixed, with white sector .	13

CHANNEL ISLANDS.

No.	Name	Light	Visible in clear weather
			Miles
1	Casquets, Alderney .	White, group flashing, 3 flashes every half-minute . . .	15
2	St. Peter's Port, Guernsey	White, fixed	9
3	Hanois Rock, Guernsey .	Red, revolving, 45 seconds interval	12
4	Verclût Breakwater, Jersey	White, fixed	10
5	St. Helier's . . .	White, fixed	6
6	La Corbière Rock . .	White, fixed, with red sectors .	17
7	Minquiers light vessel .	White, fixed	8–10

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