Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [x] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distortion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments:/ Commentaires supplémentaires:

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Includes supplementary material/ Comprend du matériel supplémentaire
- [ ] Only edition available/ Seule édition disponible
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/ Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X 14X 18X 22X 26X 30X

12X 16X 20X [X] 24X 28X 32X

1	2	3

1
2
3

1	2	3
4	5	6

A DESCRIPTION AND LIST OF THE LIGHTHOUSES OF THE WORLD.

1863.

THIRD EDITION.

BY ALEXANDER G. FINDLAY,
Fellow of the Royal Geographical Society.

LONDON:
PUBLISHED FOR RICHARD HOLMES LAURIE,
53, FLEET STREET, E.C.

1863.

THE Intro
read befo
have been
by drawin
it would b

The var
nature of
been touc
THOMAS S
will suppl

Besides
the Select
the Royal
subject of
upon almo
the Unite
Engineers
and requi

The list
by the Ad
DUNSTER

In orde
latest info
occurred
directed.

London,

This T
occurred

London,

PREFACE.

THE Introductory portion of this Book is the substance of two Papers, by the Author read before the Society of Arts on December 15, 1847, and March 3, 1858; which have been published in the Society's Transactions and Journal. It was thought, that by drawing the Sailor's attention to the methods by which the Lights are produced, it would be adding much to their utility, and prove interesting to many.

The varied features of the beautiful Systems in operation are necessarily, from the nature of this Work, very briefly adverted to; and many important topics have not been touched upon for the same reason. The excellent works of ROBERT, ALAN, and THOMAS STEVENSON, will furnish the reader with a fund of varied information, and will supply all deficiencies in this, should a further insight be desired.

Besides these works, and others of earlier date, quoted herein, the bulky Reports of the Select Committees of the House of Commons, of 1822, 1834, and 1845, and that of the Royal Commission published in the present year, if they have not advanced the subject of their inquiry, have collected and recorded a vast mass of detail bearing upon almost every relation of the Lighthouse System. Besides these, the Report of the United States' Lighthouse Board, in 1852, the works of Fresnel, and other Engineers of the French Commission, will give an excellent account of the condition and requirements of Lighthouses.

The lists of the Lights which follow have been re-arranged from those published by the Admiralty, which, under the careful superintendence of Commander EDWARD DUNSTERVILLE, R.N., have attained a completeness approaching perfection.

In order that this Work may preserve its utility for several years, by giving the latest information, a SUPPLEMENT, containing the additions and changes that have occurred during the previous year, will be annually forwarded on application as directed.

A. G. F.

London, July 1, 1861.

This THIRD EDITION has been duly revised, and those changes which have occurred in the previous year have been inserted in the respective pages.

A. G. F.

London, Jan. 1, 1863.

CONTENTS.

LIST OF LIGHTHOUSES.

PHAROLOGY;

OR,

A DESCRIPTION OF LIGHTHOUSES,

AND THEIR ILLUMINATION.

CHAPTER I.

EARLY HISTORY OF LIGHTHOUSES.

To bring before the sailor's notice the many beautiful adaptations of refined science in operation in Lighthouses,—to explain their principles, and to enable him to distinguish one description of light from another, through a knowledge of its construction, is the object of the present Introduction. These subjects, though of great interest, were but little noticed till within a few years, although they have been brought nearly to the present perfection for a long period.

Amid the wonderful progress which has characterized the last quarter of a century the Lighthouse system has been one of the foremost. Wherever civilization and commerce have spread, there has the engineer marked its advance by these evidences of his skill; and it seems more than probable, that in the course of a very few years all the prominent points of the world interesting to the navigator, wherever his commercial pursuits lead him, will be indicated by day and night by these guardian monitors; while the whole west of Europe is now so well lighted as to very nearly approach perfection. Whether Lighthouses, as now understood, were used in the early periods of history is almost more than doubtful, although there are many allusions in the mystical writings of the ancients to such existing, and conjectures have been formed that Homer has mentioned them. Vague hypothesis has also made the single-eyed Cyclopes into Lighthouses; or even, in a figurative manner, Lighthouses themselves. It is more than probable that the prominent headlands of the Mediterranean were marked, in the very early ages, by beacon lights, to guide the coasting and timid voyagers of these distant ages. It has also been surmised, but without much reason, that the famous Colossus of Rhodes, erected about 300 B.C., was also used as a signal light.

Leaving these dark conjectures, we arrive at a certainty in the history of the famous Pharos of Alexandria, one of the seven wonders of the world. It served as a guide to the ancient mariners during the period of 1,600 years, and its remains are still to be recognized. Pliny says, in his Natural History, that it was built by Sostratus of Cnidus, by command of one of the Ptolemies, about 285 B.C. The cost of it was 800 talents (£243 15s.), or £195,000 English. It was square, of white stone, consisting of many storeys, and diminishing upwards. Its height, according to the authority of the Geographia Nubiensis, was 100 statures of man, or 300 cubits, (equal 20·480 inches,) equal to 512 English feet. In the upper chambers were windows looking seawards, and in these chambers torches or fires were burned to guide vessels into the harbour of Alexandria, and we are told by Josephus that these fires were visible at the distance of 300 stadia (or $29\frac{1}{5}$ geographic miles).

This general description is applicable to nearly all Lighthouses down to the year 1811 or 1812. Its name was taken from the little Island of Pharos, on which it was erected, and hence it has been applied to Lighthouses generally, while the term Pharology was first introduced by the late Mr. Purdy to express our modern system

Other Light-towers existed at Ostia, Ravenna, Apamea, and other places, as mentioned by Pliny, Suetonius, and Stephanus Byzantinus.

During the spread of the Roman power, this mighty nation planted these evidences of their nautical skill in their conquered countries. The Lighthouse at Coruña, north-west of Spain, is perhaps the oldest existing town now used as such. It is believed to have been erected in the reign of Trajan. It was re-established as a Lighthouse in 1634, and in 1847 had one of the finest modern light apparatus erected in it.

In England we have an evidence of the Roman colonization in the Pharos which stands adjoining the ancient church on the highest part of Dover Castle, built prior to A.D. 53. A similar tower, now destroyed, existed on the opposite heights, and was called, from its hardness, "The Devil's Drop of Mortar;" another occupied the height of Boulogne on the French side. There perhaps may have been a Roman pharos on Flamborough Head, and another one on the coast of Flintshire. The known existence of these and others, and the inferred use of others in our own country, testify that these phari were among the many marks of the high civilization of those early days.

In the mediæval period, there are many Lighthouses of which we have some notices, as well as some which still are used as such. They were also frequently, perhaps more generally, a portion of other buildings. Thus, on an angle of the tower of the little church which crowns St. Michael's Mount, in Cornwall, are the remains of a stone lantern, perhaps nearly 500 years old, which is now known as the famous St. Michael's Chair. The Light at St. Elmo's Castle, Malta, has been shown since 1551. The Skaw Lighthouse, on the N. point of Denmark, recently rebuilt, dates from 1564. The oldest Lights now existing on the same sites in Great Britain, are those of Lowestoft, since 1609; Win. ton and Dungeness, 1615; the North and South Forelands and Orfordness, 1634; the Isle of May, 1635; Portland, Harwich, St. Agnes, Flamboro', &c., all in the 17th century, and several others soon after these dates.

All these structures, however, do not differ in their principles from ordinary buildings on land, and were constructed only to show by night the uncertain illumination of a wood or coal fire, or other imperfect mode of lighting. Modern science has replaced all these methods by a very different order of building and apparatus; so that, although the brief description of lights in ancient times given above is interesting to the historian, it is only within almost the last century that the true requirements of these monitors have been recognized. As a building, the first structure, as a purely nautical work, was the Cordouan Tower, in the Bay of Biscay: and the next the Eddystone Lighthouse: with these commences the history of Modern Lighthouses.

CHAPTER II.

LIGHTHOUSES AND LIGHTVESSELS.

The famous Cordouan Tower at the mouth of the Gironde, in the Bay of Biscay, is a wonderful monument of skill. This elegant structure, the work of Louis de Foix, was completed in 1611, in the reign of the great Henri the Fourth of France, and was twenty-six years in building. It is minutely described by Belidor in his "Architecture Hydraulique." It was 197 feet high, and consisted of successive galleries enriched with pilasters and friezes. Round the base is a circular building 134 feet in diameter, in which are the light-keepers' apartments, and which also forms a sort of outwork to break the force of the waves from the main building. The tower itself contains a chapel and numerous apartments, and is ascended by a spiral staircase. It has been lately modified and adapted to the modern system of lighting, and, after a lapse of 250 years, it is considered the finest Lighthouse in the world.

The Eddystone Rock, off Plymouth, has attracted the attention of the public more, perhaps, than any other of our Lighthouse sites; not so much on account of its importance, but as forming an era in the construction of Lighthouses. The first Eddystone Lighthouse was built of wood, 80 feet high to the top of the vane, from Mr. Winstanley's designs, 1696-8. The light was first shown in November in the latter year, but it was soon found that the sea rose, so as "to bury the lantern under the water," although at the elevation of 60 feet above the rock. It was accordingly raised to 100 feet. In November, 1703, the tower requiring some repairs, Mr. Winstanley went to the Lighthouse to superintend them; but the storm on the 26th of that month carried away the whole erection, and every soul perished. The wreck of the *Winchilsea*, man-of-war, soon after occurred, as if to point out the necessity of a light; but the Trinity House could not obtain the sanction of the Government to commence until July, 1706, when a new timber erection was began by Mr. John Rudyerd. It was subsequently destroyed by fire in 1755. This tower was circular, and 92 feet in height. The tower which exists here at present was erected by Mr. Smeaton, who has given an admirable description of it. The masonry was 76 feet 6 inches, and the top of the lantern 93 feet above the foundation. This noble erection, completed in 1759, stands a monument of fame to its constructor, and a lasting evidence of the correctness of the principles on which it is built. It will be self-evident, that the site of this, and similar erections, calls for extraordinary skill and solidity in their construction. They are therefore to be viewed as works *sui generis*, and must not be classed with similar buildings on land, removed from the tremendous force of the waves.

Smeaton's description has been so often referred to, that it is scarcely necessary to quote from it here. The various courses are so dovetailed into each other, and the whole secured together, that the tower is really almost as if cut out of a solid block. The immense difficulties which had to be overcome, from the first landing on the rock, on April 5, 1756, to the laying of the first stone, June 12, 1757, and the last, on August 24, 1759, render Smeaton's book one of the most interesting ever written.

The next Lighthouse in our country, of a similar nature, is the equally famous Bell Rock Lighthouse; whose constructor, the late Mr. Robert Stevenson, has also given us a most valuable account of the difficulties to be overcome, and the progress of the works, between its commencement, in August, 1807, and its completion, in October, 1810. It was first illuminated in February, 1811. The tower is 100 feet high, and cost £60,000.

A later, and the most noble erection of this kind, is that on the Skerryvore Rock, off the west coast of Scotland. This, from the designs of Mr. Alan Stevenson, the son of the engineer of the Bell Rock, and the talented engineer to the Scottish Lighthouse Board, cost in its erection, with the harbour for the tender and other necessaries, £87,000, and was first illuminated in 1844. The light is 150 feet above the sea, and the structure and its appliances exhibit every refinement that has hitherto been made in the varied particulars of the system.

The latest grand Lighthouse of this nature, and also one of the most important in the British list, is that on the Bishop Rock off Scilly, built by Mr. James Walker, 145 feet high, under the superintendence of Mr. H. Douglass, at an expense of £36,500.

The Lighthouse at Carlingford, on the East coast of Ireland, the foundation of which 12 feet below high water, is an analogous structure, 111 feet in height, though not in such an exposed situation, was completed from the designs of Mr. George Halpin, 1830.

Another noble and ornamental Lighthouse is on the West coast of France, on the Héhaux (or Héaux) de Brehat. It is nearly as high as the Skerryvore, and is deserving of all admiration. Its base is circular, 60 feet in diameter, from whence the tower rises to the height of 140 feet. It is beautifully fitted up in many respects.*

It is as difficult to estimate the nautical importance of these triumphs of engineering skill, as it is to calculate the wonderful force of waves that they have to bear against.

Mr. Thomas Stevenson, another of that eminent family of Lighthouse engineers, constructed an apparatus, like a railway buffer, that self-registered the force of the waves that struck it, which has been applied to this purpose.

In the Atlantic, according to observations made at the Skerryvore Rocks, the average result for five of the summer months, in 1843-4, was 611 lbs. per square foot. The average result for the six winter months of the same years was 2,086 lbs. per square foot, or three times as great as in the summer months. The greatest force registered was on the 29th March, 1845, during a westerly gale, when a pressure of 6,083 lbs. per square foot was exerted. The next highest was 5,323 lbs.

In the North Sea, at the Bell Rock Lighthouse, the greatest result obtained was 3,013 lbs. per square foot. This lesser force is to be attributed to the narrow space in which the waves have to travel in the North Sea, compared with the roll of the Atlantic. It must, however, be remarked, that it is almost impossible to receive the force unimpaired, as the waves are more or less broken by hidden rocks or shoal ground before they reach the instruments.

Even this tremendous force seems to be far less than that encountered at the Bishop Rock, probably the most exposed Lighthouse in the world. On January 30, 1860, a storm wave shook this tower, and tore away the bell, weighing 3 cwt., from its support at the top of the tower, more than 100 feet above the sea. Mr. Stevenson also has related some extraordinary circumstances of the force of waves at the Shetlands, which demonstrate that their power, if opposed, is almost irresistible. Therefore, if these sea-beaten towers were not, at least, equal in weight to a solid block of granite of 60 or more feet in height, they would not be able to withstand the waves.

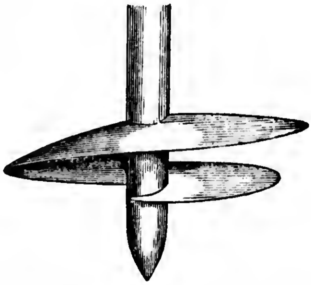
The most obvious means to avoid this enormous amount of hydrodynamic force, is to reduce the extent exposed to it to the smallest possible limits, so as to offer the least possible resistance. Iron columns have been suggested and used for this purpose. But here another difficulty awaits us, namely, that iron, particularly *cast iron*, is decomposed by the action of sea water, and this to a very great extent, the effect being to convert it into a substance similar in its chemical properties to black lead. In evidence of this, on removing the wreck of the Mary Rose at Spithead, which had been sunk for 292 years, the iron shot, upon being exposed to the air, gradually became red hot and then fell into a dry powder resembling burnt clay. This is a serious obstacle to the permanency of such erections, and it has been proposed by Mr. Gordon to obviate it by using gun metal or bronze; but whether this would answer for piles is a question. Wood has also been used, as in the Small's Lighthouse off Pembrokeshire; but as it is liable to many sources of decay, and particularly to the ravages of the *teredo navalis*, when under water, it is not adapted for such structures.

Having stated these difficulties, the description of the means employed to overcome them will be better understood. The first to be noticed is the *screw pile* of Mr. Alexander Mitchell, C.E., of Belfast. This principle was first employed in the construction of the foundation of the Maplin Lighthouse, on the north side of the mouth of the Thames, which now exhibits a red light. This was commenced in 1838, and is as firm now as when first erected. It stands on the outer edge of the Maplin Sand, which consists of sand at the surface, and afterwards of sand and mud, exceedingly soft and penetrable, and therefore the erection of a Lighthouse upon such a foundation must considered as a great achievement.

---

* See "Rambles of a Naturalist;" by A. de Quatrefages. Translated by E. C. Ott[é]. 1857; vol. i. p. 121.

The principle of the screw-pile Lighthouse, is having a series of piles, nine in number, eight in the angles of an octagon, and one in the centre. These piles consist of a shaft of hammered iron, 5 or 6 inches in diameter, having a single turn of the flange of a screw 4 feet in diameter. This pile is screwed with great facility into the sand to the depth of 22 feet, and it was calculated that each of them would bear a weight of 64 tons. These nine piles were fixed in nine consecutive days in the summer of 1838, and upon this foundation of Mr. Mitchell's, the light-room was erected under the direction of Mr. Walker, the engineer to the Trinity Board.



Extremity of Mr. Alex. Mitchell's Screw Pile.

Mr. Robert Stevenson proposed, in 1800, a structure similar to this, for the Bell Rock Lighthouse. It was intended to affix the foundation to the rocks, and that the iron shafts should support several storeys; whereas the Maplin and the Foot of Wyre Lights have but a single storey.

Mr. Mitchell previously completed a Lighthouse upon a similar foundation at the mouth of the Wyre River, in Morecambe Bay, about 30 miles north of Liverpool. It was commenced in November, 1839, and lighted in June, 1840. The foundation is formed of seven screw piles, six in a circle and one in the centre, each of them 5 inches in diameter, with a screw of 3 feet diameter, and these screws sunk 13 feet into the bank of exceedingly hard sand, which is occasionally dry at low water. On these screws is supported the Lighthouse, consisting of a floor, and the lantern above it.

The Maplin Lighthouse, erected by Mr. Walker, upon Mitchell's screw-pile foundation.

This screw-pile system has also been adopted for standing Beacons.

As far as experience goes, these Lighthouses answer all the purposes required of them, as regards stability, by offering the smallest possible surface to the force of the waves. How far the perishable nature of the iron may interfere with its permanency, must be left to time to unfold.

These pile Lighthouses have hitherto been placed in the less exposed situations, such as the Thames Mouth, Morecambe Bay, Belfast, Cork, &c., and have answered all their requirements. The proposal of Mr. Stevenson for the Bell Rock, above alluded to, was attempted on the Bishop Rock, and the structure was completed to the base of the lantern, when it disappeared in the course of a stormy night in January, 1850. The same disaster befel a similar structure on the Minot's Ledge, Boston Bay, U.S. These misfortunes have stopped any further extension of this principle, although it is of very great importance to secure a foundation on a treacherous bed in an exposed situation.

Many other plans have been suggested, among which the pneumatic pile of Dr. Potts deserves notice.

This beautiful adaptation of atmospheric pressure has been applied to the erection of several Beacons in the vicinity of the mouth of the Thames. The first experiment was upon the Goodwin Sands, on July 16, 1845, and an iron tube of 2 feet 6 inches diameter was driven into the sand to a depth of 22 feet in two or three hours. A gentleman, present at the experiment, which was made by the Trinity Brethren, said that the facility with which this large tube was made to descend could be compared to nothing better than shutting up a telescope. The method of operation is this:—One of the tubes being placed perpendicularly, an air-tight cap is fixed to the upper end. The cap communicates with a powerful air-pump, by means of which the air is exhausted from the tube, drawing up the sand or shingle with the water which ascends, and the tube immediately descends from the effects of outward atmospheric pressure. The contents of the tube are then removed by the pump, which readily draws away the sand or shingle with the water which rises during their action, and the exhausting process is then continued. The upper end of the tube having become level with the surface, the operation is stopped, the cap removed, a fresh tube is affixed and secured, and the same course pursued, and thus continued, until, with the greatest facility, this great length of tube penetrated what must have been exceedingly hard sand, nearly resembling stone, as was found by Mr. Bush in his erection of a caisson on these sands, for his light of all nations. The practicability of the scheme being proved, several Beacons, as before stated, were erected as on the Buxey, the Shingles, the Girdler, the Margate, and other sands lying in the mouth of the Thames.

Another plan has been carried into effect, at the Point of Air Lighthouse, at the entrance of the River Dee, near Chester. This, which is similar in superstructure to the Maplin Lighthouse, is by Messrs. Walker and Burges, and consists of nine hollow iron cylinders, 3 feet 9 inches in diameter, sunk 12 feet into the sand by the aid of an instrument known to well sinkers as "the Miser," which extracts the sand contained in the cylinder. In these the bases of the piles are inserted, and then filled with concrete. But this is erected above low water mark.

Another adaptation of iron to the construction of Lighthouses has met with far greater success, and promises to be of the greatest utility, whether as regards economy or facility of construction. This is the iron Lighthouse designed by Mr. Gordon. It would seem somewhat singular that iron should not have been employed in this form before, when we consider the multifarious variety of purposes to which it is now applied.

A cast-iron Lighthouse was mentioned by Mr. Rennie, in 1805, for the Bell Rock, and also, as previously stated, referring to Mitchell's screw piles, by Robert Stephenson, in 1800. Mr. Rennie, in alluding to the use of iron, says, "A Lighthouse of cast-iron might also be constructed here, and I will allow that it might have a coating of lead, or other metallic substance, so as for a long time, at least, to resist the effects of marine acid. But to make a Lighthouse that would last of such materials, would be nearly, if not wholly, as expensive as one of stone; while—I believe I need scarcely say—no human ingenuity could render it as durable." But Mr. Gordon has proved the futility of this latter assertion, in some experiments he has made. The first tower of this construction was placed on the eastern end of Jamaica, called Morant Point.

This noble tower is erected on the centre of the remarkable group of islands, the scene of Shakespere's Tempest, and the focus of the Atlantic hurricanes. The Light-tower is 105 feet 9 inches high, formed with iron plates, the entire weight of which is nearly 100 tons. It has seven storeys, and the lower portion is filled in with concrete, to the height of 22 feet, to give it stability. Nearly every portion of the edifice is of iron, and the erection of the tower was completed in ten months, finished October 9, 1845. The light is from a beautiful dioptric first order apparatus, constructed by Messrs. Wilkins and Son, of Long Acre; the lenses composing it were made by Mr. H. Lepaute, of Paris, and is one of the most efficient and powerful lights in the world.

One important point is the colour of Lighthouses. In many instances this has not been sufficiently attended to; and some of the noble Scotch towers, left of the natural colour of the stone, too much resemble the grey background. When it shows against the land, white, of course, is the best; and if against the sky, a dark colour is preferable. *Red* is sometimes used, as at Dungeness, &c.; and the extension of the use of coloured stripes and bands is recommended. This has been found particularly serviceable for day distinction in the British American lights, where the snow lies much longer against the field fences at right angles to the coast, and has precisely the same appearance at a distance as a white tower.

There is one difficulty in the use of coloured bands, and that is, during hazy weather, the appearance of the tower is frequently that of a ship under sail, the bright stripes being like the sails; this requires caution. The famous Eddystone has lately been painted in this way to distinguish it from the Bishop Rock.

The buildings we have been describing, commencing with those of ordinary land erections and terminating with such towers as the Bishop Rock, have been extended as far as human skill and power can probably be exercised. Still it is necessary, not only to mark a danger, or indicate safety, but to warn ships from the approach to a shoal or reef, or to show a channel far away from land.

The numerous light-ships which have been established by Great Britain have greatly fulfilled this requirement. Our country possesses 47 such vessels, of which 5 belong to Ireland and one to Scotland. Other countries have but very few light-ships, except the United States, which has 48; but they have only recently been made worthy of comparison with the English light-ships.

It is manifest that a lightvessel can perform its office but imperfectly compared with the stability ensured in a fixed Lighthouse. Its floating character prevents the use of that refined and enlarged apparatus which is the characteristic of a Shore Lighthouse. In addition to this, the establishment of a lightvessel is very much more expensive. The average cost of the English Lightships is £3,600; of the Irish, 6,200. Those of the United States (the best), the Nantucket New South Shoals, £4,375.

The cost of maintenance is much greater than that of a Lighthouse establishment. This is manifest from the difference of condition. Three men are sufficient to a rock Lighthouse, 11 are required to man a Lightship; consequently, while the annual cost of a first-class Lighthouse is from £265 to £340; in Scotland, £380; Ireland, £405 to £485; and in France, from £320 to £415; that of the Lightships amounts to £1,103, £1,464, and £1,320 per annum for England, Liverpool, and Ireland, respectively, and £1,354 for the United States' Nantucket vessel. These are strong arguments in favour of stationary buildings.

The question of their sufficiency depends also in some measure on the solution of a problem, which Mr. Herbert, of the Trinity House, proposes to make the subject of experiments on a large scale.

It has been proposed by him to extend the principle of lighting by establishing Floating Lights in the Fairway; the hulls to be constructed on the principle of his buoys, and the light the best known.

The efficiency of a Floating Light depends on the attention paid to the points in reference to the quality of Lighthouses, with one very important addition, namely, that it should remain on its station in all weathers.

"The best proof that the lights are efficient in the last particular is to be found in the statements of the Lighthouse authorities, which are fully confirmed by the evidence of mariners. The Lightvessels very seldom go adrift, and there is no instance on record in which the crew have voluntarily run from their stations in bad weather. When they have been driven from their moorings, the vessels have always been replaced in a very short time, and none have ever been wrecked. The mariners' evidence on this point is valuable, because the rare instances in which Lightvessels have been off their stations are repeatedly mentioned by independent witnesses as remarkable events. It does not appear that the lights have ever been accidentally extinguished." *

---

* Report of the Royal Commission, March, 1861, p. 17.

Much has to be learned about the best form for resisting the force of winds an waves when the vessel is always at anchor. The shape of the hull now varies con siderably. Some are longer than others. The part of the vessel to which the moor ings are attached, and the points where the chains enter, are different. The Iris vessels are generally longer and sharper than those in England, and set an after-sa when its use enables them to ride more easily. The testimony of the men on boar has been in favour of considerable length, fine entrance, and a low point for attachin the moorings.

The Trinity House Lightvessels are painted red. In Ireland they are black with white streak. At Liverpool, two are red and one black; and they are all distin guished by balls hoisted at the mastheads, and by other signals, and some have thei names painted on their sides. Black and red seem to be the colours which contra best with the colour of the sea, and they are, in fact, best seen.

The United States sea Lightships, where they have been constructed on th improved models of the European floats, since the establishment of the Lighthou Board in 1852, are painted either cream-colour or white.

It is a remarkable fact, that the Lightships lying in very exposed situations, as th at the Seven Stones, near Scilly, and the Coningbeg, ride very much easier than tho in shallow though sheltered waters, as at the Spurn, off the Humber; the Owers the Cattegat, or the Arklow. This is owing to the great scope of heavy cable whic is out in the one case, acting as preventive to her pitching heavily while she crosses th sea; and short cable renders a Lightship, in some positions, one of the most unple sant situations in the world. In the shoal water, when the wind is strong, the vesse sometimes ride broadside to the tide and sea. Where the swell is much larger, as the open ocean, the tides are not so strong. The efficiency of a Lightship is th impaired by her want of stability. The remedy for this serious drawback involv the grand consideration, whether it is not possible to remodel the Lighthouse syste so to speak, by the establishment of deep sea Floating Lights, if a vessel can be co structed of such a form as to ride steadily and be secure at her moorings.

The proposal of Mr. George Herbert, above mentioned, for this important su ject, is deserving of every consideration. In the case of the numerous buoys an beacons constructed and established on his principle, as shown in Liverpool Bay an elsewhere, it certainly does appear that the subject should not be relinquished till is demonstrated that modern engineering skill cannot do in this what has been do in other apparently equal difficulties. Mr. Herbert's plan of the Beacon is that whic keeps it constantly upright, with but little oscillation. His proposal is to moor a li of these large vessels along the fairway of the English and St. George's Channe showing lights of the finest character at great elevations; so that by steamers passi up channel on one side and down on the other side, much of the risk of collision (th increasing and fatal evil) would be avoided, and the anxieties and dangers conseque upon hugging the land would also not be incurred.

A few words may be here added upon *Beacons* and *Buoys*, as accessories to o present subject. In some cases Beacons approach the excellence and costliness standing Lighthouses. Thus the dangerous Wolf Rock and Runnlestone are mark with stone Beacons, the first of which cost nearly £12,000, and immense labou There are 261 structures of some magnitude erected as Beacons under the pub authorities of our country; and it is thought that our system, although capable some improvement, is generally superior to that of foreign nations.

In the form and character of Buoys there has been very great improvement of la years, especially since the employment of iron in their construction, as in the case ship-building. In Great Britain and Ireland, 1861, there were about 1,100 Buoys i position, excluding wreck, warping, and many others of minor importance; abo one-half of which are under the public authorities. They generally keep their pos tions excellently, the chief accident occurring through being run down. Out of th whole number only 53 broke adrift in 1858, and of these a very large proportion we under local authorities. Mr. Herbert's Buoys, as before alluded to, answer the purpose admirably. Peacock's refuge Buoys are also excellent; and there are oth forms, as Lenox's and Poulter's, which are very efficient. The spiral form and dark colours (black or red) seem to be the most useful. The cost of a Buoy varies from £27 to £36 for the ordinary can, up to £130 and £197 for the first class spiral Buoys.

CHAPTER III.

LIGHTHOUSE ILLUMINATION.

1.—LIGHTS.

The first Lighthouses, such as the Cordouan and the North Foreland, had originally on their summit open fire-places, or chauffers; in that of the former were burnt billets of oak wood, and of the latter, coal; and this was the only means of indicating their situation during the night. A few words will show how incompletely these must have performed their office. Of course, the time at which a light becomes most serviceable is during tempestuous weather; and a wind, blowing towards the land, causes that dread to mariners—a lee-shore; yet this wind would drive the flames of an open fire away from the direction in which they were most wanted to be seen; thus the bars of the grate were often nearly melting to leeward, while towards the sea the coals remained untouched by fire. There was frequently, however, this advantage in the open fire, that during the fog or rain the glare of the fire was visible by reflection in the atmosphere, though the fire itself could not be seen. Such a feature would be of no advantage in the modern system, as will be hereafter shown.

The North Foreland Lighthouse, between Ramsgate and Margate, will be more familiar to many than other Lighthouses, and will serve as an excellent example of the progress of illumination. This Beacon was instituted for indicating the proximity of the Goodwin Sands. The first intimation we have of its existence is in 1636, in Charles the First's reign, when license was granted to Sir John Meldrum to renew and continue this and the South Foreland Lighthouse for the same purpose. At this time it was merely a large glass lantern on the top of a timber and plaister house, which was burnt in 1683. Towards the end of the same century, the present tower was partially erected, a strong octagonal structure, having the iron grate, or chauffer, for burning coals. From the difficulty of keeping up a proper flame in windy or rainy weather, about the year 1732, it was covered with a sort of lantern, with large sash windows, and the coal fire was kept alight by means of large bellows, which the attendants blew throughout the night. This was found not to answer, and the reflected glare above mentioned was thought desirable. Accordingly, the lantern was removed, and the fire restored to its original condition. Matters went on thus till 1790, when the tower was raised to its present height of 70 feet, and further improvements made in the lantern, by the introduction of lamps and other apparatus, hereafter to be described.

After some alterations of the Cordouan wood fire, the mariners complained that they could not see the light at the distance of two leagues as formerly. But Smeaton informs us, that the coal fire of the Spurn Point Lighthouse, at the mouth of the Humber, which was constructed on a good principle for burning, had been seen thirty miles off.

The only exceptions to the fires were the noble Eddystone lights, which then used to exhibit a chandelier of twenty-four wax candles, five of which weighed 2 lbs., and the Liverpool Lighthouses, which had oil lamps, with rude reflectors.

The use of coal fires has not been so long abolished as might be imagined. In Britain they were used till 1823. Thus the Isle of May Lighthouse, at the entrance of the Frith of Forth, had a coal fire till 1310; at St. Bees Head, Cumberland, oi was first used in 1823; at the Flat Holm, Bristol Channel, in 1820, &c.

It is stated that a coal fire is still used on the Grönskär Lighthouse, East coast o Sweden. They were in operation on the two towers of Nidingen, in the Cattega till 1846.

The general use of *good* lights is of very recent date. During early times the mod of lighting were most imperfect, and the rude lamps, with their thick, torch-lik wicks, which were the best then attainable, form a ridiculous contrast to the prese universal brilliancy required.

Upon the introduction of the Argand lamp, a vast step was advanced towards t perfection of Lighthouses. This advance in artificial light was the greatest previo to the introduction of gas. It was discovered by M. Argand, a citizen of Genev about 1780 or 1785. It has remained as he left it, and appears as perfect in princip as can be looked for. Its perfection as an experiment was almost accidental. We a informed by the younger brother of Argand of its accidental discovery. He say "My brother had long been trying to bring his lamp to bear. A broken-off neck o flask was lying on the chimney-piece; I happened to reach it over the table, and place it over the circular flame of the lamp; immediately it rose with brilliancy. M brother started from his seat in ecstasy, rushed upon me with a transport of joy, a embraced me with rapture." Thus was the Argand lamp formed.

On the introduction of a more efficient means of illumination, and the conseque abandonment of the coal fires, Lighthouses assumed a more important position maritime affairs, and they were accordingly largely increased in number.

The cylindrical-wicked lamp, in its various forms, is the usual mode of lighti employed in Lighthouses. For the reflectors, the wick is nearly an inch in diamet for the lens lights, a more powerful and complicated lamp is used.

For a first-order light, this lamp consisted, in the first instance, of four concent wicks, of the respective diameters of 0·827, 1·69, 2·52, and 3·39 inches, the smal apparatus being constructed of 3 or 2 concentric wicks; but within these last 10 ye the interior wick has been removed from all the burners, it being thought that a lig of superior brightness could be obtained by allowing more air to pass into the fla on the inside, and forcing this air outwards on to it by a metal breaker or button k below the level of the flame, so as not to interfere with the rays of light emanati from all sides of it. But an undue economy has been forced on the consumption oil, and the metal button hiding some of the upper rays, it is probable that efficiency of the light has been impaired, and a portion of it screened from the up part of the apparatus. The original form of the lamp will therefore be restored.

The oil is made to flow into the burners by various means, as is stated above. Fresn invention consisted of a series of four small pumps, worked by clock-work, which for the oil upwards to the flames. Another mode was by weights acting on a piston third by a spring doing the same office, a plan which has since become in univer use in the moderator lamps. Another mode, the pneumatic lamp of Messrs. Wilki acted by means of the pressure of air in the reservoir; and another, frequently appl of late, is by placing the reservoir slightly higher than the lamp, the oil thus flow freely by its own gravity to the required level.

The fuel used in the English Lighthouses in these excellent lamps up to the y 1846, was the best sperm oil that could be procured. At that period a change made throughout the whole of the lamps, by adapting them to the use of colza refined rape-seed oil, requiring a thicker wick. This oil was in use in the Fre Lighthouses for some time prior to this, and was procured from the seed of a pecu species of wild cabbage, known in the north of France under the name of colzat, colza. This plant is extensively cultivated in Normandy, &c., the chief markets the oil being Caen, Rouen, Lille, and Courtrai. That now used by the Trinity H is chiefly refined by a patent process. This refined oil is of a superior character to sperm oil; it produces a brighter flame, does not cause so much deposition on wick, consequently, will burn longer without trimming; any adulteration in i much more easily detected than in sperm oil, and it is half the cost. It is ccellent substitute for the oil, which is annually becoming dearer, and more oen to being mixed with other and inferior oils. In the Liverpool lights olive-l has been used since 1847—a change effecting a saving of 40 per cent. on the use of perm-oil. Olive-oil is also used in the Spanish and Austrian Lighthouses. The 'nited States lights are supplied with sperm-oil exclusively. In our colonial Light-ouses other varieties of oil are used, of which one need only be noticed as being used the Lighthouses near the Cape of Good Hope. This oil is procured from the tips f the tails of the Cape sheep, and is said to be far superior to any other oil for bril-ancy of light; but the quantity consumed, and the expense, are great. It costs 10*s*. 6*d*. er gallon, and the first-order light of Cape Agulhas consumes about 730 gallons year; 482 gallons of rape-seed oil would be necessary for a year's supply.

One great advantage in the refined rape-seed oil is that it does not thicken, except pon a very great degree of cold, a qualification which places it far above sperm and many other oils for winter use. Indeed the change is a fortunate one in another espect. The untiring perseverance of the whale-fishers from the neighbourhood of Nantucket has so dispersed and destroyed their prey, that it is almost doubtful if a ontinuous and sufficient supply could be maintained, except at great prices.

The purity of the fuel, and the perfect combustion effected by the present arrange-ment of lamps, keep the flames used in the apparatus in their normal condition; but is necessary to carry off the products of combustion from the confined space of the ght-room, for, if they were not disposed of, they would both materially diminish the ower of the light, and also be a serious detriment to the health of the attendant ght-keeper, whose constant presence in the light-room is strictly required. This is ffected by the ventilating tubes devised by Dr. Faraday, with the principles of which most are familiar; they are fitted to all our Lighthouses. A plan, similar in action, ut less complete in detail, was promulgated at the commencement of the present entury by Dr. Van Marum.

That a light of such intensity will be discovered as will penetrate a fog, may be onsidered as utterly hopeless. The sun, the great source of light itself, is entirely bscured by a comparatively thin film of vapour; and although we have artificial ghts which apparently rival in brilliancy that of the sun, they are quite incapable f being seen to any great distance under such circumstances.

Perhaps it would be as well to notice here the very great distances to which lights ave been visible. One of these is recorded in the account of the trigonometrical perations in France by MM. Biot and Arago. The points to be connected with Campvey, on the Island of Iviza, and a rocky mountain on the continent of Spain, alled Desierto de las Palmas. On the former a powerful lamp with reflectors was laced. After watching for some months, a supposed minute star was identified as e signal light, and was afterwards easily recognized by the observers. This was a istance of nearly 100 miles. It is not intended by this example to say that a light ould become serviceable at such a distance, but that it is possible to cause a light to e seen so far.

All modifications of lamp light sink into utter insignificance when compared with ome other lights, produced by chemical means, from which very great expectations 'ere formed, but hitherto with very little prospect of successful introduction. The rst we shall mention is the Drummond light, generally known as the oxyhydrous or me light.

Lieut. Drummond, the first promulgator of this splendid light, was employed in the rand trigonometrical survey of England, in the course of which it became necessary connect by observation Leith Hill, in Surrey, with Berkhampstead Tower in Hert-ordshire, which were to be seen, but could not be distinguished from each other. he discovery arose from his consideration of Berzelius's experiments with the blow-ipe, as detailed in the "Philosophical Transactions," 1826—1831; and from the ntense light produced in these, Lieut. Drummond was induced to try a jet of flame om the combined gases, oxygen and hydrogen, on a ball of lime. Many trials of its ntensity were made, one of which was in the north of Ireland. A hill in Inishowen, alled Slievesnaght, was always enveloped in haze by day, and a Drummond light 'as placed on it. In the line between it and the observing station was a church tower, much nearer to the latter, and on this an ordinary reflector was placed. Drummond light, at the distance of 70 miles, was much more elevated than the ot which was 12 miles distant, and thus they appeared nearly on a level. When t were both seen, the Drummond light appeared to be much nearer and brighter t the lamp at 12 miles.

Its enormous power is evident from this, and it has been reckoned equal to Argand lamps; and this is produced from a ball of lime ⅜ of an inch in diameter, the angle which this minute object would subtend at the distance of 70 miles is 1 5-6th part of a second.

The difficulties of introducing this light, however desirable, appeared at first be insuperable. The preservation of an equal intensity of flame is almost impossi from the rapid diminution of the lime ball by fusion and volatilization, and by frequently cracking and breaking. It has also the most painful effect on the eye the attendants, and is most injurious to the sight.

The difficulties, however, of maintaining a steady light has been in part overc as an arrangement has been made by Mr. Renton which preserves the cylinder of from cracking, and then jets of the combined gases produce a most brilliant fl It has not yet been tried to any great extent in Lighthouses.

A proposition for increasing the intensity of the flame of the oil lamp was mad Mr. Gurney, in 1835; this was to impinge upon the flame jets of oxygen gas. by increasing the combustion, certainly enhanced the effects of the flame, b charred the wick; and in this case, as in the former, it would be difficult to app to Lighthouses, from their isolated position, and the difficulty and danger of produ and keeping the gas.

The method of illumination by gas has in some instances been successfully tri in the Lighthouse at Hartlepool. The burner here is that of Mr. M'Niel. Gas, a illuminator for Lighthouses, was proposed, in 1823, by Signor Aldini, of Milan.

The splendid light obtained by electricity has long been a desideratum, numerous trials and great skill has been employed in overcoming its difficulties. was hoped that the apparatus of Messrs. Staite and Petrie (1848) would have successful, but it was found to be uncertain. M. Dubosc has designed an exce lamp, which is used in philosophical experiments; but it requires delicate man ment, and is very expensive. Mr. Harrison's plan has not come into use.

There are two great difficulties in solving the problem of a steady light electricity. The first is, in maintaining an equable force from the producing elem that is, the battery, which, of course, will gradually decline in power after a time, and no means have, as yet, been devised for so thoroughly obviating this, keep up for so many hours as the light must be shown. The next is, at the outl this current; in preserving that exact distance between the two points of car through which the arc passes, which maintains the light in its normal condi These carbon points are usually formed of graphite, the substance which is f lining the inner surface of the old gas retorts. The rapid disintegration of positive pole, the less diminution of the negative pole, and the irregularity of the sumption of both under the intense action, have baffled the ingenuity of almost who have attempted to control them.

Professor T. H. Holmes has adopted another form of originating the current has hitherto been tried—that of magneto-electricity. The whole apparatus an results are an admirable exemplification of the correlation of the physical forces evidence that one power may be traced throughout a train of operations un emanates in a totally different form. The apparatus consists of a series of powerful permanent magnets, around the poles of which the helices are made to re by means of a steam-engine, and from the extent of the primary arrangement a powerful magnetic current is produced, which, passing through the carbon pe shows that splendid light which entirely eclipses all other modes of illumination.

This beautiful adaptation was used for 6 months in the upper Lighthouse of North Foreland, and was very successful. The light, which is not ¼ inch in diam as shown to disadvantage in the great lens, which, being adapted for the great mp, was not suitable for it, and appeared at a distance of a bluish colour, probably ntrast with the red or yellow flame of the adjoining oil lamps. It is to be tried the Dungeness Lighthouse.

The totally distinct character and colour of the electric light, will at once distinish it at any distance from that derived from any other source. Therefore, suposing that this illumination be adopted as an adjunct to that in present use, the ations in which it is applied will be distinguished from their neighbours without the ance of mistake, the fruitful source of accident from the present lights.

Lieut. Raper, in his admirable work, proposes another method of showing a light r sea purposes, that is, by illuminating the clouds and haze over the station by the ectric light. It was also proposed by Sir Edward Belcher, in 1833. This shaft of minosity might be inclined in various directions, or it might be made to revolve by oper optical arrangements, and this would give a great relief to the already hausted resources for varying the appearances of lights; but there is one case which ight render this system of no avail, and that is a perfectly pure atmosphere.

This brief exposition must suffice as to the source of light. The apparatus used to ntrol or economise this light is of two characters, either by reflectors or lenses, the toptric and dioptric systems.

2.—THE CATOPTRIC, OR REFLECTOR SYSTEM.

The effects of a light in giving out rays without any controlling apparatus, will be fill a sphere whose radius is equal to the distance at which the light is visible. In e light shown from a Lighthouse, those beams which are thrown upwards or downards beyond the reach of vision would be totally lost for practical utility; it becomes ecessary, to economise the light, to deflect these rays and cause them to assume that rection only in which they would be required. For all practical purposes, at prent, we may consider that those only which issue in an horizontal direction are fective, and our apparatus must be so ordered to answer the end of forming a *rizontal band or zone of light.*

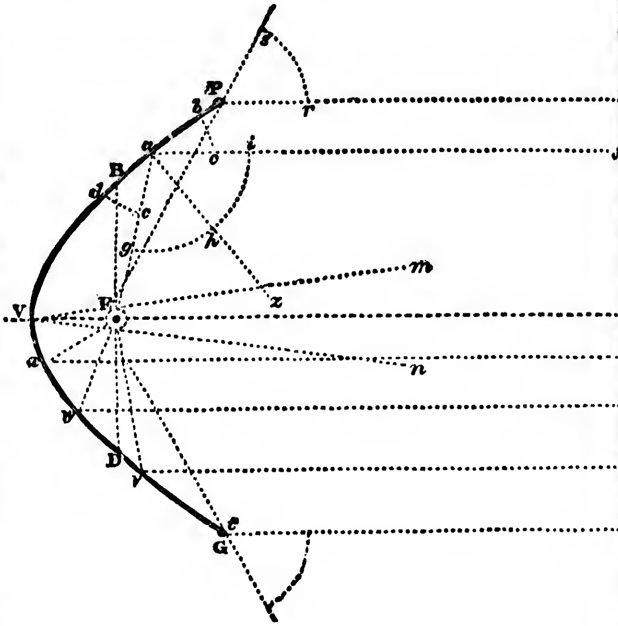
To do this we have two alternatives, the one to *reflect* the errant rays into the oper direction, by means of mirrors of the requisite form; or to *deflect* them, by using them to pass through some refracting medium for the same purpose; in other ords, to apply *lenses* of a particular form *before* the light, or reflectors *behind* the ght.

The first idea of economising light, by the means of reflectors, is met with in the istory of the Cordouan light. M. Bitri, who remodelled the lantern in 1727, ranged it for burning pit coal, of which 225 lbs. (French) were ignited at once, and sted the night. Above the fire, instead of having a hollow cupola, as it had previsly been, or of being entirely open like other Lighthouses, the circle of the ceiling the cupola was made the base of an inverted cone, whose apex projected downwards ree feet; the whole surface of this was covered with tin plates. These becoming flecting surfaces, served to increase the intensity of the light; but how they were ept free from tarnish, and the effects of the smoke, we are not informed. Here we ve the first element of the reflector system, and it is virtually the principle of the esent Bordier-Marcet apparatus. Such an arrangement would certainly answer its quirements as applied to a coal fire, and any improvement on it must be also made conjunction with some better mode of producing a light.

As the Catoptric principle depends on the figure of the parabolic curve, we will rst describe this curve.

The Parabola is a conic section, whose figure possessing certain properties, renders available for the purposes of reflection, and the true formula for its construction, as plied to Lighthouse purposes, is given by Captain Joseph Huddart, F.R.S.

The form given to the Lighthouse reflector is generated by the revolution of curve round its axis, producing a semblance to a portion of a sphere. Its propert will be better understood by the diagram. The line P V G is such a parabolic curve and within it is a point, F, which is called the *focus*, which is the situation of the lamp in the reflector, of which this may be supposed to be a section. Now it is a fundamental law in optics, that the angle of incidence is equal to the angle of reflection, that is, the ray is thrown off a reflecting surface at the opposite angle to which it is received. The peculiarity of this curved line of the parabola is, that any line drawn from the *focus*, F, to the parabolic curve, as F *a*, makes



with the normals to the curve, as *a z*, angles equal to the inclination of these sa normals respectively to lines drawn parallel to the axis, V Z. Thus a ray from lamp, F, thrown on the surface of the reflector at *a*, will be reflected in the direct *a f*, which is parallel to the axis, V Z, and the angle of reflection, *b a c*, is equal to angle of incidence, *d a e;* or, in other words, it makes with the normal, *a z*, the an *g a h*, equal to the adjacent angle, *h a i*. And this property belongs to every port of the surface of the parabola, and consequently the rays will be represented by lines F *x x'*, F *w w'*, &c. Thus it will be understood that this reflector must be m perfect in its action at that portion comprehended between the vertex, V, and rectum or principal parameter, B D. For, as any deviation from the true figure w of course, be doubled by the operation of the instrument, it will be readily seen t the acute angles made by incident rays, towards the mouth of the reflector, will much more easily distorted by any defect, than when the angles are much m obtuse, and the reflection more direct, as they will be behind the parameter. T will show, as before, that the portion at the back of the light is the most effective the parabolic reflector. There is some loss of light in the reflector, which will more particularly adverted to presently.

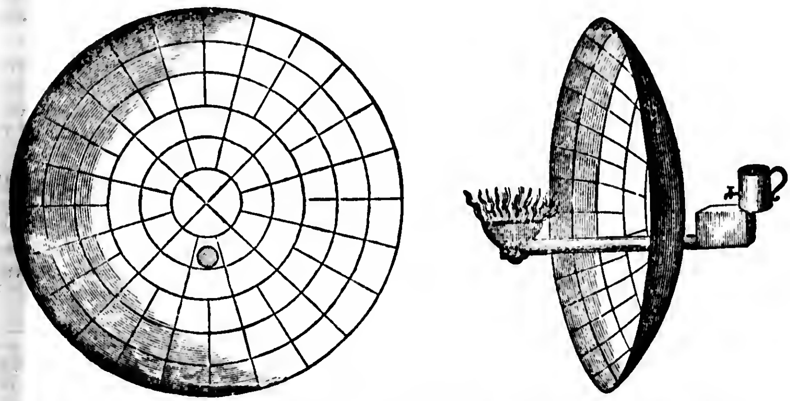
Supposing it possible to produce a perfect reflector of the foregoing figure, and its focus we were to place a *point* of light, it would send forth a *cylinder* of rays eq in diameter to its double ordinate, or the distance between G and P; and if we had construct a light apparatus which should exhibit a light in every direction azimuth, or round the whole 360 degrees of the horizon, it is manifest that it wo be impossible to do so with any number of such instruments: there would be d intervals between the directions of their axes.

But here another circumstance awaits us. The flame of one inch in diameter, u illuminating such a reflector, supposing the focal length of the reflector to be four ches, will subtend an angle of 14° 22′ at the vertex of the parabola, or the angle m s. Thus the reflected rays from the external edges of the flame will diverge from axis to one-half such an angle on either side of it. This divergence decreases in ose rays which strike the surface at greater distances from the vertex, but, comined with other circumstances, between 11° and 15° or 17° of divergence may be nsidered as effective from such an instrument. It would therefore take from 25 to 3 such reflectors to form a complete zone of light.

With respect to the invention of parabolic mirrors, we find them mentioned at a ery early period, though not in connection with the subject of illumination, but in ference to their powers of focalising the rays of the sun to form burning instruents, an inverse principle of that of lamp reflectors. In a work entitled "Pantoetria, by Leonhard Digges, published in London in 1571, the author states that with a glasse framed by a revolution of a section parabolicall, I have set fire to owder half a mile and more distant." In the prosecution of this subject, the celebrated apier and Sir Isaac Newton experimented with parobolic reflectors before 1673. nd the celebrated Buffon, with the same object, proposed the polyzonal lens, now odified for Lighthouse purposes, as will be mentioned hereafter.

The first parabolic reflectors for Lighthouses were used at Liverpool, probably in 763, certainly previous to 1777, for in that year William Hutchinson, Dock Master f that place, published his "Practical Seamanship," and in that work he fully escribes the apparatus used in the four Lighthouses built at Liverpool in 1763.*

The origin of their use is curious. It is said, that at a convivial meeting of some cientific men at Liverpool prior to this date, that one of the company wagered that e would read a newspaper at the distance of 200 feet by the light of a farthing andle. This he afterwards won by means of a wooden bowl, lined with putty, in



Parabolic Reflectors used in the Liverpool Lighthouses, erected in 1763; copied from a plate in Hutchinson's "Practical Seamanship," 1777, formed of wood and lined with pieces of looking-glass, or of plates of tin. The oil kept on a level with the flame by a dripping-pot, supplying the reservoir at the back.

---

* Lighthouses were not always looked upon as useful aids. The Mayor and Corporation of Liverpool wrote to Sir G. Ireland, their representative in Parliament, on January 5, 1670, to appear against *Reading's patent for Lighthouses* :—" In regard those Lighthouses will be no benefit to our Mariners, but a hurt, and Expose them to more danger if trust to them; and also be a very great and unnecessary burden and charge to them." See Transactions " Historic Society of Lancashire and Cheshire," vol. vi. pp. 16 and *24.

which facets of looking-glass were embedded, and formed a reflector. One of company was William Hutchinson, who, seizing the idea, thus utilized it.

These reflectors were formed to a parabolic curve by a somewhat rude proc which he describes.

"We have had," says Mr. Hutchinson, "and used here in Liverpool, reflector 1, 2, and 3 feet focus, and 3, 5½, 7½, and 12 feet diameter. The smallest made of plates soldered together, and the largest of wood covered with plates of looking-gl and a copper lamp, the cistern part for the oil and wick stands behind the ref so that nothing stands before the reflector to interrupt the blaze of the lamp act upon it, but the tube that goes through with a spreading burner mouth-piece, spread the blaze parallel thereto, and with the middle of it just in the focus or bu ing point of the reflector.

"The lamps are like the reflectors, proportional to make a greater or less blaz required; their spreading burning parts are from 3 to 12 and 14 inches broad, are trimmed every four hours.

"Thus are these Lighthouses constructed, kept, and situated, and have stood test of a fair trial, and the preference and advantages given to them even by t opponents, as there always will be to new things commonly calling them new whi till time and trial confirm them as useful improvements."

Thus writes Mr. Hutchinson, in 1777; and he also proposed other and more c plete reflectors similar to those we now possess.

The reflectors now used in the Trinity House lights are constructed, as before m tioned, according to the formula proposed by Captain Joseph Huddart, F.R.S., Elder Brother of the Trinity Corporation; and a man of whom England may proud. These reflectors are hence known by the name of Huddart's reflectors, a as far as their principle is concerned, they may be pronounced perfect. Their ma facture is conducted with every care; but, of course, it is *absolutely* impossible to p duce a faultless instrument: but as they are made, they may be considered am the most perfect specimens of workmanship.

The proposition for parabolic reflectors was made by M. Teulère, of the Fre Royal Engineers, in a memoir dated June 26, 1783, as intended for the Cordou Lighthouse, but they were in use in England many years previous to that perio They were also constructed, by Lenoir, of silvered copper, under the direction of Chevalier Borda, in 1780.

In the year 1786, reflectors and oil lamps were proposed at the first meeting of Scottish Lighthouse Commissioners. The first metallic reflectors used in the North Lighthouses were constructed by Mr. Thomas Smith, of Edinburgh. The figure given to them by a plaster mould, and the cavity was afterwards filled in, by mea of cement, with small facets of mirror-glass. This must have done its work v imperfectly, although the general figure was capable of considerable accuracy.

---

* In the admirable account of the Skerryvore Lighthouse, &c., by Alan Stevenson, E p. 205, and in his "Rudimentary Treatise on Lighthouses," p. 73, the merit of the fi application of reflectors is awarded to M. Teulère, as above. But the author quotes fro *second* (or Liverpool) edition of Hutchinson's work, in 1791. The *first* (or London editio illustrated by the same plates, and containing much the same matter, was published in 17 under the title of "A Treatise on Practical Seamanship," &c.; a different title to the seco edition. It is beyond question that reflectors were in use in Liverpool before they were the Cordouan.

Hutchinson closed a life of much usefulness and excellence in 1800. He was dock-mas in or prior to 1759. In 1764 he commenced a valuable series of tide and meteorologi observations, continued till August, 1793. In early life he was shipwrecked, and the cr being without food they drew lots to ascertain who should be put to death, to furnish revolting and horrible meal to the survivors. The lot fell upon Hutchinson, but they w providentially saved by a ship which hove in sight. He ever afterwards observed this d as one of strict devotion. "Trans. Historical Society of Lancashire and Cheshire," vol. i pp. 240, 241.

3, the first polished metal reflectors used in Scotland, were placed in Inch-Keith hthouse.

'he reflector system has been called the English system, in contradistinction to the or French system. This is because we had numerous Lighthouses in which this apparatus had been perfected before the French, who were second in this field, any systematic arrangement, which was indeed not until after 1825. In the early s of the present Lighthouses these reflectors were supposed to do their work so fectly that but little could be gained by a change to the expensive and difficult tem of lenses. Later inquiries have not entirely subverted this opinion.

It has been generally assumed that the dioptric is preferable to the catoptric tem; but while your Commissioners do not controvert this opinion, they have consive evidence that many of the catoptric lights in England are not only excellent hemselves, but *exceed* in efficiency the dioptric lights on its shores. The first part Question 7, of Circular VIII., addressed to mariners, runs thus:—"What British it have you usually seen farthest off?" And out of the 579 witnesses who have wered this question, the greatest *distances* are mentioned with reference to the its at Lundy Island, the Calf of Man, Tuskar, Flamborough Head, Beachy Head, l Cromer; and the greatest *numbers* of witnesses mention Flamborough Head, the ard, Lundy, Beachy Head, the Start, and the South Stack, all of which are optric revolving lights, with the exception of the Lizard, which is catoptric fixed, l the Lundy and Start, which are dioptric revolving."*

'he reflectors in use by the Trinity House are 21 inches in diameter for shore its, and 4 inches of focal length, having a total reflecting surface of 518·6 square hes. They cost about £31 10*s*. The Scotch are of 24 inches aperture, and cost 3. Messrs. Wilkins are proposing them of 36 inches in diameter. They are most ellently made, and have lasted, unimpaired, 30 or 40 years.

The brilliancy of the ray from this reflector is considerably stronger in the direc1 of the axis, that is, when viewed directly in front, than it is for some distance on ier side of that direction; and at great distances, in *fixed* lights, when you are in direction *between* the axes of the adjoining reflectors, the light is frequently glimring and feeble, but a small change in the position of the ship brings you again o the brighter beam of the reflector, one of which, it will be understood, is only in ht at a time. This is an important observation to the sailor, in distinguishing one ed light from another, of different description of apparatus.

When a *revolving light* is required, a number of these reflectors are fixed to the es of a triangular or quadrangular iron frame, and the whole caused to revolve in ular periods, by means of clockwork. The reflectors on each side of the revolving me, from four to eight in number, are thus successively directed to every point of horizon; and the combined result of their rays form a flash of greater or less ation, according to the rapidity of their revolution.

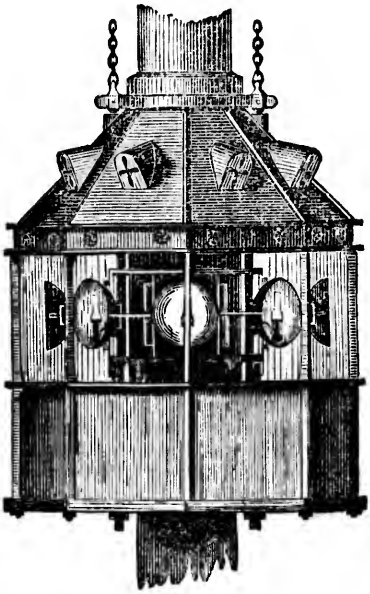
'rom the amount of divergence (13), the period during which such a light will nain visible is from 12 to 15 seconds, the light gradually increasing, and as grally diminishing. And as the action of the reflector is only in the direction to ich it is placed, the intervals between the flashes will be quite dark, for a shorter onger period, according to the distance from which it is viewed, whether it is ond that to which the unassisted flame will reach.

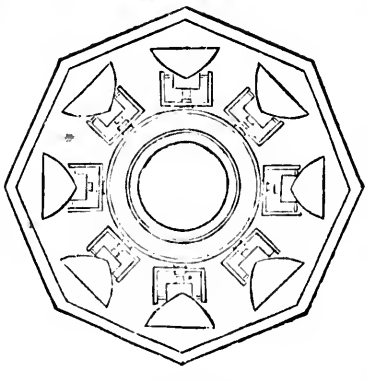
'he light from a revolving catoptric or reflecting system is much brighter than n a fixed light on either principle, as you have the combined effect of several ectors, each of which gives an equal amount of light, it is calculated, to 350 or 450 h lights without any reflectors.

n floating Lightvessels the light is always shown from parabolic reflectors. These smaller than those used in Lighthouses, being 12 inches in diameter. For fixed its, eight lamps and reflectors, each suspended on gimbals, or on ball and socketits, so that they always maintain their perpendicularity, notwithstanding the roll-

* Report of the Royal Commission, March, 1861, pp. 7, 8.

ing of the vessel, are arranged in an octagonal lantern, which goes round the m and is hauled up to the mast-head when on service, and is let down on the during the day, or while the lamps are trimming. Revolving lights for flo Lightvessels have four or eight lamps, and similar reflectors, and the lantern rev around the mast. The adjoining diagram is a representation of one of Messrs. kins' Revolving Light Lanterns. It is very similar to that of a fixed light, the c work moving it is placed between decks.





Only one English Lightvessel, that in Tees, has a dioptric apparatus. Sever the Lightvessels are now made to show volving *red* or bright lights where they formerly fixed lights, as in the case of Nore Lightship, it having been found in many cases it was difficult to disting the fixed light of the Lightvessel fron mast-head lights of the ships at anchor them.

The red revolving lights are now very efficient. The red light is made by a coloured chimney to the lamp; or, in cases, a pane of red glass is placed upo reflector. A green or blue light is some used as a pier mark, or in other subord positions; but red is the only efficient c The French coloured lights are much than ours. The best red glass is coloured chloride of gold, known in the middle a the purple of Cassius. It has only be discovered of late years. When the Rock Lighthouse was completing, there great difficulty in procuring the red pan the coloured flash.

An apparatus for producing an *interm* light, of the only appearance to which term is applicable, is in use in three Scottish Lighthouses, the invention of Robert Stevenson. It is an arrangeme means of which the light is suddenly ob by an eclipser, and as suddenly appears at its full brilliancy. This feature guishes it completely from revolving which come gradually to their greatest b ness, and as gradually decrease, and either from the reflecting or refracti paratus.

There is yet another sort of reflec use in France for harbour lights, calle Bordier Marcet apparatus, from its inv or the sideral lamp (*fanal sidéral*). It with a single lamp, and consists of tw cular reflectors about 13½ inches dia whose figure is formed by the revolution parabola around its focus in a horizontal plane; the centre of this is taken admit the lamp, which thus has all around it, above and below, a reflecting s which sends its upward and downward rays in a horizontal direction.

The lights in the ensuing list, which are upon the catoptric or reflecting s are distinguished by this mark ●. Their magnitude, or order, is not indicated class of the light is to be inferred from its importance.

3.—THE DIOPTRIC OR LENS SYSTEM.

This system,—that in which the controlling apparatus is placed before the light,—next to be considered.

There are several very early notices, which seem to shadow out this principle. One given in Smeaton's account of the Eddystone, where a London optician pro-sed to grind the panes of the lantern to circular segments, so as to form a sphere of feet in diameter. This was negatived, and we cannot learn what the particulars re, although an optician, it would be thought, would deal with refraction and nomise the light.

The use of lenses in Lighthouses dates from early times. It is more than probable t Argand's invention soon directed attention to the best mode of concentrating the ht. William Hutchinson relates an experiment tried at Liverpool with a hollow s filled with brine, which, however, was broken by the heat of the lamp. It is tain that they were placed in one of the Portland Lighthouses between 1786 and 90, by Thomas Rogers. These lenses were 21 inches in diameter, and 5½ inches ck in the centre; the flame of the lamp was 3 inches in diameter, and behind it was ced a glass (spherical) reflector, 12 or 18 inches in diameter, and by a new method vered over the convex side without quicksilver. These lenses were also adopted by gers in the Lighthouses at the Hill of Howth, and at Waterford. Similar, but smaller ses, 16 or 18 inches in diameter, carefully worked, and which cost £50 each, were use at the North Foreland. There were 15 of them placed there at the commence-nt of the present century by the Governors of Greenwich Hospital, where they nained till 1834, when the Trinity House replaced them by reflectors, which have ain recently been removed for a beautiful new dioptric apparatus.

The lens apparatus now in use is peculiar. It is called, from its figure, the Annular Polyzonal Lens.

The history of the polyzonal lens is simple. Like the parabolic reflector, it was ginally designed for a burning instrument, by collecting the rays of the sun, and no other purpose. For a very long period these instruments, of various forms, cupied a large share of the attention of the experimentalists of the last and pre-ling centuries. Modern progress has converted them into scientific toys.

The merit of the earliest suggestion is due to the celebrated Buffon, the French turalist, who, in 1773, according to Condorcet, proposed, for a burning glass, to form of three concentric circular pieces upon each other. If a lens were required of 24 hes in diameter, and 3 inches thick in the middle, then the central portion was to of 8 inches diameter, and 1 inch thick, inserted into a circular zone; ground to the ne focus, and 16 inches diameter; and this again into a similar zone of 24 inches. ffon states that the rays would be twice as powerful passing through 1 inch, as ey would through 3 inches thickness of glass.

The suggestion of Buffon was acted on by the Abbé Rochon, with some suc-s, in 1780; but his operation consisted in grinding down a single piece of ss into concentric rings. A similar lens was made by Messrs. Cookson, of weastle-upon-Tyne, and tried by the Northern Lighthouse Board. This process is cessarily attended with an enormous amount of trouble and expense, and the result st be precarious.

The particulars of Buffon's invention appear in most of the English and Scotch cyclopædias, published after 1796. In 1812 Sir David Brewster proposed a plan a built lens in the Edinburgh Encyclopædia, vol. v. This was also intended for a rning instrument, and no mention is made at this time for its converse properties, t of distributing light, as adopted for Lighthouses. There is no need of contro-sy on this. Lighthouses, at this date, had not then attained the importance they w have; and the beautiful reflectors then in use, as in the Bell Rock, were con-ered to do their work perfectly. Besides this, the polyzonal lens is not adapted *fixed lights;* the cylindric refractor for the purpose was not perfected till 1836.

It is to the late M. Augustin Fresnel that we owe the introduction of the lenti-ar system, and hence it is frequently called by his name. Its origin dates from

1819. During the progress of the great Trigonometrical Survey of France, u MM. Arago and Mathieu, powerful lights were used as signals; and one of lenses, 3 feet in diameter, constructed by M. Soleil from the designs of Fresnel, applied to a large lamp on Cape Grisnez, and other places, in the autumn of 1 Major Colby, who was employed in the operations on our side, informed Mr. R Stevenson of the particulars, in Nov. 1821. On July 23, 1823, the splendid revol apparatus of this system was first shown in the Cordouan Lighthouses.

In 1824, Mr. Robert Stevenson visited the French Lighthouses, &c., and repo on them to the Scottish Lighthouse Board. The first application of the system was in the Isle of May Light, by Mr. Alan Stevenson, the talented son of the be named eminent Lighthouse engineer, in October, 1825. Holland was the firs follow France in the use of the system. The Trinity House erected the first l cular apparatus in the Start Lighthouse, 1836.

The Lighthouses of France were very few in number prior to Fresnel's invent upon his success the French Government determined upon the establishment of grand system adopted in 1825, and of the sole application of the lens in all cas new lights. The case was different on our side. Many of the present lights exi long before the invention of Fresnel, and, having been erected as exigencies a there necessarily was not that exact order and regularity that might have attained by a total change and remodelling at any period. That our system doe suffer by comparison with those of other countries, is a grand proof of the tale our Trinity Board and other authorities, and of the skill of our engineers.

The lenticular apparatus may be thus described:—It consists of a central powerful lamp, of course emitting luminous beams in every direction. Around is placed an arrangement of glass, so formed as to *refract* these beams into par rays in the required directions.

The laws of refraction are well understood, and require but little explanation We shall just allude to it sufficiently to elucidate our subject. When a ray of passes out of a rarer into a denser medium, or *vice versâ*, it is refracted from its orig direction, and assumes that which is induced principally by the density of the se medium. This is made familiar by the bent appearance of an oar, or a mooring w it dips beneath the water. The use of the glass lens is thus to bend the rays w fall on and emerge from its 2 surfaces. The action of the bull's-eye lantern, in sending forth the rays in one direction, will explain this principle. As the normal figure of the lens is that to which its powers are due, the polyzonal lens must be considered as such a complete lens with the unnecessary portions cut away.

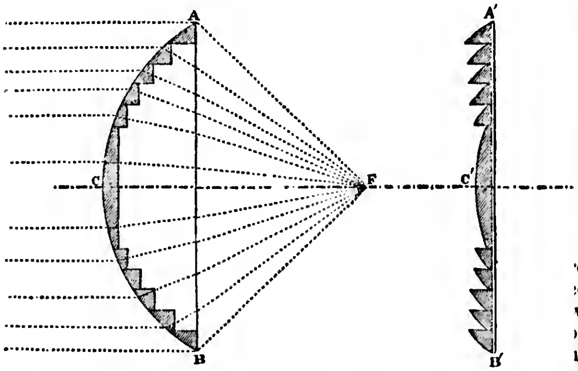
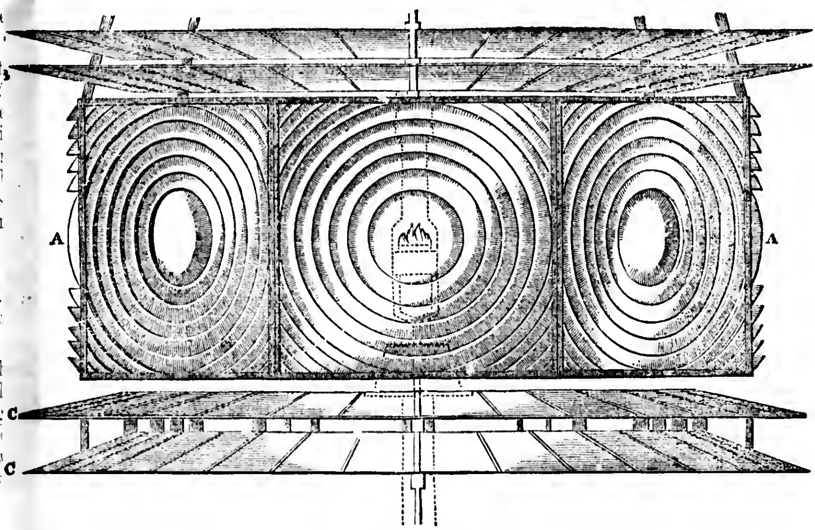


Diagram illustrative of the principle of the polyzonal lens. A B a section of an ordinary plano-convex lens, whose focus is at F. the great thickness of the central portion abstracts much of the in its passage, the convex surface may be supposed to be cut circular zones, whose section is as the shaded part of the diag and these sections being all placed in one plane, as A' B' C', the l will have all the optical properties of the former, because the surfaces are still of the same relative figure.

One great advantage in the decomposition of the original lens is that of diminishing its weight very considerably, and also the greater certainty of the more uniform density of the material from which it is made. There is also ano oint in the construction: it affords the means for correcting the aberration for phericity, a great point in the manufacture of lenses.

The principle of the polyzonal lens being thus explained, the method of applying hese to control the luminous rays of a lamp is now to be shown. For this purpose hey are built into a square figure, that is, for such lenses as are for revolving lights.

For a *revolving* light, eight of such lenses, which, for a light of the first order, have focal length of 3 feet 0·25 inches, are formed into an octangular drum which surounds the central lamp, placed in their common focus. This, then, is the principal ortion of the controlling apparatus for a *revolving* light.



The central portion of a first order dioptric revolving light apparatus (the Bermuda light). A A represents the polyzonal lenses, of which there are eight, arranged around the central lamp. The diameter of the octangular prism formed by them is 6 ft. 0·5 in. B B are two of the eight upper series of reflecting zones. These are composed of separate silvered-glass mirrors, and each diminishing in diameter, forming a cupola rising to 5 ft. 6 in. above the flame. C C, two of the four lower series of zones, which are all of the same diameter. The action of these zones will be explained presently.

The lamp which this system is applied to, contains four concentric wicks, (of the espective diameters of ·857, 1·69, 2·52, and 3·39 inches,) and the oil, by a peculiar onstruction, either by a mechanical contrivance of small pumps worked by clockvork, or of springs or weights, or else by the pressure of air upon the surface of the oil in the reservoir, is made to flow copiously over these wicks, otherwise the great heat evolved during its combustion would char the wicks. This lamp consumes a pint of sperm oil per hour; or, according to the computation of the French Commission des Phares, 570 gallons per year. This powerful apparatus being in the centre of the urrounding lenticular system, the ray impinging upon each lens is refracted into a eries of parallel, or nearly parallel beams, whose section is the figure of the lens, in he case of the revolving light, or into a continuous zone or band of light around the horizon in the fixed light. M. A. Fresnel, in the construction of the Cordouan lioptric system, used a more complicated system than that above described. A similar arrangement also is in operation at the Skerryvore, and some other stations; and in hese cases every available means is taken to economize the light.

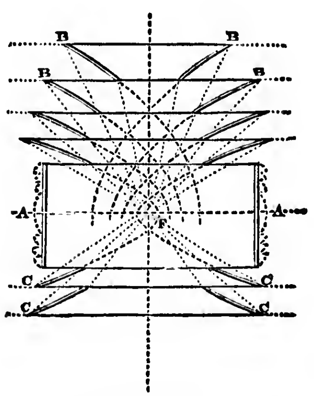
For a *fixed* light, another adaptation of the principle is used. We must suppose the section of the lens, A B (Diagram on p. 20), to revolve around the focal point, and in the same plane, which will produce a series of horizontal belts, having th vertical section similar to that of the lens in its circular form. The effect of th applied to a central lamp, will be to produce a continuous belt of light in azimu instead of a series of beams parallel, or nearly parallel, to the axis of the circu lenses, as in the case of the revolving apparatus. In the focus of this belt, or drum glass, is placed the lamp, as in the former case.

Originally this cylinder for a fixed light of the first order was made into a poly of thirty-two sides; but in 1836, the Messrs. Cookson, of Newcastle-upon-Tyne, m one entire, which was the greatest step then achieved in the construction of th lenses.

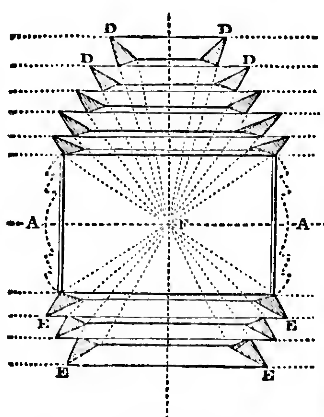
As the systems we have been explaining will only act upon those beams which comprized within the angle contained between the focus and the upper and low edges of the lenses, or about three-eighths of the whole quantity of light, it becom necessary to economize, as far as possible, those portions which are above and bene this portion of the apparatus.

In the early apparatus, the upper portion consisted of a series of catoptric zon formed of separate pieces of silvered concave glass, arranged in such a manner as reflect horizontally the beams thrown on to them. The degree of curvature and clination to the plane of the system was determined, as in the case of the parab reflector, by considering their section to be a portion of such parabolas as would, carried around the focus, form perfect reflectors, as will be readily understood by subjoined Diagram, where the dotted lines show the form of that portion of the pa bola not comprized in the catoptric zone. The same applies to the lower portion the system.

In the small, or harbour lights, instead of these reflecting mirrors, another plan first used by M. Augustin Fresnel, that of catadioptric rings, composed of glass, wh *totally reflected* the rays thrown on to them. The action of these zones or rings explained in the third Diagram.



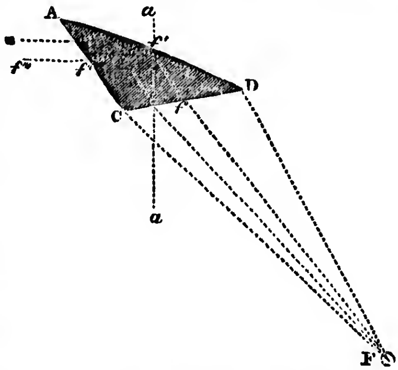
Catoptric Zones.
F, the focus of the system and the situation of the light; A A, principal lenses; B B, upper reflecting zones; C C, lower reflecting zones. The parabolic curves, of which the section of the zones is a portion, is continued round the focus in the dotted lines.



Catadioptric Zones.
F, the focus, and A A the principal lenses, as in the adjoining diagram; D D, the upper system of totally reflecting prismatic zones, and E E the lower portion of the system. The action of these prisms is explained in the next diagram.

The first example of this catadioptric apparatus was constructed by M. Tabou who was connected with the French Commission des Ponts et Chaussées, a short time before the death of M. Augustin Fresnel.

One of the most important improvements which took place in pharology was the adaptation of this accessory on a much larger scale than had previously been supposed possible, by the suggestion of Mr. Alan Stevenson, who, in his construction of the Skerryvore Lighthouse, used every means to render this important edifice most complete in every respect. In conjunction with M. Leonor Fresnel and M. François, jun., the constructors, this apparatus was added to the lower portion of the Skerryvore dioptric light, consisting of five glass zones, which replaced in the ordinary system four horizontal zones, each composed of thirty-two concave mirrors. In fixed light apparatus of the first order, nineteen of these catadioptric zones replace eleven reflecting zones.



A D C will represent a section of this glass zone, which is so placed with regard to the focus, F, that a ray falling upon it at f will be at such an angle on D A, that instead of passing out, it will be *totally reflected* from that point of incidence, as $f\ f'$, and will finally assume the direction, $f''\ f''$ of a right angle to the normal, a a, as required. This angle, in passing from glass into air, is about 41° 49′, and a greater angle of incidence gives a reflected ray. In the largest zone, the radius of the arc (the reflecting surface), D A, is equal to 28·46 feet, and the angle, D C A, is equal to 117° 26′ 42″.

"Nothing can be more beautiful," says Mr. Alan Stevenson, "than an entire apparatus for a fixed light of the first order. It consists of a central belt of refractors, forming a hollow cylinder, 6 feet in diameter and 30 inches high; below it are six triangular rings of glass ranged in a cylindrical form, and above a crown of thirteen rings of glass, forming by their union a hollow cage composed of polished glass, 10 feet high and 6 feet in diameter. I know of no work of art more beautiful or creditable to the boldness, ardour, intelligence, and zeal of the artist."

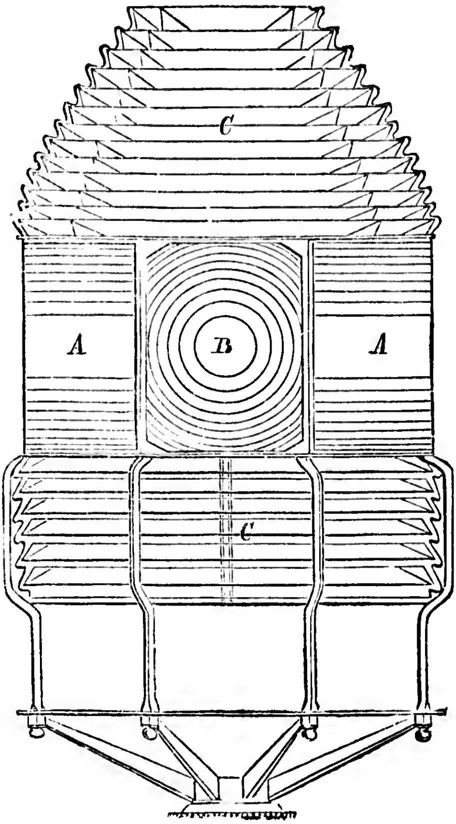
The divergence of the polyzonal lens is much less than that of the parabolic reflector, being about 5° 9′, owing to the smaller angle subtended by the flame upon the inner surface of the lenses. From this cause, the flash in a revolving light is but of short duration, while that from revolving reflectors lasts much longer, from their greater powers of divergence. To compensate for this, the light from the lenticular apparatus is, within a certain distance, continuous; the upper and lower portions of the system giving a steady light.

Fixed and Flashing Lights.—There is one character of light in the French (and other) systems which is peculiar, and requires special mention, as it does not appear to be properly understood by many, and is frequently an important distinction. This, the *feu fixe varié par une éclat* of Fresnel, has this appearance in a light whose period is four minutes: first, a bright fixed light, for above 3½ minutes; then a short, but not total eclipse, for about 10 seconds; then a very bright flash, of much greater intensity than the preceding fixed light; then another short eclipse, and then the fixed light as before. In the larger apparatus the distinction between this and an ordinary revolving light is well marked by the intensity of the fixed light between the brighter flashes, and also especially by the short eclipses preceding and following the bright flash. In the smaller apparatus the bright flash is not so well marked; but the short eclipses will be a clear index to its character.

There are different modes of producing this effect. Fresnel's plan was to have an ordinary fixed light apparatus, around the outside of which two revolving panels of refractors passed in regular succession. These panels consisted of *vertical* lenses, similar to the *horizontal* central belt. They thus received on their inner surface all the light which issued from the central lamp through the fixed lens on the angle which they intercepted, and which each refracts into *parallel* beams to the direction faces as it revolves. Therefore, instead of the rays passing in all directions on t azimuth, a portion of them are collected and concentrated in one direction for bright flash; and the angle between this bright beam and that emanating from fixed portion of the apparatus is that which forms the eclipses. The upper and lo zones, of course, are those which maintain a constant light; so that the eclipses this, as well as in most other lenticular lights, is not total within short distances.

Sometimes the flash is coloured *red*, as in the light on Chausey, Vièrge Isla Point d'Alpréch, &c.; and in a few cases *green*, as in some of the new Turk lights, &c.

In another method of producing this effect, constructed by M. Letourneau, necessity for using two lenses is avoided; and, consequently, the loss of light evitable in the absorption of a p tion in its passage through glass. The adjoining diagram explain it. In the central port of the apparatus B is one of polyzonal lenses, similar to th figured on page 21; on either of this is a portion of a fixed li apparatus, shown by the horizo belts A A. For a fixed light course, these horizontal belts carried all round; and the li appears as a vertical stripe of breadth of the flame from the to the bottom of the belt. In the lyzonal lens the light appears cover its whole surface, and is visible when in front. The w apparatus is made to revolve machinery, and the appearanc as above described: first, the f light from the portions on ei side; then a short eclipse due to light being diverted by the g lens; then the full blaze of the for 8 or 10 seconds; then ano eclipse, and so on.



This diagram will also exp another portion of the apparatu which a section is given on 23. The upper and lower porti C C, in this are the totally re ing glass zones, which have almost entirely replaced t figured on page 21, and their tion is explained before. It is part of the apparatus, as b mentioned, which is constantly sible within 10 or 12 miles in weather, and is useful in fixing the position of the light in the intervals of flashes.

It is considered by many, including the great Alan Stevenson, that the fixed flashing light is not altogether a desirable variety, its appearance being too like the revolving light; in fact, in our official lists, they were always set dow revolving lights till within the last few years.

In coast lights, when usually the light is not required all round the horizon, tha er the land in the rear, there would be a waste of the light from the great lamp, hich, of course, suffices to illuminate the whole horizon. In the reflector light this avoided, as a smaller number of lamps is used. But in the dioptric lights the light economised by the use of spherical mirrors placed on that side. These spherical mirrs, usually of silvered copper, are formed to a curve, whose radius is equal to that of e focal lenses they are applied to (in first order lights, 3 feet), having the position of e flame as a centre. They thus reflect the rays back again through the flame upon e lenses on the opposite side. Flame, being perfectly transparent, there is no loss power in this.

This method of economising light was practised, as aforesaid, by Thomas Rogers, out 1788; he used blown glass spherical segments made into mirrors. Mr. Alan evenson proposed it in 1834, and MM. François and Letourneau have made them grinding the glass to the focal curvature.

There are very many other considerations in the economy of Lighthouses that serve notice, but which would unduly extend this brief description. The excellent orks of Mr. A. Stevenson, and of his brother, Mr. T. Stevenson, will afford much struction.

THE HOLOPHOTAL SYSTEM.

As far as they were applied, the catoptric and dioptric systems acted perfectly; but ill there was some waste of light, caused in one direction by the divergence of the struments, and, in another, by their construction. The consideration of this loss of wer led to the next steps in the science of pharology; since that period, some new rangements have been proposed, by which some of the disadvantages of the dioptric stem have been partially avoided. M. Letourneau proposed lengthening the duran of the great flash of the dioptric lens, by dividing it into two portions, and setng each half at a slight angle outwards; this would produce the desired effect, but must be at the expense of brilliancy. Several other minor improvements also have en suggested, but the main features of the system have remained unaltered.

There is some waste of light in both the systems. In the catoptric it is that angle mprised between the angle formed by the lips of the reflector and the flame and the rizontal ray which strikes the outer edge of the reflector. It is the angle r P s, in e upper part of the diagram on page 14. That portion of the light which passes wards is, of course, lost for useful effect; the other portions may be considered as rviceable. In the year 1849, Mr. Thomas Stevenson, son of Robert, brother of lan Stevenson, proposed some arrangements which obviate this loss, upon what is rmed the *holophotal system.**

The ordinary paraboloidal reflector is rendered holophotal as follows:—A small rtion of the back of the reflector is cut off, behind the parameter, the line B F D, hich passes through the focus (Diagram 14); for this is substituted a portion of a *herical* mirror of the same focus. In front of the flame a lens with three diacatoptric ngs is added. The action of the spherical reflector is to return all the rays impinged it back through the flame, and thus on to the posterior sides of the lens and diacaptric rings. Therefore, all the rays which emerge from the lens, &c., will be horintal, and the remainder, those impinging on the paraboloid, will also be reflected in e same direction. Peterhead light (1859) is on this principle. The Horsburgh ighthouse, in the strait of Singapore, is fitted with 9 such holophotal reflectors; ree on each face of a revolving frame, each side of which, it is said, gives as much ght as five reflectors of the ordinary kind. This was completed in 1851. Another e, on a large scale, is at Hoy Sound, Orkney. A similar apparatus, a red light, as placed at Wick, in Caithness, in 1851.

Fresnel's revolving light system, as at work in the Skerryvore and the Cordouan, ith its beautiful but complicated upper system, is rendered holophotal by a very mple means. The zones above and below the main lenses act in the same way as

---

* "Holophotal;" from two Greek words, signifying "whole light."

the centre, that is, these zones, being made horizontal, are made of segments of c concentric with the centre of the great lens beneath and above them; and, b whole apparatus revolving, nearly the whole of the light is projected horizontal the eight directions of the octagonal prism. Proceeding upon the assumption the whole of the emitted rays from the central lamp may be made to assum horizontal direction, Mr. T. Stevenson has made several most excellent arrangem which, however, we cannot fully describe here. The simplest form is that hemispherical metallic reflector, in the focus of which is placed the lamp; befor lamp is a refracting polyzonal lens, of such a section that the whole of the direct from the lamp, and the reflected rays from the posterior reflector, are paralleliz their emergence. Carrying this principle to greater refinement, and as it was f that the totally reflecting glass prisms were effective compared with metallic r tions as 140 to 87, a hemispherical arrangement of glass is proposed, which, by r tion and total reflection, produces the same result as the metallic hemisphere i former instance. The formulæ for the construction of this ingenious apparatus calculated by Mr. William Swan, F.R.S.E. The glass refracting mirror has advantage over a metallic mirror in its powers of radiation, as in an experiment heat in the interior of the apparatus was so great as to cause the oil to boil: an in venience, however, which was afterwards obviated mechanically. Very num other applications of his principle are also proposed.*

The beautiful holophotal adaptations have been established at several impo localities. The magnificent light at Whalsey Skerries, Shetland, constructe Messrs. Chance, of Birmingham, is perhaps the most powerful apparatus yet in Lundy Island, St. Abbs Head (constructing), the Red Sea, &c., have examples o extending system.

Mr. T. Stevenson has constructed a holophotal arrangement which he cal azimuthal condensing light, by which the whole light is used down a narrow cha there are examples at Oronsay and Kyle Akin (1857), west of Scotland. An most ingenious appliance is that at Stornoway, Lewis Island, by which a Beac the dangerous Arnish Rock is made to show an *apparent* light, reflected by a pec apparatus from a light on the Lighthouse on the adjacent point.

As regards the history of the holophotal system, we may refer to Thomas Ro plan (1788), before mentioned. Sir David Brewster also proposed an arrangeme lenses, as a burning instrument, in 1812; and the same for Lighthouses, in 1 Mr. Alex. Gordon, C.E., also constructed a combination of lens and reflector, w economised much of the stray light, in 1847. The carrying this system into full p tice, by Mr. T. Stevenson, is as above related.

A first order lenticular apparatus is one of the most beautiful objects in the w It is a combination of elements, nearly 12 feet high and 6 feet in diameter, constru with the utmost skill and refinement, and involving in its structure some of highest principles of applied science.

A *first* order light apparatus, as above said, is 12 feet high and 6 feet in diame and the cost of the lenses alone varies from £1,288 to £1,536; or, with the cost o apparatus, and light-room or lantern, £2,488 to £2,984.

A *second* order of light apparatus is 4 feet 7 inches in diameter; the lens costs f £788 to £1,131, or altogether, £1,624 to £2,187.

A *third* order apparatus, diameter 3 feet $3\frac{3}{8}$ inches, costs £378 to £704, or a gether, £882 to £1,456.

A *fourth* order, or *harbour* light, is $19\frac{5}{8}$ inches in diameter; costs from £157 to £ for the lenses, or £329 to £427 complete.

A *fifth* order harbour light, $14\frac{1}{2}$ inches in diameter, costs £103 to £195, or £ to £349 complete.

---

* See "Lighthouse Illumination; being a Description of the Holophotal System," By Thomas Stephenson, F.R.S.E. London, 1859.

The *sixth* order, or smallest size of harbour, is 11¾ inches diameter; lens light costs out £70, or complete £216. *

In the early days of the lens lights we were entirely dependent on the French for eir construction. The superior character of the St. Gobain and Premontré glass, d the appliances of MM. Soleil, François, Letourneau, Sautter, &c., kept them in ssession of nearly all the construction of lenses in use. The exceptions, in our untry, were those made by Messrs. Cookson, of Newcastle-on-Tyne, who, about 36, made some apparatus, as that of Hartlepool, &c. Later, however, the Messrs. ance, of Birmingham, have largely entered on this important branch of manufacre, and many beautiful examples are the result of their enterprize.

M. Degrand, of the French Lighthouse Commission, has introduced another pross for making the lenses, by forming them of thin sheets of moulded or *cast* glass. is is in use in the Beacon light of Walde Point, near Calais.

CHAPTER IV.

GENERAL REMARKS.

It is very important that the distinctive character of different Lighthouses, and d especially of those near to each other, should be plainly marked, and easily regnized. It might be supposed that this was readily and well done, by the alternan of fixed and revolving, at different periods, flashing or double, and even treble ghts; but very numerous accidents demonstrate that mistakes frequently occur. uring fine and clear weather there is not any difficulty, with ordinary caution. It the thick haze, snow and storms, driving scud, and all other embarrassments, which, hile they tend to throw doubt on the ship's reckoning, also make it difficult to aproach an unknown Lighthouse without running into danger. Therefore any disnction, by which one light can be instantaneously distinguished from another, is ost useful. The difference in the aspect between the reflector and lens light is one these, at the sailor's command.

At long distances (say above 10 miles) the flash from the revolving light from the flector has a sensible disc, and will last a considerable time, 12 or 14 seconds if the volution is 1 minute; that from the lens light will be whiter, more star-like, and ill not last more than 7 or 8 seconds. Another distinction of the latter is, that the ght is not totally extinguished between the flashes,—the upper and lower zones eping constantly illuminated. This secondary light, at favourable times, is visible far as the horizon of the place, and from 8 to 12 miles, according to the size of the paratus, in ordinary weather. This is a marked distinction between the two stems, as the eclipse is total from the reflectors, even at short distances. But it ust be remembered that the new holophotal system has also nearly total eclipses.

The distinction between the fixed lights, on either system, is not so well marked. he lens equally distributes the light, which is equally bright in all directions: on e other hand, the reflector light is brightest when immediately in front of the flector, so that a vessel sailing past, when very distant, will find that the light at nes gets fainter, till a short distance further brings her into the force of the next flector.

Very much has been written upon the comparative merits and economy of the two stems. Perhaps the difference at times has been over-rated. At all events, it is

* These prices, which are common to nearly all manufacturers, are taken from the Tariff Messrs. Chance, Brothers and Co., Birmingham (1860).

certain, that for fixed lights the advantages are all on the side of the lens, unle are illuminated be a small one.

The English reflector revolving lights, as before stated, are not considered inf to their lens rivals. Many interesting comparisons and details will be found in Parliamentary Report, the United States Report, and the works of Mr. A. venson.

The *harbour* and *tide lights*, so numerous in the ensuing lists, have not been cially alluded to in the previous description. Where they partake of the catoptr dioptric character, it will be understood from what has been said; but in many of pier, or small tide lights, they are simply the ordinary street gas lamp, wit coloured pane to distinguish it, or even the inferior hand-lamp.

In many cases, in our own country, these local lights are not worthy the pos they occupy; in others, all improvements of construction and efficiency have used. In most continental countries, as in France, Spain, &c., these local har and tide lights being all under the Government direction, they may all be incl in the descriptions before given, as applied to the primary lights.

There is no regular system in the tide or harbour signals used in the United K dom: however desirable uniformity may be in this and other respects, the dive of use is of less importance in practice, as the peculiar character of the signal given for each place, and will be sufficient guide. More extended directions, in nexion with these signal lights, must be found in the special Sailing Directo and the charts they elucidate.

The *distance* to which the principal lights are visible is generally limited b horizon. There is no doubt but that they might be seen to very great distances, 60, 80, or even 100 miles, if sufficient elevation could be gained to view them f It is considered by many that 250 feet is the maximum height necessary or advis which will give an horizon 18 miles distant; and, by ascending the rigging, t miles off. When a light is unduly elevated it is very liable to be obscured by c or fogs, and it is frequently a great detriment to those which are so. In the Ta the height of the flame above the highest tide high-water level is given, so that the minimum range of the light; to this elevation 10 feet is added for the heig the deck of the ship above the sea. Besides the increased distance to which low will cause the light to be seen, the effect of refraction will also sometimes inc their range.

The height of the tower, from base to summit, is frequently given, as it affo means, by angular measurement by the sextant, of ascertaining the distance o tower.

Many of the Lighthouses are handsome and commanding structures, and, gene all modern erections; are made almost as available for day marks as their light for night. In many cases they are distinguished by some peculiarity, noticed in lists, as mentioned on page 7.

When the light is dipping on the horizon it flickers greatly, especially in r weather, an effect owing to the waves on the intervening horizon. The lights appear *yellow* when in the neighbourhood of large towns, as Liverpool. This is o to the smoke of the town. Observations on this point is recommended, as di lights on land appear quite bright and white during and preceding rainy wea while a yellow or reddish tinge indicate, almost certainly, a continuance or app of fine weather.

It may readily be comprehended, that if the refinement of economising the were carried to so great an extent without vertical divergence, the effect would send forth the light in such a thin disc that it would be invisible to a distant unless she were exactly on that part of the ocean which this thin disc of light tou some aberration is, therefore, absolutely necessary.

But this point has also been urged by Mr. T. Stevenson (in 1851), as one that might made useful, as a light might be made to be visible only over a dangerous reef, or a safe channel. Therefore a ship approaching such danger would be warned wh put about by its becoming visible, or by losing sight of it. It is said that a li this character was in use at Beachy Head, but the particulars have not b served.

It has frequently happened that a Lighthouse on a perpendicular cliff has not shown light to ships passing close underneath, and in some cases with very disastrous sequences. In these circumstances it is almost imperative that the light should ve a high degree of divergence in the lower portion of the apparatus. A very ful application of this has been made in some few Lighthouses, (as in Ballycotton, Ireland,) of having the lower panes of the lightroom made of red glass, so that a p approaching too near the land will be warned of it by the light changing red.

The masking of lights for the purpose of clearing the navigation of different chan-ls, is effected in the same way as the ships quarter-lights are, as is most usefully ried out in Liverpool Bay. A different coloured ray is also most serviceable, as bright ray from the Maplin, which points out a turn in the channel, or in other es where the change of colour can be made a beating mark. All these points, how-er, are familiar to the sailor. In the preceding notices are given only the leading tures, sufficient to show what the general principles are as applied to our subject, it it may be affirmed, that almost every variety of circumstance and requirement in Lighthouse System has been the subject of profound study; and so numerous the plans and inventions in connexion with all branches of them, that the mere umeration of them would be a bulky list.

The English lights are lit at sunset, and extinguished at sunrise. The Scotch have de a saving by doing so at darkening and dawn. In all cases of the public lights, all countries, the strictest supervision and most careful management are used to der them in the highest degree efficient.

The ancient Corporation of the Trinity House of Deptford Strond has had, as is ll known, the charge of the British Lighthouse System. This is one of the very v institutions (if there be another), which dates from a mediaeval period, which has ll preserved it importance and useful character, through all changes, to the present y. That it has done so, the recent Report of the Royal Commission, 1861, will tify.

"The above evidence then goes to show that the quality of British lights (speaking nerally) is equal to the quality of lights in any part of the world; and the testi-ny is especially valuable because the men who give it are mariners,—those best le to judge of the appearance of the light; and, as appears from their evidence else-ere, generally knowing nothing about the manner in which the light is produced. one witness remarked, 'They don't know the ropes,' C. and D., (catoptric and ptric,) but most of them think that first-class British lights, speaking generally, as good as most first-class lights which they have seen abroad, and better than ny."

The Trinity Corporation, which has developed our English system, under the vice and assistance of the most eminent engineers and philosophers of all riods, existed in the reign of Henry VII., as a respectable Company of Ma-ers in the College at Deptford, having authority by Charter to prosecute rsons who destroyed sea-marks, &c.; and Henry VIII., in the sixth year of reign, May 20, 1514, formed them into a perpetual Corporation, by the style and le of the "Master, Wardens, and Assistants of the Guild or Fraternity of the most orious and undivided Trinity, and of St. Clement, in the parish of Deptford Strond, the county of Kent."

This Charter was confirmed and altered by Edward VI., Queen Mary, Elizabeth, d James I. The Charter of James I. settled this constitution of the Corporation, and such it continues. The Charter was dissolved in 1647, but was renewed by Charles II. on the Restoration, and the disposal of the funds was settled partly for charitable purposes. The Charter was surrendered to Charles II., and renewed by his successor in 1685; and the charitable uses of the funds of the Corporation were again settled. These funds were derived from various charges, such as pilotage, lastage, loadmanage, ballastage, &c.

The interest which the Trinity Corporation represented having, by the extension of commerce, grown into great magnitude, the Government interfered and altered some of their privileges at different periods, especially in 1854, when the Board of Trade partook of the supervision.

In *Scotland*, the Commissioners of Northern Lighthouses are the acting body, and were incorporated by the Act 38th Geo. III., c. 58. They have had the benefit of the special services of the family of Stevensons, often noticed previously.

In *Ireland*, the Ballast Board of Dublin acts in all Lighthouse matters. (See the 23rd Geo. III., c. 19.)

Besides these three public bodies there are very numerous local authorities, which deal with local lights. The principal among these are the Liverpool Board, the Trinity Houses of Newcastle, Hull, &c. The number of these separate bodies is very great; as, for the 402 Lighthouses in Great Britain, there are, at least, 174 different authorities to direct them.

The Colonial lights are chiefly under the control of the Board of Trade.

Like many other important interests, this has suffered from over legislation, as the Chairman of the Commission of 1861 says,—"It is difficult to discover the necessity for that cumbersome system which now exists, viz., *a single government* (the Board of Trade) for Lighthouses in the British possessions abroad; *a double government* for the Lighthouses under the Trinity House; *a triangular government* for the Scotch Lighthouses and for local lights in England; and *a quadrilateral government* for the Irish Lighthouses and for local lights in Scotland and Ireland;—a system which can scarcely be expected to find favour in the present day."

In *France*, the Lighthouse service is under the ministry of Public Works, and a special Commission, called "Commission des Phares;" which body consists of naval officers, marine engineers, hydrographers, members of scientific bodies, and other gentlemen, distinguished for their scientific attainments in various professions, all of which have to do with branches of science connected with coast illumination. The general conduct of the service is under an officer called Directeur General des Phares, who is an engineer, and has other engineers under him.

In the *United States* of America, the lights are under one Central Board, constituted in 1852, and composed of a member of the Government, engineer officers, and officers of the army and navy, and civilians of high scientific attainments.

In *Sweden*, the lights are under the Admiralty, and managed by a director and officers who have military rank, and engineers.

In *Norway*, the service is under the Royal Marine Department.

In *Turkey*, it is under the Admiralty; and the system is now in course of development.

In *Hanover*, the service is under the Director-General of Waterworks.

In *Hamburg*, they are under the Committee for Harbours and Navigation.

In *Spain*, the system of administration is the same as in France; and the full development of the system is now in progress. The lights, &c., are under the department of Public Works, and under a permanent Commission composed of ngineers of superior rank of the Corps of Roads, &c., and naval officers; and he captains of ports are instructed to suggest improvements and report on the ights.

In *Denmark*, the service is under the Ministry of Marine, entrusted to one Light ngineer and two Buoy Inspectors.

In *Russia*, the superintendence is dependent from the Hydrographical Department.

In *Holland*, the management of Lights, Buoys, and Beacons rests with the Iinister for the Marine, under whom are an Inspector-General and seven nspectors.

In *Belgium*, the construction of Lighthouses is under the Minister of Public Vorks; but when built they are handed over to the general direction of the Navy, which is under the Minister for Foreign Affairs.

In *Austria*, the superintendence of all the Lighthouses, Buoys, and Beacons elongs to the Imperial Royal Admiralty. The Deputies of the Exchange, at rieste, attend to Lighthouses, — their erection, management, collection of ues, &c.

In conclusion, an inspection of these most useful monitors ‘ › the sailor is recommended to him. He will then see that the beauty of the apparatus, the discipline, rder, cleanliness and perfection of everything connected with them are not exceeded y their utility.