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# MODERN LIGHTHOUSE ILLUMINATION.

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A lighthouse presents many and varied features of interest, and attracts the attention of everyone, engineer, architect, and artist, as well as seafarer and ship-owner. Our attention, as engineers, has often been called to the progress and processes of artificial lighting in cities—the development of lighthouse illumination has been synchronous with that of civic lighting, and the same scientific advancement that has turned the vista of our main streets in the evenings into a gorgeous glare of glowing globes, has more rationally sent many a beam of radiant energy out into the darkness that is upon the face of the deep, and given the benighted mariner an objective "pou sto" in the obscure chaos that welters around him.

To secure the stability of this fixed point—to erect the lighthouse tower so that it will resist the shocks of seas which shake its solid foundations maybe, is one of the most arduous problems of the constructive engineer—to crown the work by fitting a candle on the candlestick so erected, whose range will extend horizonwards and penetrate fog and haze as far as possible, and also have a distinctive character, whereby the seaman may recognise it and locate himself, is as interesting as, if less heroic than, the building of the tower; it is to some recent modifications of lighthouse illumination that he proposed directing attention to.

The introduction of the electric light for this purpose is now a matter of ancient history, having been tried 47 years ago at the S. Foreland, and installed 43 years ago at

Dungeness, though it was afterwards replaced there by oil lamps. The first permanent electric light was at Cape La Havre, near Havre, in 1865, and in Britain, at Souter Point, between Sunderland and Shields, in 1871, while Port Said was so lighted in 1869. No very marked improvement has been made on the dynamos or lamps used since 1881, when our South Head Light, then the most powerful in the world, was rebuilt. The De Meritens alternator, with its permanent magnets seems to be still preferred in spite of its clumsiness and comparatively low efficiency, as it has proved itself eminently reliable in the hands of the light-keeper. A continuous current dynamo is unsuitable for the arc lamp of a lighthouse, where the luminous source must be maintained absolutely in the focus of the optic, a condition easier attained where both carbons wear equally, as in an alternating machine, while the crater that forms in the positive carbon is avoided; and the use of permanent magnets dispenses with the complication of the exciting continuous-current dynamo needed with electro-magnets. Some, indeed, of the recent electric lights on the French coasts are fitted with electro-magnetic alterators of modern design, having the exciting coils and accumulator on the same spindle as the main coils.

The cost of, and staff required to work an electrically lit station, are objectionable, and fresh water for steam boilers is often difficult to secure, so electricity is not being adopted, except for very important lights or landfalls. The improvements, however, which the rivalry of the electric light has brought about in our oil and gas lights, are as marked in lighthouse work as in street or domestic illumination.

One of the greatest advances in lamp lighting was the substitution of mineral for animal or vegetable oils. Train or whale oil was found to be a superior illuminant to the candles which superseded the open coal fires of two centuries ago, but with the retirement of the whale to the Polar ice fastnesses, and the decay of the fisheries, colza oil, or some other products of seeds or nuts was used, until the rise of the Scotch paraffin industry put a good and safe mineral illuminant in the market, and now it, or a similar grade of American or Russian oil, is almost universally used. For an oil lamp to burn clearly and steadily, we must have a nice balance maintained between the heated vapour from the wick, and the air necessary to burn it, which must be supplied just where and when it is wanted. If the vapour is in excess of the air supply, the lamp smokes, and loses its intrinsic brightness; if we diminish the oil supply, the wick chars and gets non-absorbent; if air is in excess the flame may be bright, but evaporation is checked, and the light is small, and, therefore feeble. A hot flame with just sufficient air supply is what is wanted, and to keep the wick from charring, it must be kept flooded with oil.

Lighthouse oil lamps are usually modifications of the old Argand burner, where the air is admitted at the centre of the flame, as well as made to impinge on the outside by a suitably curved glass chimney. Such lamps are made with multiple concentric wicks, up to six in number, one within another, which are woven tubular, and have annular air passages between them. They do not dip in a cistern, but oil is supplied to them by side pipes, leading from a reservoir above the burner, which feeds first of all another vessel by an arrangement like a "bird fountain," so that the oil in this second vessel, which supplies the burner directly, stands at a constant level, or we may have a pressure lamp, where the oil is forced to the wick by a piston in a cylindrical reservoir, pressed by a spring; or it may be pumped up to the wick by a mechanism operated by a falling weight, the same one that revolves the optic possibly; or may be forced by pneumatic pressure, from a reservoir of compressed air produced by a hand pump.

This supply is led to the wick below the burner, and keeps it flooded with oil, the surplus draining back into a waste can, to be used again. With different oils it is necessary to feed the wicks at different levels, thus, while colza or teil oil might be fed just under the tip of the wick, kerosene must be supplied two or three inches below, and heavy petroleum at an intermediate height. Good high flash kerosene burns very well when this point is properly attended to, and the air passages and deflectors suitable, but a less volatile petroleum is preferred in tropical and sub-tropical climates, as being theoretically safer. It was long a matter of difficulty to get mineral oil to burn satisfactorily in a multiple burner, even the one wick Argand lamp of commerce gives a very unsatisfactory flame with kerosene, but Doty, about 1868, overcame the trouble by carefully proportioning the annular air passages, and deflecting them at their tips, so as to give the air just where it is wanted—a disc, or button, in the centre of the flame is also used, which spreads the central air current, and sends it horizontally into the middle of the shell of flame. Douglass's lamp, used in the New South Wales lights, is practically the same as Doty's, having an improved form of tips to the burner wick-rings.

This direct use of mineral oil is of more recent date than the first trials of the electric light, and may be said to have come in about 1870; it has improved the light power very much, and lessened its cost, but it is not quite satisfactory. The intense heat of the flame is as evident as its intense light, the volume of combustion being increased more than the radiant area. The inner wicks give little direct light; though they increase the height of the flame, the outer flame is opaque to the inner light rays, but their heat increases the size and temperature of the outer flame, and its luminosity also. At full power, however, with all wicks burning, the air supply tends to be deficient, and the flame is ruddier, that is, its intrinsic brightness, or candle-power per square inch of radiant surface, is diminished. In thick weather, which is the time when all the wicks are needed, this is no great disadvantage—it is useless to try to get a light that will penetrate a fog that the sun cannot do, but red light, being less refrangible, gets farther into a fog than a white one of the same power.

But the efficiency of the optical apparatus, with which we concentrate the rays, and direct them to a distance, depends more on the intrinsic brightness of the light just at the focal point than on the candle-power of the whole flame. The electric arc is therefore almost ideal in this respect, as its small surface of light is almost wholly focal, but it requires very careful focussing and adjustment of the refractors or prisms to secure a due distribution of the rays. If the arc is a millimetre or two high or low, the light might be wasted on the near sea, instead of being mostly sent to the horizon, or it might be sent off overhead, and nearly all lost to this world. With a large surface of light or flame, there is not so much difference made by an error in position, and the amount of extra-focal surface gives a diffused light in the neighbourhood of the tower, which, however, may prevent the character of the light being noted clearly unless seen afar off. The larger the flame the more visible it is close to, in thick weather; while large and small would be equally invisible at a distance. The superiority sometimes claimed for oil or gas over electricity in fog is, no doubt, due to this effect, the area of the oil or gas flame is so great that its light cannot be nearly all sent away to be lost overboard in the fog on its way to the horizon, twenty miles off, but much remains to light up the nearer sea, and convert the fog itself into a pillar of fire.

At the South Head Light we have the arc light, with the optic arranged to send most of the light to the horizon, so that one does not get the full intensity of it till he is eight or ten miles off—there are also gas burners, which it was at first proposed to use habitually, and only to use the electric arc in thick weather—and an oil lamp for a stand-by, should the gas fail, for the electric light comes from gas, the dynamos being driven by gas engines. But there has been no necessity to use these substitutes during the twenty-three years since the electric light was installed. Lighthouses now-a-days, though, have a greater choice of illuminants. Acetylene gas gives a splendid white light, and when the carbide it is made from is pure, gives little trouble if properly generated and burnt. When the gas is overheated, by using bad types of either generator or burner, tarry deposits are produced, which choke the burner, and smoke the flame; and when the carbide contains sulphur, and especially phosphorus, burning the gas gives rise to disagreeable and unhealthy smells. Phosphoretted hydrogen is the most objectionable impurity in acetylene; it can only be derived from impurity in the lime or coke from which the carbide was made, and as most limestones have an organic origin, is very often present. Acetylene can be generated and burnt as formed, or it may be stored in a gas-holder as made, during the day, for consumption at night, or it may be generated away from where it is to be used, and conveyed by compressing it in portable cylinders, either by itself, or by absorbing it in acetone, a hydro-carbon liquid which takes up under pressure several hundred times its volume of acetylene, and gives them off when pressure is reduced. This acetone solution is safer than the pure gas compressed, with which explosions have occurred that are hard to explain.

In Canada, there is an extensive use of compressed acetylene, lighting the St. Lawrence above Montreal—the

Lake of the Thousand Islands—the beacons or buoys being supplied from a steamer where the gas is generated and compressed and delivered to the gas-holders through hose. The white, luminous flame of acetylene gives a very good light by itself, but it can also be used under a Welsbach mantle, which then gives a light far in excess of what it does with other gases. But it requires a large amount of air, twelve times the volume of the gas, for complete combustion, and the mixture is so very explosive that the difficulty is to prevent the flame striking back and burning at the nozzle, which, as every gas stove user knows, is fatal to efficiency. Special burners can be used to get over this, but there is still the trouble that the phosphoretted hydrogen, nearly always present, affects the mantle, and causes it to fuse and break up.

The use of the Welsbach or similar mantles is likely to prove the greatest improvement in lighthouse lamps since the invention of the Argand burner. In France it has been tried, with coal and oil gas, since 1895; and all the world over, attempts are being made with more or less success, to make a reliable incandescent lamp, worked by petroleum vapour, generated by the lamp's own heat. There are several fairly successful lamps of this sort for general use on land, but their perfection depends on the nice adjustment of many small but essential details; for lighthouse work something absolutely steady and trustworthy is needed, and it is not to be easily got. An apparently simple burner of this sort, as tried in France, is illustrated; but though it is said to work well if cleaned out every day, we could hardly rely on it for continuous use. Messrs. Chance Bros. have introduced a similar burner, and also Mr. Matthews, the Chief Engineer of the English lighthouse authority, which is being used successfully. In the United States, a lamp of this nature was tried in 1899, as the Engineer Secretary of the Lighthouse Board reported to last year's Engineering Congress at St. Louis:—"But it was found that it needed constant attention, and its candle-power frequently varied, and this had to be corrected by increasing or diminishing the supply of oil. Although the light itself was superior, it was deemed at the time inexpedient to adopt the lamp itself."

Mr. Matthews described his lamp at that Congress, and when the proceedings come to hand they will be interesting reading. He (the speaker) had some hopes that an experiment that is being tried in a small way here will lead to better results than the American ones. Having got the light, the next objects of the designer are to give it a far-reaching power, and distinctive character. An apparently easy way of doing the latter is to use coloured lights, by passing the white lamp light through stationary or revolving screens of coloured glass, but this is incompatable with the first object, as coloured light ceases to be visible at a much less distance than the white light producing it would be. At Point Stephens, we have an old-fashioned light of this sort, where white and red lamps in four groups of three each, are hung alternately on a revolving iron frame like a Christmas tree, and they give us a red and white flash in turn, but the red ceases to be visible long before the other, and at a dozen miles off or less, it looks like an occulting white light. While coloured lights are suitable for harbours, no new sea lights are being so made, but old established lights of this character are being refitted with improved apparatus. The oldest existing rock light tower, the famous Bell Rock in Scotland, which gives an alternate red and white flash, and worked well for ninety years with the original apparatus, similar to that at Point Stephens, has had a new lantern put on lately, which was exhibited in action at the Glasgow Exhibition of 1901. The optic was made by Stevens & Struthers, of Glasgow, to the design of Stevenson, the

"Northern Lights" engineer, the glasswork being made in Paris. A diagram of an optic of the same nature by Chance Bros. is given. It will be noticed that about three-quarters of the luminous emission is sent through the red screen, to get a red beam of the same intensity as the white, and had both flashes been white, they could each have been twice as powerful as the white flash used, with the same lamp and oil consumption.

The designing of the optic, as the arrangement of glasswork is called, calls for great mathematical ability, and it was in this business that Dr. John Hopkinson, of electrical fame, first distinguished himself, as designer for Messrs. Chance, and our South Head Light is one of his "chefs-d-oeuvres." Since it was erected, however, the tendency has been to diminish the number, and increase the size of the individual panels of the optics. The optic, of course, is a development of the simple bulls-eye lens, the first step was to cut away the superfluous thickness of a large lens, so as to get a stepped surface, with its effective faces of the same curvature the complete lens had; next, instead of cutting steps in a lens, a compound one was built up of curved prisms round a central bulls-eye; then a series of these being made to revolve round a light in their common focus, we get a series of intensified flashes. Or we can use annular lenses and prisms, which only concentrate the vertically diverging rays, allowing the horizontal distribution to go on as before, giving a strong steady light, whether the apparatus revolves or not. Such lenses and prisms acting by refraction only, can but intercept a limited zone of light above and below the focal plane; to extend their vertical range, other series set at quite different angles, are added above and below, which act with all three surfaces, the rays being not only refracted when entering and leaving the prisms, but also totally reflected internally from the third side, and so getting three bends instead of two.

Then by arranging a series of such compound lenses in a cylindrical or polygonal frame, with a radius equal to the focal length of the lenses, and revolving this round a vertical axis, the lamp being in the axis at the focal plane, we can get any variety of sequence of periodical bright flash, steady glow, or total darkness, and the concentrated flashes pierce the darkness farther than the diffused light would. Thus we arrive at group flashing lights, each of an individual character, whereby the mariner can locate them. A chart of the characters of some of our New South Wales lights is shown, the upper diagrams showing the sequence of the light as it meets the eye of an observer at sea, the heights of the white space indicating the luminous intensity of the flashes and the breadths the duration of them; while the lower diagram gives, as it were, a bird's-eye view of the lights on a hazy night, showing the haze lit up with the radiations at any given instant. The optic is revolved by clockwork driven by weights and chains, or steel wire ropes in the more recent ones, and fitted with a sensitive governor to ensure regularity. One of the greatest modern improvments has been the substitution of a mercury bath on which the optic floats, for the turntable or chariot with its rollers and circular table formerly used. The gun-metal framing of the glasswork is built on a hollow cast-iron base, which is immersed in mercury in a cylindrical pan which the float nearly fills—the whole optic then revolves on that mobile and frictionless fluid, and needs only a few guard rollers in a horizontal plane to keep it central. A comparatively smaller amount of mercury is sufficient, obviously if there were only a sixteenth inch clearance between the float and sides and bottom of the bath, the requisite displacement and buoyancy