A Few Notes

on

Modern Lighthouse Practice.

CHANCE BROTHERS AND CO.,
LIMITED,

Lighthouse Engineers and Constructors,

NEAR **BIRMINGHAM.**

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WE have frequently been requested, by those who find themselves for the first time confronted with the construction or erection of

Lighthouse Apparatus, and who naturally find a difficulty in grasping the fundamental principles governing the choice of such apparatus to suit various maritime conditions, for information as to the terms used in Lighthouse work, and an indication of those principles.

We have therefore put together the following notes, trusting that they may be of some use to those practically engaged in such work, who have not the time or opportunity to read or study the more technical books dealing with the subject.

It is not proposed to deal with the masonry portion of Lighthouse construction, which is of course a branch of engineering distinct from that connected with the lenses, revolving apparatus, burners, lanterns, etc., to which these notes specially refer.

We shall always be pleased to reply to questions on any particular points which these notes do not make clear, or assist with our advice in any Lighthouse problems with which they do not deal.

CHANCE BROTHERS AND CO.,
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A few Notes on Modern Lighthouse Practice.

CHAPTER 1.

BEFORE going into the details of construction, it will be well to explain a few of the terms specially connected with Lighthouse work, prefacing these with an indication of the general principles involved.

In all modern Lighthouses, the rays of light from the luminous source are collected and caused to travel along the desired path by reflection or refraction, or a combination of the two, by any of the following systems, the object always being to use as much as possible of the useful light available:

(1) Catoptric System, in which the light is *reflected* only, the reflector being some highly-polished surface. This system is the most ancient and is now nearly obsolete, except in Light-vessels, where metallic reflectors of paraboloid form are still used, on account of the possible danger of the motion of the vessel breaking glass lenses if that type is employed. However, the modern improvements in. balancing, etc., now render it safe to use lenses in such positions, and it seems likely that the use of the catoptric system for lighting at sea will entirely die out.

The sketch, Fig. 1, illustrates this system.

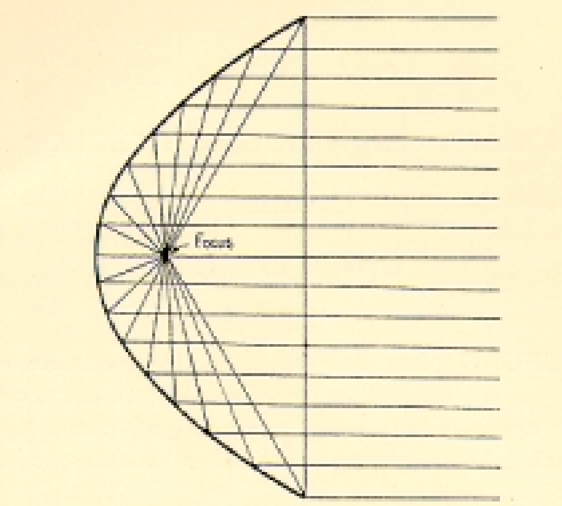
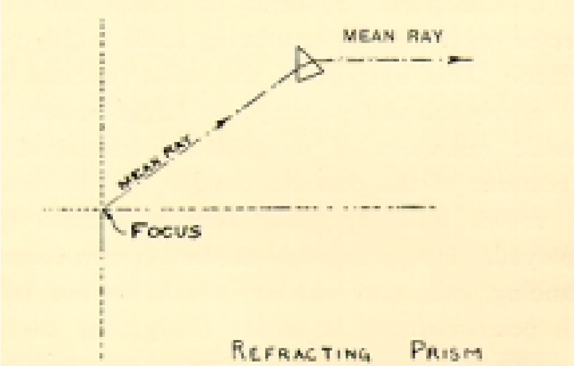


FIG. 1

2) Dioptric System, in which the light is *refracted* or bent by a glass agent in the direction required. Such agent is termed a refracting prism or refractor (Fig. 2).

This system is used in all modern Lighthouse Apparatus.

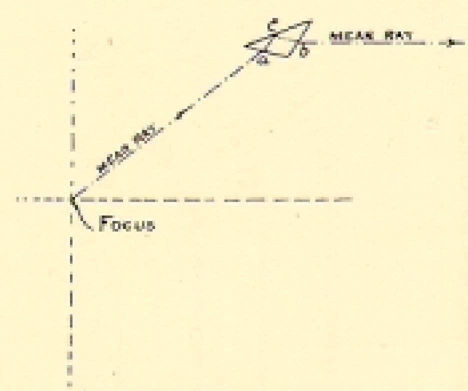


REFRACTING PRISM

FIG. 2

(3) Catadioptric System.—This is any combination of the last two, that is, it uses both refraction and reflection to bend the rays of light in the desired direction.

These two processes may take place in a single element, for instance, in a reflecting prism as illustrated in Fig. 3, where refraction takes place at **a** and **b** and reflection at **c.**



REFLECTING PRISM

FIG. 3

The ordinary Lighthouse Apparatus (see Fig. 4) which consists of refractors over the central portion of its vertical section (from **b** to **c** in Fig. 4), and reflecting prisms over the rest, is, strictly speaking, Catadioptric, as it uses both reflection and refraction, but in modern parlance it is usual to refer to any apparatus consisting of glass elements only as Dioptric."

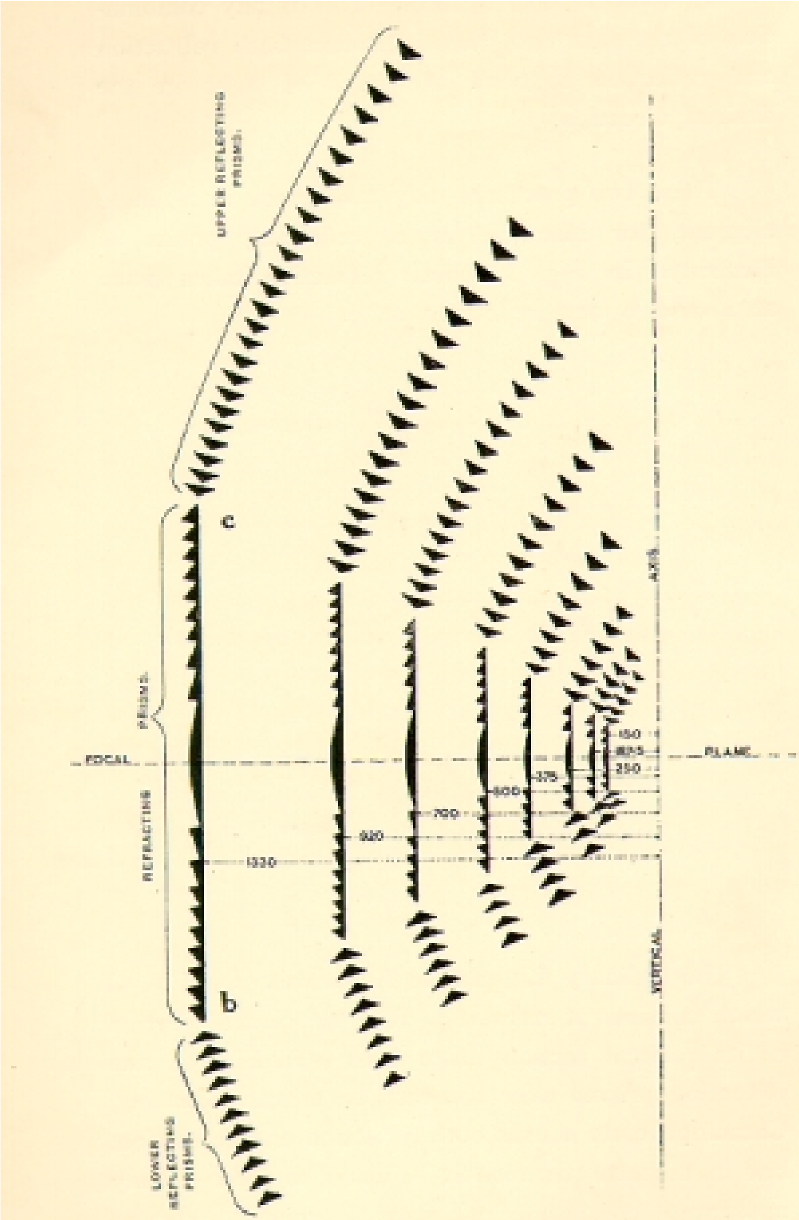

UPPER REFLECTING PRISMS.
REFRACTING PRISMS.
LOWER REFLECTING PRISMS.
FOCAL PLANE
VERTICAL AXIS
c
b
1330
920
700
500
375
250
150

FIG. 4

Mirrors.—As explained above, those of the paraboloid form, for reflecting the rays in a parallel beam, are nearly obsolete for Lighthouse purposes, but **Spherical Mirrors** are largely used to reflect rays, which would otherwise be lost, back to the source of light, thus strengthening the effect of the latter, through which they pass, and are refracted or reflected with the other rays in the direction required.

In small Lights catoptric metallic mirrors are employed.

In larger Lights, so-called dioptric (a more accurate term would be catadioptric) mirrors are used. These are made of glass divided into rings, and are so constructed that every ray of light falling on them Is reflected back to the luminous source (see Fig. 5). Their advantages over the metallic mirrors are greater accuracy—especially in the larger sizes, which if metallic are apt to get bent out of shape—and longer life, the latter being due to the greater ease with which they are cleaned, whereas in course of time a metallic reflector loses a great deal of its brilliancy owing to scratching and other defects due to the continued rubbing it must undergo.

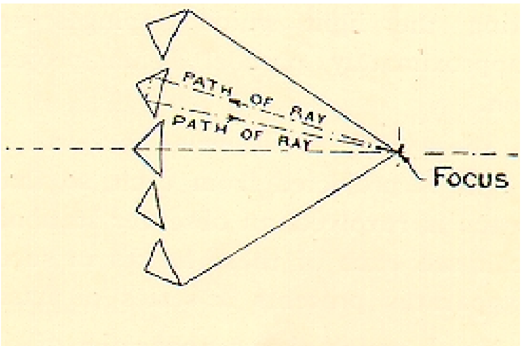


FIG. 5

The following terms are used with special meanings in Lighthouse work:

"Optical Apparatus" or "Apparatus" refers to that portion, generally consisting of glass refractors and reflecting prisms in gun-metal framework, whose function is to send the rays from the burner in the required direction.

Fixed Apparatus.—This is the type which concentrates the rays from the burner in the vertical plane only, that is, which shows a fixed and unvarying beam round the horizon through whatever angle the apparatus is designed to cover.

The glass refractors and reflectors used to obtain this result are in the form of rings having their centres on the vertical axis of the apparatus, and lenses of this form are described as of **Fixed Section.**

Flashing or Revolving Apparatus in which type the lenses are built up into faces or panels, each being in effect a gigantic bullseye lens, and are composed of separate glass elements known as refractors and reflectors, which are formed in rings having their centres on the horizontal axis of the optic.

Each lens acts upon the rays from the burner, in both the horizontal and vertical planes, thus concentrating the light which impinges upon it, into an approximately parallel beam projected to the horizon.

When there are, as is usual, several faces, a beam of light is projected from each, so that when the apparatus is revolved, an observer stationed at a distance can see each of these beams in succession, and the apparatus presents a series of flashes.

Plate No. I, which shows apparatus of different characters, will illustrate the above definitions.

A Holophote is, strictly speaking, an optical apparatus which collects *all* the light from the luminous source and throws it out in one direction, but the term is loosely used for any panel of revolving section, especially if such panels are fixed, and used in connection with "Leading Lights."

N.B.—In practice the vertical angle is about 126 degrees, and can never be the full 180 degrees, as a space must be left at the top of the apparatus for the damper tube—which carries off the heat from the burner—and it is useless to carry the bottom prisms below a certain angle, as the body of the burner and the burner-stand obstruct the light beyond it.

"Focal Plane" is the horizontal plane through the centre of the Optical Apparatus, that is, through the centre of the "belt" or "bull's eye."

The "belt" is the central refractor in an Apparatus of Fixed section.

The "bull's eye" is the central refractor in an Apparatus of Flashing section.

In both Fixed and Flashing Lights the refractors are numbered from No. 1 upwards, starting with the belt or bull's eye as No. 1, and working outwards. The reflecting prisms start in the same way with the innermost prism as No. 1, and working outwards above and below. See Fig. 4, which gives a vertical section of each of the different "orders" of Apparatus, and shows the number of refractors and reflecting prisms—top and bottom, which are usually employed to cover the full vertical angle adopted in each case.

Burner is used in the ordinary meaning of the word, and can be of any form, such as incandescent, wick, gas, etc.

The term **Lamp,** as opposed to burner, usually refers to the portion of the illuminating apparatus which contains the oil, for instance:

A Constant-Level Lamp (see Fig. 6), which automatically regulates the supply of oil to a wick burner.

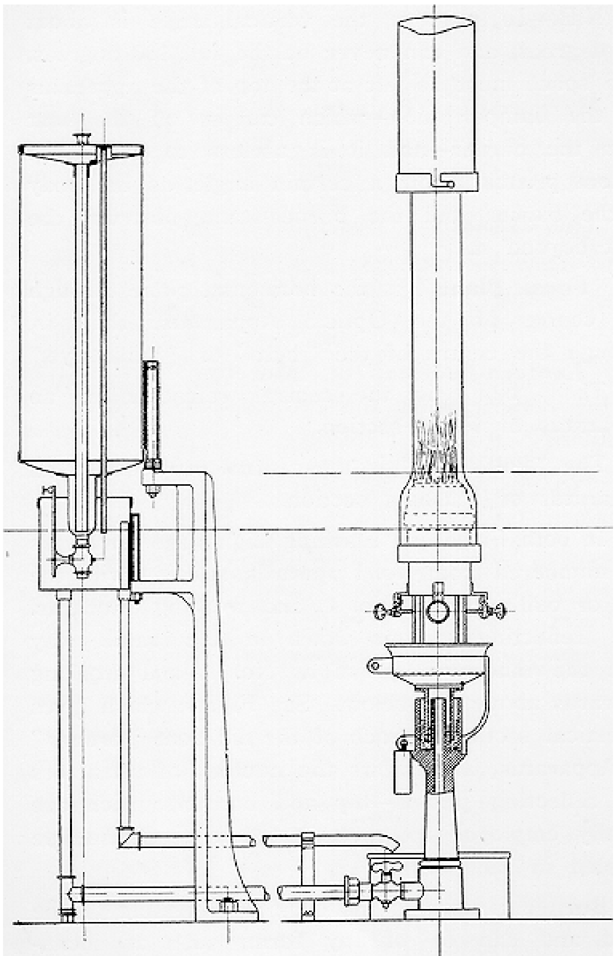


FIG. 6

A Capillary Lamp (see Fig. 19) works on the same principle as an ordinary house lamp; in this case the lamp and burner -are practically one, and it is therefore called by either name, though strictly speaking the burner is that part which holds the wick or wicks.

"Pedestal." — The column or other similar arrangement on which the apparatus rests.

Mercury-float Pedestal.—A pedestal as above, fitted with a mercury float and trough, for Revolving Lights.

The "Lantern" consists of the ventilating pedestal plates, glazing, roof and ventilator, and forms a chamber for protecting the Optical Apparatus.

"Lantern-Pedestal" or "Murette."—The portion of the lantern below the glazing, consisting of the ventilating pedestal plates.

"Clock," used with Revolving or Occulting Lights. This is driven by a falling weight in Revolving and large Occulting Lights, and by a spring in small Occulting Lights (Port-Lights, etc.), and serves either to revolve the apparatus or work the mechanism which occults the Light.

CHAPTER 2.

Lighthouse Apparatus are divided into various "orders," as follows, according to their Focal Distance, that is, half the diameter of the Apparatus on the Focal Plane:

Order.	Focal Distance, In millimetres.
Hyper-radial - - -	1,330
Meso-radial - - -	1,125
(This size is not often used).	
1st Order - - - -	920
2nd Order - - - -	700
3rd Order - - - -	500
3rd Order (small type) -	375
4th Order - - - -	250
5th Order - - - -	187.5
6th Order - - - -	150

Smaller lenses are also made, but these are generally used for gas buoys or ships' side lights.

"Range."—The range of a light is the distance at which it is visible.

The distance at which a Light is visible at sea, provided of course that the candle-power of the beam is high enough, depends, owing to the curvature of the earth, on the height at which it is placed above the sea-level. The following table gives these distances or geographical ranges for various heights, as seen by the mariner from a vessel's deck 15 feet (4.57 metres) above water:

Heights of Light above sea-level, in feet and metres.						Distances visible in geographical or nautical miles.
5 feet	or	1.52	metres	-	- -	7.00
10	,, ,,	3.04	,,	-	-	8.06
15	,, ,,	4.57	,,	-	-	8.88
20	,, ,,	6.09	,,	-	-	9.57
25	,, ,,	7.62	,,	-	-	10.17
30	,, ,,	9.14	,,	-	-	10.72
35	,, ,,	10.66	,,	-	-	11.22
40	,, ,,	12.19	,,	-	-	11.69
45	,, ,,	13.71	,,	-	-	12.13
50	,, ,,	15.23	,,	-	-	12.55
55	,, ,,	16.76	,,	-	-	12.94
60	,, ,,	18.28	,,	-	-	13.32
65	,, ,,	19.81	,,	-	-	13.68
70	,, ,,	21.33	,,	-	-	14.03
75	,, ,,	22.85	,,	-	-	14.37
80	,, ,,	24.38	,,	-	-	14.70
85	,, ,,	25.90	,,	-	-	15.01
90	,, ,,	27.43	,,	-	-	15.32
95	,, ,,	28.95	,,	-	-	15.62
100	,, ,,	30.47	,,	-	-	15.91
110	,, ,,	30.78	,,	-	-	16.47
120	,, ,,	31.09	,,	-	-	17.00
130	,, ,,	31.39	,,	-	-	17.52
140	,, ,,	31.69	,,	-	-	18.01
150	,, ,,	32.00	,,	-	-	18.46
200	,, ,,	60.95	,,	-	-	20.66
250	,, ,,	76.19	,,	-	-	22.58
300	,, ,,	91.42	,,	-	-	24.31
350	,, ,,	106.67	,,	-	-	25.90
400	,, ,,	121.91	,,	-	-	27.38
450	,, ,,	137.15	,,	-	-	28.77
500	,, ,,	152.39	,,	-	-	30.09
550	,, ,,	167.63	,,	-	-	31.34
600	,, ,,	182.87	,,	-	-	32.54
650	,, ,,	198.1l	,,	-	-	33.69
700	,, ,,	213.35	,,	-	-	34.72
800	,, ,,	243.83	,,	-	-	36.89
900	,, ,,	274.31	,,	-	-	38.98
1,000	,,	304.79	,,	-	-	40.72

Character. — The character of a Light is its appearance as viewed by an observer at some distance from it, for instance, "Fixed White," "Fixed Red," or "Single-Flashing," that is, one which shows a single flash at stated intervals. In fully describing the character of a Light, the actual duration of the flash and the dark intervals between each flash is given.

Along a well-lit coast, Lighthouses are comparatively close to each other—and it is therefore very necessary to be able to distinguish them from one another. Many of the worst maritime disasters have been caused by the inability of the mariner to do so. It is therefore essential that neighbouring Lights should be given distinct characters. Where existing Lights in which the apparatus is of fixed section are in question, this can be done by making them "occulting," that is, cutting off the light from the burner for certain periods by (a) screens revolving inside or outside the apparatus; (b) a "dropping cylinder" which rises and falls, covering and uncovering the burner; (c) where gas or acetylene is used, turning the supply on and off and using a by-pass.

Plate No. 2 illustrates the methods described above, Fig. 1 showing the dropping cylinder, and Figs. 2 and 3, revolving screens.

Any character—within certain limits—can be given with occulting apparatus.

For Flashing Lights the methods of giving distinctive characters were greatly improved by the adoption of the Group-Flashing system, which was first introduced by us, and is further discussed under that heading on page 22.

Plate No. I shows the form taken by revolving apparatus to give different characters. Each panel, consisting of refractors and reflecting prisms, throws out a beam of light in one direction, and the interval between the flashes is governed by the angle between the axes of these panels and the speed of revolution of the apparatus. Each panel must be arranged to give a beam of equal intensity, and therefore in an apparatus giving a character of red and white flashes alternately, see Plate No. I (H), it will be seen that the red panel is much larger than the white, the extra width being necessary owing to the absorption of light by the red glass.

The object of the difference in the width of the panels of the triple-flashing apparatus, as shown in Plate No. I (F), is to equalise the power emitted from them, and is due to the facts that (1) The centre panel contains a larger proportion of refractors, which, since their thickness causes them to absorb less light in transit through them, are more efficient than the reflecting prisms. (2) The centre panel is assisted by a mirror.

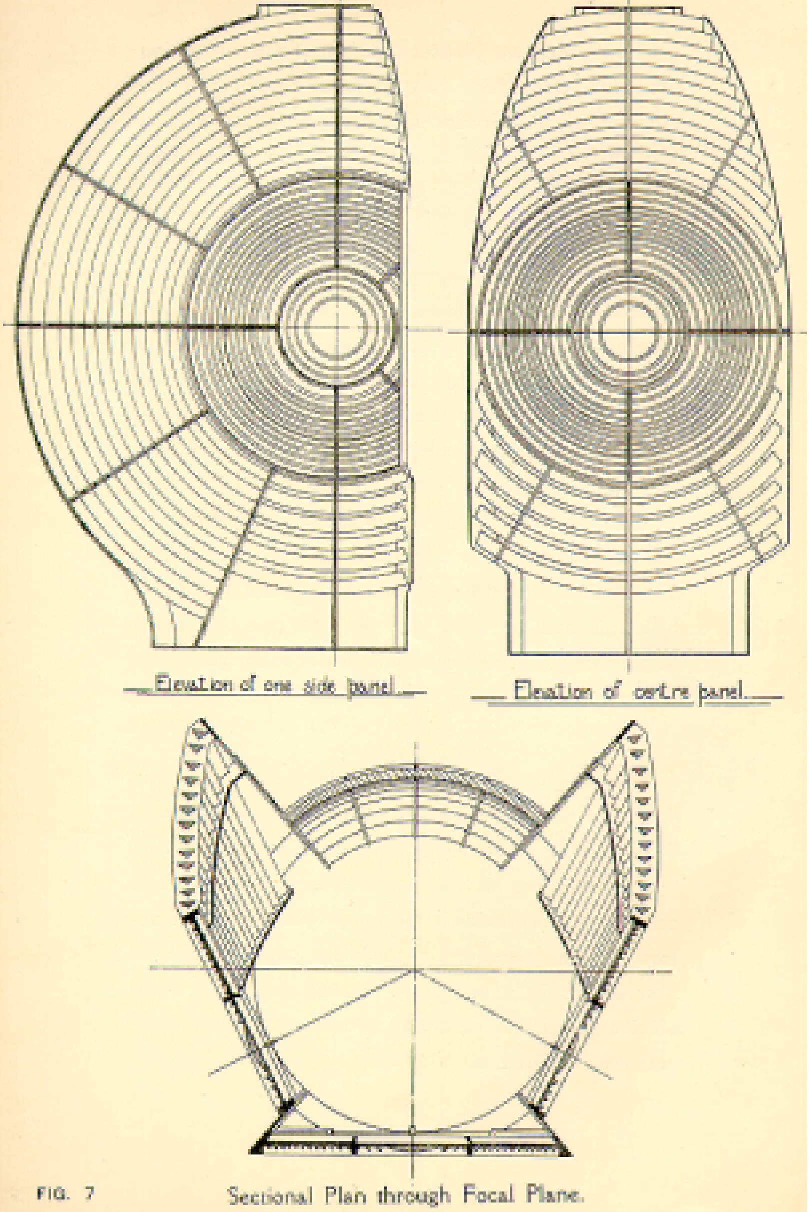


FIG. 7 Sectional Plan through Focal Plane.

It is obvious that the mariner requires to recognise a Light as soon as he sees it, and therefore a character to be good should be given in as short a period as possible.

For this reason Lights of simple character are preferable to those of mixed character. Instances of simple character are Single Flashing Lights or groups of 2, 3, or 4 flashes. Examples of mixed characters are a single flash followed by a double flash, see Plate No. I (J), or red and white flashes alternately, since in cases such as these, the character cannot be given in such a short period and therefore takes longer to repeat itself. Lights of mixed character are therefore very seldom installed in modern practice.

The duration of flash does not depend on the width or shape of the panel, unless the latter is specially designed to effect it, but on the period of revolution of the apparatus, and on the divergence.

Divergence.—If the source of light inside an apparatus were a theoretical point all the light from one panel would be emitted in absolutely parallel directions, and in apparatus revolving at ordinary speeds the beam would therefore pass a point on the horizon in an almost infinitely short period of time. But in practice the flame or mantle is of appreciable size and contains the focus within itself, and the rays coming from the sides, top, and bottom of it, must be ex-focal, that is, do not come from the true focus; such rays on passing through the lens will emerge at an angle to those coming from the focus, and the whole beam is therefore divergent, that is, a cone of light which will take an appreciable time to pass an observer on the horizon, and will therefore give a flash of appreciable length.

Fig. 8 illustrates this question of divergence. It is a rough plan view of a lens and the light behind it. O is the focus of the lens, *a b* the mantle or flame with the focus at its centre.

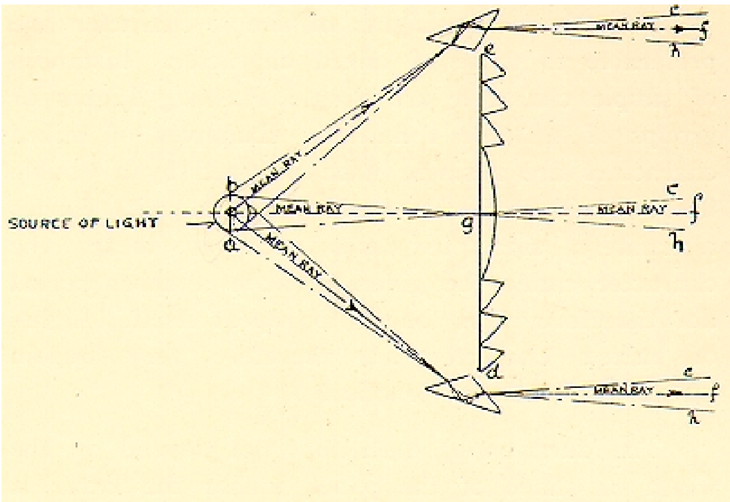


Fig. 8

Considering the rays which fall on any points *g* of the lens *d e*, it will be seen that the ray of light from *a* reaches *g* inclined at an angle *a g o* to that from the focus *o*. Therefore after refraction there will still be an angle between the rays, namely *c g f* (neglecting the thickness of the lens), which in this case will be half the angle of divergence, the full angle being *c g h*, where *b g h* is the ray from the opposite side of the mantle. The same holds good when the rays are bent by reflection instead of refraction. Owing to the height of the luminous source there is also divergence in the vertical plane, and some of the light is necessarily lost by striking the sea near the Lighthouse, or being wasted in the sky, but this has no effect on the character, and "divergence" usually refers to that in the horizontal plane only.

Divergence has to be taken into consideration not only as affecting the length of flash in Revolving Lights, but also as governing the angle covered by sector Lights, and in the latter case it is most important. With a sector Light required to show over a small angle, say up to 10 degrees, which is often the case with Leading Lights, or those to indicate a danger at a distance, a Holophote is frequently employed, and the angle covered is entirely governed by the divergence due to the diameter of the burner.

The angle of divergence is increased by increasing the diameter of the burner, and decreased by increasing the focal length of the apparatus; as the following list of angles of divergence will show:

Diameter of Burner.	Order of Apparatus.	Angle of Horizontal Divergence.
	Hyper-radial	3o 37'
	1st	5o 18’
85 m/m	2nd	6o 58’
	3rd	9o 44’
	1st	3o 24’
	2nd	4o 30’
55 m/m	3rd	6o 18’
	Small 3rd	8o 23’
	4th	12o 34’
	3rd	4o 0’
35 m/m	Small 3rd	5o 20’
	4th	8o 0’
	5th	10o 38’

Hence where a very small angle is needed the designer is sometimes compelled to use an apparatus of higher order than is really required to give the range necessary.

CHAPTER 3.

THE distinctiveness of character and the range of visibility of Lights have reached their present standard largely owing to the adoption of the three following systems, which have played such an important part in Lighthouse practice, that it may be well to describe them in detail.

I. The Group-Flashing System.

II. The mercury bath and float for revolving Lights.

III. The use of an incandescent mantle heated by vaporized oil.

Group Flashing System.

I. The first, the Group-Flashing system, has for its object the easier distinction of one Lighthouse from another. Previous to its introduction by us, all Revolving Lights had been arranged to give single flashes, and the distinction between them was obtained by one of the following methods (Fixed Lights could of course always be distinguished from each other by occulting them for different periods)

(1) Altering the period of darkness between flashes, or the duration of flash.

(2) Colouring the flashes.

(3) Making the character Fixed and Flashing.

- The disadvantages of these methods are:

(1) To give a clear distinction there must necessarily be a considerable difference in the interval between flashes, or the duration of flash, given by one Lighthouse and those given by another, and this leads, in cases where several Lights are close together, to either (a) the excessive lengthening of the interval and therefore of the time in which a Light can be recognised; or (b) lengthening the flash, which necessitates either increasing the size of the burner and therefore increasing the cost of upkeep by using more oil, or slowing the period of revolution, which has the same effect as (a), that is, increases the period necessary to recognise the light.

(2) Coloured light will not penetrate so far as white, and this therefore at once diminishes the power and range of the apparatus. In cases where Lights of mixed colour are used, for instance, a white and red flash alternately, the colours have to be carefully balanced to give the same power, and if this is not done there is a danger of the white reaching further than the red, causing the Light to appear of an entirely different character to a mariner at a distance. It is practically impossible to arrange that the different colours will be balanced in all conditions of the atmosphere, as one will always penetrate a foggy atmosphere further than the other.

(3) The means of doing this is usually to revolve the refracting portion while the reflecting prisms above and below remain stationary and show a fixed light all round the horizon. This gives a constant fixed light, with flashes of extra brightness at stated intervals, consequently the power of the

Light is greatly diminished as compared with an ordinary Revolving Light, as the top and bottom reflecting prisms spread the light all round the horizon instead of over a small angle in a flash. The two portions of the Light are also of different intensity, the flash always being stronger than the fixed light; therefore, in a fog, the character may appear, at a certain distance, as flashing, instead of fixed and flashing. This system is now universally condemned.

In the Group-Flashing system the panels are so arranged that they give a number of flashes in quick succession, followed by an interval of darkness and then another group of flashes. The number of flashes in a group varies from 2 to 6 in ordinary practice, and though a Light with a greater number of flashes in a group could be made, up to the present it has not been found necessary. This system, by giving a distinctive difference to any Light, successfully combated the disadvantages mentioned above.

Mercury Trough and Float.

(II) Mercury Trough and Float.—This is shown in Plate No. 3, from which it will be seen that the whole of the optical apparatus is supported on a circular cast iron vessel which floats in a corresponding circular bath containing mercury, thus reducing to a minimum the friction to be overcome in revolving the apparatus. It is possible to revolve an apparatus weighing several tons, if it is supported in this way, with the little finger only. Previous to this invention the practice was to revolve the apparatus on a system of rollers with which there was considerable friction, and also a certain amount of wear and tear necessitating their renewal from time to time. The adoption of the mercury float enables the apparatus to make a revolution in a very much shorter period than was previously possible. This enables panels of a wider angle and therefore greater candle-power to be used, thus greatly increasing the range of the Light.

As an example of what can be done, a 1st Order Quadruple Flashing Light was a short time ago constructed by us for the Honourable Corpor-ation of the Trinity House, which utilised, with the aid of a dioptric mirror, all the 360” of light from the burner in one group of flashes. The following details of this Light may be of interest:

The Optical Apparatus consisted of four panels of 920 m/m Focal Distance, that is, two panels of 76” and two of 84o horizontal angle, with a dioptric mirror 1,000 m/m Focal Distance of 400 horizontal and 1000 vertical angle. From each panel there emerges a flash or beam of light, of which the intensity is equal to 400,000 candles (about 40,820 carcels). The character of the Light is four flashes in quick succession every 15 seconds, thus:

Flash	-	-	0.28	seconds.
Eclipse	-	-	2.00	,,
Flash	-	-	0.28	,,
Eclipse	-	-	2.00	,,
Flash	-	-	0.28	,,
Eclipse	-	-	2.00	,,
Flash	-	-	0.28	,,
Eclipse	-	-	7.88	,,

Total period (one revolution) - 15 seconds.

The weight of the lenses, with table, etc., which revolve in the bath of mercury, is 4 1/4 tons (4,318 kilos).

The case of a Hyper-radial Light of “Chance” design recently supplied by us to Cape Race, Newfoundland, is a still more striking example of the great weights which can be revolved at high speeds when supported on a mercury float. The figures in this case were:

Weight of revolving parts (lenses with table, etc.) about 7 tons (7,112 kilos).

Speed of revolution, 30 seconds, producing a flash of 0.3 of a second every 7 1/2 seconds.

Incandes -cent Burners.

(III) Incandescent Burners.—The introduction of burners using petroleum vapour with an incandescent mantle has not only greatly increased the candle-power, and therefore the range of Lights, but also considerably decreased the cost of upkeep—except when they take the place of small wick burners of low candle power—as the amount of oil consumed by this system, compared to the old-fashioned wick burners, is very small. Until the introduction of this system the burners most generally in use were wick burners of various types, the number of concentric wicks used varying according to the size of the Light, and reaching in some cases as high as 10; such burners consumed as much as 11 pints (6.2 litres) of oil per hour. When the incandescent mantle was introduced for ordinary lighting purposes it was realised that it would have many advantages for Lighthouse work. Incandescent mantles heated by ordinary coal gas were in some places adopted, and are still used with great success where there is a good steady supply of gas available. Compressed oil-gas was also used as the source of heating the mantle, but this necessitates the use of an expensive plant for generating the gas. The incandescent oil system has none of the disadvantages of the above: (1) It is cheap, because so much less oil is burnt. (2) It is more efficient because the candle-power is so much higher. (3) It is self-contained; all that need be supplied to the Lighthouse is the oil and mantles. (4) It is simple to work.

To get a high candle-power with the old-fashioned wick burners, it was necessary to use a large number of wicks, and therefore a flame of considerable diameter. This necessarily increased the divergence of the beam, that is, in a Flashing Light spread the light over a greater angle, and therefore decreased its power and range, whereas with an incandescent mantle not only is a higher candle-power obtained, but the light is concentrated into a smaller diameter, thus producing a less divergent beam, and therefore one with a greater range. The fact that an incandescent mantle is a much more uniform source of light than a wick burner, and when seen from above, has, when compared with the latter, only a small dark centre due to its top supporting ring (so that its intensity when viewed from different vertical angles varies very little), causes the prisms which are at high angles above the source of light—say 45^{o} and upwards — to be much more efficient when used with such an incandescent burner than a wick burner, as they would take their light from the comparatively dark centre of the latter. The fact that an incandescent burner does not require a glass chimney, also eliminates another cause of loss of light. A chimney must be used with a wick burner, and necessarily absorbs some of the light.

These incandescent oil burners are now generally made in three sizes, the diameter of the mantles being 35 m/m, 55 m/m, and 85 m/m respectively, the different sizes being suited to the different diameters of the Apparatus in which they are to be used. Fig. 9 shows the 85 m/m type. A burner having a group of three mantles is also made, mostly for use in large Fixed or Occulting Lights. The following is a list giving the approximate candle-power and oil consumption of each type of these burners as constructed by us.

Number of Mantles,	Diameter. each.	Candle-power.	Consumption of oil.
3	55 m/m.	4,000 (408 Carcels).	3 1/4 pints (1.84 litres) per hour.
1	85 m/m	2,400 (244 ,,)	2 1/4 pints (1.27 litres) per hour.
1	55 m/m	1,300 (132 ,,)	1 pint (0.56 litres) perhour.
1	35 m/m	600 (61 ,,)	1/2 pint (0.28 litres) per hour.

As a guide to the saving in the cost of oil, which may be expected by the substitution of incandescent burners for the usual oil burners, the following figures, which are based on the assumption that the number of lighting hours are 4,380 hours per annum, and that the average cost of petroleum delivered to the Lighthouse is one shilling per gallon, may be of interest:

Substituting		Saving in cost of oil per annum.
3-mantle incandescent	for 6-wick oil burner	£20 10 0
85 m/m ,.	,, 6-wick ,,	£47 17 0
55 m/m ,.	,, 6-wick ,,	£82 2 0
55 m/m ,,	,, 4-wick ,,	£2 17 0
55 m/m ,.	,, 3-wick ,,	£1 7 0
35 m/m ,,	,, 2-wick	(32 gallons more oil burnt in the incandescent burner per annum.)

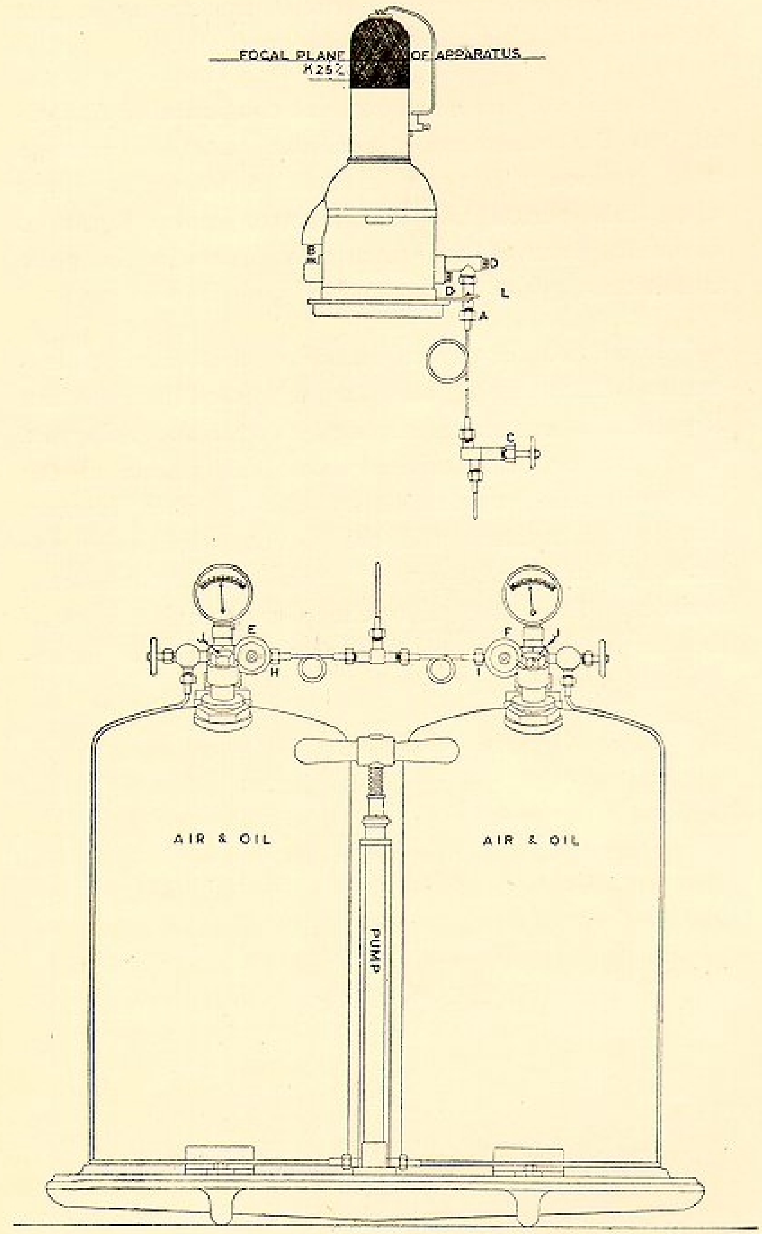


FIG. 9

Where wick burners of the "Douglass" type are replaced by incandescent burners, the saving in cost of oil will be considerably greater.

The life of the mantle varies considerably according to the treatment it receives, but with average care it should last at least from 10 to 14 days; after this period the candle-power given tends to diminish, even if the mantle is otherwise in good condition.

It will be seen from the above that the improvements which have been made give the modern Lighthouses enormous advantages over the old types. They can be distinguished more easily, due to the Group-Flashing system, they can be seen further, due to this system and the mercury-float, and the increase in candle-power given by incandescent mantles. They are also cheaper to maintain, due to the decrease in oil consumption of the incandescent system.

CHAPTER 4.

LIGHTHOUSES may be divided into the following groups, according to the duties they are required to perform:

Landfall or Making Lights are those which the mariner first sights on approaching land. For this reason Lights of this description are generally required to have a long range, and apparatus of the higher orders are employed.

Instances of the above, are The Lizard—first sighted or “made” by vessels coming to the south of England from the west and south; Fastnet Rock—off the south coast of Ireland—” made” by the Transatlantic steamers; Ushant—at the north of the Bay of Biscay, “made” by vessels entering the English Channel from the south; Cape Race— Newfoundland, “made” by vessels entering the St. Lawrence; and Navesink—at the entrance to New York Harbour.

Warning Lights are those marking some dangerous rock or headland. In very many cases Lights answer the dual purpose of Landfall and Warning Lights, for instance, Fastnet Rock, and Bishop Rock. The Eddystone and Skerryvore—off the west coast of Scotland—are Warning Lights.

Coasting Lights, which lead the mariner from one point to another along the coast.

Leading Lights, showing the line of a channel, or the entrance to **a** harbour, such as Ambrose Channel Lights, showing the entrance to New York Harbour.

Port-Lights and Small Lights, marking the ends of piers, etc.

Landfall Lights may be said to be the most important, and it is for them and the more important Warning Lights that the largest types of apparatus, namely Hyper-radial, 1st or 2nd Order, are used, according to the local conditions.

Warning Lights of lesser importance may be of smaller dimensions. When the danger to be indicated is a rock or shoal within a few miles of the shore, and on which it is not convenient to erect a Warning Light, the position of the danger at night is often indicated by means of a sector of light exhibited from a Lighthouse on the shore. Should the Lighthouse show a Fixed or Occulting White Light, an arc in the direction of and covering the danger is usually coloured.

Where such a danger is near a Lighthouse containing a Flashing Light, it is usually marked by a subsidiary sector, that is, a Light subsidiary to the main Light, and usually placed below it and shown from a window in one of the lower rooms in the tower. In these cases it is usual to make the beam coloured.

Subsidiary Lights are also often employed to indicate a channel or mark a passage between two dangers, when as a rule white sectors are shown. The actual apparatus takes many forms, according to the work it is required to do.

The source of illumination may either be a separate burner or else that used in the Main Light. An instance of the latter is to be found at St. Catherine's, Isle of Wight, where a portion of the light from the main apparatus, which would otherwise be wasted in the landward arc, is reflected, by an ingenious arrangement of. lenses and prisms, vertically down the tower, and by a second reflection this is directed horizontally through a small window after being coloured by passing through some red glass, and thus covers the danger it is designed to indicate, see Fig. 10. The objection to such an arrangement is that the first of the series of subsidiary lenses has to be very close to the source of light, and is liable to damage from the heat. It is therefore more usual to use a separate source of light.

The use of a Subsidiary Light is economical, as by it the necessity of a second tower or structure is obviated, and both apparatus being in the one building, can very conveniently be managed by the same keeper.

There are very many instances of such Lights to be found, and Fig. 11 gives an illustration of one recently supplied by us for Cape de Couedie, where the apparatus marks two dangers with a red and green light respectively, the red sector of 100 marking Lipson's Reef at a distance of 8 3/4 miles, and the green of 30° marking Casuarina Island at a distance

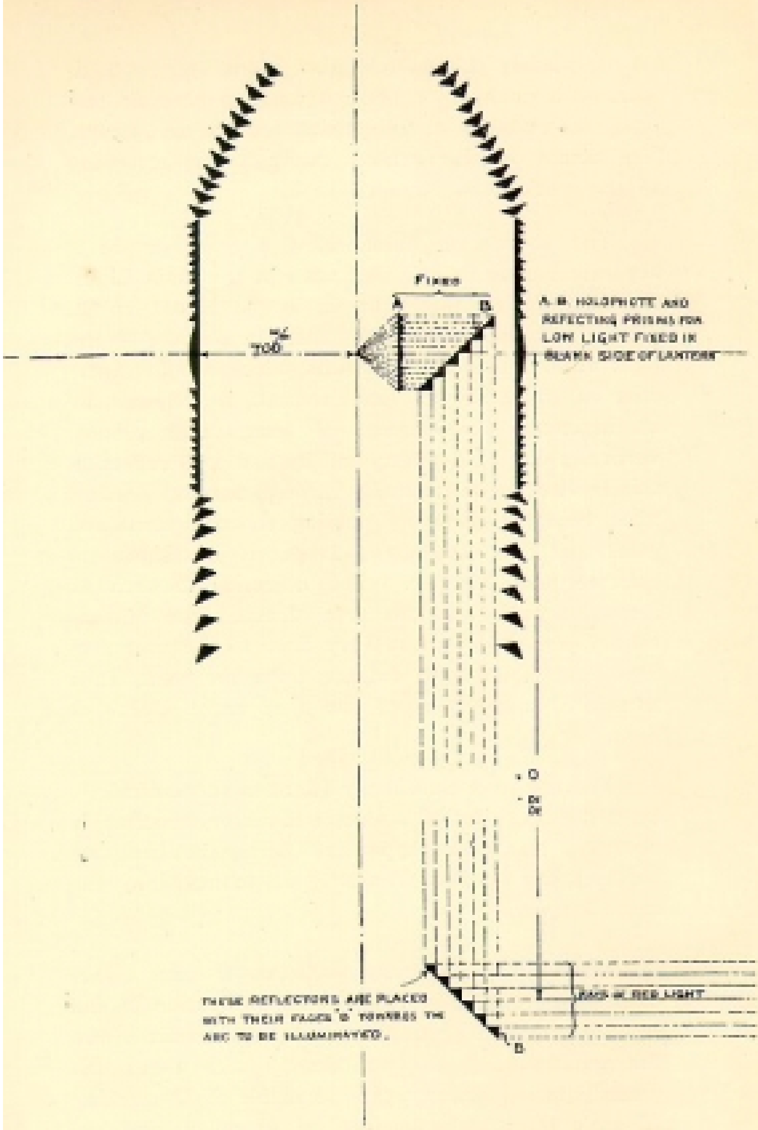

FIXED
A
B
A. B. HOLOPHOTE AND
REFECTING PRISMS FOR
LOW LIGHT FIXED IN
BLANK SIDE OF LANTERN
THESE REFLECTORS ARE PLACED
WITH THEIR FACES 'B' TOWARDS THE
ARC TO BE ILLUMINATED.
BAND OF RED LIGHT

FIG. 10

of l 3/4 miles. It will be noticed that the rays from the portion of the apparatus which shows the red sector are arranged to cross each other; the object of this is to allow of the window opening being narrower than would otherwise be possible, thus avoiding weakening the tower.

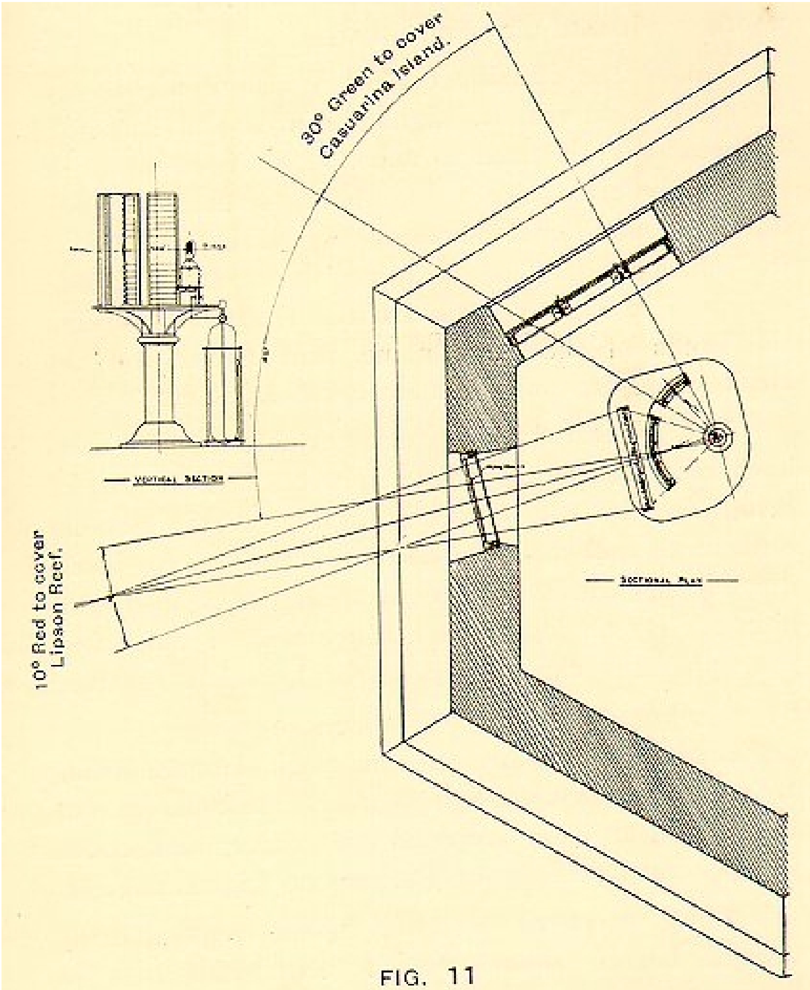


FIG. 11

The apparatus for Sector Lights have of course to be specially designed for the particular conditions they have to fulfil, and the angles they have to cover, and it is therefore practically impossible to move them from their positions and employ them elsewhere, or to alter the angle over which they show, without considerable alteration, probably necessitating the re-setting of the glass in the frames. This is not the case with ordinary Lighthouse apparatus, for instance, a Double Flashing Apparatus may be moved from one Lighthouse to another without any difficulty.

Under the classification of Warning Lights are included Light-vessels, Lighted Buoys, and Beacons. Light-vessels are used to mark shoals upon which it is impossible to place a Lighthouse structure. They have the additional advantage of being movable, if the shoal shifts, as is often the case. Notable examples of Light-vessels are the Goodwin, marking the sands of the same name near Dover, off the coast of Kent; and Sandettie, off Dunkirk.

The apparatus which can be used in Light-vessels have recently been greatly improved, and instead of being on the old catoptric system with metallic reflectors, the most modern practice is to instal dioptric apparatus similar to those used in Light-houses. By an ingenious arrangement of balancing, the apparatus can be kept vertical, and is revolved by a clock, as in a shore light.

Lighted Buoys are used to mark dangers which are not important enough to warrant the expense of Light-vessels. They are dealt with under the sections which treat specially of Permanent Lights, page 68.

Along parts of a coast much frequented by vessels, Lights should be so distributed that in ordinary weather conditions the mariner before losing sight of one Light should come into the range of the next. There are of course lengths of coast removed from important Trade routes, along which such a constant succession of Lights is unnecessary.

The above consideration must not, of course, be taken to mean that “Warning Lights” should not be placed wherever necessary, quite apart from the desirability of having “Coast Lights” round them.

Leading Lights. On account of the modern requirements for quick transport and delivery of goods, it is very necessary that vessels should be able to enter a harbour at night, as a delay of 12 hours outside may be very prejudicial to trade, apart from the danger incurred by lying in unprotected waters. Where a harbour is wholly or partly artificial, and is protected by breakwaters or piers, the Lights which mark the pierheads will in most cases enable a ship to enter. In many instances, however, the approach to a harbour is more complicated, being either up the estuary of a river or through channels dredged between shoals. If this is so, special Lights have to be provided to indicate these channels at night.

In the case of a winding and comparatively narrow channel, for instance, up a river or through shoals at the mouth of a river, it may be best to do this with a number of small Lights placed at intervals either side of the channel, those on one side being coloured differently from those on the other, for the sake of distinction. These Lights may be quite small, and are arranged either on posts on shore, on pile structures in the water, or on buoys, as most convenient.

Where a straighter channel is to be indicated, there are two methods of marking it, which may be adopted; the use either of one Light, throwing a narrow beam along the channel so that a vessel when out of the Light is out of the channel,* or two Lights, at a short distance one behind the other, and so placed that when the mariner in an approaching vessel sees them vertically in line, he is in the correct channel. The respective merits of these two methods are further discussed on page 43.

Where such Lights are required to mark a long channel, or a passage at some distance from them, they must consist of apparatus of one of the higher orders, for instance, the example cited previously, namely, one of the Ambrose Channel Lights, which is a holophote of the 2nd Order. On the contrary, to show the entrance to a dock leading out of a river, or any such position, two small Lights are sufficient.

If there is any likelihood of the channel shifting from any course, one of the Lights, if of a small type, can be arranged on rails so that it may be moved accordingly.

Port Lights. Little explanation of this type is needed; they are usually of the 4th Order, or smaller. For positions where they are subjected to rough seas breaking over them, it is advisable to put them in separate lanterns, otherwise they are usually supplied in "lantern mountings," that is, so arranged that the drum of the lenses forms the glazing of the lantern (see Fig. 12), access being had to the interior through a door formed by part of the lenses hinged in their framework, or in the dark arc, if the apparatus illuminates less than 3600 horizontally. It is often advisable, for the purpose of distinction, to make this type of apparatus occulting, which is done by a spring-driven clock, and revolving screens (see note on "character," page 16).

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*With such Lights the question of divergence is of importance (see page 21).

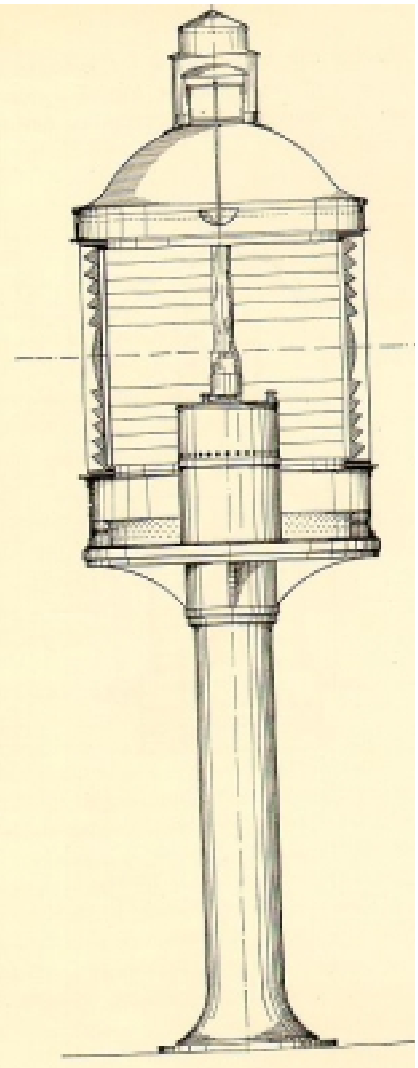

FIG. 12

Port-Lights can be arranged for hoisting, so as to exhibit them at night at the top of a mast, and lower them for convenience of cleaning during the day (see Fig. 13).

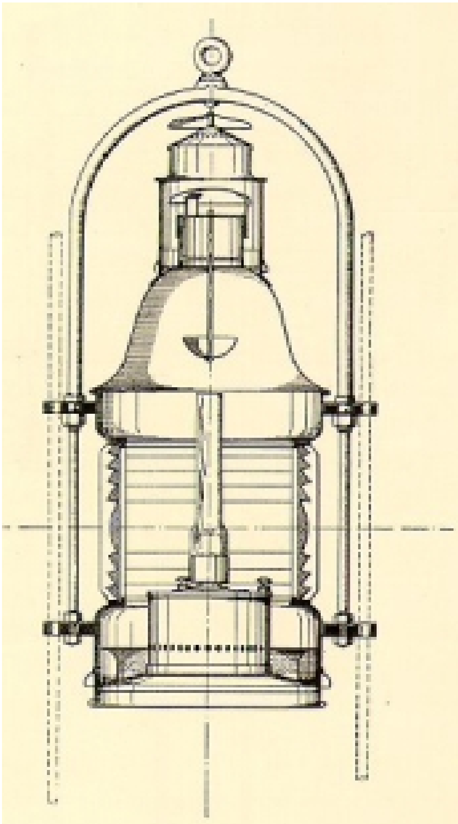

FIG. 13

CHAPTER 5.

THE choice of a "Light."—It is impossible to give any absolute rule as to the choice of the type and order of Light most suitable for any position, owing to the innumerable and varying local conditions and requirements, but the following general remarks may be of some help.

It is most important to remember that the time when a Light is most needed is when the atmosphere is not clear. A fog, or anything approaching that condition of the air, is the mariner's worst enemy, and it is when contending with such conditions that he needs most help. Therefore a Light which is only just up to its work, that is, will only give the range required under the best atmospheric conditions, should never be chosen, but one which is a size larger and more powerful.

The views of Lighthouse Authorities on the most suitable length of flash also vary considerably. A few years ago it was held by some authorities that a flash of 1/10th of a second was sufficient, and some Lighthouses with electric arcs were arranged on this principle, but it was found that this was too short from the mariner's point of view, and it is now generally agreed that 3/10ths of a second is a satisfactory length of flash for a single flashing Light. For a group flashing Light, however, a slightly shorter flash is frequently employed.

The largest-sized Lights, Hyper-radial, are only required where a very great range is necessary, or much fog is experienced. Within the last three years we have supplied Lights of this order for Cape Race, Newfoundland, and Manora Point, Karachi, India. The first of these is not only a most important landfall Light, but is also in a district much subjected to fogs; the latter is in a position which is surrounded by a haze at certain periods of the monsoon.

For a first-class Light, to work under average conditions of atmosphere, a First Order Light is usually supplied. For positions which are not so important, or where the atmospheric conditions are better, Second and Third Order Lights are often sufficient. The great increase in the speed of vessels which has been, and is still being made, causes them to approach a danger much more quickly, and they therefore need warning at a greater distance than previously.

An Apparatus which has panels of as wide an angle as possible should be chosen, provided, of course, that other necessary conditions are adhered to. Thus if a Double-Flashing Light is required, one arranged with four panels, each covering 90 degrees in the horizontal, should be chosen in preference to one having six panels of 60 degrees each, provided that sufficient duration of flash can be obtained.

The character of the Light should of course be chosen so as to ensure its being easily distinguished from other Lights around it. In this case again it is impossible to lay down any rule as to the distance apart at which it may be safe to place two Lights of the same character, as this must depend on the particular case considered, and the way in which a vessel would approach the position.

With regard to the use of Fixed or Occulting Lights, these are seldom, if ever, to be recommended for positions of any importance, on account of their small power as compared with Flashing Lights. It is not often that they are nowadays required larger than the 3rd Order, and they are then mostly used for marking the ends of breakwaters or other such positions round a harbour where there is another "making" Light of the Flashing type. An example of such a position is to be found at Dover, where there is a Flashing Light of the 2nd Order at the end of the Admiralty Pier, while the detached breakwater is provided with two 3rd Order Occulting Lights.

When it comes to the question of "Leading Lights" for showing a particular channel or channels, each individual case must be carefully considered and schemed for separately, but generally two Lights in line give a more certain direction than a single Light showing over a narrow angle, although the latter type is often adopted. If two Lights are adopted, one of them—preferably the front Light— may be of the Holophotal type, giving a beam over a restricted angle, which enables it to be of a smaller order than the other, which is of fixed section, showing over a fairly wide angle. The objection to the use of a single Light is that there is a possibility, though certainly a remote one, of the luminous source being slightly out of position, which would at once alter the angle covered, whereas when two Lights are used, even should such an accident occur, there is no possibility of the line between the two altering. With two Lights in line, it is also possible to give a narrower limit to the channel, especially if this is at any distance from the Lights.

The difference in the height of the two Lights should be at least six feet for every mile of the distance at which they must show. Thus a couple of Leading Lights required to show four miles must have a difference of at least 24 feet between their heights. If there is not sufficient difference, the Lights will blend before the required range is reached.

The apparatus for smaller Lights used in harbours, on the ends of piers, as beacons to mark the channel up a river, etc., are usually of fixed section. They can be obtained, when not to be placed in positions which are too much exposed to the sea, in “lantern mountings,” that is, so arranged that they can be exhibited out of doors without further protecting lantern, and are usually termed “Port-Lights.” They are supplied from the 4th Order size downwards.

To distinguish such Lights from each other—as there may well be two or three comparatively close together—some are often coloured or made occulting in character, either by revolving screens, or if the illuminant is gas, by turning this on and off. Owing to the high-powered Lights, electric arcs, etc., which are often found nowadays round wharves and jetties to enable work to be done at night, Port-Lights of the above type are sometimes almost indistinguishable from other Lights around them, and it is difficult to recognise them even if they are made occulting. To counteract this, we have designed a Revolving Port-Light, which can be used with any illuminant desired, and gives a very powerful flash (see Fig. 14). With an acetylene flame the candle-power of the beam is over 4,000 (say 408 carcels). This Light can be left unattended, if burning acetylene or gas, and is a great advance on the ordinary Port-Light, as it not only gives a much more powerful light, but is at once distinguishable by its character, which can be arranged to suit any requirements.

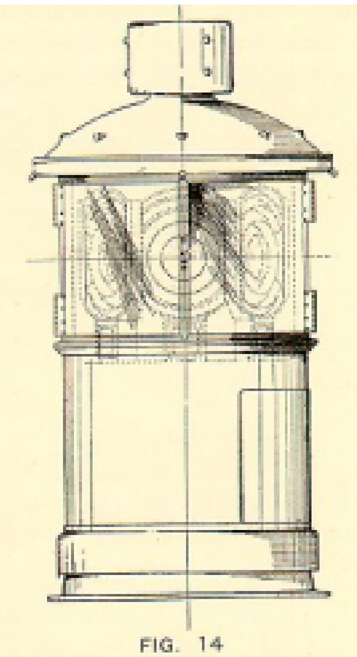

FIG. 14

With regard to the illuminant to be used in such Lights, for ordinary positions, the simplest is a wick burner of the capillary type, which can be left unattended all night, and gives a very satisfactory result. For positions which are close to or in a town, the ordinary gas supply may be laid on to the Light; the candle-power in this case can be greatly increased by the use of an incandescent mantle. If it is desired to leave the Light unattended for several days at a time, owing to the possibility of access to it being prevented by heavy seas, or other cause, a by-pass can be put in, by running a subsidiary pipe up to the position, so that the gas can be turned off at a distance, during the day, but in this case it would not be advisable to use a mantle. For isolated positions, or those where it is desired to leave a Light unattended for long periods, months at a time, acetylene in some form or other may be employed with great advantage.

The question of Acetylene and Permanent Lights is dealt with more fully in another place.

CHAPTER 6.

Remarks on the particular parts of a Lighthouse which come within the scope of these notes

PLATE No. 3 shows the general arrangement of an apparatus of the 1st Order, on its mercury float and pedestal, in a lantern, the whole design being of the "Chance" standard type, and, taking this as an example, it is proposed to make a few remarks on points connected with the several portions of it.

Lantern.—The Lantern is essentially merely 'a protection for the apparatus and the parts connected with it. It may be divided into three parts, the lantern-pedestal or murette (A), the glazing (B), the roof (C), with its ventilator (D).

Access is gained from the tower by a well-hole in the floor, and one, or sometimes two doors in the murette give access to the gallery on the top of the tower, which is surrounded by a balustrade (E).

A lantern should be designed to give comfortable room all round the apparatus and its pedestal, to cut off as little light as possible from the apparatus, and to give efficient ventilation. The last is a most important point. An insufficient supply of fresh air will not only cause the burner to work badly, but also cause condensation on the glazing, and as a very thin film of condensed moisture cuts off a large percentage of light, it at once greatly diminishes the effect of the apparatus; while a draught may break the mantle—if one is used—or at any rate will cause the burner to work unevenly.

To ensure a well-ventilated lantern, the following methods as illustrated on Plate No. 3 have been adopted by us. The murette is generally of cast iron, lined with steel sheets, and is made in sections bolted together. The air inlets are at (a), near the bottom of each section, and the air can circulate all round the lantern pedestal, emerging into the lantern through the hit and miss ventilators (b), one of which is provided in the lining of each section of the murette, and any ventilator can be closed at will. Owing to the air circulating inside the lantern-pedestal, an ample supply can be provided under any part of the glazing, irrespective of the direction of the wind outside the lantern. The roof is of copper or steel sheets, and in the case illustrated is double; some of the air passes through the holes (d) into the space between the inner and outer sheets, thus ensuring that a current passes up close to the glazing, and also helping to keep the roof cool; with the rest it is drawn out through the top by the roof ventilator. Instead of a double roof, a ceiling is often fitted inside a single roof, according to the conditions to be met with. The ventilator we recommend is that of "Trinity House" type, as shown, which, after long experience we have found the most efficient for general use, though in some cases the ball type is preferred as being somewhat cheaper.

The framing holding the glazing may be arranged with the bars vertical as shown in the illustration, or helical — see Fig. 15. The latter type is almost a necessity for Fixed Lights, as a vertical bar cuts off a considerable portion of the light, which in this case is a comparatively narrow vertical band, whereas an inclined bar crossing this band of light at an angle, obscures little of it. The larger section of the beam which is obtained from a Flashing Apparatus avoids the necessity for inclined bars, but some Authorities prefer the type with helical framing for general use as being stronger.

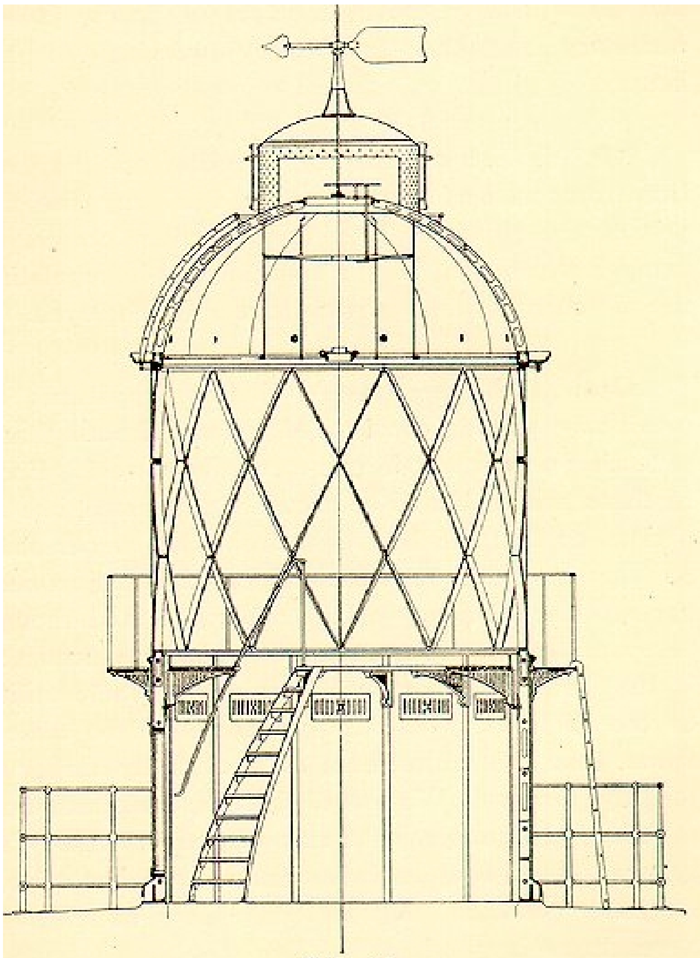

FIG. 15

For cleaning the glazing, galleries run round the lantern inside and out, and ladders are provided for reaching the top panes. A copper dish (F), is provided just below the ventilator to catch any water which may possibly be driven through the latter; the heat from the burner below very soon evaporates this.

A wind-vane (G), which by means of gear wheels indicates the direction of the wind on the dial (e) is usually provided. This of course is not necessary for the satisfactory working of the lantern.

"P" is a heat-tube for carrying off the heat from the burner, protecting in this way the top prisms, and generally keeping the lantern cooler. A damper is provided in this tube for use in regulating the air current when a wick burner is employed.

Optical Apparatus.—A modern apparatus as previously stated, consists of glass refracting and reflecting prisms, set in gun-metal framework. Each of these prisms has to be accurately adjusted, one at a time, so that the best light from the burner shall be sent to the horizon. Upon this adjustment depends the efficiency of the apparatus, and though every prism may be ground with absolute accuracy if they are not correctly adjusted, the whole utility of the Light is gone. It will therefore be understood that this adjustment is necessarily rather a lengthy process. We have given special attention to the fresh problems in this direction, which the general adoption of incandescent mantles has raised, and are confident our methods give as efficient a result as is possible.

After the prisms have been adjusted as above, the optical apparatus is erected on its pedestal, and if of the revolving type, is accurately balanced, so that it floats evenly on the mercury, that is, so that the ring (j) to which it is attached, and therefore the focal plane, is absolutely horizontal.

The apparatus may take many forms, and in spite of the number of Lighthouses round the coasts of the world, there are comparatively few optical apparatus between which there is not some difference, though it may be in some small detail— such as the number of top or bottom prisms. The following are a few of the more distinctive forms met with, besides the ordinary type illustrated on Plate No. 3.

Lens Lights—Fixed or Revolving.—Those using the refractor portion only, having no top or bottom reflecting prisms. In such Lights the refractor portion usually covers 80 degrees in the vertical plane, instead of 57 degrees as is customary when reflecting prisms are used.

With wick burners the proportion of the total light emitted by the refractors to that coming from the reflecting prisms, was fairly high, the accepted estimate being :—

Refractor	...	70 %
Top Prisms	...	20 %
Bottom Prisms	...	10 %

This led to the adoption of Lens Lights in a certain number of instances.

With an incandescent mantle as the source of illumination, a far larger proportion of light comes from the reflecting prisms, and except for special reasons, there is now no call for apparatus of the above type.

Bi-form. — Where a Light of great power is needed, two apparatus—one above the other—see Fig. 16, are sometimes used, the object of arranging them in this way being that a light of high power can be obtained with a lantern of comparatively small diameter. Notable examples of this are the Fastnet and Bishop Rock.

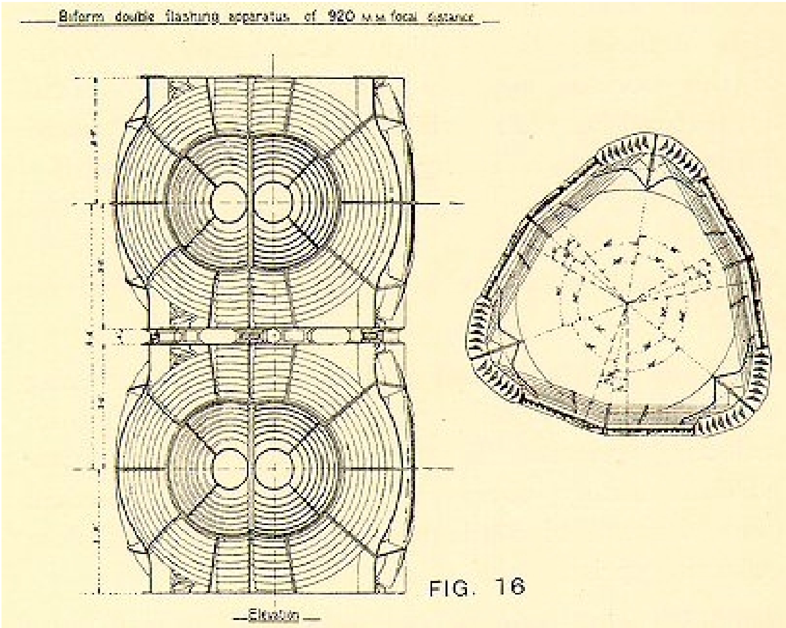

FIG. 16

As many as four apparatus have been superimposed, but in this case each is a Lens Light only.

The French Authorities have installed several "twin" apparatus (Appareils jumeaux). These, instead of being superimposed, are placed alongside each other, see Fig. 17, on a revolving iron plate, and are so arranged that their panels are parallel, and therefore send out parallel beams. Apparatus of comparatively small type only are used, and need very careful adjustment. Modern improvements have so increased the candle-power obtainable from a single apparatus, that the Bi-form and Twin types are not now often required.

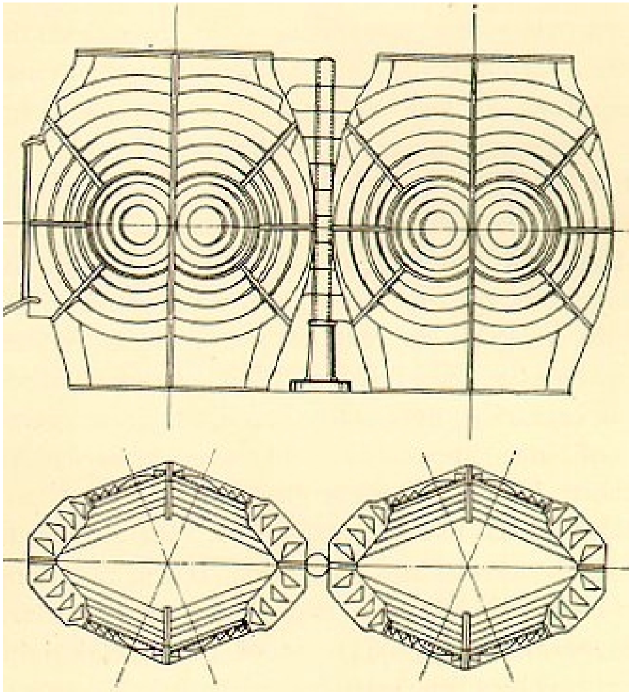

FIG. 17

Within the ring (j), Plate No. 3, on which the apparatus is fixed, is a cast iron platform (h) called the “Trimming Stage.” In apparatus of “Chance” design, of the 3rd Order and upwards, this is always fixed to the top of the column and does not revolve. Upon this trimming stage the burner is supported, by means of a column or other similar arrangement on the top of which is the stand or crutch into which the burner fits accurately, thus ensuring that the flame or mantle is in the exact position in the apparatus which it is designed to occupy. In apparatus of 3rd Order and upwards, it is necessary to get into the interior to clean the inside of the lenses and prisms, and also to attend to the burner. To enable the keeper to do this access to the trimming stage is gained by a ladder (i) leading from the base of the pedestal. The former operation is of course performed when the apparatus is at rest, but the latter must often take place when it is revolving; it is therefore, in our opinion, a great advantage for the trimming stage to be fixed. If it is not fixed, but revolves with the lenses, the weight of the keeper when standing on it necessarily upsets the balance of the apparatus, thus putting the focal plane out of the horizontal, and causing one part of the ring (j) to rest on the vertical rollers, which increases the friction. The keeper, when inside, necessarily cuts off the light from some portion of the apparatus. In the majority of cases there is a certain angle towards the land over which it is not necessary for the Light to show; this is termed the dark arc. If the trimming stage is fixed, the keeper can stand in this dark arc, and therefore cuts off none of the useful light, but if it revolves he revolves with it, and affects the light all round the horizon. A further advantage of a fixed stage is that the burner and its accessories, for instance, air and oil containers if of the incandescent type—can also be fixed and can therefore be arranged either in the lantern as shown at (N) in Plate No. 3, or if more convenient in a lower room of the tower, where they can be got at easily at all times. In our design of the smaller apparatus, from Small 3rd Order downwards, where there is no room for the keeper to get inside the apparatus, we have arranged the pedestal so that, though the trimming stage or table supporting the apparatus revolves, the burner is stationary; the air and oil containers can therefore be placed on the lantern-floor in the usual way. We attach so much importance to it that we have made this feature of a stationary burner a *sine qua non* of all our pedestal designs.

Pedestal.—The apparatus, if fixed, is supported on a plain cast iron column of some form. If revolving, it is attached to a cast iron ring (**j**) (see Plate No. 3), which in its turn is supported on a cast iron float, which revolves in mercury in the corresponding trough **(t).** There are horizontal and vertical rollers **(f** and **g**) for steadying the whole apparatus, so as to prevent any oscillation. When properly balanced and set on the column the revolving ring (**j**) should just clear the vertical rollers (**g**).

The trough is supported in various ways, either on a single large column, as in the illustration— which is the form we have adopted for all apparatus up to and including 1st Order—or else on several lighter ones arranged in a circle. In each case these must be designed so that the trough can be lowered for the purpose of cleaning, the weight of the apparatus being taken in the meantime by the vertical rollers (**g**).

In the single column type illustrated, the column has a screw cut on it, and the trough is supported on a circular table **(m)** which screws up or down on this. To clean the trough is therefore a very simple operation. Tommy bars are inserted in the holes provided in the table **(m),** and by this means it is screwed down until it is clear of the float, which remains supported on the vertical rollers. The mercury can be drawn off by the cock provided, and the necesary cleaning done. This trough should not require cleaning more than twice a year.

The apparatus is revolved by means of a clock (L), and is driven by a pinion at the end of a vertical shaft, which gears with a circular rack on the ring (**j**). In the type as illustrated, the vertical shaft has its lower bearing on a bracket attached to the pedestal, and the only connection between it and the clock is through a pair of bevel wheels, so that should the latter be slightly moved from its correct position by any cause none of the parts will be strained, and as long as the wheels gear the motion will continue correctly. The clock is driven by a falling weight, at the end of a steel wire rope coiled round a drum, and is controlled by a "Slight" governor. A wire rope is now generally used in preference to the more old-fashioned chain, as the latter wears more and is somewhat clumsy. It is our practice to put sufficient weight on to just start the apparatus from rest, which ensures that it will restart itself if it gets stopped inadvertently. Our clocks are now all designed so that any particular shaft can be removed without taking the side frames apart, by simply taking out three or four screws, and withdrawing a gun-metal bush. When the apparatus is heavy, or has to revolve at a high speed, the clock-shafts are run on ball-bearings, to reduce the friction.

The length of time during which a clock will run without winding depends on the height of fall available for the weight. In most cases it is possible to arrange for this to be about 1 to 1 1/2 hours. Some Authorities prefer that this should not be too long, so as to make sure that the keeper in charge is constantly on the watch, which is ensured by the fact of his having to wind up the weight at frequent intervals.

The weight usually falls down a "weight—tube" consisting of a metal or wooden tube provided to protect it, and generally fitted with an arrangement to warn the keeper, either by an electric bell or suitable gear for striking a gong, when the weight is nearing the bottom of its fall.

For small occulting apparatus, port-lights, etc., spring clocks are used for revolving the screens. These can be made, where specially required, to run for 48 hours without re-winding, but for ordinary cases 16 hours, covering the full length of one night, is sufficient.

CHAPTER 7.

DIFFERENT forms of illuminant used in Lighthouses :—

(i.) The most important of these, being the type which is most generally admitted to be the best for Lights of any importance, is oil used in conjunction with an incandescent mantle, the advantages of which have already been mentioned on page 26 (where Fig. 9 illustrates it).

The method of working is briefly as follows :— The oil contained in a suitable air-tight vessel is put under an air pressure of about 65 lbs. per square inch (5 kilos per square c/m) and by this means is forced through a small copper tube up to the burner, where it passes through the vapourizing tubes, which are heated from below, and is gradually turned into vapour. At the end of these tubes it passes through a very fine hole in the "nipple" in the form of vapour, and draws air with it through a larger tube to the mixing chamber. Here some of it is turned aside and passes down to the Bunsen tubes where it burns, serving to heat the vapouriser. The greater portion of the vapour however, passes from the mixing chamber through the wire gauze at the top of the burner, where it burns with an intense heat, causing the mantle placed around it to become incandescent, and give off a brilliant light.

To start up, the vapourizing tubes must first be heated, and this is done with a small burner, using methylated spirit. This should heat the tubes sufficiently in from six to eight minutes, and the oil may then be turned on and the burner lit.

Such incandescent burners are suited for oil having a flash point of from 145° to 160° F (62° to 71° C), so that the same oil can be used in them, and also in the ordinary type of wick burner, thus avoiding the necessity of storing different kinds of oil for the main burner and the stand-bys.

(ii.) Wick burners may be divided into two classes, according to the way in which the oil is supplied to the burner.

(a) Those in which it is forced up to the wicks either by pressure put upon it, as in the different types of Pressure Lamp, or by Gravity, as in the constant level type.

(b) Capillary lamps in which the oil is caused to mount the wicks by Capillary action as in an ordinary house lamp.

A Constant Level Lamp has been shown in Fig. 6, and Fig. 18 shows the Pressure, and Fig. 19 the Capillary types.

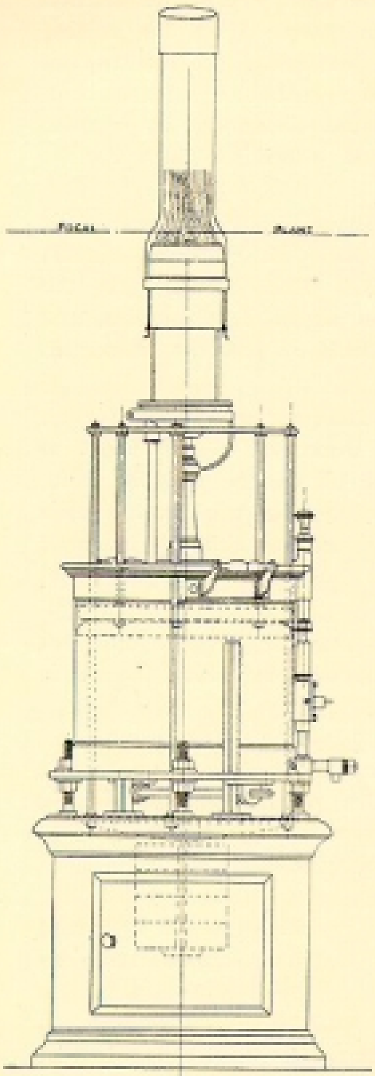

FIG. 18

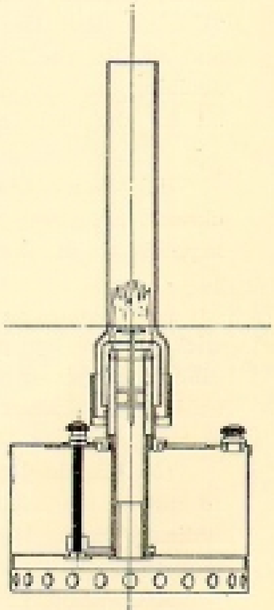

FIG. 19

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The former type *(a)* gives comparatively high candle powers, and is for use in large lights, but has now been practically superseded by the incandescent oil burner, and is seldom supplied except as a "Stand-by" to the latter.

The second *(b)* is used for small lights, and from its simplicity needs little description. Burners of this type are made with either one or two wicks, preferably circular, and giving 25 and 50 c.p. respectively.

The containers are made to hold sufficient oil to burn for a night without refilling, and though the candle-power diminishes slightly after a certain number of hours, it is quite safe to leave them without attention.

It may be well to mention here the question of stand-by burners, namely, those supplied to take the place of the regular burners in the case of the failure of the latter.

Assuming that the regular burner is one of the incandescent oil type, which in most cases it is, in our opinion, there is little real need of any stand-by, but if one is required, a 2-wick capillary burner is sufficient.

With our incandescent installations, three complete burners are supplied. The keeper should always have one in readiness to substitute for that in use if necessary, and if he cleans the burners and tubes properly, it should never occur that all three are out of order. Should it be necessary, however, that he has at a moment's notice to bring the stand-by into use, a capillary lamp, though it does not give such a high candle-power, can always be started at once, while to bring a comparatively complicated form of stand-by such as a pressure or constant level lamp into action, necessarily takes some little time. It is of course most important that the light should be out for as short a period as possible, and this appears to us such a strong factor that in view of the very probable delay mentioned above, we recommend the adoption of the simpler type as a stand-by.

(iii.) **Coal Gas**.—Where a Light is close to a town, or in any position where a gas supply is available, it is often convenient to use it for Lights that are unattended during the night, but on account of the low candle-power given, as compared with incandescent oil, it is not usually installed in Lights tinder the observation of a keeper.

It may be used either with or without an incandescent mantle, preferably the former, unless the situation is so exposed that there is a danger of the mantle being shattered.

Coal Gas is convenient owing to the little attention the burner requires.

(iv.) **Electricity** is not used very largely as a Lighthouse illuminant. In large Lights it takes the form of the Electric Arc, and in smaller the incandescent filament lamp.

The intrinsic brightness of the electric arc, which is higher than that of any other illuminant used in Lighthouses, gives it in some ways great advantages, but in spite of the fact that in clear weather its intense beam can be seen at distances greater than that from an apparatus with an incandescent oil installation, it has been stated that in foggy conditions of the atmosphere—and it cannot be mentioned too often that this is the condition tinder which the mariner most needs to see a light — the colour of its rays prevent it penetrating relatively so far as the yellower light which is given by the latter.

Both the first cost and that of running are of course incomparably higher than for incandescent oil, and for these reasons, though there are a number of Lighthouses in existence where the electric arc is used, practically no new installations have been put down since the perfecting of the incandescent oil burner.

Incandescent electric lamps are only suitable for small lights, such as 4th Order Port-lights and smaller. Whatever the form of the filament, the light is necessarily rather more spread out than with other burners, this effect is however hardly noticeable in apparatus of small diameter, and where current is available, a good result is obtained by the use of such lamps in them.

(v.) Oil Gas is a form of gas made from oil. It requires a special plant to manufacture it, and is supplied from the manufactory to the place where it is to be used, compressed into cylinders from which it is ptimped into containers on the spot. It is mostly used for lighted buoys and small beacons, and occasionally in light-vessels.

Acetylene.—This has lately been introduced as an illuminant for sea lighting. It is claimed by many of its advocates that it has a specially penetrating power, and candle-power, for candlepower will show through fog further than other illuminants. This statement, however, needs further confirmation, as it has hitherto been held that the more red and yellow rays a light contains, the greater will be its penetrating power in a foggy atmosphere.

Acetylene is made very simply by the action of water on calcium carbide, which can now be obtained universally. The gas can either be manufactured on the spot as required which is the more usual method, and that practically always adopted where any quantity of it is used, that is, where a burner of high candle-power is required— or obtained in the form called "Dissolved," compressed into cylinders, containing a patent absorbent which renders it absolutely safe to transport them. There are a great number of different forms of acetylene generators on the market, but in our opinion the majority are rather complicated, and have too many moving parts, especially if they are to be used with unattended Lights. For Lighthouse use, where a breakdown for even a short period may be attended by such serious consequences, it is essential that everything should be as simple as possible.

We have designed a special generator, working on the water to carbide principle, for use with Lights on shore, in which the water and the gas are the only things which move, there being no movable gas-holder, levers, etc., which is the case with most generators. This generator can be opened up at any time with very little waste of gas and carbide, the latter being attacked by the water in small quantities only, as gas is required.

Where a high candle-power is required, such as in the case of large lights, the consumption of gas and therefore the size of the generator, make both the first cost and upkeep incomparably more expensive than that of incandescent oil, and as in such cases there is almost always a keeper in attendance during the night, there seems little need to employ acetylene.

There are many types of burners, but in our opinion the best form is that giving a small fish-tail flame; the number of burners, which can be arranged in a group as desired, varying according to the candle-power required. Such burners use from 3/4 to 3/4 of a foot of gas per hour, and give from 10 to 30 candle-power (from 1 to 3 carcels) each.

Acetylene burners can be constructed for use with a mantle. This of course greatly decreases the cost per candle-power, but it is still considerably higher than that of incandescent oil.

Though for reason of cost acetylene is very little used for large Lights, there is no doubt that it is well suited for an illuminant in unattended Lights of all kinds, and in this field it is now competing successfully with compressed oil gas, and in some cases taking its place. The difficulty which was at first met with was the clogging or carbonizing of the burner, but this has been overcome by passing the gas after generation through a special purifying material, and there is now no need to fear trouble on this score. Lights may be safely left to burn for six months and more without attention.

We have made a special study of such burners, and have designed one employing small mantles, which can be used either singly or in a group of three, there being a special attachment which ensures that the light is practically unimpaired even if one mantle is broken by a shock or for any other reason. This burner was intended specially for use in the Revolving Portlight mentioned on page 44, and when placed inside this, a very intense beam results.

In Buoys, which are an important type of unattended light, the Acetylene generator is arranged in the interior of the body, or else cylinders containing the gas in the Dissolved form, are inserted in it. When used for Beacons, the generator can be placed wherever convenient, and the simpler the form the less protection it will require.

To give a distinctive character to a Light using either Compressed Oil Gas or Acetylene, a special "Flasher" is used. By means of these, of which there are several types, practically any character can be given, the gas being automatically cut off and allowed to pass as required. The gas of course reaches the flasher after passing through a governor, so that the pressure is constant, and in consequence there is no variation in the period of the character. It is usual to make the period of light shorter than that of darkness, as by this means the gas is economized.

The points in favour of acetylene are therefore as follows :—

(1) Adaptability for "permanent" Lights.

(2) Ease of manipulation in the case of beacons—as compared with oil gas—it can be made on the spot and as required.

(3) Ease of giving any occulting characteristic as compared with an oil burner which requires a revolving screen or other device to occult it.

(4) Portability (in carbide form).

The points against it are :—

(1) Its cost if required in large Lights.

(2) The danger of explosion, if it collects in an enclosed space. In the case of small Lights placed in the open, this may be neglected if reasonable care is taken, but in larger Lights, where the generator and burners are in an enclosed space, such as a Lighthouse tower or lantern, special precautions are necessary.

Burners usually used in Unwatched Lights are described in the following chapter.

CHAPTER 8.

U **NWATCHED or Permanent Lights.—**There is a class of Lights usually termed “Permanent Lights,” which it is either necessary or convenient to leave unattended for considerable periods on account of their isolated position and inaccessibility, for instance, buoys and beacons on small rocks in the sea, in out of the way places on land, or on breakwaters which are washed by the sea. In such cases the burner and a suitable illuminant are of course the chief difficulty.

There are several forms of permanent oil burners using a wick namely :—

(I.) The Wigham burner, in which by an ingenious arrangement of floats the wick, which burns not at the end, but at a point where it passes over a small roller, is slowly moved over the latter, thus causing a fresh portion of it to be constantly arriving at the position where combustion takes place and preventing it carbonizing.

(II.) Various types using wicks made of carbon. These permanent wick burners give a comparatively small candle-power only, and the light from them diminishes somewhat after they have been burning any length of time, 10 days or upwards, and they are therefore not suitable for positions where the light is of more than secondary importance.

Coal Gas, as has already been mentioned, can be used for permanent lights, but the two illuminants which really hold this field are oil gas and Acetylene.

Oil Gas, as also mentioned above, is compressed into the body of the buoy or into containers arranged conveniently near the beacon as the case may be, and supplied to the burner through a governor or pressure reducer.

The use of Acetylene in permanent Lights has already been discussed.

The length of time during which any permanent Light will burn without attention depends essentially on the size of the containers, and the amount of gas consumed per hour; with oil gas this is usually from one to three months. With Acetylene it may vary from one month or less up to six months, or even a year. In practice, Lights are very seldom left longer than six months without examination, as among other reasons the lenses gradually become dimmed by the deposit of dust and the salt from the sea spray, and where they are fairly accessible, a period of three months is perhaps sufficient.

Floating Lights. — These have already been referred to under several headings in these notes, and it is not proposed to do more than give a short sketch of their uses and particular points.

Floating Lights may really be divided under the same main heads as Lighthouses, except that they seldom take the place of “Making Lights.” The larger and more important take the form of Light-vessels, and the smaller of Buoys. The majority of Light-vessels are Warning Lights.

It will be readily understood that there are many dangers to the mariner such as shoals upon which it is impossible, or at best, very difficult to erect a Lighthouse. These dangers are guarded where they are near important sea routes by mooring Light-vessels over or near them; where they are more remote or inshore, a buoy is generally sufficient.

Light-vessels.—With the actual vessel, which is of course designed to suit the conditions of sea, depth of water, etc., it will have to withstand, we are not here concerned. The Light is shown from the top of a mast, which in modern light-vessels really resembles a miniature Lighthouse tower.

Until comparatively recently the catoptric system (with metallic reflectors) was used in all light-vessels. A sketch of the type of reflectors used is given in Fig. 20, showing also the burner and the way in which it is placed in the reflector. These burners usually have two wicks, consume ordinary light petroleum oil, and give about 65 candle-power (6 1/2 carcels). The intensity of the beam from a standard 21” reflector being given by the Trinity House as

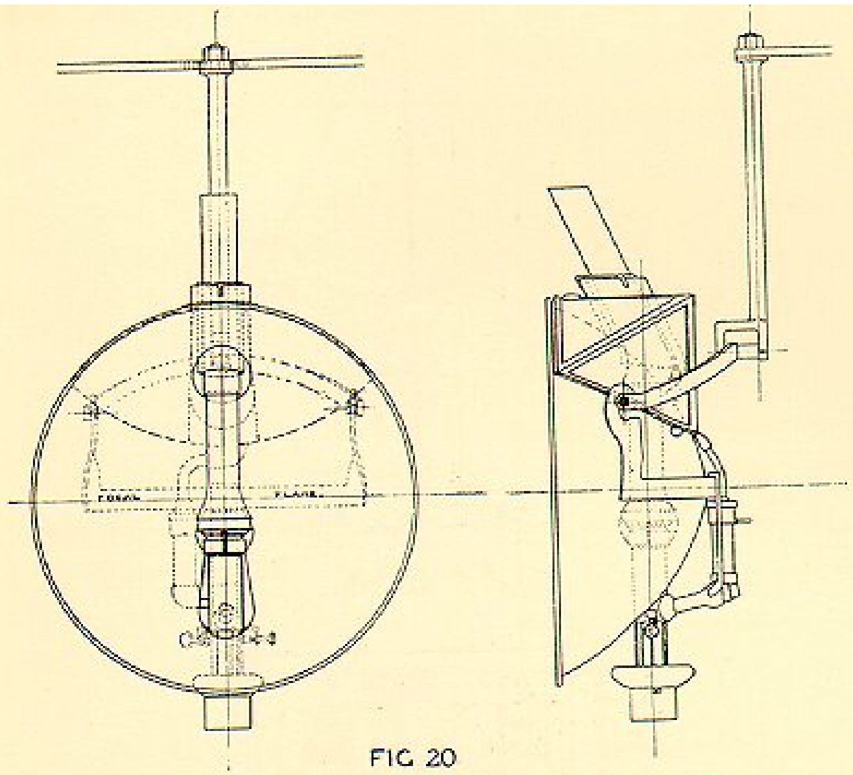

FIG 20

PARABOLIC REFLECTOR AS USED IN LIGHTSHIPS.

4,000 candles (408 carcels). If the character of the light is to be "fixed," a number of such reflectors are arranged in two superimposed circles round the mast, so that the beam from each just overlaps those from the reflectors on either side of it, and in this way a fixed light is thrown all round the horizon. The beam from such reflectors has necessarily a fairly large angle of divergence, owing to the size of the source of light, and the number necessary to cover the 860 degrees is about 16 (see Fig. 21). Each reflector is hung on gimbals, so that it keeps practically vertical in spite of the motion of the vessel.

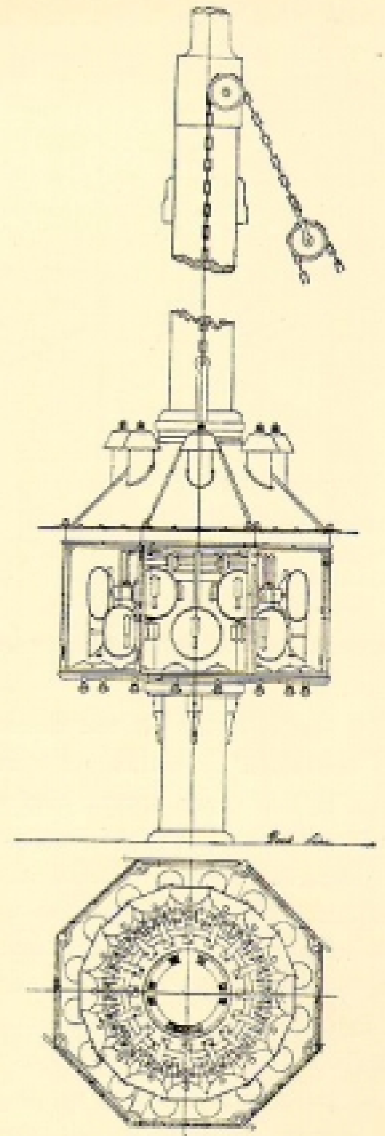

FIG. 21

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If the character is to be flashing, the reflectors are arranged in groups, all those in each group having their axes parallel so that they send out a beam in the same direction. These groups thus correspond to the panels of a Dioptric Lighthouse Apparatus, and the groups can be arranged and spaced so as to give any desired character. All the reflectors are hung on gimbals, fastened to a framework which revolves round the mast, see Plate 4, which shows a plan diagram of reflectors arranged to give a triple flash, and also a vertical section of the lantern.

Such an apparatus using a number of catoptric reflectors is inferior to an ordinary dioptric apparatus, for the following reasons:

(1.) The beam is inferior in candle-power unless a great number of reflectors are used.

(2.) It is expensive in upkeep, owing to the number of burners which must be employed, one being necessary in each reflector.

(3.) The cleaning and trimming of all the burners is a considerable labour.

Hitherto the chief objection to using Dioptric Apparatus in Light-vessels has been the fear of breakage, and also the fact that if the apparatus was allowed to roll with the vessel, unless special arrangements were made to give it an extra vertical divergence, there would be a danger of the beam being thrown entirely above or below the horizon.

This objection has, however, been overcome, and the modern practice is to use a dioptric apparatus which is very carefully balanced and swung on gimbals; the roller path is fixed, and the apparatus revolved by clockwork in the ordinary way. Plate No. 5 shows a lantern and apparatus arranged in this way, which we have recently constructed for the Humber Conservancy. The illuminant is usually compressed oil gas, and this is so in the case illustrated. Storage cylinders for the gas are placed in the body of the vessel (see Plate No. 6), and the gas led up through a pipe to the point A (see Plate No. 5), just below the pendulum of the apparatus. Here there is a mercury joint, allowing of a revolving connection which is turned by a train of wheels from the clock, and the gas is carried through two rubber pipes to the burner. The stand-by oil burner is one of the ordinary capillary type. With such an arrangement properly balanced the apparatus is never more than a few degrees out of the vertical.

Acetylene may also be used as an illuminant for Light-vessels.

Precautions should be taken in the design of a vessel using either compressed oil gas or acetylene, to prevent the possibility of an explosion. In ordinary cases where these gases are used on shore, they are not confined in any way, and there is comparatively no danger; but in a vessel the gas is in most cases contained in cylinders below, and led up through a pipe to the top of the mast. Should there be the slightest leak anywhere, the gas will slowly collect, and being confined either in the hold, or the bottom of the mast or elsewhere, an explosive mixture will be formed. Great care should therefore be taken to give efficient ventilation, and also to prevent the possibility of such explosive mixture collecting in the proximity of any oil engines which may be fitted on board for the purpose of compressing air for a fog-signal.

We have recently devised a system whereby our incandescent oil burners can be used instead of compressed oil gas or acetylene in Light-vessels, thus not only very largely increasing the candle-power, but also effecting considerable economies as regards first cost and upkeep. Comparatively few pipe connections are needed, and all the expensive storage cylinders for holding the gas are done away with, the space that would be otherwise required for them being available for other purposes.

Buoys.—For minor positions where Lights are required but the range to be covered is not so great, lighted buoys are sufficient. A buoy should never be placed in an important position which is at all remote. There is always the possibility of a buoy being run down in a fog, and if this is not at once reported—and the master of a vessel may prefer to keep the accident dark—the loss of it is a source of great danger to other vessels. Though a Light-vessel may be run down it is impossible for various reasons to avoid reporting it at once.

The illuminants which may be used in buoys, acetylene, compressed oil gas, or ordinary oil on the Wigham system, have already been mentioned under the heading of Permanent Lights. If acetylene is used, it is either generated automatically as required in the body of the buoy, or, if in the "Dissolved" form, is contained in cylinders in the buoy. With compressed oil gas the body of the buoy acts as a container to hold it, the gas being pumped in under pressure as required.

The size of the optical apparatus used, which is of the fixed type, varies from 4th Order (500 in/in diameter) down to the small gas-buoy size (100 m/m diameter). The apparatus is contained in a lantern which must be specially designed to give efficient ventilation without letting any water in when waves break over it.

CHAPTER 9.

FOG SIGNALS.—As before stated, there is no occasion on which the mariner requires more assistance from warning signals than when he is finding his way through a fog, and all Light-stations situated in districts which are subject to fog should therefore be provided with a sound-signal of some description. These may take any of the following forms: Sirens, Explosive Signals, Reed-Horns, Whistles, or Bells.

A Siren consists of a cylinder or disc with longitudinal or radial slits in it. This fits into or on the top of a similar cylinder or disc which is fixed. It is revolved at a high speed, and air, previously compressed, is forced through the slits, thus producing the sound (Fig. 22, A and B).

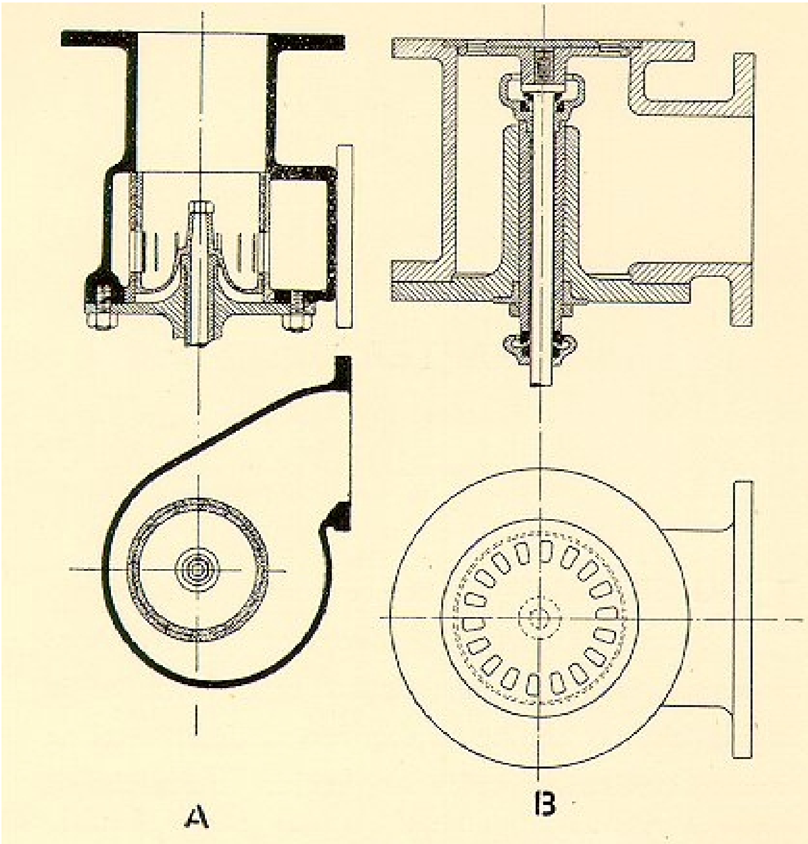

FIG. 22

A form analogous to the siren is the “Diaphone.” In this a cylinder having circular slits in it, is given a reciprocating motion under the action of compressed air.

A **Reed signal** works on the same principle as an ordinary organ pipe. A metal tongue closes the end of a pipe, and air under pressure is forced against this, causing it to vibrate (Fig. 23).

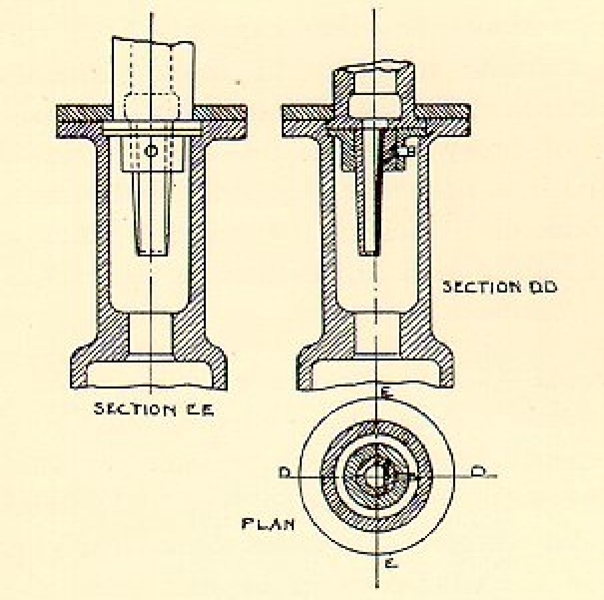

FIG. 23

Instruments of the above type, such as Sirens, Diaphones, and Reeds are placed at the end of *a* trumpet, which should be chosen to suit the particular note which is given, every trumpet having a particular note which best suits it. One advantage claimed for the "Diaphone" is that it automatically adjusts its note to that of the trumpet.

Whistles, which are of the ordinary steam locomotive type, are now very little used, except in some cases on the coast of the United States of America.

Bells.—These are made of a special mixture of copper and tin, and are struck with a hammer. They are not very efficient as fog-signals.

For the most important Lighthouses, and where a long range of audibility is necessary, either a Siren worked by compressed air, or an Explosive

Fog Signal, is generally employed. The latter consists of a tonite or other explosive fired from the top of a mast; this type of signal demands constant attention, and where there is a considerable amount of foggy weather, the annual cost is very high, and it is therefore only used for stations where it is difficult to instal the siren system, as for instance, on a rock lighthouse, or for some other special reason.

Sirens. — The system chiefly employed is the Siren, which is worked by compressed air, the air being raised to a suitable pressure by means of air-compressors of the piston type. The method of driving the compressors varies considerably, depending upon the conditions to be met with; the most general being oil-engines, owing to the ease of starting in case of sudden fogs. The size of compressor and power of oil-engine are varied to suit the duration of the sounding time, as in the case of two signals, if one is to give a duration of sound twice the length of the other, the former will require double the horse-power of the latter, while the power of the blasts will be identical. It will therefore be evident that in this system of signals alone the possible combinations of size of compressors, type of motive power, arrangement of plant, etc., are innumerable.

Plate No. 7 shows a complete Siren plant, with engines and compressors in duplicate. When the siren is being sounded, the air is compressed into the main air receivers (A), and passes from them to the sounding receiver (B), which may be placed in a separate house with the siren, connected to the main receivers by a pipe line. The signal is automatically sounded by means of clockwork, which may be made self-winding, the necessary power being supplied by the compressed air. The usual working pressure is 25 lbs. per square inch (1.75 kilos per square c/m). In order to be able to start working at short notice, in case of a sudden fog, air is stored in the main receivers at a pressure of 100 lbs. (7.03 kilos or upwards, so that there is sufficient to sound the signal for a certain period while the engines are being started up. When working off the receivers at 100 lbs. (7.03 kilos) pressure, a reducing valve is necessary to bring the pressure down to that required at the siren, and this is placed in the siren house on the pipe line before it enters the sounding receiver.

There should always be an extra engine and compressor to act as a stand-by in case of a breakdown.

Next in order come "Reed" instruments, worked by compressed air, which are very suitable for Port or Harbour Signals. The power of the blast can be modified somewhat, as one trumpet and one reed can be used, or two trumpets and two reeds working in unison. The remarks made in connection with Siren Signals, re air-compressors and method of driving them, apply generally to this system.

The smallest type of compressed air signal is the "Manual Reed." This, though originally designed to be worked by hand, we have on several occasions supplied with a small oil engine attached, as illustrated in Plate No. 8, thus enabling us to raise the sounding pressure and obtain a more powerful note. If there is any breakdown in the engine, the signal can still be worked by hand at the lower pressure.

There are many varieties of trumpets, opinions differing considerably as to the most efficient type. That shown in Plate No. 7 is the Scotch type, in which the greater length of the trumpet has its axis horizontal; it is arranged so as to be turned through an angle of about 180°, so that the mouth can be turned in the direction which is most suitable, according to the wind.

The type of trumpet in use at St. Catherine s Point, Isle of Wight, with a 5-inch (127 m/m) cylindrical siren, is shown in Fig. 24. In this case two sirens are used, and the two trumpets are arranged so that the angle between their axes is 120°.

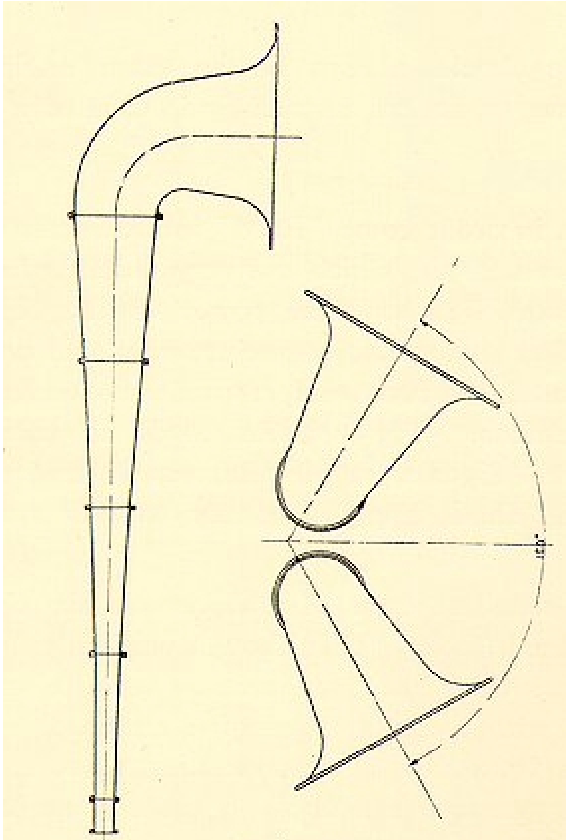

FIG. 24

If it is desired to distribute the sound all round the horizon, as from an isolated rock or a Lightship, a mushroom trumpet, see Fig. 25, may be used.

Lord Rayleigh has designed a trumpet of elliptical section (see Fig. 26), with the major axis vertical, the special object of which is to distribute the sound equally over 180 degrees of the horizon.

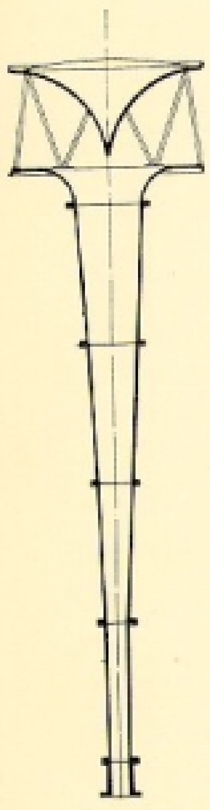

FIG. 25

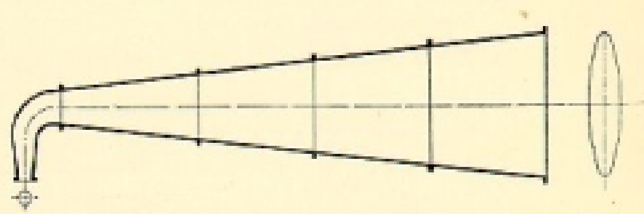

FIG. 26

Bells are mostly used at the end of piers or breakwaters, where it is not desired that they should be heard at a great distance. The hammer for striking them is worked by clockwork mechanism, and where there is a Revolving Light, the clock for working the Light can be - used for the hammer also. In some cases the hammer is driven by a motor (see Fig. 27), so that the bell can be placed in an isolated position, and started or stopped by means of a switch on shore.

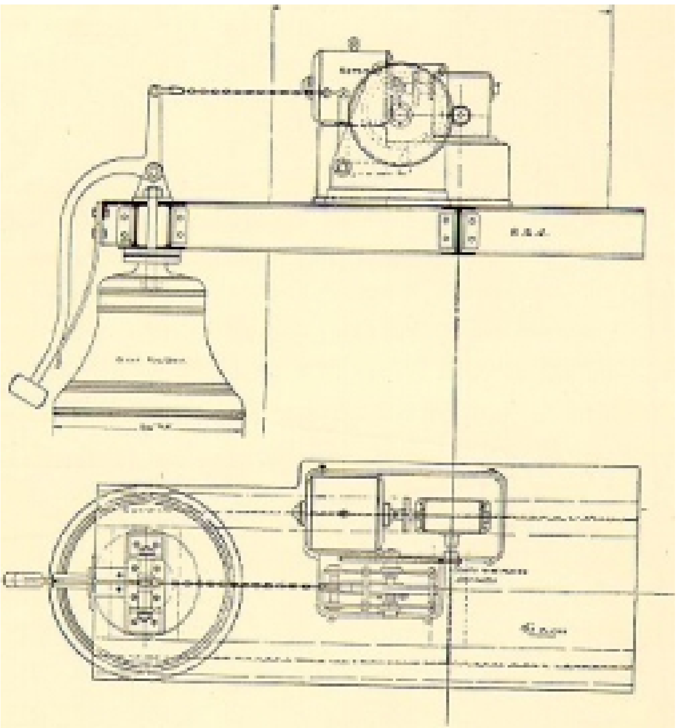

FIG. 27

Range Audibility.—The problem of the range of sound is so complicated, and depends so entirely upon atmospheric conditions, that it is impossible to specify any special plant as having a certain range; this is generally recognised by Lighthouse Authorities, and the attention of mariners is called to it, as for instance, in the list of Lights issued by the British Admiralty. The air may be very clear to vision, and yet very opaque to sound.

It has been proved by experiment that there are soundless zones in the atmosphere: for instance, if three observers were stationed at distances of 2, 6, and 10 miles respectively from the signal station, and all in one straight line, while the observers at 2 and 10 miles distant, might hear the signal distinctly, the observer at 6 miles might be unable to hear it at all. Of course a condition of the atmosphere such as would give the foregoing results is considered an exception; nevertheless, such cases have been frequently known.

As to the character of fog-signals, we do not ourselves advise a combination of high and low note which is sometimes used, for the reason that one note may carry further than the other, thus altering the apparent character to an observer at a distance.

With regard to the length of blast, we would advise about 2 1/2 seconds for each single blast, and a total period not exceeding 6 seconds per minute. It is not desirable to allow the pressure in the sounding receiver to drop appreciably during the blast, any alteration in pressure tending to cause a difference in the note, and a length of blast greater than that given above tends to make the size of the receivers, or else the horse-power required, excessive.

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