appeared of a dirty brown colour, very different from what "Bishop's ring" used to be, and I have thought that often it has not been in the upper atmosphere, but at a lower altitude, and most visible when there has been more or less smoke; so that it seemed not improbable the smoke was the cause of it. Has anyone else noticed such a phenomenon connected with smoke? "Bishop's ring," as still seen at sunset, is evidently not caused by smoke, but doubtless arises from the same circumstances as made it so conspicuous an object at its first appearance in November 1883, and gradually less so since.

The whitish wisps occurring in and near the ring about sunrise and sunset continued visible at intervals, and varying greatly in distinctness, up to the 31st ult. I have not seen them since, but they have been invisible for longer periods before.

T. W. BACKHOUSE.

Sunderland.

A REVIEW OF LIGHTHOUSE WORK AND ECONOMY IN THE UNITED KINGDOM DURING THE PAST FIFTY YEARS

I.

IT may be useful to recapitulate very briefly the various steps of progress in this important branch of engineering and optical enterprise since the beginning of the Queen's reign. And a few words may be added on the statistics and economics of the subject.

A lighthouse or lightship is naturally to be considered under four heads: (1) tower or hull and its lantern; (2) optical apparatus and its mechanical accessories; (3) lamps and illuminants; (4) auxiliary sound signals.

In 1837 a high degree of excellence had been attained in the first division, at least as regards stone towers and wooden vessels, but in the others *stare super antiquas vias* was a practice largely submitted to. The number also of established lights was comparatively small, about seventy of all kinds being in England and Wales, less than one-fifth of the present number. France, where there had been from 1824 to 1827 an active movement in the direction of coast illumination, possessed in 1836 about 100 lights. In 1822, and again in 1834 a Parliamentary Committee had inquired into the character and management of our lighthouses, with results to be noticed by and by.

In 1837 the old working Phari of Greece, Carthage, and Rome, from Alexandria to the Pillars of Hercules, had long since disappeared, leaving only a few vestiges, chiefly on the shores of France, Spain, and Britain. Of modern times the most notable towers were, on the Continent, the imposing Cordouan at the mouth of the Garonne (1610), and the tourist-haunted Lanterna of Genoa, the latter still being the tallest lighthouse structure in the world; while at home Smeaton's Eddystone (1759), prototype of British towers, the Bell Rock (1811), the Tuskar (1815), and the Carlingford, on Haulbowline Rock (1823), stood as the most striking examples of such edifices. But in 1838 the great tower of Skerryvore was begun by Alan Stevenson, whose father, Robert, had built the Bell Rock Lighthouse. These accomplished engineers have respectively left a graphic and instructive narrative of their work, which may be fitly classed with Smeaton's memorable account of the third Eddystone.

Skerrymhore or Skerryvore (*ysgar-mawr* = great divided cliff, or rocky islet, as in *scar*, or the hills Skerid Fawr, and Skerid Fach) is a nearly submerged reef adjacent to the Island of Tyree, exposed to the full force of the Atlantic, and surrounded by innumerable rocky points constituting "foul ground" along a line of seven miles. It is thus perhaps the most dangerous of all the *skerries* in British waters, and differs essentially from the Eddystone, which, though formidable in itself, rises from the deep sea, and can be approached more nearly in calm weather. Obviously, then, the 72 feet of elevation of the Eddystone lantern-centre, and even the 93 feet of the Bell Rock, could not afford the necessary range to a light intended to give timely notice to mariners of the outlying perils, and a height of 130 feet was adopted for the Skerryvore edifice, which, permitting one of 150 feet from focal plane to high water, insured a geographical horizon of about fourteen nautical miles, or eighteen miles to a vessel's deck. The mean diameter given to this tower was 29 feet, slightly greater than that of Bell Rock, that of Smeaton's Eddystone being 21 feet. The cubic contents are more than four times those of the Eddystone, and more than double those of Bell Rock. There are ten stories below the lantern, for water, fuel, keepers' rooms, and other purposes. The work was completed early in 1844, after extraordinary difficulties and perils, and it is a splendid monument to the energy and skill of Alan Stevenson. Its cost was £87,000.

Yet perhaps some of the towers of the great nation which charges no dues for its lights, but presents them a noble offering to the world, are fully as remarkable. Minot's Ledge (1859) on the Massachusetts coast, and Spectacle Reef, Lake Huron, are examples. The latter structure was begun in 1871, and, though for an inland water, cost £60,000, the special difficulty having been ice, and the laying, by means of a cofferdam, of the lower courses of masonry on a jagged slope of dolomitic limestone 12 feet under water, and eleven miles from land, like the Eddystone. So in the case of Minot's Ledge Tower, the foundations of which were laid on a rock barely visible at extreme low tide, and in the full swell of the ocean, the distinguished engineer General Alexander was able to secure but thirty hours of work in the first year, and 157 in the second.

The Bishop Lighthouse, on the south westernmost rock of the Scilly Islands, was completed in 1858 at a cost of £34,560. After a quarter of a century's service it has been found expedient to increase the height, and to erect a more powerful optical apparatus, which will be ready during the present year. Other notable towers of the Trinity House are the Smalls (entrance of Bristol Channel), the Hanois (west end of Guernsey), the Wolf, and the new Longships; all being generally alike in design, and not differing widely in dimensions and cost. The Wolf Tower received its light in January 1870, having been begun in March 1862. It was planned by Mr. James Walker, then Engineer to the Trinity House, but carried out by his successor, Mr., now Sir James, Douglass, and by his brother, Mr. William Douglass. This lighthouse is situated seventeen miles from Penzance, and twenty-three west-north-west of the Lizard. It has a mean diameter of nearly 30 feet, and a total height of 110 feet from high water to lantern-centre, being solid for 39 feet from the base, and containing 44,500 cubic feet of granite, weighing 3300 tons. Each face-stone is dovetailed vertically and also horizontally—the latter was not done in the Eddystone tower—and the courses further secured together by metal bolts. Roman cement was used for the work below water, and Portland cement for that above, the whole mixed with a peculiar granitic sand from a Cornish tin-mine. Very great difficulty, as with all these exposed towers, was experienced in the erection of the Wolf and the new Longships, owing to the terrific seas that assaulted the rocks. The Longships, so conspicuous an object from the Land's End, and so well known from Mr. Brett's luminous pictures, with an original elevation of 79 feet above high water, was so drowned by the waves that the character of the light could hardly be discerned, and a granite column of 110 feet was adopted.

In Scotland the sea-tower of Dubh Artach, or, less correctly, Dhu Heartach (1872), and in the Isle of Man that on the Chicken Rock (1875), may be named and the list of the chief structures of this type may be summed up in the Eddystone of Sir James Douglass, from which a light was first shown in 1882. The rapid disintegration of that part of the reef on which Smeaton's tower stood made it absolutely clear in 1877 that a new tower must be built if a disaster (such as that which befell the Calf Rock Light a few years later) were to be avoided. It had been suggested to destroy the reef by blasting, as it had been persistently suggested since 1844 to remove the Goodwin Sands. But in either case not only would such a thing be impracticable on account of the enormous expenditure of money and time; but also there is a positive advantage for navigation in retaining a lighthouse or a lightship on these sites. The new Eddystone tower replacing that of Smeaton, which had made the name memorable for 123 years, has an elevation from lantern-centre to high water of 133 feet, commanding a horizon of seventeen and a half nautical miles (to a vessel's deck). The corresponding horizon of the old tower was about fourteen miles, with an elevation of 72 feet. The extended range is ample for all maritime needs. The structure contains 63,020 cubic feet, or 4668 tons, of Cornish and Dalbeattie granite. The tower springs from a solid cylinder of granite about 45 feet in diameter and 20 feet high, set indissolubly on the rock. The mean diameter is about 30 feet. It is solid up to 25½ feet above high water, except as regards space for a water-tank which holds 3500 gallons. It has seven chambers for stores and keepers' use, and a room for exhibiting a small light 15° in azimuth to denote a danger called Hand Deeps. These chambers all have a diameter of 14 feet. There are besides two others below them of less size. Two massive fog-bells are fixed under the lantern-gallery. Very little inflammable material is used. The doors, window-frames, and other fittings are of gun-metal, and every modern resource has been employed to make the building weather-proof and enduring, and to insure the comfort of the three men confined in it, and the unfailing exhibition of the powerful light which crowns it. The time occupied in the work was about three years and a half, the cost less than £80,000.

It is unnecessary to refer to the numerous land towers erected by lighthouse authorities during the half century, because these, being reared for the most part on cliffs, and little exposed to stress of sea, present no difficulty of construction or novelty of type.

All the towers hitherto named are of stone, but iron has not been overlooked as in some circumstances a practicable material for a sea structure. The designs of the late Mr. Alexander Gordon, C.E., in cast and wrought iron, for the towers of several West Indian and South African lights are well worthy of attention, as are also those of Messrs. Grissell for Russia, &c.; and, more recently, the tall iron towers designed and made by Messrs. Chance, of Birmingham, for Australasian sites, are not less remarkable. At home, the Fastnet may be taken as a successful instance of the application of iron. The rock so called is four miles south-west by west of Cape Clear, and has been symbolised as the "Tear-drop of Ireland," being the "last of the old country seen by emigrants." This tower was begun in 1848, and completed in 1853. It is composed of a casing of cast-iron plates with a central column and girder floors, forming five chambers 12 feet high. The lowest story is partly filled in with masonry, leaving space for a coal-vault. The other stories are lined with brick. The internal diameter of the tower is 12 feet, the height from base to gallery 64 feet. The focal plane is 148 feet above the sea. The cost of the work was £19,000. The engineer and designer was the late Mr. George Halpin.

The lightships established in British waters are of great interest. There are now about seventy-five, sixty being on the English coast, of which the larger number date from since 1837. Several of these peculiarly English vessels were placed on their stations in the last century, the historical Nore, for instance, in 1732.

Iron had been in use for light-vessels in the Mersey before 1856. In 1843 it had been discussed by the Trinity House as a possible material, but was not then deemed desirable. The first Trinity iron vessel was stationed in 1857 on the Goodwin Sands, the next in Cardigan Bay in 1860. The usual length of a Trinity lightship is 80 feet when constructed of wood, and about 90 feet when of iron, the width is 21 feet, the average tonnage 155 to 160 tons when of wood, and 180 tons when of iron. The focal plane of a light is generally 38 feet above high water. The cost averages £3600 for wood, and £5000 or £5500 for iron. An immense service is rendered by these modest and vigilant sentinels of the deep which surround our coasts in positions impossible for a lighthouse, and for the most part close to the dangers of which they give warning, or to the channel of approach which they indicate. It has long been proposed to connect these vessels, as also rock and pile lighthouses, with the shore, and (in some cases) with one another, by an electric cable; and a Committee is now engaged on the subject. In this way communications may be made as to the safety and requirements of the station, and as to the passing shipping, and to wrecks and other casualties, though it is doubtful whether reports on the last heads are a proper addition to the functions of a light-keeper, or one that is likely to be satisfactory in the result to the persons concerned.

A curious and ingenious plan of combining the lighthouse with the lightship was conceived by Mr. George Herbert in 1853, and much discussed and recommended at the time. On the assumption that the form of a ship is not the best for a stationary floating body, he proposed a circular vessel, moored from its centre of gravity, and supporting a central tower of about 40 feet high, with lantern, gallery, &c., of the usual kind. A candlestick set in a wash-tub may not be too familiar an illustration. A position north of the Stones Rock, on the Cornish coast, was suggested, at an expense of about £10,000. The Trinity House did not adopt this plan, but in 1859 two beacon buoys on the same principle were successively placed off the Stones, and after a few weeks' service were driven from their moorings and destroyed.

The use of screw piles for the foundation of a lighthouse in sand was first demonstrated at Fleetwood in 1840, and Maplin in 1841, and afterward at the Chapman, Gunfleet, and other stations. The method is that of Alexander Mitchell, improved by Mr. George Wells, who has erected many such structures in various shallow seas.

The lantern, that is the framework of glass and metal, which contains the illuminating apparatus, whether in land or floating lights, has been much modified during the past fifty years. At the accession the lantern of a first-class light was from 10 to 12 feet in diameter, with perhaps 8 feet of glazing in polygonal panes. The bars were heavy and intercepted much light, the ventilation defective, the construction more or less weak and unequal. Successive improvements have been effected by the engineers of the Trinity House and Northern Lights Commission, and by Chance, of Birmingham. In its highest type, that of Sir James Douglass, as in the Bishop Rock example, the lantern of to-day for a first order lighthouse is well worthy of the perfected optical instrument which it protects. It has a diameter of 14 feet between the glass surfaces, a height of glass of 15 feet, and a height from base to vane of about 32 feet. It is cylindrical in form, with solid gun-metal bars, helically inclined and of wedge-like section towards the flame, comprising sixty-four openings of diamond and sixty-four of triangular shape. The polished plate-glass is three-eighths of an inch thick, and bent accurately to fit in these openings. Nine-tenths of the incident light from the lamp is transmitted through this glass. Not more than $\frac{3}{100}$ of light is stopped by the lantern framing. Thus the maximum of stability and the minimum obstruction of the rays are obtained. At the same time every expedient to promote perfect ventilation, from the tubes of Faraday to the longitudinal valves and the roof-cylinders of Douglass, has been adopted, this being indispensable for the combustion of the great concentric flames now employed. The dome is of rolled copper, the plinth or base of massive cast-iron lined with iron sheets. The cost of such a lantern is about £1700. The lantern of recent lightships has been treated in the same way, having regard to its lightness, mobility, and smaller dimensions. The diameter has been extended to 8 feet, the height of plate-glass to 4 feet, the cylindrical form substituted for every other.

It does not seem possible to construct lighthouse towers and lanterns of better designs and materials than those which have been described. An important amplification of the dimensions may, however, be resorted to in the future to meet the increasing radii of the lenticular apparatus, and the increasing size and height of the central flames. This is on the assumption that electricity does not displace petroleum and gas as illuminants. It may be counted as an additional claim of the arc to be the light of the future that it requires no apparatus larger than Fresnel's first order of 920 millimetres focal distance, and that therefore no lantern exceeding 14 feet in diameter with 10 feet of glazing, and no tower with a diameter of platform greater than 23 feet, would certainly be needed. The merits and prospects of the rival illuminants will be discussed in a subsequent article. J. KENWARD

(*To be continued.*)

CONDENSATION OF GASES.

AMONG the numerous subjects which have engrossed the attention of the knowledge-seekers of the present century, probably none have surpassed in fascination and in the wealth of results which have followed persistent effort the question of the possibility of liquefying those gases which for ages had been considered permanent. Immediately after that epoch-making period in chemistry and physics, when Faraday, following in the footsteps of Northmore who in 1806 had succeeded in liquefying chlorine, announced to the world the fruitful results of his experiments upon the liquefaction of gaseous sulphurous, carbonic, and hydrochloric acids, nitrous oxide, cyanogen, and ammonia, came a long interval, during which all attempts to induce hydrogen, oxygen, nitric oxide, marsh gas, and carbon monoxide to take up the liquid state yielded little more than negative results, and the subject appeared almost without hope. When one looks back to the end of the year 1877 and remembers the thrill of excitement which ran through the civilized world when the double announcement was made by the French Academicians that oxygen had been independently liquefied by Cailletet and Pictet, and then, in the mind's eye, reverts to the long years of trial and experiment during which these and other workers were slowly but surely building up future success on present failure, one cannot but be cheered by the thought that patient work inevitably brings its own reward. The fundamental principle upon which both based their experiments was, that the gases must be simultaneously exposed to very high pressures and to temperatures lower than their critical points. Pictet, whose apparatus was a triumph of mechanical skill, evolved his gas to be liquefied from a strong wrought-iron cylinder, from whence it passed into a closed copper tube surrounded by a cold bath of rapidly evaporating liquefied carbon dioxide, which reduced the temperature to – 130° C. Cailletet arrived at the same end by using a hydraulic press to compress his gas, but instead of using a very cold bath he caused the gas to effect its own reduction of temperature by suddenly releasing the pressure, causing rapid evaporation, and hence such a considerable cooling that the gas condensed in drops of liquid. Pictet, on January 10, 1878, further succeeded in crowning his results by liquefying hydrogen at a pressure of 650 atmospheres and at a temperature of – 140°, and finally, on releasing the pressure, by actually solidifying the hydrogen, which fell "like so many drops of steel" upon the ground.

But now came the question of the possibility of producing still lower temperatures, so as to effect the same result at correspondingly lower pressures, and so successful have efforts in this direction been that the more permanent gases have at last been liquefied at pressures nearly approaching atmospheric, and retained in the liquid form under even less than atmospheric pressure. This is a great leap in advance, for it not only enables us to determine the boiling-points of the liquefied gases at ordinary pressure, but also to determine their densities in strictly comparable numbers. This happy consummation we mainly owe to the untiring efforts of Dr. K. Olszewski, whose latest results have just been given to the world, and a short description of whose work will probably be of general interest

The most critical portion of any apparatus for such a purpose is of necessity the glass tube in which the liquefaction is to occur, the capacity of which for withstanding rapid changes of both temperature and pressure is put to the severest test. Olszewski paid particular attention to the preparation of his tube, heating it for some time almost to redness in an iron tube packed with calcined magnesia, and allowing it to cool slowly beneath a thick layer of hot ashes, thereby obtaining a tube in which more than a hundred experiments were performed without a single explosion. The open end of this tube, *a*, was attached to a brass flange, *b*, the upper part of which was furnished with two openings, one for the hydrogen thermometer, whose bulb reached to the bottom of *a*, the other uniting the tube *a* with a branched copper tube *e*, by means of which connexion could be made at pleasure with (1) the manometer *f*, for use with pressures smaller than atmospheric, (2) an air-manometer, *g*, for use with higher pressures, (3) a large air-pump for reducing the pressure upon the liquefied gas, (4) an aspirator, *r*, used as afterwards described in the density determinations, and (5) an iron Natterer cylinder, *i*, in which the gas to be liquefied was stored up under a pressure of 60-80 atmospheres. A caoutchouc stopper, *k*, held the liquefaction tube within a system of glass cylinders designed for the reception of liquid ethylene, which was used to effect the reduction of temperature, and for preserving the same from the warming influence of the surrounding air. The four vessels were held within each other without touching by pieces of cork and felt rings, so that the ethylene was separated from the surrounding air by badly conducting layers of air, and the evaporated ethylene, passing in the direction of the arrows between the walls, still further counteracted the influence of radiation from warmer surroundings. In the outer cylinder were placed a few pieces of chloride of calcium in order to dry the air and prevent the deposition of hoar frost. The liquid ethylene was supplied from a second Natterer cylinder, *l*, fitted with a siphon arrangement and placed in a mixture of ice and salt; on the way to its receptacle the ethylene passed through a spiral copper tube surrounded by a freezing mixture of solid carbon dioxide and ether contained in a double-walled vessel, *m*. On connecting the vessel with the air-pump and reducing the pressure, the temperature of this freezing mixture sank to – 100°, and 150 c.c. of liquid ethylene were obtained, which remained perfectly quiet for hours under atmospheric pressure. The glass tube *n* was then connected with the air-pump, by means of which the pressure was reduced until the ethylene began to boil; here however a difficulty, for a long time insurmountable, presented itself; for it was found that inequalities of temperature in the ethylene column caused violent disturbances, and the liquid rapidly disappeared out of the vessel. A simple expedient, however, that of forcing a regulated stream of dry air through the ethylene, was eventually hit upon and