# THE PRESENT STATE OF THE TECHNIQUE OF MARITIME LIGHTHOUSES

by

Capitano di Corvetta ROMANO CIPPICO.

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(Translated from the Italian)

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The major part of the subject-matter of the present article is drawn from the Report of Proceedings of the 3rd International Assembly of the Directors of Maritime Signalling Services held at Berlin in 1937.

The presence, besides, of many scientists and technicians with allround knowledge and experience, conferred on the Assembly an outstanding importance. The discussions entered upon, and the conclusions arrived at, by the Assembly are. therefore, of very great value to the students and technicians in this branch of activity, and are, on the whole, of great interest also to all navigators. It is for *them*, in fact, that maritime signalling was created, and it is to *their* requirements that this service must be fully subordinated. It is for the navigator to say which type of signal satisfies him and which other type, on the contrary, is inadequate. The task of the signalling service is therefore often that of developing these suggestions and turning them into practical realities.

However, as a rule, the seaman does not concern himself with the nature and construction of the signals of which he makes daily use, and is hence unaware of the many difficulties encountered on this path and the amount of labour necessary to overcome them.

The aim of the present article is to give a concrete idea of this labour, and, consequent thereon, a picture of the actual state of the technique of maritime signalling, as far as the most important part of its realm, *viz.* that of the luminous signals, is concerned.

## PART I.

a) *Luminous Power of Lighthouses.* b) *Effective luminous Power of flashing Lighthouses.*
c) *Luminous Range of Lighthouses.* d) *Indication in the Light Lists.*

The above-enumerated items had formed already in 1933 the subject of a discussion at the Paris Conference, which in this connection dealt particularly with flashing lights. Formulas were then evolved to be used by all the States for the calculation of the intrinsic brilliancy of the various illuminants when no direct photometric measurements are available; a formula for the determination of the optical range and, finally, a definite formula for the calculation of the effective luminous power of the flashes emanating from the revolving optical apparatus. It was set down that the optical range should be deduced from Allard's well-known formula

$$\varepsilon = \frac{I}{t^2} \sigma^t$$

in which I is the luminous power (specific luminous density $\times$ by the surface of the illuminant), $t$ the optical range, and $\sigma$ the degree of transparency of the atmosphere (coefficient of transparency), the limit of perceptibility of the light being $= 2.10^{-7}$ lux.

For the coefficient of influence of the flashes in the calculation of the *effective luminous power of the flashes*, it was agreed to use the expression

$$p = \frac{t_{max}}{0,2 + t_{max}}$$

in which $t_{max}$ represents the theoretical duration of the flashes calculated on the basis of the size of the source of light, of the focal distance of the optical system, and of the speed of rotation of the apparatus.

The values assumed for a part of the symbols in these formulas are liable to be amended as new investigations and experiments determine them with ever-increasing accuracy. For I it was not considered desirable to make the determined values international. An examination of the various factors appearing in the formulas will give an idea of these evolutive processes.

## CALCULATING THE VALUE OF I.

Someone expressed the wish that, for the calculation of the luminous power, besides the formulas, the nominal values of the intrinsic brilliancy of the various luminous sources be also standardized, in order that in all the States the values of I should be calculated in an identical manner.

This is impossible practically, due to the fact that the various forms of illuminants hardly ever develop the same intrinsic brilliancy.

In the petrolium oil lamp with a wick, the brilliancy depends on the draught, the type of deflecting cone (flame-splitter) and numerous other elements; the brilliancy of the petrolium vapor incandescent lamps (P.V.I.) is influenced by pressure of feed, the size of the incandescent mantle, its thickness and the fabric it is made of; the matter is more intricate still in the case of the electric incandescent lamp, in which the candle-power is influenced by the shape, diameter, arrangement and composition of the filament, the degree of vacuum, the kind of gaseous filling of the bulb, the supply voltage and the charge.

The determination of the intrinsic brilliancy of the various lamps must, therefore, be made according to each individual case, when lamps of considerable size are concerned. Anyway, this should raise no difficulties, since photometric determinations belong to the ordinary routine operations of all Lighthouse Services.

In the electric incandescent lamp, two elements are of outstanding importance with regard to the luminous power radiated from the optical apparatus. These elements have been disclosed by Dupouy in his study of the "Conditions for the use of the electric incandescent lamps of lighthouses". The elements in question are:

1) The exact focussing of the incandescent body, and;

2) The influence of a cylindrical filament with vertical axis on the efficient surface of the optical system.

The first requirement is determined by the fact that while, on the one side, the demand for ever-greater brilliancies has led to more and more concentrated and shorter filaments, it has been necessary, on the other side, to concede the manufacturing firms certain inevit able tolerances in the size of the bulbs, in the accuracy of centring of the filament, and in the caps of the lamps. Thus, it does not suffice that the chandelier located in the optical system be only adjustable in height. It is necessary that it be accurately movable also in a horizontal plane. In very tall lighthouses, the convergence of the light beams toward sea is effected generally by slightly raising the luminous source with respect to the focal plane of the optical system. But, as may be readily appreciated, such operation entails a raising of the rays emitted from the catadioptric parts, with a consequent proportional loss of light of the depressed beams. It is therefore necessary that the raising of the lamps above the focal plane be accompanied by an adequate inclination of the optical panels toward the exterior, preserving, of course, the focal distance. In one of the most important French lighthouses (Créac'h d'Ouessant) excellent results have been obtained by this procedure.

With regard to the influence of the cylindrical filament on the luminous power of the lenses, it has been found that beyond a certain angle $\alpha$ above and below the horizontal plane, no ray issuing from the light encounters any longer the incandescent filament ($\alpha = 26°30'$ for $\frac{h}{d} = \frac{1}{2}$, $18°30'$ for $\frac{h}{d} = \frac{1}{3}$, etc). It follows that for all the angles subtended from the lens to the light greater than $\alpha$, no light-ray is emitted horizontally from the lenses. It is therefore a mistake to imagine that with an increase of diameter $d$ of the filament (as often requested by the navigators in order to augment the length of the flashes), leaving unaltered the product $h\ d$ and the intrinsic average brilliancy, the luminous power of the light does not change. For instance, by doubling, the length of the flash (by doubling the diameter of the filament), the luminous power emitted by the panels is reduced to one quarter. Moreover, in the fixed optical systems such drawback

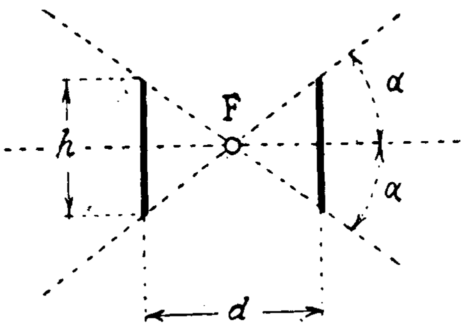


Fig. A

manifests itself in a troublesome manner also. by lowering considerably the efficiency of the upper and lower elements. The last elements of the upper prisms and lower prisms emit practically none other than deflected rays.

## DETERMINING THE VALUE OF $\sigma$

The indication of the mean luminous range of a lighthouse, whether the mean range (50 %) or the small range (90 %) is concerned, entails the knowledge of the coefficients $\sigma$ of the zone for both ranges, unless, by exception, direct observations of the lighthouse in question, carried out for years at the two limits of optical range, are available. In one of his works (1) Mr. van Braam van Vloten, head of the Dutch Lighthouse Service, describes a method which renders possible the approximate determination of $\sigma$ 50 % and $\sigma$ 90 % from observations of lighthouses, even if such observations have been effected from a few observational posts only. It is naturally assumed that here mean values of the transparency of the atmosphere will suffice and that short stretches of coast are involved, as is precisely the case in Holland. The method consists, in substance. in referring the mean relationship between $\sigma$ and the corresponding percentage of frequency to a system of rectangular coordinates, and drawing the middle lines of the bands of points, thus obtaining for $\sigma$ 50 % and $\sigma$ 90 % mean values with consequent possibility of calculating the range on the basis of the already-mentioned formula of Allard.

The calculation of the range is however fraught with difficulties in all cases in which exhaustive observations on the visibility of the lighthouses, and therefore the knowledge of $\sigma$ is lacking.

In these particular circumstances, it may be useful to employ the method suggested by Illing and Feyerabend, by means of which it is possible to deduce values of $\sigma$ on the basis of the observations of diurnal visibility carried out in a great many places according to the international scale of visibility. Between the diurnal visibility S in nautical miles and $\sigma$ there exists, in fact, the relationship.

$$S = \frac{3150}{\log 1/\sigma}.$$

Rey also, in his work on the determination of the $\sigma$ s for 20 French localities by comparison of observations of lighthouses and of neighbouring meteorological stations, arrives at a certain relationship between the visibility in km. and the coefficient of transparency. Worth noting is the fact that the nocturnal visibility of these zones corresponds to the mean visibility at 7 a.m. and 6 p.m. and that it is thus possible to determine the value of $\sigma$ for a certain percentage of frequency.

(1) "The range of the Dutch lighthouses on the basis of the observations made from 1927 to 1935".

However, comparing the results arrived at applying the two methods, appreciable differences are disclosed. Rey, for instance, has found that to a visibility of 8 km. there corresponds a coefficient of transmission $\alpha = 0.8$ per km., or $\sigma = 0.66$ per nautical mile. ( $\sigma = \alpha$ 1.852). Such a value gives, on the contrary, with Illing's method, a visibility of 17 km. The table below shows the rather inconsistent differences between the results with the two systems .

| COEFFICIENT OF TRANSMISSION | | DIURNAL VISIBILITY | |
|---|---|---|---|
| $\alpha$ per 1 km. | $\sigma$ per naut. m. | Rey | Illing and Feyerabend |
| 0.5 | 0.28 | 1.9 km. | 5.6 km. |
| 0.6 | 0.39 | 3.4 » | 8.0 » |
| 0.7 | 0.52 | 5.2 » | 10.5 » |
| 0.8 | 0.66 | 8.0 » | 17.0 » |
| 0.9 | 0.83 | 12.5 » | 40.0 » |

The appreciable differences which appear prove that comprehensive studies and a great number of observations will still have to be made before it is possible to obtain accurate values for $\sigma$, a factor of capital importance in the calculation of the optical range of lighthouses.

## ON THE EFFECTIVE AND USEFUL POWER OF REVOLVING FLASHING LIGHTHOUSES.

We have already cited the formula $p = \frac{t_{max}}{a + t_{max}}$ (in which, as agreed in 1933, $a' = 0.2$), which might be defined as the formula of influence of the flashes and $p$ the coefficient of the flashes. As a matter of fact, on examining the expression, it is seen that the influence of $a'$ increases with decrease of the duration $t$ of the flash, and *vice versa*.

It will be necessary to examine here also what result the most recent researches on $a'$ and $t$ have led to.

Experiments carried out in 1934 by Toulmin-Smith and Green on light flashes have shown that the value of $a'$ set down by the Paris Conference, *viz.* 0.2, should be changed to 0.15. The opportuneness of the change was substantiated also by the indirect method. Shortly after the afore-said experiments, and making use of same, Hampton, putting $\varepsilon = 2.10^{-7}$ lux, found for the constant $a$ of the Blondel-Rey formula (the basic formula on the relationship between luminous power and duration of the flashes) the value 0.09 (1). At present it has been shown precisely (2) that the value 0.15

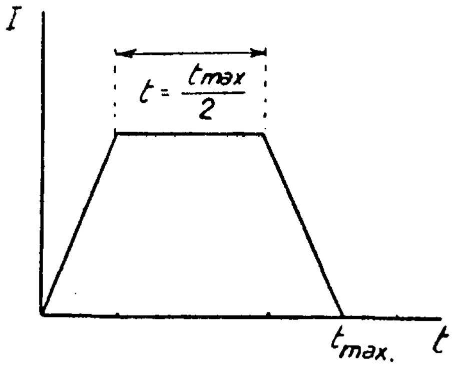


Fig. B.

(1) For flashes of sudden lighting up and extinguishing. In the Blondel-Rey formula ($i\ t = a + b\ t$), $i$ is the intensity of illumination which the eye receives (supposed constant throughout its duration), $t'$ the duration of the phenomenon, and $a$ and $b$, constants depending on the value set down for $\varepsilon$.

(2) Van Braam van Vloten. - "Effective luminous power of flashing revolving lighthouses".

for $a'$ is that which, with trapezoidal characteristic luminous lines, with $\frac{t_{max}}{2}$ as upper side and applying the lately-mentioned equation, best answers to the value found by Hampton for $a$.

It has however been found, meanwhile, that the hypothesis of the fields of trapezoidal radiation with $\frac{t_{max}}{2}$ as upper side cannot be generalized. With the use of electric incandescent lamps, even in the case of double-spiral filaments of a well-designed shape, there exist, for instance, relationships between $t'$ and $t_{max}$ which attain $1 \div 8$. For the determination of the coefficient $p$ of influence on the flashes, the record of the characteristic line and the application of the graphic system appear today preferable in every respect to the calculation by means of the trapezoidal formula in which $t' = \frac{t_{max}}{2}$.

The coefficient $p$ is also given by $\frac{Io}{Im}$ in which $Io = \varepsilon = 2.10\text{-}7$ lux and Im is the mean luminous intensity in the course of the flash. At the experimental field of Friedrichshafen, experiments are in progress in order to ascertain the practical applicability of the values of $p$ graphically determined from the characteristic line.

The investigations were not terminated at the time of the Berlin Conference, but they had already led to the conclusion of the applicability, in principle, of the above-mentioned Blondel-Rey formula. For $b$ ( $= Io = \varepsilon$) $= 2.10\text{-}7$ lux, the value of $a$ is 0.09. But such value depends on the physiological quality of the observer and is derived from observations carried out in a laboratory; this value will most likely have to be augmented for practical application. On the ground of the experiments in hand, values of $a = 0.15$ and $a = 0.28$ have been calculated, which applied to the known trapeze yield $a'$ equal to 0.25 and 0.45 respectively.

As concerns the *duration* of the flashes entered in the Light Lists, and which in France and Germany are referred to a short distance from the lighthouses, whilst in Holland, on the contrary, they are referred to the limit of visibility, the adoption of one uniform method is desirable for all countries. Considering that, owing to the unequal distribution of the luminous intensity of the light beams, the duration of the flashes and of the flares (splendori) lessens as the limit of visibility draws closer, it might be desirablel that the value of the duration entered in the Lists should be referred precisely to these last conditions. It should be noted, on the other hand, that the maximum duration of a flash is given by the relation $t_{max} = \frac{d\ T}{2\pi f}$ in which $d$ is the diameter of the source of light, T the time elapsed for a complete rotation of the optical apparatus, and $f$ the focal distance. Such maximum duration beyond a certain distance of the lighthouse does not, of course, correspond to the effective and really visible duration.

By introducing the coefficient $p$, i.e. the already-examined coefficient of influence of the flashes, the effective time of duration of the flashes becomes, in effect:

$$t_o = t_{max} \left( 1 - \frac{p}{2} \right)$$

In this manner, for $a' = 0.15$, we have, for $t_{max} = 0^s.2$, a $t_e = 0^s.14$, for $t_{max} = 0^s.05$, a $t_e = 0^s.14$, etc.

## ON THE LUMINOUS RANGE OF LIGHTHOUSES.

As regards the luminous range of the lighthouses to be entered in the Light Lists, a first uncertainty arises from the fact that in 1932, at the 3rd International Hydrographic Conference, the meaning of the word "portée" (range) was in no way specified. It is therefore necessary that it be laid down whether it is a question of "geographic range", the eye of the observer being supposed to be 5 metres above sea level, or of the "luminous range". Of the latter, on the other hand, there exist a minimum range, certainly exceeded on a high percentage of days of the year, a mean range, and a maximum range, which obtains only on particularly clear days. Numerous discussions on the advantages and disadvantages which are derived from the inscribing of the one or the other of these ranges have led to the following conclusions:

(1) It is appropriate that in the Lists there should be entered the geographic range for a height of 5 metres of the eye of the observer above sea level.

(2) It is desirable that the navigator should be provided with a means enabling him, on the basis of the luminous power of the signal and of the actual conditions of visibility, to estimate approximately the luminous range. This might consist of a tabulation, easily interpreted, annexed to the Light Lists, in which would be given the relationship between luminous power, luminous range, coefficient of transparency and visibility, according to the international scale.

(3) It is very desirable that he meteorological organizations should carry out also observations of visibility, both diurnal and nocturnal.

(4) It is premature to take action re the definition of the luminous range of flashing lights the German experiments in this domain being still in progress on a huge scale.

(5) Before the next conference on maritime signalling takes place, the question as to whether it is appropriate to enter in the Light Lists the maximum (calculated) duration of the flashes. or the effective duration thereof, should be considered.

As a basis for the tabulation proposed in par. (2) one might utilize the representation drawn up by Illing and Feyerabend on the range of lighthouses of from 0.2 to 100,000,000 HK (Hefner candles), in relation to the visibility according to the international scale.

The various discussions have revealed very interesting facts on the particular conditions under which some lighthouses work. There are English lighthouses situated in industrial districts, as for instance the Souter Point lighthouse, which, owing to the smoke and mist engendered by the factories in this zone, display extremely diversified ranges, according to whether the wind blows to seaward or to landward. A comparison organized by the Service of Scotland between two lights, one with electric arc, the other with an incandescent petrolium oil vapor burner, of a calculated luminous power of 26 and 1 1/4 million candles repectively, showed, after three years' observation, the following appalling results: the visibility of both lights to a distance of 7 naut. miles is practically the same; at 21.5 naut. miles the strongest light was sighted in 2.5 % of cases only; and at the geographical range of 30.5 naut. miles it was impossible to note any difference between the two lights. While realizing that, due to the spectral composition of the electric arc light, the same is absorbed to a higher extent by the atmosphere than that of a petrolium oil vapor burner, the extraordinary similarity between the practical effects of lights with such considerable differences in intensity can but amaze us. Experience confirms, in the main, that electric arc lights, despite their extremely high luminous power, are among the least suitable from the point of view of mean luminous range in regions with frequent mist or fog.

## PART II.

## NOMENCLATURE AND CHARACTERISTICS OF LIGHTHOUSES.

It is realized how the argument must give rise to two kinds of discussions, to wit:

(1) Which are the most suitable characteristics for lighthouses and lights ?

(2) How can the various characteristics be defined in a simple and definite manner ?

Whoever is charged with the assignment of the characteristics to a certain lighthouse has to take into consideration a rather lengthy series of factors and of often contrasting necessities. (The characteristics of the lighthouses already existing in the zone, the kind of source of light and of optical system, the required luminous power, the particular nautical and meteorological requirements of the locality, the operative cost, etc.). Besides, as the Berlin Conference has shown, he will have to choose the characteristics in such a way that they may be contained within certain categories which, for obvious reasons, it is sought to standardize internationally, in order to give the navigators lights belonging to a determined number of types, standardized throughout the civilized world. It is plain why the argument in question gave rise to very lengthy discussions; each student, in actual fact. is instinctively led to give a predominant weight to his own ideas, borrowed from the particular requirements of the coasts of his own country. It can nonetheless be said that the major part of the difficulties for the standardization is now overcome, and it may be forecast that at the forthcoming conference in Holland the last obstacles will be smoothed out.

To review all the arguments brought forward on the issue would lead us too far, although very interesting facts have thereby been disclosed.

Summing up the main points, it may be said that the present trend is towards simplification of the characteristics, as well as giving them rapidity of rhythm which takes into account the modern requirements of navigation. For ordinary lights, i.e. lights which display the same characteristic and the same colour over the whole horizon, or in the major part of the horizon in which navigation is interested, it is sought to divide them up into three single large groups:

(1) Lights in which the flashes or groups of flashes are shorter that the eclipses,

(2) Lights in which the duration of the flash is equal to that of the eclipse, and,

(3) Lights in which the flashes or groups of flashes are distinctly longer than the eclipses.

In order to dispell any doubt regarding the category of a light as to whether it belongs to the first or the third group, all nations are prepared to adjust the lights on a ratio between flash and eclipse of 1 : 3 for the first group, and 3 : 1 for the third group.

It is obvious that the characteristic may not be reduced to those proportions in all lights without a more or less great amount of work. Much time will therefore elapse before the tendency will have found an integral realization. It is however important to take them into consideration, especially in new plants.

Another class of lights, which counts an ever-increasing number of applications, and which might be listed in the second group, is that of the isochronuous lights with a rapid rhythm (quick-flashing lights).

If it be borne in mind that the characteristic of the lights belonging to the three groups, while respecting the cited proportions, may have different rhythms and, thus, be confused (a flashing light of characteristic: light $0^s.3$, eclipse $0^s.9$ might be easily confused with a quick isochronuous light of light $0^s.6$, eclipse $0^s.6$), it is at once apparent that there should necessarily be laid down the minimum and maximum of luminous duration of the flash of each group. This is, in theory, an easy matter, but difficult to bring about in practice. Depending on the mode of thought of the individual lighthouse services previous to these tendencies the alterations to be introduced in the lighthouses vary in importance and cost. The proposals put forward in this sense at the Berlin Conference are extremely diversified and in many points widely separated from one another. Let us take one single example: In an effort to preserve the proportion 1 : 3 likewise between one class of lights and the other, and in order to eliminate every possibility of confusion between the normal and the rapid intermittent isochronuous lights, it was proposed to settle for the normal ones a maximum number of 20 apparitions per minute, and for the rapid ones a minimum number of 60 apparitions in the same lapse of time. According to the proposal, therefore, the rapid isochronuous lights cannot have a duration exceeding $0^s.5$. Lights as short as that are not realizable with all the sources of light: those with incandescent gas mantle, for instance, do not allow a lighting up for a shorter duration than about 2 seconds. The countries, therefore,which operate this form of illuminant on a huge scale, are not in a position to bring about, with the existing apparatuses, the required characteristics for rapid intermittent lights and would, in certain cases, have to undertake vast works of alteration. Standardization thus encounters practical obstacles of this kind.

The periodic meetings of the Directors of Lighthouse Services have, on the other hand, already begun to shape a mentality tending toward agreement, which, doubtless, will be reached on all basic points within a comparatively short time.

As far as nomenclature is concerned, this question also has needs to be brought up to date in order to express in adequate, clear, and intelligible terms the various forms of lights, without leaving room for doubt or confusion to arise. The bringing up to date is in progress in the various countries. It is natural that one should seek to avail one's self, as far as possible, of the old terms already familiar to navigators.

With regard to the nomenclature of the various countries, the expressions used in each language for the same kinds of lights are, therefore, as is logical, not literal translations, but terms which in each language best define the appearance of a given luminous characteristic.

## PART III.

a) *Permeability of the Atmosphere for white and coloured Lights, and corresponding Values of* ε *for the Determination of the Range.* b) *Use of yellow Light in Lighthouses.* c) *Tone of Colour, Saturation and luminous Permeability of coloured Glasses.*

Relative to item (a), up to now there are not available the results of a sufficient number of experiments to permit a definitive conclusion. The research work in this line is actively pushed by the lighthouse service of Germany. We would also mention, in this respect, the investigations of Illing and Wiedemann, and of Arndt. The first two investigators are concerned primarily with the determination of the value of $\alpha$ and $\beta$, which enter in the development of the previously-mentioned formula of Allard, extended to the range of coloured lights. The expression at issue is:

$$\beta\,\varepsilon = \frac{I}{1852^2\, t^2}\,(\alpha.\sigma)^{t}$$

in which I, $t$, $\sigma$ and $\varepsilon$ are the expressions already given to define respectively the luminous power for coloured lights in HK, the luminous range in nautical miles, the coefficient of atmospheric transparency, and the limit of perceptibility of white light ($\varepsilon = 2.10^{-7}$ lux).

The factor $\alpha$ is the ratio

$$\frac{\sigma_c}{\sigma} = \frac{\text{Coeff. of transp. for coloured light}}{\text{Coeff. of transp. for white light}}$$

and $\beta$ termed also *photochromatic proportion*, the ratio

$$\frac{\varepsilon_c}{\varepsilon} = \frac{\text{Limit of percep. of coloured light}}{\text{Limit of percep. of white light}}.$$

At the German lighthouse service there are now in progress investigations on the values of $\alpha$ for $\sigma$ varying between 0.1 and 1.0 for all colours of the spectrum.

With regard to the determination of the values of $\beta$, i.e. of the photochromatic proportion, other series of investigations have been inaugurated. The first results, not yet confirmed, have given for Standard red-coloured and green-coloured glasses of the German service, the following results:

| Colour | TOTAL PERMEABILITY | | Wave-length Tone of colour $m\mu$ | $\beta$ |
|---|---|---|---|---|
| | Flimmer photom. | Visual comparison | | |
| Red ........... | 22.5 | 22.7 | 616 | 2 approx. |
| Green ......... | 11.1 | 11.7 | 532 | 12.5 approx. |

Also remarkable are the investigations of Arndt on the value of $\varepsilon$ absolute, (i.e. for white light), accommodation of the eye to complete obscurity and for visual angles inferior to 1°.

Arndt has found $\varepsilon_{abs}$ = const. = $10^{-9}$ lux. This value of $\varepsilon$, while answering, as regards the visual angle, to the actual conditions in which the navigator views the optical system of a lighthouse, cannot, of course, be integrally applied in practice, as long as the eye of the navigator is not in the condition of absolute ambient obscurity, or exactly oriented in the direction in which the lighthouse should appear, or is thoroughly trained to this kind of experiment, and, lastly, is not, as often happens inconvenienced by atmospheric influences.

A great many experiments reproducing as far as possible the various conditions under which the eyes of the navigators are placed will, therefore, still be necessary to arrive at the determination of actually serviceable mean values of $\sigma$ , $\varepsilon$ , $\alpha$ , and $\beta$ .

The researches for $\varepsilon_{c\ abs}$ have already led to important findings, as for instance, that by using a normal red glass for lighthouses, the luminous density of the source of light must be, for red, 70 times that necessary for obtaining the same results with white light. We have here, of course, to do with laboratory researches, in which the illumination of the field (a circumstance always existing in practice) is lacking, and with observations at the limit of the luminous range, i.e. when the colour is not yet discernible, but only the luminosity. Thus, none other than theoretical values, which may nevertheless serve as a basis for future experiments.

At the coming conference, important novelties will no doubt be brought to light on this point, owing to the fact that part of these investigations are being conducted employing the metal vapor lamps as luminous sources.

## USE OF YELLOW LIGHT IN LIGHTHOUSES.

André Blondel, the illustrious French scientist who passed away lately, concerned himself, among many other things, with this problem also. In his work "On the use of yellow screens in maritime and aerial lighthouses" he proposes equipping the more powerful lighthouses, as well as the lighthouses of maximum range, with screens which absorb the violet and ultra-violet radiations, with a view to eliminating the danger of dazzlement in the areas adjoining the lighthouses themselves. For harbour lights, Blondel proposes also yellow screens, but rather for a better distinction of these lights from the common land lights, than for the dazzling effect.

The tinting may, of course, be obtained either by employing tinted lenses, tinting the bulbs of the electric lamps, or using coloured glass sleeves. Blondel has carried out extensive studies on the yellow colour of light, which have already borne remarkable fruit. The most suitable tone appeared to be, not the golden yellow (amber colouring), because of its greater light absorption, but rather the canary yellow (jaune serin) produced by seleno-cadmium glass, which, depending on the type, absorbs all the radiations from 450 to 475 $m\mu$ .

The investigations were conducted employing two kinds of glass of a luminous permeability of 75 and 60 % respectively. Always on the basis of Blondel's researches, it is now known that the lessening of the luminous range of a light in clear weather is of the order of 10 to 15 % respectively.

As for $\beta$, i.e. the above-cited photochromatic proportion ($\beta\ \frac{\varepsilon_c}{\varepsilon}$ ), the same is true for the two glasses of 46 and 50 respectively. In other words, one must multiply $\varepsilon$ and, consequently I, by 46 and 50 respectively, in order that the luminous zone, reduced to extremely small dimensions, should still appear coloured. By means of artificial fog (soapy water), which reduces the range of white light by 50 %, Blondel was able to verify that the yellow screens have but an extremely slight influence on the range, whilst $\beta$ increases rapidly to the values of 225 and 290 respectively. He concludes therefore that the greater $\beta$ , the more a coloured light behaves like a white light at great distances. The yellow tint hence precludes that in case of a fog the light may be confused with the red, as occurs occasionally with wick petrolium oil lights.

At the Berlin Conference there were cited yellow lights already in operation for several years with satisfactory results. One of these is the landfall light of the Schleimünde harbour, in operation since 1929 and equipped with a yellow screen of transparency 60 %. Another example of the use of yellow light is on Lake Zürich, where the landfall places of the Routes Communication Service (3 1/2 km.) are signaled by sodium vapor lamps, which, as is known, yield a monochrome yellow light. The lamps in question are visible, with the local fogs, at 100 m. by night and 60 m. by day. It should be noted that these are lamps of low intrinsic brilliancy and devoid of optical apparatus.

The French lighthouse service intends to install in the port of Dieppe, for experimental purposes, two lights of equal luminous source and of same intensity. One of them will be left white, whereas the other will be provided with a yellow glass. The captains of the cross-channel ships will have to make a decision in favour of the one or the other light.

The question of yellow light in lighthouses is a question which is at present in its beginning only. For this reason there still lacks a complex of data which it will not be possible to obtain otherwise than by a great number of tests and experiments, above all practical. The opponents of the yellow colour obtained by means of screens argue, in substance: 1°) that it is not as yet definitively proved that yellow light (of a tone such that it does not absorb a greater proportion of light than that enunciated), dazzles less than white light. 2°) That the yellow screens absorb a part of the energy emitted, and, consequently, diminish the luminous range of the lighthouse. Such fact is important, especially in the larger lighthouses where it is necessary they be sighted from the maximum possible distance. 3°) That the yellow screens cut away from the light emitted by the lumiminous source, that portion of blue radiations which in the powerful lighthouses are sighted at the greatest distance, and often in the shape of a glare, even beyond the geographical range.

What may now be said on the argument may be summarised as follows:

1°) The yellow tint does not seem suitable for the more powerful lighthouses of which the whole of the luminous range should be fully utilized. It would, in effect, cut away a valuable fraction of light, and, on the other hand, such lighthouses are so tall, that in their neighbourhood, i.e. in the zone in which the danger of dazzlement would be greatest, the light beams pass above the navigator.

2°) It is maintained, per contra, that the yellow tint is susceptible of yielding good results in its application to less powerful lighthouses,which may be those of secondary ports. dykes and moles (piers). The latter being lower and the navigator passing, as a rule, in their immediate vicinity, the danger of dazzlement is greater, while the use of their full range is generally not of fundamental importance. It should be added that a great many navigators, such, for instance, as the fishermen, care much more for the colour of a luminous signal than for its characteristics. Yellow enables the light to be readily distinguished from the many white lights generally displayed on shore, and nothing necessitates recourse to red or, worse still, to green, both of which absorb extremely high amounts of light.

A typical example of this second case is given by the lighthouse at the head of S. Vincenzo pier. The same, as is known, displays a flashing light and is of moderate luminous power; it has to serve the whole of the Gulf of Naples, and must supplant the strong city lights. Its height is such that the navigating bridge of a medium-sized vessel lies on about the same level as the optical system. It follows that the incoming and outgoing vessels, which have to pass at a very short distance from the lighthouse in question, are dazzled by the flashes during the manœuvre which requires much caution on account of the intense permanent local traffic. A yellow screen applied to this lighthouse, by way of experiment, might furnish valuable information.

## TONE OF COLOUR, SATURATION AND LUMINOUS PERMEABILITY OF TINTED GLASSES.

Regarding this item, of appreciable importance, are three papers presented at the Berlin Conference, *viz:*

A paper by Holmes entitled "Coloured glasses for lighthouses", one by Illing and Feyerabend entitled "Normal red and green glasses for lighthouses", and, finally, a work by Blondel entitled "Method for the comparison of tinted glasses for lighthouses by means of punctiform lights produced in the laboratory".

The first work, i.e. that by Holmes, gives a brief description of the modern methods for the measurement of colours and shows, by illustrated examples, the influence of the luminous source employed (*temperature of the colour*) on the total luminous permeability (transparency) of the various glasses made use of, as well as on the saturation and position of the resultant colour in Maxwell's chromatic triangle. Referring to Blondel's experiments, the author emphasizes the difference of limits of perceptibility ($\varepsilon$) with a sharp perception of the colour and without perception of same, and the importance of this phenomenon in regard to the luminous range.

As had already been found in the course of the Paris (1933) Conference, the various lighthouse administrations do not employ the same tints in their coloured glass, and neither does there exist a uniform method of determining the acceptable limits of tolerance of the glasses. At the instigation of the Chance brothers, manufacturers of glass and crystal, a questionnaire on the glasses in use was sent, subsequent to the 1933 Conference, to all the lighthouse administrations which had attended the Conference. In Holmes's work is to be found a summary of the replies, supplemented by the author's own experiments. This is a really valuable chapter, rendered more interesting still by a comparison with the data furnished on tinted glasses by railway and air-line administrations. At the end Holmes cites a requisite series of red, green and yellow glasses, quoting their advantages and disadvantages.

His investigations resolve into a few proposals which aim at:

(1) The application of a standard method for the determination of the colours.

(2) The standardization, or at least an approximation, of the specifications and requirements of the particular individual lighthouse administrations as regards the total transparency and the tint of the coloured glasses.

For the determination of the colour, Holmes employs the trichrome method set down in 1931 by the International Commission on Lighting, according to which each colour is determined on the basis of the three coordinates of its point in the chromatic triangle. The "tone of colour" is defined by means of the wave-length in a m $\mu$ of the corresponding spectral colour, and the saturation by means of the density of the spectral colour. The latter factor is of outstanding importance, because it conveys a precise idea of the degree of purity of the tint, or of the proportion with which the spectral (pure) tint enters in the composition of the global colour.

The coloured glasses produced by the glass-works ought, therefore. to be inspected (by comparison with sample glasses, limits), either spectrally, or, as regard the total luminous permeability, with luminous sources of a temperature of 2360° K.

On the basis of his studies, Holmes proposes the following limits as the best for the red, green and yellow colours of the screens to be used in lighthouses:

Red for lighthouses

2360° K

$\lambda > 0.610\ \mu$
$y < 0.334$
$z < 0.010$

(Colours with $\lambda < 0.610$ are not reliably defined as *red,* but rather as orange coloured in certain cases).

Luminous permeability $\tau$ and saturation { spectral chromatic density $p$ / spectral chromatic proportion $\sigma$ }

| Sort of glass | LIMITING VALUES OF $\tau$, $\delta$ AND $p$ WITH | | | | | |
|---|---|---|---|---|---|---|
| | Petrolium oil lamps | | | Acetylene gas, electric incandescent, and P.V.I. lamps | | |
| | $\tau$ % | $\delta$ % | $p$ % | $\tau$ % | $\delta$ % | $p$ % |
| Selenium ruby red...... | 15-34 | 100 | 100 | 15-30 | 100 | 100 |
| Gold ruby red........... | 15-25, 8 | 94-98 | 93-97 | — | — | — |
| Copper ruby red........ | 15-19, 8 | 98-99 | 97-98 | — | — | — |

Green for lighthouses

2360° K

$y > 0.385$ (limit towards blue)
$x < y - 0.140$ limit towards white, and
$x < 0.333$ limit towards yellow
$\lambda$ between 0.495 $\mu$ and 0.553 $\mu$.

| Sort of glass | Petrolium oil lamps | | | Acetylene gas, electric incandescent, and P.V.I. lamps | | |
|---|---|---|---|---|---|---|
| | $\tau$ % | $\delta$ % | $p$ % | $\tau$ % | $\delta$ % | $p$ % |
| Copper green............ | 10-24.8 | 25-36 | 44-58 | 10-28 | 27-38 | 47-58 |
| Chromium green......... | 10-14.5 | 80-84 | 92-94 | 10-18.5 | 80-84 | 92-94 |

Yellow for lighthouses

2360° K

$y$ between 0.402 and 0.430
$z < 0.010$
$\lambda$ from 0.589 to 0.594 $\mu$.

| Sort of glass | Petrolium oil lamps | | | Acetylene gas, electric incandescent, and P.V.I. lamps | | |
|---|---|---|---|---|---|---|
| | $\tau$ % | $\delta$ % | $p$ % | $\tau$ % | $\delta$ % | $p$ % |
| Yellow for signals (selenium-cadmium) .... | 70-78.8 | 94-98 | 93-97 | 59-68.8 | 99-100 | 98.5-100 |

In the work of Illing and Feyerabend on normal red and green glasses for lighthouses, these authors give a description of the normal glass used by the German lighthouse administration. The data, which refer to the co-ordinates of the chromatic triangle $\lambda$, $\tau$, $\sigma$ and $p$. and those regarding the spectral composition of these glasses, are determined for the temperatures of the luminous sources employed at the lighthouse administration, i.e. from 2160° K to 3160° K. The normal green glass is a glass ranging between copper green and chromium green, the red glass a selenium glass. The luminous permeabilities vary, depending on the temperature of the luminous source, between 8.7 % and 11.2 % for green, and between 18 % and 24 % for red.

The method of testing and of measurement in use is based on the norms for the "Evaluation and measurement of colours". extracted from the German industry norms (D.I.N.). Temperature of reference 2848° K.

The efforts of the German lighthouse administration are directed towards the search for green and red glasses which, with the same luminous source, have approximately the same luminous range. This takes for granted that the elements which define such conditions. *viz.:*

(a) The total transparency.

(b) $\varepsilon_c$ with clear chromatic perception, and

(c) the coefficient of atmospheric transparency $\sigma$,

have practically the same values. both for red and for green.

The first part of Blondel's work is dedicated to the examination of the coloured glasses for lighthouses, and, in it, the author develops the physiological bases for the measurement of the coloured points of light, and describes in detail the working of the eye and its constitution. The physiological phenomena which emerge therefrom are gone through, one by one, in the most comprehensive manner.

The author arrives at the conclusion that the common systems of measurement of coloured points of light are fraught with serious obstacles, on account precisely, of the difficulties of a physiological order which are met with in practice. He sees the solution of the problem in the development of a method of measurement permitting the determination of the transparency, wave-length and saturation, which meets the particular requirements of the lighthouse administrations, without incurring the errors deriving from the difficulties of a physiological nature, and which, at the same time, would render possible the evaluation of the photochromatic proportion and of the behaviour of the coloured rays in foggy atmosphere. (It is recalled that by photochromatic proportion should be understood the factor by which it is necessary to multiply I in order that the point of light which, at the limit of perception, appears to be grey, should acquire a first sign of colouring). In fact, the knowledge of the elements $\tau$, $\beta$ and $\sigma$ is necessary, in order to be able to obtain some idea of the range of a coloured light.

The second part of the work is devoted to the description of an instrument designed and constructed by the author himself a few years ago and gradually improved.

The instrument in question is the "photomètre comparateur" which makes possible, in a very simple manner, the determination of the transparency of a coloured glass, of the photochromatic proportion, and of the length of the emitted luminous wave.

The latter value enables even the degree of chromatic purity, or saturation to be ascertained. The instrument, in contrast to what occurs in the photometric systems in which luminous *surfaces* are compared, compares *points of light*, which are made to appear for a very short time (less than $1^s$) only, so as to prevent the eye from having the possibility of shifting the image to the periphery of the retina.

With the aid of his "pharomètre", this French scientist also carried out interesting experiments on the passage of the coloured rays through soapy water, which, as regards its practical effects, is a good substitute for a foggy atmosphere.

Discussions and attitudes in connection with the above-mentioned work have not been wanting. The trichromatic process, as Blondel himself emphasized, is by no means free from defects, the cause of which resides primarily in the uncertainty of the international curve of the ocular sensitiveness; nonetheless, the existence of a specific and objective method for the evaluation of a colour, seems to be such a valuable factor, that its acceptance is justified, even though it should be affected with a few shortcomings. It is desirable also that a standard definition of the saturation be agreed upon, tied, as already stated, to the value of $\beta$. The German norms for instance, discriminate, in the saturation, between the "spectral chromatic proportion", defined by

$$\sigma = \frac{y - y_b}{y_s - y_b}$$

and the "spectral chromatic density", expressed by

$$p = \frac{y \ (y_s - y_b)}{y_s \ (y - y_b)}$$

in which $y$ is the green co-ordinate of the point of colour (in the trichromatic system), $y_s$ that of the corresponding wave-length $\lambda_c$ of equal tone, and $y_b$ that of the Standard white ($y = 0.333$).

The limits proposed by Holmes for the red, green and yellow colours, in regard to the position of the points of these colours in the chromatic triangle, are accepted generally; the characteristics of the tinted glasses adopted by several lighthouse administrations are already included therein. The sole questionable value perhaps is that which delimits the clear red. Holmes proposes 610 mμ, whereas, according to the belief of others, 615 mμ might perhaps be better, in order to exclude more positively any possibility of confusion with the orange colour. Such contingency was emphasized by a Dutch sub-committee of the International Commission on Lighting, as a result of experiments executed by a great many observers. Once the limits for each of the three colours laid down in an unequivocal manner, the method for determining the elements $\tau$, $\lambda$ and $\sigma$ would not need to be standardized and might be left free to each State. Holmes selects for each colour two pairs of limiting screens (one towards the light tone, the other towards the dark tone), exactly, one pair for luminous sources from 1900° to 2360° K the other for temperatures ranging between 2360° K and 2848° K. The German lighthouse board, on the contrary, utilises for each colour and all temperatures one single sample screen of mean luminous permeability, with reference to which fixed tolerances have been laid down.

The testing of the tinted glasses by visual comparison can be but a makeshift. The use of the trichromic method, especially for the recording of a curve of the transmission for the various temperatures, seems inevitable, in general, but is important chiefly for green, in order to judge of the spectral shape and behaviour of same with foggy atmosphere.

The determination of the total luminous permeability is of high economic value, inasmuch as this factor influences in a decisive manner the energy which the source of light should emit in order to obtain a given range. The glasses recommended by Holmes are spectrally well separated from one another, from the white and from the yellow. It seems on the other hand still questionable whether it will be possible to find a yellow zone permitting a trustworthy distinction from the red and the green. In a foggy atmosphere, in fact, certain tones of yellow may turn to red, and sometinmes the white to yellow. The conclusions arrived at by Holmes agree, to a great extent, with those of Trinity House, particularly as concerns the clear limit of green, which must be discernible from white, the latter being sometimes rendered greenish by the nature of the luminous source and by the effect of the optical apparatus, whose crystal may tend towards green.

Independent of the various methods for the determination of the quality of the tinted glasses, the intricate problem of the colouring of the light of lighthouses may be summarized as follows:

A scheme or definition, by means of which the lighthouse engineers throughout the world may be assured that a certain glass has a definitely determined appearance when used with a given luminous source, is necessary.

Practically, this means the possibility of being able to say to the navigator: a glass with such and such a characteristic is undoubterly red, and another glass undoubtedly green.

## PART IV.

## PROGRESS IN THE DEVELOPMENT OF ELECTRIC INCANDESCENT LAMPS.

The lamps now in service in the lighthouses belong, as regards characteristics, to a very great number of types.

The filaments are of extremely varied shape, the supply voltages oscillate between 6 and 220 volts, and more, the cross-sections of the filaments vary within very wide limits. There exist lamps constructed to replace the petrolium oil vapor incandescent luminous source, the filament of which resembles a large cage with approximately the shape and dimensions of the grid (mantle) of the P.V.I. apparatus, lamps with cylindrical filament and vertical axis, others with truncated cone filaments, and so on.

In recent years, as a matter of fact, progress in this domain has been made by trials. Now there is beginning to predominate a type of filament which, maybe, will finish by asserting itself victoriously for a while. *viz.*, the double-spiral filament, twisted so as to form a cylinder with a horizontal axis. The Lighthouse Board of the Netherlands has been using such lamps for some time in the revolving optical apparatus, with very promising results. The types chosen and in service are two, *viz.*, one of 2 KW fed from a 60 V supply, the other of 4.2 KW, fed from 70 V. The same have a luminous output of about 20 Lm/Watt, with an average life of 800 hours.

The investigations of late on the lamps have borne on the increased valuation of certain factors which have a decisive nfluence on the output of the lighthouses, namely:

(1) The luminous power of a panelled optical apparatus, for a parity of energy expended

depends on the ratio $\dfrac{\text{intrinsic brilliancy}}{\text{dimensions of the lum. source}}$.

It follows that the shape of the electric incandescent body should be reduced as much as possible. The condensed shape of the filament permits, furthermore, also a greater development of the temperature and affords a higher protection against caloric losses. The reduction must naturally be contained within limits such that they do not excessively lessen the amplitude of the light beams.

(3) The luminous power and the life of the lamps increase with the increase in thickness of the filament. With stout filaments therefore, the duration of their life being maintained invariable, it is possible to obtain a better luminous efficiency. The use of filaments of large diameter affords, besides, the possibility of reducing the voltage of the supply current. Stout filaments withstand high charges and permit, for a given number of Watts, a reduction of voltage. The importance of this factor is obvious. If, for the above-mentioned reasons, the filaments are wound in closely-spaced turns, with the increase of the tension the danger also increases of the occurrence between two adjacent turns of ionisation of the gas which fills the lamp, thus causing an arc discharge and the destruction of the lamp itself.

It is known and proven, that for each power of lamp of a given category, there exists only one optimum supply tension. From the point of view of output, it does not therefore appear to be advisable that a uniform voltage be adopted for all lighthouses, but that, instead, the supply voltage bear a definite relation to the lamp employed. It is easy, by means of transformers, to obtain any desired voltage, and at the same time to reduce the number of types of lamps to a very few.

Voltages which numerous experiments have shown to be an optimum for the various luminous powers are, for instance, 24 V for 1000 W, 60 V for 3000 W, 70 V for 4200 W.

The progress in the realm of electric incandescent lamps for lighthouses may be summarized as follows:

(1) The use of stout filaments able to withstand charges up to 95-100 Amp.

(2) The adoption of the double-spiral winding forming a cylinder with horizontal axis.

With such a form the upper part (catadioptric) of the large optical apparatuses receives a much greater quantum of light than with the old lamps, thereby realizing a considerably greater luminous flux in each beam emitted

## PART V.

## USE OF METAL VAPOR LAMPS.

The gas-filled discharge lamps, such, for instance. as the well-known "neon tubes" of the luminous display signs, have found but scanty application in the domain of maritime and aerial signalling.

This is largely due to their faint intrinsic brilliancy (0.2 HK per sq. cm., against the 2.3 HK per sq. cm. of the plain wick kerosene lamps), a circumstance which practically excludes this kind of illuminant. It seemed therefore as though the gas-filled discharge lamps were to be debarred outright as illuminants for lighthouses. In 1933, however, through the labors of Bol, a high-pressure mercury vapor lamp was developed, with which, within recent years, considerable progress has been realized. Two large firms produce, at present, lamps of this kind on a large scale. The intrinsic brilliancies of the arcs of discharge in mercury vapor (with pressures up to 100 atmospheres) attain extremely high values (up to 40,000 HK per sq. cm.), with luminous outputs of the order of 60 Lm/Watt, hence more than gratifying results, which have induced, for some time already, a study of the application of these lamps to lighthouses. Of the two lamps developed commercially, one has a discharge water-cooled quartz cylinder, the other a discharge quartz involucrum without any special cooling.

One of the difficulties encountered consists of the extremely minute dimensions of the arc of discharge, which, in one case, is of 12.5 × 1 mm., in the other case, of 4.5 × 1.5 mm.

By applying such an illuminant to an ordinary revolving optical apparatus, light beams of an extremely narrow aperture would be obtained. The horizontal spreading would thus be distinctly insufficient and the flashes would be of such reduced duration that they would lose in effective intensity and would not reach their maximum. We are, as a matter of fact, already in the domain in which $I_{eff}$ diminishes proportionally to the time.

Should mercury vapor lamps with extremely high pressure actually show. with incresed knowledge, that they possess the requisite requirements for their employment in the lighthouse services, it will be necessary to resort to systems apt to create an artificial dispersion of the light. In consideration of this fact, either a grouping of various lamps, each provided with a condensation lens or with a parabolic mirror, or the use of ground lenses with a dispersive profile, or, again, the insertion of dispersing prisms would be indicated.

The largest lamps of the kind produced up to now are of 500 W, with a supply voltage between 400 and 700 V. If it were proved that serious difficulties impede the construction of higher-powered lamps, it would be necessary, for this reason also, to have recourse to the grouping of more lamps together, seeing that in many cases much larger quantities of radiated energy are required in the lighthouses.

One of the objections urged to high-pressure metal vapor lamps is the possibility of explosion and hence the danger in the use of same. This objection seems, however, invalid since opportune examinations and precautions in handling will reduce this danger to acceptable proportions.

Formidable competitors of the cited kind of lamp are doubtless to be seen in the new high-efficiency arc lamps that have been introduced recently in several French lighthouses. The same provide some 50,000 candles per sq. cm., with a crater 32 m/m wide; hence an intrinsic brilliancy superior to that of the most progressive highly-compressed metal-vapor lamps.

## PART VI.

## THE OPTICAL APPARATUSES AND THEIR ACCURACY.

It is known that for the concentration of light in the lighthouses, plano-convex lenses constructed on the Fresnel system are almost exclusively used. In order to give the rays issuing from the focus of the lens a direction parallel to the optical axis of the lens itself, the latter should have an external profile in the form of a spherical curve. But, for practical structural reasons, there have in actual fact, been chosen for the external profile of the lenses the arc of a circle. Consequently, the major part of the rays issuing from the lens is affected with deflections and hence with the so-called "spherical aberrations", whose essence and direction depends on the radius and the position of the centre of curvature. These two factors are, as a rule, so selected that, in each element of lens, positive and negative deflections arise, the algebraic sum of which may be reduced to a minimum. Positive deflections are those towards the optical axis (convergent), negative those which tend away from the axis (divergent).

As regards the catadioptric parts of the optical system, the same should, on the basis of Körte's fundamental studies, have concave profiles on the ingress and exit sides, and convex ones on the reflecting side. The theoretical profile of the convex reflecting side. approximately and arc of ellipse, is, here also, for structural reasons, replaced by the arc of a circle. The aberrations which ensue therefrom are, anyhow, very small; such, in effect, as not to exceed the maximum aberrations compensated by the dioptric elements. One has therefore abstained from any particular compensation of the catadioptric elements, which, consequently, impart exclusively negative deflections.

The tendency to diminish the number of elements of the optical apparatuses, in order to augment their soundness and reduce their price, finds naturally a limit in the necessity of reducing the aberrations to a minimum.

Next to the errors which are involved by substituting for the exact theoretical lenticular profiles those of an arc of circle, there are the inevitable errors due to the manufacture. With the methods now practised, this latter error does not, as a rule (and according to the accuracy required), entail deflections which differ by more than 40' from the calculated deflections. It is possible, without special structural difficulties, to obtain departures of not more than 20', and in special cases an accuracy of even 4'. (A deflection of 40' yields on a screen perpendicular to the optical axis of the lens, and placed at 1 m. distance from the same, a linear departure of 12 m/m). It should be observed that the same accuracy is not always required for the dioptric elements as for the catadioptric ones.

It is important now that we should seek to determine what should be the accuracy of the lenses, seeing that the linear dimensions of the modern sources of light, already reduced as compared to the older ones. will tend, for multifarious reasons, to diminish still further. To regulate the accuracy of grind on the required angle of aperture of the luminous beams and on the dimensions of the incandescent body only, does not seem excessive. None of the luminous sources in use today have, as a matter of fact, a spherical shape, i.e. a shape such as to present the same appearence in all directions.

The lens is, hence, unable to yield the same accuracy of emergence in all its surface or height. The question cannot therefore be given an answer of a general character. but has to be dealt with in each individual case, in relation to the particular requirements of the individual signals, to their importance, and to the shape of the luminous body.

Some special types of lenses will obviously have to be produced for aeronautical lights, or for those lighthouses which are to serve both for maritime and aerial navigation. It is beyond doubt that, owing to the extremely reduced incandescent surface involved, the luminous sources constituted by the high-pressure mercury vapor lamps, will create new problems in the construction of the optical apparatuses. In fact, the duration of the flashes of the revolving apparatuses must not fall below a certain minimum of about $0^s.35$. From shorter flashes the eye catches but a part, for which reason, at a certain point, the quantity of light sighted and thus useful, diminishes in proportion to the diminution of the duration of the luminous flash. All that which on the one side is gained with the greater intrinsic brilliancy, is therefore lost in the incomplete ocular perception. It should also be realized that the luminous intensity of the beams emanating from the revolving optical system is not uniform, but is actually a maximum towards the centre and a minimum at the edges. The observer stationed towards the limit of range of the lighthouse sights therefore only the central part of the luminous beams, the peripherical part having been absorbed along the trajectory. There exists hence a certain distance from the lighthouse, beyond which the duration of the flash diminishes gradually. The law according to which this diminution takes place depends substantially upon the degree of accuracy of the lens, upon the shape of the lens in relation to the shape of the illuminant and the dimensions of the latter.

## PART VII.

## UNWATCHED LIGHTS AND LIGHT-BUOYS.

The systems of lighting at present in use in unwatched lights and in light-buoys are varied and may be grouped as follows:

(1) Electric lighting:

(*a*) with connection to the normal power system (mains);

(*b*) with feed supply by means of dry or wet cells, or batteries.

(2) Gas Lighting:

(*a*) with naked flame by acetylene gas;

(*b*) with incandescent mantle, using one of the following gases: oil gas, Blau oil gas, Pintsch gas (liquid), B.B.T. gas (catalytic gas), acetylene and propane.

The electric lighting of lighthouses with connection to the normal power system (mains) is taking on increased importance. This is largely due to the ever-greater degree of reliability reached by such system in the course of years, and to the creation of better adapted lamps.

The unattended lights of this kind (and of these there exist, especially in America, quite powerful and important ones) naturally require a few safety devices which necessarily complicate them, thus increasing the cost of the plant, as well as the maintenance of same. Total safety may now be said to have been practically achieved, because of the numerous existing improved devices for the automatic changing of the lamps. Of these some contain as many as 6. In case of failure of current in the system, the lamp is automatically fed by a battery or by internal combustion engines. The latter are always two in number, one being in reserve, and entering automatically into operation when the first stops due to a breakdown. Other systems provide automatic substitution of gas for the electric luminous source.

The long-life dry-cell and accumulator systems have been particularly well developed. The "Wallace and Tiernan" system, for instance, has recourse to two properties of the low-power electric light for obtaining very long charges, *viz.*:

(1) The possibiliiy of very small ratios of characteristic (i.e. characteristics of the order of 1/20: light $0^s.1$, darkness $2^s.0$).

(2) The great intrinsic brilliancy of the incandescent filament.

But, given the necessarily extremely reduced dimensions of the latter, the dispersions are proportionally small. This precludes, at least for the time being, the use of such systems in light-buoys in which, on account of the rolling, rather great vertical dispersions are essentiel, *viz*, of the order of 8°. For buoys which, by their location, are much subjected to great oscillations, it is hence impractical to adopt very short flashes, because many of the flashes emitter with the inclined optical apparatus will not reach the eye of the navigator.

For terra firma lights, on the contrary, the possibilities of the system are good, as proved by the many plants in operation. The small motor for the characteristic does not consume more than 40 Watt-hour in the year.

The naked flame acetylene gas light is indisputably the most widespread form of lighting for unattended signals. This is due to the well-known qualities, to the reliability of operation, and to the possibility of use of the naked acetylene gas flame. The only two disadvantages of this gas are the following:

(1) It is more costly than the other gases mentioned at the beginning of his chapter.

(2) It requires more precautinos in use, especially in warm climates.

Oil gas is being gradually eliminated from the lighthouse services of all States and is therefore excluded from the new plants, principally on account of the difficulty of its transportation. Pintsch gas. Blau oil gas and B.B.T. gas, according to the heads of the lighthouse boards of the various States, are practically equivalent. Slight differences in cost are, in general, compensated by corresponding difficulties of use.

The disadvantages generally claimed for these gases by supporters of the naked flame acetylene gas are:

(1) That they require the use of a mantle, the delicate point of a light, especially on buoys, which reduces the reliability of the light, the basic requirement for all maritime signals.

(2) That the mantle illuminants do not allow of very rapid characteristics.

But, by statistics, we find that the danger of breakage of the mantle is now-a-days very slight. The Lighthouse Administration of the Netherlands, in many years of operation, has ascertained that each buoy did not require, on the average, more than two mantles per annum, including in this number the mantles (and these are quite numerous) which break at the moment of mounting them in the light. If it be considered that the Dutch buoys are among those most subjected to sharp and ample movements on account of being moored in shallow waters, it may be said that this speaks in favour of gases more economical than acetylene.

The last-comer of the series is propane, a gas which seems likely to have a great future, although ,until now, more precise data and thorough knowledge regarding the decanting of this gas from one container into the other are lacking. Owing to its higher specific gravity than that of the other gases, propane requires also a greater quantity of air for its combustion. This factor entails, consequently, an alteration of the burners in service.

Propane is a very economical gas which may be produced in various manners. All the crude oil refineries are in a position to supply it in large quantities. Its utilization in maritime lights can naturally only be realized by accumulating it in the liquid state. Propane offers above all the advantage of a low weight for its container and the possibility of accumulation in large quantities for each litre of capacity of same. Experiments of control of buoys have shown that in temperate climates, in the height of the summer, tanks constructed for a service pressure of 9 atmospheres, owing to the refrigeration of the tank by the water, may be loaded without danger with 40 kg. (88 lbs) of liquid propane per cubic metre of capacity.

A glance at a diagram showing the trend of the pressures in relation to the temperature shows that with 20 kg. (44 lbs) of propane per cubic metre, for example, the pressure of the vapor rises swiftly up to 26° C, when it is of about 9 atmospheres. From this temperature, the liquid being totally vaporized, the pressure increases but slowly, exceeding only slightly 10 atmospheres at 65°. The same diagram shows also that for loads inferior to 10 kg/cubm., propane yields practically 0° of temperature in excess, is always in the gaseous state with pressures varying from 3.6 atmospheres (at 0°) to 4.8 atmospheres (at 65°).

From a study made by the firm of Pintsch, in Berlin, on propane, some very interesting data are revealed on its use, and chiefly on the decanting of same, as well as on the method of measuring the residual content of a container. The decanting may be effected in three manners, *viz.:*

(a) Heating up the container to be emptied.

(b) By means of a pump inserted in the circuit of the liquid.

(c) By means of compressed gas which is caused to act on the surface of the liquid in the container to be emptied.

The first method has appeared up to now to be the less appropriate, because a great quantity of heat is squandered (about 1/3 of the total) solely to warm up the mass of the material of the container and the liquid part of the gas.

The decanting by means of a pump requires special machinery, due account having to be taken:

(1) That propane dissolves the lubricating oils.

(2) That the aspirating duct present no constrictions (in order to obviate heavy falls in temperature and possible formation of hydrates of propanol).

(3) That the valves be so contrived as to obviate any vaporization of the liquid.

(4) That the container from which the pump aspirates be placed at a higher level than the pump itself.

The third method seems, at least for the time being, to be the most convenient for the refuelling of the buoys.

For the measurement of the residual propane in the partially consumed bottles, there exist various methods which operate either with gas-meters or by means of gauge-tubes, or simply by counting the time the light was in service. The latter method can naturally only be applied to lights burning day and night and takes for granted that adequate allowances have been made for losses through all the joints in the piping.

At the time of the Berlin Congress, there were already in service a score of propane buoys between Belgium and Holland. Derangements occurred in diverse cases and were almost exclusively due to the low winter temperature of the North Sea. When introducing into the tank the normal quantity of propane (from 30 to 40 kg/cubm.), the following phenomenon is observed: the sea water being warmer than the superimposed atmosphere, the liquid propane in the tank attached to the buoy tends to escape through the tubing which leads to the lantern, thus finally reaching the pressure regulator. In the latter, consequently, extremely low temperatures are developed causing the formation of hydrates of propane which arrest the functioning of the apparatus. This inconvenience may however easily be remedied either by filling the tank to a pressure of three atmospheres only (all the gas being then in the vaporized state) if there be no impediment to the charge being reduced to three or four months, or by adding to the propane a chemical preparation of negligible cost which obviates the formation of the hydrates. Experiments are in course.

It cannot be doubted that the various drawbacks now still extant in the lighting with propane will. shortly, have been overcome and that in a comparatively near future it will acquire considerable importance in practice.

## NEW APPARATUSES FOR THE LIGHTING AND EXTINGUISHING OF UNWATCHED LIGHTS.

Few novelties are to be recorded in this field. The same are rather improvements and simplifications to the many devices already long in existence to create the intermittence of the various luminous sources susceptible of characteristic.

A new type of solar valve designed by the firm of Pintsch in Berlin deserves special attention. The innovation consists in substituting for the partly chrome-plated, partly blackened customary copper rods, wires of a special steel of high coefficient of expansion. The central wire, which replaces the blackened copper rod, is run in a glass cylinder with double walls, the space between which is evacuated. We have thus a Dewar vessel of cylindrical shape. That part of the inner wall which is turned towards the exterior is coated with a metal layer that strongly absorbs the caloric rays, thus causing the wire in the interior of the cylinder to expand. The advantages of the new apparatus consist in the reduction of the metal masses and the lesser time necessary for the heating up and cooling down. This sort of valve is less sensitive to shocks and is speedier in its action than the ordinary valve.

## PART VIII.

## USE OF THE LIGHTHOUSES BY DAY.

The question of the use of lighthouses during day-time in misty or foggy weather has been the subject of discussion on various occasions, both by navigators and the heads of the maritime signalling administrations. With some States, in actual fact, the light-vessels and lighthouses light up their lamps also by day, or at least some time before sunset, when the fog sound signals are in operation. In some cases, effectively, the light is sighted somewhat before the sky-line of its building or vessel; but often also, particularly in the case of a not very powerful light, its sighting occurs simultaneously, if not immediately after, the sighting of the mole or pier of the structure.

A few years ago, Bloch determined that the sighting of a white light by day in *clear* weather requires a luminous power which, on the average, is about 400 times that which is necessary by night for the same results. If this result be extended to foggy weather, it follows, for instance, that a powerful lighthouse of 2,000,000 HK is sighted in relation to the density of the fog, by day, with $\varepsilon = 8.10^{-5}$ lux at the following distances only:

| Grade of fog | Diurnal visibility | $\sigma$ (per naut. mile) | Range, metres |
|---|---|---|---|
| Faint | 100 m. | $10^{-3}$ | 2300 |
| Moderate | 500 m. | $5.10^{-7}$ | 1200 |
| Strong | 200 m. | $2.10^{-16}$ | 575 |
| Very strong | 50 m. | $10^{-63}$ | 175 |

For a light of 10,000 HK only, ranges of approx. 1200, 700, 360 and 115 m. respectively would, on the contrary, have been obtained. With a very thick fog, therefore, the passing of 10,000 to 2,000,000 HK generates an increase of some sixty odd metres only in the range. These, of course, are approximate values, but which convey nevertheless an idea of the phenomenon.

Experiments have been attempted also with the infra-red rays of $\lambda$ lying between 1 and $2\mu$. These experiments show that such radiations have a greater power of penetration than white light for vapors only, but not for fog. This circumstance is, besides, explicable by the law of Rayleigh, according to which the dispersion of the luminous rays is inversely proportional to the fourth power of the wave-length, and hence the same is all the more reduced the longer the length of the wave. This law holds, however. only in the case in which the intercepting particles of moisture are small as compared with the wave-length of the radiation. And, as magnitude of the fog droplets. on the average, equal about 5 to 10 $\mu$, the above-cited law holds only if for the infra-red light $\lambda > 15\ \mu$. According to the investigations of Langley, however, layers of aqueous vapor of a certain thickness are impenetrable to waves of $\lambda > 5\ \mu$. It is therefore improbable that on these lines concrete results may be attained.

In the diurnal visibility in a fog some advantages may perhaps be realized by using, according to Blondel's suggestion, a spy-glass of high luminosity and magnification, but with an eye-piece of extremely small diameter (about 1.5 m/m). In this manner the illumination of the field adjoining the object is considerably reduced and the latter acquires an enhanced relief. The system will undoubtedly be perfected, when the relations between $\varepsilon$ and the value of illumination of the field shall have been more thoroughly studied. Studies in this connection were carried out in America by Langmeier and Westerdorp and in Germany by Bloch. Others are in progress presently at the firm of Philips. This is perhaps the only way in which it is possible to achieve some slight improvement of the visibility of lighthouses in a fog.

The possibility of increasing, even by one single nautical mile, this visibility, would already allow the ships to carry out the necessary manoeuvres to avoid a danger. The matter is all the more important as, at short distances, the function of the radio-beacons are in default. That would mean the filling in of a dangerous gap existing at present.

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