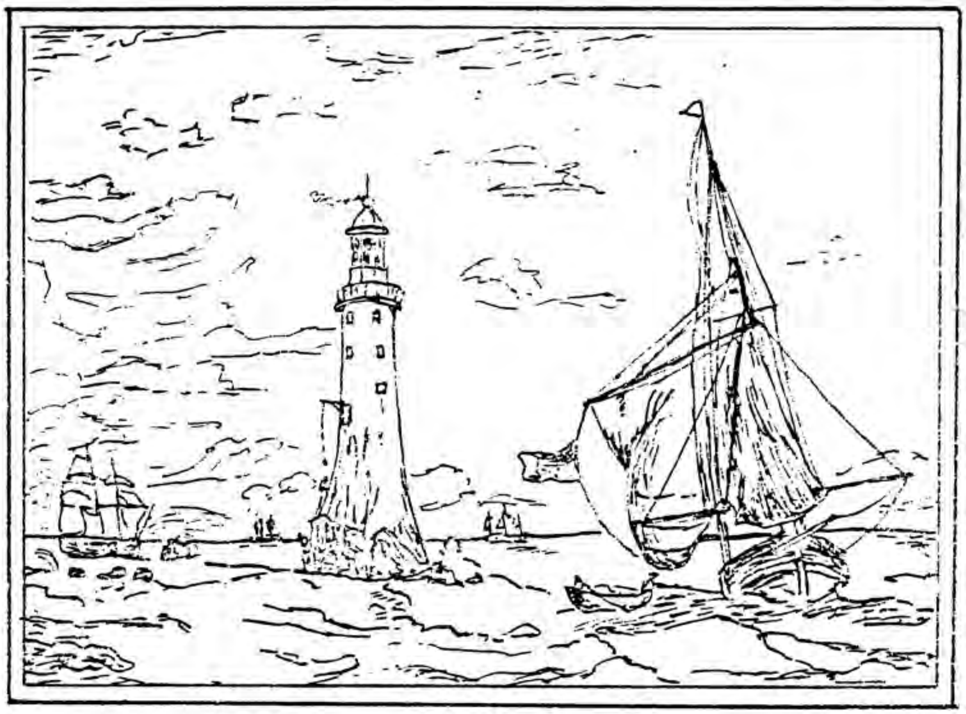
TWENTY YEARS

IN

LIGHTHOUSES



The Eddystone Lighthouse

F. W. COOPER B.Sc, C.Eng., F.I.Mech.E., F.I.Prod.E.

LIGHTHOUSE DEPARTMENT

CHANCE BROTHERS LIMITED

1924 – 1944

1979

Preface

F. W. Cooper, who was known as Wally, wrote this document in 1979. Wally produced a hand written two-part manuscript that was never published. The first part covered lighthouses and the second covered aerodrome lighting. The manuscript was hand printed in a tiny size and liberally illustrated with hand created drawings and tables. Mr. Cooper apparently gave a Xerox copy to one of his friends. That copy was, many years later, sent to a gentleman in Canada who was writing a story about lighthouse clockworks. I read that story and noted the reference to Mr. Cooper's manuscript. I contacted the man in Canada and was sent the entire manuscript. I have a strong feeling that this manuscript should not be lost to the lighthouse community. The following is a typed version of the original "20 Years in Lighthouses" manuscript with a few slight modifications for clarity.

Thomas A. Tag

You will find a biography of Frederick W. Cooper in Chapter 21.

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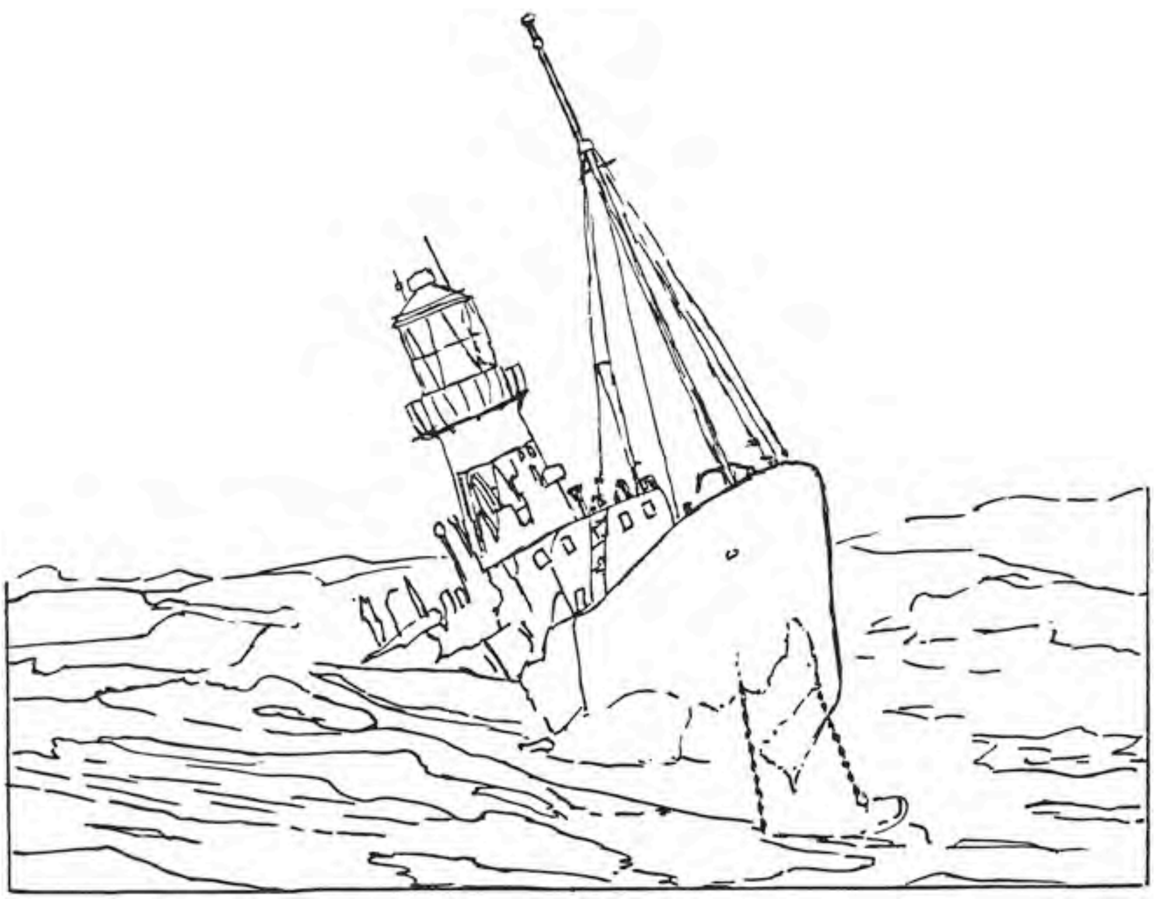
Chapters



The new "Channel" Lightship, off the Lizard, in tow from THV "Winston Churchill" in a force eight gale. 1-1-79

Memories

Whilst writing this book my thoughts have gone back to those I worked with during the period 1924 to 1944. Many, of course, came and went in those 20 years and it is inevitable that I have forgotten some names and, even when remembered, cannot recall the jobs of those in the last block below.

So I attempt to list those who contributed to my experience as a practicing engineer – so necessary since engineering is, but an 'art based on science'. How better to learn it than by working with such engineers as Jack Dodds and George Freanson.

Directors: Messrs Stebart and Wharton, Gell, Major Gubbins and Dr. Hampton

Managers: Jack Dodds, Raith, Fred Beaumont, 'Tobby' Hallett

Foremen: Tommy Slira, Harry Pitchford, Arthur Sleigh, Jack Corbett, Phil Robinson

Charge hands: Messrs Wilde, Penrose, E.J. Beaumont, Joe Harford, O. Perry, Rhodes
Sid Goughs Grigg, Parish, Griffin, Millichip, T Fenton, Stone

Erectors: Ernie Barratt, Frank Cartwright, Freddie Tickle, Fred Plimley-Fisher

Drawing Office: Bill Richey, George Nicol, Frank Hopkins, Harold Gough, Jack Andrews, Arthur Clark, Fred Dangerfield, Archie Chance, E. R. Hooper, Charles Torrence, Norman Stacy, Eric Jones, George Holloway, Donald MacDonald, Bill Dimmock, Edwin Hird, Phil Duff, Sid Peters, Gilbert Parr, Norman Fieldhouse, Jack Batten, F.C. Hind, Johnson, Graber, Infram, Wilford Allbrooke, Miss Henning, J. Appleby, S. Doyan

Buyers: Jimmy Lord, H.J. Hopkins, George Thompson, E. Moore, J. Smith

Office Sales: Sutton-Jones, Len Neenan, A. Wise, D. Nash, F. Sendall

Research: E Hedley, F.A. Jones, Goetzl, Tommy Slade, Bertenshaw

Secretaries: Maud Felton, Doris Allbrooke ne Lockley, Lilian Gregory ne Parish

Tracers: Mary Madden, Flourence Giregh ne Hammond, Rose Macdonald, ne Thornton

And: W.J. Jones, T. Butler, B.M. Aurney, M.A. Latin, G.F. Oldnall, W. L. Geoffries, D.W. Rabone, J.H. Spooner, B. Wakeman, W. Plimley, W. Brittain, N.J. Perkins, H. Davis, W. Cashmore, Bill Hitchens, A. Stevens, L.W. Blake, Arthur Lowe, Len Wordle, F.L. Fellows, G. M. Taylor, A.W. Russell, J. Hemming, A. Williams, R.C. Harris

Glass Works: It gives me pleasure to mention some few from the Glass Works who from time to time contributed to the Lighthouse Department: J. Herdy, Sir Hugh Chance (for his several kindness to me), George Franson, John Holmes, Tuohy, Arthur Reeves and of course Dr. Hampton.

Acknowledgements:

I am much indebted to:

Bill Dimmock, Ernie Barratt, Len Barker and Tom Crouch for their considerable contributions to the writing of this book, and to Kitty Bennett, Frank Cartwright, Bob Aston and Ian Blair, and Harry Bowen for *The Smalls*.

For the use of publications, reports and papers from:

Chance Brothers: *Lighthouse and Light vessel optical systems and P.V.B's*, the same for *Electrical Illuminants*; *Automatic Beacons and Buoys*; and *Auto-generating Plant*.
South African Authority: Details of Cape Columbine.
Stone-Chance: Several leaflets on Buoys and Beacons and on Fog Signals; Powertrane
AGA News: *Supertyfon*. The Central (winter 1967) Lecture by the author
BSI: *Calculating the Intensities of Lighthouse Beams No 942-1941*
Trinity House Gazette: *The Corporation of Trinity House*
J. W. Tonkin: *Navigational Fog Signals*
Ivor Emlyn: *The Smalls*
Bill Richey: *The Eddystone Light*
Sir E. Birkett; *Clocks, Watches and Bells*
Dr. W.M. Hampton: *Investigation into a Beam from a standard Lighthouse Lens*, and his staff: *Measurement of Sound Intensity* and *Theory of Sound Distribution*.
Bureau of Lighthouses, Washington: *Report of Fog Signal test at Cape Henry, Virginia*
A, B, and P Ltd: *Calculations of Time of Oscillation of a Buoy*
Melken: *Light and Sound*
Jones Mulholland: *Acoustics*
Fred Majdulany: *The Red Rocks of Eddystone*
D.B. Hague and R. Christie: *Lighthouses of England and Wales Their Architecture, History and Archeology*
Also **BBC TV Programs** based on "Bishop Rock"

Use of national papers and periodicals: articles dealing with every day events in the world of Lighthouses and Lightships.

Poems and Prose snippets: I am deeply grateful to the many poets and writers, from Homer to the unknown author's of the Ballard *The keeper of the Eddystone Light* for their interest in 'Lights and Lighthouses'.

Lastly the understanding, patience and interest of my wife in the many hours spent compiling this book.

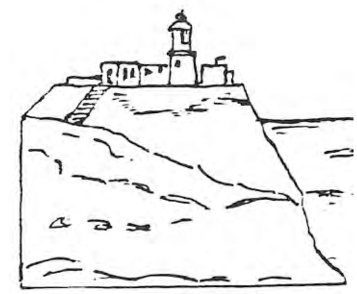
I have gratefully drawn on the above for many of the sketches and figures.
Two deserve special mention;

Cover: *Trinity House tender with supplies for Smeaton's Eddystone Light*: Artist unknown.
This beautiful picture (the original I mean) was found in Chance's archives by me and reproductions were used for the next issue of Departmental Christmas Cards. The original was presented to Trinity House but was alas destroyed by enemy action in World War II.

Contents page: from Trinity House Gazette. The Channel Lightship was eventually positioned at the southern end of two shipping lanes in the English Channel with the hope that the ½ million ton oil tankers and other ships will note and digest its meaning and use the lanes! The towing operation shows but one of the many jobs undertaken by Trinity House under all conditions.

1 Introduction

I use as an introduction to my subject a lecture I was pleased to give to the Old Centralians in 1967. It is, I think, brief and includes sufficient history for my present purpose, except that the saga of the four Eddystone lights must find a place in any book on lighthouses. My talk had in it a little science but not to worry, all will be resolved later.



Strumble Head Lighthouse

Lighthouses and Fog Signals

"Or as to seamen o'er the wave is borne the watch-fires light". - *Homer*

Maybe to the mariners the germ of an idea realized in the Pharos of Alexandria, ca 280 BC. The splendid Roman pharos in Boulogne, and two in Dover, a lighthouse in Norfolk in 1272 and later the agitation in Plymouth in 1690 to light the Eddystone Rocks, take there rightful place in a history of lighthouses.

Illuminants

Wood and coal fires had a long run terminating in the United Kingdom in 1822 at St. Bees. The life of the humble candle, or rather a cluster of twenty-four six-pounders, is best illustrated by their long use in the Eddystone Light from its founding in 1698 until 1813. A more compact source of 10 candlepower, Argand's circular-wick colza-oil lamp of 1782 (greatly improved when mineral oil became available) lasted until 1898 when a really brilliant light source was invented. This was a mantle burner (with mantles from 35 mm to 110 mm in diameter) using vaporized paraffin and giving a brightness of 40 candles per sq. cm of mantle. I guess the majority of the 17,000 or so major lights in the world still have mantle burners.

1935 saw the introduction of electric lamps of wattages up to 3,000 and a brightness of at least 500 candlepower. Earlier arc lamps were not successful the light source being too small. The ratio of 40 to 500 gives an idea of the decrease made possible in the size of optical systems. Parallel with the mantle burner and the electric lamp must be mentioned the versatile fish-tail burner using acetylene, oil gas or propane. As with the electric lamp such burners can be switched on or off to give a wide range of signaling characters.

Light Signaling

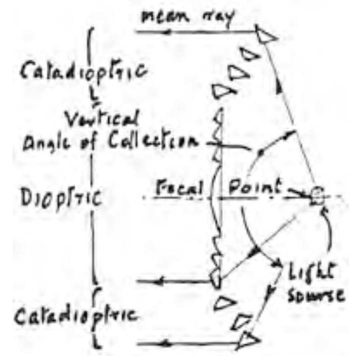
The compact light of the Argand wick burner stimulated the use of reflectors and paraboidal mirrors giving a beam of about 1,000 candles. These were certainly in use on the Isles of Scilly in 1792. Even now mirror lights with their cheap initial cost are popular, and with electric lamps it appears to matter little if only one third of the available light is collected and directed to the horizon.

Fixed and Revolving Lenticular Apparatus

In 1852 when Chance Brothers Limited started making lighthouses the design of the prismatic elements shown in Fig. 1 was complete. It is seen that the dioptric and catadioptric prisms effectively collect the light in a vertical plane.

If we now generate (or revolve) the prism sections about the vertical axis through the light source, or focal point, the result will be as Fig. 2, namely a drum shaped optic. The observer will see a vertical band of light equal in width to the diameter of the mantle.

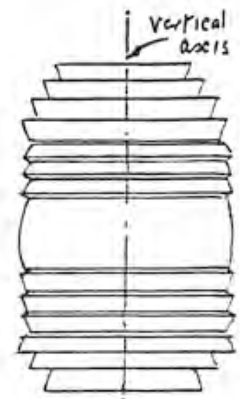
To get an approximate value of the candlepower of such a fan beam we will take the height of the optic as 200 cm, the diameter of the mantle as 8 cm, the brightness of the mantle as 40 cp, the average efficiency of the transmission of light through the prisms 0.7 and the transmission efficiency of the lantern glazing as 0.8. The candlepower will be the lit area x brightness x the two efficiencies; or about 36,000.



Sectional Elevation

Fig. 1

Although many of these ‘fixed’ lights (that is the optic does not revolve) still exist, those now made are very small and are suitable for harbor or buoy lights using ‘on off’ electric lamps or fish-tail burners. The old lights can be made to signal by having screens revolve around the burner or ‘up and down’ shutters. A typical character would be 2 short and one long light period. Green or red glasses, if used to color a beam, ensure a loss of light of up to 85%.



Elevation

Fig. 2

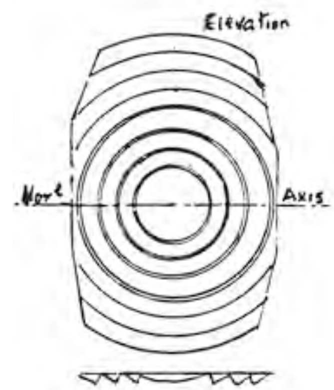
Revolving Apparatus

If we now generate the prism sections of Fig. 1 about the horizontal axis through the focal point we get a lenticular panel as shown in Fig. 3 which to the observer will be ‘flashed’ or illuminated over all its surface.

If, for a given geometric arrangement of the optic panels, say 8 flash panels, the average width of each panel was, say, 100 cm. then the candle power per panel would approximate to the areas flashed, is 450,000 – a very real increase. We have only to mount this optic on a revolving table and the powerful, slightly divergent beams of light will sweep majestically over the sea.

Group Flashing Systems

These date from 1874 and are achieved by the geometric arrangement of the optic panels. Plan view Fig. 4 illustrates four of the characters obtained. The speed of rotation can also be varied to give, for example, two flashes in 30 seconds or, say two flashes in 60 seconds. The range of characters available should keep even the worst of navigators out of trouble.

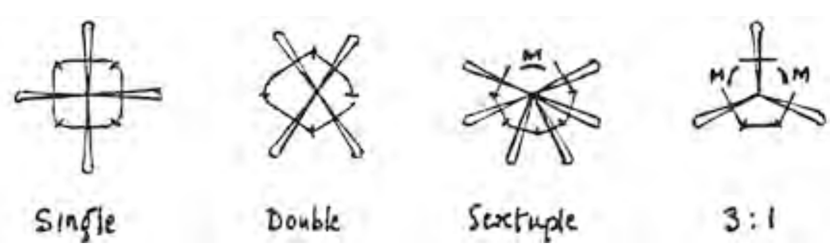


Sectional Plan

Fig. 3

The Stationary (Io) and Apparent (Ia) intensity of Revolving Beams

The human eye can not fully appreciate the actual intensity, Io, of a revolving beam since the illumination varies as it crosses the eye.



All four plans are drawn through the focal point
— a light beam,
—, ⌐ or — optic panels,
M – a mirror.

Fig. 4

A simple formula relates I_a to I_o, $I_a = I_o \times t/0.15 + t$ where t is the duration of the light 'flash', t in turn is dependent on the horizontal divergence of the beam, which can be found using the diameter of the mantle; the focal distance of the optic and the speed of rotation of the beam.

If, for example, t = 0.15 second, then half of the intensity is lost to the observer. Values from 0.3 to 0.5 seconds are satisfactory. But, obviously, a very small light source however brilliant is not the answer.

Geographical and Luminous Ranges

To be of use to the mariner the beam or beams must be dipped to the horizon. Fig. 5 shows the geographical range for a light 120 feet above sea level with an additional distance for a ship's navigator 30 feet above sea level. If the beam is powerful enough or the weather very clear, the loom of the beam on low clouds can be useful to mariners. Having said this, the astronomers at Herstman Ceuse have no love for the new Royal Sovereign Light! The faintest loom upsets their observations.

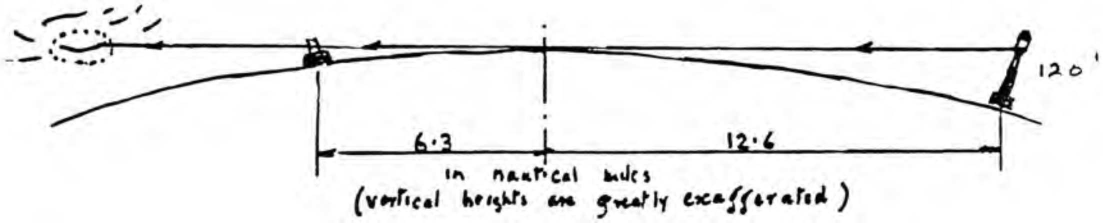
The luminous range (λ) in nautical miles can be found if the atmospheric transmission per nautical mile (T) is calculated from $I_a \times T^{\lambda} = 0.67\lambda^2$.

The results are startling for different values of 'T'. For example 'T' in the eastern Mediterranean can be 0.85 and on the Atlantic coast but 0.65. For a range of 18.9 nautical miles the respective candle powers necessary for the beam would be 5,300 and 1,000,000. Perhaps after all, the Pharos of Alexandria was seen 35 miles away. Perhaps!

Revolving gear and power supply

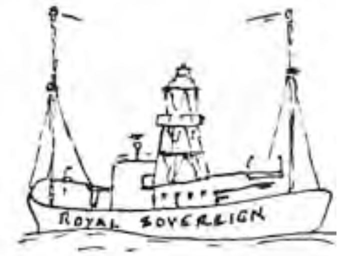
The large revolving optics of the past weighed many tons and with only a weight driven clock to revolve them the speed of rotation was very slow and consequently the optic panels were many in number and narrow in width. Hence a small candle power. However, at the turn of the century mercury flotation was available and as a result speeds of rotation, panel width, and candle powers increased.

In turn the powerful electric lamp greatly reduced the size of the optics and so the weight revolved and a ball-bearing pedestal with a motor drive sufficed. Such lights lent themselves to automatic working with considerable savings in labor costs. Automatic generating sets triggered on and off by light cells are available if the lighthouse is remote from a mains supply of electricity. Buoy lights powered by batteries and with a set of standby lamps can run for two years without attention.



Geographical Range
Fig. 5

Lightships present problems in that the focal height is only about 40 feet and in order to keep the beams pointing to the horizon the optic must be mounted on gimbals. Several well known lightships – to save labor and maintenance cost – have recently been replaced by immense buoys, or by towers partially pre-fabricated on the sea shore and then floated out to the sandbank concerned.

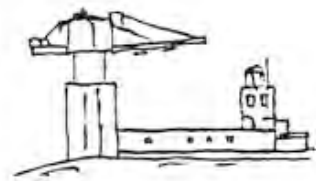


The Old
The old Lightship

Fog Signals

When the weather really closes in the falling value of the light transmission 'T' ensures that the hard won beam of light is rapidly rendered useless and we have to use for the transmission of sound a medium, 'air', that is notoriously fickle. Moreover 'big' fog signal installations are very expensive, both to purchase and run, meaning that Lighthouse Boards are quite selective in installing such signals.

Sound tends to travel across the sea in lumps and heavy rain and wind are sad handicaps. The mariner in turn has to cope with the noise of the wind and of the ship's engines. It is obviously nonsense to closely specify ranges of fog signals. All this has led to much innovation resulting in many types of fog signals.



prefabricating on shore the two part tower and platform.

Bells - Bell Rock – remember Sir Ralph the Rover? – indicates a very early application of clappered bells, however unreliable they were. Now they are mainly used on bell buoys and their dismal clanging is known to all travelers by sea.

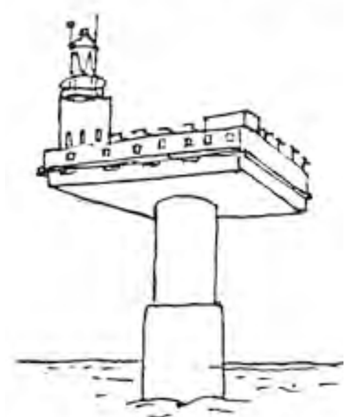
Whistles - The motion of the sea can compress air in the tail tube of a deep water buoy and so periodically sound a whistle. The range is better.

The platform on pontoons ready for towing to site.

Reed Horns - The Reed Horn was used at Wolf Rock in 1870 and on several lightships. Air is compressed by power to 15 lb. per sq. inch or, mercifully for the crew, by hand to 5 lb. per sq. inch. The note is one of 450 cycles per second and various characters can be signaled. The range is much improved. Air consumption is 1/3rd cubic foot of free air per second of blast.

Acetylene Guns - The Acetylene Gun is simple, good and can be left unattended. These guns are still used.

Explosives - Explosives have a very great advantage in range and since little space is required they are very useful in 'rock stations' – for example Bishop Rock. A charge is fired every two to five minutes.



The New
Royal Sovereign
Lighthouse

Sirens - A typical Siren has a 6 inch diameter rotor revolved in an axially slotted cylinder by a speed governed air motor. The note is about 200 cycles per second (a value providing a good range). The range is less than the explosive signal but better in narrow waters.

The Diaphone - Chance Brothers Ltd. has been making this very successful signal for over forty years. A circumferentially slotted piston is oscillated at 90 cycles per second in an identically slotted cylinder with compressed air (35 falling to 30 pounds per square inch) fed to the outside of the cylinder. The note obtained is twice 90 = 180 cycles per second, but by cutting off the ‘driving’ air a fraction before the ‘sounding’ air, at the end of the blast, the slowing down of the piston gives an elephantine grunt which not only travels a long distance, but is a characteristic signal readily recognized by the mariner. Depending on the size of the instrument, the air consumption per second of blast is from 1 to 60 cu. feet of free air.

A single diaphone covers with sound, at least in theory, an arc of 120° in plan. If two diaphones are synchronized and set at 100° to each other in plan, and their resonators spaced one half wavelength vertically apart, then the resulting flattened beam covers an arc of around 200° in plan. The longest range reported to Chance Brothers was one of 23 miles off the coast of Norway. A freak condition of course!

Signal characters could be, for example: Single – 3 sec. sound, 57 sec. silence; Double - 1 ½ sec sound, 3 sec. silence: 1 ½ sec. sound, 54 sec. silence.

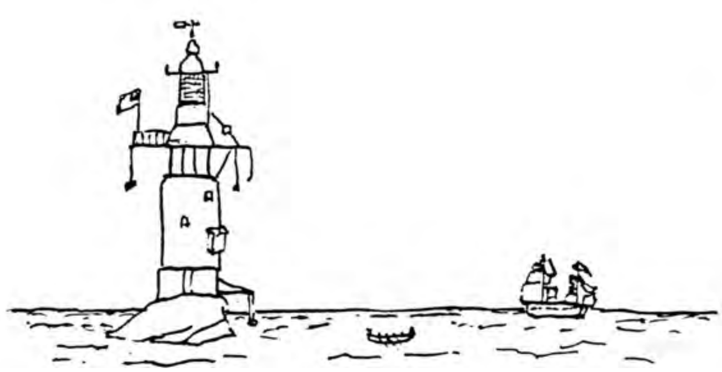
Submarine Bells: Submarine Oscillators: Radio Beacons

Such bells have been replaced by oscillators having a note of 1,050 cycles per second (useful in water) using 2 kilowatts of electricity. If a ship has a receiver then a range of 50 miles is possible. Even without a receiver 5 miles is possible indicating that water is a very good medium for transmitting sound. Used on lightships together with a radio beacon, bearings can be taken.

Other Diaphragm Oscillators – In Air

Individual oscillators, ‘all round’ or directional, use but 100 watts and have, for example, a note of 450 cycles per second. The grouping of units is readily obtained, and six ‘all round oscillators’ would have a range of about 2 ½ miles. Four banks, each of three units, consuming 1,200 watts, would give a directional range of about 5 miles. Such oscillators are obviously economical in running costs and in space required and should a blind zone be found later, one or two extra units could easily be added.

This brief review of one of mankind’s better endeavors may be illustrated by Louis XIV’s angry retort when told that Winstanley, whilst supervising the building of the first lighthouse on the Eddystone Rocks, had been taken prisoner by a French privateer: “I am at War with England, not humanity”



Winstanley’s Eddystone Lighthouse 1698

2 Ranges and Losses

"The ship was cheered
the harbor cleared.
Merrily did we drop
below the kirk
below the hill.
Below the lighthouse tower."
The rime of the ancient mariner

We will cover, from an optical point of view, the mariner's requirements and, in some detail, look at the candle power of a revolving beam of light to give, under agreed conditions, the range required.

The Requirements:

(a) The beam should be visible to the full extent required. This implies that the Luminous Range of the beam should be, at least equal, under specified weather conditions, to the Geographical Range.

Geographical Range is dictated by the curvature of the earth and the heights of the light source and the observer, above mean sea level.

The Luminous Range for a revolving beam is governed by the type and assembly of the optic, the illuminant, the speed of revolution of the beam(s) and the atmospheric transmission.

(b) The signal must be distinctive to the mariner from any other light in the immediate neighborhood. Nowadays the color of the beam rarely comes into the matter.

(c) The taking of bearings on the light is important to the mariner, hence the pattern of signal must be sufficiently long enough for this. This also implies that the lighthouse should be a good day mark.

(d) The apparatus must be efficient and reliable and this can involve the choice of optic and illuminant. With the Keepers the motto is: "The light must always shine," and it does.

The Geographical Range

This is found by adding the distance from the light source to the visible horizon to the distance from the observer to the visible horizon. As exemplified in Fig. 5, on page 3, the Geographical Range is 12.6 + 6.3 nautical miles.

The value of (x) = 1.06 where h is the height in feet of the light, and also the observer above mean sea level, (x) will be in nautical miles. This expression for (x) is derived from pure geometry and must not be confused with values (x_r) given in British Standard No. 942 and in practice used by Chance Brothers and which is an empirical formula which allows for refraction of the light beam. Table 1 shows the difference between (x) and (x_r).

Height above sea level (h) of light source or observer in feet	Distance to visible horizon in nautical miles (x)	Distance to visible horizon in nautical miles (x_r)	Angle of dip to horizon (λ) in minutes ' and seconds " of angle
10	3.36	3.63	3' 22"
40	6.73	7.25	6' 44"
100	10.60	11.50	10' 36"
200	15.04	16.20	15' 02"
15	4.12	4.44	
30	5.82	6.28	
50	7.50	8.11	

Table 1

One is obviously on the safe side to use x_r when calculating the candle power of a beam for a required Geographical Range. A reference is given in the book "Elements of Navigation" to the formula and it is stated: "It is useful for the determination of the exact distance at which a light of known height can be seen." Exact or not we use it!

Example: for a light 200 feet and an observer 30 feet above sea level we get from Table 1 x = 15.04 + 5.82 = 20.86 nautical miles and x_r = 16.20 + 6.28 = 22.48 nautical miles for the Geographical Range.

Dip of the visible horizon (λ)

The value of λ in minutes of angle 1 is very nearly equal to the numerical value of (x).

Example: Using Table 1 if h = 200 feet we get 15.04 nautical miles for (x). Hence λ = 15.04' = 15° 02". Which is a very small angle.

Such a value would be used when setting individual prisms in an optic frame to ensure that the light from each prism is directed to the horizon and for setting the center of the illuminant slightly above the focal plane of the optic.

Height of the center of, say, the filament of an electric lamp above the focal plane (D)

For electric lamps, focusers are required, for which see page 20.

For Petroleum Vapor - P.V. Burners the distance from the focal plane to the actual top of the burner, with the mantle not fitted, can be calculated by decreasing this dimension by D mm. The customer is always supplied with a drawing of the burner installation with this dimension clearly shown.

A string across the optic at the focal plane and a small gauge enables the platform supporting the burner to be adjusted in height once and for all. For the usual standby wick burner a similar procedure to its adaptor**,** fixes its height.

Example: for a 3rd order optic, (f) = 500 mm and the angle of dip λ = 15' 2", then D in mm = f x λ in radians = 2.18 mm. This is a very small distance compared with the 500 mm but vital in directing the beam of light to the horizon.

Units of Light

The luminous Range for revolving beams of light. This at any instant depends on the intensity of the light, the atmospheric transmission and the necessary illumination at the eye of the observer.

They are related by: $Ia \times T^x = E\, x^2$ where Ia is the apparent intensity of the light corrected for the lantern glazing, in candles:

> x is the distance to the observer in nautical miles, T is the atmospheric factor per unit distance (a nautical mile), and E is the illumination at distance x (taken as 0.67 nautical mile – candle).

This formula is, arithmetically, very tiresome to handle and resource will is made to a 'semi – log' graph of Luminous Range versus Intensity for various values of T from 0.85 to 0.60.

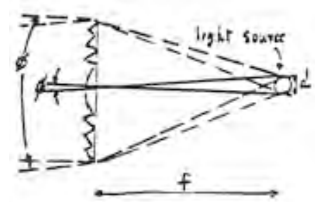
Examples: (1) If x = 16.7 nautical miles and T = 0.65 then the required intensity is 300,000 candles.
(2) If the fully corrected intensity is 1 million candles and T = 0.60 then X = 16.7 miles.

Lantern Glazing Losses

The optic, pedestal etc. - and the keepers – must be protected from wind and rain so an enclosure, invariably a curricular glazed room called the lantern, tops the tower. The many panes of glass are often of 3/8 inch thick plate.

A revolving beam of light falling on the inside of the glazing suffers, light absorption, light reflection and direct losses due to the blockage of light by the lantern framing (see also p. 40). It has been agreed internationally "that to obtain the final intensity all computed intensities should be multiplied by a reduction factor of 0.80.

Light duration of revolving beams (t)



Sectional Plan
Fig. 6

Fig. 6 refers. This duration is dependant on the angle of horizontal divergence of the beam and the speed of revolution of the optic. The formula gives 0 = 57 (d / f) degrees and t = 9.55 d / (n x f) where d = horizontal width of the illuminant, n is the speed of the optic in revolutions per minute and f is the focal distance in mm.

At this point we are not concerned with the vertical divergence of the beam. Later when considering Lightships we shall make an unusual design which required a collodion mantle of height at least double its width or diameter.

Apparent Intensity of Revolving Beams

The actual intensity of a light beam sweeping across the eyes of an observer is not fully appreciated. A reduction has been internationally agreed. This is called the Bondel – Rey formula, namely Ia = t / (a + t) x Io where: Ia is the apparent intensity in candles, Io is the stationary intensity in candles and t / (a + t) is the Blondel – Rey factor where a = 0.15 and t is the duration of the light flash in seconds.

An example to summarize the losses:

Let us assume that 620,000 candles are required for a given Geographical Range and that the value of t / (a + t) is 0.67. Applying the agreed correction factor of 0.80 for the glazing, then we get for Io 620,000 / (0.67 x 0.80) = 1,160,000 candles.

We have lost 46% of the light from each optic panel!

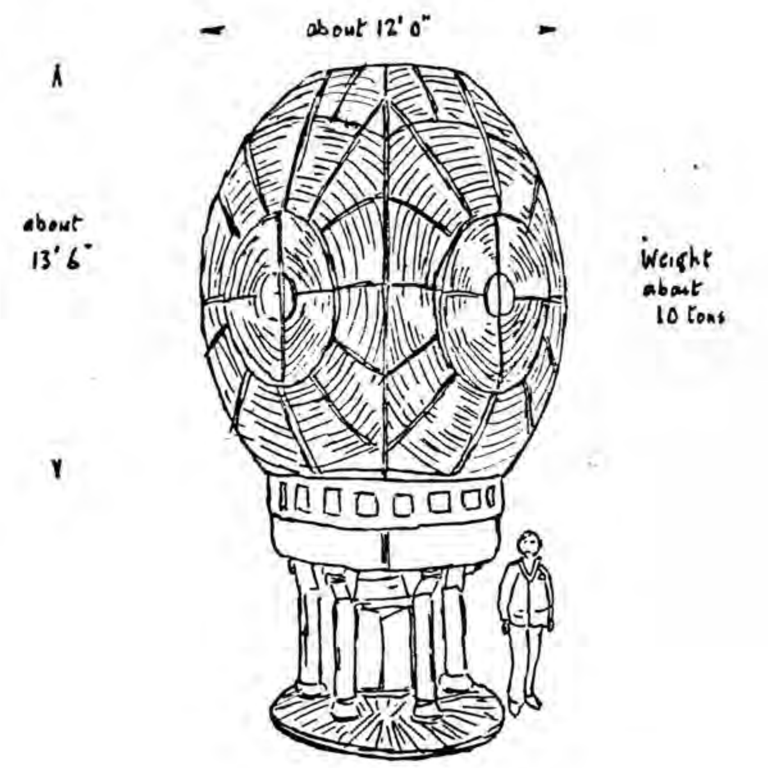
Table 2 gives examples of values of t and the factor t / a + t for different sizes of optic, different P. V. Burners and electric lamps and different speeds of revolution of the optic.

The opportunity is taken of including trade descriptions used by Chance Brothers for optics of different focal lengths. For example: 700mm = 2^{nd} order: 150mm = 6^{th} order: 1330mm = Hyper-Radial.

Chance's Size	Focal Distance in mm (f)	Width of Burner or Filiment in mm (d)	Speed of Optic r.p.m. (N)	Angle of Divergence in Degrees (ø)	Durration of Flash in Seconds (t)	Blondel-Rey t/a+t a =.15
1st Order	920mm	110mm PVB	2 r.p.m.	6.8	0.57	0.79
2nd Order	700mm	85mm PVB	2 r.p.m.	6.9	0.58	0.8
3rd Order	500mm	55mm PVB	2 r.p.m.	6.3	0.45	0.75
Small 3rd Order	375mm	55mm PVB	3 r.p.m.	8.4	0.47	0.76
4th Order	250mm	35mm PVB	3 r.p.m.	8	0.45	0.75
3rd Order	500mm	3kw 39mm	2 r.p.m.	4.5	0.37	0.71
Small 3rd Order	375mm	1.5kw 26mm	2 r.p.m.	3.9	0.33	0.69
4th Order	250mm	1kw 18mm	2 r.p.m.	4.1	0.34	0.69
4th Order	250mm	500w 16mm	2 r.p.m.	3.6	0.3	0.67

Table 2

I have not mentioned the largest optic made around the turn of the century, namely one of 1330 mm focal distance. This giant was undoubtedly designed to wring the last candle out of the multi-wick lamp.



1330 mm focal length Optic
with mercury float pedestal

Having now the tools to do the job we will, in Chapter 3, look at the design of an optic. In our imagination, at least, the end result will be a handsome assembly of glass prisms set in a gleaming gunmetal frame.

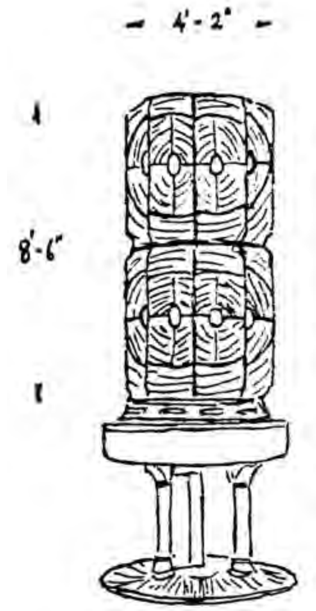
3 Group Flashing Systems

"And yonder light is the Start Point light and yonder comes the sea."

Masefield

We will commence with a very brief description of how, at Chance Brothers, the prisms were made from, often large, prismatic rings of ground and polished glass, which were then, often after cutting into various lengths, focused and mounted in a framework of gunmetal. Finally, we will see how these optics are designed to give the candle power required and the panels of prisms positioned in plan to give the light signal required.

The great names in the design of prisms include the famous French physicist, Fresnel (see page 16), the Stevensons of the Northern Lighthouse Board, Douglass of Trinity House, James Timmins Chance and John Hopkinson at Chance Brothers. James Timmins Chance and John Hopkinson introduced group flashing optics.



Hartland Point a Bi-form 3rd order Sextuple flashing light.

The two outer panels are hidden at the back of the four panels shown.

Either to replenish stock or for a new order the Lighthouse Department would order from the adjacent Glass Works enough pots of crown glass (refractive index, a measure of its ability to refract or bend light, 1.51). When ready 'one of our men' from the Glass Grinding Department would ladle the molten glass into heavy iron moulds, working it in very thoroughly. A 'crude' job demanding much skill to produce often huge rings of glass without flaws. These very rough looking rings, after annealing, would, using pitch, be mounted on the large horizontal table of a cumbersome grinding machine and these ground by an iron slipper periodically charged by the woman operator with water and sand of different grades. The final polish used a felt pad charged with rouge. Later carborundum of various grades down to fine flour replaced the sand.

The slipper in moving up and down coupled with the rotation of the glass ring gave the usual wavy motion required for grinding and polishing. Not all sides of the prism are straight and a circular surface called for the slipper to move in a curved pattern instead of straight line motion.

As a young engineering apprentice one learned a lot outside engineering when running the gauntlet of a bevy of "Black Country" girls whose earthy remarks could be heard above the shriek of glass being ground!

Calculating the intensity of a beam from an Optic Panel

To ensure that a customer can compare tenders from different manufacturers it became necessary to introduce in the 1930's, a standard method of calculating the candle power of a panel using an internationally recognized method. This was by British Standard No. 942 of 1941.

It must be said immediately that actually measuring the intensity of a manufactured panel is a long and expensive business.

Dr. W. M. Hampton (Research Director of Chance Brothers), paper *An investigation into the beam from a standard lighthouse lens*, was a powerful piece of work which made the standard possible.

I quote from the standard:

In a Pencil Beam generated around the horizontal axis for Refractors (Dioptric) and Reflectors (Catadioptric). Io = (a_2 x B x c_2) + (a_3 x B x c_3) where Io is as before the stationary intensity.

a_2 The melt glass area in cm^2 of refractors projected on a vertical surface to the axis of symmetry.

a_3 Ditto for the reflectors.

B The brightness of the light source in candles per sq. cm.

c_2 A correction factor depending on the subtense angle of the refractors from (British Standard) Fig.8 if the panel is symmetrical about its horizontal axis or (British Standard) Fig. 9 if asymmetrical. When the panel is asymmetrical the right and left portions must be considered separately and the area of each portion multiplied by the appropriate value of c_2. The sum of these two quantities when multiplied by B corresponds to the first item in the above equation, and c_3 = 0.7.

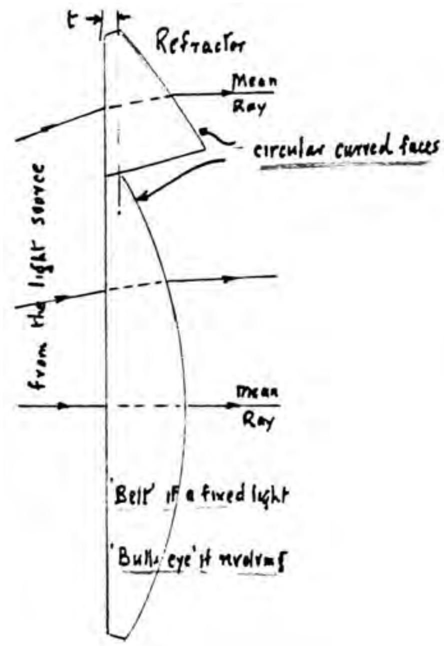
If the above seems complex I must refer you back to page 2 where the candle power of a panel was obtained from its frontal area x B x an efficiency factor. But, now we must be more accurate and recognize that the brightness of the refractors is very high at the bull's eye but falls rapidly as their diameter increases. No such problem exists with reflectors there brightness being very uniform and an efficiency factor (c3 above) of 0.7 is used.

Example – as best we can we will test out the above formula using Fig. 11 (page 15), which shows the optic for Ashrafi Lighthouse – a splendid 2nd order optic with a very unusual character of 3:1. You will see it has two symmetrical panels of 80° in the plan and two symmetrical panels – one right hand, the other left hand – of 71 ½ º in the plan.

The 3 KW electric lamp had a brightness (B) of 975 and the standby 85mm P.V. Burner a brightness of 45. Using these, the Chance designs obviously had a target near 15 million candles with the electric lamp and 660,000 candles with the standby.

But pity them juggling with flashed areas of mixed refractors and reflectors in order to get both types of panels on the required target for Io as in many engineering problems a lot of art and a little science!

Portion 'T' of the prisms allows the rings to be 'nested' when a frame of dioptric prisms is being assembled. Reference to Fig. 11 page 15 shows that our 'cross bar' is sufficient to prevent the rings being pushed outward.



Dioptric Prisms
Refractors

FIG. 7

Description of the Panel	Panel Areas in cm^2 a_2	a_3	$\theta°$	Angle in plan in °	C_2	Areas $a_2 \times C_2 \times B$	$a_3 \times C_3 \times B$	I_o in candles
Symetrical - 80° in plan	7180	15100	35	35	0·64	4,480 000	10 300 000	14 780 000
Asymetrical - 71½° in plan	3590	18600	35	35 but on one side only	0·64	2,240 000	12 700 000	14 940 000

B = 975 and C_3 = 0·70

Table 3

Loss of light in prisms

Although losses in prisms – and the design of the same prisms (refractors and reflectors), is mathematically beyond this book we might with Dr. Hampton's assistance look at two obvious losses. Fig. 7 shows the two kinds of refractors and a pencil of light being bent on entering and leaving the prism. Fig. 8 shows a reflector where in addition there is a total reflection in the longest side of the prism, but let us be quite clear – this long side is not silvered.

Refractors

The refractive index if glass varies with the different wavelengths of light and it follows that a pencil of white light incident on one face of the prism, emerges as a colored pencil at the other. The light path through the prism averages 2 centimeters in length and with absorption at 4% per centimeter the loss due to this is about 8%. So with increasing chromatic absorption the brilliance at the center of the bull's eye diminishes as we move outwards. Some few examples of the correction factor c_2 now follow using Figs. 8 (a) and (b).

Example (1): For a symmetrical panel, if Θ =12° (that is for the bull's eye only) c_2 is 0.81. If Θ = 20° c_2 = 0.77. If Θ = 40° c_2 = 0.59.

Dr. Hampton recommended that Θ should not exceed 30° at which point c_2 = 0.7 = c_3.

Example (2): For an asymmetrical panel. If Θ = 30° and the left side in plan = 10° and the right side in plan 30° then it is seen that for the left side c_2 = 0.73 and for the right side c_2 = 0.69.

Reflectors

Since the light is totally reflected and suffers two refractions in opposite phase it appears there is now chromatic aberration. The average light path is 5.5 cm and the loss due to absorption prism is 0.4 x 5.5 = 22 or 22%. The brilliance is good and remarkably constant, hence the value of c_3 = 0.70 which is used over reflector prism, all three the whole of vertical area of the panel covered by reflectors.

Angles of Collection of Light

(a) In a vertical plane: With but an incandescent mantle we endeavor to collect a large proportion of the light by surrounding it with prisms set in panels, and so we move into the realm of the 'Big Lights'.

In the vertical plane we do very well and Fig. 9 shows what a splendid angle is possible. We do, however, have to keep away the searing heat rising from the burner and during the day watch the keepers are required to clean the burner and the prisms. The latter poses a problem in, say 3rd order lights and it becomes necessary, as shown in Fig. 9, to replace the 'receding' type lower reflectors by the 'up and down' type. Unfortunately not all the rays are collected and dark spaces 'D' between the prisms are left in the emergent beam. Let me hurriedly add that you have to be close to the optic to observe the gaps since the divergence of the beams quite rapidly fills in the spaces.

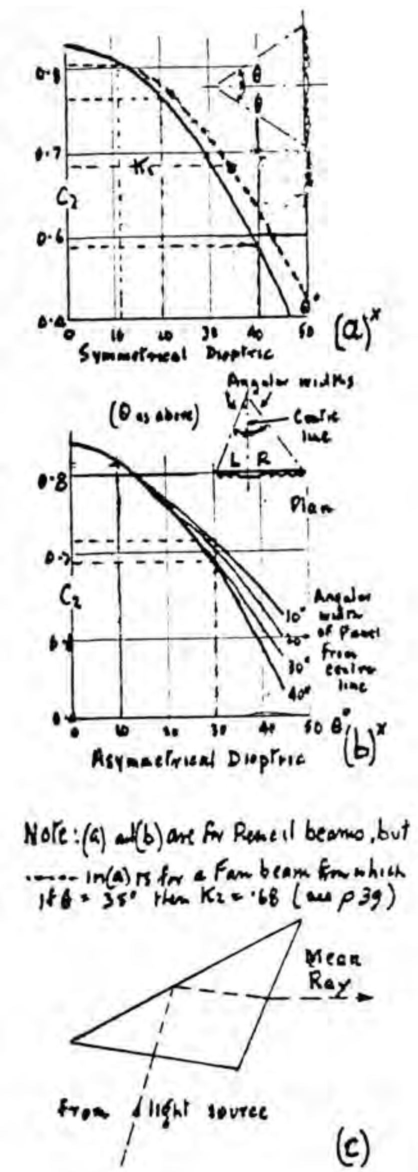


Fig. 8

As with dioptric prisms, one side of a catadioptric prism is usually a circular curve. As for a piece of Chance 1852 reflector prism all three sides however, are straight.

Other designers have curved the totally reflecting face, but mostly the face on which the light from the illuminant impinges is circularly curved.

Shown in Fig. 9 is a bank of mirror prisms (two refractions and two reflections. Such prisms are, as for a fixed light, generated about the vertical axes through the focal point. The light falling on them is reflected back to the light source. More on this later.

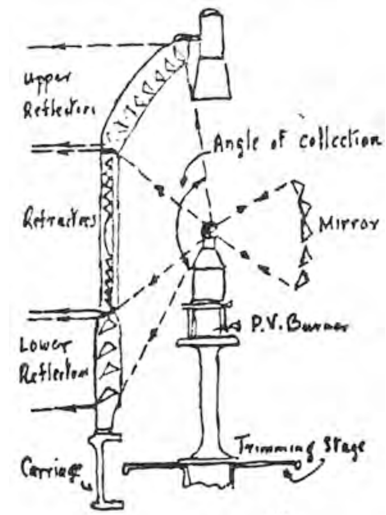
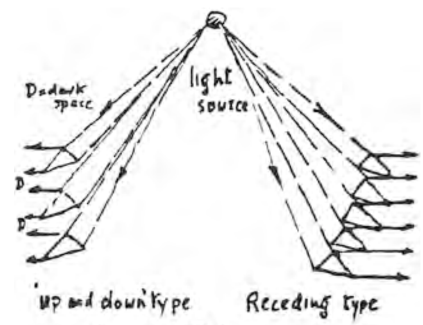


Fig 9



Lower Reflectors

(b) in a horizontal plane: Firstly we will recall what we mean by the character of a light:

Single flashing
Each cycle comprises, 1 flash and 1 long interval dark.

Double flashing
Each cycle is 1 flash, 1 short dark, 1 flash and one long dark.

Triple flashing
Each cycle is 1 flash, 1 short dark, 1 flash, 1 short dark, 1 flash and one long dark.

Quadruple flashing
1 flash, 1short dark, 1 flash, 1 short dark, 1 flash, 1 short dark, 1 flash and 1 long dark.

Quintuple flashing
1 flash, 1short dark, 1 flash, 1short dark, 1 flash 1short dark, 1 flash, 1 short dark, 1 flash and one long dark.

Sextuple flashing
Quite rare but see Hartland Point sketch on Page 10.
1flash, 1short dark, 1flash, 1short dark, 1flash, 1short dark, 1flash, 1short dark, 1flash, 1short dark, 1flash and 1 long dark.

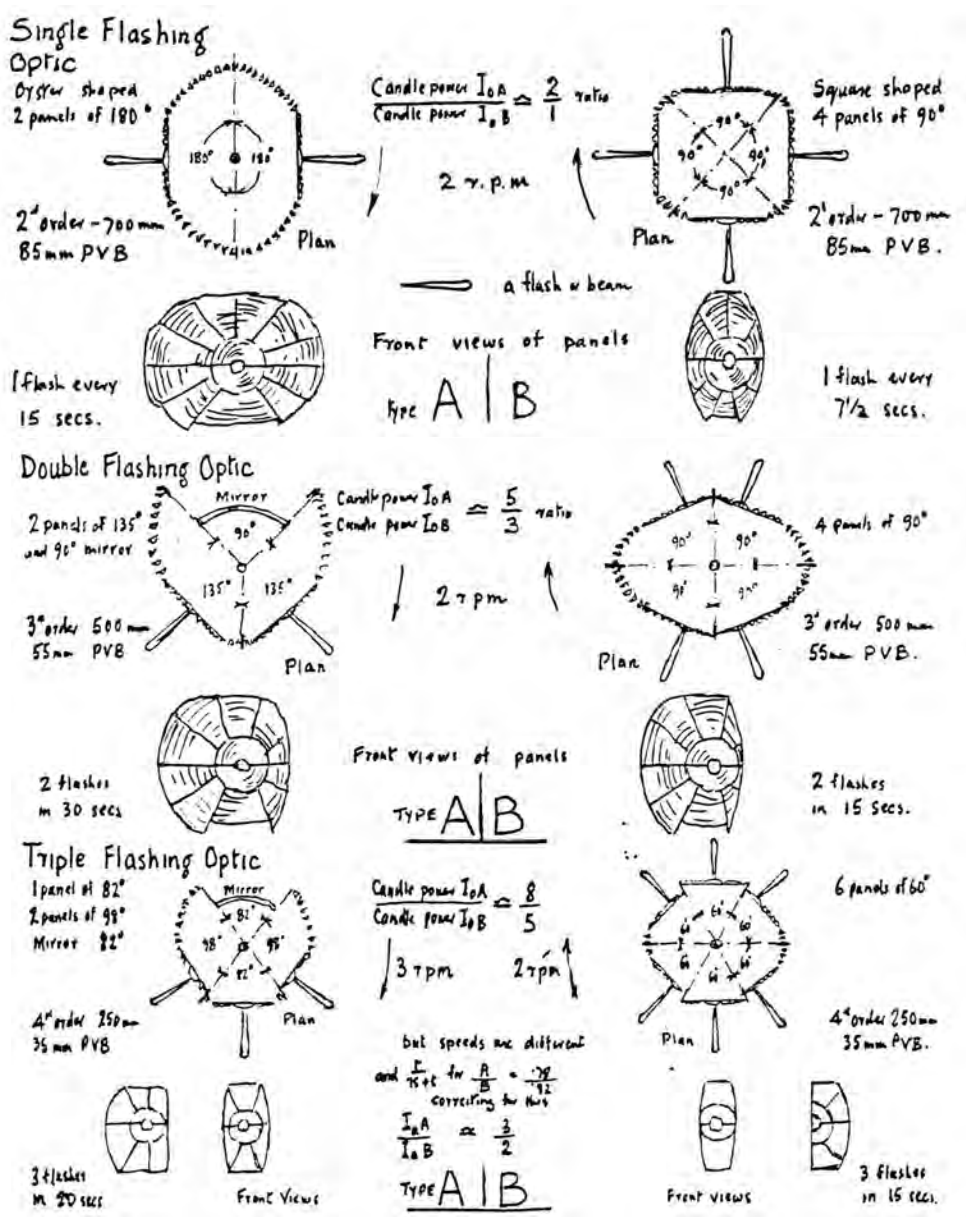
Special – for example Ashrafi a 3:1 character. (See Fig. 11, page 15)
1 flash, 1 short dark, 1 flash, 1 short dark, 1 flash, 1 long dark, 1 flash, 1 long dark.

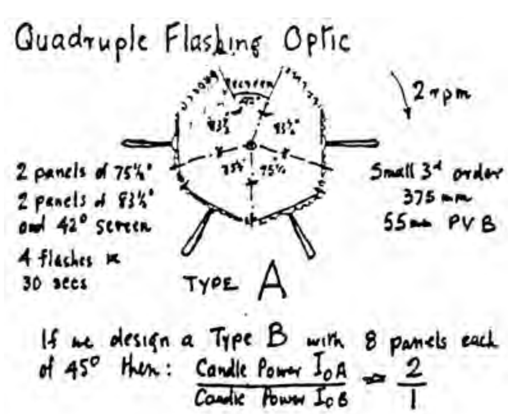
We must now immerse ourselves in light signaling, using different characters, by varying the position of the panels in plan. By 'plan' we mean that you are looking down on to the top of the optic and if you did this at night you would see a beam of light coming from each panel and sweeping across the sea. Except, of course, if the transmission factor (T) – see page 7 equaled one or zero, if T = 1 – think about it – light is invisible! If T = 0 then the fog is pudding thick!

A visual aid I use when lecturing on lighthouses, and on group flashing in particular, is a cork and six needles. The cork is the optic the needles the beams of light. The needle can be inserted in different positions to indicate the character we require.

In Fig 10, I show two alternative arrangements of panels – (A) is the minimum number of panels and (B) double that number.

Additional information is a rough elevation of the panels: the speed of rotation of the optic; the ratio (A) to (B) of the candle power of the panels and a note on the Blondel – Ray factor.





$$\frac{\text{Candle Power } I_{0}A}{\text{Candle Power } I_{0}B} \simeq \frac{2}{1}$$

Fig. 10

Quintuple and Sextuple Flashing

Such optics are invariably of the A type and are incidentally quite rare. However Hartland Point – see sketch on Page 10, was a biform sextuple flashing light of handsome appearance. Quadruple flashing optics are usually of A type.

The large numbers of panels of the B type must be very narrow and so of such reduced power. Worse still from the mariners view point is the dangerous shortening of the long dark period. He could possibly misread the character. The Ashrafi optic shown on (Fig. 11, Page 15) was very unusual with a 3:1 character.

To summarize – given the character of the light; the height of the focal plane above sea level; the value of the transmission factor and the type of illuminant we have seen the steps that must be taken to design the optic: The most beautiful? – The big oyster shape.

Building the Optic

First a story, of the 'dangers' of short cuts in describing, for example, the reflectors. I was in the lighthouse at St. Catherine's Point on the Isle of Wight puzzling out an electric rewind for the clock when the Principal Keeper (P.K.) arrived with a posse of visitors. The P.K. in his 'talk' said "These prisms are called reflectors because they reflect the light back to the electric lamp. He must have heard my eyebrows shoot upwards for when the next visitors had assembled he fished me out of the entwining pedestal and announced that a Mr. Cooper, of the makers of the light, knew a lot more than he did about optics – so over to me! Later we became firm friends and with my wife was able to visit his home (right below the light) and see the light around midnight and on another occasion to get our ears blasted off by the Trinity House designed fog siren.

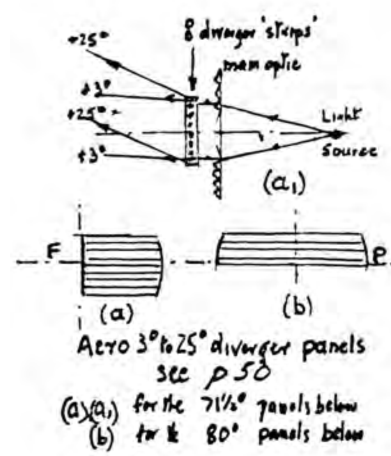
Late in World War II we were deeply shocked to hear that a German sneak raider had dropped a bomb on the engine room and killed him and two other lightkeepers. The Sun King turned in his grave."

Following a request from the present keepers of St. Catherine's Lighthouse, a commemorative plaque will be placed in the base of the tower to record the deaths of:

P.K. - R. T. Grenfell
A. K. - C. Tompkins
A. K. – W. E. Jones

On 1 June 1943

If you will look yet again at Fig. 11 (below) – The Ashrafi light, you will see that for handling, the panel is divided into sub-panels or frames (the flat bronze bars forming the frames are termed 'racks).



The frames are mounted on a table carried by an elevated platform in Chances main fitting shop adjacent to a very large plate glass window. About 200 feet away a small electric lamp is suitably mounted on a rotatable bar so representing an artificial horizon. On the vertical axis at the optic is a sharp pointed rod, the point being a very small distance above the focal plane (See Page 7) with a prism threaded through the racks, the position of this prism is shortly adjusted until the image of the small lamp 'sits' on the sharp point of the rod. This ensures that it's little bit of the total beam is directed to the horizon.

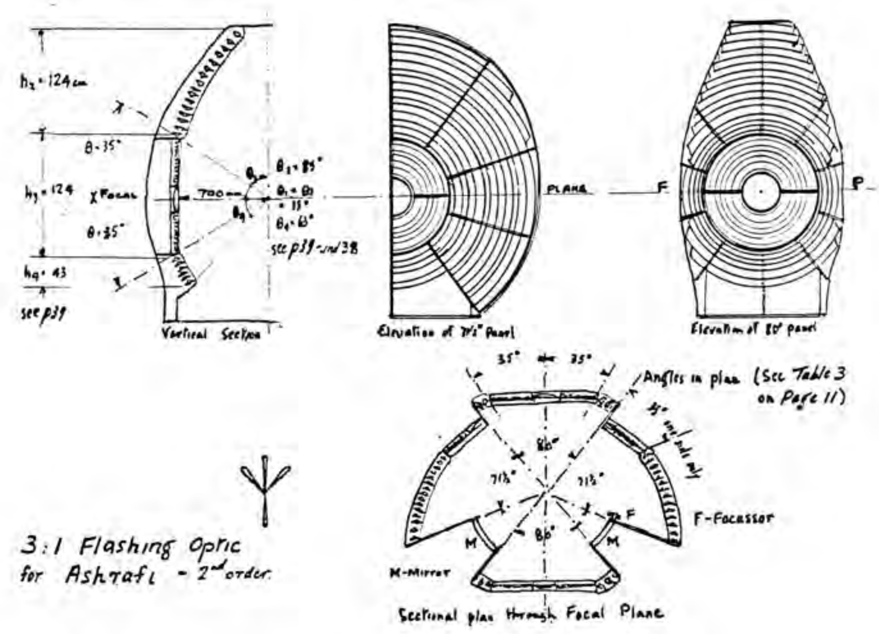


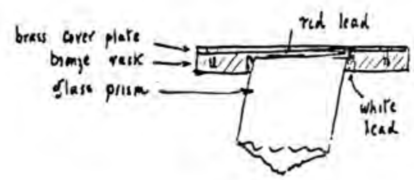
Fig. 11

The prism is then held in the racks with small wooden wedges and when all the prisms have been so adjusted and wedged the frame is removed and sent to the optic fitters.

In one wing panel alone there are 6 frames and 77 pieces of prism! So building an optic is painfully slow and very expensive, but when all the frames are fastened together to form a panel and, in turn, all four panels are assembled, we have a very good looking optic.

Little wonder that when the electric lamp as an illuminant reduced an optic from, say, 1st order to small 3rd order or even a 4th order. Lighthouse Boards the world over heaved a sigh of relief.

The wee sketch shows how the glass prisms are 'cemented' into the racks so forming the frames of the optic. Red led is chiefly used, but the inside is finished with white lead. The brass cover plates running the whole length, and the width, of the bronze racks are secured by screws.



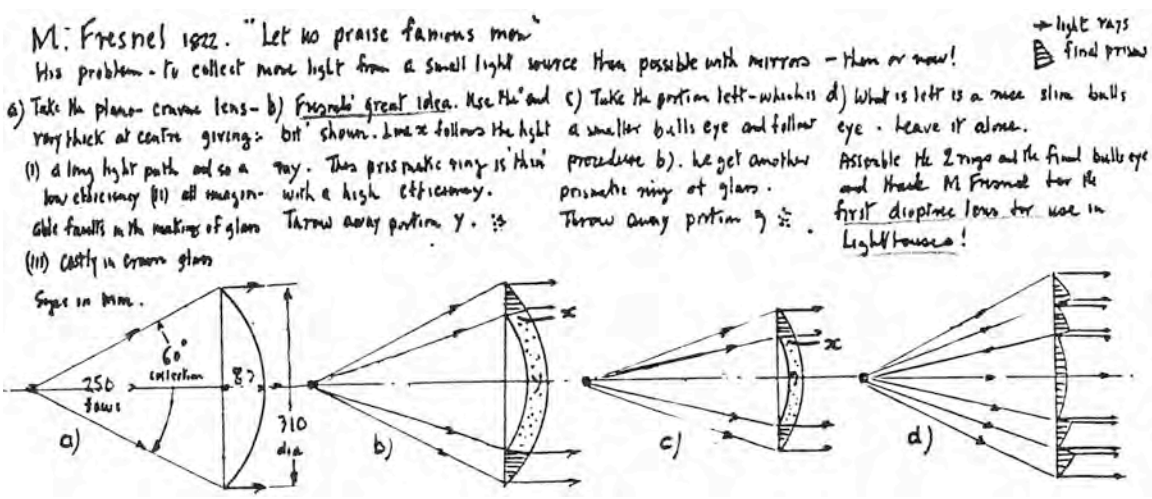
When completed each frame is a work of art embracing the skills of many craftsman, the detail draughtsman, the pattern-maker, the foundry molder, the glass maker, the glass molder, the glass grinder and the various optic fitters.

But as I write this, optics are being made of plastic! Good grief!

Summary

We have been immersed in optics for some considerable time and although we still have to do fixed optics, a change seems advisable.

In the next chapter we will look at illuminants such as wick lamps, petroleum vapor burners, fish tail burners and electric lamps.



4 Illuminants

"We sailed then by Beachy, by Fairlee and Dungeness, then bore straightaway for the South Foreland light" - the Spanish Ladies

Wick Lamps 1782 – ca 1900

I saw but one multi-wick lamp in for repair although it was difficult, even in the 1920's, to see it going back into service. Perhaps as a treasured relic in the office of some Lighthouse Board.

It was a masterpiece of sheet metalwork with eight concentric wicks, all individually adjustable for height. The flame was of eight shells of translucent flame of incredible size and constrained by the chimney glass. An exquisite sight when burning.

Single circular wick lamps were however usually supplied as a standby illuminant for P. V. Burners. The faulty burner, however ho, could be quickly disconnected and removed and the wick lamp dropped on the burner support plate. I found however that most Principal Keepers detested their light working at a reduced candlepower, and what a drop it was, and preferred with but little extra delay to put in another P. V. Burner with its mantle already 'blown'.

Petroleum Vapor Burners 1898 – ca 1960

Fig. 12 gives an impression of such a burner with its air and oil containers and a few bits and pieces.

The oil, which has a close flash point of 155°F or 68.5° C, is forced into the vaporizing tubes below the burner via the regulating valve. The oil is vaporized and emerges from the nipple as a fine spray, and passes into the burner together with the in-drawn air. The mixture is consumed inside the mantle, which is made incandescent.

When working, the heat for vaporization of the oil is supplied by a built-in Bunsen tube positioned beneath the vaporizing tube. Initially the heat has to come from a spirit lamp using methylated spirit.

I am sure my rough sketch of a 55mm burner gives no impression of the handsome looks they have. The outer parts are of cast brass or brass sheet. An impressive supply of "tools, etc" includes cleaning wire and a scraper for cleaning the vaporizing tubes and a pricker for the nipple.

Incidentally the later explains why the clock driving the optic runs only for one and one-half hours per re-wind. Despite all efforts with straining the oil these burners do occasionally require pricking which means it is essential the keeper is in the lantern at least every one and a half hours!

Dr. Hampton in his tests on the Hartland Point panels also used the standby, a 55 mm P.V. Burner, with interesting results on the functioning of a (gas) mantle. The three sketches show the aspects of the mantle from three viewpoints. The two lower graphs are vertical polar diagrams of candlepower and brightness. The uniformity of candlepower from +60° to -10° is just what is required, the peak value being 1140 candles on the focal plane. From - 40° the fall away is severe (400 candles at -70°). The brightness varies considerably being 30.2 at +60º, 39.1 at 0° (on the focal plane), a peak of 47.7 at -40° and 46.0 at -70°. The high values at the bottom end are due to the near proximity of the Bunsen flames inside the mantle.

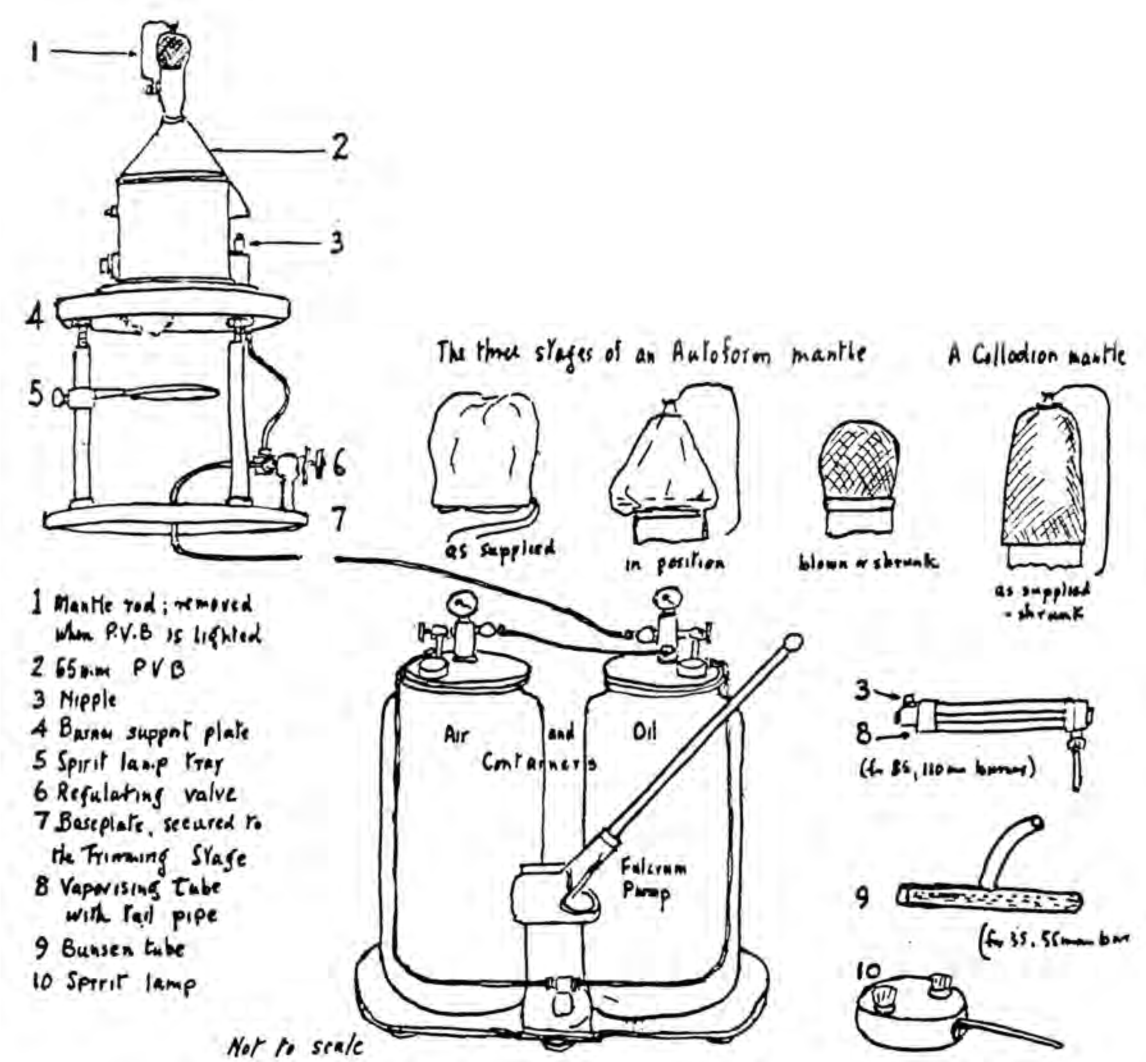


Fig. 12

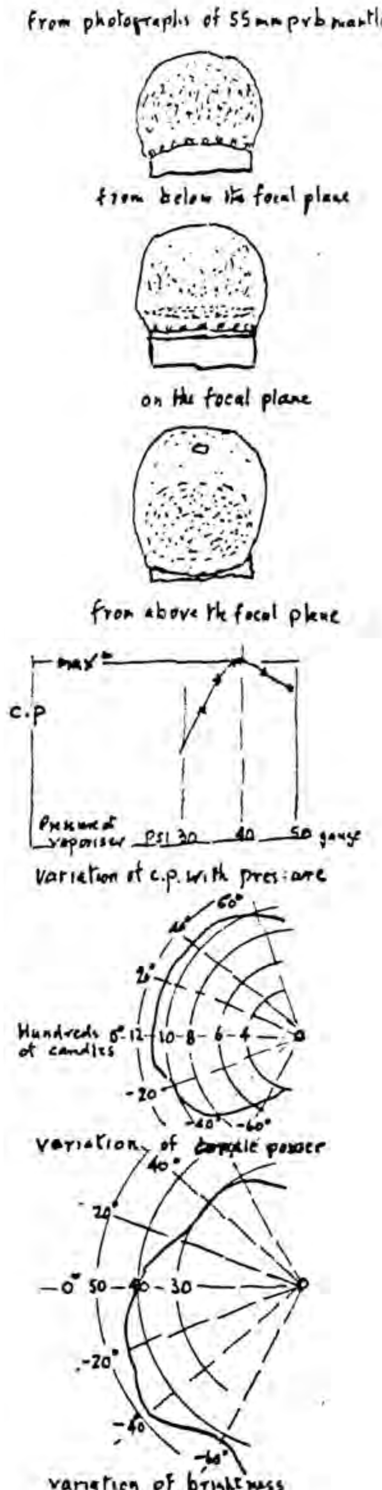
The remaining graph is of candlepower against pressure in the vaporizing tube and here a test pressure gauge was inserted between the regulating valve and the tail tube. Dr. Hampton remarks "the pressure is controlled by the regulating valve and is independent of the container pressure, provided the latter is high enough – the maximum candlepower occurring at 40 pounds per square inch gauge." Later we will attempt a calculation showing what the load is on the keeper to preserve the 40 psi.

A Miracle?

The penalty of avoiding "quantity of light" is that sooner or later someone is going to ask "We start with a 3000 cp. burner and finish with four beams each of 600,000 cp. how come? It looks like a miracle! Let us imagine the burner only at the center of a huge sphere of light – impressive, but of no use for signaling long distances. Now let us by using surrounding prisms squeeze all this light into, say, four narrow pencils of light. Surely we would expect great concentration of light in these beams, that is, greater intensity, and so a greater luminous range. Far from conjuring up more light we know we have lost a great deal in absorption - and in not being able to collect all the light from the burner.

Air and Oil Containers

Each of the containers shown in Fig. 12 is of ten gallons capacity. Of the oil in the right-hand container 7 gallons would run a 110mm burner for 18 hours leaving 3 gallons as a necessary reserve. The fulcrum type air pump was far less arduous than the older 'up and down' type.



* The above sketches are taken from Dr Hampton's paper "An investigation into the beam from a standard lighthouse Lens" given in 1928 to the Optical Soc.

The job of topping-up the air pressure to maintain 40 psi at the burner, after a refill the air in the left hand container will be 1.61 cubic feet. Chances require a max pressure of 70 psi gauge and a minimum of 60 psi. Consider an 85 mm burner using 2 1/4 pints per hour and a four hour run. The extra air space would be 1.13 gallons or 0.18 cu ft. Hence total air space = 1.61 + 0.18 = 1.79 cu ft.

This means that when using an 85 mm P. V. Burner the keeper must re-top the air every 4 hrs. Other times can be found from Table 4. This Table gives the candlepower, the average brightness and the oil consumption for the P. V. Burners made by Chance Brothers.

P. V. Burners were first made with Collodion mantles – see Fig. 12, as indeed in household lighting. Except for the Calcutta Lightships - see page 61, they are no longer in use.

The Autoform mantle was introduced by D W. Hood, then Engineer in Chief of Trinity House. Its main advantages being: greater brilliancy, a near spherical light source, the mantle rod can be removed immediately, the mantle is 'blown' or shrunk and most importantly, it never arrives at the lighthouse shattered, the fate of many Collodion mantles.

Autoform Burner size (Base dia. of mantle	Candlepower (Candles)	Average Brightness (Candles per sq cm)	Consumption of oil per hour (pints)	Duty for the consumption of 7 gals. (hours)
110 mm	3010	39	3·00	18
85	2500	45	2·25	24
55	1205 *	49 *	1·31	42
35	612	40	0·67	83

* These figures should be compared with those given in Page 18

Table 4

Mr. Hood also designed a P. V. Burner which whilst the same in principle as Chances it looked much different. The outer parts were made of cast iron that nested together (that is no screws) which made the morning dismantling and cleansing of the various parts much easier for the keeper.

A story from World War I;

Chances received orders regularly from all over the world for spare parts and tools for P. V. Burners - the individual quantities were of course, quite small. Imagine the surprise when the Turkish Lighthouse Authority ordered enough nickel gauges and nickel mantle rods to last them 200 years or more! Someone at Chances was awake and so Germany did not get the nickel she needed!

Electric Lamps

By 1935 the reliability of electric lamps and generating sets (and for that matter the reliability of a mains supply in the remote places lighthouses are usually to be found) had reached a stage at which Chance Brothers, and others, were prepared to recommend them to Lighthouse Boards.

The advantages of the electric lamp lay in the great brilliance or brightness, around a thousand candles per sq. cm., which meant that much smaller optics could equal or even out-do the big optics. The door was opened for automatic, unmanned lights. With the coming of the electric lamp Southwold Lighthouse went ‘unmanned’ in 1938.

The Board of Trade in 1975 suggested to Trinity House that they should consider women keepers. Trinity House replied; “It is just not conceivable!!”
The disadvantages are: the smallness of the filament resulting in a fall off of light output, particularly if a P. V. Burner is being replaced by an electric lamp in a big optic, the comparatively short life of a gas filled lamp, 600 hours for large lamps to 800 hours for smaller lamps, the lack of homogeneity of the groups of filaments, and in these days when half hearted cries go round “to save energy” the sad fact is that the optic designer no longer endeavors to collect as much light as possible, but is content to use a ‘bull’s-eye’ plus a few refractors or a mirror with a small lamp thereby ensuring that two-thirds of the light output is wasted. However, there are only some 17,000 lighthouses in the world, so throw it away!

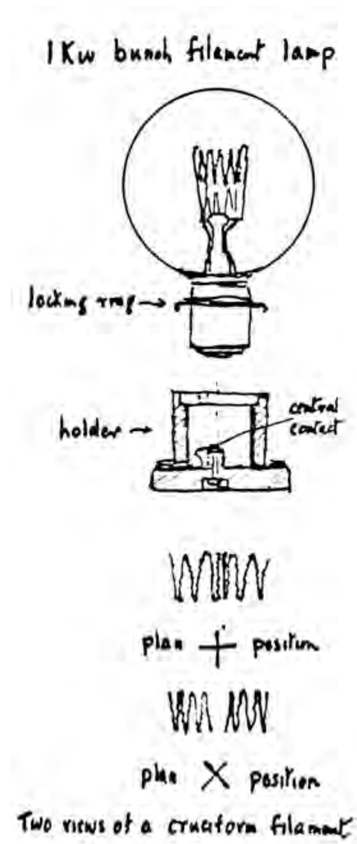


Fig. 13 shows a bunch filament lamp of 1000 watts 230 volts with a pre-focus cup and holder. By pre-focus is meant that the makers will finally position the locking ring relative to the center of the filament. One can only hope that the bottom central contact of the holder has a good margin of vertical travel. It is very annoying when the lamp will not go in the holder! Also shown is the cruciform filament of a 3kw lamp used in the Hartland Point light. The + view shows an ‘open’ filament; the x view two solid areas.

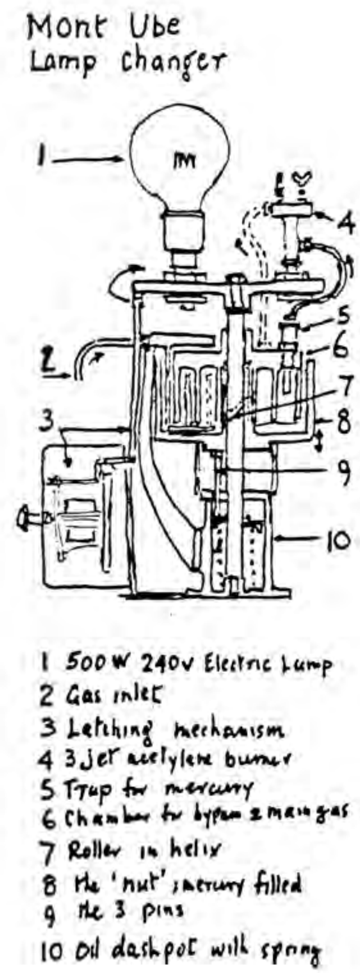
To increase the life of a lamp one can, for those of small wattage, use a 10% shunt, which softens the initial shock when switching on. For 500 w or above it is best to ‘under-run’ the lamp. For example, the 500 w 120 v lamp for Fort Cornwallis Lighthouse, Penang has a transformer to get down to 375 w 90 v. In general a voltage of around 100 gives a higher current and so a thicker filament. Discoloration of the bulb is best dealt with by scrapping the lamp after a certain number of working hours and not waiting for it to ‘blow’. The Table of Fig. 13 gives ‘typical lamp characteristics’

Rating	Filament			Horizontal Candle Power	Brightness Candles / sq cm	Life hours.
	Form	Height cm	Width cm			
3 Kw	Cylindrical	1·3	3·9	4700	970	600
1·5	"	1·3	2·6	2400	750	"
1	Bunch	1·58	1·8	1700	610	800
500 W	"	1·1	1·6	890	500	"
250	"	0·9	1·4	400	320	"
100	"	1·0	1·0	100	100	"

Focusers – see page 7

Fig. 13

If the optic can be revolved around the lamp or lamp changer then one focuser is sufficient to set the center of the filament the necessary distance above the focal plane. If the lamp changer is in such a small optic that it must revolve with the optic then cross sighting calls for two focusers. They are merely small telescopes with a graticule. Fig. 17 shows a focuser alongside the mirror of the Ashtafi Light. After initially setting a pre-focused lamp in its holder, the focuser is used only occasionally as a check. Valuable because of the small height of the filament.



Part Fig. 14

Lamp – Changers

Why are these needed? Take a large light with a 3kw lamp using mains supply. The standby is a 55 mm P.V. Burner and the lighthouse is fully manned. Fair enough, no lamp changer. If you can afford a few minutes to put in the P.V. Burner on a mains failure then you can afford even less time to replace a blown lamp by hand.

A second example. A lighthouse attended only for an hour or two every morning - mains supply with a fully automatic standby generating set. Certainly a two lamp changer is required with adequate warning so that the part-time keeper will know the reserve lamp is being used.

Another example. A completely automatic light visited but occasionally by an engineer. Certainly at least a two-lamp changer but what if the mains fail and the automatic set also? You have two choices: first a one lamp plus one acetylene fish-tail burner (or an acetylene mantle burner): secondly, if you don't like running with much reduced luminous range, then go the whole hog and have a two lamp changer plus the acetylene burner. But again you need a local person who will respond either to visible alarm signals or who will accommodate alarm signals in his home and who will notify the Authority immediately.

After the removal of the arc-lamp (the last one in Great Britain), at St. Catherine's Lighthouse had a '2 lamp + fish-tail burner' lamp changer with mains supply, and this although the station was fully manned. Trinity House did, however, use St. Catherines extensively for testing new equipment. I recall a B.B.C. broadcast saying that St. Catherines was working with much reduced power. In a windstorm a tree had fallen across the mains cables, so the acetylene burner had taken over.

In an unattended station it is very annoying if the mains go: number one and two bulbs run through and the acetylene burner is then lighted and within a minute the mains supply is restored. A changer that rewinds back to No. 1 lamp is required, and is very complex. Chances made one for test purposes but, I think, not pursued.

Lamp changers come in two types, 'rotary' if there is space for the lamps to rotate inside the optic or 'tilting' if, for example, the changer is inside a 4th order bi-form optic and just cannot revolve.

Design of lamp Changers

In the early days we used gravity to move the lamp table. This was particularly easy with the tilting type and for the rotating type we used the nut and screw type. Imagine a heavy loose fitting nut on a screwed rod. The nut can fall under gravity but is prevented from rotating, so the rod revolves and turns the lamp table!

The Mont Ube Changers

This is shown in some detail and is one of my earliest attempts. No safe flexible piping was available so with some misgivings a decision was taken to use a mercury seal for the main and bypass acetylene supplies.

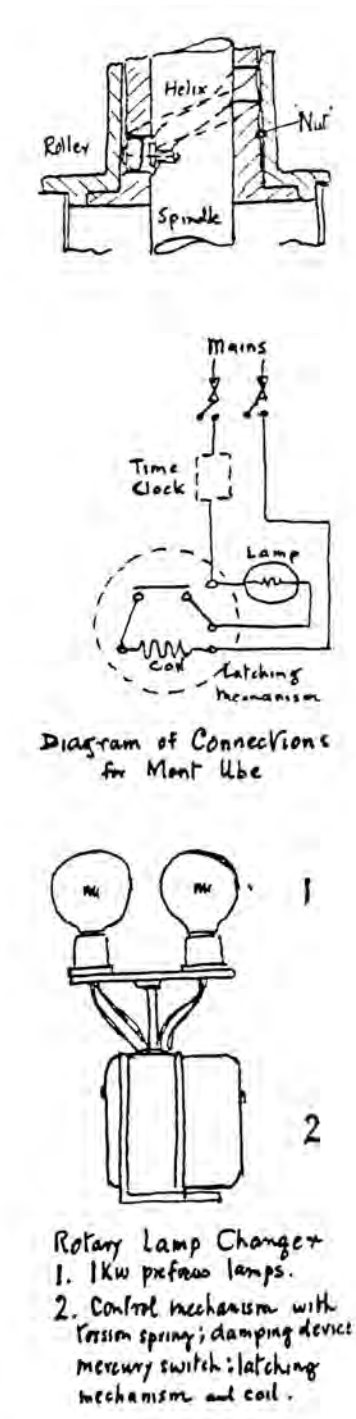


Fig. 14

Fig. 14 refers. The 'nut' is the lower half of the seal and the helix cut into the bush and the three pins entering the dash-pot can, when the latch is released, turn the spindle through 180°. The screw thread is but a small roller working in the helix (see enlarged view). When the lamp fails you will see from the diagram of connections that the series coil is de-energized and the coil arm falls away. In doing so it pulls the small bell-crank lever which in turn pulls the vertical latching rod down until it clears a stop peg on the lamp table. The 'nut' or the lower part of the seal can now fall and in doing turns the table though 180° at which instant the rod gently hits a longer stop peg. The acetylene burner is now in focus and lights up. How?

Gas for the two bypasses is unobstructed in its flow through the seal whereas the main burner gas cannot flow until the 'nut' has fallen sufficiently to clear the bottom of the small tube, which in the outer chamber dips below the mercury. While mercury does not 'wet' a surface it loves to leave behind a number of minute balls of mercury, in this case, at the inlet of the small tube. So the rush of gas promptly blows these upwards. Fortunately, the mercury trap did its job since the thought of one minute ball filling the equally minute gas holes in the fish-tail burning was quite appalling. Unless acetylene burns correctly it can be a magnificent maker of that filthy stuff 'carbon black' – pounds and pounds of it!

To reset, after the blown lamp has been replaced, the table is turned by hand back though 180° and the control knob pushed in.

Rotary Lamp Changer with Two Electric Lamps

This simple changer is shown in Fig. 14. Instead of gravity a torsion spring is used to rotate the lamp table and a neat nest of small gears turning an air vane is used to damp the motion and so prevent damage to the filament of No. 2 lamp. Also instead of a mechanical switch to light up the second lamp a mercury-tilting switch is used. Oil impregnated brass bushings obviate the need to lubricate the spindle bearings. The lamps take 1 ½ seconds to change and re-setting is a simple manual operation.

Mains Failure – Alternatives

Battery supply: a) The two lamp rotary changer above could have a No. 2 lamp specifically for a battery supply which would come in if No. 1 blew or the mains failed. b) A small 'fixed' dioptric light suspended from the lantern roof (immediately above the main optic) could have a lamp fed by a battery with the lamp coupled to a flashing mechanism giving the same character as the main optic. See Fig. 30, page 39. We shall discuss later under "Energy sources' the generation of electricity at the lighthouse either in its own right or as a standby if the main supply fails.

Fish-tail Burners

I imagine that the fish-tail burner is as old as the first supply of town gas but nevertheless it is still a feat of engineering that the two very fine jets of gas emerging from the burner should impact together so perfectly that a perfect fish-tail shaped flame is produced. Several gases will so burn with a brilliant white light but Chances used acetylene only. Chances made flashing mechanisms (flashers) using such burners as did the famous Swedish firm of AGA (see page 23).

Burners can vary from one fish-tail burner to a cluster of nine and all require from one to three pilot lights, or bypass lights, which are of course a small pea size flame requiring a good ventilation system if they are not to be extinguished.

The following consumption figures are at 4 inches water pressure and 60°. In single burners the smallest consumes 10 liters of acetylene per hour and has a flame width of 14mm. The largest uses 35 liters per hour with a flame width of 43mm.

Clusters of Burners:

The smallest two 20 liter burners with two bypasses and a maximum flame width of 40mm; a fairly large cluster five 25 liter burners with three bypasses 66 mm wide. Fig. 15 shows the Mont Ube burner head. For Calculations of candlepower (see page 45)**.**

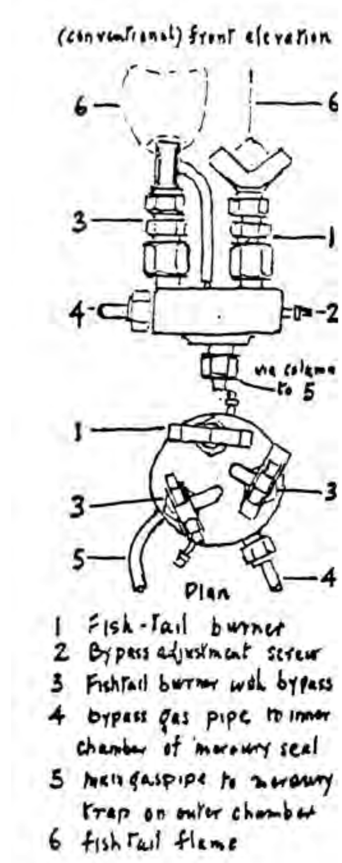


Fig. 15

I would here like to pay a sincere tribute to the late Dr. Dalen. He was for many years, managing director of AGA Ltd. of Sweden – a great scientist and engineer. At the remarkably young age of 24 he was a Nobel Prize winner for Physics and although blinded shortly after by an acetylene explosion continued, all his life, to invent and produce, among other things, flashers, burners, light valves and optic drives for lighthouses. AGA products, in automatic or unattended lights, were indeed the 'Rolls Royce' in quality. A great man and what a competitor to have!

The Electric Arc Lamp

We record this solely because we had the pleasure of meeting at, yet again, St. Catherines, Isle of Wight the last of the steam knowledgeable Principal Keepers.

Arc lighting resulted from the cooperation of Sir James Timmons Chance and Michael Faraday. They decided to try the then new electric arc lamp and although one worked at St. Catherines for many years it was not, in the light of subsequent research, a great success. For example the brilliant white craters of the positive carbon are only really useful if set up at the focus of a very large mirror of, say, a search light. Faraday was compelled to use a 'flaming' arc (by adding certain 'salts' to the carbon) since the optic surrounded the lamp. Even with this it was a small light source in a large optic.

A minor trouble I experienced was the very hard carbon dust that fell from the carbons and then found its way into the driving clock. The dust gets pressed into the gunmetal gear wheels and forms a perfect lap that plays havoc with the steel pinions.

However, back to the steam generated electric supply for the arc. The boiler was inclined with the horizontal steam engine under it. From this a belt went right across the engine room to drive a generator which looked mighty old. It had in fact been exhibited at the Great Exhibition of 1862. Bare copper strip carried the electricity up the tower but more impressive were the voltmeter and amp-meter. Lovely dials with porpoises, whales, urchins, sailing ships etc.

To conclude: We shall deal with the supplying of energy to the various illuminants in Chapter 17.

5 Pedestals

Pedestals support the revolving optic. Until just before the turn of the century the lot of the lighthouse designer was indeed a hard one: His only illuminant was a multi-wick oil lamp which (certainly has a tremendously wide flame) was one of low brilliance. In turn this meant a Big Optic often weighting many tons and with but a roller bearing, meant, even with a very large weight driven clock, a slow speed of rotation of the optic. Resulting from this was a multi-sided optic with narrow panels giving a small stationary intensity Io, which was, however, not greatly reduced (to Ia) since the speed of rotation was small.

From the mariners viewpoint he saw but few flashes per minute, which for sailing ships was satisfactory, but with their increased speed, steam ships had little time for evasive action.

Fig. 16 is a sketch of the 1869 Wolf Rock light which was a 1st order (920mm focal length) single flashing, red and white. You will notice that alternate panels are about double the width and carried red glass shades (only one set is shown). The upper reflectors again appear to double the others in width – ingenious, but confusing! The pedestal is completely filled with a clock of awe inspiring complexity.

It would help later when considering (page 41) “loss of intensity of colored beams” to find an approximate value of the ratio of the frontal area of the red panel to the white panel, which turns out to shoe that 2.7 times the size is needed for red.

So the P. V. Burner coupled with the Mercury Float pedestal (at the turn of the century) whilst still requiring big lights resulted immediately in larger optic panels and hence larger Io’s at higher speeds of rotation and most of all in the introduction of Group Flashing systems of greater complexity.

The Mercury Float Pedestal

Fig. 17 names the various parts but first the theory of mercury flotation.

For a body floating on a liquid the friction at very low speeds is itself very low but builds up due to wave formation at higher speeds. Since an optic does not exactly tear along we have in mercury, although very expensive, an almost frictionless medium.

Now to Archimedes: “the weight of liquid displaced equals the weight of the floating object”.

Let us now take the two ‘U’ sectioned rings, the trough and the float. Machine to a fine polish the inside of the trough and the outside of the float leaving between them a 1/8 inch to 5/32 inch gap.

If mercury weighs 49 pounds per cubic inch then the floating weight that can be supported can be up to 6.7 tons.

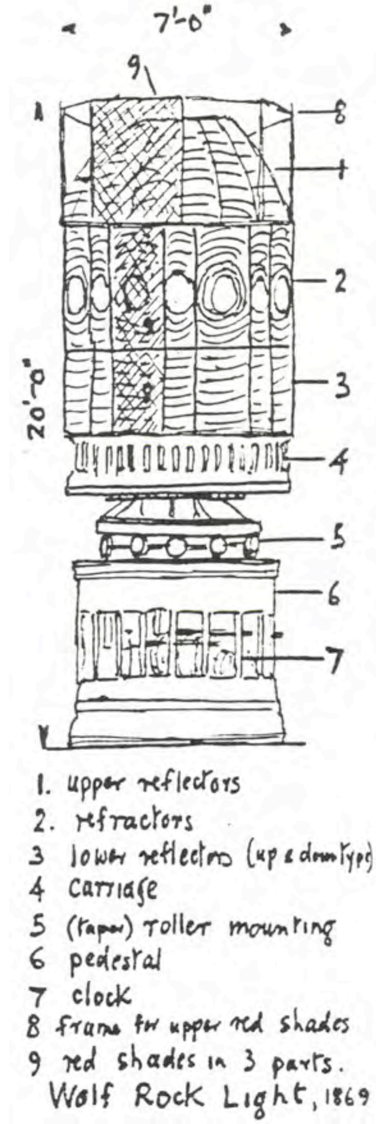
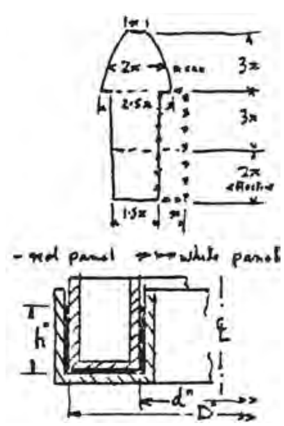
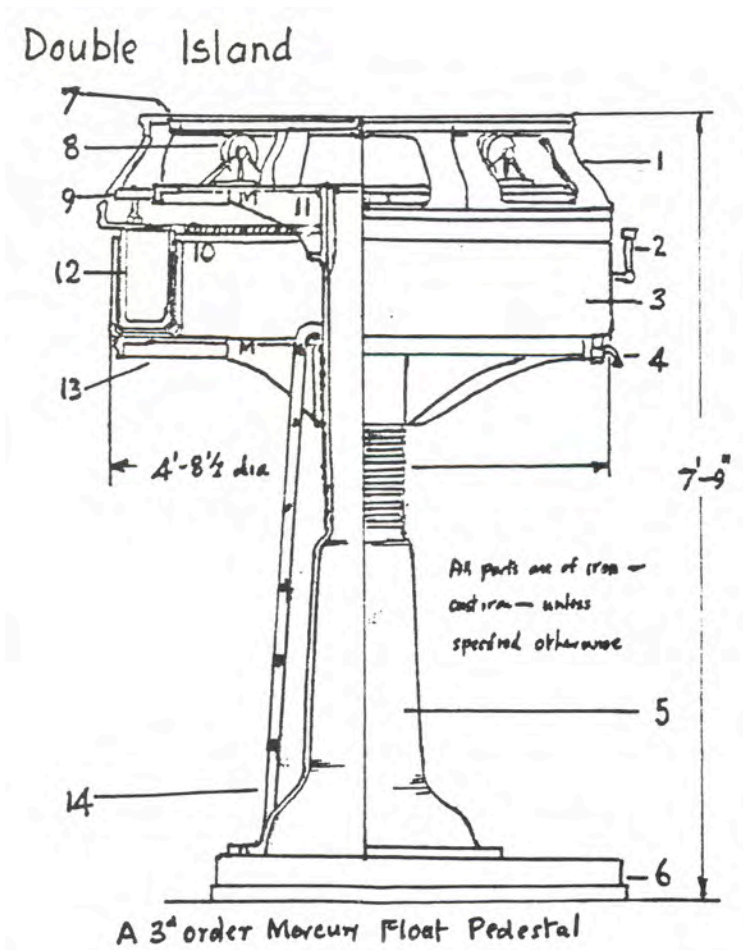


Fig. 16



Part of Fig. 17

On a production note the castings in iron for the trough and float present one major difficulty, a porous patch or two. Such a patch is far from obvious even after the machining is completed and a lot of money is spent on this. So after machining an area of the shop was cleaned and laid over with brown paper. The trough is lowered on this and sufficient mercury is poured in to get a full head when the float in turn is lowered in and then weighted to the calculated floating weight plus. An anxious period of up to a week follows with an equally anxious search every morning for tell-tail balls of mercury on the paper or inside the float, if so either one or the other or both are scrapped.



Pedestal parts

1 Carriage for the optic
2 Mercury filling valve – steel
3 Trough
4 Mercury Draw off valve – steel
5 Column, square threaded
6 (Banjo) Baseplate – to take the clock
7 Steel ring for the vertical rollers
8 Vertical rollers
9 Horizontal rollers
10 Race wheel (and internal gears) Gun metal
11 Trimming stage
12 Float
13 Table for the trough, square threaded
14 Steel ladder, removable
M – manholes in 11 and 13

Fig. 17

Design points in the Chance Brothers pedestal:

The horizontal rollers (9) by lightly touching the trimming stage center the float in the trough. The vertical rollers (8) have a dual purpose: a) although the optic is carefully balanced the little residue will be taken up by a roller or two as the carriage revolves b) if the lighthouse is situated where the atmosphere is not all that clean it will be necessary, say, every fifth year to draw-off the mercury and filter it through a chamois cloth. The opportunity is usually taken to examine the surfaces of the trough and float. Cleaning and re-lacquering may be required. Choosing a longish day in the year the ladder and vertical shaft are removed and the trough table turned down with a tommy bar. Since the mercury is already drained away the optic, carriage and float are resting on the vertical rollers-their second purpose. Gearing (10) with this is the race wheel pinion secured to the vertical output shaft of the clock (see page 33). The upper bearing for this shaft is usually attached to the trimming stage. The trimming stage (11) can be reached through the two manholes shown.

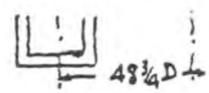
The Table to Fig 17, now given, is from a table, dated 1912; Chance Brothers pertaining to 3rd order mercury float pedestals.

Seconds for one rev. of the optic		Total floating Weight in lb.	Driving Weight of Clock			derived by author
			How looped	Falling speed in ft per min	Actual weight in lb	Driving weight reduced to "direct fall"
10	(1)	3488	not – 'direct fall'	0·375	386	386 lb.
10	(1)	3945	twice	0·093	1367	342
15	(1)	3213	once	0·187	441	220 lb
15	(7)	2977 to 3066	once	0·187	416 - 418	208
20	(1)	4259	once	0·187	377	188 lb
40	(1)	3036	once	0·187	253	126 lb
40	(1)	4408	1½ times	0·130	396	132
60	(1)	3800	twice	0·093	372	93 lb.
90	(1)	3116	once	0·187	125	63

Until we deal with the driving clocks we will note the increase of driving weight with speed of revolution of the optic – Columns 6 and 1 and calculate the minimum amount of mercury required for the heaviest and lightest floating weights (Fig 17 shows the 3 revolving parts are the optic, carriage and float).

b) Given the diameters of the float are 54 ¾ inches outside and 42 ¾ inches inside for all the above cases. The area at bottom of float = 910 sq. m. To give a depth (head) of mercury of 10 inches we get:
Heaviest = 4408 lb. of mercury
Lightest = 2977 lb. of mercury

Fig. 17, which is to scale, would not accommodate this. So both float and trough must have been specials. The minimum weight of mercury required for flotation:
Heaviest = 256 lb.
Lightest = 188 lb.



Other types of mercury float pedestals

The small Chance type suitable for small 3rd order optics Fig. 18 refers. The principle is identical with the larger type, but the float is stabilized by two small ball journal bearings; and the floating weight, when cleaning the trough and float, is taken by a small ball thrust bearing. You will see that the race wheel is now an external gear.

The Trinity House type for 1st and 2nd order optics.

Chances have made these handsome pedestals for many years for the England – Wales coasts and, for example, for the Bahamas Islands. Having praised their appearance let me say they have only one other advantage namely they are low in overall height which can help if the lantern murette (see page 72) is also low in height.

Other use, and to use modern words, they are ergonomically lousy! The machine does not match the man. See two of the stories below!

To clean and inspect the trough and float (which are inside the main columns) requires, with the jacks in position, removing the bridge brackets and the two winding shafts of the clock, which in turn is buried in the middle of 2 columns! To adjust the speed of rotation, the control screw of the clock governor is near base plate level. To get at it requires winding ones self, face down, through the columns and finally trying to hold a mirror (to see the screw) and a screwdriver in the left hand!

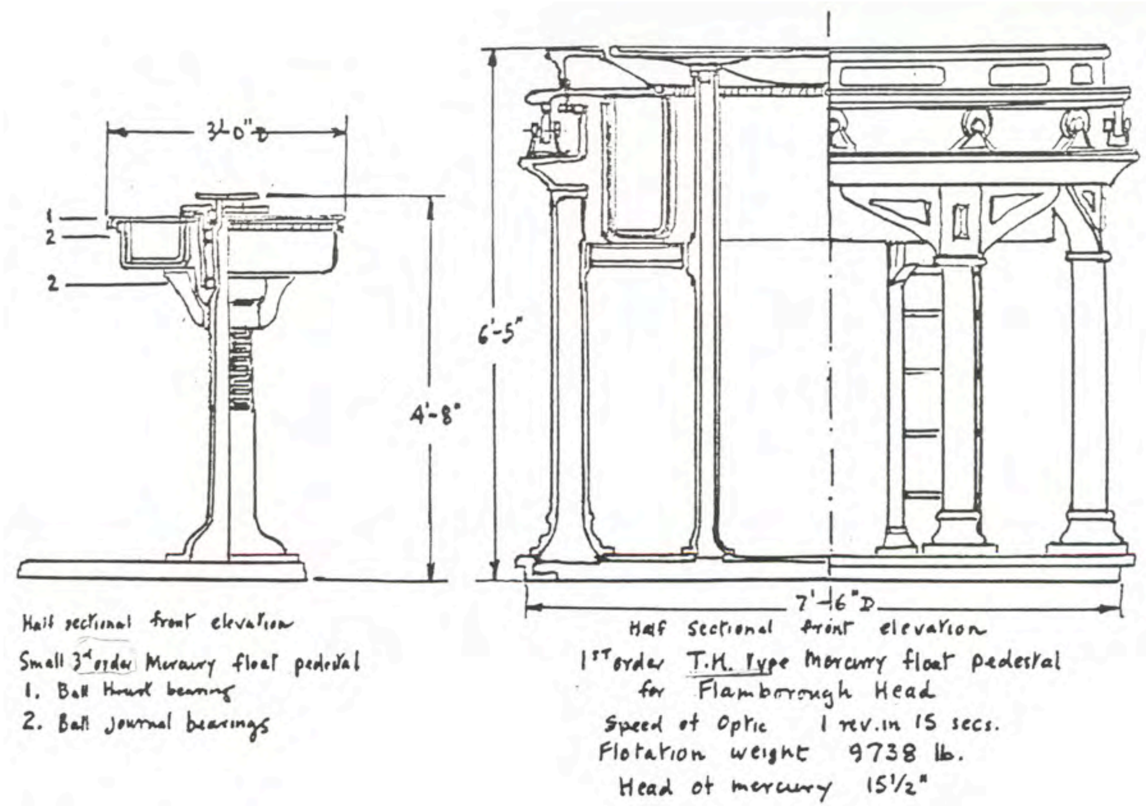


Fig. 18

The Hartland Point type

Being of tender age my only work for the Hartland Point light was a collecting gear to transmit current to the (revolving) top electric lamp. I had thought the pedestal was designed specifically for Hartland (see page 10) but the huge light sketched on page 9 completely disproves this. Indeed it now seems possible that the very first mercury pedestal was of this type. You can see that the float and trough are outside the columns and so cleaning presents no problems as the brackets supporting the trough can be swung away.

Hartland is not good looking. A bi-form lens demands an extra large trough and float – having to float in effect two optics. It makes the pedestal look very spindly and small.

Trouble!

After a spot of trouble with the porosity of a trough it was decided to fabricate (that is welding steel plates together) the trough and float. Just bending, cutting and welding was bad enough but, when under pressure, every inch of the 30 ft or so of welding just oozed mercury! For two weeks the main shop echoed with the din of peening hammers bashing away at the welding. It worked, but never again did we use steel!

Erection at site

For the assembly of pedestal, clock and optic the erector is usually faced with building a cat-head for the lift of 100 ft or so and removing a section of the lantern framing and glazing. You will see from the figures I gave for a 'biggish' light that whilst we may get away with the one ton float the column and trough are often to heavy. It is not unusual for Chances to be asked to make the trough in halves and the column in two portions.

New optics and pedestals were often too high for the existing lantern murette and for example, three foot high blocking plates (sometimes glazed) had to be inserted immediately underneath the glazing. This involved more complex scaffolding and pulley blocks to lift in one great piece the gallery and roof of the existing lantern – a stinking job particularly in a hurricane area. The erector in charge kept his hurricane map up to date and prayed a lot. (See Fig. 64 page 72)

Some weights: Optic 6440 (but made in many frames) Trough 2780, Column 2660, Float 2250, Carriage 1870. Trimming stage 1690, Column nut 1600, Baseplate 1430 lb.

Access to the burner or lamp changer:

It will be obvious that for the smaller pedestals and optics, that access to burner or for cleaning the inside of the optic glass is impossible and an optic panel must be hinged to make a door that can be opened outwards. It is a nice piece of solid geometry designing the frame but with a hundred years of experience behind it! One of the panels marked (3) in the sketch of Wolf Rock 1869 just had to be hinged to get a Keeper inside the optic. (See Fig. 16, page 24)

Quicksilver tales:

1. A demonstration given by a keeper to a posse of visitors. A household pin is pressed against the carriage and, hey presto, a few tons of optic is rotated smoothly without bending the pin!

2. Bill Richey, my old chief, told an amusing story on how the Chance square threaded column came into being. It seems that around 1900 he was called to Dublin to discuss a new light with the Chief Engineer of the Commissioners of Irish Lights. Richey proposed a multi-column pedestal somewhat as the sketch on Page 10, but this design necessitates, when cleaning the float and trough, the use of three long screw jacks under the trough, and these have to be operated somewhat in unison by the three keepers. Richey was startled when the Chief Engineer indignantly demanded where three keepers, all sober at one instant, might be found. So poor Richey was told to go back to England and design a pedestal assuming one sober keeper only! Hence the screwed center column, which whilst the table has three holes for tommy bars could at a pinch be lowered with the aid of one sober keeper with one tommy bar! This type of pedestal subsequently became the standard for Chance lights.

3. The purchasing of mercury at Chances was a job for the departmental director who was deemed to know the metal market well. It was purchased for stock in fair quantities (the example on pages 24-25) The floating weight of 6.7 tons required 1100 lb of mercury. It was delivered in very small, but very heavy iron bottles.

4. The Gold coast. Chances erector faced with landing heavy components for a light by surf boat decided to hire a team of porters to carry overland all that could be assembled into head loads. The drill was to lay in a line all the loads and then the porters lined up about 30 yards away. At the word ‘go’ there was a mad dash to get what appeared a light load. Invariably the biggest porters finished standing over a small bottle and the smallest ones by a towering bundle of lantern curtains. Pity – the small bottle weighed 60 lbs or more of mercury.

We never supplied bottles only half filled – they cannot be carried!!!

5. The Bahamas. One of Chances erectors had just poured in the mercury when the very small island he was on was hit hard by an hurricane. The tower although of mass concrete shook so badly that he and the twenty or so islanders (with children, goats and fowl) were rained on by a mist of mercury jolted from the pedestal by the badly vibrating tower. His description of how, later, his endeavoring to collect blobs of mercury from the several floors, was heart rending. His bungalow, although anchored by heavy harnesses set in large concrete blocks, was blown out to sea together with all his tools, clothes, cooking and refrigerating equipment!

Ball Bearing Pedestal for a 4th order, or below, light with an electric lamp:

The revolving weight is much smaller than for the 'Big' lights and an electric motor driving through a geared reduction unit will mean, throughout the lighthouse world, that mercury flotation will not be used.

Fig. 19 shows at (a) a pedestal suitable for a 'fixed' lamp changer in a 4th order light and at (b) one for a 'revolving' lamp changer (necessitated by the small space inside a 5th order light) with the necessary slip rings and brushes to get the electric supply to the changer. In both cases a race pinion, mounted on the vertical output shaft of the reduction gear, can slip on starting and stopping of the electric motor. Without this the fast get-away speed of a fractional horsepower motor and the inertia of the heavy optic would ensure the same output shaft twisting in two as easy as a carrot! (See page 36)

Ball Bearing Pedestal for a 4th order, or below, Light with a P. V. Burner;

Testing the slipping device mentioned above showed that the frictional resistance of a ball bearing pedestal was enough to allow a standard weight driven 'clock' to drive the optic. Moreover the clock frame is strong enough to allow the (shortened) pedestal to be mounted on top of the clock and this makes an attractive assembly. Fig. 19c refers.

No slipping device is required since this pedestal would be used in a manned lighthouse and the keeper will use the clutch and brake of the clock.

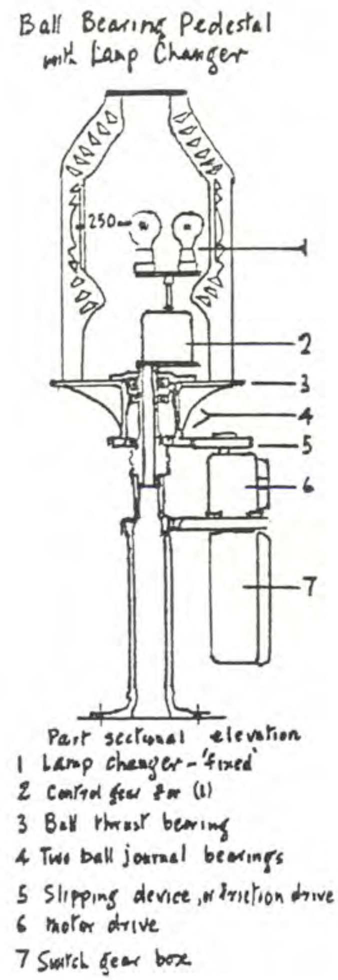


Fig.19a

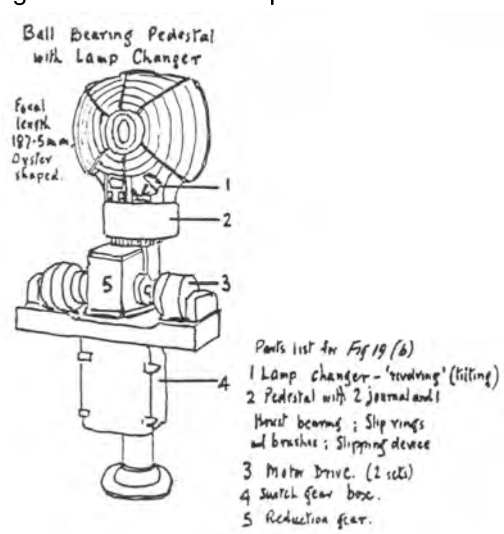


Fig. 19b

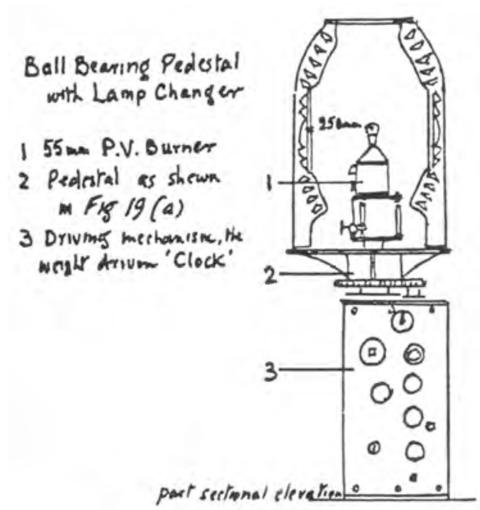


Fig. 19c

6 Mechanisms for rotating Optics

Abaco (Hole in the Wall) Lighthouse. Bahamas. The red and white Lighthouse.

First to be considered will be weight driven clockwork rotating mechanisms to be known hereafter as clocks, not that they even dimly resemble clocks. But, brevity and custom wins and "clocks" it shall be!

These clocks were really handsome with heavy steel side plates machined to a polish; top and bottom of cast iron; inside a mass of steel (gear) pinions and gunmetal wheels, both machined all over; gunmetal housings for the shaft ball bearings; a clutch; a brake; a frictional speed governor; a one minute timer; a gleaming drum grooved for the wire rope: a winding handle; for the big lights an emergency turning handle; a vertical output shaft usually disappearing upwards into the pedestal and, often, an electric alarm system.

Good to look at, very expensive and calling for a wide awake designer.

The clock fitting section at Chances was led by a charge hand who at first sight did not impress. He was badly bullied by the foreman and always ran to work to avoid being late. But, he had one trait unique among the charge hands of being able to anticipate trouble, which was a boon to one young apprentice at least! Would it surprise you that he fathered three Ph. D's, two sons and one daughter?

Fig. 20 on page 31 shows a clock, which is typical except in one respect. It was ordered by British Honduras Authorities as a standby clock for two existing Lighthouses, Half Moon Cay and Northern Two Cays. As both these lights were fairly new it was difficult to see what impending disaster was anticipated. However, in more ways than one, 'orders are orders'! So the special features were the supply of two vertical-shafts (only one is shown) each with different bevel gears and different worm gears for the 'one minute' drive, both to allow for the different speeds of rotation of the optic. Likewise shaft 'C' carried an extra bevel gear and the 'one minute' shaft two worm wheels.

A clock is just a train of gears, driven by a weight falling down the centre of the tower, and the sub-assemblies mentioned above are:

1. **Maintenance gear**: when the driving weight is being re-wound, that is, bringing it to the top of the tower the optic must continue to revolve in the same direction and at the same speed. The nest of epicyclic gears (more on this later) is fitted 'between' the drum and 'A' wheel its function being to keep the driving force, in magnitude and direction, on the 'A' as it was before.

2. **Speed Governor**: a simple arrangement of two ball-ended arms that move outward as the clock speeds up. This motion pushes a circular plate along the shaft until two corks

(nothing more!) contact a fixed arm whereby friction between the cork and the plate absorbs the surplus energy coming through from the barrel. Working speed around 145 revolutions per minute and accuracy not less than 95% (a +/- 5% error).

3. **Clutch**: to throw the bevel, on the bevel shaft, out of gear with the bevel on the vertical shaft. Never try to stop, say, 5 tons of optic suddenly. Let it slowly run down under its own momentum!

4. **Minute shaft**: this is driven by the vertical shaft by worm gears and it always makes one revolution per minute. A small finger is held finger tight on the taper end of the minute shaft. Behind it is a dial engraved in 0, 5, 10 --- 60 seconds. Now every lighthouse has in the lantern a (real) clock with a ‘second’ hand. To check the optic speed the keeper pulls out the finger to disengage it from the taper and steadies it over the 0 (or 60) mark. Being in a position to see the (real) clock he waits until its second hand is over the 0 (or 60) mark, when he smartly engages the finger. If the optic is at correct speed then both finger and the second hand of the (real) clock will move in unison. Clever? If the speed is more than 3 seconds out, he will adjust the governor.

It could be asked if +/- 5% is good enough for the mariner? Assume he is seeking verification by a light charted as “triple flashing every 20 seconds.” Will he worry if his watch gives 19 or 21 seconds? Of course not! How do you read to a second accuracy in such circumstances?

5. **A brake**: a very crude screw-in type, the keeper using this, together with the clutch, morning and night.

6. **Glass doors**: are sometimes asked for by the Lighthouse Board if the air is sandy or dusty. The ‘door’ nearest the pedestal lifts out but the outer one is hinged. These improve the appearance of an already handsome mechanism.

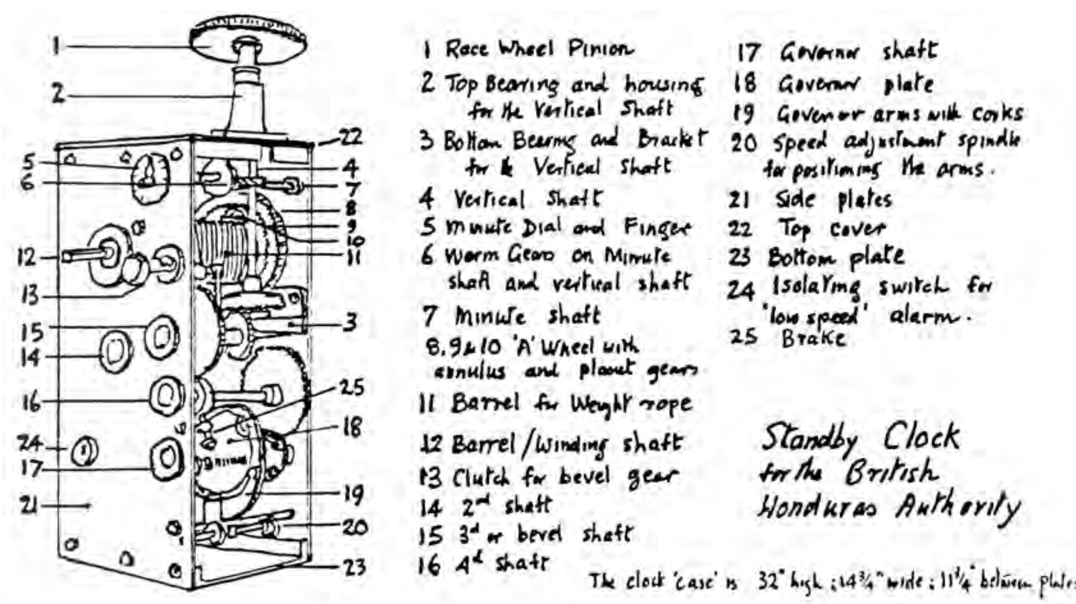


Fig. 20

General: I introduced at Chances a few features, which not only saved money but improved the performance.

1. All shafts and the barrel were mounted on ball bearings.

2. A simple maintenance unit which drove the ‘A’ Wheel 20% faster than the barrel and which left the winding/barrel shaft stationary when the optic was being rotated (this offered the possibility of a simple electric drive for re-winding the clock.

3. A governor which could be adjusted by someone of normal build! A lighthouse which shall be nameless had a Trinity House type pedestal resulting in the Principal Keeper adjusting the speed of the optic by tightening up or slackening off an old fashioned journal / thrust bearing at the top of the vertical shaft!!

4. The bronze gear wheels had been designed and cast with four arms which meant filing all round them, quite expensive. My chief was always worried because, out of the clock, they rang like a bell. As a result of a suggestion from him that five arms would stop the ringing I decided on no arms, but instead a plain disc wheel machined (cheaply) all over. They rang better than ever! He missed the point that, with ball instead of plain bearings, in the clock, they produced a very gentle tickling which was welcomed by the Keeper on duty in the service room below. He at least knew the optic was revolving!

Designing a Clock

Required to know:

1. The speed of the optic and details of the race wheel attached to the pedestal carriage.

2. Fall in feet available for the driving weights and the time in hours from one re-wind to the next. As for the latter you might ask why not make all clocks run 18 to 20 hours which would see through the longest winter night? A Petroleum Vapor Burner may require ‘pricking’ so get the keeper up in the lantern every 1 ½ to 2 hours. If he has to re-wind the clock every, say, 1 ¾ hours then he is in the lantern! Simple as that!

If the available fall is small one can juggle with looping-up the wire as shown in Fig. 21, but, for example, if we loop-up once (see (a)) to keep the driving force on the barrel as for a direct fall, then we double the driving weight and, still further shortening the available fall, we double the length of the (total) weights on their holding rod. Unless we go over to lead for the weights instead of cast iron! Lead weights have to be thin in order to lift them and they cost the earth! – so they are avoided if at all possible.

Chances got into sad trouble with a harbor light on the Isle of Wight. The weight tube was part of the structure and was made in cast iron. The weight was looped-up 1 ½ times – quite a rarity.

We received constant complaints that the weight was catching on, or fouling, the weight tube although the clearance was a good inch. First guess was ‘core bumps” left by the foundry on the inside of the column. We made a very special periscope to locate them – but, there were none at all!

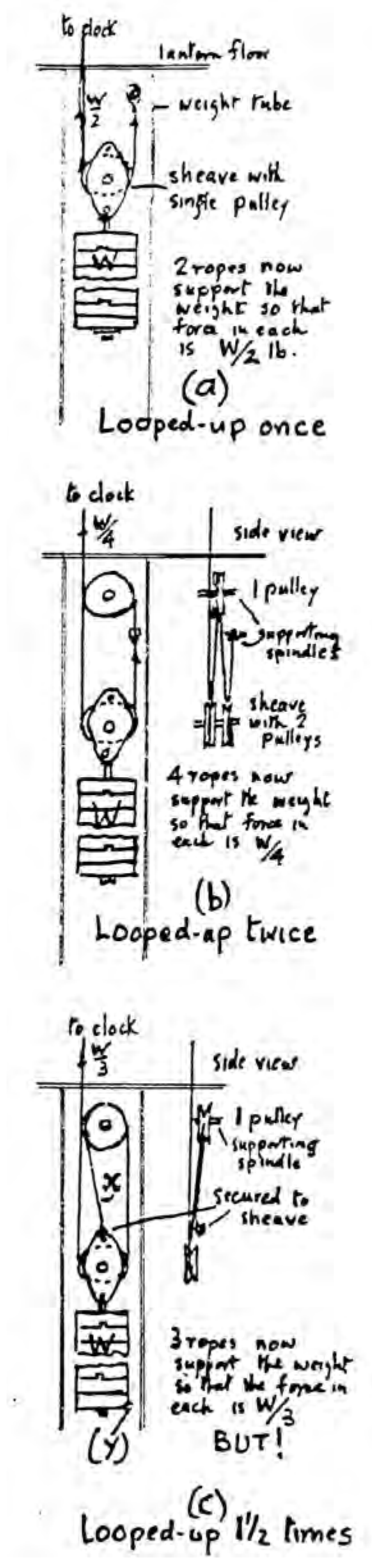


Fig. 21

I'm sure it was one of the Drawing Office juniors, who at the local Technical Collage was studying moments of forces or torques, who saw that if the line of action of rope (x) see Fig. 21c was continued it passed to the right hand side of the sheave spindle. In other words when the weights were near the top of the column the whole weight assembly was slightly turned anti-clockwise ensuring that corner (y) scraped against the tube! Decision – never again to use "looped-up 1 ½ times"

However, back to our design. We will analyze a clock made for West Volcano in 1936.

Data: speed of optic 1.5 rpm; duration, rewind to rewind 1 ½ hours; fall available for weight 22 feet; 4th order light, mercury flotation; race wheel 240 teeth.

1. First stage of design - Clock barrel. Duration: weights, try 5 inch diameter barrel, 6 inches long with 24 - 7/32 inch wide groves for the weight rope which leaves barrel at 22 feet per hour (looped-up once the fall will be 11 feet per hour). Capacity of drum = number of effective groves x circumference = 34 feet. Check duration = 34 over 22 = 1.5 hours. Check real fall of weights for 1 ½ hours = 16 ½ feet. Estimated weights 250 lb. cast iron, length of weights, sheave and bottom buffer = 4 feet. Total 20½ feet, of the 22 feet available. Speed of 'A' wheel (this clock had the old type – see below – of maintenance gear.) Speed in rpm = 0.286.

2. Second stage of design, speeds of all gears data: 'A' wheel 0.286; vertical shaft = 4.5 rpm using a race wheel pinion of 80 teeth, minute shaft = 1 rpm. Governor speed 140 to 145 rpm; highest gear ratio is below 6 to 1.

Table 5 is a table of gears, shafts and speeds is drawn up together with a development of the clock – meaning "laying it out flat"

Gear teeth and pitch	Speed rpm	Shaft Remarks
A 84 3/8"	0·286	part of the main maintenance gear
B 16 "	1·46	2nd
C 60 "	1·46	
D 15 "	5·87	3rd or bevel shaft : a bevel gear
E 36 5/16"	5·87	
Race Wheel 240 3/8"	1·5	part of the pedestal
" " Pinion 80 "	4·5	Vert. Shaft
F 47 5/16"	4·5	: a bevel gear

Gear teeth and pitch	Speed rpm	Shaft Remarks
G 91 1/4"	5·87	also on 3rd or bevel shaft
H 17 "	31·4	4th shaft
J 72 "	31·4	: a bevel gear
K 16 "	141	5th or Governor shaft. " " "
L 6 starts 5/16" *	4·5	also on Vertical shaft
M 27 " **	1·0	minute shaft

* Left hand worm. ** Worm wheel – angle of teeth 12° 31'.

The clock 'case' was 2'-4½ high: the distance between the 7/16" plates was 11¾"; the width of the plates was 16¼"

Table 5

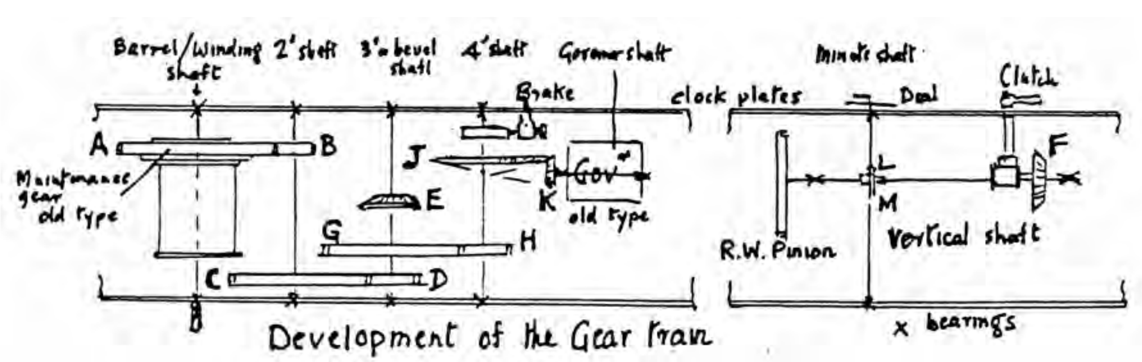
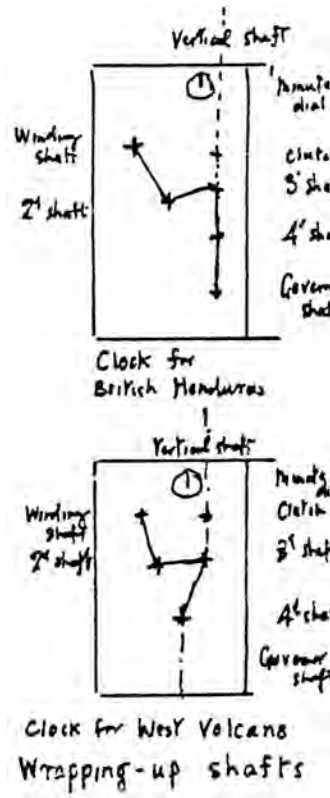


Fig. 22

It helps in determining the ratio of the various pairs of gears if the bevel on the 3rd shaft (I here use West Volcano clock) revolves about 30% faster than the vertical shaft. This gives a nice pair of bevels and it helps in getting up to the governor speed.



We should mention that the gears for driving the minute hand have crossed shafts. Chances were rather limited with gear cutting and one can only describe the two gears used as something like a worm and worm wheel. The former was on the vertical shaft and had 6 starts and was left ‘hand’. The latter was on the minute shaft and had 27 teeth set at an angle of 12º 31’ to suit the worm.

3. Third stage of the design. The clock must be able to nestle in the pedestal, or sit alongside it, and it’s final overall dimensions must “match the main”. Most important is the height of the winding shaft and of course the clutch, brake and minute dial. So we have to ‘wrap up’ the shafts and decide on the final height and width of the clock plates. Examples are given for the Honduras clock, see Fig. 20 page 31 and for West Volcano, see development etc. Fig. 22, page 33.

Care is required that no gears cut through a shaft, for example between shafts 2 and 4 or shaft 3 with the barrel shaft. One unlucky new member of Chances Drawing Office had a clock thrust on them by an equally new Chief Draughtsman and two sets of clock plates were scrapped. They rather quickly ‘departed’!

Fig. 23

Weights, Ropes and Tubes

The 7/32’ diameter weight rope is galvanized multi-strand steel of excellent flexibility. The weights, are more often than not, of cast iron 10” or 12” diameter and maximum thickness of 2”. Except for the bottom height they are slotted and spigot together. The weight tube is of mild steel 12” or 14” diameter and is, at the bottom, fitted with a door which is most necessary if a new rope is to be assembled.

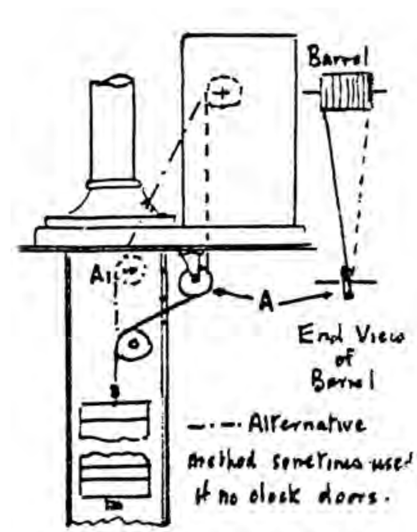


Fig. 24 shows the method of getting the rope from the barrel to the weights and the problem caused by the rope moving across the barrel when working or being re-wound. Pulley (A) must be mounted on a ball self-aligning bearing. The sketch shows the weight falling ‘direct’.

Fig.24

Alarms

1. When the weights are nearing the bottom of the weight tube. This alarm uses the near extreme position of the sloping rope shown in Fig 24. A roller on the end of a cranked lever lightly presses on the rope and in the near extreme position, closes an electrical contact of a bell circuit (dry battery operated). This device is built into the clock.

2. The clock slowing down or stopping, due to a serious fault in the clock or pedestal or the weights nesting on the buffer at the bottom of the weight tube. A wee bevel gear drives a small spindle fitted with two ball arms, which when the clock slows down or stops, brush against a contact ring and so again ringing a bell. An isolating switch prevents it ringing from dawn to dusk.

The Maintenance Gear

The reason for this important unit, which is integral with the barrel and the winding shaft, is given at the bottom of page 30. Clock makers think Chance's design too elaborate and expensive but it suits manufacturing processes in an engineering works. Fig 25 (a) shows the old type and (b) the new type that I introduced.

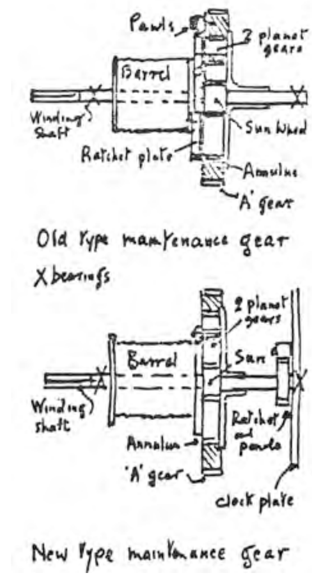


Fig. 25

Old Type:

The barrel is secured to the ratchet plate and runs free on the shaft. The two pawls are secured to the 'A' wheel which also runs free on the shaft. The planet pins are also carried by the ratchet plate. The sun pinion is integral with the shaft. The ratchet and pawls keep barrel and 'A' wheel at the same speed and same direction when the optic is being driven.

Typical gears: Sun 14 teeth: the two planet wheels 28 teeth each and the "A' wheel, with internal as well as external teeth, has 70 teeth for the internal gear – the annulus (Ann)

New type:

The barrel runs free on the shaft but it also carries the two planet gears. The sun wheel and the ratchet wheel are part of the shaft. The 'A' wheel moves freely on the shaft. The pawls are carried by the clock frame so that the shaft with the sun wheel are held stationary except during winding-up. When driving, if the barrel makes 1 revolution, the 'A' wheel will make = 1.20 revolutions. A nice bonus of 20%.

Hand Winding Gear:

The clocks for the big lights had a hand winding shaft just in case the near impossible happened. This could mean the keepers working hard for a long night or two before the Board's Engineer arrived to repair the damage.

I did some work on an optimum design of the gear and found that 20 revolutions per minute with a handle of 10 inch throw and a load of 4 lbs. was considered 'comfortable".

3rd order lights usually carried a hand wheel on the vertical shaft for hand turning whilst 4th order lights required the optic carriage to be pushed round by hand. Both sound very uncomfortable jobs particularly when looking at the wall clock and the minute hand at the same time.

In Central America a clock did break down and by the time the engineer arrived the keepers had put in three hard nights. A month or so after the breakdown the engineer paid a 'check' visit and was amazed to see the keeper hand-winding a perfectly good clock! He liked doing it!! I'm sure our social scientists could explain why.

This breakdown occurred when clocks had plain bearings. For delivery Chances always grease packed these, but on site the engineer had forgotten to strip and clean them prior to using Chances clock oil (Sperm whale oil). In the tropical conditions the grease had hardened and undoubtedly with some dust present had ground an unbelievable 1/16 inch to 3/32 inch off the end of each shaft.

Hundreds of pounds to a few ounces. Why?

Using the clock for West Volcano (Table 5 and Fig. 22), shows that whilst we have a (direct) load of 125 lbs. on the barrel then the driving force on the Race Wheel is 16 ounces assuming the resistance at the governor is 3 oz! Well the power input is, as we might suppose from a slowly falling weight, very small = 0.014 hp. Secondly the frictional losses in a multi-train clock are severe (and we have ignored ropage loses) but, lastly, torque decreases directly as the speed rises – and from the barrel to the governor is a rise of or approximately 500 to 1.

Electric Motor Drive

It took some years for the prejudice against fractional horsepower motors to die away, in fact not until the makers understood the full meaning of “the light always shines” and Chances ceased thinking of 1/20th hp. motors and decided on larger motors which were more robust and so reliable.

For example, Trinity House preferred to add an automatic electric motor winding gear to the existing clock since it seemed rather silly to rewind by hand every two hours when electric lamps were used as illuminants. At St. Catherine’s Lighthouse the old time maintenance gear was a pain in the neck since, as we have already seen, the winding shaft revolves slowly whilst the optic is revolving, and the reduction gear through which the motor drives is irreversible (because it is a double worm gear each of a high reduction ratio). Moreover even with a geared winding device I could not go above 120 rpm for the output shaft of the reduction gear box.

With reluctance we decided the clutch better be the conical type using what little centrifugal force comes from the “ball” arms at 120 rpm. Since none of this force can be wasted, the clutch must ‘fall out’ under gravity, and this it is reluctant to do. Fig. 26 shows the final design. The mean diameter of the clutch is 10 inches: The height, baseplate to winding shaft 28 inches.

But, back to the Electric Motor drive proper! Fig. 19 shows the layout for a rotating mechanism comprising two constant speed motors in duplicate driving the reduction gear back through centrifugal clutches. The whole is mounted on a bracket attached to the pedestal column. A centrifugal switch is incorporated at the free end of each motor shaft for auto-detection of motor failure. One of the motors is held in reserve and the change over is automatic on failure of the duty motor.

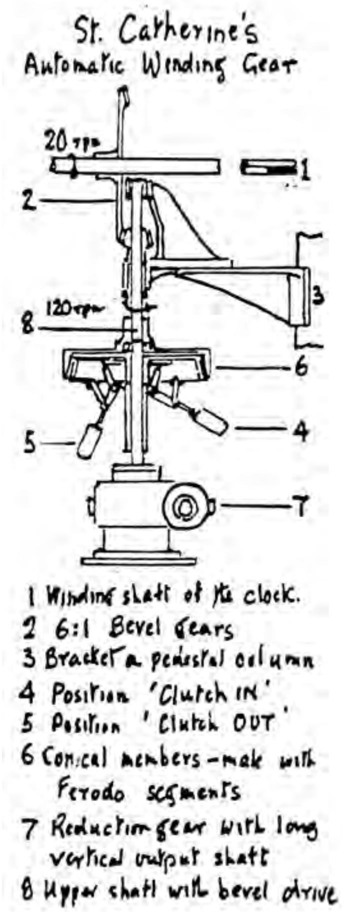
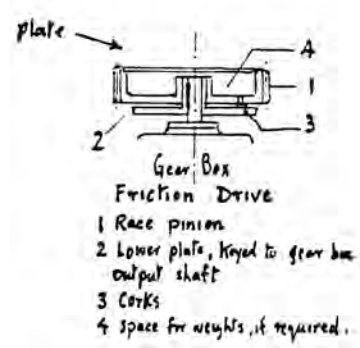


Fig. 26

The vertical output shaft of the reduction gear has keyed to it a plate on which rests the race pinion (which if necessary can be weighted.) This has three corks on its lower face which rest on the lower plate. So we get the vital slipping on starting and stopping. The keeper when cleaning the optic can readily pull it round, the race pinion slipping easily. The A.C. motors find little difficulty in keeping within the acceptable +/- 5% for the optic speed. In the case of motors operating on DC a speed regulator for each motor is provided.



We will conclude by looking briefly at the torques involved in Electric motor drives noting that, as opposed to weight driven clocks, only one problem presents itself. Taking 1/8 hp motor at 1450 rpm the torque on the motor shaft will be 5.5 lb. inches. If the output shaft of the reduction gear has a speed of 3 rpm, the torque here will be 800 lb. inches at 50% efficiency.

Now for a complete change we move to Fixed Lights.

7 Fixed Lights

We had made out the red light in that bay and steered for it, guessing it must mark some small coasting port.
Joseph Conrad.

You will recall, as shown in Fig 2, that by generating the prism sections about a vertical axis through the focal point, we produced a fixed optic. We also observed that the optic showed a not very strong vertical strip of light, equal in width to the horizontal size of the illuminant and visible for all points of the compass.

In my twenty years at Chances few big fixed lights were made and it is possible that the life of those existing has been extended only by the advent of large electric lamps nigrescing (switching on and off) to give the required signaling character. But, whilst the big fixed lights have been decreasing in numbers the small and very small lights have always been in demand for buoys, beacons and harbor lights and, as I write, for oil drilling and pipeline platforms in the North Sea and elsewhere.

The great majority of fixed lights signal a character since without nigrescing or occulting a steady white light fails to attract the attention of the mariner. Put it in the center of a seaside town with promenade and house lights and he would probably miss it!

One special use of a fixed optic (or rather part of one) is to direct at a local hazard, a small island or jutting reef, a colored beam of red light.

Much ingenuity has gone into this matter of readily identifying the light being observed. A flashing system can be any one of the following: revolving screens inside the optic, a falling cylinder over the P. V. mantle; nigrescing the lamp or fish-tail burner or even Trinity Houses' hair raising device of a nickel cup being slapped over the mantle!

Signal Characteristics

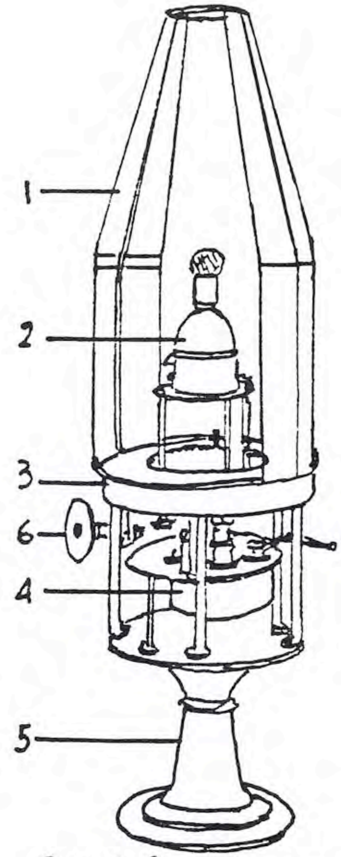
It may be required, however rarely, to have the total period of light greater than the total period of eclipse. Particularly with a P. V. Burner a fixed optic would be used obscured, as required by revolving screens.

More probably an existing large fixed light is brought, some what, up to date to be more discernable to the mariner. Falling cylinders, moved up and down by a clockwork mechanism, gave way to a spring driven clock revolving, inside the lens, occulting screens. Fig. 27 refers.

At a suggestion of Trinity House I designed a weight driven clock which obviated the use of mercury flotation so necessary with a spring drive. Trinity House ordered quite a few and these are shown in Fig 28.

Except for the rope drum which was of moderate size to allow, if the fall was sufficient for the small driving weights, for an all night run of up to 16 hours.

The revolving table (2) was of cast aluminum alloy and was mounted on ball bearings. The screens (1) were of aluminum sheet and you will see that the top portion tapers off to (suit) the vertical profile of the lens. The clock (3) has a self maintaining gear, a centrifugal governor and a hand-turning gear for use in an emergency.



Spring Clock Driven Occulting Screens
Fig 27

1 Screens
2 P.V. Burner
3 Mercury Float and Trough
4 Spring clock
5 Column
6 Upper wheel of hand driving gear
Dimensions: diameter inside screens 24": overall height 7'-6"

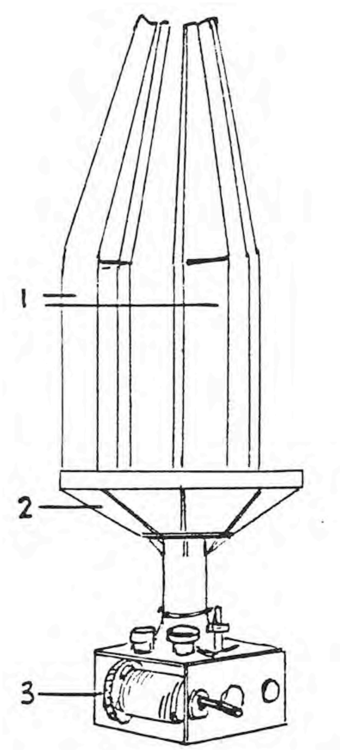
Test on a single spring clock for Mont Ube

Details: Spring 50 feet long, 2 inches wide, 17 gauge .056 inch thick, diameter of drum 11 5/8 inches diameter of inner boss 1 ½ inches. Winding gear bevels: on spring shaft 34 teeth: on winding shaft 25 teeth.

Gear associated with vertical shaft, pitch circle diameters, are given: on output shaft 6 inches, gearing with vertical shaft 1 inch; race wheel pinion 3 inches: race wheel 14 inches, velocity ratio, spring to output shaft – 239 to 1.

Number of turns on winding shaft	Number of turns of spring.	Force in lb. on winding handle of 7½" throw	Torque on winding shaft in lb-in (Col.3 × 7½)	Torque on spring shaft in lb-in (Col 4 × 34 ÷ 25)
6	4·40	11·5	86	117
12	8·80	17	127	173
15	11·00	19	143	195
18	13·25	25	188	253 ← 239
21	15·25	34	255	348

Example; If we take just one (very) convenient torque from Column (5) of 239 lb. then since the velocity ratio is 239 to 1 the torque on the output shaft is 1 lb. Moving on to the vertical shaft, the torque will be = 1/6 lb. in. The tangential force on the race wheel pinion (and so on the race wheel) then = 1/9 lb. Just about 2 oz! Fortunately the tangential force at the race wheel as applied to the float was around 1/25 lb! Hurrah for mercury flotation! Safety first, I always watched the spring being offered to the drum from distance! Decapitation always appeared a possibility.



Weight driven Occulting screens

1 Screens ; 2'-0" diameter.
2 Table
3 Clock

Fig 28

Designing the Occulting Screens

1. Height above and below the focal plane. Remembering we are dealing with Big lights we will use the prisms shown in the 'Vertical Section' of Fig. 11, page 15. Below, we must cover the angle of 63° and above (we must commence tapering the screen once we have cleared the angle of 35° and we must cover the angle of the 85° line.

2. In plan we will take as an example a character of 5 seconds dark, 5 seconds light 5 seconds dark and 25 seconds light. If the screen revolves once in 40 seconds we get a plan view as Fig. 29 (a) at least if we ignore the horizontal size of the mantle.

Let us examine the upper part of (b) we have drawn the two extreme rays of light from the mantle and see that the truly dark area is less than 45° and also there is an arc x° of reduced light. Now in the lower part of (b) let us increase the width of the screen by half the width of the mantle (y). We see that the truly dark area at 45° is preserved but of course xº remains. This causes a waxing and waning of the light. However, I think a problem lies between 45º and 90º in (a) as two half widths of a big mantle will seriously decrease the arc of light. It appears advisable to leave well alone, resulting in screen Z being exactly as drawn in (b).

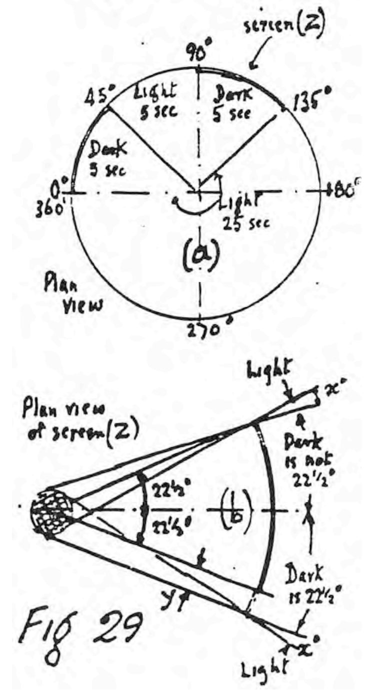


Fig 29

The Land Arc

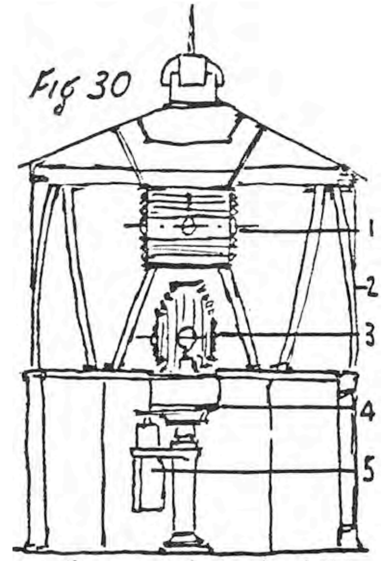
If a fixed optic is on a small island, or stuck on top of a buoy, it should in plan, cover 360° of the horizon with light. If it is on a coast then there is little sense in throwing light inland and a cover at, for example, 240° might be sufficient. The 120° dark arc, called the Land Arc, could be part mirror, part (fixed) screen or alternately just paint out the lantern glazing. Remember few local people enjoy a powerful beam of light sweeping across their bedroom!

Signal Characteristics with an Electric lamp as the illuminant

Two widely different examples will be given. The first is a lighthouse right in the town of Southwold on the Suffolk Coast. The big fixed light is lighted by a large electric lamp switched on and off entirely for a dark period. It can also be de-rated, that is, run at a reduced voltage.

The second example is the use of a 4th order (250mm focal length) fixed light, with an electric lamp, used as a stand-by in case of mains failure putting out of service the main light which is a 5th order revolving optic, motor driven. The stand-by uses a stand-by battery sufficient for three nights and an electric impulse-type flasher nigresces the lamp with a character identical to that of the main light. The flashes could be shorter than one second.

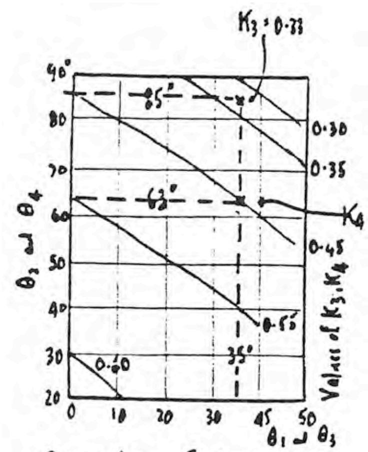
The candle power is, of course, much reduced and the height of the lantern glazing must accommodate the two optics. Fig. 30 refers. This scheme is based on a reliable mains supply



Battery operated standby light
1. 4th order fixed optic
2. Extra-high glazing.
3 5th order revolving optic
4 pedestal with motor drive.
5 control gear.

Calculating the Intensity of a Fan Beam, generated around a vertical axis, for refractors (dioptric) and reflectors (catadioptric). We made a very rough calculation of a fan beam, from a fixed light, on page 2 but now with the aid of British Standard No. 942-1941 we will split the optic into three parts, the upper reflectors, the refractors and the lower reflectors and use different transmission efficiencies or correction factors for each. The intensity (Io) of the fixed white beam is: $Io = h_2dBK_2 + h_3dBK_3 + h_4dBK_4$ where:

h_2 is the glass height of the refractors projected on to a vertical surface; h_3 for the upper reflectors and h_4 for the lower reflectors (all in cm)
d is the horizontal width in cm of the light source.
B is the brightness of the light source.
K_2 is the correction factor depending on the subtense angle Θ of the refractors
K_3 is the average correction factor depending on the limits of the angles Θ1 and Θ2 of the upper reflectors, using British Standard Fig. 7.
K_4 using Θ3, Θ4 for lower reflectors using Fig. 7 (British Standard).
A reproduction of B5 Fig. 6 is given in Fig. 8(a) – the dotted line … and this will be used to find value of K_2 for the refractors. A reproduction of British Standard Fig. 7 is given herewith and from this we will find K_3 and K_4. Fig. 31 refers



Correction Factors for Fan Beam (Catadioptric)

Fig. 31

Example: The prism sections given in view "vertical section" of fig. 11, page15 will, this time, be used to generate our (fixed) fan beam. Marked on this view you will see that h_2=124; h_3 = 124 and h_4= 43 cm. Also Θ1=Θ3 = 35° and Θ2 = 85° and Θ4 = 63°. As before (page 11) B = 975 candles per sq. cm for 3kw lamp and 45 for a 85 mm (8.5 cm) P. V. Burner. d for the lamp is 3.9 cm and d for the P.V. mantle is 8.5 cm. From the dotted line on Fig. 8 (a) page 12. K_2 is seen to equal 0.68 From Fig. 31 K_3 is seen to be 0.33 and K_4 0.45. The calculations produce: 542,000 candles for the 3KW lamp or 58,300 candles for the 85 mm P. V. burner.

Losses of Light

Lantern glazing, lantern glazing framing and optic framing. Framing losses can be minimized by using helical standards and bars instead of vertical ones. The sketches given in Fig. 32 indicate the danger of vertical obstructions weakening the light in particular arcs. Moreover drum lenses (d) will be much stronger in resisting any twisting of the completed frame – and on buoys this is important.

(a) shows how the narrow strip of light is partially blocked.

(b) and (c) show typical optic frames designed to reduce losses Fig. 30, page 39 shows helical (think of a very course screw thread) glazing for a lantern.

(e) shows a glazing framing for a big Light - called 'two diamond'

British Standard 942 recommends a reduction factor of 0.80.
For a steady white light the Ia values would be 433,000 and 47,000.

Blondel-Rey Factor – again the full intensity is not appreciated by the human eye. However the beam does not pass across the mariners eye so that the factor is modified to: $Ia = t / (0.10+t) \times Io$

Eclipse by a shade
In most lights using revolving screens or an 'up and down' shutter the value of t will be above 2 sec. Let us take a few values of t and find the percentage decrease due to the Bondel-Rey factor.

Value of t in secs	Value of $t \div (0.10+t)$	% decrease in value of I_o
1	0.91	9
2	0.95	5
5	0.98	2
10	0.99	1

The waxing and waning of the light period British Standard 941 states: "Near the limit of the range the light will not be visible until the lamp has reached practically full intensity. For the purpose of the Blondel-Rey formula above the incandescence time to be taken shall be that required for the lamp to attain 90% of full intensity. British Standard 942 states "the durations of the beam (t) should be taken as the time which elapses between the movements of the screen or shutter through the mean position when exhibiting and eclipsing the light respectively"

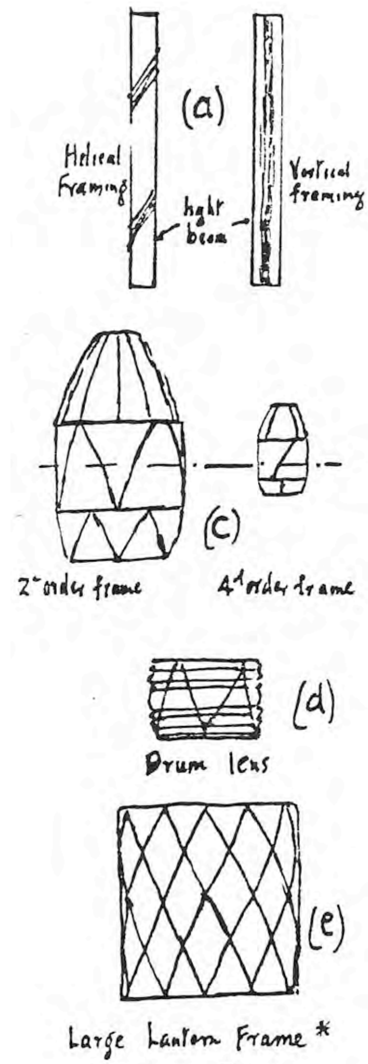


Fig 32
* invented by Sir James Douglass

Eclipse by extinction or vertical extinction of light source.

(a) **Acetylene fish-tail flames,** when the beam is eclipsed by a flasher mechanism which cuts off the main gas supply (the pilot flame must burn all the time), it has been shown that the times for incandescence and nigrescence are negligible. But, we still have to find time (t) for the Blondel-Rey formula. Chances did this by recording over a suitable period, the gas consumption of the flasher set (i) at its flasher character and (ii) with the flame's burning continuously.

Example: using a flasher with a 1/10th character set to 0.1 sec. flash 0.9 seconds dark with a single 35 liter per hour acetylene burner, the consumption's could be - for test of 30 minutes – flashing 2.0 liters ; continuous 17.5 liters. True duration of flash 0.12 seconds and the true dark 0.88 seconds.

(b) **Electric lamp**, when the beam is eclipsed by switching an electric lamp circuit the time from where the circuit is closed and that at which the lamp attains full intensity depends on the current rating of the lamp and the resistance in the circuit. British Standard 442, 1941, in British Standard Fig. 11, gives two graphs:
(1) for finding the time of incandescence of lamps; incandescence time in seconds to 90% full intensity – filament current in amps, assuming the circuit has a negligible resistance compared with that of the lamp when incandescent and

(2) for finding a correction ratio if the above assumption is not correct; correction ratio equals the circuit resistance / the hot lamp resistance. A few values obtained from these graphs are given:

Lamp Size	Current Rating at 100 Volts	Incandescent time in secs to 90% full rating (as (2) above)	Correction Ratio $\frac{\text{Circuit Resistance}}{\text{Hot Lamp Resistance}} = 0.2$	Corrected Time Col(2) x 1.17
3 KW	30	1.07	↑	1.25 sec
1 KW	10	0.73	1.17	0.85
100 W	1	0.15	↓	0.17

The incandescence of electric lamps is virtually instantaneous.

Completing the example on page 39 by using the corrected time above of 1.25, for the 3 KW lamp lighted for, say , 2 seconds then ‘t’ for the Bondel-Rey factor = 0.75 seconds. The Blondel-Rey factor = .88 so that Ia = 477,000 candles, and again, correcting for glazing loss of 20%, the final Ia = 380,000 candles using a transmission factor of 0.6 the range would be 15.4 nautical miles.

Loss of Intensity of Colored Beams

Chance’s Glassworks have always made colored glasses particularly for signaling lights. **Table 6** gives correcting factors used:

Light Source and Colour Temperature in absolute degrees	Colour of Beam			
	Red		Yellow	Green
	Selenium	Gold		
	Factors to be used with average glasses			
Incandescent mantle of a P.V. Burner 2720°K	0.22	–	0.55	0.20
Gas filled electric lamp 2848°K	0.20	–	0.50	0.20

°K are absolute temps. on °C scale.

Since we are concerned with green and red beams we can conclude we lose four-fifths of the light so dearly won!

The properties of light in terms of the three primary colors and the theory of transmission of colored light is beyond the scope of this book but a few facts can be listed for red and green glasses suitable for lighthouse use. (see page 143)

“These two glasses should not be so dark that the luminous range of the light is very seriously reduced.” 80% loss is quite bad enough! The colors should not be so pale that at the extreme range it is mistaken for a white light:

Red glasses should not get too close to the orange-yellow:
Green glasses should not be too near the yellow.

(1) You will have noticed that for rail and road signals using red, amber (or orange) and green lights that the green is definitely a “blue-green” to keep it well away from the orange light.
(2) In the Chance Lighthouse ‘finished glass stores’ was a sorry sight of a shelf full of optic prisms made from red glass!! A transmission of but 20% and a light path of about 3 cm ensured that no light got through!

Some Lighthouse Board Engineer had dropped a clanger and Chances a bigger one in agreeing to make it. Perhaps another case of “orders is orders!”

8 Beacons

When does a lighthouse become a beacon? Chances say "if its power is 20,000 candles or less." Usually it's much less with acetylene burners.

"... his eye lit with a brightness that seeemed caught from some faraway sea beacon."
KennethGraham

Certainly the fixed lenses are small as indicated by the focal diameters, repeat diameters – 100, 140, 150, 200, 300, 6th order 375mm (5th order), 500mm (4th order) and sometimes 750mm (small 3rd order). These are dioptric lenses, their height overall the prisms being slightly less than the diameter.

Catadioptric lenses are usually 4th, 5th and 6th order and rarely small 3rd or 3rd order. Although used in narrow waters they are often quite inconspicuous in the daytime and due to their inaccessibility are mainly unattended.

The coasts of Norway, Sweden and Yugoslavia with their hundreds of islands illustrate very well the many types of beacons and there function and, of course, there use on harbor jetties and breakwaters. Not all are equipped with light-valves or photo cells to cut off the gas at dawn and to restore it at dusk.

In exposed positions the lantern often resembles a buoy lantern and indeed they can be identical. Fig. 36 shows a few types, but before going into details of the construction of the beacon lantern and structure we will look at the lighthouse and how it is "fuelled."

In my twenty years we used acetylene gas for the pressure regulator and 'flasher', with the Chance Light Valve when specified.

Gas Cylinders and arrangement of piping.

The principle of storing acetylene gas in a dissolved state: The gas is stored in weld-less steel cylinders, which are filled to a pressure of 15 atmospheres (that is, 220 lbs. per square inch pressure). The medium size (BOC Ltd CS type) weights 210 lb. (95 kg) changed; is 10 3/8 inches diameter by 4 feet 6 inches long and stores 220 cu. ft. (6200 liters) if filled to 15 atmospheres at 60º F and 14.7 psi. In other words a nasty mauling job to manhandle in difficult conditions.

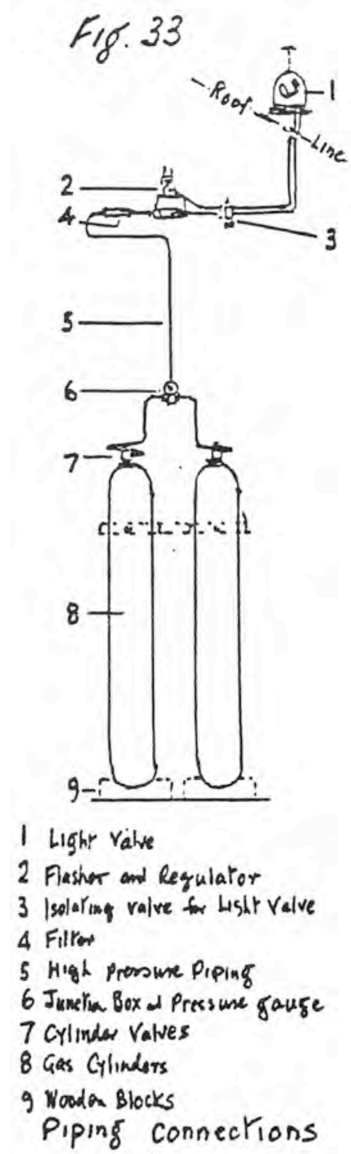
Rockall is 280 miles from the east Scottish coast. As the rock is swept by the seas the maker AGA, put in a flatened beacon. However, sever storms exthinuished the light in its first winter.

Acetylene storage is so unique that it deserves a line or two: Acetone is a liquid which will absorb 25 times its own volume of acetylene at 60º F and 14.7 psi. Moreover for every one atmosphere of extra pressure it will take up an extra quantity. In turn the acetone is held by the cylinder being filled with a special granular-type charcoal! It should be little surprise that in use acetylene has some unusual characteristics. First the pressure does not decrease with use but varies with the ambient temperature; secondly, if it is used too near to the exhausted condition some acetone may come over. Should it get into the flasher mechanism it will gum everything up; lastly, if perchance the fish tail burners are working in an oxygen starved atmosphere it will produce a tremendous covering of carbon-black (filthy stuff!) inside the lantern!

Fig. 33 shows a typical arrangement for two gas cylinders, flasher and regulator and a light valve. From one to twelve cylinders can be accommodated. Two features deserve mention – the high pressure piping is of steel, copper covered and the filter is of felt to prevent moisture and dust reaching the flasher.

Burners, the Pressure Regulator and Flasher

Burners have been described on pages 22-23 but to rectify one omission, the gas consumption of a pilot in 24 hours is 10 liters.



Pressure Regulator and Flasher; Fig. 34 shows a Chance medium size single character flasher suitable for a single or cluster burner of capacity from 10 to 100 liters and a duration of flash for the 10 liter burner of 8 seconds maximum to 0.375 seconds minimum and for the 100 liter burner from 1 second to 0.2 second.

The Primary chamber or regulator is, in effect, a reducing valve bringing the pressure of the gas down from 240/220 lb per sq in to 14" water pressure (0.5 lb/sq. in). The secondary chamber with its associated diaphragm and valve mechanism, meters the gas in precise amounts and at suitable intervals to the fish-tail burners, the gas in turn being ignited by the continually burning pilot light.

More complex flashes can give group flashing characters: that is double, triple etc. Even more intricate mechanisms can give group changing, on site, say from double to quadruple character. Chances largest group-changeable flasher caters for burners from 50 to 250 liters; from 8 seconds flash to 0.2 second for the 50 liter burner to 2 seconds and 0.1 second for the 250 liter burner.

To conclude this section it is believed that to approach the reliability of a P.V. Burner, tended by the keepers several important things are required:

The regulator and flasher must be of the highest quality and reliability, well tested over a long period and in countries using a fair number of flashes a well-equipped and manned repair depot must be established.

The gas cylinders must be carefully changed with very pure gas – and a log book recording weight of each and every change noted for each cylinder. The only real way of finding if a cylinder is nearing exhaustion is to weight it, which is far from real if a remote site is visited, primarily for changing the cylinders, once or twice a year. The local Engineer must design the installation to suit his visits and if he is wise he will charge the cylinders before they are completely empty of gas.

In my time it was believed that a board of enquiry, sitting after a mishap at sea, assumed that a manned light was always lit where as for an unattended light it was not necessarily so! I wonder what the board does now!

A near disaster occurred at Chance Brothers with a two cylinder installation assembled in a lantern to await inspection. A fellow working inside the lantern (similar to that shown in Fig. 36), reported to the foreman that the neck of one of the cylinders was getting hot. Having verified that it was dammed hot the foreman called for volunteers to get it out and on to a yard adjoining the department. Regretfully by this time all had fled! However, he was able to close the valve and disconnect it and (remember the weight of 220 lb) get it through the door. By this time one or two had, rather shamefacedly, returned and it was got on a low truck and hastily dumped in the yard. The cylinder quickly assumed a red heat at the neck and, remarkably, blew a belt around the cylinder! But it did not burst and later it was returned to British Oxygen Ltd. as a curio. I should mention that the foreman concerned had been a well-known gymnast in his youth and still retained his strength.

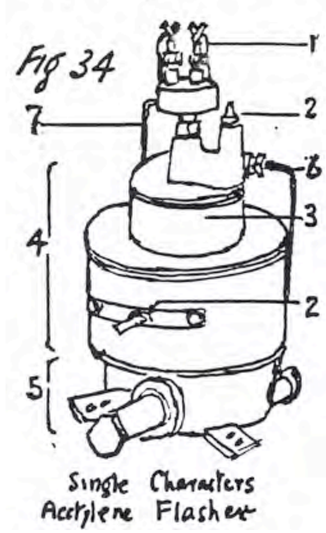


Fig. 34: 1) Burner, 2)Character Changer, 3)Gas Chamber, 4) Flasher, 5) Regulator, 6) Pipe from Regulator to Gas Chamber, 7) Pipe to Pilot Lights

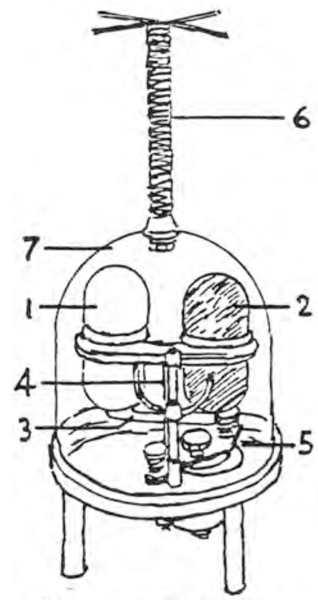
Fig. 34 enables some little extra detail of the functioning of the flasher to be given. First the regulator and flasher are separate units. Flasher (4) operates its valve mechanism by the rise and fall of a diaphragm. Pipe (6) feeds the gas chamber (3) with gas at constant pressure from the regulator (5). The diaphragm falls until, at a curtain point, it trips a mechanism which opens the valve and so allowing gas to pass to the burners (1). As the gas is used the diaphragm rises, closes the valve to the burner and so on.

Of interest is the valve and seating are magnetized giving a snappy closure of the valve (necessary with acetylene); since the length of flash for, say, buoys is but 1/10th of a second there is little time to lose at beginning and end of the flash particularly when you think of the Blondel-Rey factor.

Pipe (7) feeds the pilots direct from the regulator. Key (2 lower) and screw (2) are used to adjust the duration of the flash as given in paragraph 1 of page 43. For the more complex group flashes the reciprocating motion of the diaphragm can easily be converted to the circular motion required by the valve cams.

Light Valve

Fig. 35 shows the Chance Light Valve, its purpose is to save on average, 30% of the acetylene or, not so frequently in my time, electricity for the light source. Whilst voyaging among the islands of Europe one sees many ingenious devices for getting the heavy gas cylinders out of a boat, then over the rough landing place and finally up numerous steps. The changing of cylinders remains an arduous job! The less visits to the light per year the better.



Chance Light valve
1 Clear bulb.
2 'Black' bulb
3 Lower tube
4 Tilting rod
5 Lever
6 Bird scare
7 Glass dome

Fig 35

Let us be clear at the outset that light valves truly work on a change of light at dawn and dusk – bright sunshine is not necessary.

As an apprentice I wondered why Chances did not use the differential expansion of varying metals – particularly since the Chance light valve, whilst excellent on land, could not be used on a buoy. AGA held the patent! However, I think you will see that the Chance design is most ingenious.

Glass bulb (1) of clear glass and bulb (2) panted matt black are connected by the lower tube (3). In daylight bulb (2) by absorbing more heat than (1) is hotter and consequently vaporizes the highly volatile liquid, petroleum ether, which partially fills the bulbs. This vapor condenses in (1) until the greater vapor pressure in (2) is balanced by the greater weight of liquid in (1). This extra weight tilts the bulb assembly and through rod (4) and lever (5) closes a suitable valve for the acetylene supply. At dusk a reverse process occurs and the light is 'switched' on. Creativity in design is not common but after trying many times to prevent seagulls from using the valve as a lavatory someone tried the negative–positive approach by adding to the phrase "we cannot stop birds landing on the valve" the words, "but what can we do next"? So as you see the four horizontal spikes of the Chance bird-scare (6) are a perfectly landing–ground, but the very flexible vertical spring promptly tips the offender off and adds to his discomfort by poking him in the pants as he falls off! Never a spot on the glass dome (7). Whereas, before, in a week we would see the dome completely light-proofed.

The necessary rocking of the bulbs means the valve cannot be used on buoys but many authorities prefer to have buoys lit 24 hours a day, so obviating the use of a light valve.

Candle Power of Beams from fixed lenses with Acetylene Burners

Sample values are given in Table 7 for Range, Dioptric and Catadioptric Lenses as obtained by Chance Brothers from, I suspect photometric results.

Consumption of fish-tail burners, single or cluster in ltrs per hour		Flame width of flame/s	Type: Range Lens, 150mm F.L. lens	Range Lens, 187 F.L lens	Dioptric Lens, 250mm dia. lens	Dioptric Lens, 375mm dia lens	Catadioptric Lens, 375mm dia lens	Catadioptric Lens, 750mm dia lens
15	Single	20 mm	3140	5560	115	265	Note: FL = focal length	
25	"	32	4100	7260	180	400		
35	"	43	4060	8800	240	550	1120	1480
75	Cluster	45	(for Range lens see p 48				1950	2600
125	"	66	Fig. 39)				2950	4100
205	"	80					3800	5600

Table 7

Since the only variable, column by column, is the brightness of the light source (B) it is clear that this varies nearly directly as the consumption of acetylene. This is very different to the variation with the size of a P.V. mantle burner – see page 19, Table 4, but the pattern of variation of the electric lamp is somewhat similar – see page 20, Fig 13.

Photometric tests, are not difficult with small lenses and another important factor must be the odd shape of fish tail burners, particularly when in a cluster. Values used by Chances will be used in the example that shortly follows.

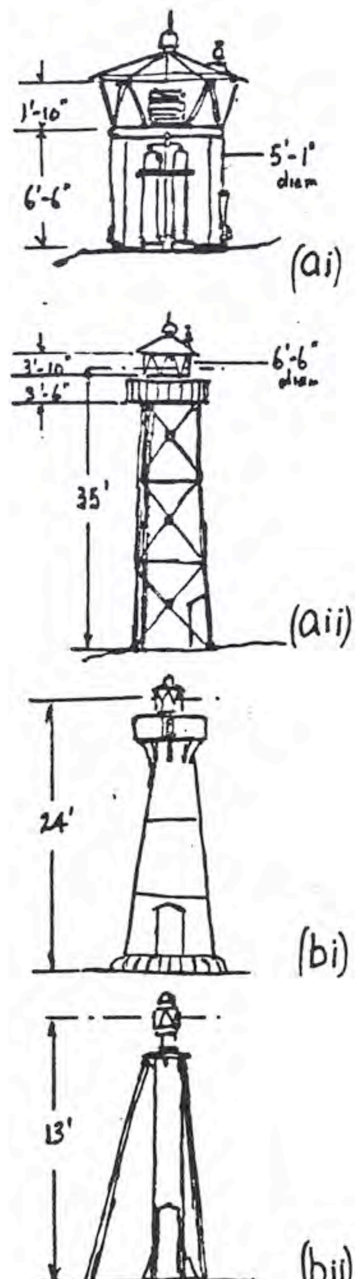


Fig. 36 - see over

Types of Beacon

Fig. 36 shows but a few of the many types.
Long/medium range for harbor location – erected on, say, a headland or breakwater. type (ai) is most seen on a headland of moderate height, but type (aii) is necessary if the land is not much above sea level.

For breakwaters – type (bi) if exposed to heavy seas or type (bii) for isolated rocks or promontories or shallow water – types (ci) or (cii) medium /small range – on a quay or protective wall in harbors (di) or (dii)

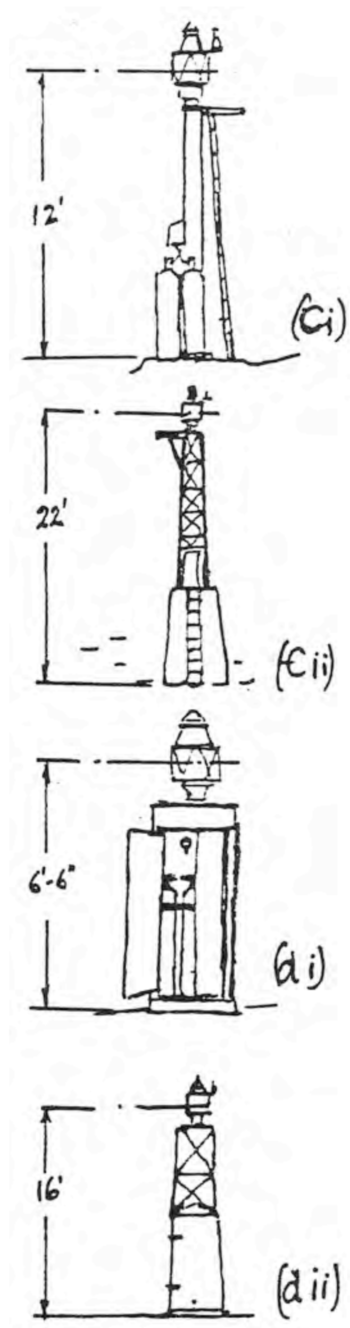
Example: The Authority's Engineer concerned will supply: the height he requires the focal plane of the light to be above sea level to give him the required geographical range together with an average height of the mariner's eye above sea level for the type of boat using the light at extreme distance. Let us assume focal plane above sea level = 30 feet. Mariners 'height' = 10 feet then using Table 1 on page 6 we see that the (total) geographical range is 9.91 nautical miles.

The engineer will also give either the transmission factor (T) of a neighboring light, obtained over a long period or will indicate the average weather under one of the headings now given:

Atmosphere	Very clear	clear	average - good	slightly hazy
Value of T	0.85	0.80	0.7	0.6

Given also that the acetylene flasher will be 1/10th character with a light period of 0.375 seconds (light 0.375, dark 3.375 = total 3.75 seconds) then t in the Bondel-Rey formula = 0.375 and the Blondel-Rey factor is: t = 0.8 and Io = 760 candlepower. Finally, applying a corrective factor of 0.80 for the glazing the final Io = 950 candlepower.

Now using a data sheet, of which Table 7 above is but a part, our first choice will be a dioptric drum lens of 500mm diameter using a 50 liter/hour cluster burner comprising 2-25 liter burners and 2 pilots – the width of the cluster being 48mm. This flasher will be one of 10/100 liter capacity as shown in Fig. 34, page 43. Now to the number and size of gas cylinders required – using a light valve with a saving of 30% gas. (The lantern will be of the buoy type).



Cont^n of Fig 36

Consumption for the cluster burner/ day = 84 liters/day, plus 2 pilots at 10 liters/day = 20, plus 10 % to avoid 'draining' the cylinders. Suggesting 6 month replenishment (183 days) = 21,000 liters. Using large cylinders (2 cubic feet) charged with 6200 liters of acetylene we will need 4 large cylinders.

Second choice: a catadioptric lens with a single 30 liter burner (with one pilot) and width of flame 38mm. The 500mm diameter lens has a candlepower of 1020. The gas consumption = 50 plus 10 for pilot = 60 liters per day. For six months = 12,100 and hence number of large cylinders = 2 large cylinders.

Third choice: a single fish-tail in a large optic gives a pronounced unilateral light distribution. Whilst this may suit the shipping lanes we should, I think, offer the customer a small cluster light, say 2, 20 liter burners with 2 pilots, with the same 500mm catadioptric lens the candlepower = 1150. Gas consumption = 68 plus 20 for 2 pilots = 88 for six weeks = 17,800 plus 10 % = 96.6 per day. Hence number of cylinders = 3 large cylinders. So the total Lighthouse Board must weigh up capital cost against annual replenishment cost for the three types of beacon rendered.

Fig. 33 page 43 shows a typical 2 cylinder installation.

Further details of the Beacons shown in Fig. 36.

(ai) Quite common, the small diameter murette (the lantern body below the glazing), but rather tall indicates the storage of gas cylinders in the lantern; the small height glazing accommodates a dioptric (drum) lens and the outward inclined glazing denotes there being heavy snowfalls in the winter.

(aii) The larger height glazing accommodates a catadioptric lens; the cupboard-like housing at the bottom of the structure holds the gas cylinders, hence a small height murette . The tower is of mild steel, a material which salt water spray will soon corrode away if not galvanized and then regularly painted on site.

(bi) This cast iron tower was supplied for the part of Takoradi on the Gold Coast, Ghana and was subject to heavy surf. The sharp conical shape of the tower and the heavy base sustain the battering it gets. The lantern is a modified buoy type.

(bii) I designed this for the little port of Port Isaac, Cornwall, but on tendering was a little put out when the Harbor Board Engineer wanted three ties, as shown, to brace the column – and he suggested they be second hand railway rails! Well the customer is always right, and indeed he may have been so, since I saw it twinkling away happily in a heavy sea thirty years later!

(ci) For calm sea: and an equable climate! Has a buoy lantern and a light valve is shown.

(cii) On a concrete base in shallow reasonably calm water. This type of lattice tower is however very strong and so suitable for high winds. Again buoy lantern with light valve.

(di) A nice little job for a busy harbor holding 3 gas cylinders, this light could be manually switched on or a time-clock used.

(dii) Again a strong tower with ample space for cylinders.

Beacon (or Buoy) Lanterns with drum dioptric lenses

These are really splendid things and before painting, are a gleaming of copper, brass, bronze and plate glass. Nothing to rust on these!

With fish-tail burners, in such a confined space, ventilation must prevent the glass from sweating up and the pea-size pilots must not be blown out. Imagine the problem particularly when the lantern is mounted on a buoy – in a North Sea gale of force 9: The buoy tossing wildly about, pulling at its mooring chain and a full gale of wind full of spray and 'solid lumps" of sea water! Let us see how this near miracle of keeping the "light always shining" is performed. Fig. 37 and 38 refer.

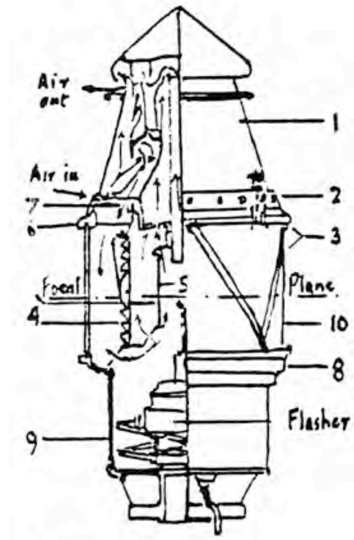
First we will describe the components of the lantern, and secondly trace the passing of incoming air through the lantern.

The Lantern: The ventilator (1) comprises 9 copper spinnings plus the heat tube and forms a labyrinth of air passages. It is mounted on a cast brass ring (2) which is hinged on the helical framing (3) we note that both the drum lens (4) and the colored glass shade, if fitted, (5) are held down by the pressure ring (6) and a set of springs (7) respectively. Proceeding downwards we see that both lens and colored shade are carried by the cast support ring (8) which in turn is carried by the helical framing (3). The lantern body comprises a brass sheet cylinder and a cast base (9) sturdily designed for attachment to the beacon or buoy structure. Bosses on the top of the helical framing carry a bracket for the light-valve if this is supplied.

Ventilation: The only air inlets are in ring (2) and from these the air moves upwards dividing into three streams (4) directly up and out, (b) into the middle annulus and out and (c) which curls down between the lantern glazing (10) and the lens (4).

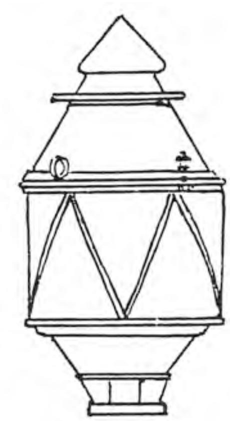
Will we follow streams (c) assuming a colored glass (5) is fitted. (c) flows through the support ring (8) and splits between lens and shade and to inside the shade to support combustion of the burners. Most of the latter will, fiercely heated go up the heat tube. The remainder of (c) finds its way through ring (2) upwards to the undulating passage in the top cone of the ventilator.

To summarize – fire glass surfaces swept with air; main flames and pilots with never a quiver and not a spot of water in the lantern. Bravo!



1 Ventilator
2 Cast Ring
3 Helical Framing
4 Drum lens
5 Coloured Glass shade
6 Pressure ring
7 Springs
8 Cast support ring
9 Base
10 Glazing

Half sectioned Lantern with 200mm diam lens
Fig 37



Lantern with 300mm diam lens
Fig 38

9 Range, Sector, Leading and Temporary Lights

> I marked the lofty beacon light stream from the church tower, red and high.
> Jean Inglelow
>
> The church of St. Marys and St. Eanswythe, Folkstone 1138
>
> ... and the magnificent tower rebuilt about 1400 and raised to provide a platform for a beacon to guide channel shipping
> Gregory Holyoake

Range Lights are powerful lights of narrow angle used on occasion to lead a ship along a sea or (rarely) river channel or through a narrow entrance.

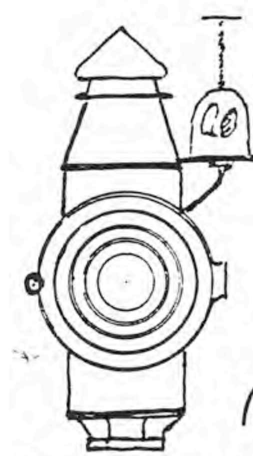
Leading lights, if low lights are used to indicate a channel these are called leading lights. The lower light is usually on the shore line and the upper light some way inland.

Sector lights, some lighthouses have the dual purpose of displaying not only the main, say revolving light, but incorporate, usually in the room bellow the lantern, a subsidiary light of distinctive character to indicate danger such as a group of small islands, a low lying promontory or a reef.

Range lights

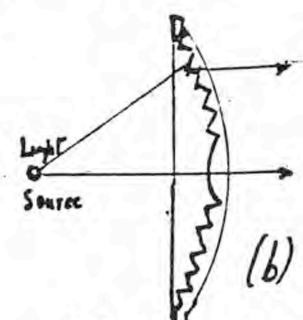
The lens for these is called 'holophotal', If you will refer to Fig. 11 page 15, the elevation of the 80º panel shows a circular panel comprising the bulls eye and several refracting prisms. Imagine this panel to be used as a fixed optic it will give a pencil beam of light with some slight divergence. In this guise it is a range light.

In reality holophotal lenses are much smaller and Fig. 39 shows two types. The first has ground and polished dioptric prisms of focal distances 113, 150 and 187.5mm. Typical candle powers are: 113mm – 1320cp with a divergence of beam 7.1º, 187.5mm – 8800cp with a divergence of 13.1º. The fish-tail burners are singles at 15 and 35 liters respectively. Fig. 39 (a) shows the adoption of a buoy lantern for such a lens.



(a)

Range light, 187.5mm ground and polished lens.



(b)

Sectioned Elevation Holophotal pressed lens.

Fig. 39

The second type of lens is of 113 mm focus, of pressed glass with a smooth outer face which is self-cleaning and requires no plate glass front to protect it from the elements. Fig. 39 (b) refers.

Both types are fitted with reinforcing mirrors behind the burner. Pressed glass lenses are made by dropping a gob (sorry, a trade term) of molten glass in the bottom iron mould and then bringing down the top mould. Between them the glass is pressed into shape. You will have noticed that road traffic and railway signal lenses of colored pressed glass are used.

Leading lights

Usually the lower or forward, light has a wide angle lens, the upper, or rear, light a small angle lens. Both lenses can be just a sector of a dioptric drum lens or, rarely, a sector of a catadioptric lens. Fig. 32 (d), page 40 and Fig. 2, page 2 refer.

In Harwich – Dover Court two sets of disused leading lights can be seen. Both sets were made redundant by the sandbanks moving. We imagine that twice was enough as buoys now guide ships in and out of this busy port. However, in Fleetwood a set of leading lights built in.1840 is still working since it guides ships along the River Wyre.

If you look for them a useful hint is that the upper light appears to be a memorial column whilst the low light has the look of just of a house of dubious period.

For use in the daytime both upper and lower light must be plainly visible to the mariner and certainly the old ones mentioned above had substantial towers. Otherwise day marks must be added to the light structure, and in Fig. 40 the thumbnail sketches show a few of the many hundred types. (a) and (b) are for leading lights and (c) for a range light.

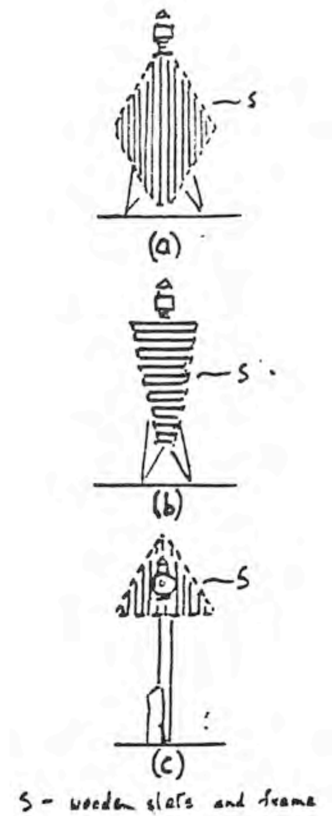


Fig 40

Subsidiary Sector Lights

The sector of danger to be lighted is often over a very small angle and is met by using a small sector (in plan) of a dioptric fixed lens. For example the Eddystone Lighthouse has a fixed white subsidiary light to cover ‘Hands Deep’ between bearings of 112º to 119º. The candle power is 8000.

The Milterton Beach Lighthouse in South Africa has a subsidiary exhibiting a red light over a 90º sector of submerged rocks near the lighthouse. The illuminant is a 500 w 110 v electric lamp with a stand-by lamp incorporated in the lamp changer, in the form of two metal strips, fitted in a slide at each (plan) end of the optic, are sector setting, or cut-off, screens. These are finally set on site to ensure the accuracy required by local mariners.

The red light gives a power of 2520 candles. This is an unattended light and should the subsidiary completely fail the main light is also extinguished. Better for the mariners to grope around rather than run aground on unlit rocks. Fig. A1 (a) refers.

Another typical example is shown at (b). This is a ‘twin sector’ system installed in the room below the lantern, requiring, of course, two windows of suitable size in the tower. Red glass filters are incorporated in the optic frame.

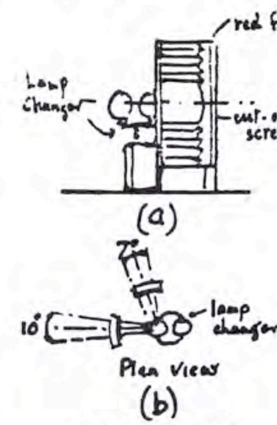


Fig. 41

The Old Fixed Lights

If the main optic revolves then subsidiary sector lights must, if required, be supplied but more ingenuity was used to take some of the light in the landward sector and then divert in by mirrors and banks of prisms through a suitable window fitted with a red filter in the service room or through a red filter attached to the lantern glazing. Possibly 5% of the light tapped off emerged as a red beam! In Fig. 42, shown diagrammatically, are two possible ways of juggling with light beams from Big Fixed Optics.

Other Devices

Should the natural divergence (see page 8) for a Range light be insufficient, and it could be with a small electric lamp, then a diverging lens can be added to the frame of the holophotal lens. Fig. 43 refers.

If for a range light a mirror is used precautions must be taken for certain duties to limit the light to the natural divergence. Louvers can be added to the lantern to cut-out direct light from the illuminant. Fig. 44 refers.

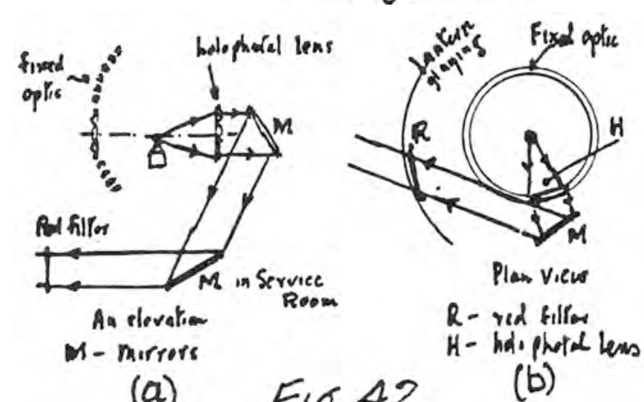


Fig 42

The circular rings tend to be too close together at the centre of the light, but, since the bulb of the electric lamp is taken to be a 100% obstruction to the light from the mirror, the opportunity is taken of putting in a mirror at least the diameter of the bulb. The light reflected back goes to the focal point. The rings are of aluminum strip, painted matt black, and held together by radial tubes and pins. Fig. 44 refers, parts 5 and 6.

A Marine – Aero light

In the late 20's Chances built their first "Aero" light. This was a flood-light to illuminate a landing ground and it was a 180º (in plan) 3rd order fixed optic with one of the earliest GEC 10KW electric lamps.

From then on they have made many other types of floodlights, beacons, contact or runway lights, obstruction lights, wind indicators and even 'lit' mooring masts for flying boats.

However, in my time, only one authority, the Egyptian, asked Chances to make a marine-aero light. It appears that their new light, Ashrafi, was on an important commercial air route so why not sacrifice about 10% of the four beams of the marine light which were already very powerful. (see Table 3, page 11*)*.

So four panels of plano-convex diverging lenses were attached to the main optic panels throwing a fan of light upwards from + 3º to + 25º above the horizon. I have shown these in Fig. 11 page 15 but not assembled on the two - 71º panels or the two 80º panels. I hope, in these days of scientific methods for navigating an aircraft, that they have been dismantled and put in a museum! Never say no to a 10% increase in a marine beam!

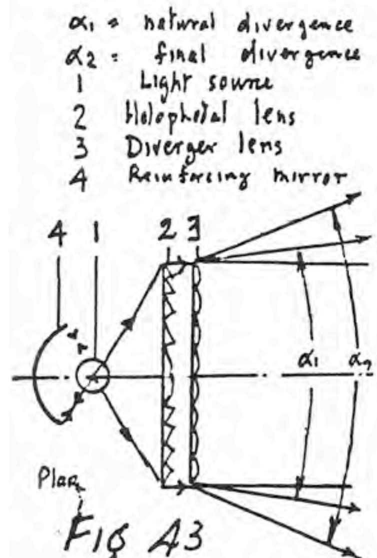


Fig 43

You will see that diverger lengths on mounted horizontally for sending a beam upwards whereas for the range light, Fig. 43*,* they are mounted vertically to spread the light sideways.

To design the lens for Ashrafi – to the half section of the plano-convex lens design the "thin end" to give the 25º change in direction of a light ray and cut off the "thick end" when a 3º change is reached.

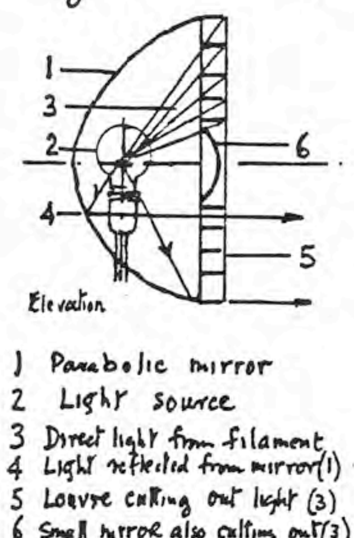


Fig 44

A Temporary Light

So very, very occasionally that I am rather hazy on details, Chances were asked to supply a temporary light for use whilst extensive re-building of the main light was in progress. This light was stored in a remote store and only three times in my 20 years was it brought out, re-painted and fitted with the required change gears for the clock and the required light source assembled.

It was splendidly designed to give the engineer on site but two tasks, first to wind-up the double spring clock and secondly (if fitted) to fill up with oil the single circular wick oil lamp.

I'm almost sure it was a 6-60º dioptric optic of 150mm focal length with the prisms mounted in aluminum frames, and floated on mercury. The lantern which enclosed all this was a dapper affair and I doubt if the overall sizes were more than 24 inches diameter by 5 feet high. If the light was a big one the space between the lantern murette and the balcony handrails was sufficient and from this superior height (of course on the sea-ward side) it flashed away merrily. By blanking off (with thin sheets) the optic could display from single to quintuple characters.

Red Faces! – on one occasion the return of the (subsidiary) temporary light was followed by a letter from the local Lighthouse Authority (Chances were not involved in the electrification of the main light) giving extracts of reports received from the local fishermen and the skippers of coasting ships and asking for our views. Believe it or not the locals said, can we have the little light back? The main light, having now an electric lamp instead of a P.V. Burner, showed a lot of haphazard flashes and the light was blue and not yellow!

First – replacing what was originally a multi-wick oil lamp of possible flame diameter of 6 inches by a filament under 1 ½ inches in width had got quite a few boards into trouble. I believe it possible that in the last century the individual prisms were not focused on the focal point of the optic but rather at some point each side of this. This was an attempt to allow for the considerable width of the oil lamp flame. If so a lot of light in the resulting beam would be ex-focal, giving, a “spiky” beam showing more than a few irregular flashes to observer near to the lighthouse.

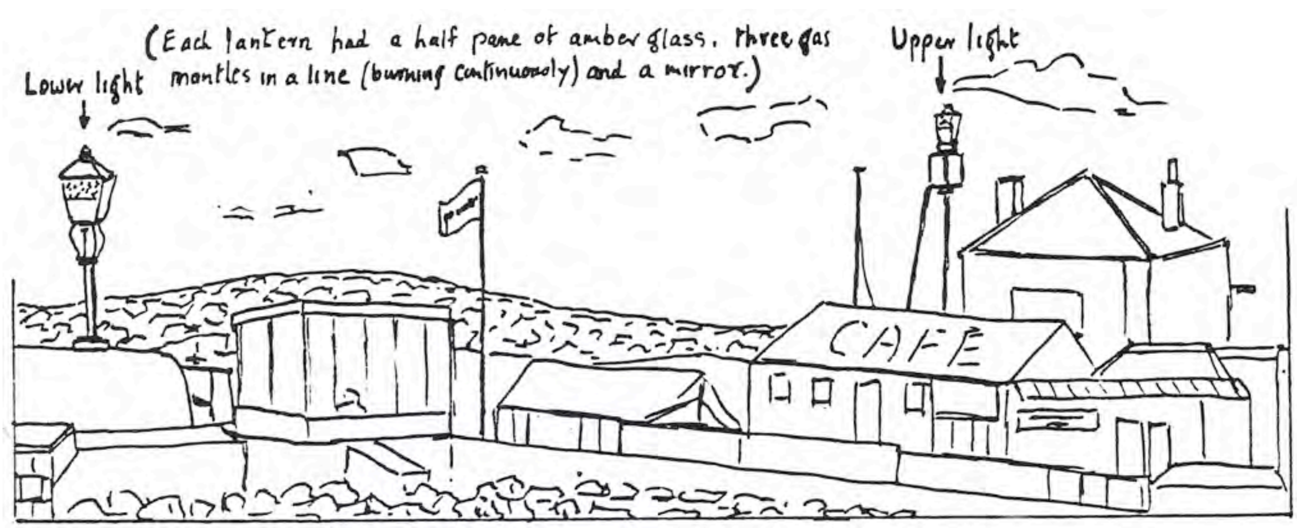
The locals would miss, also, the considerable vertical divergence (see page 56*)* of the temporary light due to the very small focal length of the small optic (150mm) and the fairly considerable height of the flame from the single wick oil lamp. This would enable the flashes from the temporary light to be seen nearly up to the entrance door of the lighthouse whereas the main light went, in more ways than one, over their heads. The preferred yellow tint of the little light against the blue tint of the main beam is, I had found, a general preference, possibly because the human eye is most sensitive to the green-yellow zone in white light.

I am sure we recommended the purchase of a smaller light more suited to an electric lamp as the source of light!

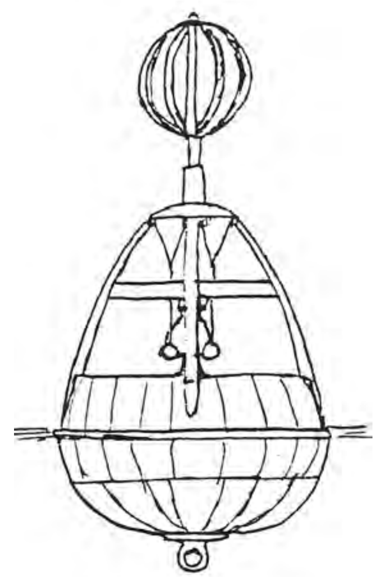
Now to sea with its many buoys and its not so many Lightships.

Woodbines
The pressed light of Fig.39b reminds me of another job initiated by the Drawing Office Juniors.
The design and manufacturing methods of such a lens was checked in the darkroom. The vertical slit of light was photographed using, initially, artifical smoke. An exposure of one hour was not unusual. The chemical smoke was detected by all and it took a genious to suggest buying the junior a packet of Woodbine cigarettes, then sit him on a box under the lens and let him puff away, and meditate, for an hour! The photographs were excellent.
Incedentally the illuminant was a “point a lite” developed by Mullard wilst with Edison Swan. A nice 2mm diameter tungston ball was raised to a vivid white light by an electric arc.

Not a Chance but a very homely sort of Leading Light at Exmouth!



10 Buoys and Lightships



Bell Buoy, c1880

Here we go afloat either on the sheltered waters of an estuary or the often very unpleasant open sea.

Navigational buoys were first used in German waters in the 11th century, but it took until 1536 before a primitive wooden buoy appeared in the Thames. Around 1880, lighted buoys appeared with a clappered bell, but the buoy sketched has but a day mark and a bell (Bells will be dealt with when we reach the chapter on fog Signals).

There are dozens of shapes and sizes of buoys and many methods of mooring them. Daymarks are often, to me as a non-sailor, most confusing, but I can recognize the cone, can and sphere type! One thing, however, is quite certain, if an Admiralty chart says a buoy is at xº West and yº North then Trinity House will indeed see that it is there.

Buoys in sand bank areas or in estuaries have on occasion to be re-positioned and wrecks must be marked by a wreck buoy without delay. I have frequently watched at Harwich the Trinity House “Patricia” or one of the other tenders in the harbor, sail with a deck cargo of buoys for an unknown destination. The often picturesque name painted on the buoys is seldom helpful – to a land lubber. I recall a few weeks before ‘D” day in World War II getting an SOS of all SOS’s. A line of buoys was due to be laid enroute from England to the Normandy beaches, but someone had forgotten to order from Chances the lenses for the buoys! We worked 24 hours a day until they were completed.

Buoys can be classified into two main categories:

1. Shallow draught buoys with flat bottoms – for shallow waters and, if required, they can settle on the mud at low tide. By their very geometry they can capsize hence the height of the structure and the weight of the buoy lantern are restricted. Fig. 45 (c) and (b) refer.

2. Deep draught buoys with tail tubes – for deeper and more exposed conditions. They cannot capsize, at least if they retain their tails and there by hangs a tale to be told later. Fig. 45 (c) and (d) refer.

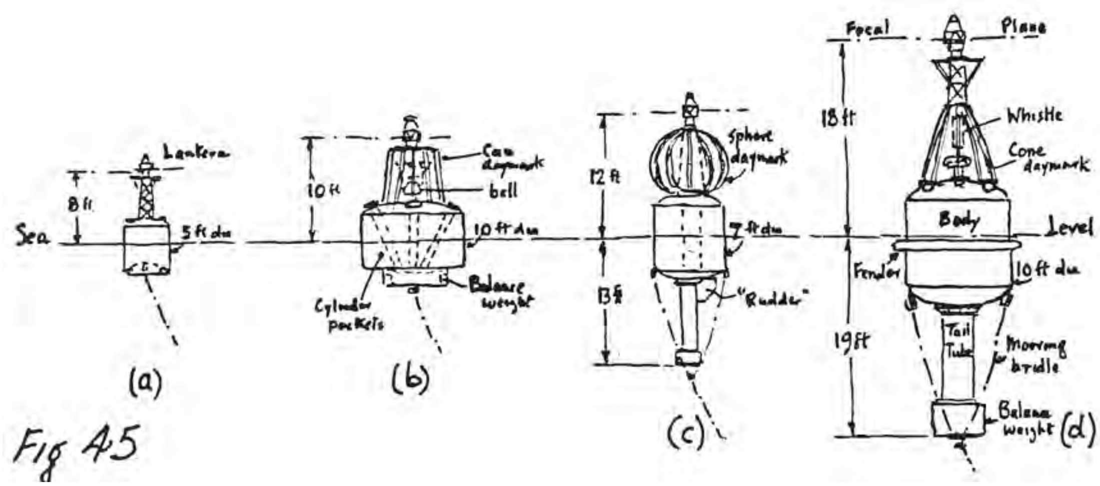


Fig 45

Further particulars of Buoys shown in Fig 45: 8

Reference and Type	Service Conditions	Sea Conditions	max. Current in knots	mooring depth in fathoms min max	Max height of focal plane in feet	Body plate thickness in ins	Mooring Cable in ins.	Sinker weight in tons	Sound Signal (if any)	Max. size of lantern (optic)	Pockets for gas cylinders
45 (a) Shallow Draught	General purpose: small	sheltered	3	1 15	8	5/16	3/4" open link	½-1	none	200mm	1
45 (b) Shallow Draught	Channel open Sea	moderate - heavy	5	1 20	12	½	15/8" " "	2-3	up to 3cwt bell	500	4
45 (c) Deep Draught	Channel Fast current	moderate	6-10	3 30	15	3/8	13/8" " "	1-2	whistle	375	4
45 (d) Deep Draught	Open sea	Heavy	5	4 50	20	½	15/8" " "	3-4	whistle	500	4

Chance Bros 9

Going	Character of light	Details of 'single flashing' for burners of low consumption	Daymark. *	* Sphere - special, often for wrecks.
Port	single flashing Red or group flashing White	120 flashes per minute	Can	† starboard or side on R.H. of mariner when going with main stream of flood tide or entering a harbour, river or estuary from sea ward.
Starboard †	single flashing White or single flashing Green	60 flashes per minute	Cone	

A few further details: Can, Cone or Sphere daymarks can be fitted to most types of buoys. Chances had no facilities for making buoy bodies so if they were the main contractors the buoy complete with structure, tail tube (if any) and fitments to take the Chance buoy lantern; gas cylinders etc. was ordered from contractors such as Ashmore, Benson & Pease Ltd. We and the customer's agent would inspect at their works and the complete buoy would be shipped direct to the authority.

On other occasions 1) the body maker was the main contractor or 2) the authority itself ordered the buoy and moorings from elsewhere. In these cases Chances only supplied the buoy lantern with flasher, piping and other fittings but quite often not the cylinders.

Motion of a buoy

The periodic motion of the prevailing waves, on average, must be given by the customer since if the natural oscillation of a buoy coincides with the period of the waves then violent oscillation of the buoy will occur.

The shallow type of buoy can be designed for a complete oscillation, there & back again, of from 2 ½ to 4 seconds and the deep draught type from 4 ½ to 8 seconds. With shallow buoys the natural period of the sea is generally greater than that of the buoy and so the buoy tends to conform to the wave period and the lantern inclines to the hollow of the waves. See Fig. 46 (a).

With tail or deep water buoys the wave period is generally smaller than the period of the buoy and so the sway is much smaller than that of the shallow buoy and the lantern inclines to the crest of the wave. (b) If the careen, the tilt or sway on one side, angle is greater than the semi-vertical divergence of the optic then the beam is either over the mariner's head or below his feet!

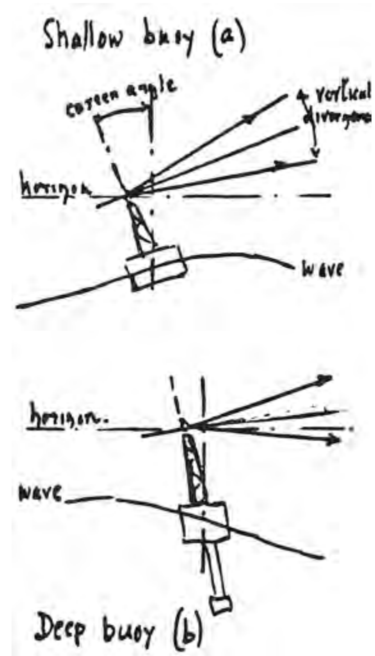


Fig. 46

The Buoy Whistle - If the tail tube is left open from the top of the body to its very bottom and the buoy is lowered into the sea the water inside the tube will rise to the sea level. If we now bolt on an airtight cover at the top, the trapped air will, by the up or down motion of the buoy, be at a pressure higher than atmospheric or, on the down stroke; lower. In the chapter dealing with sound signals we shall see how this variation of pressure is used in a Buoy Whistle.

" I saw my first mark since the Eddystone Light - awhistle buoy abeam"
Francis Chichester

Sea Current – If high the mooring chains should ideally be attached at the centre of pressure of the current on the submerged part of the body of the buoy. The double chains or bridle also resist the tendency for the buoy to turn around. This is a hit or miss business since the current decreases towards the sea bottom or ground. Fig. 45 (c) shows how, on request, a 'rudder' can be attached.

Wind – This can accentuate the tilt particularly if a daymark is fitted.

Some brief notes on anchoring or mooring systems

I believe that the type of moorings and anchors must be left to the local engineer who must know better than someone 10,000 miles away the quirks of local seas and condition of the 'ground'. Chances could certainly order them from a local, Black Country, firm and inspect them – and get the test certificates. Again with anchor type (c), shown in Fig. 47, is obviously home-made.

I hope Fig. 47 is self explanatory and will only remark on the need for a lifting chain to get at the main mooring shackle and the need to take some of the weight of the chain off the buoy in very deep water. If the position of a buoy is very critical, two anchors connected near the bottom to the vertical chain will help. If the ground is rough the lower part, termed the wearing-off portion, of the chain should be of a heavier pattern.

Replenishing of gas cylinders and maintenance

There is little doubt that very many buoys have work done on them whilst on station – and a mauling, dangerous job it must be. It does one good to see Trinity House completely prepare a buoy to replace another at sea and then hoist the 'old' one out and drop the new one into the sea, having checked its position.

If you are at Harwich, or another Trinity House repair yard, have a look at the wonderful variety of buoys, moorings etc. in the yard and the reserve Lightships in the harbor. And take a look at the Trinity House flag, takes you back a few hundred years, years of splendid endeavor. Then take a pint at the old 'pub' on the front with Trinity House men and those of the Merchant Navy – they depend much on one another!

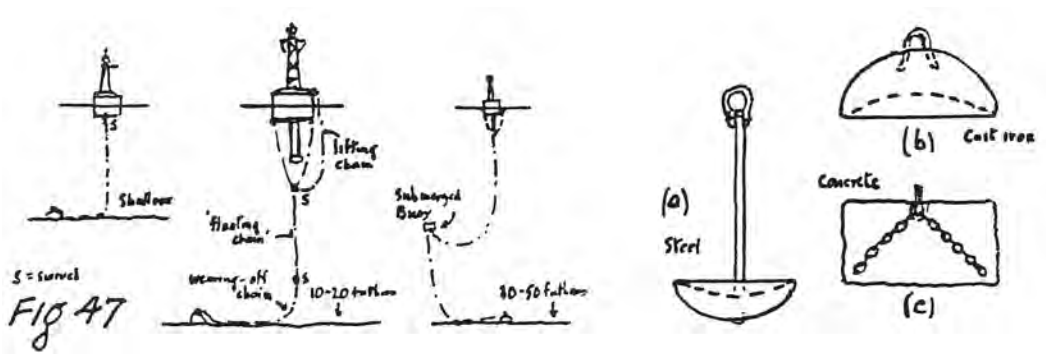


Fig 47

To conclude we have two stories to tell – one about tails:

1) A mini-skirted buoy, in size between (a) and (b) Fig. 45, strangely 'found' its way to my design board for 'getting out' the balance weight, and the required period of oscillation. My chief noticed with horror that the centre of gravity of the, complete buoy plus some of the mooring chain, was above the centre of buoyancy (the centre of volume of the sea water displaced by the body of the buoy). Quite rightly he said "that will capsize"." I replied, "Yes it could and so could every ship sailing on the seas". He lacked all interest in ships and their passengers and demanded the center of gravity be below the center of buoyancy. I replied "ok but most of the body will be below water and that will be a strange sight particularly as the body is a good daymark" – or rather should be.

It was done and the buoy on being lowered into the buoy pond went lower and lower until the side wall of the body was completely submerged! So off came some of the weights and everyone – well nearly everyone, was happy.

2) This is a tale of missing tails of some buoys in size between (c) and (d) supplied to the Chittagang Board, then India. One sad morning after a vicious typhoon the buoys appeared to be missing, but were later found floating upside down with no tails!

Rusty bolts holding the tail to the body finally took the blame, but it took some imagining to believe that a few dozen bolts all broke in one night! With not a little hindsight I think little credit for these buoys went to the local board, the makers and to Chances. I suspect little team work between them in such matters as sea conditions, the strength of the attachment tail to body, the true design and protection of the bolts and even how it was shipped as deck cargo. Take the latter, could not the tail tube have gone from the top of the top crown of the body right to the bottom of the tube? Was vibration of the tube in a storm taken into consideration when designing, when tightening and (not) protecting the bolts from corrosion? The old story of piecemeal non-systematic design.

Buoy Lanterns – have been dealt with on page 47, Figs. 37 & 38.

Stability of Buoys

The buoy in question was a 7 feet 6 inches diameter tail buoy with a total length – focal plane to bottom of the balance weights, of 24 feet 6 inches and a weight of 14000 lb. (6 ¼ tons).

Lightships

Before considering these fine ships in detail let us look at the amazing amount of equipment they have to carry, all in a ship on average, 140 feet long, 25 feet wide, 15 feet deep and 500 tons or so. The focal plane is usually around 40 feet above sea level, the light being, for example, four pairs of mirrors (adjustable from single to quadruple flashing); each mirror has a 375w, 100v lamp and a total candle power of around 300,000. The equipment is now listed:

1) A lantern on the mast top with a dioptric/catadioptric lens or a mirror light mounted on gimbals and diesel engine – generator sets supplying the electricity for the lamps and driving motor.
2) An air-operated fog-signal – usually a Chance Diaphone (a thousand elephants trumpeting!) with its air containers, timing gear and its associated engine – air compressors.

"Far to the right stretched out the flat cold plain of the Atlantic – that enormous darkened looking-glass: only a distant lightship ever and again stealthily signalling to us with a lean phosphoric finger from its outermost reaches"
Walter de la Mare

3) A submarine bell or an under-water oscillator.
4) A radio beacon and generator.
5) Believe it not two cannons which can be fired (no shot only noise) as a last resort at the oncoming ship which is either trying to founder or rundown the lightship. Its navigator is possibly sitting mesmerized in front of a radar display screen!
6) Power for ship's lighting, galley and ships equipment, but no propelling machinery. The 30 or so TH ships have to be towed to site. One method of knowing precisely where your ship is to aim it at the lightship, at least certain lightships. I remember in a thick fog off Liverpool running so close to the Bar Lightship that the proverbial encyclopedia could have been dropped on the head of an unsuspecting member of the lightship!

The crew comprises the master and five or six others – seamen, engine room men and lamp-men. One supposes one of the crew is also the cook. Then let me say that if you like black treacly tea that just oozes from the pot then get invited to have one aboard any lightship!

These snips are, of course, anchored and hence a setting target for bad weather (in certain seas the cable has to be shortened). If you are in the engine room in bad weather looking with not a little awe at the engine tilting 15º or so at you and wondering, which is the quickest and safest way aloft should you need it, then a snatch at the anchor chain decides it very quickly.

Lightships can reputedly tilt 40º each side of the vertical but around 20-25º the XX gear of the light must be jacked up.

My first lightship was 'Sunk' off Harwich (notice the capital 'S') – what a name! In trying to get off the TH pilot boat on to the deck I wished I could do the splits with the ease and comfort of a ballet dancer! Of the visit more will be told under Fog Signals.

Why a Lightship?

Rock stations such as the Eddystone, Longstone, Bell, Needles etc. are indeed on rocks or reefs dangerous to ships. Land stations can cover local dangers, sometimes with a subsidiary light, but sandbanks such as those off our East Coast which project into major shipping routes require a major light not merely buoys and so (they are so expensive to run and maintain) almost as a last resort we have a floating 'lighthouse' – a lightship such as *Sunk*, *Royal Sovereign*, Mouse, North Carr, Bar etc.

Vertical Divergence of a light beam

Almost as soon as we get down to details on the optic and mounting gear used for lightships we shall require to know the horizontal & divergence (see page 8). This is found by looking at the elevation (not plan) of the optic and light source, as in Fig. 48.

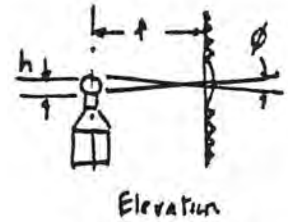


Fig. 48

Example 1. A fish tail burner in a buoy lens 200mm diameter, flame 25mm high requires a horizontal divergence of 14º 21'.
Example 2. A 1KW electric lamp, filament height 16mm in a 250mm focal length optic requires a horizontal divergence of 3º 40'.
Example 3. (A very special lightship see page 61) A collodion mantle 85mm high in a 250mm optic requires a horizontal divergence of 19º 30'.

If you will now go back to page 53, Fig. 46 and compare the half angle of the divergence with the careen or tilt angle of the buoy. Part (a) of the Fig. shows the careen angle as the greater so that the mariner will see only an irregular beam. Part (b) shows the beam straddled across the line to the horizon and the mariner will see the correct character of the buoy light.

For a very expensive and important light, in the form of a lightship, every effort must be made to see that the optic remains upright (the beam being directed to the horizon). Mounting the optic pedestal on gimbals does this except, as we shall see, in very, very severe storms. Since the half divergence, see example (2) page 56, for the *North Carr Lightship* was, but 1º 50’ we have a very difficult job to do.

On the other hand the very special *Calcutta Lightship* – see example (3) page 56 – the half divergence is 9º 45’ which is suitable for the estuary waters in which it is stationed.

Smith’s Knoll Lightship - See Fig. 49 below.

Shown below is the Smith’s Knoll Lightship stationed off Great Yarmouth. This one has been chosen because it shows very clearly the Diaphone Fog Signal, lying just fore of the tower. You will note the vertical flared trumpet with its mushroom top – an endeavor to get ‘all-round sound.

You will note also the height of the glazing of the lantern is much higher than the optic. It is hoped that Fig. 51 shows clearly why this must be so for the designed careen of about 25º. The tower supporting the lantern is an openwork steel structure which is now favored by Trinity House I imagine, on the grounds of expense. Having no head for heights I prefer to climb up a tubular tower and not see the sea or deck below me!

Possibly the last thing of interest is the experimental landing pad for a helicopter, an early attempt to reduce maintenance costs. As I wrote this in 1977 Trinity House have decided to replace all lightships except those on the North Sea sand banks where as I have mentioned before the cable has to be shortened in very severe storms. Trinity House say, “This is not possible with one of the replacing (40 ft diameter!!) buoys” – and thank goodness a man is still required on occasion! Already shown on page 4 is the other type of replacement. To me it looks nothing like a lighthouse and you might guess it has other functions.

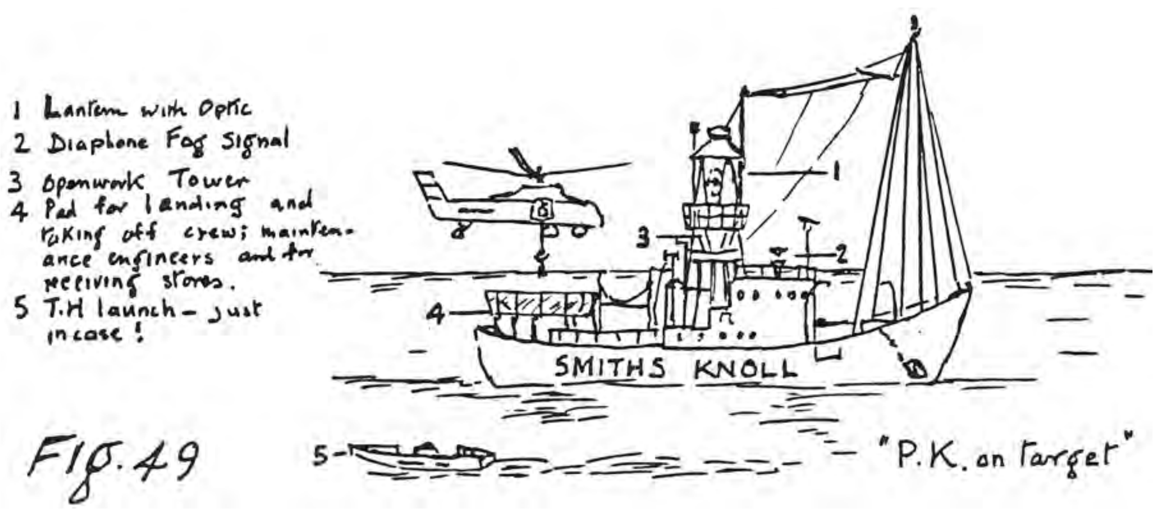


FIG. 49

The Pendulum

First how do the gimbals, the essential part of the pendulum (Fig. 51 refers), keep the optic vertical no matter how the Lightship mast swings to and fro? Please refer to Fig. 50 and note that “bearing ½ “ means the bearing between parts 1 and 2.

If the mast moves part (3) must remain stationary. Let us see:
a) Consider the mast to tilt along axis yy then since in effect parts 1 are fixed to the mast they will revolve around axis xx. Bearings ½ enable part 3 to remain stationary.
b) Consider the mast to tilt along axis xx then parts 1 and 2 will revolve about axis yy. Bearings 2/3 enable part 3 to remain stationary.
c) If the mast tilts about any other axis, say zz between axis xx and yy, the motions of the parts will be compounded between motion a) and b) above and part 3 will remain stationary.

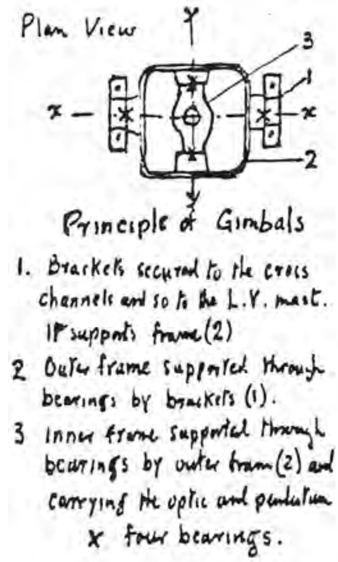
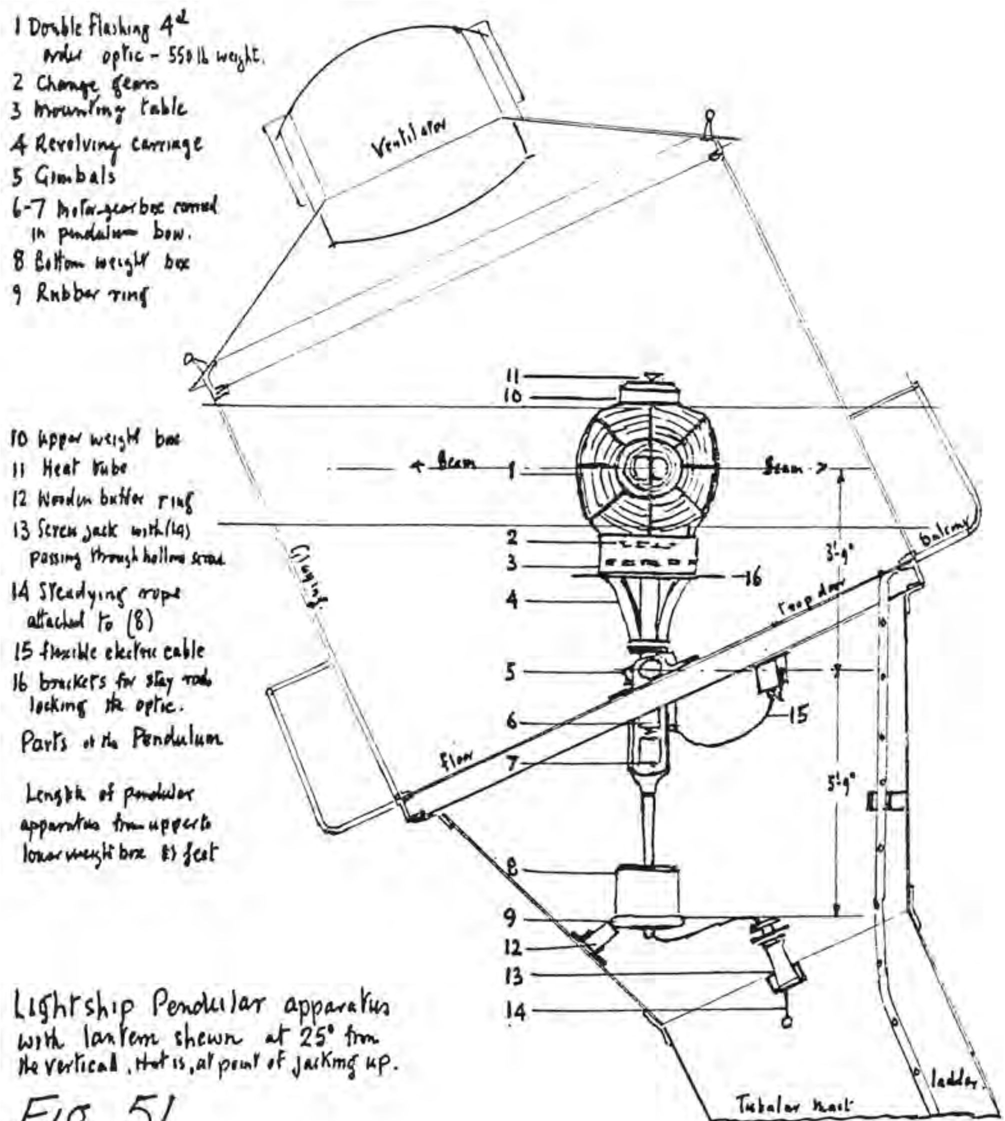


Fig. 50



Lightship Pendular apparatus with lantern shewn at 25° from the vertical, that is, at point of jacking up.

Fig 51

Parts of the pendulum – Fig. 51 refers.

The pendulum is a compound type, with a weight distribution above and below its pivot – in this case the gimbals. It consists of the optic with upper weight box; the gimbals; the electric lamp and stand; the pendulum bow with the motor drive unit at the bottom weight box.

In more detail: The optic has a more than usual rigid 'body' to withstand the possibility of a bump in rough weather – and it carries the upper weight box (little used except for a lightweight optic).

The mounting table with the carriage carries the optic and rotates on ball thrust and journal bearings located on the upper end of the forged steel main spindle, which incorporates part 3 of Fig. 50. The spindle projects slightly above the optic table to form a housing for the gears and a stand for the electric lamp.

The lower end of this spindle is fitted with a cast steel bow which carries the motor drive and the junction box for the electric cable. The driving shaft is in the hollow core of the spindle and is ball bearing mounted. The (fixed) junction box on the murette carries a regulating resistance to control the motor speed. The bow, though a second spindle, holds the main or lower weight box, which incorporates a very large rubber ring just in case the wooden buffer ring on the murette is hit. Two rolled steel channels fitted to the murette carry the gimbal frame and so the complete pendulum. The bottom of the carriage is grooved to take a round belt from a hand turning device (not shown) mounted on the lantern floor. It obviously cannot be used until the pendulum is 'jacked up'.

Jacking or locking up

Whilst the Lightship mast may tilt 40º, an unbelievable figure, the mind boggles at the task of designing a lantern to accommodate this awful tilt. So we jack up at about 25º that is just before contact occurs between weight box and wooden buffer – at least we hope so but a freak wave can cause bad trouble. First a hard blow would break the long filament and secondly might crack a prism or two. Fig. 51 shows the nasty job of hanging on to the bucking ladder, waiting for the jack to approach the weight box, hold it with the rope and then running up the jack spindle until it is in the weight box!

The optic then moves with the mast, the beams going skywards or into the waves. Better something for the navigator than nothing.

Should the tragedy occur of the mooring cables parting the light is extinguished. Here 'nothing' is better than a light from a drifting ship!

"Earlier the Sea King crews had been standing by to go to the aid of the *Seven Stones Lightship* at land's end. The lightship had dragged its anchor, but later reported that its position was satisfactory."
Dasily Telegraph
1-2-1978

Another more 'delicate' locking device using brackets (16) on the carriage to lock, by means of light stay rods anchored on the lantern floor, the optic whilst cleaning it or renewing the lamp. (The anchor brackets on the floor are not shown).

Lightships in reserve

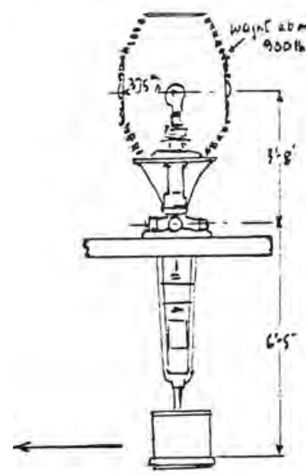
All Lightships in their turn are in, say, Harwich Harbor, as reserve, to prepare them, to replace another on station, four alterations are usually required; a) the character of the optic; b) the speed or revolution of the optic; c) the character of the fog signal and , of course; d) painting over, and painting on, the enormous lettering denoting its station. And possibly many other 'seagoing' matters as well.

The Optic:

Mirror lights present no difficulty in changing from, say, single to double flashing. Just a few slackening of bolts. On page 65 this is shown. Dioptric, catadioptric lights for many years meant replacing the old optic, until the two "optic experts" at Chances buckled to and designed an optic with jig-saw type frames that could be, amazingly, reassembled, say, from double to triple flashing. Apart from a little more gun-metal 'racking' and a few odd angles of framing little difference from a normal optic could be seen in the design a really advanced knowledge of solid geometry was required.

Compare with the 4th order apparatus as shown in Fig 51, p 58.
Note: the optic is mounted directly on the carriage: no upper weight box and a larger bottom box.

The top gear train: the motor-gear base in the pendulum bow only covered part of the reduction required (say 1500 rpm to 2 rpm at the optic), but assembled in the spindle housing was a nest of gears with one pair easily replaceable. In effect a very simple job to change from an optic speed of, say, 1 revolution in 20 seconds to 1 revolution in 45 seconds.



The Diaphone timing gear: since the cam plate made 1 revolution in 60 seconds it was east to add a cam or two to change from single to double sound-character with possibly differing length of sound blast.

North Carr Lightship

To set the scene for this rather sad story, it should be said that:

a) The pendulum gear was designed by Trinity House and quite a lot had been made by Chances for Trinity House. No complaints had been received. Indeed the pendulums were an fine job of precision engineering.

b) The balancing of the pendulum was carefully carried out by Chances and, in drawing form, a record was kept of all weights, their exact positions and, of course, the weights in the two braces. None were removed for assembly at site. The time of oscillation was also recorded.

c) Testing: Chances had no facilities and whether Trinity House did any was not known! But no complaints, must be O.K.! To be noted was that Trinity House supplied and fitted the electric lamp required by each station.

So with Trinity House permission to use their design we quoted and received an order from Scotland for *North Carr Lightship*, the range required suited the rather narrow waters and our optic experts specified a 4th order light (see this pendulum (not the lantern) in Fig. 51 page 58). Trinity House used a small 3rd order with a 1 kw lamp. Trinity House used 2 or 3 kw for there open water stations.

It was a nasty shock, just after she was on station to receive copies of reports from local mariners declaring the light was showing very irregular beams. "So the pendulum was out of balance". Chances fell for this and it took a visit "on station" and one with the ship in dry dock to prove it was balanced. Well at least balanced when not at sea!

An old colleague of mine, now with Trinity House assures me that in narrow waters "wild light' direct from the electric lamp 'creeping' under the lower reflectors or mirrors could have a real nuisance value. But, I never remember the experts doing much about it and one fancies that in open waters it never was a problem.

The vertical divergence in Trinity House ships was even smaller than *North Carr*, so what? So it fell to me to do something about it. A list of possible faults in the pendulum was made: a) Friction of the gimbal bearings, b) the drag of the bottom rope and flexible cable, c) Gyroscopic effects of all moving parts (revolving) mounted on a mooring 'platform,' the mast, d) and this seemed important, if I assumed the gimbal pivots moved in space with simple harmonic motion due to the mast making a complete (there and back again) oscillation in 6 seconds, there would be:
1) an acceleration at each end of the swing of the mast.
2) a force, maximum at each end, but zero in mid swing, acting of the centre of gravity of the pendulum.
3) acting about the pivot of the gimbals this will slightly move the pendulum out of vertical.
4) the 'swing' of the pendulum being too near the fundamental or harmonic oscillation of the mast. this could not be since for a 6 second period of the ship, Chances adjusted the bottom weight to give a period of 9½ seconds for the pendulum. Incidentally this gave a center of gravity of the pendulum above, 0.3 inch below the gimbal pivots.

But, my '20 years in Lighthouses' was quickly drawing to an end as I was moving into 'pastures new' in further education. However, the 'not troubled' Trinity House nagged and it seemed necessary to look elsewhere. An Admiralty chart of the coast of Holland revealed '*Lightship Terschellingerbank*,' to the northwest of Terschelling – in the open North Sea! But, the Germans were still occupying Holland so the only hope was to contact our Patent Agents to see if the Dutch Authorities had a patent for a stabilizing device for a lightship pendulum. I had reached the point of suggesting opposing weights to slide across the top of the weight box to oppose the slight tilt due to accelerating forces.

A little of the Dutch coast

Believe it or not, on my last day at Chances a Dutch patent was on my table. It was clever. On the top of the weight box was a steel disc with four pockets of mercury, cross joined by tubes with needle valves. As the pendulum moved out of vertical (at the middle of the mast swing) the flow of mercury contracted the tilt! But why, oh why, did the Dutch need such a device, but Trinity House did not? A quick report to my director and I was away on a new career. Thirty-four years later all is forgotten – so the story is unfinished.

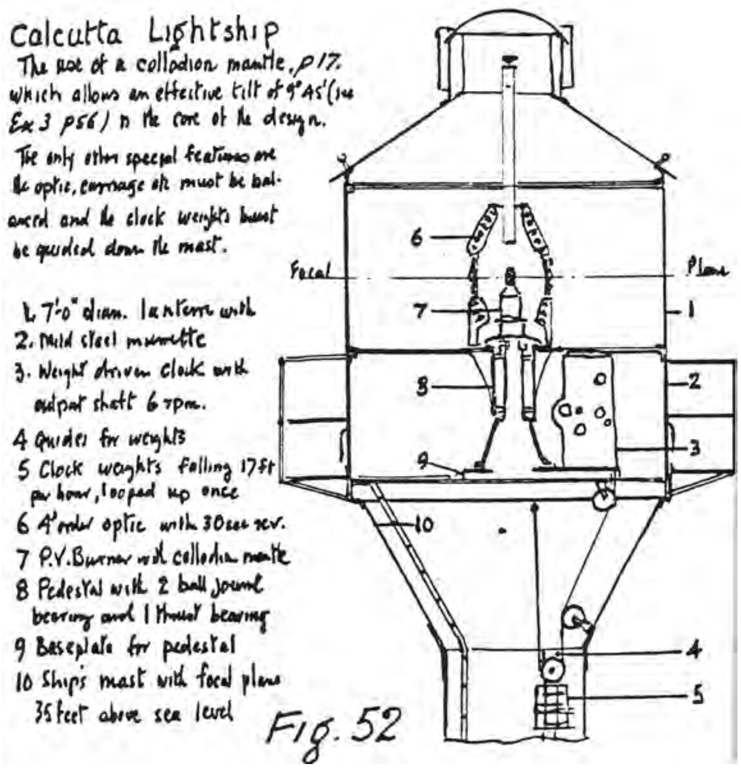


Fig. 52

Before continuing with *Calcutta Lightship*, it must be said that Chance had a pendulum apparatus very many years before the Trinity House design came about. I'm very hazy but I'm sure that a float pedestal (with a narrow neck to avoid spillage); a weight driven clock suspended between heaven and earth; a single air/oil container as a bottom weight box; a collodion P.V. Burner and much more dangled in mid air, and reading that the breakage of mantles was terrific. Makes ones heart bleed for the pre-electric lamp designer of pendulums. The *Calcutta* design for quieter waters must have been a boon!

Further details to those shown in Fig. 52.

The collodion mantle whilst larger in candlepower than its equivalent auto-form mantle has a smaller intrinsic brilliance. It is supplied 'burnt', that is desperately fragile and must always hang from its fireclay mantle rod. Effective tilt of 9º 45'. Whilst the mast might swing beyond this the character of the tilt will be erratic with beams wandering skywards and seawards. However, 'loom' on clouds or even haze at high altitudes on a clear night can help a mariner particularly since the geographic range for a light, but 35 feet above sea level is only 11.2miles (with a mariner 15 feet above sea level). The total candle power of the beams is usually much higher than the 11,000 necessary.

In my '20 years' we were on one occasion surprised to be ask to quote, and later received the order, for another *Calcutta Lightship* light. My old chief who had an excellent memory told me to get the old file from the 'strong room' as he recalled some trouble on erection at site. Blowing off the dust of ages and handling the crumbling papers with respect we found a batch of letters full of grumbles, but little or nothing on what Chance did about it all!

The gist was a) the optic revolves 'fast and slow during every single revolution' and b) the driving weights were insufficient.

So the argument between us started!
My old chief: "You know we never balance a ball bearing pedestal but only mercury float ones! True, but all those work in a (fixed) vertical position, this one tilts with mast. Let's imagine the clock to be de-clutched while the pedestal tilted a little. If say the optic is unbalanced the heavy side will 'run downhill'. With the optic clutched we shall see the optic speeded up on one side and slowed sown on the other, and that's what the authority said happened." Me (in full song), "Now the clock weights. They are guided by two steel channels on each side with 4 fairly wide slots in each weight. OK, if the mast remains vertical, if not, the weights slump sideways on to the channels and the friction must be formidable. Hence the effective pull on the clock barrel is decreased. In any case rollers were required on the weights and not slots." Me (in full flight), "Did we try running the weights tilted?" My old chief (forcibly), "We didn't, we couldn't, we---".

Shortly after this we received a letter from India asking us to give particular attention to this! A good filing system in Calcutta! So I got my £20 (a tremendous sum in those days!) for balancing and getting the clock weights right.

Well you know now what is up the mast and to complete the work done by Chances for Lightships we have only to consider in a little more detail the lanterns and in a lot of detail the fog signals, which are an utterly essential part, especially, for those sitting like a duck in the busiest sea-lanes in the world!

11 Mirrors and Mirror Lights

Only towards the end of my 20 years did I see mirrors other than the type shown in Fig. 53 which was used extensively, I put it crudely, to plug the gap between two panels of an optic. That such a mirror returned all the light collected from the light source, a P.V. Burner mantle, seemed a little incidental. Used with P.V. Burners it became even more so when British Standard 492 said that "The incandescent mantle is deemed to be non-transparent". So over very many years it had been just a very nice looking screen preventing direct light from the mantle from streaming out to sea! The mirror shown was for a 1st order quadruple flashing light for the Bahamas. Using Ashrafi again Fig. 11, page 15, you will see in the sectional plan two mirrors each of angle 28 ½ °. Other optics with such mirrors are shown diagrammatically in Fig. 10, page 14.

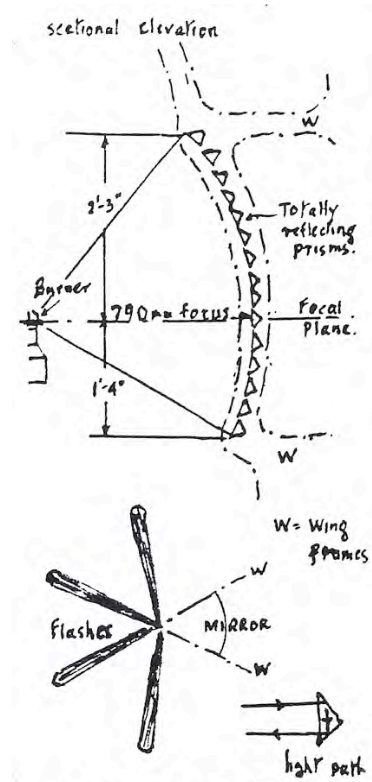


Diagram of Flashes
A catadioptric reinforcing mirror used with a 1st order light.
Fig 53

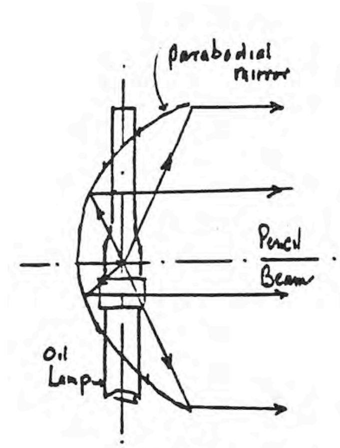
The sketch in Fig. 53 shows that if a radial ray of light from the light source, passing through the inner face, hits the back face at less than the critical angle, it will be totally reflected to the other back face and yet again totally reflected towards the front face and so returned, rudely, to the light source.

To repeat once again – the back faces are not silvered!

Mirror lights: The use of mirrors was stimulated at Chances by their use in lighting equipment for aerodromes and we did later supply a mirror light, a big one for Ireland and a few mirror lights for Trinity House Lightships. The latter was really a throw-back to the paraboidal copper-silvered mirror used with a constant level single-wick lamp used from 1792 onwards (see page 1). As I had the luck to see one of these lights we give a sketch of this as our first of a new type of mirror, namely there for beam projection.

The mirror was beautifully made of beaten copper, finished on the inside with thin silver sheet, rolled and beaten in. No plating in there in those days! A hole in the top took the glass chimney and a larger one in the bottom took the body of the oil lamp. You will note that, whilst the angle of collection of the light is not bad, we have to subtract from the projected area of the mirror the projected area of the lamp including the glass chimney.

The argument in favor of re-introducing mirror lights goes something like this: lenses superceded mirrors in order to collect more of the small amount of light then available. The electric lamp now has sufficient power to throw half of it away so hurrah for mirror lights! And – they are cheaper!



C 1792

The Catoptric system

1) The paraboidal silvered glass mirror will produce a pencil beam if a point source of light is situated at the focus of the mirror then the rays of light impinging on and then reflected by the mirror are parallel to the axis of symmetry. This is what we want from the paraboidal to give us a pencil beam of light.

Intensity of the pencil beam British Standard 942 – 1941

If Io = A_1 x B x C_1 where:
A_1 = the net area in sq. cm. of the mirror projected on to a vertical surface per perpendicular to the axis of symmetry, less the projected area of any obstruction. The glass bulb of an electric lamp is rated as an obstruction.

B = brightness of the light source is candles/cm sq.

C_1 = effective reflection factor
= 0.8 for silvered glass mirrors
= 0.75 for anodized aluminum electrolytically brightened mirrors

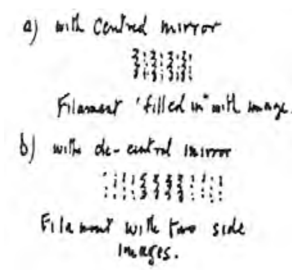
Divergences of the beam:
These can be calculated, horizontal as page 8, and vertical as page 56. It will be obvious from Fig. 54 that the divergences so calculated are true for the center of the mirror only. The divergences decrease as we proceed outwards to the edge of the mirror. This of course occurred also with lenticular systems. BS 942 ignores the matter.

Obstruction of the beam and wild light.

Since the glass bulb is a 100% obstruction let us put directly in front of it a screen in the form of a centered or de-centered reinforcing mirror. A lot of the 'wild' or direct light from the filament will be turned back by the mirror to the filament or alongside it.

Centered or de-centered mirrors: BS 942 gives
a) centered mirrors which can be spherical shaped metallic mirrors.
The multiplying factors to obtain the increased intensity are:

1) Catoptric:	Factor	For an electric
Silvered glass: Silver on metal: anodized aluminum electrolytically brightened	1.4	filament in a clear glass bulb
2) Catadioptric: lenticular totally reflecting prisms	1.2	ditto



b) de-centered catoptric reinforcing mirrors
This system comprises two small mirrors which throw an image each of the focal filaments, so giving a greater horizontal divergence over the arc covered by the reinforcing mirrors. This arc is shown in Fig 54; BS 942 rightly states that such a mirror does not reinforce the whole area of the main mirror.

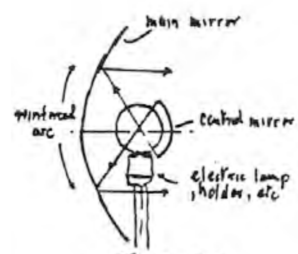


Fig 54

Example:
Let the diameter of a silvered glass mirror be 50cm and the total obstruction 200 sq. cm, electric lamp flat grid filament 500w, brightness 400 candles per sq. cm, centered reinforcing mirror covering an area of the main mirror equal to a circle 30cm diameter, obstruction of centered mirror 80cm sq.

Io without reinforcing mirror 520,000 is candlepower. Now adding the effect of the reinforcing mirror – see Fig. 54. Additional candlepower = 80,000 cp totaling 600,000 candlepower. With two units, one above the other we get per beam a very useful total of = 1,200,000 candlepower.

Bi-form Lights

Although a bi-form light of considerable beauty, at Hartland Point, was shown on page10. I will now elaborate on such lights as the majority of bi-form lights are mirror lights.

Prismatic optics are either as at Hartland Point, or as shown in Fig. 55 for Lowestoft, the optic having four dioptric panels, in side-by-side pairs. As the lamp changers must be of the tilting type, rotating with the optics, slipping and brush gear for the lamp supplies and controls are necessary.

To save an awkward tall stage inside the optic for Hartland, the upper lamp revolved with the optic. The lamp was large with a heavy current so playing safe it was decided to mount on top of the upper optic two 'U' shaped steel rings filled with, yes, you are right, mercury with a positive and negative steel dipping rod attached to a bracket held on the lantern 'ceiling'. Rather to my surprise (the electrical experts thought it a poor job) it was still working thirty years later!

Hartland Point lends itself to thoughts on economizing on clear nights by switching on the lower electric lamp only. This is done and, I suppose that the Principle Keeper uses his discretion when to bring in the upper lamp. A few figures may interest you:

	Apparent C.p of the optic Ia	Transmission Factor (T)	Luminous range, n.mls.
Example (1)	1 optic only 200 000 cp	0·80	27·0
	2 optics total 400 000 cp	0·65	17·3
(2)	1 optic at 200 000 cp	0·65	16·0
	2 optics total 400 000 cp	0·65	17·3

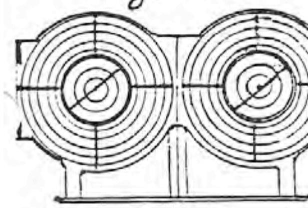
Example (2) shows how little we can push the range by doubling the candlepower. Never the less in poor weather (and 0.65 is!) even 1.3 miles is valuable.

The Lowestoff optic would, I think, be cheaper than one optic of dioptric–catadioptric type of the same candle power. One is also "insured" against total failure by having, in effect, two systems. The panels are hinged.

Mirror lights for Lightships – consist of two tiers of four mirrors each, giving a total of eight mirrors. Each is complete with an electric lamp and holder and a de-centered mirror. The mirror frame has a circular base with multi-drilled holes to allow swiveling on the baseplate (or the front tier plats) to give the four characters shown at (a) to (d) in Fig. 56. In supplying such lights to Trinity House for mounting on pendular gear Chances carefully balanced each type of character and supplied four sets of weights with drawings of same. Also shown were the angular settings for each mirror frame, again for the different characters. You will see that the job of getting the appropriate character of light for a reserve ship, about to relieve another lightship, presented no difficulties.

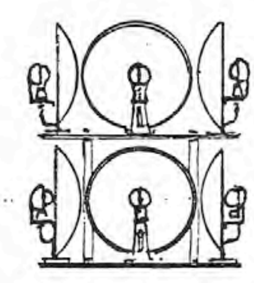
A large Mirror Light for Ireland – This was, I think, an experiment, using, but one large electric lamp at the focus of several part paraboidal mirrors. Since the light from the lamp towards the mirror is reflected back on itself there must be a hole or space on the opposite side on the light for the beam to pass through on route to the horizon. So, willy-nilly, 50% of the light from the lamp is wasted. Also unless we screen the space mentioned above a lot of light, direct from the lamp; goes out to sea.

Fig. 55



Lowestoft
Single flashing 4th order 'twin' optic with electric lamp changers. Mounted on a mercury float pedestal with a weight driven clock. 1939

Fig 56



Mirror light for Lightship

De-centered mirrors should cover all the open spaces! To do this effectively it is tempting to put all the mirrors in one half of the light and use one reinforcing mirror in the other half to cut out all direct light. This light would look awful and would require some hefty balance weights!

The mirrors could be thought of as a portion of a very large paraboidal mirror, as shown in Fig. 57(a) – but they are certainly not made like that!
(b) shows a possible design for a single flashing light with a lot of direct, and unwanted, light coming through the 'opposite spaces'.
(c) shows a possible triple flashing light with much less direct light. If we visualize a single flashing light with one huge mirror we come down, to say, a 150 cm diameter parabolic mirror as used in searchlights during World War II. In fact, well before this, a famous French Light was designed on this principle – and it used the crater of an arc lamp as its illuminant. The loss in candle power must have been terrific with its minute horizontal divergence.

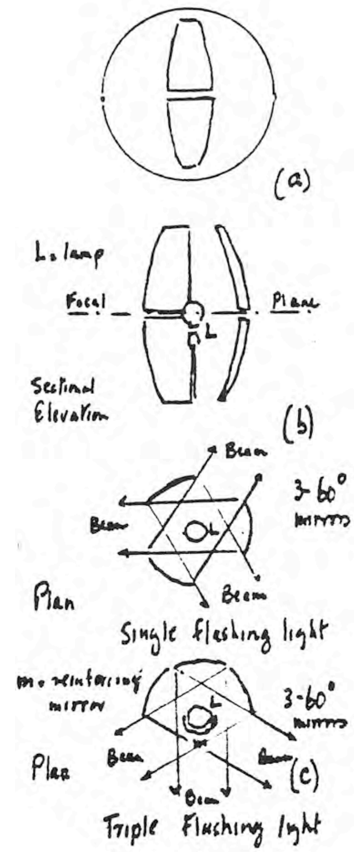


Fig 57

However, the biform for Slyne Head was most interesting and yet another example of the willingness of the Irish Authorities to "have a go." I wish I could have seen Slyne from the sea if only to convince myself it wasn't a "waxer and waver', as opposed to the clean 'on and off' of a prismatic light. Personally I did not like its appearance or its lack of efficiency in light collecting, but it was cheap. It was early days for mirror light, but I preferred the multi-integrated mirror-lamp units as Fig. 56.

Producing the mirrors

I mean glass mirrors, which I suppose is natural to anyone employed by a glass making firm such as Chance Brothers.

It may help to study, before mirrors, the manufacture of a condensing lens as used in a projector. Three types are shown: see Fig. 58.

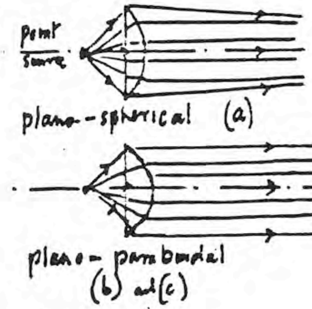


Fig 58

(a) is ground and polished on both faces and as shown the converging beam is the least efficient of the three. Why make it? Only because a spherical shape is easy to machine grind and polish.
(b) is a cast lens with the plane surface only ground and polished. It is remarkably efficient.
(c) is shaped as (b) with the plane surface ground and polished, but with the paraboidal surface machined with a diamond tool. A truly lovely job and of course the most efficient of the three!

A mirror could be cast and then spherically ground both sides. The resulting beam is as (a) Fig. 58. An alternative is to start with a sheet of plate glass (ground and polished on both sides, of course), heating it until plastic and mould it by sinking and pulling it by a vacuum into a very highly machined iron mould of true parabolic shape. With a point source of light the beam is as (c) Fig. 58, that is a truly parallel beam of high efficiency.

The glass should be free from color, bubbles, string or other defects and the deposited silver free from clouding, spots or other defects. The silvering is protected by a coating of copper electronically deposited and further protected by a special varnish and paint backing of very durable quality. And, by the way, always anneal glass after heating and cooling otherwise sooner or later, usually sooner, it will, with the report of a gun, shatter itself to pieces owing to the internal cooling strains in the glass.

→ Stripping of Silver on Mirrors.
occurs when stress in silver is greater than stress in glass.
If silver is deposited at 10°C then the breakdown temp. is:
Ordinary sheet glass 350°C
or heat resisting 260°C

12 Lanterns

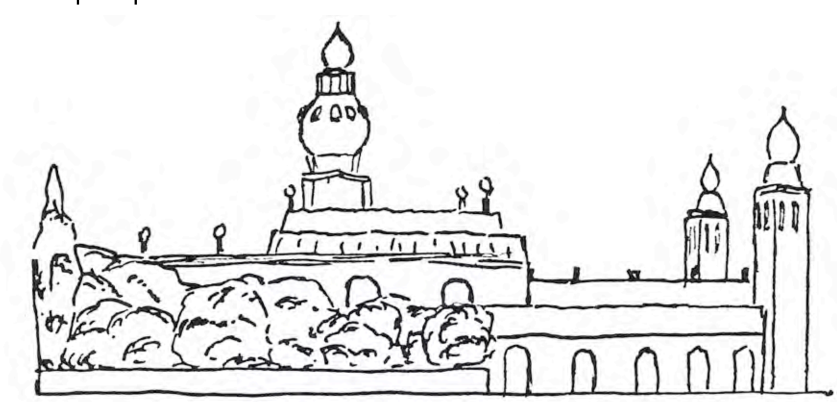
"So you're going to the Lighthouse." Well, car or no car, you will have to walk some way, but courage, the lighthouse is always round the next corner! Even when in view there is often a flight of steps up or down, or both. And what do you see? A substantial wall surrounding 2 or 3 houses for the lightkeepers and usually a hefty tower-painted white-surmounted by a lantern.

"They, the Buchans, finished sea trout and watched skuas, black backed gulls and gannets sitting in rows on the rock of Muckle Flugga, the most northerly lighthouse in Britian."
Janet Adam Smith

Sometimes the cliff or headland is high enough to require no tower and in other places one of, but little height. We can consider this by looking at Beachy Head Light first built on top of the white cliffs, but now a rock station. It had been found that the beams originally passed over the mariner's heads particularly if they were enshrouded in a low mist. An interesting thought, if the air had been quite clear, then as far as the mariner was concerned, it could have been a thousand miles away.

A light with a focal plane 200 ft above sea level would seem to be ample since the geographic range is 16.20 nautical miles, a good distance. Another important function of a lighthouse is to be seen in the daytime when it becomes a valuable navigational aid. Hence the white painted tower, or black and white, or red and white. On all Admiralty Charts we find the position of each and every lighthouse given in terms of latitude North and longitude West. A few examples: *Seven Stones* lightship 50º 04' N, 06º 05' W. Fastnet Lighthouse 51º 23' N 09º 35' W, Trevose Head Lighthouse 50º 33; N, 05º 02' W, Smalls Lighthouse 51º 43' N 05º 40' W.

A visit in the afternoon finds most Keepers willing to guide you over the lighthouse, but not if the fog signal is working. The principle keeper or an assistant will lead you up, the often many, stairs and you will note the immaculate cleanliness everywhere. The last flight leading to the lantern is often very steep so see that when you descend you about turn at the top and so come down as you went up, that is, face the stairs. Your guide will 'do his stuff' very well but page 14-51 does mention one error due entirely to the jargon used by lighthouse engineers. To them a prism labeled "reflector" means a catadioptric capable of bending a ray of light by two refractions, and one total reflection. To the non-expert 'reflector' could mean a mirror. In fact a mirror prism, which has, but two total reflections is a catadioptric prism!



The Madras Lighthouse – and the Law Courts!

As a boy at Chances I had come across a drawing of a most amazing lantern for a light in Madras. It had an enormous onion roof and no murette. No details were given of the onion so I concluded Chances did not make it.

Later I found that the lantern was set high in the main towrr of the Madras Law Courts.

I put it on a list (carried in my imagination) of places to be visited in the world. Forty years later I ticked it off my list.

To resume, you are now in the lantern admiring the optic and adding to your knowledge. As for the lantern it is just a cylindrical housing largely of plate glass, to protect the complex equipment of optic, pedestal, illuminant and clock, and the keepers when they are attending the light, from the elements; wind, rain, sea spray, snow, sand and insects!

Fig. 59 shows a magnificent example of a lantern for a 2nd order quadruple flashing light for Jaigarh, India – indeed one of the big ones. It's height approaches that of a two story house! So that you may appreciate just one of the many tasks of the keepers, the glazing shown has an area (both sides) of 550 sq. feet whereas a typical two story house has a total window area of around 280 sq. feet. But, in the lighthouse, the outer surface is subject to salt spray and some lights on migratory routes may, on occasion, have the glazing horribly plastered with dead birds. And, if housewives will forgive me, this glass has to be always bright and polished. Remember we lose 20% of the light under the best of circumstances.

A brief specification used for Cape Columbine Lighthouse, South Africa, details the various parts of the Lantern which houses a 3rd order single flashing light: You will find it helpful to look at Fig. 59.

The Murette consists of cast iron segments bolted together on machined surfaces with the bottom flange and the top (to receive the glazing) to be machined when so bolted. The interior lining shall be of steel sheets each fitted with a rectangular gunmetal ventilator with insect gauges.

Service Galleries are to be fitted, inside and outside, at the top of the murette primarily for cleaning, inside and out the glazing. Galvanized railings are bolted to the outside gallery (and must carry a man's weight since the keepers stand on them to clean the upper glass). A ladder from the outside gallery to the bottom of the murette is also fitted. Access to the outer gallery is provided by a steel door, with bronze hinges and lock, in the murette.

The Vertical Glazing Standards are substantially made of mild steel and fitted with hand grips. Two sets of gunmetal astragals (giving a glazing three panes high) are fitted between the standards.

The Circular Glazing shall be of best quality plate glass (ground and polished on both sides) 3/8" thick (4 lb per sq. foot). Three spare panes are to be supplied.

The Sill at the top of the glazing and the gutter segments is to be bolted together on machined faces and machined to receive the glazing and standards. Four copper down pipes are to be secured to the standards. The interior of the sill carries a mild steel curtain rail complete with curtain rings.

The Curtains are to be of unbleached calico (These are to prevent the sunlight passing through the prisms from 'cooking' the keeper and the equipment).

The Roof ribs are of cast iron the ends being machined for bolting to the sill and top roof ring. The roof is double with hard beaten copper plates both outside and for the lining. An external, curved, ladder from the sill to the top of the roof was fitted.

The Ventilator is cylindrical and of copper sheets with brass and gunmetal foot and hand rails and a double vane wind indicator with connecting gears to dial inside the lantern. Copper wire insect gauze shall be fitted where necessary on the ventilator. A heavy brass heat tube with a cover plate and funnel end shall be supported by suitable bracing.

Lightning Conductor comprising a copper tape, necessary slips and an earth plate shall be supplied (this is solidly connected to the bottom of the murette).

Two coats of paint are necessary for all iron and steel work.

The Jaigarh lantern below has rather special features:
It is completely insect proof and has not only gauze's in the top ventilator and in the murette ventilators, but has a box porch with one door in the murette and two side doors to the outer gallery, the roof is not lined, but has a large conical ceiling.

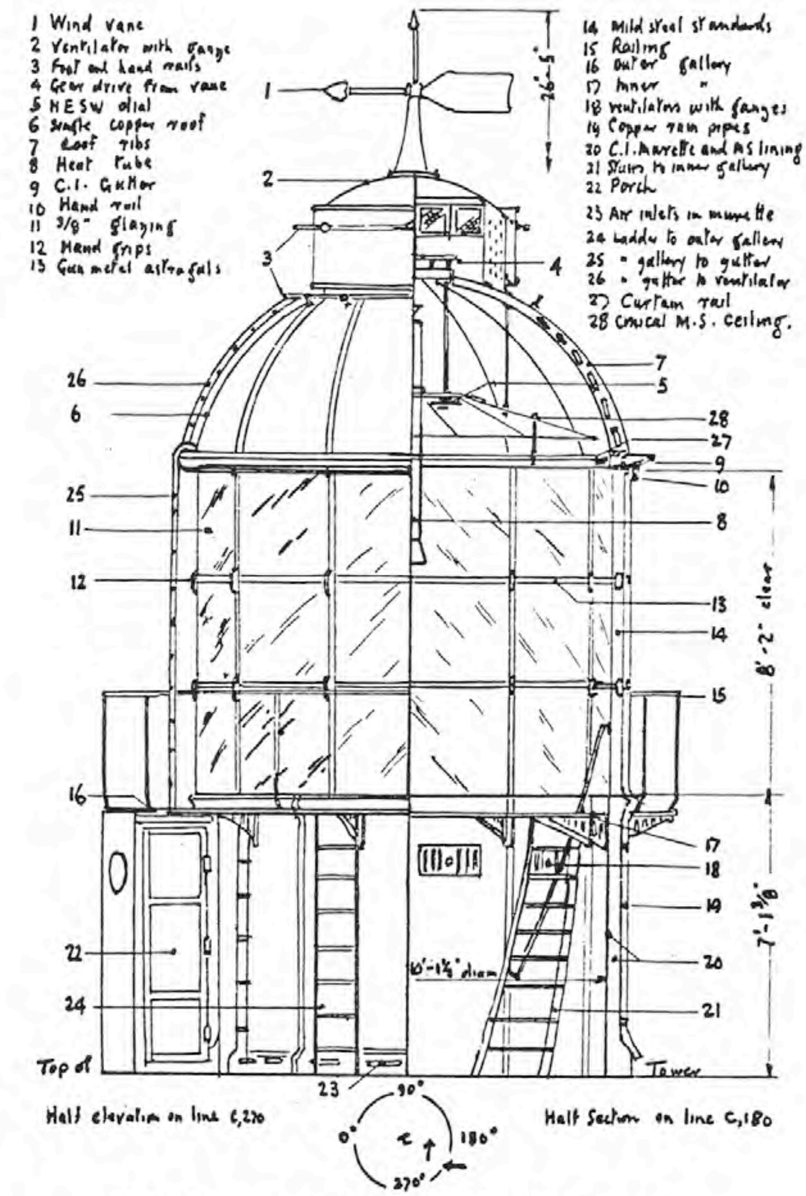


Fig. 59

10'-1½" diameter Lantern for Jaigarh Lighthouse, India.
Scale : 1/48

Lantern Ventilation

The system shown in Fig. 59 was designed for wick lamps and P.V. Burners, but remains just as essential for an electric lamp. The air enters through inlets (23) at the bottom of the murette (20) and flows upward between the lining sheets, and the outer wall of the murette plates. It escapes through the adjustable ventilators (18) and gives an ample air flow between the optic and the glazing (11) and so obviates misting up the latter. The powerful flow of air, at a searing temperature (from the illuminant), up the heat tube (8) ensures an ample flow of air inside the optic and, when fitted, for the combustion of the oil or acetylene used by the burner.

From the heat tube the hot air mixed with the "de-misting air" flows out through the annulus at the top of the inner cylinder of the top ventilator (in this case gauze curved as shown) and escapes to the atmosphere through a maze of holes in the middle cylinder. The outer cylinder is a baffle against down drafts, beating rain and spray.

Some very special Murette Ventilation for Ireland.

Small inverted mantle burners using acetylene gas were made by AGA and are a brilliant source of light eminently suitable for a 5th order revolving light. AGA even had a mantle changer using a specially prepared wooden "fuse" which burns through and breaks under the fierce flame rising from a partially broken mantle. This trips off the changer, which removes the faulty mantle and puts on a new one.

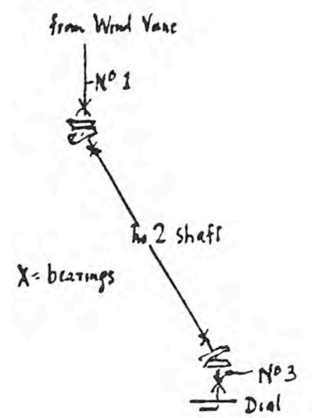
We had the pleasure in cooperating with the Commissioners of Irish Lights for a (then) unique light using an AGA mantle burner. A rather large pressure regulator, through a bell-crank lever and a ratchet and pawl pecking mechanism, rotated the optic which was mounted on a mercury float pedestal. The Chief Engineer of Irish Lights really went to town in designing very special ventilators for the lantern.

A light circular sealing disc was suspended by a vertical rod mounted on agate bearings. Normally the valve hung open, but a drop in pressure, caused by the wind, on the leeward side of the lantern closed the ventilator. Although the ventilators on the windward side would be fully open no cross draught resulted.

The Wind Direction Indicator

In Fig. 59 the use of an idler gear in gear drive (4) is to insure that both wind pointer and vane point, say North at the same time! I don't much like the near central position of the dial since it possibly requires the keeper to climb yet a few more steps up to the inner gallery to see the dial! Particularly for a double lined roof (with a much smaller drip dish and no ceiling plate). I prefer the arrangement shown in Fig. 60. The dial can be readily seen from the lantern floor.

One must record that a designer, very new to Chances' work and bitten by the cheapens bug, ordered a dial which (reading clockwise through N) read NESW instead of NWSE. Too bad that when the vane was at W the dial read E. It sometimes pays to look heavenwards! To add to his efforts he used one universal joint to connect shafts 1 to 2 which, since the velocity ratio of such a joint is not constant, resulted in another startling disagreement between vane and dial pointer.



Drive for wind direction mechanism
Fig. 60

Glazing Standards

After reading page 40 you may be surprised that both Cape Columbine and Jaigarh lanterns have vertical standards, but these are revolving lights where the beams of light from the optic are anything but radial from the focal point. Never the less it is just as well that the very narrow panels of the optic for Wolf Rock (see Fig. 16, page 24*)* was housed in a lantern with the old style diamond glazing as shown in Fig. 32 (c), page 40. Again from the point of view of strength the lantern for lightships and for buoys should be helical. For revolving lights in general vertical standards will do, and they are certainly much cheaper. In Fig. 61 cross sectional views are shown of three types of standards.

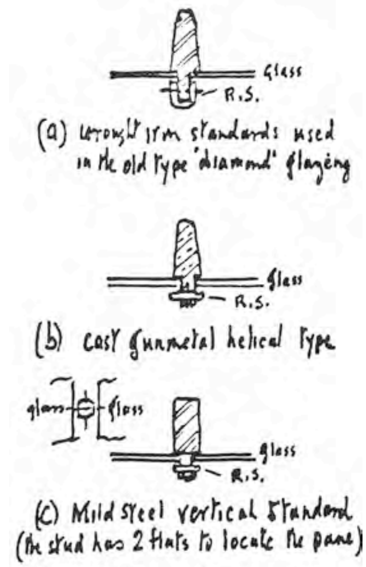


Fig 61

The lantern fitters at Chances test every space for the glass panes with a steel template if only to see that the spare panes supplied will fit anywhere. Some lighthouse sites have a bad reputation for flinging stones at the light during bad storms and the authority will sometimes order a steel sheet somewhat larger than the panes, which, with a stretcher bar and bolt, can be hastily put over the broken pane. Chances' records mention that in a hurricane a lantern had some panes sucked out on the leeward side, indicating that the retaining strips should not be too flimsy. If of cast gunmetal the hand grips can be incorporated.

The Roof many of the older lanterns had a conical roof, and this has persisted with smaller lanterns. However, the appearance of the copper spherical roof is very good and particularly in hot climates the extra roof space must be appreciated by the keepers. A copper lined roof with vent holes at the bottom is better than that shown in Fig. 59. In Fig. 62 is shown the shape (or development) of the individual copper sheets before they are beaten into shaped cast iron molds. You will see that beating does not affect the thickness of the sheets. The top dome of the ventilator is usually made in halves.

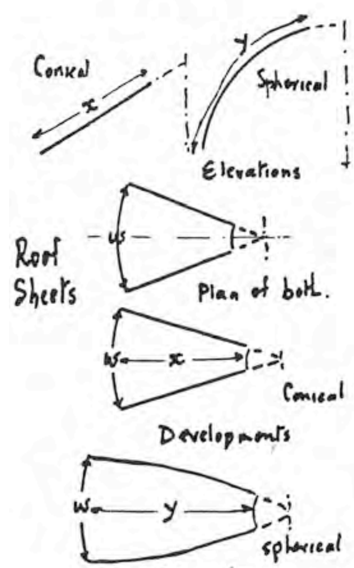


Fig 62

The Murette when casting these large plates (7ft x 3 ft) the foundry had difficulty in holding the curvature (a large area of molten metal resting on sand) so the designer had cast on two masking strips. You will note later (page 78*)* tower plates treated the same and adding to the appearance of the tower. Fig. 63 refers.

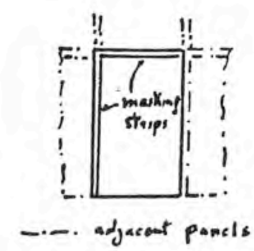


Fig 63

A joy to me as a lad was the amount of smithing required in a lantern, always fascinating to watch. Possibly putting on the airs and graces of a budding designer I once fell foul of the foreman smith who announced that "he owned more horses that I had ha'pennies in my pocket". He was dead right. Such foreman in the late twenties headed a 'gang' of senior workers and apprentices; put in their own price for a job; when completed they shared out the money! I got 12 shillings and sixpence per week!

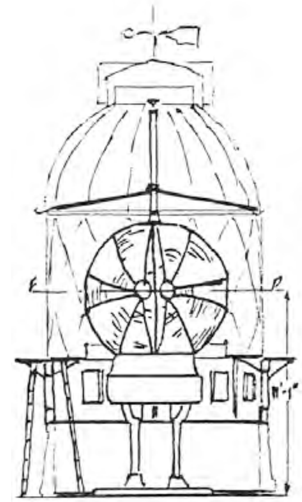
Alternative designs of lanterns – as shown on page 39, Fig. 30, page 40, Fig. 32 (e): page 45 Figs. 36 (a) and (b) and page 69 Fig. 59. Lanterns for unattended lights are very simple and so quite cheap.

Table 10 gives glazing diameters for fixed and revolving lights:

Order of optic	Diameter inside the glazing	
	for Revolving lights	for fixed lights.
3rd order, 500 mm f.l.	8'-9¾"	7'-1"
4th order, 250 mm f.l.	7'-1"	5'-0¼"
6th order, 150 mm f.l.	5'-0¼"	5'-0¼"

Watlings Island, or San Salvador, Bahama Islands

A very long time after Christopher Columbus landed at Watlings Island (believing it to be off the Coast of China) Chances converted a very old light by supplying the following:
1) A set of glazed murette plates 3 feet 4 ½ inches high by 11 feet 4 ½ inches inside diameter. This set is to raise the lantern glazing and roof by 3 feet 4 ½ inches to suit the new mercury float pedestal and revolving optic. The plates are glazed to leave the lighting on the lantern floor much as it was.
2) New inside and outside galleries with ladders.
3) New heat tube and bearings.
4) New optic with pedestal, clock and P.V. Burner with air and oil containers.
5) New stairs for the service room (this is immediately below the lantern).
6) New lantern floor. Fig. 54 refers.



Watlings Island, Bahama Is.
Conversion
(New work shown in black)
Fig. 64

The only snag in all this is to raise the glazing cage and roof, with ventilator, the 3 feet 4 ½ inches required, in a hurricane area! It requires the removal of all the old equipment inside the lantern and then erecting a steel structure, complete with pulley blocks for lifting, around the lantern. The danger period is from when lifting commences until the glazing cage is lowered on the new murette plates. Advice was sought from the Bahama Weather Authority and hurricane charts daily kept up to date. Fortunately all went well.

The danger is less when, with a portion of the glazing frame removed the trough, float, optic panels etc. are lifted and swung into the lantern.

The Migration of Birds

In the bad old days, if a lighthouse happened to be in the path of migrating birds, it was the scene of horrible slaughter of hundreds of birds who flew, completely blinded into the lantern glazing. You can imagine the equally horrible mess that faced the light keepers in their job of ‘keeping the light shining’.

So many years back, Trinity House agreed to erect around the lantern a circle of slatted panels just inside the light so that the birds could make a safe landing! Where, well you’re right again, St. Catherine’s 10 W – in my opinion the most interesting light in England. See some examples below:

Extract from letter January 5, 1980 from Principle Keeper S.N. Fearn:

“The plumb bob still hangs from top to bottom of the main tower and we read the brass plate on the ground floor every month. It hasn’t changed for a month and still reads 1 ½ inches North West.

St. Catherine’s Lighthouse is built on the Niton under cliff – that is betwixt and between the upper (land) cliff and the lower (sea) cliff. The soil is on a constant move and the original engine room, many years back, split in two! The plumb bob is a ready means of anticipating serious trouble. I’m sure I saw it once at 3”!

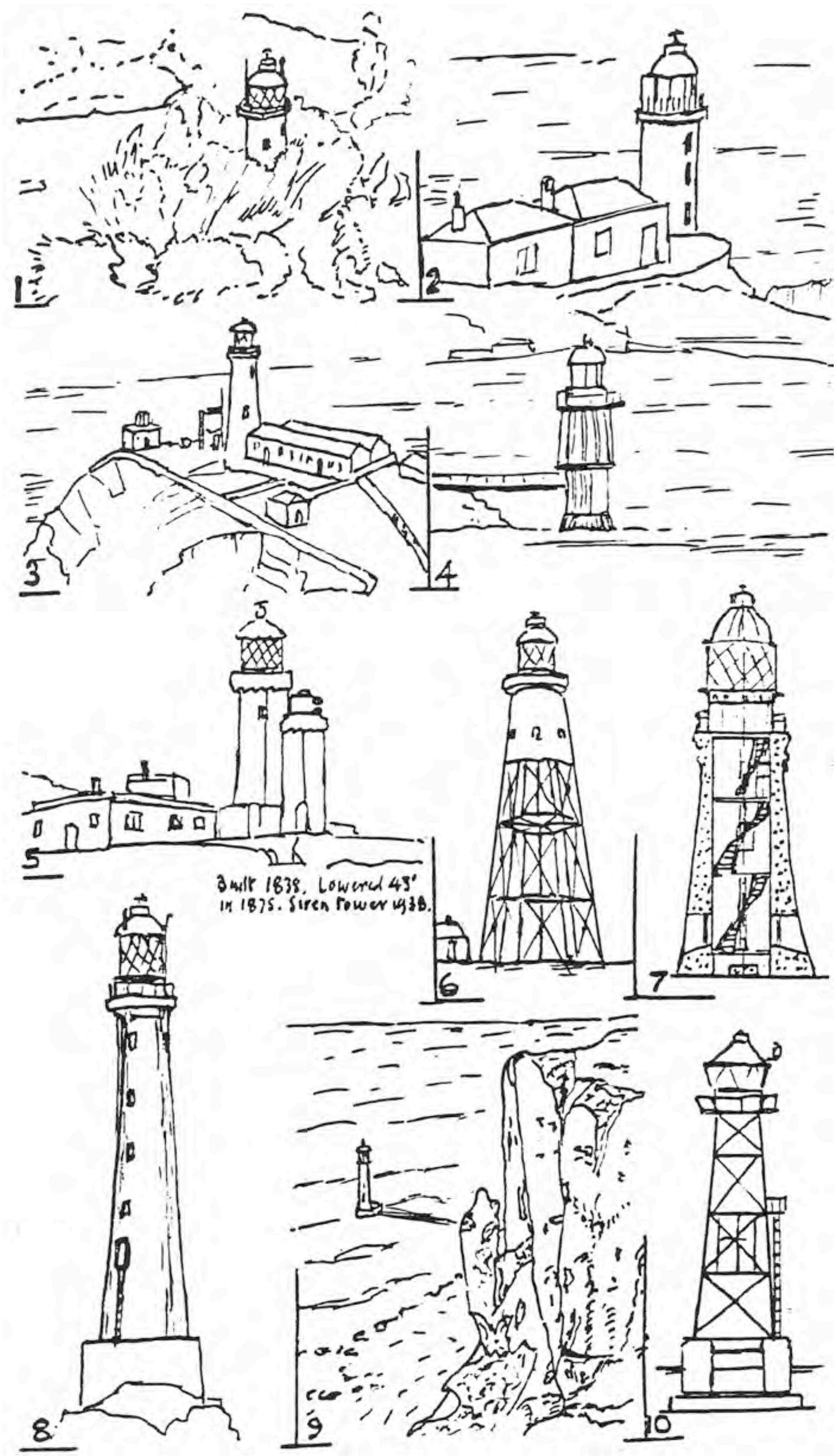
Dungeness Point – Trinity House magazine “Flash” 12/79

“The whole tower has been floodlit – since May 1962 – to assist identification from seaward. This floodlighting has reduced the bird mortality rate at this lighthouse during the migration season”.

13 Towers

Each and every tower looks different to me and vary from the beautiful, Bishops Rock, to the run of the mill land types. Mostly they are designed by the local Lighthouse Board and built using local labor and local materials. A few types are shown.

1. Wolf Rock off Land's End in heavy seas.
2. Isle of May, Firth of Forth
3. South Stack, Holy Island (near Holyhead)
4. Port Jackson. Australia
5. St. Catherines, Isle of Wight. Note the 'tower' for the Fog Signal built against the main tower.
6. Cape St Paul. Gold Coast. A six sided openwork tower.
7. Watlings Island. Bahama Is. (shown is a vertical section through the tower) The stairs for the three rooms in the tower are indicated. For Lantern and light see Fig. 64 on page 72.
8. Bishop's Rock off the Isle of Scilly. The noblest of all lighthouses and the tallest in the U.K.
9. Beachy Head – and the white cliffs of Dover. Originally built on the cliff top, but now truly a rock station.
10. A typical unattended light built by the North Queensland, Australia Authority. Openwork tower on a concrete pillar base.



Trinity House Lights
Heights

Number in Fig and Name.	Height of Tower in ft	Height above MHW in ft.
1 Wolf	135	110
3 S. Stack	99	129
5 St Catherines	84	136
8 Bishops	167	143
9 Beachy	142	103
✓ Royal Sovereign (see P4)	159'	93'

Fig. 65

Listed are some of the factors that appear to determine the type of tower:

a) The required height of the tower to give the luminous range demanded by local shipping requirements. However, when using weight driven clock there must be a suitable fall for the driving weights.

b) The tower should be a distinctive day mark as many a bearing will be taken by navigators on each and every lighthouse.

c) The necessity in some few cases to accommodate in, or on, the tower, a fog signal. Fig. 65 (5) shows the auxiliary tower for a twin horned siren.

d) Local materials and the availability of stone masons or experts in reinforced concrete etc. The rare cast iron plated tower (see Fig. 67, page 78) or the mild steel openwork tower usually denote a paucity of suitable materials perhaps for the steel type just cheapness. In the old days the United States Lighthouse Board was very found of 8 sided openwork towers with the central staircase enclosed in a larger tube. The height was often 175 feet or more. I suspect Sombrero Tower (Fig. 69 page 80) was of similar design.

Other Lights.
Heights
(Fig 65 refers)

No in Fig and Name	Ht. of Tower ft	Ht. above HMW ft
2 Is. of May	about 50'	240'
6 Cape St Paul	" 80'	—
7 Watling's Is.	47'	—
10 North Queensland	42'	51'

e) The usual 'two':

1) A screw pile tower designed and erected by Chance Brothers. The foreman erector, in my time, was a change hand at Chances. He had a good collection of (old) photographs, several showing gangs of laborers screwing into the (submerged) sand banks, from temporary wooden platforms. The piles, at the bottom end of which was a enormous iron screw. Just like gigantic corkscrews! When they had gone in as far as they would, all were cut off to the same level and building the tower proper commenced. Working in the Red Sea must have been hellish and he certainly picked up recurrent malaria.

2) Drawings existed at Chances of a large tubular tower, supported on a single ball, braced with (slack) thick tie rods with thin (light) ties stretched tight over the main stays. Supposedly in a earthquake the thin ties would break but the thick ones would bring it to rest when it keeled over. If it was ever built, in China, one can only hope this horrific design kept the evil spirits away!

f) Local conditions such as prevailing sandstorms, showers of stones in a storm, plagues of insects, impact of rains on rock stations or just plain hurricanes, which could result in wind pressures up to 80 lb. per sq. foot.

g) Rock stations deserve a special mention. The Eddystone light is best known since Winstanly pioneered this type, but more of this light in *Chapter 18.* Bishops, the most beautiful of all stone towers, is shown in (Fig. 65 page 73). First lit in 1858 it was near the limit of height and required strengthening in 1874 and in 1881.

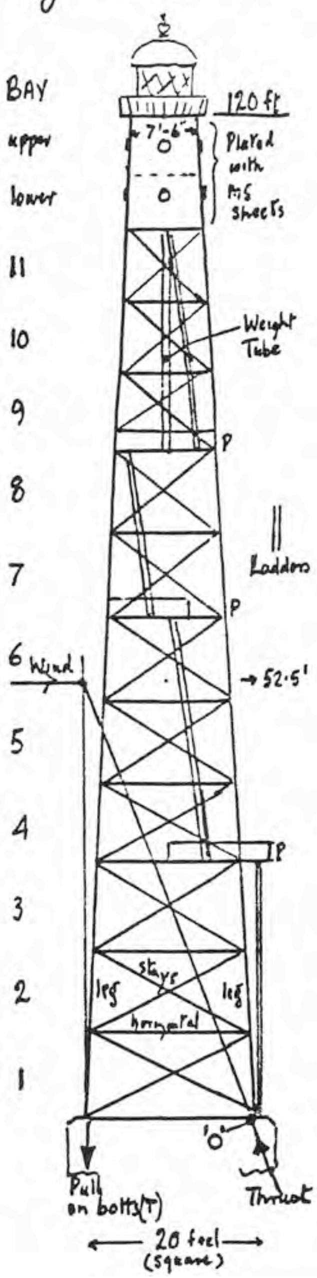
A unique feature of a rock station is that it is the home of three keepers month in, month out. Since the tragedy on Smalls (*see Chapter 19)* always three keepers, never two!

I have mentioned in the preface, the BBC T.V. program featuring Bishop's Rock. An excellent program but behind it the query "Why does any man want to be a (rock station) lightkeeper?" I trust the producer noticed that the Principal Keeper was sunk "hook, line and sinker" on a life he greatly liked! But, aren't we all fond of telling others what they should like or dislike?

I have always found the lighthouse keepers, and particularly the Principal Keeper's, excellent types. Sad that a black box staffed with 'solid physic's' is now replacing them. Cheaper, of course. Better, no pleasing to social do-gooders, I fear so!

Three Towers: Towers last a long time and consequently Chances received few orders for these. I have chosen three I worked on, which gave a range of design. a) a 120 ft. M.S. openwork tower for Sarawak. b) a 46 ft. cast iron plated tower for Jaigarh and c) a conversion job for a 107 ft. openwork tower for Sombrero.

Fig 66 with Table



Sarawak: A 120 ft M.S. Openwork Tower

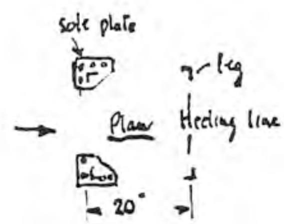
Wind Load	Arm	Dead Load	Size of Members: Legs	Horizontals	Stays	Remarks
→ 6870 lb.	120'	↓ 9500 lb		Lantern Floor 6"×3" [		Lantern Floor
→ 3900	113.5'	↓ 7920	3½"×3½"×⅜" L	Service Room Floor 6"×3" I	2½×2½×¼ L	Service Room
→ 3320	107	↓ 2757				
→ 2250	98.5	↓ 2347		2½"×2½×¼" L		End of Weight Tube
→ 2650	90	↓ 1177				
→ 5340	80	↓ 2723	5"×5"×⅜" L			Platform
→ 3590	70	↓ 3768		3"×3"×¼" L		Note I Beams
→ 5820	60	↓ 2268				Platform
→ 4300	50	↓ 4905			3"×3"×¼" L	
→ 4350	40	↓ 2623	6"×6"×½" L	3½"×3½"×5/16" L		Note: L Equal angles
→ 7840	30	↓ 3603				Platform
→ 5520	20	↓ 6922		4"×4"×5/16" L		Note: [Channels
→ 5530	10	↓ 3246		4"×4"×⅜" L		
→ 4250	0'	↓ 4642		Base 8"×4" [		Base of Tower
65620 lb (33T)		58471 lb (26T) (W)				

Summation of Wind Loads × respective 'arm' = Overturning moment = 3866200 lbf = 1720 T.ft

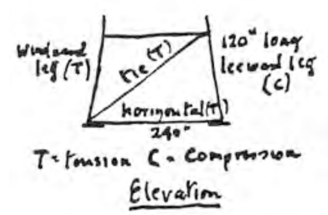
Before proceeding could I mention that whilst studying for the London External degree a fellow student, with whom I became friendly, was a practicing Structural Engineer whereas I was a Mechanical Engineer, but mutual cooperation on the two related papers proved very successful. In particular I admired his legal interpretation of the Building Code particularly when I could not even understand the section under review! I concluded one got orders for structural work by not using even 1 lb. of redundant steel.

One night we had a substitute lecturer, who to my friends 'delight' was the Local Authority Structural Engineer who had just rejected one of his designs for grillages! The rest of us spent 2 hours listening to a legal wrangle on the interpretation of the Building Code for grillages!

1) **Sarawak, Indonesia; a 120 foot Openwork Tower**
Now this tower came to me because of a wrongly directed letter. Chances had the order for the lighting equipment but the Sarawak people had specified a consultant engineer to supervise its design and manufacture by a well known firm of structural engineers. The letter was from Sarawak saying the tower when erected looked rather slender. Although none of Chance's business, I thought I would analyze it because I suspected it contained not 1 lb. (pound) extra weight in steel. As you will see much of the work is laborious:



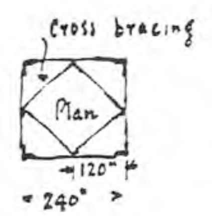
Wind Loads: The following assumptions are made: The loads act at the bay joints; the wind is 'flat on' one side of the tower; that its value will be the projected area of all members (and the lantern etc), the stated wind pressure per sq. foot and a coefficient for the various shapes under pressure. The values given allowed for the wind slipping around a cylinder: The partial suction behind a large flat sheet and the air being trapped by an angle placed vertically. We calculate a pressure of 135 lb. per sq foot for all of the frame.



Dead loads: As with so many structures one assumes what all members will be, although you have not yet designed them! Experience and past jobs may get you near enough! If not, you start again.

For small structures (or non–competitive ones) the total weight of the tower and its top load is often assumed to set on the top of the tower, half on each leg.

Analyzing a tower already designed: with experience it is usually enough to examine the holding down bolts and all members in the bottom bay. Members in torsion are usually ok, but the leeward leg, which is in compression, that is a strut, needs watching. To a lesser extent the horizontal member also.



I think Sarawak was justified in asking their question since no one could suggest that needless steel was used in constructing the tower. Certainly when standing on the lantern floor, and looking down, it's slimness was impressive! Bishop Rock with its 6000 tons of granite is said to swing 3 foot each side of the vertical in a heavy gale, I wonder how much the Sarawak tower moves in a Beufort 12 wind!

2) **Jaigarh, India; a 46 foot 3 inch cast iron plated tower.**
The uniqueness of this tower lay solely in its construction from cast iron plates. Many years before Chances had supplied a similar, but taller tower for Slangkop, South Africa. The order was received in 1932 and with the exception of the 2nd order (720 mm focal length) quadruple flashing optic the rest lay with me. You will find the 10 foot 1 ½ inch diameter lantern fully detailed in Fig. 59 page 69.

The prevailing dust and clouds of insects must have been a pest requiring gauze to be fitted in all tower windows. Additionally, a porch was necessary at the main entrance.

Fig 67 shows the tower, which, with no modesty, I thought looked pretty good!

Leaving, for a moment, a description of the tower, which must be given alongside the sketch of the tower (see page 78) a few general points arise:

Firstly yet another story about my old chief. He had a treatise in his possession of the calculations for the Slangkop Tower and insisted that I read it and pay particular attention to the holding down bolts, since the local authority specified a wind velocity giving 60 lbs. per sq. foot pressure, a typhoon area obviously.

It was well done, but on around page 3, a 'dammed dot' appeared ensuring that all wind pressures were ten times their actual value! This went right through the analysis ensuring that 24 - 2 ½ inch diameter bolts were used. I returned the work to my chief saying, that few if any were required. When he got down from the picture rail I was ordered to put'em in again: 'dammed dot' or no! You will see on page 78 that it only just failed, with no bolts, to remain put in a '12' gale. However, it would have looked very queer without any bolts so in they all went!

Fig. 67 page 78 shows fairly detailed views of this tower.

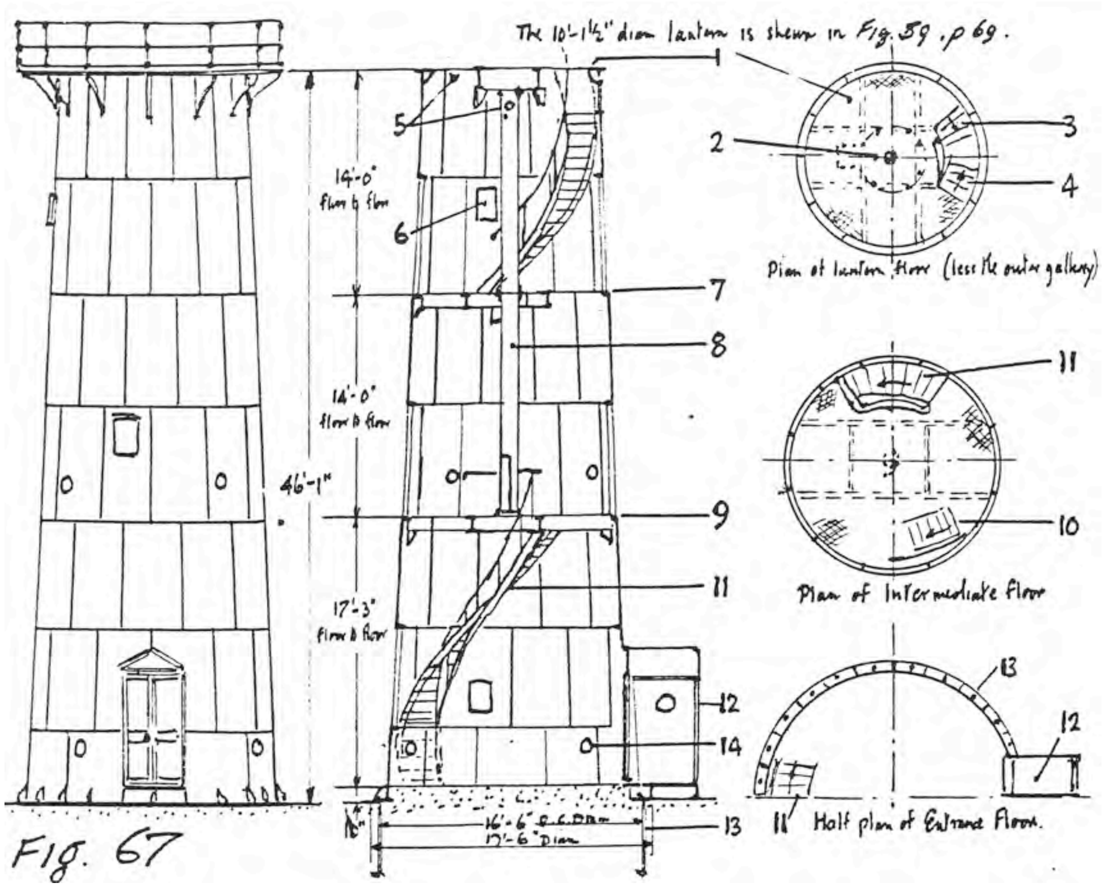
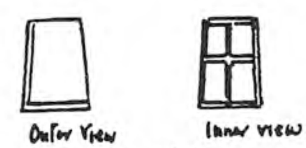


Fig. 67

Parts of the Tower:

1. Lantern floor of checker plate and rolled steel I beams.
2. Banjo base of optic pedestal showing bolting to floor.
3, Stair up to lantern inside gallery. Protects the well hole.
4. Stair down to service room floor.
5. Pulleys to guide wire rope leaving the clock drum.
6. Window with gauqe frames. (gunmetal.)
7. Service room floor with checker plate and I beams.
8. Weight tube with access door and buffer at bottom of tube.
9. Intermediate floor with checker plate and I beams.
10. Stairs up to service room.
11. Stairs down to, or in, the entrance room.
12. Porch with double teak doors.
13. Holding down bolts. 24 foot 1 ½inch diameter 4 foot 6 inch effective length.
14. Gunmetal “hit and miss” ventilators.



Tower plates.

The tower plates are of cast iron with outer masking strips and inner cross ribs (for clarity neither shown in above drawing). The side flanges are planed and the upper and lower flanges planed or turned. The stairs are truly spiral, the outer stringer is snug with the ribs and flanges of the tower plates. Note the brass handrail is carried above the floor to protect the well hole. The porch had inventing design features in that it springs from a conical surface. The Chance pattern maker added many odd looking flanges to his wooden patterns. Two circular gunmetal windows were included, since the doors were solid teak. The service room is the duty or watch room and would have in it the air and oil containers.

The intermediate room contains the cupboard for mantles, burner spares, tools etc. and a stand for spare glass lantern panes.

Stress in the tower plates and the H.D. bolts Fig. 68 refers.

To conform or correct initial impressions mentioned on page 77 we will take out a few rough figures. Using a wind load of 60 lbs. per sq. foot, which results in a total wind load of 46 tons acting 27 ft. from the base of the tower. This gives an overturning mount of 1240 tons per foot.

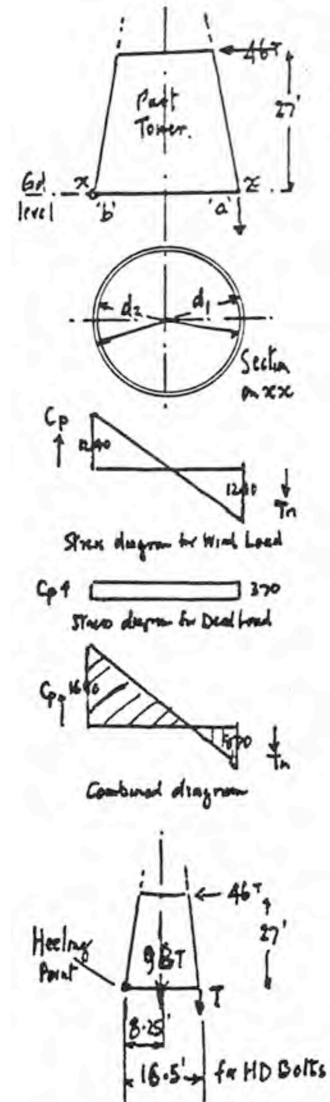


Fig. 68

Dead load: The weight of the tower, complete with lantern, optic pedestal etc. is 98 tons and this is spread evenly over the annulus.

Heavy Duty Bolts: The bolts are 2 ½ inch diameter and the working stress (as for Sarawak) is 6.6 tons/in. One bolt will therefore take a load of 32 tons. We have 24 of such bolts of which at least 4 could be taken as fully strained. So honor was satisfied, past and present!

3) **Sombrero Lighthouse, Virgin Islands – A conversion.**

I inflict this on you for several good reasons:
a) The existing tower was one of many designed and erected by the American Lighthouse Authority, Sombrero's tower was 106 ft high, but several were, quite astoundingly, up to 175 feet. I believe the American engineers drew on their experience with railroad bridges. I recall seeing in one of the deeply cleft gorges in the Finger Lakes area in New York State an incredibly slight bridge rising every inch of 200 feet from the river bed. And on top of it was a single track railway bridge which looked as if it carried a model 'T' Ford rather than a train!

The tower, which you will find on page 80, was built of just angles and flats, no I or L sections. However over many years the bottom 25 feet had badly eroded; the stairs in the central 'tube' were dangerous: a mercury flotation pedestal with clock together with other minor fittings such as teak doors and windows for the lower rooms (new) were required.

b) The chief engineer of Trinity House was appointed consultant and it was decided to remove all structural members except, of course the legs, from below 26 feet 9 inches. The 5 foot diameter staircase tube would suffer the same fate.

The legs were then encased in concrete on a new 1 foot 6inch base, with a middle and top of reinforced concrete rings. A central 10 foot inside diameter room was constructed and braced to the ring and columns. The first portion of the room formed the entrance with a main stair to the intermediate floor where the 5 foot 6 inch staircase now started on its 80 foot climb. On the top ring was built a new structural steel base for the tower and this included a conical roof for the 10 foot room; sole plates with very long (27 foot) bolts to the new foundation and radial girders to the 10 foot top room. In all - a most interesting solution.

A black and white stamp issued in 1952

FAME AT LAST!

c) So the staircase, the entrance stair and the teak windows and door fell to me at the tender age of 19! The 5 foot staircase was quite a challenge, but of an even greater one to my friend W.E. Bennett who had the very testing job of patching up the 5 foot tube and putting in the staircase with its many landings and windows.

25 years later there was a Virgin Islands stamp with Sombrero's Lighthouse thereon. Fame at last!

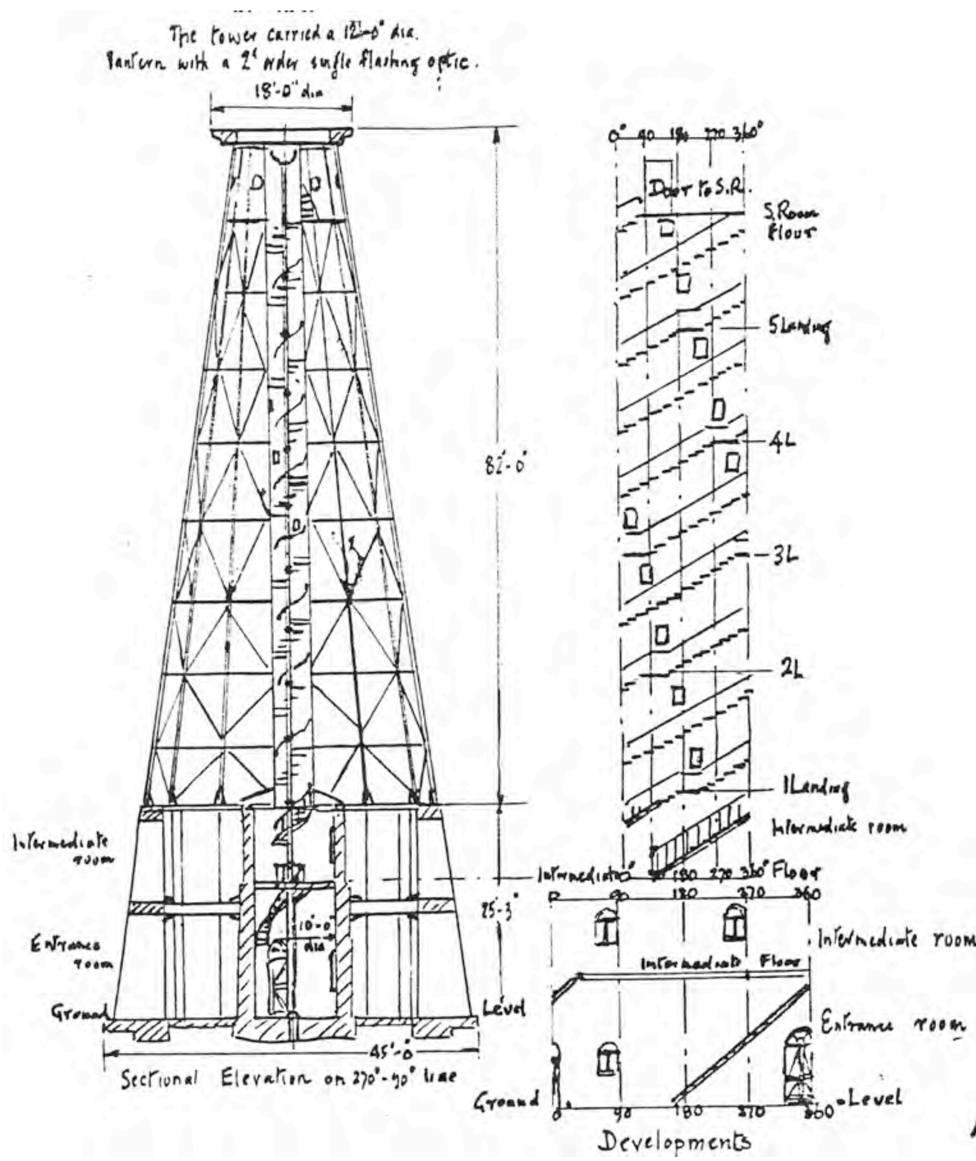


Fig. 69

The 5 foot staircase, design points:

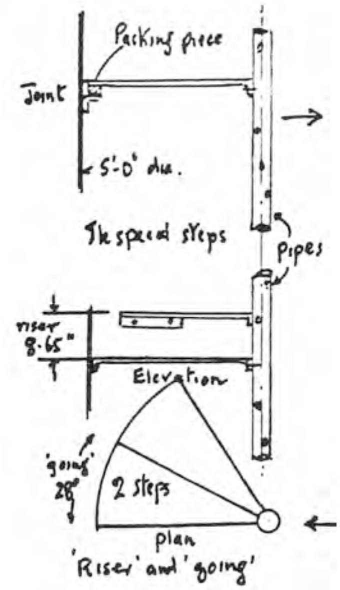
1) Total height – service room floor to floor of intermediate room (for the latter since the 5 foot tube had been cut away we use a helical M.S. stringer to carry the outer end of the steps) is 79 feet 3 inches.

2) The stair has to finish on a 90º line to suit the (existing) door from the 5 foot staircase to the service room.

3) The 5 foot tube is in sections, the joints made from two internal angles coincide with the horizontal members of the tower. The normal steps must miss these and preferably a special step must be just over the top angle of each joint and bolted to it.

4) Use "90º going" landing with a window over each and another window in between.

5) The wire rope from the clock must fall freely down the centre of the tower and then when it reaches the entrance room, enter a 14 inch weight tube and be looped up over. This requires the weight tube to be out of the center of the room by the radius of the sheave pulley.



6) The stair in entrance room is usual helical type, starting on the 150º line to the 30º line, a total of 240º in plan.

7) Windows in the 5 foot tube are of gunmetal.

8) The windows and door in the entrance and intermediate rooms to be of heavy teak with 'Chance' gunmetal furniture.

9) Each step to have a riser of about 8 ½ inches and 'going' about 30º (the 'going' can't be in inches since the steps are sector shaped)

Solution:
1) Start the staircase on the intermediate floor at 90º giving 10 turns. Use 5 landings each 90º and so 10 windows. Total 'going' for the steps is 3150º. Try 109 steps 110 spaces giving a 'riser' of 8.65 inches (ok) and a 'going' of 28.7 inches (ok). The ordered arrangement of windows, Landings and steps can be clearly drawn on the development shown.

2) For the center column it was decided to use standard (water) pipes giving a good 4 inch clear hole throughout. These came in 7 foot 3 inch length made up with a short length in the intermediate room. They had one tapped hole per tread and two for each landing. Each step had two bolts screwing it to the 5 foot tube.

Production problems:

1) Each pipe carried tapped holes in a helical curve, except where broken by the two holes for a landing. Since the pipes were not machined marking off their positions accurately demanded holding each pipe between centers, one of which carried a large circular plate marked with the cumulative angles I had worked out for each tread and landing.

2) Whilst we could and did erect the stair for the entrance room we could only show the Trinity House Inspecting Engineer J. P. Brown, a bundle of pipes, a stack of steps and bags of bolts and screws, and he wouldn't like it. He didn't! He arrived on a Friday afternoon and was escorted down to the Fitting Shops by the Departments Works Manager: He blew up when he saw the pipes all apparently different and riddled with oddly spaced holes. He wanted to see who had designed 'em', so very quickly a very young potential Mechanical Engineer faced an eminent Civil Engineer. "Who had checked my calculations?" "No one!" The works manager evidently knew, at that moment of time, what the position was in the Drawing Office, so he hurriedly suggested "I take home all my calculations and drawings and check them myself."

Alas it was not to be: Saturday was a fine day and with my wife-to-be we played tennis for Chances. Sunday fine also and we did our usual 15 miles walking in leafy Warwickshire. So on Monday I hastened to tell my works manager that the calculations were immaculate! Anyhow checking ones own work is very unproductive!

Erection at site. A stinking job for Mr. Bennett, but he did a splendid job and suffered not from any error of mine!

14 Tower Fittings

Stairs: If we see a stairs 'going around and around we say "spiral stairs," but the average person has never seen a truly spiral stairs. Helical stairs yes but not spiral. Only when designing at Chance Brothers did I use the words helical and spiral, since a room in a lighthouse tower could be a true cylinder or a truncated cone. Couple this with the requirement that the outer stringer always fitted flush with the wall of the room.

Let me define the curves of the inner and outer stringers:

Helical curve – a curve on the surface of a true cylinder which advances up (or down) equal distances for equal angles in plan.

Spiral curve – ditto, but on the surface of a cone or furcated cone.

You will see that for a helical stair the stringers are parallel strips, for example outer, 7 feet x ½ inches flat, 13 feet 3 inches long, which a steel distributor can easily supply (the inner was 4 foot x 1/2 inch 11 feet 9 inches long).

For a spiral stair the stringer is a curved flat which can neither be purchased nor economically made. Fortunately the (truncated) conical rooms in lighthouses have, but little difference between floor and ceiling diameters. Hence as shown on page 83, the Point Saline spiral stairs, we can design using a mean radius of ceiling and floor radius, leaving it to the fitters in the shop to 'adjust' the two helical stringers until they become spiral stringers, at least near enough! Indeed I can think of no commercial method of mating truly spiral stringers.

Making the stringers - Using a 3 roll power driven rolling machine one can produce a curricular ring by advancing the steel strip or flat into the rolls at 90º to the rolls. Advancing the steel flat into the rolls at the helix angle of a helical curve we obtain a helical stringer, since mercifully the helix angle is a constant. It's a skilled job for the blacksmith's and I would hate to give them a curved flat and then tell them to advance in into the rolls at an ever increasing helix angle necessitated by a truly spiral curve. I'm sure the result would be worse than by the 'adjusting' method and the cost out of this world!

You will realize, of course, that the handrail for the stairs also has to be a true helical curve or an 'adjusted' spiral curve, not that the spiral one needs any real adjustment since compared with the stringers it 'flaps in the breeze' until positioned by the handrail brackets or vertical standards.

My Father was the Keeper of the Eddystone Light.

And he slept with a mermaid one fine night.

And of that union there came three.

A porpoise and a paugle and the other was me.

Yo ho the wind blows free, O' for a life on the rolling sea.

One night as I was trimming the glim, and singing a verse of the evening hymn.

A voice from the starboard cried 'Ahoy' and there was my mother sitting on a buoy.

Then my mother she asked of me what has become of my children three?

One was exhibited as a talking fish and one was served up in a chafing dish.

With a phosphorous flash in her seaweed hair

I looked again and my mother wasn't there.

And a voice came echoing out of the night

To hell with the Keeper of the Eddystone Light!

Point Saline – Stairs for Receiver Room. Fig. 70

The well hole being small this stair is steep requiring a ‘facing-in’ decent. The total ‘going’ is 315º through 0º to 45º that is 90º. Manufacture - the fitters lay out on the shop floor the spiral curve for the outer stringer (see plan) using the three centers and radii. The inner spiral cone is 24 inches inside this. A string scaffold is erected around those curves and the two stringers and handrail are jacked in until a plumb bob from the outside of the stringers is on the spiral curve. The holes for the cleats are of course, drilled before the stringers are bent by the smith.

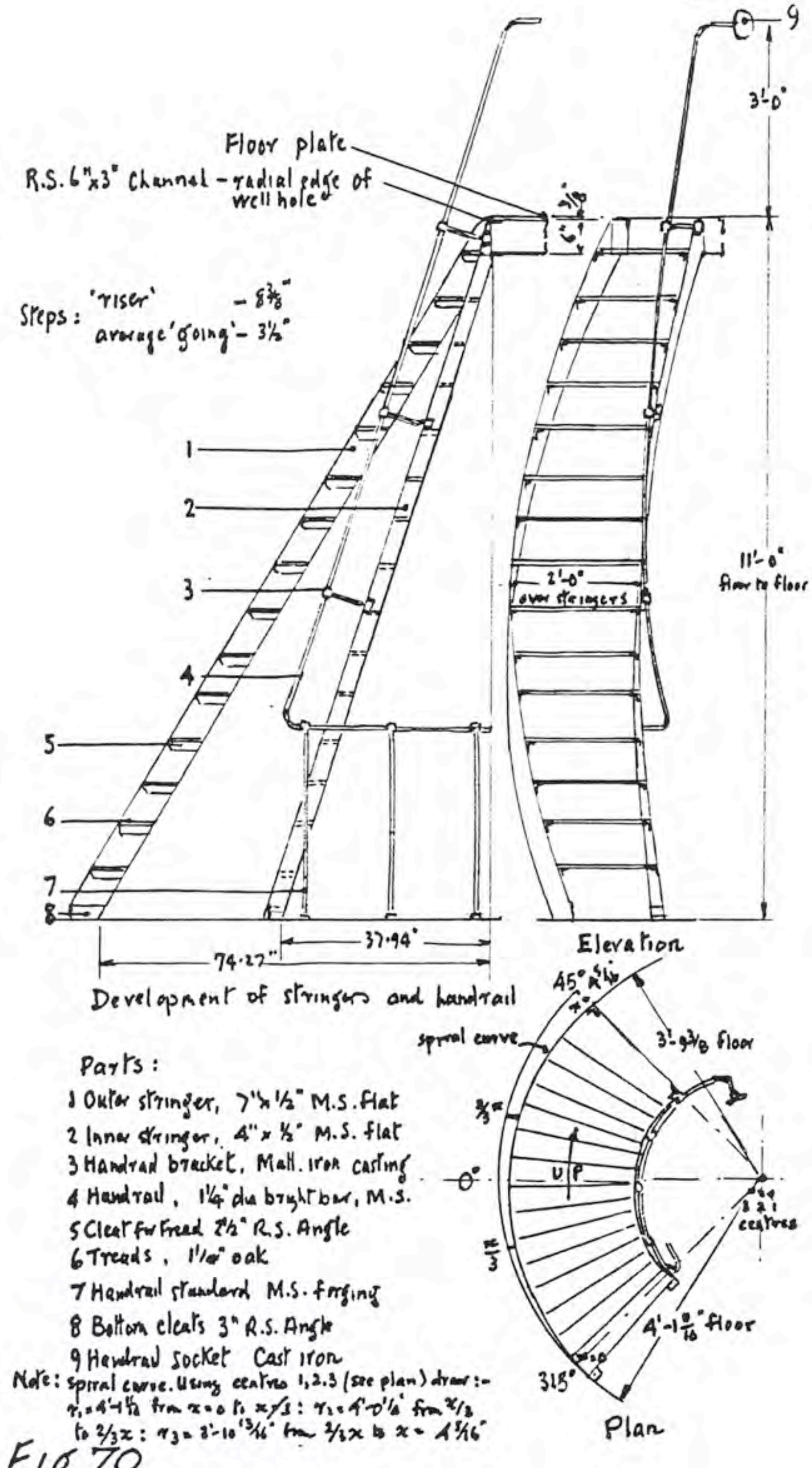
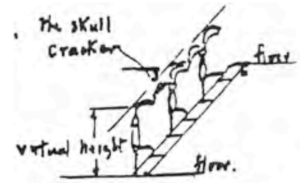


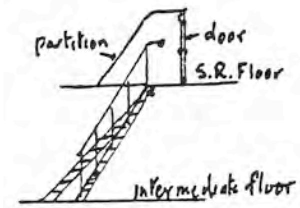
Fig 70

Variation in stairs

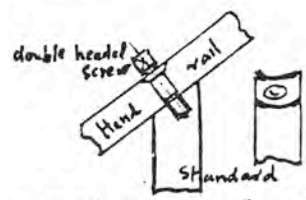
The more common step is of cast iron with a ‘diamond’ non-slip surface. Service room handrails can be of solid drawn brass tubing and looks very well. Such a rail, and solid rails, can be nicely secured to the handrail standards by special set-screws shown in Fig. 71. With a well hole of 90º or more the stairs are not so steep and with the stringers wider their thickness can be reduced.



To provide a little more comfort for the Keeper’s on watch some Authorities ask for the stairs to be plated with a thin steel sheet on their underside. The sheet is attached to the bottom edges of the stringers and does at least, hide the big boots of the Keeper clumping up and down the stairs. A distinct benefit is obtained by covering the well hole in the Service Room floor with a partition complete with a wooden door. This is shown in a sketch herewith. I have seen such a partition built on the lantern floor, but think it unnecessary. It hinders cleaning the glazing and the optic, and cuts out the wee tinkling of the clock gears, an all’s well signal to those in the Service Room. Well holes not so protected by a partition will be ‘encircled’ by the stair handrail positioned by handrail standards and well sockets as shown in Fig. 70, page 83.



S.R. Partition



The site engineer will saw off the square head and then file it flush with the handrail.

Special setscrews

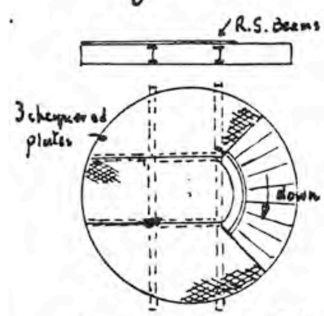
Fig. 71

Lantern Floors

Floors carrying a very heavy optic and pedestal, the latter being the multi-column type with a round baseplate of cast iron, are well carried by the radial beam-drum type floor shown in Fig. 72 (b). Such a floor could easily carry 10 tons dead weight. The five, 60º floor plates are also sketched, these are of cast iron.

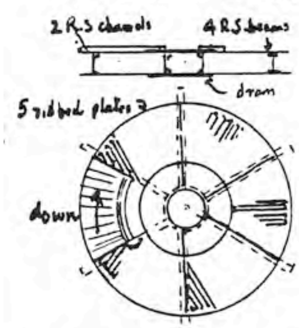
The Chance type pedestal with its banjo baseplate is better supported by a simpler floor, which not only is much cheaper but offers a 90º well hole. The floor plates would be mild steel checkered plate, again cheaper. An alternative floor ‘covering’ for the type of floor shown in Fig. 72 (b) and very clean and non-slipping, is to have 5 slabs of Delabole Slate, 2 inches thick.

A nice problem was posed when I found, for my first slate floor, that the slabs, whilst beautifully polished and dead flat, slightly varied in thickness. A worse surprise was to find the redial mild steel beams also varied in height. It had not occurred to me that the quarry people didn’t realize that the finished floor should also be flat and certainty structural steel hand books gave no warning that the most important (from the point of view of strength) dimension of a I beam could be less than that stated. The lesson learned was “assume nothing” and always add limits to drawings sent to outside suppliers. In the end the fitters balanced out the thick slabs with the shortened beams so that all was well.



Chance type floor (a)

One lantern floor with a very small well hole and deep beams compelled me to design a very steep stair and even then the keeper stood a good chance of being brained by hitting the back beam of the well hole. I lacked all knowledge of the vertical height of a person climbing such a stair (*see above sketch).* I suspected it was grander than actual height. Friend Barnett, who stood 6 foot 2 inch was going to erect the stair and was likely to be the first victim. So he consented to be a guinea pig and ascend at varying speeds another stair then being built, whilst I got his vertical height. Even then for 6 foot 2 inchers I covered the bottom of the offending beam with a pad of soft rubber! Years later in British Rails second gas turbine locomotive I saw a really good solution. In one compartment they had a real skull breaking (vertical) hardwheel, but mounted to this by a light spring was a light dummy wheel. One touched it and ducked away! Splendid!



Radial beam-drum floor (b)

Fig. 72

Crash!

Only the lantern floor carried a real load, but if a weight tube did not end on the ground floor, but on an intermediate floor it might on a rare occasion receive a resounding blow. Chances always supplied a spare wire rope for the clock weights, not that we heard of a rope breaking. We might peruse the mater of a break by looking at the three towers Sarawak, Jaigarh and Sombrero.

Sarawak - Willy-nilly the weight tube can't go down 100 feet so it ends on the floor of bay 9. (see Fig. 67 page 75)

Jaigarh - The tube was confined to the service and intermediate rooms because 28 feet was sufficient and I suppose the entrance room looked better without it. (see Fig. 67 page 78)

Sombrero - It is ironic that in a tower 107 feet high we should have to confine the weight tube to the 16 feet or so in the entrance room. Only a single rope could go down the central 'pipe' of the 5 foot staircase but we 'looped up once' in the weight tube, which, incidentally, was half a pulley diameter eccentric in the entrance room. Only in this case would Mother Earth take the blow of freely falling weights. (see Fig. 69 page 80)

"Purdy had got permission to take the children up the Lighthouse; and so the three of them went up and up and up a staircase that twisted like a corkscrew, hundreds of steps till they came to where the great lamp was that shone at night. Tightly holding hands they walked round the little narrow platform outside and looked down at the sea, all bubbly and frothy and the white roofs of the houses."

Henry H. Richardson

Let us assume
1) a 500 lb. weight
2) if the rope broke at the top of the weight tube it could fall 25 feet.
3) the buffer, at the bottom of the weight tube, comprised two wooden discs sandwiching a coil of heavy rope – all expendable!
4) Energy (potential) lost in falling 25 feet = 12500 foot pounds.
5) Velocity of weight at impact is 40 feet per second.
6) Resisting force of buffer – say a 6 inches thick sandwich disintegrating into a heap of debris 2 inches high = 16 tons!! Fortunately a very transitory load and obviously breakage must be minimized by periodical examination for wear or fraying. An examination of the lights logbook could reveal its probable life.

This story comes from an Irish Lighthouse and a reliable source, but it occurred, of course, in the bad old days of the 'big' lights! It couldn't happen now, no clocks, no Keepers, no stories. Any how even with their little weaknesses the Irish Keepers knew their job. This Keeper preferred to take a nap in the entrance room, with the (bottom) door of the weight tube opened and a cushion over the sharp bottom edge of the tube. He slept happily on the floor with his head inside the weight tube. When the weight touched his forehead he hurried up the stairs to wind up the clock!!! One trusts he slept lightly and was stout of heart !

Weight tubes – details.

These came in 12 inch outside diameter, thin walled steel tubing for 10 inch weights and 14 inch for 12 inch weights. 10 inch weights in cast iron could be lifted by one man whereas a 12 inch lead weight was not only very expensive, but an almost impossible lift. The top end carried, as required, spindles for the rope pulley and rope eye, and an access slot for threading on the rope. At the bottom there was just a door for threading on the weights, and a buffer. As mentioned before most clocks carried an alarm to ensure that the weights never rested on the buffer. Should this occur it was possible for the rope to pull out of the clock drum and slide down the weight tube! The standard method of 'securing" the rope to the drum was to braze on the end (top) of the rope a brass thimble and then to poke the wire into a similar sized hole in the drum. It held well if there was a good pull on the rope.

Furniture for the tower of Point Saline, 1931

I had the rare fortune of designing a complete set of furniture for a land station. It consisted of (a) An entrance door in teak, 2 foot 11 inches wide by 6 foot 8 ½ inch high with 4 inch x 4 inch jambs.
(b) A teak door for the service room partition, 2 foot 1 inches wide by 6 feet 6 inches high.
(c) An oak cupboard for the entrance room of height 1 foot 2 inches and a dimension of 3 foot 5 inches at the base.
You will see that the cupboard, as well as items (d) and (e) snugly fitted against the walls of a conical tower! It was a lovely piece of furniture.
(d) A hinged table for the service room. Oak and 2 feet 6 inches high and on average 2 feet 10 ½ inches wide.
(e) An oak stand for spare glass panes for the lantern; 2 foot 6 inches high by a dimension width of 4 feet 4 inches.

We did see at Chances a drawing for the bunks for Beachy Head and at first sight it appeared that the old joke that the keepers slept curved up was true. But, the length was such that even a six footer could sleep straightened out.

Oak Cupboard for spare P.V. Burner; stand by wick burner; burner spares, tools, utensils and auto-form mantles.

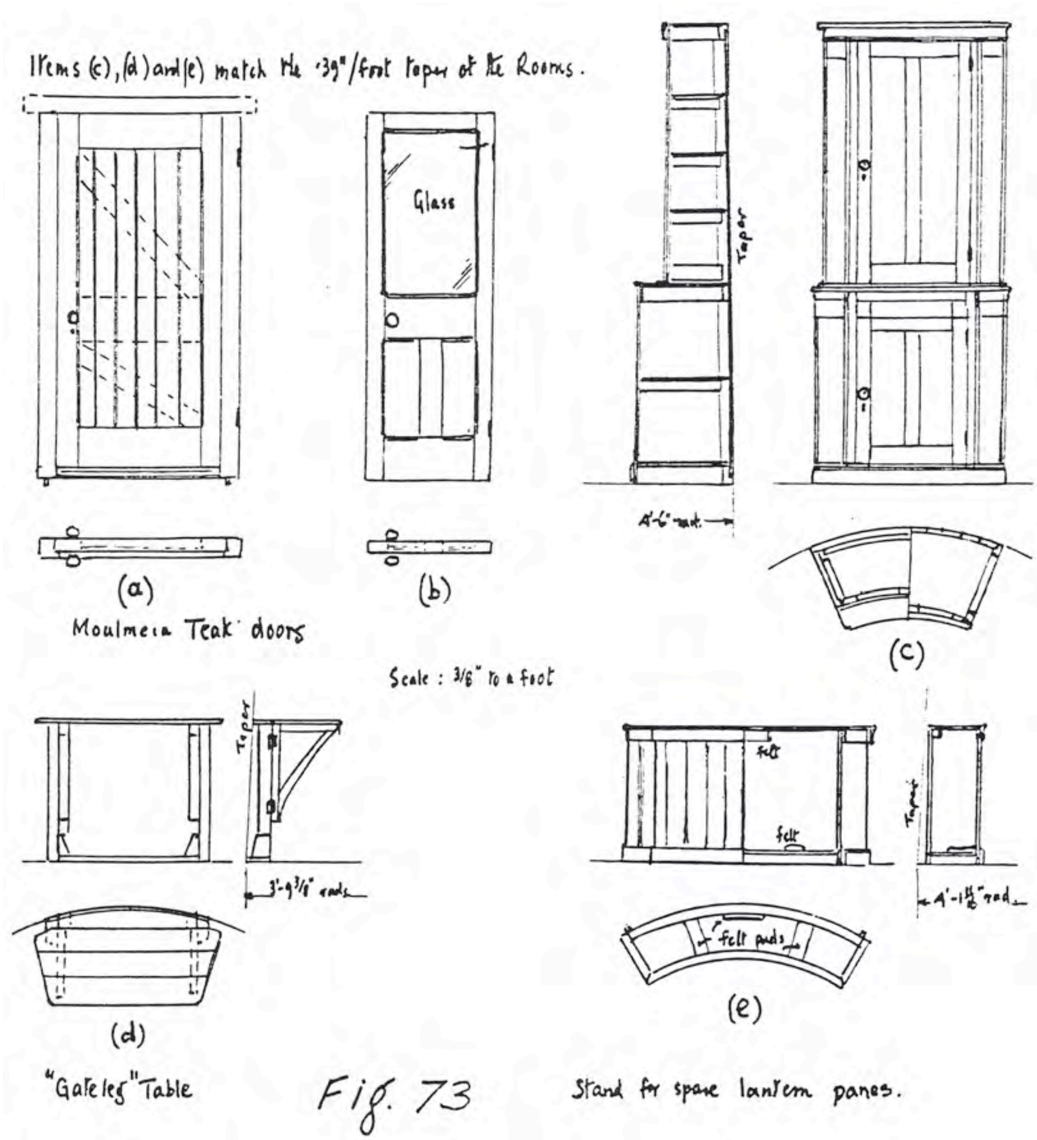


Fig. 73

15 Fog Signals – in particular Diaphones

A fog signal is a must for rock stations, however, little the accommodation, and also for lightships, and here I also have in mind the safety of the lightship and her crew.

Stories have been told of a mad skipper who boasted about the number of lifeboats he had whisked off the Nantucket Lightship off New York, and of his last voyage as an officer when he cut the Nantucket in two with a wicked wastage of lives.

Other important lights usually have a fog signal, but the expense is great. The larger signals are usually confined to single or double 'characters'. For example 2 ½ second silence, 1 ½ second sound 57 ½ second silence (single) or 1 ½ second sound, 3 second silence, 1 ½ second sound. 51 second silence (double).

Blasting off!

Let me set the scene in 1930 in Cape Columbine Lighthouse, which is a South African light situated on the west coast about 90 miles north of Cape Town. The Principal Keeper is on the lantern gallery looking towards Duming Point and again to Paternoster Point, and the visibility is worsening. Weather wise the SW here is paralleled only by the Peruvian coast. At both an ice-cold current is flowing north from the Antarctic and fogs are prevalent.

I can vouch for being driven south of Lima on the Pan-American Highway, very much in a desert and one moment in brilliant sunshine, the next in a thick fog, and headlights on and 10 mph!

So at Cape Columbine the fog is rolling in and the Principal Keeper must quickly decide when to start his air compressor and then to hope that the Diaphone fog signal, to date the largest in the world, recently supplied by Chance Brothers of England, will cover the 215º arc from Martian Rock 13 miles to the NE to Fish Point 20º E of S and 11 miles away. The South African Railways and Harbor Board allow the Principal Keeper 10 minutes to blast off.

The installation which I designed and tested had two 'K' size diaphones each consuming 45 cubic feet of free air per second of blast, at 35 lb per sq. inch, pressure. The two massive conical 'trumpets' were set at an angle of 120º to cover the 215º specified, and located on the 2nd floor of the tower. The signal was 'single', one blast of 2 ½ seconds every minute. The note was a rough one of about 180 frequency since at that period of time no Lighthouse authority had asked for synchronization of the diaphones, preferring indeed a rough note which traveled well over the sea. Additionally the diaphone had a tremendous grunt (in this case 2000 elephants grunting) at the end of the note, which made it very distinctive to navigators. For the next few hours or days, the keepers will be very painfully aware that their fog signal is sounding.

The compressor sets (total of two, one being spare) compressed by a 45 HP electric motor, 1000 rpm, driving a 3 cylinder air compressor, delivering 260 cu ft of free air per min. at 35 psi gauge. An impressive array of 6 foot diameter by 8 feet high receivers saw that the pressure never dropped below 32 psi. When his 'master' gage recorded 35 psi the keeper would start the air-driven timing gear, and the diaphones would **Blast off.**

In a night fog the Principal Keeper would have been very aware that the optic beams were shortening rapidly.

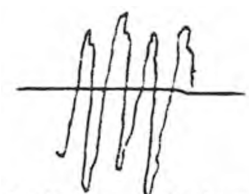
I propose in this Chapter to deal in some detail with Chance's Diaphone signals and then later to deal with the two bells, the two red signals and the two sirens I handled. Chance's greatest contribution was the Diaphone used world-wide with considerable success.

Transmission of sound in air.

First a few facts:
Value of velocity of sound at sea level taken as 1100 feet per second.
Frequency and wavelength of sound emitted by four fog signals:
Diaphone 200 – 180 cps, 6.17 and 5.5 feet; Read 450 cps and 2.44 feet: Siren of Irish Lights 128 cps and 8.7 feet: (Portishead) Bell 200 cps and 5.5 feet.

Quality of sound or timbre: The diaphone is well blessed with overtones and is illustrated by an analysis by Mr. Northey, the inventor of the diaphone, from a test at Cape Henry, Virginia, 1936. Mr. Northey appears to have used an air pressure of 40 psi gauge as against Chances 35 psi. This seems to explain the high frequency of the fundamental note of 107 cps, that is, the frequency of operation of the diaphone piston with no sounding air. On the rare occasions, I did this whilst testing, the note seemed a pleasant buzzing and nothing like the racket that ensued when the sounding air was let in.

Frequency of cps	107	214	321	428	535	642
Frequency Structure	20 to 40	200/60	40/100	200/300	20/120	20/50



Oscillogram of 'F' diaphone

Mr. Tonkin, then Chief Engineer, Irish Lights, in the test of his 128 cps siren remarks: "In connection with the pitch (for a fog signal) it is of interest to note that of the two factors in human speech the energy is at a peak of about 150 cps while the intelligibility is at a maximum around 1000 cps. It appears that 180 plus or minus 50 cycles is the most effective for a fog signal, but it is certainly inadvisable to have high and low notes".

His last remark was possibly directed at the relative ease in designing a two-tone siren. Also I think he was aware that Chances had just purchased a two-tone diaphone from Northeys and were trying to interest Trinity House in it. Trinity House was quite right in not being interested. The same trouble existed in the "old days" with red and white light beams from the optic. One cannot guarantee that the navigator always sees a red and white light or hears the high and low tome.

Attenuation and absorption of sound.

A few samples will illustrate the near impossibility of saying "the range of this diaphone will be x miles under all conditions.

1) Skomvcer Light, south of the Lofoton Island Norway, still holds the Chance long range record of 23 miles. A 'G' size diaphone, cataloged range 4-6 miles; calculated range 2-6 miles!

2) Douglas Head, Isle of Man – a 'C' size diaphone. Whilst visiting the Isle of Man, Scottish Lights asked me to report on its performance. Report: faint / medium at 5 miles, lost at 4 miles: loud at 3 miles: faint at 2 miles: loud at 1 mile. Catalogued range 2 to 2.5 miles: calculated 3 to 4 miles. A typical humping of sound!

3) Off Harwich – a distant Lightship with a vertical ‘K’ size diaphone I have often heard the signal, well outside the cataloged range, but invariably only the grunt which came through very clear! The rougher the better!

4) Wolf Rock – way back a large bell hung underneath the lantern gallery, it was eventually rusted away! The story goes that a sailing ship was nosing its way through thick fog near Wolf, “Rocks ahead!” yelled the look-out. She veered off safely. The look-out swore he could see the hammer hitting the bell, but neither he or the skipper heard a thing”. The way of all bells!

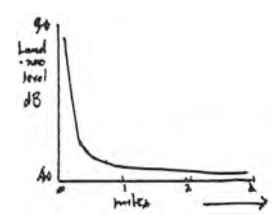
5) The name escapes me, but originally the signal was a twin ‘F’ diaphone, for no obvious reason the diaphone failed to reach on one flank. Eventually we agreed with the local Authority to replace the ‘F’ in question by a ‘G’ size diaphone. Fortunately there was ample air available. Now a unique F/G diaphone!

6) A ‘Cooper’ observation of bell buoys, just to say that the rusty pivots of the hammers can sometimes be heard before the bell. Just like a bell!

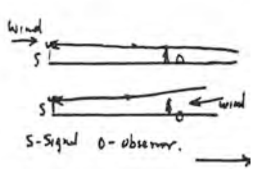
7) Mr. Tonkin, Irish Lights, “With the special mixture for the explosive (signal) cartridge we get a vivid burst of light as well as a usually excellent ‘bang’. It is ironical at times to see the flash of light but to hear nothing.”

8) The Recorder. It is significant that major fog signal stations have a recording mechanism, which not only permanently prints out the duration and period of each blast, but also the air pressures in the air receivers”. No good the poor skipper saying “he never heard it”, the Lighthouse Authority can produce a long strip of paper showing that at the lighthouse the signal was happily blasting away, and possibly humping its across the ocean. Pity it passed over the skippers head !

The above makes one’s heart bleed for the “researchers” at Chances and elsewhere. One of them on testing for range, “The effect of momentary wind pressures and possible other momentary air conditions are indicated by the irregularity of some of the curves “and again”… the whole theory of low frequency sound distribution by interference would be open to question.” But, enough, many reports Chances did not offer customers, the world over, collaboration in tests en situ!



1) The attenuation of sound (as light, the inverse square law) is so small compared with absorption that it can usually be neglected.
2) Absorption of sound is dependent on frequency as well as atmospheric conditions and it has been established that the timbre of sound changes with distance due to the overtones being more highly absorbed than the lower frequency. In part this is responsible for the absorption in dB per mile or kilometer being very much greater when measurements are taken near the signal.



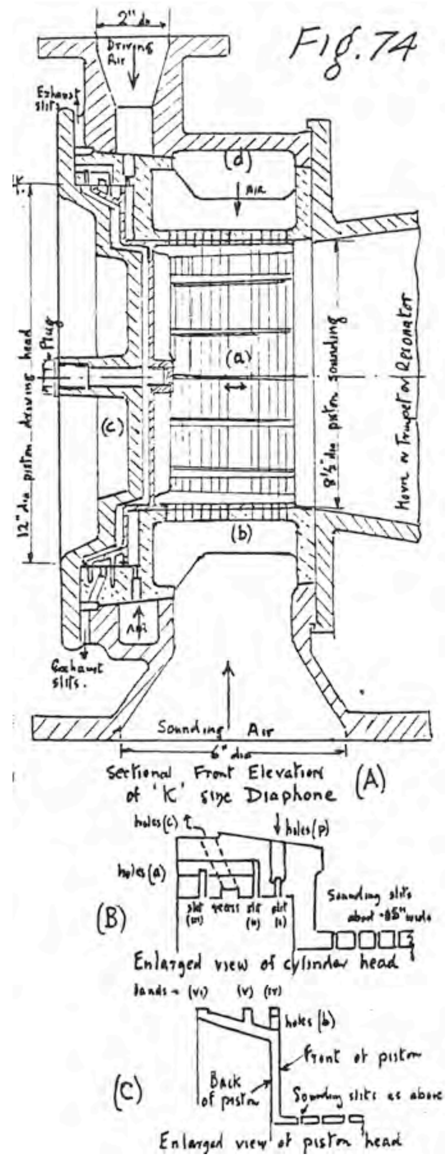
3) Humping of sound it is thought to be the effect of wind direction and the differing temperatures and humidities of layers of air above the surface of the sea contribute to humping.
4) The noise level of a diaphone immediately after commencement of the blast increases by about 2 dB, then falls as the pressure falls to a figure dependant on an length of the blast, then suddenly rises at the ‘grunt’ by 6 dB (you will see later that the smaller diaphones A, B and C can not ‘grunt’).
5) Ships noise – one report states ‘to hear a signal of 20 phons the ship would have to be stopped; to overcome average background of noises 40 phons would be necessary. (He states, 20 phons is about the noise level of a average suburban garden). Another gives 60 phons for ship proceeding: 40 phons, stopped and 20 phons in a quiet area.

The Diaphone Fog Signal

We refer to Fig. 74 (A) which is a cross-sectional view showing the slitted piston (a) The cylinder, identically slitted (b), the back cover (c), and the casing (d) of a ‘K’ size diaphone.

How it works – driving the piston (a) backwards and forwards with a stroke of about 0.3 inches and at 90 cps. Let us consider the driving head of the cylinder Fig. 74 (A) and (B).

1) Compressed air is feed into the casing at the top 2 inch hole by a very high speed valve (not yet shown) at a pressure of 35 psi gauge, falling during the blast to a minimum of 32 psi gauge, passing through holes (p) shown in (b) of the figure it expends its full pressure on the front of the piston – always. It moves the piston to the left.



2) After a little movement land (v) starts to uncover slit (ii) the air en route having passed through holes (b).

3) This enables the air to pass to the back face of the piston via, slit (ii), holes (e) and slit (iii). Acting over the larger area the piston is halted and then moved to the right.

4) After a short movement land (vi) opens the exhaust recess in the cylinder and the air at the back of the piston exhausts to atmosphere via exhaust holes (c), the annulus in casing and cylinder and the exhaust slits in the casing (see A). All is repeated at the amazing speed of 1/100th to 1/30th of a second.

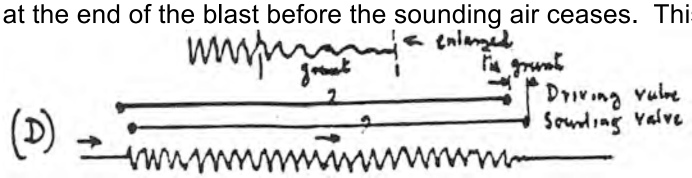
Now for the sounding slits, about 0.05 inch wide, 13 in number and at mid strike of the piston coincident, thus allowing the compressed air (at 35-32 psi gauge) which has entered through the 6 inch hole, via a 6 inch high speed valve (not shown yet), and surrounds the outside of the cylinder, to pass into the resonator, twice per stroke. These tremendous puffs of air through the 13 slits gives a tremendous blast of sound of fundamental frequency of 180-200 cps. The resonator to some degree concentrates the sound outwards from itself.

This most ingenious device of Mr. Northey gives the most powerful fog signal known. Chances had the right from him to make and sell these for all coasts except the America’s.

Table 11 page 92, gives the vital statistics, or rather sizes, for the seven sizes made by Chances. The air consumption ranges from 1 to 60 cubic feet of force air per second of blast.

The 1000 elephant grunt

Sizes F, G, K and L have separate driving and sounding operating valves. A, B, and C use such a small amount of driving air that it is bled off, inside the small casing, from the main supply. As you will see no grunt is possible for the A, B, or C. Let both valves open for say 2 seconds, but displace them by say 1/20 seconds then 1) the piston in moving smoothly at say 90 cps before the sounding enters and 2) the piston is slowly down at the end of the blast before the sounding air ceases. This is the ‘grunt’.



The mariner appreciates the distinctive grunt of the diaphone, particularly since the type of fog signal is marked on his chart and at double the loudness level it travels splendidly (see Harwich on page 89)

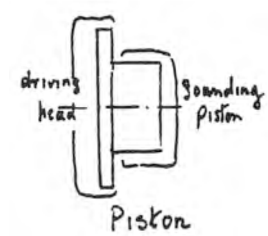
Points of design

1) I imagine Mr. Northy firstly designed the F, G, and K sizes, and then to meet demands of Harbor Authorities, extrapolated downwards to the A, B, C sizes. I did not like the A and B, but until we put a 'C' size into Mumbles Head (Swansea) Light I trusted it (this involved quite an adventure, which I relate later in this book). So then all three had the bad habit of coming to rest on the back cover plate (similar to part (c) Fig. 74). Once there the piston stopped there! The hammering showed on the driving head and at the worst the sounding part cracked where it joined the 'front of piston" (see sketch (c) of Fig. 74). However Chances tried, all three sizes lacked reliability.

Chance Brothers then extrapolated upwards from K to the L size, but the increased loudness did not warrant the extra capital cost or running costs.

For A, B and C, I believe one cannot get a true scaling down of the driving head slits, lands, etc and that leakage put the lands is heavy in proportion.

2) Good points (a) the wear on the piston and cylinder is very small, although when the piston is inserted in the cylinder the only lubrication is a smear of 'Gredag' (grease + graphite dust) – and afterwards only the trace of oil and water coming through from the air compressor. (b) Perhaps not so good each piston has it own frequency of vibration, and this in a given cylinder, which appears to depend on its weight, friction with its cylinder and the minute imperfections in the sizes of slits, lands etc. Also it varies with the air pressure. Again the different sizes have their own range of frequencies. You, of course, realize it (the piston) is free floating and not susceptible to outside forces.



3) The total air consumption is largely the sounding air and this varies with the width of the sounding slits and the frequency of the piston. Since most Lighthouse Authorities add but 10% to the catalog air required per second of blast one plays safe with the width of slits. But, the wails that go up from the machine shop, fitters and 'casts' are heart rending if you are compelled to widen the slits because the air consumption (and so the noise) is to low on testing!

4) Every piston is weighed although, since the only portion of the piston not machined is the inside of the sounding portion, the limits are close.

Manufacturing

Only the piston is difficult and that is the very devil since it must weigh so little. You will see from Fig. 74, page 90, that when finished the sounding portion is but 12 fragile rings held precariously together by the slender internal ribs. the piston diameters (see below) and the driving head are held to 0.0002 inch and the slits, lands and position of same to 0.001 inch.

The gun metal cast piston is positioned from the inside of the sounding portion and the diameters, diamond turned to a lovely silky finish. Grinding is impossible as the pressure of the grinding wheel distorts the final shape of the sounding portion. Cutting the sounding slits is the last nerve wracking job with the machinist receiving strict instructions not to cut too deeply into the ribs. this invariably left thin shavings of metal at the bottom of the slits, and since no one else would risk it I, as tester , had the job of removing 'em. A loose piece coming adrift whilst testing could scour the piston and cylinder and that meant a few £100's down the drain.

Type	Air Consumption, free air per second of blast cu ft/sec	Range in Nautical miles Calculated	Catalogue	Pitch cps	Size of Piston in " Sounding diameter ins.	Length of sounding portion	Slits Number x width	Operating Valves	Other information
A	1	2·7	1-1½		1·40"	1¾"	4 x ·027"	1"	
B	3	3·4	1½-2		2·15	2¼"	6 x ·040	1¼"	Wt of piston 25 oz.
C	5	3·4	2-2½	180	2·88	2½	7 x ·040	2"	Dia. of sounding head 4"
F	15	4·1	3-5	to	5·00	3⅛	9 x ·048	3" + 1"	" " " 7¼
G	23	4·5	4-6	200	6·13	4	10 x ·060	4½ + 1½	
K	45	5·1	6-8		8·5	4½	13 x ·050	6 + 2	" " " 12"
L	60	5·8	7-10		10·0	7¾	15 x ·050	8 + 3	

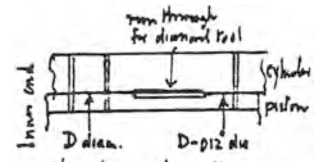
Weight of 'F' piston 77 ozs. Length of Resonators – F = 4'-2¾" L = 5'-9". Spacing of slits ·21" to ·40". For "free air" see p97

Details of Diaphones

Table 11

Assembly

Again the piston! Using a steel rod screwed into the back of the piston advance it into the cylinder, get it crossed, can't get it out, £100 of scrap.



the two diameters.

You will see in Fig. 74 (a) page 90, a wideish gap between the first 8 slits in the speaking portion and the next group of 5 slits. In this gap both piston and cylinder decrease in diameter by about .012 inch. Result, no difficulty in advancing the piston into the cylinder, at least for horizontal diaphones.

Vertical diaphones

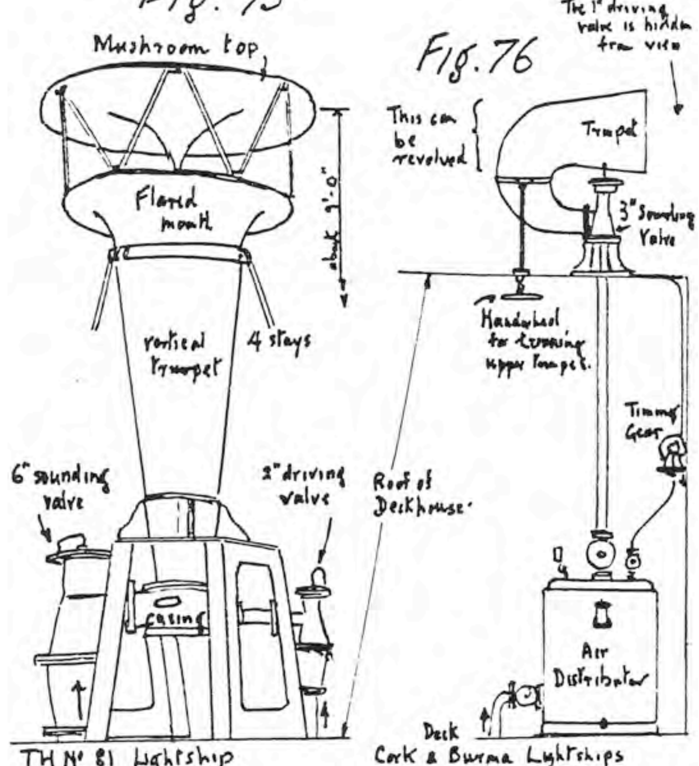
For lightships and rock stations we need all round distribution of sound. You will see later (Fig. 88 page 103) that Mr. Tonkin of Ireland preferred 3 vertical sirens, nested together, to a diaphone with a 'mushroom top', Fig. 75 below and also the previous effort of his for *Cork Lightship*, Fig. 76 below.

The effectiveness of the vertical trumpet with a mushroom top was much criticized by the scientists particularly since the diameter of the mushroom was smaller than the wave length of the sound. As one rather sadly remarked "the trumpet concentrates the sound but little, but when we removed the mushroom the sound was considerably diminished". Too bad! Anyhow it satisfied Trinity House and others. The mushroom did to some extent keep out rain and green seas, and thereby hangs a tale!

A Chance employee (not to popular in the works) visited a Trinity House Lightship. Despite a warning from the crew he would stand close to the (vertical) diaphone as it first sounded. He didn't lose his ears, but about 40 gallons of water shot up the trumpet and curling down felled him to the deck. Fortunately no injury, he was just soaked to the skin. The story lost nothing in going the rounds!

Fig. 75

Fig. 76



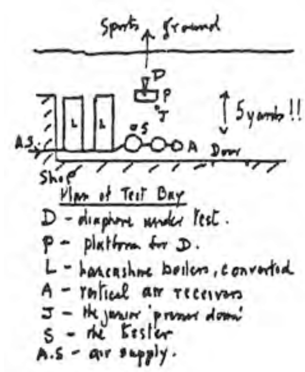
TH No 81 Lightship 'K' size diaphone

Cork & Burma Lightships 'F' size diaphone

The two diameters again. The new problem is shown in Fig 75. If the piston is to be fed into the cylinder, you can lie either face upwards or on your tummy and a crick in the neck. Most people in these positions lose what sensitiveness in arms and hands they may have and completely fail, even with 2 directions to get the piston in. So a 'cradle' to carry the piston was spigoted on the casing (the corner is of course removed) enabling the piston to be dead central with the cylinder and then pushed upwards.

Before dealing with twin diaphones and sound distribution, a little light relief with my side of the little testing Chance's did. Strangely I was involved, in 1924 and aged 15, in a demonstration of the first diaphone Chances purchased from Mr. Northey. Being an "A" size and something like an outsize, old type motor horn it was erected with its small compressor and receiver in a disused glass making house. The department's directors and Sir Hugh and Sir Walter Chance were present with several others. My job was to press down a valve which in turn opened the one inch combined operating and speaking valve. This I did, and was appalled to see a blanket of several year's accumulated dirt and soot descending from the roof. We all looked a pretty sight, when choking and covered with soot, we finally got outside. Why I'm not sure, but from there it became a tradition that the latest junior in the Drawing Office always pressed sown the valves, but in the open behind the Lighthouse Shops. The view from the test platform was the works boundary wall and a dairy farm!

So a month or two later I had 2 buttons or valves to press for the first 'F' diaphone. Press I did, only to see 30 cows with tails erect charging the wall in fount of me. Next morning an irate farmer arrived with a sizable bill for spoilt milk! This went on for a short time until Chances decided to buy the farm and convert it into a sports ground. In the meantime the householders on the adjacent main road were bitterly complaining and the local newspaper invented the "1000 elephant grunt". However, we pressed on, hoping that we gave our employees and others in the vicinity a warning that we were going to blast off. The customer always required an air consumption test of the 3 pistons (1 in use, 2 spare) in the single cylinder, and full test of the engine, compressor or motor-compressor if Chances were the main contractor for these.



The fitters would inform me when the diaphone was ready and the appropriate air receivers charged to 35 psi or so. So with a massive master pressure gauge and a stop watch and pad and army type ear plugs we proceeded to the test buy picking up the latest recruit as the valve "presser – down". We plugged his ears with cotton-wool and wound a scarf around his ears and gave him a piece of wood to press down the 1, 2 or 4 valves. When the pressure in the receivers being used was about 36 psi, I signaled the 'lad' to press down. The time for a pressure fall from 35 to 32 psi was recorded, four times per piston. The total storage capacity gave me a bare 2 seconds blast for a twin 'L' installation.

What was it like? The lad looked like a scarecrow shaking horribly! Myself, what seemed to be a 'depression' of the chest made me feel very sick! Always!

For big diaphones the gulp of air suddenly taken from the receivers used to lower temporarily, the pressure well below 32 psi and it was necessary to wait until it climbed up to a final figure. (For calculations see page 97)

Cork and Burma Lightships – see Fig 76 page 92

How near the unique trumpet with its swan neck came to the all-round distribution of sound required on lightships, I so not know. Certainly it was sensible to keep the rotatable horn pointing into the light wind during a fog, whatever the unlucky members of the crew thought of the monster blasting away, a few feet above his head.

Twin diaphones

Why two diaphones? Chances worked on an effective spread for a single diaphone of value 120º and in very many locations this served well the needs of the mariner. But, if you will turn back to the map on page 87 you will see that the C. Columbine diaphone had to cover 240º. In the early days we arranged the two diaphones as Fig 77 (a) herewith. A 120º positioning this covered an angle of 240º - just about satisfactory for C. Columbine.

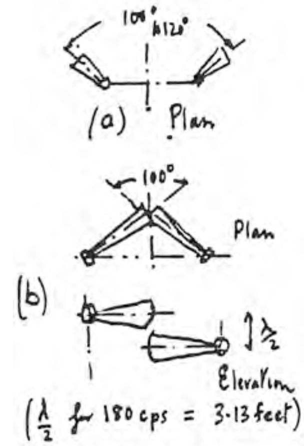


Fig 77 (a)

Later I suggested we might, in order to flatten the beam of sound, use the arrangements shown at (b), separating the axis of the trumpets by a distance of half the wavelength. It would mean doing some research on the odd length of present trumpets; find how to synchronize the two instruments and having done this find what the resultant frequency really was.

Ironically the arrangement was adopted, but Trinity House and others would not have synchronized diaphones. They wanted a rough note which would certainly be produced if one diaphone had a frequency of say 182 and the other say, 188 cps. And of course moving out of phase. So I shelved the synchronizing job until one day the Chinese demanded it, to our great surprise. Anyhow (b) looked a nicer scheme than (a).

China – a twin 'L' and the biggest ever!

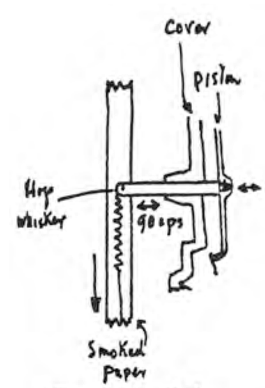
Chances received an enquiry, got it translated and quoted for this enormous installation, consumption of air per seconds of blast 120 cu ft of face air at 35 psi! And we got the order and to clarify a few points, had the translation checked. Horror of horrors a complete sentence omitted, "The instruments shall be synchronized". No money to do it, even if we knew how to do it!!! Panic stations.

Mr. Tonkin had written in 1940 (and by this time the Japanese had destroyed the lighthouse in China, the Sun King turned in his grave?) "……it points to the use of a multiple instruments and here the diaphone is weak as it is not practicable to keep two or more instruments (air driven) in unison or in phase". Too bad no one had told him well before 1940 that we could do, and did, the impossible, for very few pence!

Creativity – so they say!

The problem, to get any two out of the six pistons in either of the two cylinders, normally all would have slightly differing frequencies and be out of phase, synchronized.

1) The first idea, remove the plugs from each cover plate, see Fig 74 (a) page 90, screw a close fitting rod in the piston letting it project outwards from the cover; fit coils to the cover and devise an electoral circuit so that the impulses would pull end piston into identical movement. I should say here that on the very rare occasions that the frequency was measured a similar rod carried a hogs bristle which traced the motion of the piston on a strip of smoked paper moving at about 20 inches per second. The paper was then unwound in a way to give a permanent record, see such a trace in Fig 74 (d). Idea abandoned because the (risk of) side pressure on piston could burn it out. Satisfactory for a few seconds of testing, but too risky otherwise.

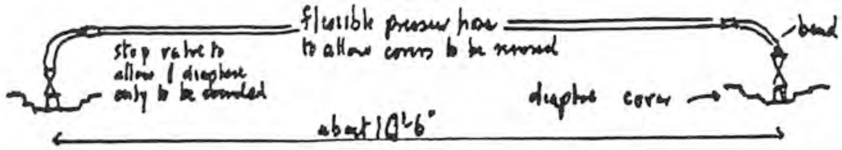


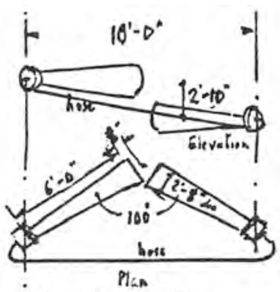
Frequency test

2) The idea: The air space between the back of piston and inside of the cover plate had a pressure between 35 psi and 0 psi exhausting 90 times a second. I recalled that I had once removed the cover plug and screwed in an old pressure gauge just

to see how it would respond to changes from 35 psi to 0 psi at the tremendous speed of 90 times / sec. I read 35/2 = 17 ½ psi without a quiver! So the problem was solved – I had just to join the two air spaces with a pipe and in a very short time, during which there could be a couple of tremendous 'beats', the pistons would be in unison and in phase. Fig 77b refers.

To test this idea required a length of piping shown herewith:





A synchronised twin 'L' size diaphone installation

Fig. 77(b)

I found the noise would be tremendous having never tested a 'L' size let alone a twin 'L'. Beats were something quite new and possibly quite awful, at two grunts likewise! All were warned, and we blasted off! My reactions were very mixed. Firstly in what I guessed was under a fifth of second the pistons were synchronized and in place, were preceded by two beats of alarming intensity and a wonderful grunt. All in 2 seconds. Secondly I was aware of a shattering of glass windows in the main lighthouse shop and quite quickly what appeared to be a lynching party of shop workers, who made it quite clear what would happen to me next time. So for about £2 the job was solved! The Chinese inspectors were quite impressed, awfully!! It was amusing many years later (early 1950s) to meet an old (Chinese) friend on the Euston, Birmingham train. Says he, "Was going to call on you at the Collage, remember the twin Chance 'L' destroyed by the Japs." "Yes." says I, "They were synchronized." "I know." says he, "But, we can't find any drawings of your device." "No." says I, "Wasn't worth one, but it's on a part list somewhere." So I told him – and I'm still waiting for the consultants fee!

Two other unusual installations:

Chorley: Chorley is a government factory comprising many individual shops covering a very large area. At a push of one of three buttons, an instantaneous sound signal was to be sounded including i) an Air Raid Warning ii) Fire Alarm iii) approaching thunderstorm. So we put a vertical "F' on a high tower with an air receiver of sufficient size for a total of 18 seconds sounding and a special three cam timing mechanism. The air receiver was automatically "topped-up" to 35 psi – always. Forty years later I met an old employee of Chorley works and he told me that the signal was still working well.

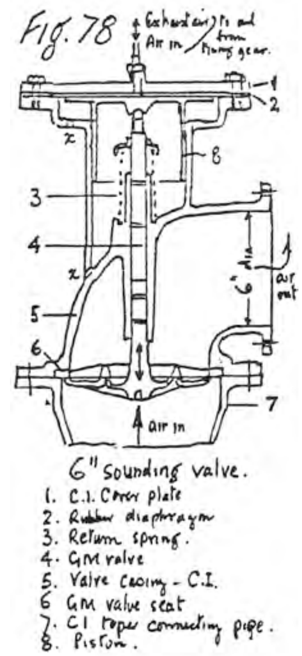
Hellyer of Hull: fishing for halibut with a diaphone!! Hellyers had then converted a large ship to carry (we believe) thirty motor boats from which line fishing for halibut, off Newfoundland, took place. It was evidently uncomfortable if the 30 or so were standing off the mother ship when a fog descended and some of them couldn't find their way back, the ships hooter being too weak. So again a vertical 'F' diaphone with a steam engine driven air compressor, it did its job.

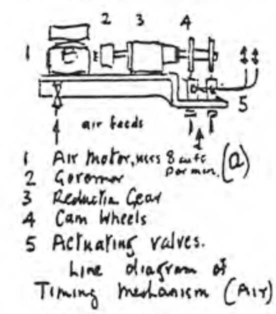
The Diaphone installation:

1) The Driving and Sounding Valves These are shown clearly in Fig. 75, page 92. There purpose is to let in very quickly, possibly 1/100th second, the tremendous quantity of air required by the diaphone all in, say, 2 seconds all sizes from 1 inch to 8 inches work on the same principle, namely the air from the timing mechanism is fed by a small bore copper tube into the space above the rubber diaphragm. This slams down the piston and so the valve proper. The valve is closed by the action of

the spring. I would draw the attention of young designers to holes (x) in Fig. 78 herewith, with the hope that there would be no second thought of omitting them!

We received an amazing order from Hellyers (see page 95) for a replacement of the 3 inch valve cover (item 1 in Fig 78). We naturally asked "how come" and rather sadly were told that the original was on the sea bottom off Newfoundland together with the 2nd Engineers cap! It seems he had just about taken off the last nut holding the cover when it blew off, and together with his cap described an arc and both then disappeared to join the halibut in the sea. Could have lost his head! How it happened remained a mystery although I did add to our instruction, "Never stop the timing mechanism with the cam(s) pressing down the sounding driving valve actuating valves"





Timing Mechanism – 3 types

1) Air driven, comprising as shown in Fig. 79 (a) an air motor (as used for pneumatic tools but stripped down and all grease removed; a forced feed oil lubricator added together with a speed governor. This is coupled to a reduction (around 700 to 1 reduction) gear with a longish output shaft to take the cam wheel, one for A, B and C sizes; two for single F, G, K and L sizes and usually four for a large twin installation. It is common sense to use an air drive for air operated signals. However cheapness prevailed so:

2) We sometimes supplied a timing gear chain driven direct from the compressor shaft and mounted on the engine-compressor bedplate. Two snags (a) it can be a long way from the diaphone whereas the air drum type can be only 6 feet and (b) what about the spare compressor set, well it means duplication!.

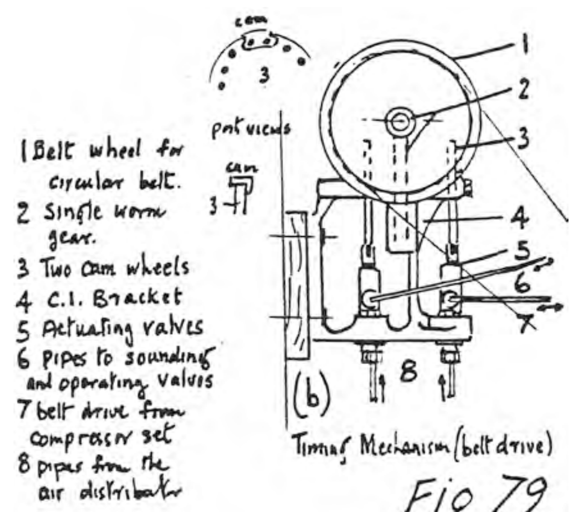
3) Or in the early days quite often a belt-driven timing gear fastened to the engine room wall and so, usually, right underneath the single diaphone. The belt was the small, round type in 'V' pulleys, the compressor set pulley being half the coupling between engine and compressor. Two belts of different length were supplied, one for the compressor set in use, the other for the spare set. One could be removed and the other belt fitted in a short space of time. (see Fig. 79 (b)).

Manufacturing:

The cams were cut from a mild steel ring each piece being left slightly long. After testing and adjustment they were hardened and carefully positioned on the cam as Fig. 79, page 96 (b).

The slip of the belt was around 5%, but the belt wheel was always left a little large on the 'V' diameter and amended later following a time check with the compressor driving the timing mechanism. The actuating valves also exhaust the air behind the rubber diaphone of the main valves.

See the C.I. Bracket (b). As a youngster I set out to design this all in one piece. Some time later Jack Dodds, the works manager, sent for me. On entering his room I found the foreman Pattern-maker present and the table littered with a pattern and several core boxes. Said Dodds, "Cooper, I've seen that timing gear you designed, it looks and works well, but looking at the pile of wood on his table, next time make such a thing in two parts and we shan't lose money!"



In order not to lose you in the many bits and pieces of a diaphone installation, we must pause here and bring you into the picture with a diagram.

No.	Part	page
1	Diaphone proper	90
2	Air receivers	97
3	Engine/Compressor set	109
4	all X's are stop valves	—
5	Resonator	94
6	Diaphone	90
7	Driving valve	96
8	Sounding valve	96
9	Timing mechanism	96
10	Air distributor	92
12	Oil Engine	110
11	Air Compressor	110
13	Fuel Tank for engine	97
14	Engine exhaust system	97
15	Cooling water tanks	97
16	Blast and pressure recorder	89

Note: the spare engine/compressor set is not shown.

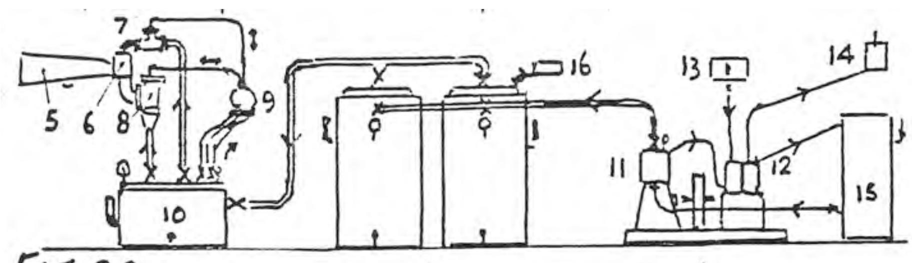


Fig. 80

Diagram of complete installation for a diaphone. Fig. 80 notes:
Air distributor (10). Essential for a twin fog signal. Very desirable if the diaphone is more than a few yards from the air receivers (2). High pressure air storage will require a very large reducing valve to get from (say) 120 psi to the usual 35 psi. It can be fitted on side of air distributor. Cooling water system: note the sequence please. Cold water from tank (15) to air compressor (11): air compressor to engine (12); (12) to top of water tank. Why? A compressor runs better if cool; the engine if hot (but, not too hot). Relative positions: Receivers (2) can be in the engine room if space is available, if not, just outside. Cooling water tanks, depends on a ambient temperature. Usually just outside engine room. Diaphone set on the roof of engine room or just outside or in a lower floor of the tower or as La Corbiere, Jersey, some 100 ft or so away, due to rock formation.

Air Receivers

The critical pressure drop of 3 psi (35 to 32 psi) requires the volume of the air receivers to be calculated with some accuracy. We will take as an example a twin K with a blast of 2 ½ seconds every minute. Fig. 81 (a) here with refers.

For this exercise we will go into the matter starting with the volume and checking the pressure drop: Total volume of receivers etc. - The main battery of 6 foot diameter by 8 foot high receivers 1058 cubic feet: The distributing receiver 40 cubic feet air piping etc 12 cubic feet. Total 1110 cubic feet. Delivery of air compressor is 260 cubic feet free air per minute. Consumption during blast is 214.5 cubic feet. In calculations we must use absolute pressure, by adding atmosphere pressure at 14.7 psi to the gauge pressure and specify 'free air' which is air used in cubic feet in terms of air at 14.7 psi, which figure allows a margin on the allowable 3 psi.

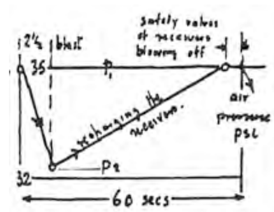


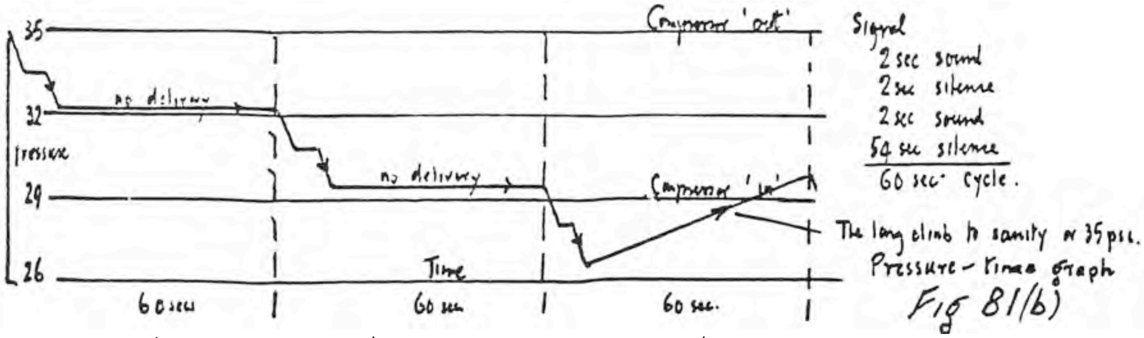
Fig 81(a)

Unloading and drying?

You will notice in Fig. 81 (a) that we are wasting air for a few seconds by blowing off. Shocking?

Let me tell yet another story!
Our old friend took it upon himself to order a compressor set working under his usual philosophy that "everything done in the past was wrong". Quite often true, but not always! He knew that every road drill compressor and just about every compressor for shop air supplies unloads and moreover the latter has a water separator to dry the air. What is unloading? When the pressure gauge on the compressor reaches (in our case 35 psi) its highest pressure, a valve is lifted on the compressor, meaning that whilst it is still revolving, compression of the air is impossible. So the engine or motor runs light and saves fuel. But this unloading required a 6 pound drop in pressure

before the compressor came in again!!! Indeed some of them require more. What might it have done to the diaphone? Fig. 81 (b) beneath refers.



The result: 1st minute – OK. 2nd minute – unsatisfactory! 3rd minute – horrible. That is one minute good, followed by 5 minutes very unsatisfactory! And the water separator? Necessary for shop operations using pneumatic tools, of course! But, the diaphone piston 'lubrication' alas none!

So our friend ordered a very expensive unloader which in theory had a 3 psi drop, actually 4 psi. I think in the end we consigned both unloader and separator to the adjacent canal!

Protection from dust

Only once in my time did a local authority ask that the mouth of the Diaphone Trumpet, when not working, be covered up to prevent local dust storms blowing up the trumpet and the dust wreaking havoc with the piston and cylinder. It was easy enough to lower a cover down inside the diaphone turret but it was not good enough to hope that the Keeper would remember it when the next fog came along. I couldn't visualize what would happen if the first blast hit the cover and I had no desire to try it! Also I had little faith in 'indicators'. The solution was to put a standard actuating valve in the pipeline to the timing gear and interlock it with the operating lever. Fig. 82 refers.

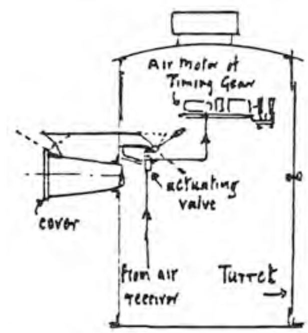


Fig. 82
(Diaphone proper not shown)

An all-round Diaphone

It always seemed to me that the mushroom top diaphone and even more so the Cork / Burma diaphone left something to be desired in directing the sound over 360º in plan. So I produced towards the very end of my twenty years an instrument with an inverted cylinder and piston, central with two large saucer resonators. Whilst the piston was still in one piece the cylinder had separate driving and sounding portions and the piston worked outside the latter. The air puffs at 180 per second proceeded rapidly between the two saucers. Fig. 83 refers.

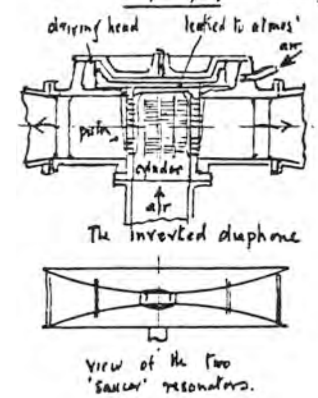
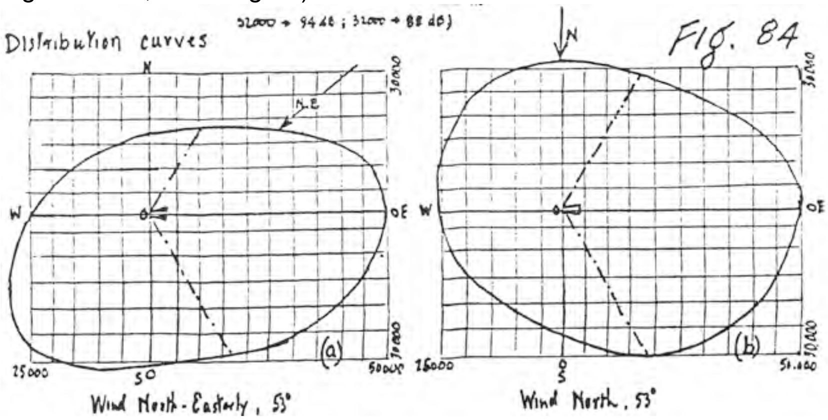


Fig. 83

The works laboratory were then very active on the theoretical aspects of sound distribution and the design went to them. I believe they thought it necessary to have enormous saucers, which may well have overlapped the sides of the lightship! I think it was patented, but little else. It would have been quite expensive and that possibly decided the matter in view of the small market for all-rounder's. A little could be saved by slitting the cylinder in three circular areas, spaced at 120º in plan, and fitting three conical trumpets.

Distribution curves of sound emitted

Of the many I have, I show in Fig. 84 two of interest and would ask you to note the loudness ratio of 2 to 1 before and behind the diaphone. (Fig. 84 from "Fog signals, Cape Henry" Bureau of Lighthouses, Washington)



(Wind speeds not known) Loudness field Patterns at 300 feet from Diaphone (F) size) Sounded at 40 psi. consumption 15.3 cubic feet free air per second. Curve (a) – My reaction is "it looks right". For (b) "it looks wrong," whatever the wind speed may be! With a medium as sound it could be said that anything might happen any time and this applies to the taking of measurements for such diagrams. Never the less the values on the trumpet axis are remarkably the same as is the E-S sector.

Trumpets or Horns or Resonators

The mushroom top resonator: It has been said, "We can dismiss the mushroom top trumpet as being too narrow in width of mouth: as a resonator the sudden change in cross sectional areas increases the acoustic impedance. The mushroom is a poor reflector". Granted, but it works! The conical horn of semi-angle of cone 10º: "as normally used has the object of re-directing the sound from unwanted into wanted areas." (See (a) and (b) Fig. 84 above). "But, the horn also acts as a resonator enabling the oscillating air column to affect the surrounding air space". Again "an A size diaphone gives a polar distribution which is approximately circular, showing little concentration effect of the horn. But, take the trumpet off and the intensity is considerably reduced". The concentrative factor ie: the number of times increase the axial direction is over a uniform source of sound. (See (a) and (b) above) Chances physicists remark "since the frequency is the same for all diaphones (it isn't! It varies size by size; piston by piston: cylinder by cylinder! All horns should be proportional to the wavelength and all should be the same. There is no justification for the erratic and arbitrary sizes at present. Not for the A, B and C, surely, harbor work!

Twin resonators - Lord Rayleigh stated "the bigger the mouth of a trumpet the more the sound is concentrated on its axis and when the mouth does not exceed λ/2 (λ is the wavelength) the intensity is uniform in all directions". I have seen but one 'Rayleigh' trumpet, on an old rotary siren. It was immense with an enormous elliptical mouth. See sketch of Bull Point on page 103.

The Chief Engineer of Trinity House with the St. Catherine's twin trumpet siren had an interesting approximation to the ellipse of Lord Rayleigh.

Separation of sound sources	·25 λ	·5 λ	·75 λ	λ
Concentration factor	2·4	3·3	3·5	2·8

(Chances used Separation of ·5λ)

To conclude: If two sources of sound are placed 5λ apart the field strength in a vertical direction is limited while the sound is concentrated in the horizontal plane If of course they are synchronized and in phase.

16 Bells, Reeds, Sirens and others

Bells – for buoys – To add briefly to what has gone before. I always looked with amazement at the bells on buoys brought into the Trinity House yard at Harwich for repair. These bells are clappered by three hammers and whilst on station had changed in shape from circular to three sided. Obviously good ductile bell bronze!

I remember but two installations - the first being for Portishead, near Bristol. Chances had quoted for a 'C' size diaphone, but the local press (and what a grapevine journalists have!) revived the '1,000 elephant' business although, of course, the 'C' couldn't grunt! Anyhow local agitation was sufficient for the Local Authority to switch to a bell! Much to my disgust since I knew nothing about bells! I guess that due to my known liking for classical music, I got the job of designing it!!

One would like to imagine the Authority Engineer gathering together a few of the protesters (including one who could put a 'letter' to a given note) outside one of Bristol's more famous churches and eventually agreeing to "the A flat one'. Anyhow it weighed twelve hundred weight and had a diameter 40 ½ inches.

At Chances we had a wee library and, on rare occasions, we consulted Sir Edmond Birkett's book 'Clocks, Watches and Bells,' published, by Crosby Lockwood in 1883. It appeared that in the dim past it had been treated with great reverence as far as the design of bells was concerned, so making it quite a shock when Mr. Johnson Director of Gillott and Johnson, bell-founders of Croydon, told me "Birkett did more good than anyone for the clock and watch industry, but more harm than anyone to the bell industry." You may care to know the Edward Birkett QC (later Lord Grimthorpe) was one of several in his profession to do good work, as a hobby, in the design of clocks. Reading his book reveals a self-opinionated man, but, at least, he will be remembered for his design of the world famous Westminster clock, a splendid job well past its century now. Sadly, his hour bell, Big Ben, when his seven cut hammer hit it, promptly cracked and remains so to this day! Too much tin in the bronze, and he lightened the hammer!

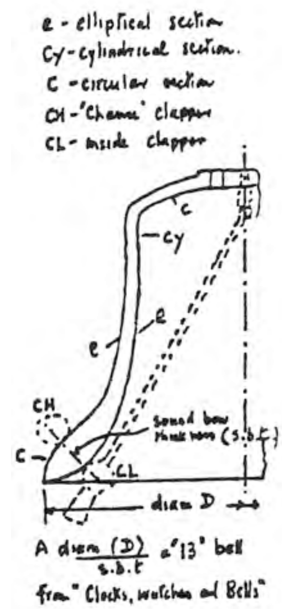


Fig. 85

However, back to his book, we gathered that if one knew the note, the book gave you the weight and so the diameter of the required bell.

The order eventually went to Gillott and Johnson's but since I have always firmly believed that engineering is "an art based on science" and being quite sure that the founding, machining and turning of bells was 90% art, I'm glad I avoided teaching Mr. Johnson how to suck eggs! But, the time came for me to inspect the bell at Croydon with no little apprehension as to 'A flat'! However, Mr. Johnson took me under his wing and I spent some two hours or so, the least of which concerned the Portishead bell, going over his works with some considerable pleasure and profit.

His bell turner was foreman of the machine shop and evidently one with a 'prefect ear.' Turning is performed by machining inside the sound bow and sometimes inside the waist. The foreman was due to retire shortly and Mr. Johnson wondered where the next 'perfect ear' was to come from! My own difficulty lay in clearly picking up the fundamental since bells are so rich in harmonics.

Clappering a bell

How a good bell should be tolled and 'raised and set' (swinging through 360º!) to get the sweetest tome from it and, of course, a peal of bells must be so treated. Possibly the Doppler effect caused by the source of the sound, the bell, moving towards, then away from you. But, for chiming and fog signals the bell is mounted vertically and fixed and (for fog signals) struck with an external hammer.

'On the rocks.'
Portishead, 1939
4' order light and fog bell.

Birkett "warns clergymen and churchwardens against allowing the lazy and pernicious practice of clappering, that is, tying the bell rope to the clapper and pulling it, instead of the bell".

The sketch herewith gives a little idea of the Portishead lighthouse and you will see that the bell is hung from a scaffold with the striking gear mounted immediately above it. The character was 'single' so one hammer was sufficient.

A triple character harbor bell

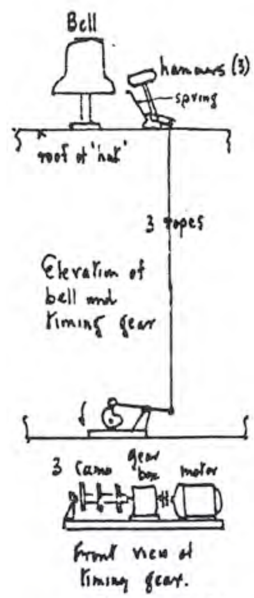


Fig. 86

This was a more interesting job although the bell was smaller. In clappering the hammer is raised by a cam mechanism and then falls under its own weight on to the sound bow. But, if a character is, for example, clapper at 0.3 and 6 seconds every minute, that is a triple character, it requires three hammers since it is poor engineering to attempt to raise a single hammer every third second and leave the timing gear idle for 54 seconds.

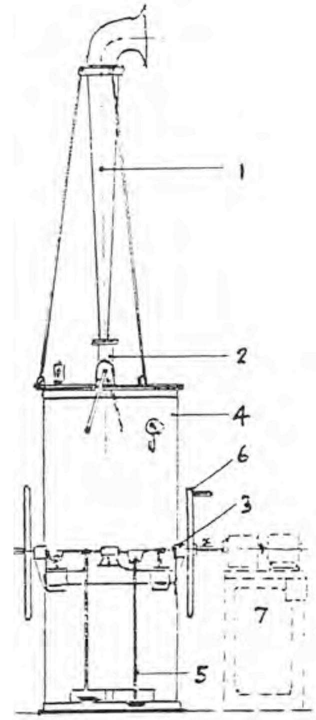
So three hammers were mounted parallel to each other and operated by three cams as shown in Fig. 86. The outer hammer heads needed careful shaping to ensure a single point of contact and this on the centre line of its cam.

The hammer head must come off the bow immediately it has struck and this is done by letting the shaft of the hammer hit a flat leaf spring an instant before it strikes. For a very small fraction of a second the spring holds the hammer off the bow and the cam then takes over to raise the hammer once again. The bell should be turned round periodically to even the wear. It looked a nice job and, however fickle a bell is, I'm sure the large fleet of fishing boats that used the harbor found it a benefit in fog.

A Reed Signal

Fig. 87, page 102 shows a hand (and foot) driven signal and was supplied for lightships, such as *Calcutta* – page 61. which had no power supply. It was operated by two of the crew manning, we imagine, either the hand-wheel or the treadles. Both would appear a bit of a strain! the receiver had to be kept at 5 psi gauge or thereabouts. The operating lever was attached to a semi-rotary valve at the bottom of the reed box. Either a watch or 'pinging' clock was presumably used to keep the blast correctly timed and in character. The steel reed is about 3 inches long by 1/8 thick and the note is 450 cps; the air consumption is around 0.3 cubic feet per second of blast and this allows for a total sounding per minute of 6 second (I can't imagine the crew getting above 20 revolutions per minute). The air receiver is 2 feet 6 inches diameter by 6 feet high. The horn follows Rayleigh in "the bigger the better" and with its flare looks quite handsome. The air pump or compressor has 2 cylinders 3 ½ inches diameter by 7 inches stroke and is obviously air cooled.

The second and last order again did not concern me except for testing for air delivered by the compressor and the air consumption of the reed working this time at 15 psi, the compressor being driven at 70 rpm by a motor-reduction gear unit. The customer, the Manchester Ship Canal Co., called for a single character of 3 seconds sound and 9 seconds silence. Among the several things I cannot recall is if a timing gear was supplied (I think not); whether standby hand operation was specified (in which case I would think no treadles; shaft (x) to be disconnected and handles fitted to the wheels, which since they functioned as, very necessary, fly wheels) must be fitted.



Reed Fog Signal
1 Horn
2 Reed box and valve
3 Air compressor.
4 Air receiver 2'-6" dia., 6' high.
5 Treadles.
6 Hand wheels

Fig. 87

7 (if supplied) Electric motor: reduction gear to 70 rpm: stand and switch gear.

Little need be said about the design except that having the cylinder block bolted to the receiver, air delivery pipes were not required. The design of the reed signal predated my time at Chances by many years. Fig. 87 herewith shows the hand operated model.

Tests: Data. Character 3 seconds sound, 9 seconds silence equivalent to 15 seconds per minute. Volume of air receiver = 30 cubic feet. Swept volume of air of the air compressor which has 2 cylinders = 5.45 cubic feet per minute.

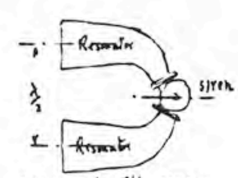
Results: Pump up test, that is receiver charged by air-compressor from 0 psi to 15 psi gauge. Time required 6 minutes.

Air consumption test with compressor not running: Initial pressure 15 psi gauge: final pressure after sounding for 10 seconds = 13.5 psi gauge.

Findings: Air consumption efficiency.
Free air at 15 psi in the receiver = 60.7
Free air at 0 psi gauge = 30
Air delivered in 6 minutes = 30.7 cubic feet
Swept air in 6 minutes = 327 cubic feet
Hence volume efficiency of compressor 94 %, which can be expected from such a slow moving compressor.
Air consumption: Free air at 15 in receiver = 60.7 (as above)
Free air at 13.5 in receiver = 57.4 cubic feet.
Air used in 10 seconds = 3.3 cubic feet, and so = 0.33 cubic feet per second sounding is the air consumption of the reed and air used in 15 seconds per minute = 4.95 which is satisfactory.

We can conclude by saying that the performance of the reed horn is so very much better than a bell.

Sirens



Sketch of T.H. siren.

Believing that sirens were 'dead' Chances were surprised when Trinity House and, I believe, Irish Lights placed orders for "bits and pieces" of sirens which the Engineer in Chief had designed. Both solve the in phase-synchronized requirement and the Irish Light siren is particularly interesting since it met the needs of Bell Rock, an isolated rock station, requiring all round distribution of sound.

Trinity House siren installed at St. Catherines, Isle of Wight. The sketch herewith shows a single siren with twin trumpets, the rotor being driven through gears by a speed controlled air motor. It made an impressive noise fully appreciated by my wife and I during a visit towards the end of a three day fog. The siren was blasting away and from the inside of the cabin (see Fig 65 (5) page 73) on top of the 'little tower', most impressive particularly for my wife. Later the fog cleared and with my old friend the Principal Keeper we were on the lantern gallery admiring the sea view.

We had not been there long before the Principal Keeper said, “The Patricia (the Trinity House tender) is out there and is signaling.” You can judge his devotion to duty when with never an added word he spelt out “Continue to sound siren for another 24 hours!” And for three days it had been blasting down the chimney of his house, which lay alongside the tower. We should explain that Trinity House used St. Catherines for experimental fog signals from 1900 or so.

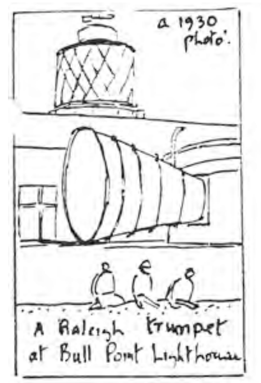
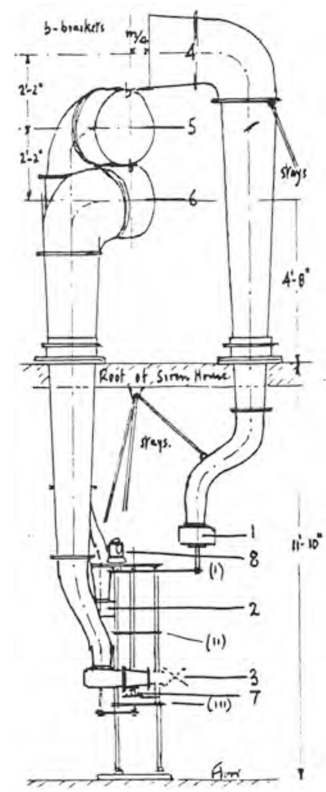


Fig 88
Bull Rock triple siren.

You will recall that in a Diaphone the piston oscillates in the cylinder, which, as the piston, is slitted circumferentially. In such sirens the rotor revolves inside the starter, both of which are slitted axially.

The gear drive of the Trinity House siren was very noisy in picking up speed before the sounding air was ‘injected’. This possibly determined Mr. Tomkins to use a chain drive, anyhow he was driving three sirens!

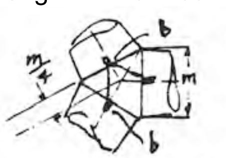
The Irish Lights all-round siren. Fig. 88 refers.



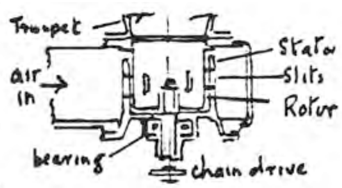
Details:
1,2,3: Sirens, 6 inch diameter with 9 ports 1 5/16 inches by 5/8 inch with a pitch of 2.09 inches on the 6 inch diameter. Speed 860rpm. Maximum air pressure 25 psi gauge and air consumption for each second on blast 27 cubic feet, per siren. Total air consumption per minute = 324 cubic feet for the three sirens, which allows a maximum sounding time on a one minute cycle of 4 seconds. Note of 128 cps.

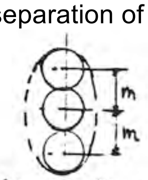
i), ii), iii): chain drives to the three rotor spindles from the central motor shaft. The rotors are ganged up – hence are synchronized and in phase.

4,5,6, the trumpets. The wave length λ of 128 cps = 8.67 feet (Mr. Tomkins states that the ‘pipe-length’ is 4.33 feet for open tube length). The trumpets are 2λ in length with a mouth diameter of λ/4, which is also the separation of the mouths.



Part Plan of Trumpets.





Ld Rayleigh Ellipse

7. Governor controlling speed by friction (see identical type of governor used for clock Fig. 20, page 31)

8. Air motor, 4 cylinders 1 inch diameter by 1 ¼ stroke driving a central shaft from which speed is geared down 1 to 1.52 to drive the siren rotors.

I regard this design as a most interesting, and successful, attempt to get ‘all round’ distribution of sound and shared Mr. Tomkins pleasure when he remarked “the siren gave a smooth note of considerable power and the range obtained is always satisfactory. Taking into account interest on capital expenditure, the cost of running the siren is about equal to that of an explosive signal firing a 4 oz. shot once every 5 minutes.”

Design–wise I like the monolithic group of trumpets, and the little material used to get this in order to combat the wind forces on the trumpets. The (top) portion of the trumpet is dipped 2º below the horizontal to drain off rain water. Correction:- although the trumpets are physically 2λ long, in theory the height for design should be from the apex of their cone (if you like, continued backwards into the siren.

Other types of fog signals:

On my part very much a nodding acquaintance, there work being in the hand of "short engagement researchers reporting direct to Dr Hampton the Director of Chances research laboratory.

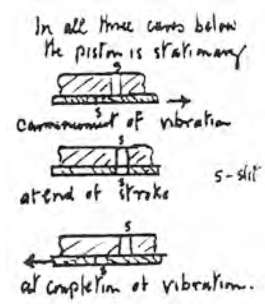
1) A sort of rotation whiz-bang!

The local Technical College had given to them in the depressed 1930's a single cylinder compressor, ignition engine, but alas with no exhaust silencer, and certainly at that time there was no money for a silencer. It was little used since the noise was far too much for adjacent classes. Every puff of exhaust was like a monstrous whip cracking and to one interested in fog signals it seemed that, say, six of these engines could really make a horrible noise!

So did many others and years later a delightful old engineer armed with the idea of a rotating petrol fed 'engine'. Briefly there were pockets into which petrol vapor was drawn and as rotation proceeded it was compressed and ignited with the exhaust "exploding" radically outwards. It did have a noise, but starting and even running were uncertain.

2) Whistles for deep draught buoys:

In my time Chances made, but one of these and that, either to an old Chance design or the Authority's. The buoy shown in Fig. 45 (d) page 52 has the tail tube open at the bottom and except for an air pipe going to the valve chamber of the whistle is closed at the top. With the valves (large solid rubber balls) open, the height of sea water in the tube will be the same as the (level) sea outside, But, in a choppy sea when the buoy 'bobs' down the air will be in compression. This will emerge from the annulus slit at the top of the valve chamber and impinges on the bottom sharpened edge of a thick cylinder. This is set in vibration resulting in a doleful moan even more dreadful than a clappered buoy bell. In such a sea its performance is better than a bell.



3) A two tone diaphone purchased from Mr. Northey:

This was a novelty sounding, say, for half the blast the usual note of 180-200 cps, followed by a note of 90-100 cps. This was produced by a special driving head and an auxiliary valve, which in effect, halved the stroke. The sketch herewith shows, but one slit in the piston (sounding portion) and one in the cylinder. You well see the piston does not uncover its corresponding slit twice in one vibration. So if the high note is 196 cps the low note will be 98 cps.

Fundamentally the design is all wrong, as wrong as the very ancient white-red beam optics (See Fig. 16 on page 24). At extreme range of such a light you cannot say to a mariner "you will always see a white-red beam, more likely it will be white only and he could therefore be misled as to his position. Remembering the grunt only from lightships (see page 89, (iii) Harwich) and the varieties of ranges for differing frequencies I do not see how anyone could say "you will always hear high followed by low".

I give a comparison of measurements made by the research staff:
(1) a '2 Tone' made by Northeys of Canada - high tone 79.5 phons: low 78.5 phons
(3) an identical '2 Tone' made by Chances – high tone 78 phons: low 80 phons.

Chances with difficulty: got the Chief Engineer of Trinity House, interested enough in the ‘2 Tone’ to agree that such a diaphone be erected on *Sunk Lightship*, then standing off Harwich. When completed I was sent to meet the ‘Chief’ on the ‘Sunk’. Well he was late, very late, so the Assistant Chief (mechanical) had the unloader brought in on the air compressors, frankly the only use I ever saw for the device, but even this brought disaster! When at last the Trinity House tender was sighted the diaphone was sounded, but, horror of horrors, the first low note was bad, the second uncertain and the third packed up half way through the ‘low’ blast. Obviously low pressure, and on dashing down to the engine room observed the unloader coming in, but the pressure was well below that required (see top of page 98 for a similar case). I got the dam thing off and shortly the ‘2 Tone’ was satisfactory. But, damage was done, and as the Chief remarked “he hadn’t come from London to hear a 1 ½ tone diaphone”.

When the opportunity arose I asked the Assistant Chief what the hell had happened. It seemed that it was always done, always, to have all equipment working when the chief visited a station. Sadly this included a submarine bell which was clappering away twenty feet below the waves! And it was air operated!! So that was that as far as Trinity House were concerned. In retrospect I think there is another good reason for not using a two tone fog signal. Simply it is not required!

Lighthouses with fog signals are not very ‘thick’ on the coasts of the world and sufficient difference between “adjacent” fog signals can be obtained by using single, double or at the most a triple character. However, the short silent periods between the double or triple blasts should be as short as possible consistent with the character being clearly maintained. By this means erratic atmospheric changes should not take place in the few seconds of sounding the two or three blasts. (See second paragraph page 87)

4) Electrically operated oscillators – air transmission.

Chances around 1939, with a new specialist engineer, designed, made and tested two diaphragm oscillators: a) A 100 cps 20 inch double diaphragm type using 1600 watts with resonators similar to the Trinity House siren (see page 102). The mouth diameter was 16 inches. In loudness tests 94 phons were recorded on axis and 90 phons at 90º to the axis. This was equivalent to an intensity on the axis of about three times greater that at right angles to it. A possible reduction of range would be in the proportion 3 to 2 ¼. This dispersion was deemed suitable for a single instrument of 100º to 120º distribution in plan.

However, an ominous note was struck by a short uncertain period after switching on. On one occasion when the oscillator was set at 100 cps in the (warm) shop, the frequency fell to 99 on being tested outside on a cold day. However, on a second occasion with bright sunlight the frequency changed to 106 cps. this was coupled with a stabilizing period for the heat generated by the magnet stampings and the coil both of which were attached to the center of the diaphragm, which was 20 inches diameter by 1/8 inches thick.

It transpired that this diaphragm fell between ‘thin’ and ‘thick’ diaphragms. The natural period of vibration of the former was governed primarily by the applied (mounting) tension whilst for the latter the mass and elasticity of the diaphragm material was more important. This oscillator was therefor deemed impracticable. (b) Also designed and made was a 300 cycle 20 inch double diaphragm oscillator, which was not subject to the above troubles. But, “it was more costly to supply than a diaphone at similar output and also that no considerable saving in running costs would be made. The 300 cps and the very short period per minute for the load posed several electrical and cost problems. So this also was abandoned.

Other fog signals

I think the reader should have the opportunity of learning a little about submarine bells; submarine oscillators; air operated oscillators for air transmission; radio beacons and explosive signals.

However, they were not made by Chances and so I will deal only with the exception of the explosive signal.

Explosive fog signals:

I break my rule solely to relate a most amazing accident, and its sequel, which occurred on an Irish Light Rock Station. This is a very good signal for all-round sound distribution such as required on rock stations. Additionally the equipment mounted alongside the lantern, occupies little room and is not costly to install. Until I saw the BBC film featuring Bishop Rock Light I thought the cartridges were inserted in the firing arm from inside the lantern. It appeared in this case that the keeper sat by the lantern door, which was open!

Ranges up to 20 miles have been recorded. The (sound) report is caused by the explosion of a charge of 4 ounces of gun cotton detonated by a copper cased detonator filled with about 15 grains of fulminate of mercury. This is inserted in clips, which in turn are connected by cables to the firing 'station'. Current is supplied by three dry cells which, on average, last for a year. Firing is effected by closing a hand switch at the appropriate time given by a 'pinging' bell nearby. This occurs once every 2 ½ to 5 minutes.

The type used has the keeper snug and dry but the arm has to be 'wound-up' and after firing lowered. There is an electrical interlock on the firing arm to prevent premature firing. To conclude with the disadvantages: high cost of cartridges etc; high cost of maintenance; the continual hand working by the keeper and the difficulty of differentiating between one station and another.

Now the story

Scene: An Irish Light rock station. During the summer of 1912, Assistant Keeper Denny Duff and the two other men stationed at Rathlin Island East were notified that the steamer *Princess Maud* was to pass their station and steam around Rathlin Island, carrying a group of tourists from Belfast. They quickly decided to fire a salute to the steamer using their 18-pounder fog gun.

Assistant Keeper Duff loaded the fog gun and a salute was fired for the *Princess Maud.* The keepers decided that a three-blast salute would be the most appropriate and Denny hurried to reload the gun. Unfortunately, he was in such a hurry that he failed to swab the barrel first, and as the second charge of gunpowder was pushed into the gun barrel, it contacted burning refuse from the first shot and ignited prematurely. The resulting explosion blew the ramrod and charge into Denny Duff, gravely injuring his arm. Duff's arm was shattered and he was bleeding badly when the two other keepers reached him. One keeper frantically tried to stop the bleeding while, by some great stroke of luck, the other keeper noticed a White Star Liner on the horizon approaching from the north on its way to Liverpool, England.

The keeper immediately raised a distress signal and the liner changed direction toward the lighthouse. The liner lowered a boat that proceeded toward shore as the two keepers carried Denny. The liner's boat crew ferried Duff out to the waiting liner where medical assistance was rendered by the ship's doctor.

Scene: A few years later. Chances, phone call from the Chief of Irish Lights, could we possibly find a job for an ex-keeper they no longer employ. He lost an arm a few years back and is a widower with three boys, the eldest now seeking a job. By chance the Department was getting it's own entrance from an adjoining main road and wanted a gate keeper. Maybe we could take the eldest boy Phil, as an apprentice. He served under me for some time.

Scene: Thirty years later. R.A.C. Melbourne. Phone call: An Irish voice "I heard you being interviewed last night by local radio, what's my name." "Phil," says I: "Surname," says he, "Sorry can't." says I, "Phil Duff," says he." The eldest boy of the old P.K. What was he? "Chief Mechanical Engineer – Woomera Range!

We celebrated over some few glasses of Aussie beer!

17 Energy Supplies

We will name the type of energy supplied to, and in, lighthouses and it's use for the differing types of lights and fog signals.

A1. The Big Light – with a P.V. burner, stand by wick burner and a clock driven pedestal. Just a paraffin oil (specific gravity 0.817 and close flash point 68.5º c) for the P.V.B and wick lamp, and methylated spirit for starting up the P.V.B. Manpower for winding the clock and, perhaps, a dry battery for the clock alarm. (*see also Calcutta Lightship)*

A2. As A1, but a rock station with an explosive fog signal. Add explosive cartridges as specified on page 106. The oil would probably also be used for lighting the tower and for heating and cooking.

B1. Smaller lights including beacons – and unattended. Just enough bottles of dissolved acetylene or oil gas – and daylight to operate the light valve. See page 43 Fig 33.

B2. For an unattended revolving light the reduction of pressure of the gas can first revolve the optic and secondly burn in a mantle as the illuminant for the optic.

B3. For a harbor light on the harbor quay coal gas from the towns mains can be used as a mantle illuminant.

C1. Conversion of a Big Light to an electric lamp with a multi fish-tail acetylene burner as a standby: to a motor rewind for the clock driving the pedestal.

Typical is St. Catherines, Isle of Wight. The electricity is drawn from the mains and transformed to the lower voltage required. A bottle of acetylene completes the needs of the main, but standby, illuminant.

I recall the B.B.C. in a "warning to shipping" that St. Catherines was showing reduced power. You bet it was – from a 4 KW lamp to six fish tails of acetylene! A bad storm at the Isle of Wight had brought a tree down on the overhead mains cables.

C2, as C1, but using its own generating set and with a diaphone fog signal. Since Cape Columbine, South Africa, is situated on a lonely spot with little supply of water, it is thought this could well be used as an example of many lighthouses in the world that are indeed in very lonely places on very barren coasts.

Power Plant:

a) Main generators, 3 Ruston horizontal airless injection oil engines each developing 47 h.p. and coupled on a common bed plate to a Crompton Parkinson shunt-wound D.C. generator given 27 KW at 220 V at speed of 290 rpm

b) Starting air compressors, 2, driven through gearing from 220 V. DC motors. This plant was not, thank goodness, the type where the engine in it's dying moments, compresses air into large starting bottles. If in next starting, you are unsuccessful and drain the bottles, then you've had it! A bad example lacking a 'systems approval' in its design. But, even for Cape Colmbine a standby hand pump was supplied!.

c) Water coolers – 2 Heenan Froude coolers complete with 220 V. motors.

Switchboard, supplied by Chances. The circuits below are fed from either set of double bus-bars on double pole, double throw switches:

i) 3 circuits for main generators numbers 1 to 3.

ii) 2 circuits each for water cooling motors; starting air compressors and 6 circuits for general lighting.

iii) 2 circuits for main light motor generator sets.

iv) 2 circuits for diaphone motor circuits.

v) 1 circuit for battery changing motor generator set to be fed to either set of duplicate bus bars.

d) Motor generator sets:

i) 2 – 4 KW Motor Generator sets – a 220 V D.C. shunt motor coupled on a common bed-plate to a 4 KW 110 V D.C. compound wound generator. (The lamp is a 4 KW 110 Philips pre-fused with a high amperage and a stout filament. The life of the lamp is aided by voltage regulator down to 40-50 V under load at start)

ii) 2-3 KW Motor Generator sets – a 220 V D.C. motor shunt-wound coupled on a common bed-plate to a 50/72 D.C. generator.

e) Diaphone air compressing sets – 2 sets of a Broom Wade air compressors delivering 260 cubic feet of free air at 35 psi gauge (3 cylinder 6 ½ inch diameter by 5 ¼ inch stroke) directly coupled on a common bed-plate to a Crampton Parkinson 220 V, 1000 rpm motor.

f) 2 – Water distillation plants, coil-less, to deliver 2 pints per hour – supply 220 V D.C.

Notes:

i) The Radio beacon, in the daytime, with no generators running is operated from the main battery (supplying ½ KW, day and night, at 24V).

ii) The standby arrangements allow for no generators working in the day time; for one set on clear nights and 2 sets on foggy nights. The use of 2 out of 3 sets is generally good economics.

iii) The twin 'K' diaphones sound for 2 ½ seconds each minute so with the timing gear using 8 cubic feet per minute, coupled with an overall 10% extra air the total air required is 256 cubic feet.

g) Energy required is

i) fuel oil for the main generator engines.

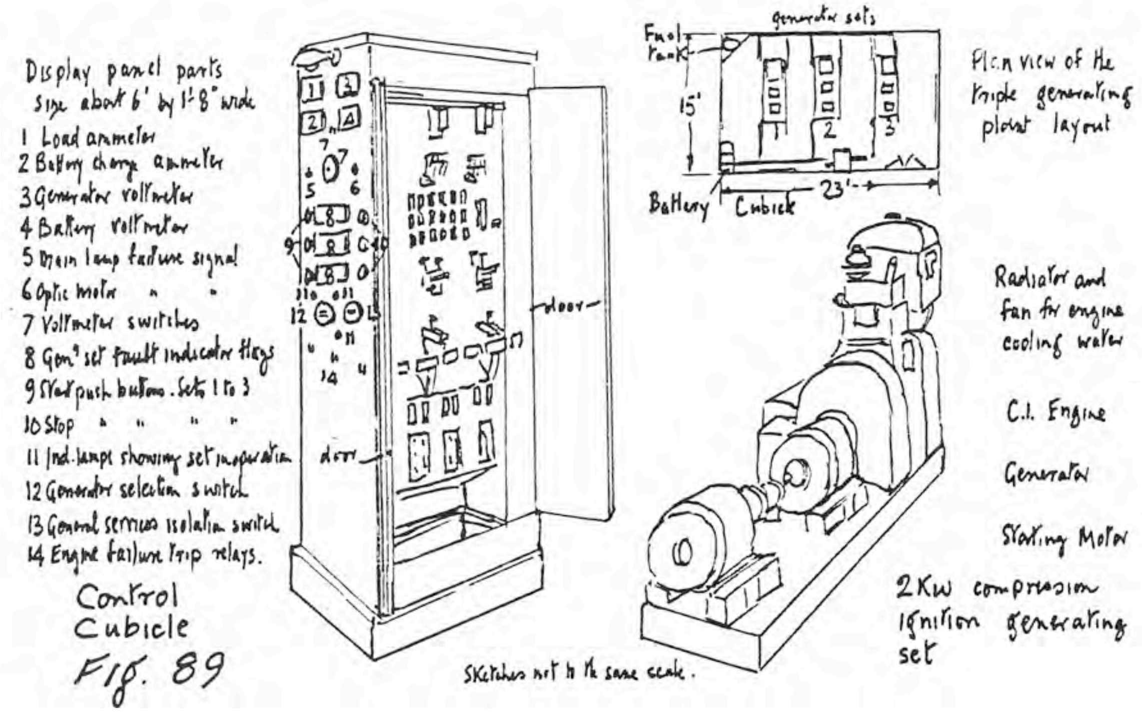
ii) manual for hand winding the clock driving the 3rd order revolving optic.

iii) a dry battery for the clock alarm.

D1 – A new Lighthouse with electric lamp and motor drive for the optic where a (normally) 300 amp mains supply is available: The design includes: a tilting lamp changer with one standby lamp, a duplicate motor drive for the 5th order optic and a standby 4th order fixed lens with a low voltage electric lamp.

If the mains should fail the revolving light will become completely inoperative, but the standby lamp will be replaced by an electric flashing mechanism. The battery for the standby lamp has sufficient capacity for three nights. Fig. 30, page 39 shows the light. Energy required is but from the main supply.

D2 – As D1, but mains supply not available. The scheme includes i) a implicate electrical generator plant with a starter battery, designed specifically for un-skilled labor with periodical servicing by staff from the Authorities main depot. In effect if one set is "down" for a major overhaul, a running set and a standby set are available. The engines are cold starting compression ignition type. ii) A central cubicle incorporating automatic features including failure signals for the main lamp and optic motor and indicator flags for the generating sets. Fig. 89 refers.



Control Cubicle
Fig. 89

Operating procedure:

The plant is specifically designed for un-skilled labor, but with periodical servicing by staff form the Authorities depot. The drill is: in the evening the light valve rings an alarm bell which stops only when the keeper starts 1 of the 3 generating sets (9). A rotary switch (12) connects up the load to the set, the position of the switch being determined by indicator lamps (11). Should a lamp (11) not show the keeper tries another engine. When the battery is fully charged the rate of charging is reduced to a trickle. Engine failure or circuit overload or failure of lubricating oil pressure or overheating of cooling water will close down the set and ring the keeper's alarm bell. On starting another engine the alarm ceases.

In a similar manner if the main lamp 'blows' a second one is brought into focus and lit. The next morning the keeper will see the appropriate indicator flag (8) showing. The principal applies to a failure of one of the two driving motors for the optic. The energy required is thus only engine fuel oil.

Testing fog signal engines and compressors:

Usually there is one engine–compressor set in use and one standby set. I recall being on a lightship (which was rolling not a little) whilst a hot bulb engine was being started. To start a ceramic bulb has to be brought up to red heat with a blow lamp and then, with a prayer, the starting air bottle is opened. A bit like Dante's Inferno! As a land-lubber I objected to seeing engine sets, and the switchboard, leaning over me as the boat rolled. A second story involves me whilst as an apprentice studying some engineering science Chances had delivered to them a rather early Edwardian looking compressor set. Surprisingly the top of the compressor cylinder was crowned with a water pot, which had to be filled up periodically! The older members of the Drawing

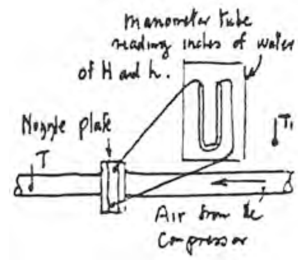
Office thought that Squirting water into a shiny cylinder very irresponsible. Says me, “Iso-thermal compression of air uses the least energy and taking up the latent heat of converting the drops of water into steam would go some way in getting iso-thermal compression.” Not a word was spoken by the others, but the message “Big head!” came over loud and clear! We never saw this method used again.

Testing air compressors using 1) a pump-up test. ii) an orifice test.

Compressor (f) pump up test. Data: volume of air receivers and piping as used on test = 1230 cubic feet. Initial pressure in receivers 0 psi gauge or 14.7 psi absolute. Final pressure = 35 psi gauge or 49.7 psi absolute. Compressor speed 935 rpm.

Results: Time for pumping up from 14.7 to 49.7 psi absolute = 11 minutes 35 seconds. Free air initially at 14.7 psi = 1230 cubic feet: free air at 49.7 = 4157 cubic feet. Hence air delivered per minute = 253.

The customer specified 260 cubic feet/ minute with compressor running at 1000 rpm. OK This test is not liked as the compressor is pumping against a load of ‘nothing’ to ‘full.’



Compressor (B) – oil-free test. *See sketch herewith*
This test has to find the volume-metric efficiency which equals free air delivered per minute per swept volume per minute.

Results:

Hence free air delivered = 58.4 cubic feet per minute at 79.5 % volume-metric efficiency, which is a satisfactory figure.

Testing the Engines:

The information required is Brake Horse Power (BHP); temperatures of cooling water, pressure of lubricating oil, governed speed and fuel consumption.

Inspection:

The engine-compressor set was usually tested in the presence of the customer’s agent and a representative from Chance Brothers and shipped from the makers works.

Rarely the customer would ask for a ‘full plant’ run at Chances that is with compressor sets, the air receivers for the job and the diaphone sounding its correct character. I do not recall a customer asking for a sound frequency analysis.

Export orders:

It is interesting to observe, over my period at Chances, the great difference in the plants ordered for diaphone fog signals, using Australia, then developing its engineering manufacture.

example : ✓ ordered from Chances ✗ made in Australia

Table 12

	Diaphone.	Air Receivers.	Cooling water tanks.	eng-comp sets.
In 1924 the	✓	✓	✓	✓
1930 Australians	✓	✓	✗	(Engine only ✓)
1938 world order (✓)	✓	✓	✗	✗
In 1944	✓	✗	✗	✗

Drawings and Instructions

Drawings – The Crown Agents were often the agents for orders from Commonwealth Countries. One foible was the demand for certain Chance drawings to be reproduced in black on white, linen backed, photographic paper. The drawings fell into two classes a) general arrangements say for a lantern (see Fig 59, page 69) or b) to facilitate the ordering of replacements of worn parts (after about 50 years of course!), say, for a clock (see Fig. 20, page 31 and Fig. 22, page 33).

Worse still these prints had to be flat washed in differing colors to represent various materials.

For example:
Cast iron – a gray
Mild steel – a red
Brass, Bronze – a yellow
Glass – a green
Wood – a brown

This job of 'flat-washing' fell to the least important junior members in the Drawing Office. It was regarded as a chore of chores. The paints were made into a very weak color, were liberally applied and then immediately blotted with a large sheet of clean blotting paper. The results were usually quite pleasing, and quite expensive. Let me add hurriedly not due to the junior's wages. I started at 12 £ 6 pence per week with a 2 £ 6 pence rise after the first year! In 1924.

Operating Instructions – did not appear to receive as much care and it was considered an awful bore if in some countries English was not spoken. For the one order from China near panic ensued when an enquiry was received written in Chinese!

Some lighthouse keepers even demanded that pressure gauges be calibrated in kilos per square centimeter instead of lb. per square inch! I suppose now that the use of, Newtons per square metre, has driven the designers of gauges to use their wits and use one black line for atmosphere pressure and one green line for working pressure! Certainly we had to employ a translator for the working on cubicle labels (see Fig. 89, labels 1 to 14, page 109.)

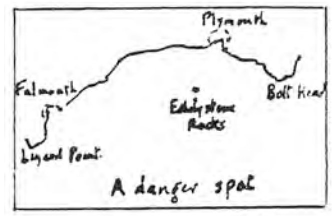
Some amusing results when the machine tool industry started using 'pictorial' instructions, for example, a hare for a 'fast' control; a tortoise for 'slow'. In many countries the poor machinists were completely foxed, having never heard of these animals, certainly never saw them! But hold it, they knew not the fox! Anyhow they would be in a state vividly described by each and every engineer. Alas not reproducible here!

Conclusion – Except for a bibliography this concludes a brief review of the lighthouses I helped to design and build in the period 1924 – 1944.

But, I cannot omit the saga of the four Eddystone lights and I will not omit the unsung saga of the Smalls Light, and I may even give you a very mini-saga of Mumbles Head diaphone.

18 The Saga of the Eddystone Light

The Eddystone Rocks are roughly 14 miles SSW off Plymouth and obviously a great danger to shipping in the much used 'lane' between England and France.



The reader may well say that T.V. (Blue Peter etc), radio, the press, and several books, have told him, or her, so much, that what else can be said? Little, but do famous, and brave-men ever get their praises sung sufficiently?

We must not be surprised at the main occupation of the early builders of lighthouses. If we call a wave operated bell a lighthouse then an abbot put the bell on Bell Rock; Winstanley was a Wonder Man; Rudyerd a silk merchant and Whitehouse who built the first Smalls Light was a maker of Violins. To a greater or lesser degree gifted amateurs, now derided, but still, I think valuable contributors to our well being.

For the Eddystone we had to await Smeaton, one of the select band of architect-engineers which included the Stevensons, the Brunels and Telford, to come into his own.

The Builders of the four Eddystone Lights:

1. Henry Winstanley, born 1644. A Wonder Man to the well-to-do, arranging fireworks, water-shows, magical displays and a fanciful architect. As good business men did in those days, he had enough ships to have two wrecked on the Eddystone! The building of the light was due to agitation in Plymouth (which had just acquired a naval dockyard) to stop the constant procession of ships piling up on the rocks with the loss of valuable cargo and hundreds of lives.

Winstanley was a brave, determined man who expressed the wish to be on the light in the worst storm ever. He was and lost his life, but his last Wonder, which deeply satisfied him, broke through the barrier of building a tower on a wave swept and barren rock. We know that once a barrier is down, others will follow. So effectively, on the Eddystone, that subsequent lights stood for 45, 125 and the present one, to date, 97 years.

To add to his difficulties, in the building period, 1695 to 1698, he was taken prisoner of war (off the rock whilst he was superintending!) by a French privateer and hopefully presented by his captor to Louis XVI. He promptly got an angry rebuke from the Sun King "I am at war with England, not Humanity!" Winstanley was returned to his rock a richer man than when he left it!

2. John Rudyerd, building from 1706 to 1708. But, two weeks elapsed, after the destruction of Winstanley's light, before another wreck. After five years of no losses the merchants and the people of Plymouth demanded an immediate re-build. So John Rudyerd, a silk merchant, but with some knowledge of shipbuilding, was commissioned the lessee of the rocks. Wisely his two leading workmen were shipwrights. Rudyerd came from the poorest of Cornish families and strangely disappeared forever once the light was built.

He came very near, with his conical tower, to the shape finalized by Smeaton and structurally it has still sound when destroyed by fire after a splendid life of 45 years.

3. James Smeaton, F.R.S. Rudyerd's light was also a great financial success, meaning no delay in rebuilding, and Smeaton (born 1724) a young, but already famous Civil Engineer was appointed to rebuild the light. He used a curved tower, in shape likened by many to a branch of a tree. Certainly the waves could slide by and the top gallery of the tower was sufficient to curl over a high rising wave. Three years were sufficient, 1756 to 1759, for Smeaton to build his solid masonry tower of which the really solid portion remains alongside the present tower and the 'roomed' portion was taken down and, as a memorial, re-erected on Plymouth Hoe, a fitting tribute to a great engineer. Half a century later Robert Stevenson, one of a succession of Stevensons who built many great lights, for the Commissioners of Northern Lighthouses, paid a long wished for visit (he having built a lighthouse on the Bell Rock) to Smeaton's Eddystone in 1812, only to notice, with some dismay, the undercutting of the giant slab of rock on which it was built. Seventy years later Trinity House dismantled it!

4. Sir James Douglass

By this time the light belonged to Trinity House who took this opportunity, demanded by new and more powerful illuminants, to increase the height of the tower. The Douglass's nearly rivaled the Stevenson's for service to Lighthouse Boards, starting with Nicholas, born ca 1798, who entered Trinity House in 1839 and rose to be Superintendent Engineer. He worked on the first and second Bishop Rock, and fathered James Nicholas, born 1826 and William, born 1833.

William Tregarthen featured in a remarkable accident on the Eddystone, when on the failure of a chain, he fell 61 feet from the top of the tower, but was miraculously saved from sudden death on the rock by a large wave, which swept up and caught him, enabling him to be pulled from the sea.

William completed the Wolf Rock during his 26 years with Trinity House and followed this by becoming Chief Engineer of the Commissioners of Irish Lights, for 20 years. William Tregarthen, son of Sir James worked with his father in 1878 on the Eddystone and was later Resident Engineer at Bishop and Round Island.

We are however chiefly concerned with James Nicholas, later Sir James, Chief Engineer of Trinity House from 1867 to 1892. He was Resident Engineer on the Smalls (*see Chapter 19)* and later Wolf Rock. As Chief Engineer he designed twenty new towers including the 4th Eddystone and the reconstructed Bishop Rock. Although he could but follow Smeaton's design I feel even Smeaton would have been proud of Douglass' new tower and light, built from 1878 to 1881.

4 or 5 Towers Total?

We might consider writers who on the basis of Winstanley courageously pulling down the first tower, too small in height for the seas running on the rocks, that the total Eddystone lights number five. I prefer to consider only the final light produced by the four builders!

The Four Eddystone Lights

1. Winstanley's: spells its own doom, no quick drying cement and the dreadful open gallery and the even worse load on the gallery uprights. Even so few authors (Fred Majdalany is a worthy exception) underline the awful severity of the November 1703 storm that brought the tower down. It was the tail-end of a Florida hurricane and on the night of 26-27 November, south of a line Bristol to London the devastation of the country was complete. Henry after a long delay got on the rock on the 25th ! Between the hours of 2 and 5 am the screaming wind veered SW to W, then to NW and back to W. By 8 am it was all over and all that remained of the light was a few holding down bolts. Winstanley had had his wish, and the Man of Wonders was dead.

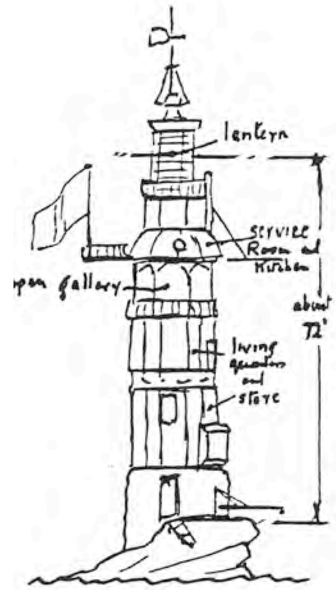


Fig. 90

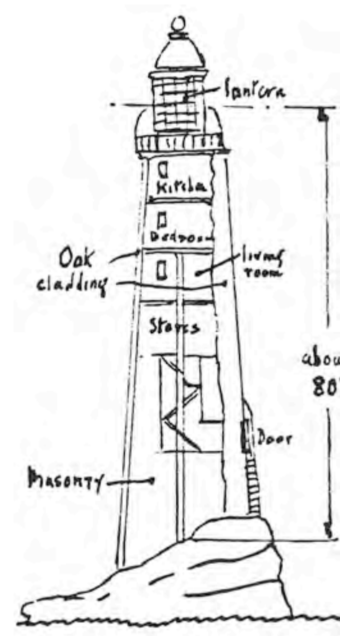
2. Rudyerd's:

He arrived at Eddystone an unknown, but like so many of his class he had a great interest in science, and of greater use in his task of rebuilding Eddystone Light, a knowledge of shipbuilding. His concept was sound, a tower, light at the top; heavy at the bottom, conical in shape and clad all over with oak. The timbers projected upwards from the stone base, so providing the upper half of the tower which housed four rooms, from the bottom, a stores room, a living room, a bedroom and at the top a kitchen. His shipwrights who had no difficulty in keeping a ship dry saw to it that sea-water did not penetrate the tower. Fig. 91 refers.

The lantern was cylindrical and plain and contributed to the ability of heavy seas just slipping past the tower. Essentially the outer surface of the tower had no chinks. The force of a green sea is measured in tons per sq. foot, but the pressure of air trapped inside the chinks is of explosive pressure. It is the later that reduces so many stone breakwaters and protective walls to a shambles of heaped stones! The tower put up a wonderful performance of lasting 45 years, then to be sadly burned down.

The roof of the lantern was heavily coated with candle wax and soot. The chimney from the kitchen passed through this mess and possibly a split in this pipe started a fire which rapidly spread downwards through the wooden walled rooms. The keepers were driven on to the rocks and indeed into the water from which they were mercifully rescued by a fishing boat.

On reaching Plymouth one keeper rushed dementedly through the crowd and was not seen again. Another Henry Hall aged 94 (yes he was the oldest) was badly burned and kept saying he had swallowed some lead which had cascaded down from the roof of the lantern. He died 12 days later and an autopsy revealed a 7 oz lump of lead in his stomach. The excited doctor sent it to the Royal Society and was as good as called a liar. He then tried to prove his point by feeding chickens with molten lead, only to get a wigging from the Royal Society for cruelty to animals! If you're in Edinburgh go and see the lump of lead, in the Royal Scottish Museum.



(Tower shown partly sectioned)
Fig. 91

3. Smeaton's:

He had a long wait until he could get on the rock, but he meanwhile studied the drawings of Rudyerd's tower. His model of a tree branch and of seeing curbstones dovetailed together have been well recorded. To get a large and heavy base for his tower he used, for the curved shape, a concave elliptic frustrum (you can see what this is from the waist (e) of the bell shown in Fig. 83 and its application in Fig. 92 herewith) with a 'skin' of moorstone (a Devon, Cornwell granite) with an inner core of Portland Stone. The bottom 30 ft of the 68 foot tower was solid masonry.

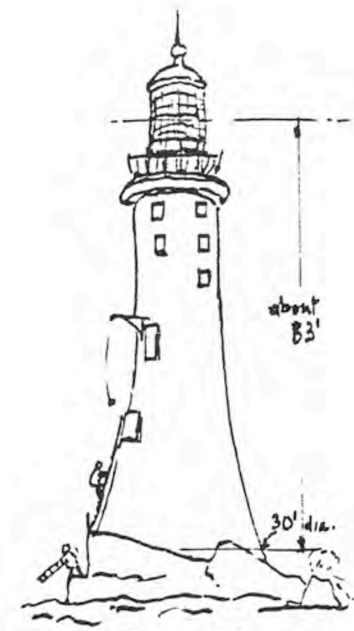


Fig. 92

The work took four working seasons and his masons shaped and laid about 1500 pieces of stone weighing a total of 1000 tons, all locked and wedged together. As nearly a monolithic structure as possible. This great engineer had designed and made a lighthouse rock tower that those who followed him could only build bigger, but not better.

Smeaton could not get on the rock for the 'opening,' but watched from Plymouth Hoe and saw the light from the 24 tallow candles quite clearly, on 16 October 1759. Could he have forseen that 125 years later his tower undermined by sea action would be re-erected a few yards from where he stood? A fitting memorial for a great engineer!

4. Douglass':

Trinity House announced a re-building program in 1877, under their Chief Engineer, James N. Douglass, involving demolishing Smeaton's light. A public outcry saved Smeaton's tower or at least the portion now on Plymouth Hoe. In 1887 Douglass had chosen a new rock about 50 yards from Smeaton's tower, but this was so low that a coffer dam had to be built before work on the foundation could commence. When it was possible to get on the rock the coffer dam had to be drained first! Work started in July 1878 and based on Smeatons design the magnificent and taller tower of 133 ft to the focal plane was completed in 1882 (lit on 18 May).

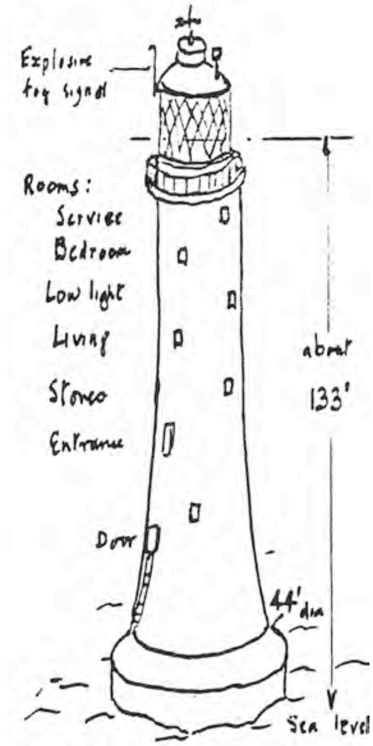


Fig. 93

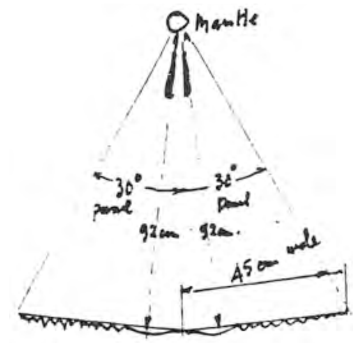
From the set-off of the foundation the tower was solid for 25 feet except for two water tanks, holding 4700 gallons of water sunk in the entrance room floor. The walls of 8 ½ feet thickness decreased to 2 ¼ feet at the lantern floor. The entrance doors had an inner door of teak and outer door of bronze weighing a ton. I hope this was not the light where the designer put the hinge pins of the bronze door on a slope (to follow the slope of the tower). Alas not even three keepers could open it until Chances supplied a screw jack type opener!

It is recorded that Douglass used 2171 blocks of granite, the smallest weighing 2 toms! The total granite used was 4,668 tons. It is interesting to compare the weights of the towers, Douglass' and Smeaton's. For similar bodies of the same material 5500 tons compared with 4668 tons, we next note that Douglass used a smaller height for his solid portion, which more than counter-balanced the cylindrical base.

The light proper – in my time

The main light:

A biform 1st order (920mm) white double flashing light, both upper and lower optic have six sets each of two (30° in plan) panels and the speed of revolution is 1 revolution in 3 minutes (180 seconds). The Character is 1 second light, 5.5 seconds dark, 1 second light, 22.5 seconds dark totaling 30 seconds. Candle power with upper and lower P.V. Burner on is 300,000. Supplied by Chances for the new Douglass light in 1881.



Plan through focal plane of 1 set of 2 panels only

Fig. 94

Facts we can draw from the above – working backwards:

1. 1 revolution in 3 minutes is very slow, meaning the pedestal is the roller type (see Fig 16. page 24). In any case mercury flotation was not available in 1881!

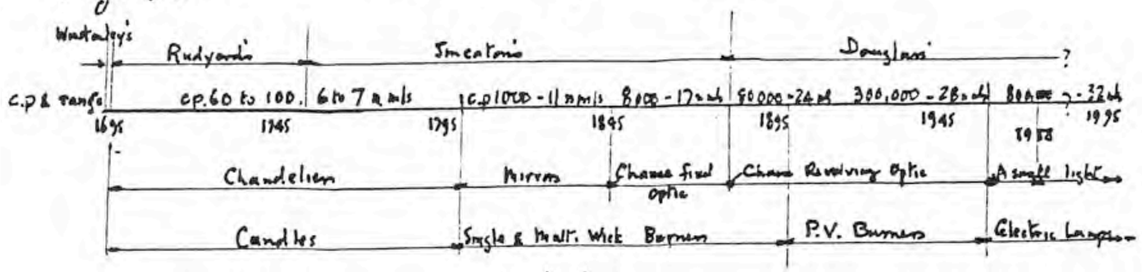
2. The flash is correspondingly long, 1 second. Using this and the focal distance of 920mm we find the diameter of the mantle was 35mm, the smallest of the chance P.V. Burners. From Table A, page 19 we find the average brightness is 40 candles per square centimeter of mantle, and a very economic consumption of oil.

Quite an impressive optic, 3 meters across by 3.75 meters high or 6 feet 8 inches by 12 feet!

To conclude this saga by looking at the rate of change of science and technology as accomplished by the illuminants of the four lights:

Fig. 95

The four Eddystone Lights



Candles: burn 'em at one end but eat the others!
"Old Lighthouse Keepers always kept a good supply of stearin candles – for an emergency ration"
Lord Mountevans (Scott's 2nd in command) recollects he had an occasion to eat Prices candles and had survived to tell the tale!

Note:
Luminous Ranges in nautical miles are for a Transmission factor of t = 0·85 (clear).
The early candle powers (cp) are very approximate.

So ends the story of the four men who built the Eddystone Lights. I share their pride in having the opportunity of so benefiting mankind.

19 The Saga of the Smalls Light

The Smalls is a cluster of twenty or so rocks, mostly submerged at half tide, in latitude 51° 43’ North and longitude 5° 40’ West, bearing West South West from St. David’s Head, Pembrokeshire and some 22 miles from Solva Harbor. The rocks are in three reefs about ¾ mile long, their breadth being about ¼ mile. The Hats and Barrels, equally dangerous, are nearby.

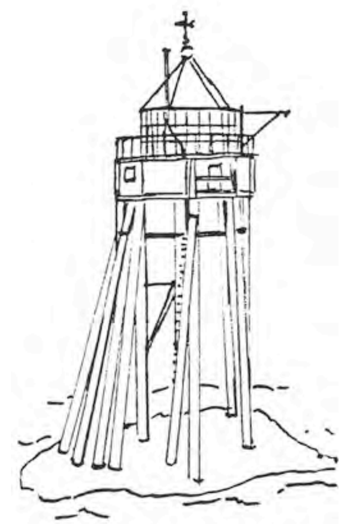
The Builders of the two Smalls Lights. I use extensively a wee book (but 6 inches by 4 inches with 28 pages) given me by a very old friend. H. Bowen OBE: Chief Engineer whose grandfather was an Inspector of Lighthouses on the Welsh Coast. It is “The Smalls, a sketch of the Old Lighthouse and Builder” by Ivor Emlyn, printed and published by John Williams of Solva in 1858.

1. Henry Whiteside, born 1746

In 1770 a Mr. Phillips, a Quaker and a native of Cardiganshire, a merchant and shipowner of Liverpool, determined to “obviate the mischief arising from this dangerous space of ocean, that covered the coast every year with wrecks”

Emlyn the author “does not ask whether the light was erected as a commercial proposition or as a great holy good to serve and save humanity”. Sufficient to say that it cost Trinity House £400,400 (in those days!!) to acquire the light.

Of the many designs received by Mr. Phillips preference was given to a 26 year old maker of violins! Granted that he, early in life, had a mechanical taste, and that later he made spinnettes and upright harpsichords. Obviously yet another gifted amateur! His name Henry Whiteside, of Liverpool.



Smalls Old Lighthouse
ENE view

2. James Nicholas Douglass (see page 113)

In 1856 the Honorable Trinity Corporation determined to supersede the present wooden structure (*the Old Lighthouse*) by a stone building. J. N. Douglass, then an engineer with Trinity House, was appointed Resident Engineer for the New Smalls Light. Whiteside arrived on site in 1772, Douglass in 1856, a span of 84 years! What an amazing life for the violin maker’s tower of oak tree trunks.

The Two Smalls Lights:

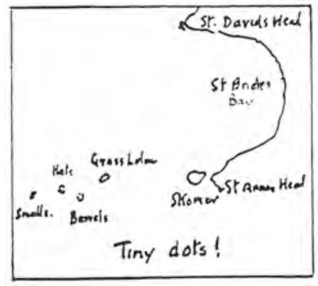
1. Whiteside’s

Smalls Rock at low water
A Old Light
B New Light
C Coal Cellar
A: • pillars
/\ etc stays

Fig. 96

1772 – Summer: Whiteside arrived at Solva Harbor in a smack from Liverpool with six Cornish miners whose task it was to pierce the chosen rock, which was some 12 feet above low water, for the insertion of eight cast iron pillars. The lot of Whiteside and the miners proved particularly hard when inserting the long fixing bolts. They spent most of their time in scrambling from rock to boat; clinging disparately to ring bolts they had secured to the rock, with their clothes being stripped off them by the pounding seas and often being marooned for long periods whilst the boat stood off.

1773 – Summer: the foundation was fully prepared and the flanged cast iron pillars, in six foot lengths, were received from Liverpool. Whiteside, wisely, believed in prefabrication on land (Solva), but when they were erected, at least to some height, he realized that their lack of elasticity and the opening of the flanged joints rendered them quite unsuitable to stand the shock of heavy seas. As did Winstanley he had the guts to revise his ideas and to use five oak pillars and but three cast iron ones.



1775: Structure erected, but no light. A storm loosened the joints of the three iron legs and Whiteside had them removed and replaced by oak pillars.

1776: All completed and the keepers took up their job. The lantern had an elevation of 70 feet.

The Tower: Over the long period as Whiteside maintained his tower he was compelled on occasion to prop up the pillars at North East Corners with oak props to preserve the uprightness of the main pillars comprising the octagon. These props evidently came and went during storms. The plan in Fig. 96, page 117 shows nine props, but I feel it doubtful if this maximum occurred at any one time. In fact it finished its life with but three. Just before Mr. Phillips disposed of his lease, he was so short of money that he could not replace some missing props. A much needed central pillar was added later and must have relieved the poor keepers of the anxiety that the living room floor would disappear beneath them. It actually did in 1834! The outer pillars were about 45 feet in length, a solid trunk of an oak tree! A stout rope ladder (ugh!) was suspended from the living room floor and secured to the rock. It is recorded that if a keeper left the trap door open he was heavily fined, presumably by his mate. It seems like a bunch of flowers for the late departed! A covered coal cellar was cut out of the rock (see plan of Fig. 96), about 8 tons of coal being used in a year for heating and cooking. General repairs demanded much smithing and a portable smithy could be erected on the rock. The bellows when not used was lashed to the undersides of the floor!

To conclude the tower:

With such little bracing on the octagon, each pillar could only slightly distribute a wave load to the other seven. Fig. 65 (see St. Paul) page 73, shows the wealth of radial, 'circumferential' and diagonal bracing used in a modern tower. Anyhow a strut or pillar 45 feet long leaves much to be desired (see bottom of page 76).

The Lantern:

The octagonal dwelling or living room gives access to the lantern and appears to be about 8 feet high and 24 feet or so across. The SW angles are partitioned off as a store for oil, coal, provisions and extra berths for visiting mechanics. A door in the NE corner leads on to a small platform with a ladder to the lantern gallery. This platform also accommodates a pillar crane.

The present Smalls Lighthouse

Fig. 97

height above MHW 126'
height of tower 141'

The Illuminant:

Emlyn states the light was but four lamps with glass reflectors (what! no candles!) increasing to eight in 1817 and again to 16 with 'silver" reflectors. A novel kind of ventilating apparatus was installed in 1845 to handle 27, yes 27, Argand lamps, just as well.

2. Douglass':

In 1856 Trinity House determined to build a new light (Fig. 97) and J. N. commenced work on a masonry tower some 50 feet higher than the old structure and following Smeaton in the clean lines of the tower. The foundation was ready in June 1857 and our author pays great tribute to the Resident Engineer in that "the work has progressed beyond the expectation of all." James Douglass had built at Solva a depot or wharf with sheds, smithies, carpenters shops, saw pits and a reading room for the workman. Moreover "no accident deserving the name has occurred to the men employed." Prefabrication again was the order of the day. His list of men employed is impressive. In addition to Douglass and his Clerk we find: Granite masons: Foreman and 37 others. Carpenters 4, Smiths 4, Miners 2, Laborers 9. Seamen: Steam tug, the Master and 6 crew; the Tender, the Master (Capt. Henry Morgan!) and 5 crew; Bargemen 1 for each of four barges.

An extract from a list of stores sent for on 13 Aug. 1810 :
11 casks oil
8 tons coal 1 ✓ Trough (?)
1¾ lb brown sugar
3½ doz. candles
3½ soap
12 lb tea 12 lb rice
2 lb mustard
1 pepper 1 ginger
2 barrels tar
12 lb white paint
24 lb cotton wick.
1 Bdh(?) Cask Hoops
1 small quantity of thin sheet copper
to (?) the chimney, 6 ft by 3 ft.
1 Winchester white (?) &
a few stores for ?arnish Tubs(?)
Hy. Whiteside.

To resume the saga of the Old Lighthouse:

1777 – February. Extract form letter from Mr. Whiteside (who was on the Smalls with three keepers) to Mr. William the Agent, at Solva: "Fetch us off before spring or we shall perish; water nearly all gone: no fire: no candles or oil." Accompanying letter from the keepers: "no light for want of oil and candles, which make us murmur and think we are forgotten". One barrel fetched in a creek at the bottom of William's garden!!

1802 – (For many years two keepers only had been on duty on the rock). Although the light continued to shine a distress signal was shown and reported by many ships, but due to vile weather it was, amazingly four months before a landing on the rock could be made. The body of one keeper in a rough coffin was found on the lantern gallery. The other was unrecognizable by his friends such had been his terrible mental and physical suffering. Thomas Griffeth had been taken ill and died after many weeks of suffering. His mate Thomas Howell (an ex-Copper) was afraid to bury at sea in case he was accused of murder. Apart from the one distress flag he could not communicate with the shore! From then onwards in all rock stations, throughout the world, there were three keepers, never two.

As I write this on 15 Oct 1978 :
"The Christos Bitas (with 32 000 tons of crude oil) was heading for Belfast when she ran on to rocks between the Smalls lighthouse and Grassholm (a bird sanctuary) on Thursday (12 Oct)"
Dear, dear – could it have been yet again, modern navigational aids and to hell with the lighthouse ?

She slid off (see 1858!) and drifted North. It's now costing millions of pounds to keep her in one piece and to deal with an oil slick 10 miles by 6 miles !!

1811 – 1812 winter. Mr. Whiteside, this time in Solva, had forwarded to him from Newgale, part of the keepers living room!!! He quickly observed that although the lantern, all of it, had been ripped off (and the piece of living-room) by a hurricane the structure seemed intact. The keepers lived through it!

1833 – February – A real North Wester carried away four stays and again the lantern and part of the dwelling room. At the height of the storm the central flooring was entirely displaced, the stove being thrown into the sea. A time-piece finished up in a berth opposite to the wall on which it usually hung! A new lantern was made and erected the same year.

From the Keeper's Log-Book: Just a few of many entries:

1835 – Ship dismasted: 1836 ship lost its top mast: 1839 schooner hits N.N.E. rock, but gets off: 1858 a brig strikes same rock, drifts off south sands, but then sinks. The crew jumped on to the rock and were well received by the keepers!

From the Sunday Telegraph
See also map top of P 118

A tribute to the brave men who manned one of the most remarkable structures in the world concludes this SAGA of the Old Lighthouse – which was in the words of Emlyn the author: "A pigeon-hole of a dwelling-house, towering mid-air amongst tempest maddened waves, which gathering strength in their furious sweeping over an unbounded space of our Western Ocean, dash wildly and convulsively against it, making continual war, as it were, for its occupation of so small a portion of their oceanic territory."

And that, let me say, in tribute to our author, is pure Welsh music.

20 The – Saga of the Mumbles Head fog signal

The lighthouse at Mumbles Head was, officially, a rock station since at high tide it was just, by a few yards, isolated from the headland. It was a small unattended electric light with a 'C' size Diaphone both controlled at dusk and dawn by Coast Guards at the end of the headland.

It must have been just inside the Swansea Harbor since the Chief Railway Engineer was responsible for its care.

Going west from the lighthouse was (then) the beautiful Gower Coast, but, even then, the well known tram (if you were a stranger you called it a double deck train with a trailer, running on its own track), starting at the esplanade at Swansea, attracted too many people to the headland and its delights.

The Blow fell.

It was a cold January morning in the West Midlands when a phone call from a slightly disgruntled Chief Railway Engineer at Swansea informed Chances that the 'C' Diaphone was working erratically, and would we send someone along at once!

I told my chief that I feared the 'C' Diaphone had succumbed to the 'deadly' hammering and sticking of the 'A' and 'B' Diaphones. He did not share this view as we had made quite a few 'C's which had been trouble free. He thought it more likely a malfunction in one of the many 'black boxes' full of electrical equipment necessary for the remote control of the light and Diaphone. He thought it wise if Fred Plomley of the Electrical Section accompanied me and that we had better collect details of the signal and related electronics and get off immediately.

I was quite convinced I was not going to enjoy the visit since the Design Section looking into the troubles of the 'A' and 'B' had come up with nothing. Moreover there was no sign of money becoming available for a real probing into the 'hammering' troubles. see page 91 (I).

The Journey.

So the two Fred's went home to placate their wives, to have meal, to pack our bags, to then meet at Snow Hill Station, Birmingham. In the meantime Fred Plomley had contacted the electrical erector who had installed the electrical gear about two years before and got from him an address in a village near the headland where we could get 'digs'. A phone call to the lady of the house: even in late January would have us for one or two nights. I arranged with the Chief Railway Engineer that we would report to him in his Swansea office in the morning.

We arrived at around 9 pm and was it cold! We caught the 'train' for the headland, but 200 yards from the station calamity struck!

Calamity, oh Calamity

It was a power failure that not only put the train out of action, but a large area of our surroundings. In the event it lasted and lasted and after about 20 minutes we were ordered out and then trouble hit us. First it was unbelievably cold, the wind went right through!; secondly it was one of the three nights that I remember when it was completely dark, one seemed to push the darkness away, a black wool; thirdly, never an electric torch between us and lastly we only knew generally the direction to the house where our room was booked.

We groped our way along the track, nearly crawled up to the road, turned seawards and soon were utterly without hope of finding our way 50 yards let alone half a mile! We could not see a hand touching our nose! The sound of waves breaking on the rocks below was daunting and it was getting late. The one or two people shuffling by (not that we could see'em) made no answer to our request for help.

Boarding Houses.

We decided to about turn towards Swansea and hoped that before all went to bed that we might find a boarding house (no hotels around) still open in January! We mercifully got a little light from candles in windows and rooms, but window after window showed 'closed'. At last we saw one with the blessed sign 'open,' but was it dingy. We were frozen to the bone!

Well, eventually the landlady appeared complete with candle and I can but suppose that even by that dim light, and well after 10 pm we must have looked fairly honest. If we didn't mind a blackout house we could have a room.

We were shown into a room, one candle burning, and sat down to await a promised supper. Not true to say we sat down, we just hit it and up! The furniture was covered with horse-hair cloth, which in the ice cold room was electrifying! Eventually some unrecognizable cold meat with unbelievably cold lemonade was served, we ate it muffled in our coats.

And so to bed.

In the attic and seemingly no heat in any room. Fred Plomley with the candle led the way up the rickety stairs. One step from the first floor landing he stumbled on a particularly loose tread and sprawled heavily on the landing and watched the rapidly failing candle disappear through an open door!

I just sat on the stairs and laughed until my ribs ached! On his knees he found the candle, but 'quiet' some one was in the bed!

We resumed our upward journey praying that the stairs would not collapse beneath us. The attic by candle light looked like Dickens at his grimiest. The bed held two; had a heavy brass head and tail and was bulbous to the 'n^{th}' degree. On the harbor side the windows were at ground level and the ceiling sloped down to them! The marble topped wash stand held a bowl and jug the latter scum covered and frozen!

Sleep; how blessed.

Fortunately we had (the now old fashioned) thick winter pajamas and leaving the dirt on us we climbed into a bed so cold that not even the bedclothes shocked us. Fred's teeth were clattering like a pair of castanets. Some minutes later I poked my head up and looked down the bed. It had lightened a little and to my astonishment we appeared to be under a white haze, in fact a regular white-out! We were drying out the damp sheets! I suppose I was young enough to sleep intermittently even with the castanets alongside.

Dawn found us stiffened with cold and trying to dress was agony. I remember at one stage looking at my collar stud in my left hand, but being unable to grasp it with my right. Somehow we partially dressed, no wash or shave, and staggered down the creaking stairs for breakfast.

We could have wept! It was still cold meat and lemonade. Fred swore the electric bill hadn't been paid and that the supply was cut off. It seemed most likely.

To Swansea by tram (or train)

Well we paid up, stumbled on to the pavement and headed towards Swansea hoping the next 'station' was not far away. My knees promptly gave way, but by crawling to the house railings pulled myself up and supporting each other we staggered on. Thank goodness our coats covered our partial nakedness. We completed our dressing on the top deck of the train and eventually reported, on time, to the Chief Engineer, but having first 'phoned' our would-be landlady to tell her our sad news. She sounded nice and promised a real and hot breakfast whatever time we arrived. Joy and rapture!

The Chief Engineer's words were "you two look rough, anything happened?" Before we had finished telling him two steaming mugs of coffee appeared and we finally thawed out. Yes, he had done something to the Diaphone, but the piston had been damaged by hammering. It would be! Then "could we see him at 12:30?" "Of course" says we, "I mean 12:30 am" says he, half past midnight. An emergency railway job prevents him being with us at the next low tide. Good grief we thought, and hoped our new landlady would be tolerant of guests who left her house at midnight and reappeared at 2 am or so! We hurried back to the train, found the village round the corner from the headland, and a delightful bungalow it was.

The Gomer Coast.

After 'cleaning up' we discussed, over an excellent breakfast, how to spend the time until midnight. As it was a lovely sunny, if cold, day we decided to walk west along the Gomer Coast, hoping that lunch would be forthcoming somewhere. It was splendid to walk and walk along that most pleasant coast and indeed we did get a sandwich and a pint for lunch. Later when I took up teaching, my wife and I used to spend a sun tide week at Worm's Head at the extreme west of the peninsula.

So back to an excellent dinner and then to look at the specifications and drawings we had brought with us and to discuss tactics. I explained to Fred the 'A' and 'B' Diaphone troubles and my fear that whilst the driving head worked very well for the 'F' to 'L' sizes the drastic scaling down for the three smaller sizes appeared not to be successful. Possibly air leakage's or restricted flow caused the uncertain movement of the piston.

Fred said, "Assuming it is that fault what do you think the Chief Engineer has done to get it to work?" I responded, "assuming that, as Chances, he has no idea as to the real trouble he has possibly protected the piston from hitting the rear cover and also has 'rebounded' it back into its normal stroke, by securing to the center of the rear cover a piece of resident material". Fred said, "that sounds Heath Robinson" I responded, "Chances last hope!" Fred said, "Assuming it is not the fault you expect, but a fault in the electrical controls for the Diaphone, what do you require?" I summarized, "Full working pressure for the first blast after starting up and the same for each successive blast, and of course the timing gear giving the correct cycle. Not that the Chief Engineer will allow a sounding of the Diaphone on a clear night, and at 1 am. Frankly, you well know what you are doing. I hope the fault is in your field as I haven't any idea what to suggest." See page 122.

Midnight:

When we reached the headland the Chief Engineer and an assistant were already there and between them had four electric lamps. From the cliff road we gingerly descended on well barnacled ramps to the rocks below and then on to partly submerged mud pats. It was neither as cold nor dark as the night before, but we hadn't proceeded more than 20 yards when the Chief Engineer said, "hold it, the wind is holding up the tide." So we each chose a substantial mud pat and for an hour talked and talked about nothing in particular!

Once inside the lighthouse the assistant whips off the back cover of the Diaphone and displays, go on guess it, a thin Sorbo rubber disc secured to the central diameter of the cover. Well, well !!!

So congratulating the Chief on his solution, and not mentioning Heath Robinson, I could but say that I would recommend replacing the slightly damaged piston and that research an the trouble be initiated without delay. In the meantime would he leave the Sorbo on? He would.

So at 2 am we let ourselves into the bungalow and found a flask of hot coffee and some biscuits awaiting us, and so to bed, which this time, was dry and warm, and so the mini-saga ends.

(i) Tut, tut, (ii) a good man. (iii) a necklace for the Snow Queen.

i. The day after our Director had our report we received a note from him in which he hoped that spending two days doing nothing would not be repeated! Tut and again Tut!

ii. I found Fred Plomley a delightful companion in misfortune and indeed he was one of the very few whom I have met who was a good man. Later in life when the opportunity arose he left Chances to further his work for those in dire trouble. On the rare occasions we meet the first greetings were "thimbles to you" and "And to you."

iii. A certain proof that although the darkness of that horrible night beat us, the coldness, which would have put a brass monkey at risk, was shown in a way I had not seen before or after. Going into Swansea after the night we saw that the coastline of the very large bay had a vivid white necklace. On leaving the tram at the esplanade we saw it was a bank four feet high or more of frozen spray left by the high tide in the night. Truly a necklace for the Snow Queen!

21 The Lighthouse Department of Chance Brothers & Co. Limited, Glassworks, West Smethwick (now Warley)

I am still being asked how any firm could keep in business if it only made lighthouses, incidentally something that occurred only in my apprenticeship, 1924 to 1929. The department founded in 1850 was, however very independent (see page 15) of the glass works although I do not doubt it was a financial burden in the early 30s. It was one of but five companies in the world making lighthouses the others being in North America, Germany, France and Sweden.

Orders mainly came from the Commonwealth countries, although until we supplied the diaphone for Douglas Head, Isle of Man no orders had been received from Scotland for many a year. Evidently a falling out between the Chances and the Stevensons! At times orders were thin, but in 20 years I do not remember a slack moment.

In the early 30s the large electric lamp became available for aerodome lighting and Chances bought up the Austinlite Co. of Banbury, makers of lighting sets for homes. A new and large electrical shop was built to make lighting sets for marine and aero lights, emergency sets for railway signaling, traffic lights, Post Office repeaters, submersible pumps, switches, clutches, etc, etc. Aero equipment included floodlights, beacons, wind indicators, runway and obstruction lights, etc, etc.

The department also had several large machine tools, which we kept busy doing machining for other companies. These were kept very busy in World War II. 1937 saw a very large program of Army searchlights, sound locators, predictors: of Air Force, beacons and floodlights with mobile generating sets, etc; and for Navy RADAR nacelles, fire switches and lights. Personal rose from, roughly, 250 to 650 and the following new shops were built – welding, plating, testing, precision assembly, a new drawing office, etc. We also acquired a disused tram shed on the Birmingham – Oldbury Road for truck mounted equipment.

Staff – generally but one director and one works manager with four foremen (fitting, machining, glass grinding and electrical). The several charge-hands led the "gangs" for producing optics, pedestal, lanterns and tower fitting, flashers and equipment, fog signals, switch-gear, generating sets, etc. and, of course, the sections supplying the components: machine shop, inspection, stores, patterns, smithing, welding, etc, etc.

Drawing offices – general lighthouse; electrical and tooling, with jigs etc.

The department was thus able to broaden its products and I well enjoyed my six years as Assistant Works Manager coupled with Chief Inspector etc. I finished as Chief Mechanical Engineer. My external London degree enabled me to do some engineering teaching at the Chance Technical College (named after Sir Hugh Chance, Chairman of Governors) and in 1944, I followed Jack Dodds into pastures new, and became an Assistant Lecturer at the College. After a short spell at the Birmingham College of Technology I returned to Smethwick as Head of Department (everything but Commercial Management) and for my last five years, Principal. Much building took place in these years. In 1957, I managed to combine my academic knowledge with industrial experience in becoming Assistant Secretary (technical and education) at the Institution of Production Engineers. This happily included visits to many European countries and to India (twice), Australia, South Africa, Canada, Singapore, U.S.A., and Peru. I retired after 49 ½ years work in 1973.

Chances and the Royal Navy

In World War I, 1914 – 1918, the Navy was caught out using German glass for range finders etc. so come 1918 the admiralty paid for the building of a research laboratory in the works and the salary of a research director. A certain quantity of optical glass had to be made each year. The long sightedness of this became apparent in World War II, but this time it was the Royal Air Force that needed optical glass and not the Navy. In 1937, Chances received a letter from the Royal Navy saying they proposed to build on the roof of this laboratory an obersvation post (for movement of aircraft), which would be manned by an officer and seven men of the Home Guard. Secondly, the firm would build an underground room (in telephone communication with the Home Guard) to be manned by the director and senior managers. Thirdly, no employee would be released to His Majesties forces except for flying crews of the RAF! From 1939 to 1945 we lost but 24 hours on production of optical glass. I commanded the Home Guard of Chances plus two other works, plus the electricity generating station and the gas works (+ 400 men). In my spare time I fire-watched in my road and in the College and distributed petrol coupons for local traders!

Come 1944, 25 of the works personnel were permitted to try for the REME Officers pool. I got into the pool but evidently at 36 was to old and haggard to be dished out!