The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

ILLUMINATING ENGINEERING PUBLISHING COMPANY, LTD.

PUBLISHING OFFICES :—ATHENÆUM PRESS, 13, BREAM'S BUILDINGS, LONDON, E.C.
Tel. No. 2120 Central.

EDITORIAL OFFICES :—32, VICTORIA STREET, LONDON, S.W.
Tel. No. 5215 Westminster.

EDITORIAL.

THE message of Dr. Louis Bell, the president of the Illuminating Engineering Society in the United States, which we print in our present number, should be read with interest and encouragement by all those in this country who have the improvement of existing methods of illumination at heart. We do think that all, reading Dr. Bell's remarks, will agree with us that the record of the Illuminating Engineering Society in America, which has only been in existence for about two and a half years, is an exceptionally fine one.

It is not only to the exceedingly rapid growth of the society to which we would draw attention. It has already achieved solid, useful work which no other society was prepared to undertake. It has been the means of bringing together all the many trades and professions—architects, medical men, electrical and gas engineers, fixture-makers, &c.—who are interested in the subject of illumination, in order to work for a common aim. It has enabled the gas and electrical societies to come together and work in harmony, and one important result has already been brought about owing to such co-operation—namely, a temporary agreement upon a single accepted unit of light and the recognition of a single authority, the Bureau of Standards, as arbitrator in cases of dispute.

We must also express our admiration of the organized efforts of the society to promote the improvement of illumination in schools and public buildings. This is a subject to which we have already repeatedly called attention. The case of schools, in particular, demands the attention both of lighting engineers and medical authorities, and we have recently strongly advocated the systematic inspection not only of the eyesight of school-children, but also of the defective conditions of illumination which are admittedly partially responsible for the defects in eyesight, &c., known to exist. As an illustration of the evident desire on the part of engineers in the United States to keep in touch with the very latest developments, we may mention that Dr. Bell, among others, is paying a special visit to the chief European cities with the express object of studying the different methods of street-lighting.

Illumination from the Standpoint of Municipal Authorities.

In our present number we give an account of the recent lectures and demonstrations of the measurement of illumination at the Municipal Exhibition which was opened on the 1st of last month. The object of these lectures and demonstrations was to call attention to the need for consideration of matters in illumination on the part of the municipal authorities responsible for the lighting of our streets and public buildings.

Naturally our suggestions, while attracting some attention, have not escaped criticism, and one of our contemporaries comments upon the matter in the editorial remarks of two recent numbers. As far as we understand, it does not seem to be disputed that the objects that we have in view are good, or that illumination really does deserve very much greater consideration from the hands of authorities than at present. The only difficulty appears to consist in the problem of realizing the ideal conditions. In this connexion our contemporary remarks: "Municipal authorities are responsible for a great deal of artificial lighting......But there are few among the thousands of municipal councillors in this country who understand anything of the principles of illumination; and personal and municipal interests and official influences play a greater part now, and ever will do, than any scientific principles in determining the form of illumination to be applied in any place."

We of course agree that the principles of illumination are not as generally appreciated as we desire them to be; otherwise we would not be calling attention to the matter. It is unfortunately true that comparatively few of our municipal councillors realize the importance of good illumination, and the main object of the demonstrations described in this number was to draw public attention to the subject.

But we must also enter a protest against the assumption that because the present condition of things is unsatisfactory it is destined to remain so for ever. The mere fact of our having been invited to undertake the lectures and demonstrations referred to is in itself gratifying evidence that the importance of good illumination, from the municipal standpoint, is beginning to receive recognition; we only see in the present defective conditions an inducement to persevere in order that there may be improvement in the future.

No doubt, as our contemporary remarks, there are "walls of Jericho" to be overturned or pierced, and we are not so sanguine as to suppose that they will immediately succumb to the blast of our trumpet. We are aware that much patient work will be necessary in order to make any great progress. But 'THE ILLUMINATING ENGINEER,' aiming, as it does, at an impartial and international outlook, is at least unhampered by walls of its own making, and relies upon the assistance of many friends, in different camps, but all working for the same fundamental objects.

In the same way we cannot agree that because different people have different ideas as to what constitutes good illumination, therefore we should abandon our endeavour to come to some agreement on these questions of dispute. On the contrary, we only see in this fact a reason for gathering such people together in order that mutually conflicting views may be put forward and discussed.

If this is done we shall eventually come to understand what is essential in good illumination and what is not; if, on the other hand, we adopt a policy of *laisser faire*, naturally no progress will be made, and we shall merely continue to hear vague and conflicting statements on matters that have never been properly investigated.

While laying stress on the value of actual measurement and specification of illumination, we, however, have no desire to see any rigid system of measurement rashly and suddenly adopted. The matter requires careful consideration. Then by all means let it be carefully considered. But as long as the problem is shirked and the existing difficulties, instead of being inquired into and met, are regarded as insuperable, the details of the scheme cannot materialize. It is for the very purpose of discussing problems of this nature that we desire to see an illuminating engineering society established in this country.

And we can only feel that an engineer who dismisses the illuminometer as unworthy of consideration shares the prevalent want of knowledge of what has already been done in developing such instruments. We cannot agree that the use of an illuminometer, in order to test the actual existing illumination, can be anything but beneficial to the central station engineer in his dealings with the consumer. For he would then have at his command an actual test to prove beyond dispute that the illumination under actual conditions is as high as it should be. As long as we continue to rely upon ocular demonstration instead of actual measurement, he is at the mercy of a fluctuating standard in the mind of the public as to what is required. But when it has been definitely agreed that the illumination is not to fall below a certain value, the engineer is empowered to determine for himself by actual measurement whether the complaints of the consumer are justified.

The General Interest in Illumination.

We have occasionally heard laments that but little progress in arousing interest in the subject of illumination has been made in this country since the movement was first brought into prominence about two years ago. Those of us who have been following the development of interest in the matter closely have certainly no ground for complaint. The only wonder is that such gratifying progress has actually been made. The change in the general outlook has been so gradual as to escape the notice of those who have not been in a position to trace the slow but sure course of events. Of course such changes take place slowly, but it is right that this should be so. One has only to compare the contents of the technical journals of to-day with that of those of only two or three years ago in order to realize the increase in the number of those anxious for information on the subject. At that time articles dealing with illumination were few and far between; to-day the task of keeping in touch with the constant stream of literature dealing with one or other aspect of illumination is no light one, as we have good reason to know.

We naturally feel that the starting of our own journal represents a very great step in the right direction. Moreover even the non-technical reader has become aware of the importance of the subject of illumination, as those responsible for the organization of public lectures or demonstrations relating to lighting will readily agree.

Recent Progress in Gas and Electric Lighting.

The recent papers by Messrs. Handcock and Dykes and Mr. Hirst dealing with the metallic lamp situation afford evidence of the general recognition of the importance of these recent developments both to the electrical industry and the general public. We ourselves cannot believe that the introduction of more efficient means of producing light if properly handled can ultimately be anything but beneficial both to the consumer and the lighting industry.

One of the most gratifying features of the discussion of the latest paper mentioned was the emphatic condemnation of unshaded metallic filaments by several speakers and their realization of the fact, constantly urged in these columns, that the advent of the metallic filament lamp with its higher efficiency enables us to bear without flinching the relatively small loss in light caused by such adequate methods of screening the filament from the eye. Dr. Bell, indeed, paid a tribute to the growth of appreciation of this point in the United States when he declared that in that country none would now attempt to utilize metallic filament lamps without a suitable diffusing shade.

Those who were present at Mr. Hirst's paper could not fail to be impressed with the rapidity with which the situation has developed, but we question whether they could have fully realized the immense number of workers now engaged in the field and the great variety of metallic filament lamps which are either on the market now or likely to be shortly. It is wonderful to consider that in about two years we have seen the development of a metallic filament from a high C.P. low voltage scientific curiosity to a serviceable high voltage, and relatively low C.P. lamp claimed to be able to burn in any position.

Some of us, it is true, were aware of actual achievements of manufacturers in this direction very much earlier, but now they are actually on the market and available to all. Those who are in touch with yet more recent experimental developments can hardly doubt but that still more remarkable results will be achieved in the near future. In this connexion we may draw attention to the articles by Dr. Weber and Dr. Jacobsohn in 'THE ILLUMINATING ENGINEER,' in order to give some impression of the extent of the work that is being done and the immense number of important continental patents bearing on the subject.

When we bear in mind the number of processes which the metallic filament lamp must undergo before it arrives at its final state of perfection, and the great chemical and physical difficulties which they entail, one can only wonder at the ingenuity and scientific knowledge which have already achieved so much and are vanquishing, one by one, the existing obstacles. The contractor may well be dismayed at the ever-increasing variety of lamps at his disposal, and he is certainly in need of expert guidance to determine his choice.

Meantime those interested in gas-lighting have not been idle. The number of incandescent gas-lights available is increasing continually, and improvements both in mantles and in the direction of attaining higher pressures and the most perfect mixtures of gas and air, and utilizing this mixture to the best advantage, are constantly being made. The very complete description of the tests undertaken in connexion with the Scottish National Exhibition, which Mr. Herring has kindly sent us for inclusion in this number, contains a variety of information which will doubtless be found of considerable value by those who wish to form an estimate of the performances of different incandescent gas-lights under certain specified conditions. The article illustrates very clearly the constant efforts that are being made to improve incandescent gas-lighting and the large number of makes of lamps now available.

We make special comment upon the matter in order to illustrate the contention in the editorial of our last number, which those interested in electric lighting will do well to realize, that, while such great strides are being made in electric lamps, the development of gas-lighting is also proceeding rapidly.

LEON GASTER.

Review of Contents of this Issue.

Mr. A. P. Trotter discusses the various ways in which examples of STREET-ILLUMINATION MAY BE COMPARED. He treats the consideration of the average or mean illumination over an area by geometrical methods, and taking a simple theoretical case, and avoiding any difficult mathematics, shows how this mean may be calculated.

Dr. Louis Bell, the president of the Illuminating Engineering Society, contributes A MESSAGE TO THE READERS OF 'THE ILLUMINATING ENGINEER.' He explains how the recognized need for a body of men, well acquainted with all aspects of illumination, has led to the development of the Illuminating Engineering Society in America, and how the society has already been the means of bringing together those interested in all these many aspects.

He also cites some important results which have arisen through this cooperation, such as the agreement on a common standard of light, the promotion of an organized inquiry into the conditions of illumination in schools and other public buildings.

Prof. E. W. Marchant contributes a discussion of some recent experiments carried out with the object of comparing the merits of FLAME AND OTHER ARCS FOR EXTERNAL ILLUMINATION. He points out the great difference in the shape of the polar curve of distribution of light in the case of arcs having inclined and vertical carbons respectively, and shows how the merits of each system depend upon the conditions under which the lamp is to be used. He also draws attention to the large amount of light frequently absorbed by the globes used in connexion with flame lamps, and refers to the question of the penetrating power of light of different colours in fogs.

Dr. C. V. Drysdale continues his treatment of LUMINOUS EFFICIENCY AND THE MECHANICAL EQUIVALENT OF LIGHT. In the present section he reviews the existing work that has been done on this subject and the various methods employed, and gives the results of a series of investigators on a large number of different illuminants, ranging from the candle to the vacuum tube.

Dr. F. Jacobsohn contributes a comprehensive review of the recent developments in the subject of METALLIC FILAMENT GLOW-LAMPS. In the previous article on the subject he dealt with the matter in a general manner, and he now enters into greater detail, describing the chief methods of preparing tungsten filaments and also the various suggestions relating to the practical utilization of other materials for glow-lamp manufacture. The article is accompanied by full references to the recent patent literature on the subject.

Mr. Haydn Harrison deals with the MEASUREMENT OF STREET ILLUMINATION. He sums up the various factors that enter into such problems, and discusses the chief difficulties arising in deciding upon a method of measurement. He also classifies the errors to which measurements by means of illuminometers are mainly due, and gives a number of hints for the benefit of those who use these instruments.

Dr. W. Biegon von Czudnochowski contributes a description of A NEW FORM OF ILLUMINATED SIGN recently exhibited at the "Augur" exhibition in Berlin. The essential feature of this sign consists in the mounting of the various mottoes or emblems to be illuminated on a dark surface, the sign itself consisting of some highly reflecting material.

Mr. W. R. Herring contributes an exhaustive report of the GAS LIGHTING AT THE RECENT SCOTTISH NATIONAL EXHIBITION. The results embrace a very large number of different type of lamps, full details being given of the conditions under which the various lights are tested. Special interest attaches to the test on the new Keith high-pressure gas light, yielding 60 to 70 candle-power per cubic foot of gas.

Mr. Chas. W. Hastings continues his articles on the EDUCATION of those concerned with ARTIFICIAL ILLUMINATION. In the present case he dwells on the number of different spheres of knowledge with which the gas engineer dealing with lighting questions must make himself acquainted.

The **Special Section** in the present number is devoted to the lectures and demonstrations on the subject of ILLUMINATION AND LIGHT MEASUREMENT AT THE MUNICIPAL EXHIBITION, which took place from the 1st to the 12th of May. The two lectures of **Mr. Leon Gaster** and **Mr. J. S. Dow** dealt with 'EFFICIENT ILLUMINATION AND MUNICIPAL REQUIREMENTS,' and 'THE MEASUREMENT OF LIGHT AND ILLUMINATION' respectively.

Mr. Gaster dwelt upon the importance of illumination to those who are actually responsible for the lighting of our streets and public buildings. He also drew attention to the effect of light conditions on eyesight, pointing out the great importance of ensuring adequate conditions of illumination in the schools throughout the kingdom.

The subject of street illumination was also briefly touched upon, and the suggestion put forward that the different municipalities interested should combine together to equip a joint testing institution where impartial tests, by recognized authorities, could be properly carried out.

The lecture by Mr. Dow consists mainly of a popular review of recent progress in the measurement of illumination. It is pointed out how much more precise is the science of light measurement at the present day compared with that of a few years ago. A plea is put forward for greater co-operation between those interested in photometry, but representing different systems of lighting.

The section also contains a complete description of the various instruments exhibited, and there is also some account of the various lighting exhibits.

Among other articles reference may be made to that on a new method of SHOP LIGHTING BY GAS, according to which the lights are situated behind diffusing panels of frosted glass, placed above the goods contained in the window.

The paper by **Dr. Louis Bell** on the PHYSIOLOGICAL BASIS OF ILLUMINATION is concluded in the present number. This section of the paper deals mainly with colour phenomena, such as the Purkinje effect, the behaviour of the rods and cones on the retina, and the results of want of achromatism of the eye.

The recent paper by **Mr. Hugo Hirst,** before the Institution of Electrical Engineers, contains a résumé of recent progress in the manufacture of TUNGSTEN METALLIC LAMPS. The author sums up the historical development of the metallic lamps, and describes the chief processes by which tungsten lamps are now made. In the last part of the paper a series of practical cases are considered, and a number of useful tables given relating to the saving to be accomplished by the use of metallic filament lamps under various circumstances, the losses in small transformers, &c. There is also an abstract of the main points raised in the discussion following the recent paper by **Messrs. Handcock and Dykes**.

A paper by **C. A. Bond** gives an account of the various STANDARDS OF LIGHT USED FOR THE TESTING OF GAS in the United States; after reviewing the existing standards the author expresses himself as being in favour of the 10 c.-p. Harcourt lamp, which has been much utilized in America. In this connexion he gives several interesting examples of the accuracy with which such lamps are reproduced and tested.

At the end of the number are to be found the usual **review** of the existing TECHNICAL LITERATURE ON THE SUBJECT OF ILLUMINATION, and the **Patent List**.

TECHNICAL SECTION.

[*The Editor, while not soliciting contributions, is willing to consider the publication of original articles submitted to him, or letters intended for inclusion in the correspondence columns of 'The Illuminating Engineer.'*

The Editor does not necessarily identify himself with the opinions expressed by his contributors.]

Illumination, Its Distribution and Measurement.

By A. P. Trotter,
Electrical Adviser to the Board of Trade.

(*Continued from p.* 363.)

Bases of Comparison of Cases of Illumination.—There is a tendency in many branches of knowledge to attempt to express a very complex quantity by a single figure of merit; but this is often done at the sacrifice of lucidity, and with the loss of anything that can be called description. The horse-power of a steam-engine carries no idea of its weight or the number of revolutions, if any, per minute; the tonnage of a ship tells nothing about its shape or suitability for blue water. The figure of merit of a galvanometer may seriously mislead one who is choosing an instrument, and the mean hemispherical candle-power of an arc lamp is almost as vague as any of the other examples.

Various suggestions have been made for a basis of comparison of different cases of illumination; for example, of two streets, one lighted by gas and the other by electric light. The eye is the ultimate judge. No amount of theorizing can establish any better criterion, and if any rules, formulæ, or curves can be found to express the degree and the distribution of illumination, those will be best which agree best with the opinion of a commonsense critic. Some writers have suggested that the minimum illumination is all that matters, and the rest may take care of itself. Others have argued that the mean illumination is the best measure. Others have proposed that the practical measure of the efficiency of lighting is given by the difference between the brightest and the dimmest parts of the illuminated area.

A curious unit, called a "candle-foot-yard," has been used. It is intended to express the average illumination over an area. A number of measurements were made along a street, from lamp to lamp; an illumination curve was plotted; and the "total effective illumination" was said to be the mean illumination as deduced from the average height of the curves, multiplied by the length of the street along which the measurements were taken. Though the comparison of a number of different cases reduced to this unit affords some useful comparison between the different lamps, and may justify comparisons of costs based on these measurements, a little reflection will show that such a method cannot describe the illumination of the street. It is true only for an indefinitely narrow strip along the line of measurements, and if this is the line of the lamps, the true average is considerably lower than the value thus found.

It has been suggested that the term "luminous flux per unit area" ought to be used instead of "illumination" in certain mathematical considerations,* but in general, for the practical engineering point of view, the more the ideas of flux and 4π are suppressed the better. In considering the average illumination over an area, the idea of flux cannot be avoided; but it is not necessary to use difficult mathematics. The curve in Fig. 26 is the duplication of Fig. 9. It represents the illumination due to a lamp emitting light uniformly in all directions. All that goes above the horizon, that is, one half, is lost; the other half falls on the ground at a greater or less distance. The total flux of light emitted in all directions by a radiant point is 4π (see p. 182), and the useful flux emitted and received on an indefinitely extended horizontal plane is one-half of this, or 2π.†

The figure of revolution of the curve—in other words, the hill of which Fig. 26 is a section—has a solid volume of 2π. Its height over any point on the plane is a measure of the illumination at that point.

Consider it as a hill of sand on a floor of infinite extent. The layer of sand becomes thinner and thinner, theoretically never diminishing to nothing. As the hill theoretically extends over an infinite number of square feet, the average weight per square foot is infinitely small. In order to obtain any appreciable average, a limited area must be chosen. The problem is: a circle of a given radius being described about the axis of this hill, to determine the average height over that circle, or, in other words, the height of a cylinder having that circle as a base, and having a solid content equal to that part of the hill which is within the circle.

Imagine the source of light to be at the centre of a globe partly transparent and partly opaque. Let the transparent portion be just large enough to allow light to pass to illuminate the given circle, and let the opaque part cut off all the rest. Then the area of the transparent part of the globe is a measure of the solid angle, and this measures the flux or total light.

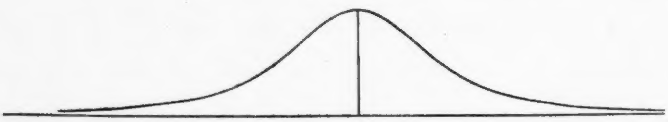

FIG. 26.

This solid angle may be expressed trigonometrically, and the calculations may be carried out by integral calculus; but though these are rapid they are not necessary. The matter may be treated more intelligibly for most people by Archimedes' theorem. Let A B P C D be half of a sphere of unit radius, and A E D F a circumscribing cylinder. Let O P be the axis common to the sphere and to the cylinder, and let G L B C K H be a plane perpendicular to the axis, cutting the sphere at B and C and cutting the cylinder at K and L. Archimedes found that the surface of the half sphere and of the cylinder are equal, and are 2π; that the spherical surface B P C is equal to the cylindrical surface L E K F, and

* E. P. Hyde on 'Geometrical Theory of Radiating Surfaces,' Bureau of Standards, America, *Bulletin* 3; also 'Science Abstracts' 1148, 1907.

† The equation of this curve is $y^2=\left(\frac{1}{1+x^2}\right)^{\frac{3}{2}}$, taking the foot of the lamp-post as the origin. It may be shown by integral calculus that the solid contents of this curve about its vertical axis is 2π. See Trotter on 'A Dioptric System of Uniform Distribution of Light,' *Proc.* Inst. Civil Engineers, 1883, vol. lxxviii. p. 335.

the spherical surface A B C D is equal to the cylindrical surface A L D K.

A quadrant of a sphere of unit radius being drawn (Fig. 28), let O A and O B be rays falling on the plane at the points A and B. Erect perpendiculars at D and E. The lengths A D and B E represent the flux falling within the cones swept out by O A and O B. They also are a measure of the solid angle.*

By this construction, a number of points such as D and E may be ob-

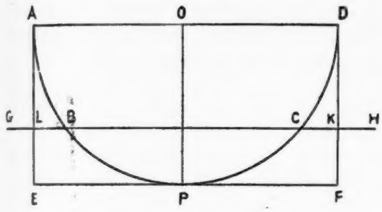

FIG. 27.

tained, and thus the curve (Fig. 30) may be constructed. The vertical scale on the right gives the flux or solid contents. At an angle of incidence of 60 degrees, that is to say, a circle subtending 120 degrees, one quarter of the total flux of 4π is received, or one-half of that which is emitted in one hemisphere.

In the explanation of the illumination of inclined surfaces (p. 97) Fig. 6 represented a beam passing through a hole

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* The trigonometrical treatment is as follows: Let O A be a ray falling on the sphere at A. Through A draw the perpendicular B A C. Then A C measures the solid angle, since it is equal to the height K F (Fig. 27) of the cylinder.

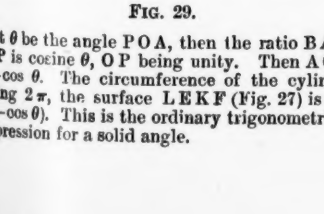


FIG. 29.

Let θ be the angle P O A, then the ratio B A to O P is cosine θ, O P being unity. Then A C is $1-\cos\theta$. The circumference of the cylinder being 2π, the surface L E K F (Fig. 27) is $2\pi(1-\cos\theta)$. This is the ordinary trigonometrical expression for a solid angle.

one foot square, and it was shown that as the screen was tilted, the illuminated area increased and the illumination decreased. In that elementary treatment it was desirable to keep the idea of flux out of sight, but we may now regard illumination as the flux divided by area. In the Geneva units the lux is equal to the lumens per square metre.

We can now deal with the problem, first arithmetically, and afterwards graphically. Taking a case from Table I., p. 185, let A B (Fig. 31) be unity, and the radius B C be 1·702. This is the case when the angle θ is 59 degrees 34 minutes (Tan. 59 degrees 34 minutes = 1·702). Cos θ is found in the table to be 0·507. Then $1-\cos\theta = 0{\cdot}493$, and $2\pi \times 0{\cdot}493 = 3{\cdot}1$. This is the solid content of the hill within the

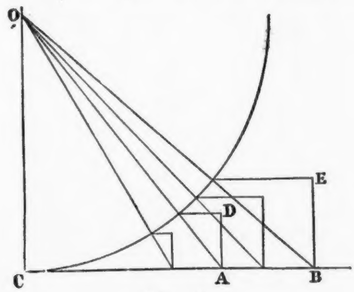


FIG. 28.

circle. The area of the circle is $\pi \times 1{\cdot}702^2 = 9{\cdot}11$. The height of the cylinder having a base 9·11 square units, and a solid content of 3·1, is $3{\cdot}1 \div 9{\cdot}1 = 0{\cdot}341$. The maximum illumination being 1, and the minimum being 0·13, the mean is 0·341. The mean height of the section in Fig. 31 is 0·507, which is a very different matter, being about 65 per cent. higher than the true mean. It may be observed that the mean height of all the ordinates of the cosine cubed curve up to any point is the cosine at that point.

In Fig. 32 the same problem is solved graphically. Let A B be the height of the source of light, and be numerically equal to unity, and let B C be the radius of the circle. In A C cu off A D, making A D equal to A B. Drop the perpendicular D E, then D E is

$1 - \cos\theta$. Make B F in B A produced equal to B C; draw F G parallel to A C.

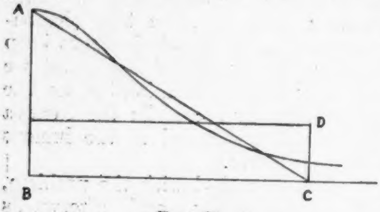


FIG. 31.

Then (A B being 1) 1 : B C : : F B : B G; therefore $BG = BC^2$. In B G cut off B H equal to twice D E. Then $BH = 2(1 - \cos\theta)$. Join G A, and through H draw H K parallel to G A. Then G A : 1 : : H K : K B. Therefore $KB = 2(1 - \cos\theta)/BC$. It will be seen that K B (Fig. 32) is equal to D C (Fig. 31).

Although this calculation of the mean illumination can be easily carried out by means of the tables and a slide rule, or, in the absence of tables, by the graphical construction, the simple case of a source of light of uniform candle-power in all directions, and of a circular area, is not one that is likely to occur in practice. It is introduced here to explain the theoretical principle of a mean illumination.

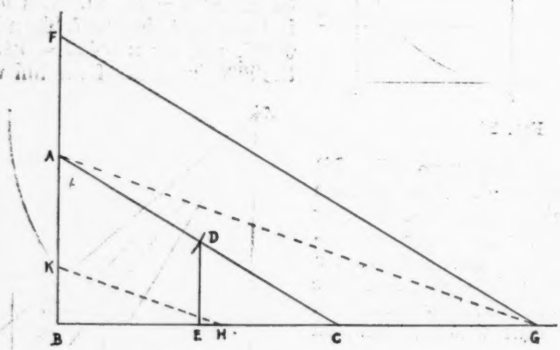


FIG. 32.

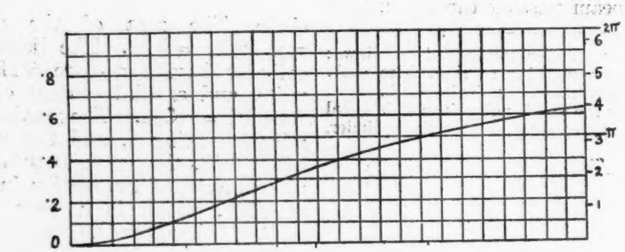


FIG. 30.

(*To be continued.*)

Message from Dr. Louis Bell of Boston.

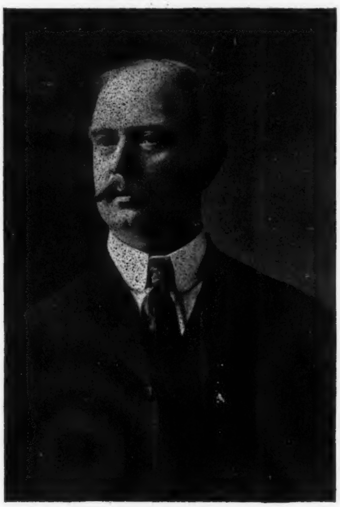
President of the Illuminating Engineering Society of U.S. America.

To the Readers of 'The Illuminating Engineer.'

It may not be inappropriate to give some account of the growth of illuminating engineering in the United States.

The Illuminating Engineering Society was formed about three years ago, in response to a very definite feeling among those who were interested from various sides in artificial illumination. Though their interests are apparently diverse in many things, they are really the same in one thing—to wit, the proper utilization of the means of artificial lighting now at hand. There had come to be a very strong feeling that artificial lighting, through the advent of new illuminants, was verging on a fresh career of usefulness, and that it was high time to take advantage of the new means at hand to put illumination, as such, on a proper scientific basis. It is just as important, from the purely practical standpoint, to double the effectiveness of the illuminant sources actually at hand, as it is to invent a new incandescent lamp, or progressive lamp burner, of twice the efficiency of the old. The utilization, therefore, of illuminants as they are, in the most useful and efficient manner, is the primary object of illuminating engineering, as contradistinguished from electrical engineering, which deals with the means rather than the end, or gas engineering, which occupies a precisely similar position with respect to the great gas industry.

The Illuminating Engineering Society was therefore formed to further this eminently practical purpose of improving the art of artificial lighting, and of promoting such a mutual study of the technique and science of lighting as would lead to useful ends. The membership of the society, now about 1,000, has been, as might have been expected, drawn from no particular profession, but very many professions and branches of business. The membership includes many electrical engineers and gas engineers, managers of electrical supply stations and of gas stations, a considerable group of distinguished oculists, who are interested in improving the hygienic situation of present illumination, architects, teachers, contractors, and business men who have to deal with the difficulties of getting proper illumination, even when an adequate supply of illumination is at hand. It is this



Dr. LOUIS BELL,
President of the Illuminating Engineering Society in the United States.

heterogeneous membership that best bears witness to the fact that illuminating engineering is not a branch of any one fashion, but deals rather with a new and extremely practical set of problems. The work of the society has been in large measure a campaign of education—self-education, as well as education of the public—and it has met with a gratifying degree of appreciation. As a convenient meeting ground of all lighting interests, the society has been able to accomplish some very practical things in the way of bringing those very lighting interests to a common view-point.

One of the important steps taken has been the establishment of a modus vivendi whereby the gas and electrical industries have settled in a friendly way upon an identical working value for the standard candle: this will serve to avert many disputes. There had been an outstanding difference between the units customarily used in the electrical incandescent lamp industry, and those used by the gas engineers. Gas lighting in the United States has, in the past, depended, through statutory requirements, on the old British sperm candle and its alleged unit of light. As everybody now knows, this particular unit is both inconvenient and unreliable, yet, under existing conditions, it was continually being used by municipal gas inspectors, and was a source of perennial dispute between the supply companies and the municipalities, even when each body was trying in good faith to do its best to come to an agreement. A committee of the Illuminating Engineering Society secured the friendly co-operation of committees from the Institution of Gas Engineers and Am. Inst. of Electrical Engineers, and all three bodies, with no friction or difficulty, came to an amicable understanding, so that from now on they will be able to work with the common unit, and all disputes can be referred to the National Bureau of Standards with the certainty of a settlement on the practical basis of which all minds are agreed.

Another line of work in which the Society has been specially active is the promotion of good lighting in schools and public buildings. Considerable work in the way of investigation has been done by the various members working along various lines, and all directing proper attention to the hygiene of illumination, a subject much neglected, both in America and in this country, and one which has a peculiar importance on account of the enormous intrinsic brilliancy of the new illuminants, such as metal filament incandescent lamps and high pressure gas burners. These sources of light require very careful treatment in order to secure suitable illumination from them without subjecting the eyes to undue strain. A technical matter of this kind cannot be settled offhand by any electrical or gas engineer who chances to be confronted with the problem, requiring as it does, a close knowledge of the physiological aspects and intimate acquaintance with the technique of both gas and electric lighting.

The rise of such problems, and their importance from a purely practical standpoint, is sufficient reason for the existence of a body of illuminating engineers, who can well devote much of their time to the study of some intricate conditions which do not lie within the ordinary sphere of the electrical or gas engineer. As new illuminants appear, they bring with them new conditions, which must be followed up and studied, if these illuminants are to possess the usefulness which one may hope for them.

One can hardly say, of course, that illuminating engineering as a profession can take independent rank, in comparison, for example, with civil or electrical engineering. It makes no such pretence, but it is co-ordinate in importance with many branches of the engineering professions in which the development of new conditions has compelled specialization to a degree which a few years ago was totally unnecessary. In this sense illuminating engineering may properly claim full recognition in the engineering profession, and, let it be hoped, with the attention which has been drawn to it of late, will lead to a better understanding of the means available for artificial illumination, and more efficient utilization of the illuminants now at hand and rapidly appearing.

Mankind is becoming more and more a nocturnal creature. The modern city has to adjust itself to conditions where artificial lighting is predominant, and, consequently, the scientific use of artificial illumination must steadily assume greater and greater economic importance.

A Novel Method of Shoplighting by Gas.

In a recent number of the *American Gaslight Journal*, to the courtesy of whom we are indebted for the use of the blocks accompanying this article, appeared a description of a novel method of shoplighting employed by the Welsbach Company in one of the drapery stores of Philadelphia.

The window was boxed in, in the manner shown in the illustration, and a number of the wooden panels above the goods were removed and sheets of frosted glass substituted. As a rule, the side of the glass presented to the goods is the frosted portion. The sources of light used to light the window were then arranged at intervals behind this glass, as shown in Fig. 2. As a result a pleasing and uniform illumination is produced, the light being thrown down upon the goods without the possibility of very bright sources of light bewildering the eye of any one looking in at the window. In the case of the store shown in Fig. 1, the wooden panels have been entirely replaced by diffusing glass, with the object of producing well-distributed and uniform illumination. It is, however, also possible only to utilize a few individual panels with the object of producing bright local illumination.

FIG. 1.—Night View (12 minutes' exposure).

The same purpose is served by placing lights of exceptional brilliancy behind certain of the panels; we then obtain the moderate distributed illumination usually required *plus* special intensity in certain directions with the object of drawing attention to certain varieties of goods.

Besides the advantages already mentioned it is very convenient to have all the lights arranged in the easily accessible manner shown in Fig. 2, which enables any number of lamps to be turned on or off, mantles to be replaced, &c., without disturbing the contents of the window. It is also possible to arrange for several alternative methods of distributing the lamps placed above the diffusing screen, according to the nature of the goods to be displayed in the window.

It will be seen that in this case each burner is equipped with a reflector intended to concentrate the light on the goods below. It would, of course, also be possible to arrange for the sources in question, besides lighting up the goods through the ground glass, to illuminate horizontally a transparent sign carrying the name of the shop, and placed above the window.

In Fig. 2 the general plan of the connexions is shown. The pipe enters at the floor and runs across above the window supplying the various lights employed. Each burner is fitted with an independent shut-off cock. The main supply-pipe is fitted with a special ball-weighted cock, to which is attached clockwork arrangement arranged in such a way that the gas is cut off automatically at a certain prearranged time when no longer required.

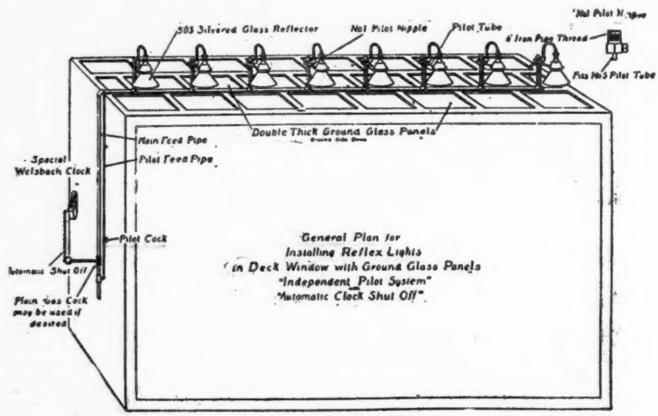


FIG. 2.

Co-operation in Street and Shop Lighting.

BRILLIANT lighting is now recognized to be one of the best advertisements. Mr. James Seager, in *The Business Man's Magazine*, recently referred to the plan of action adopted by the traders who banded themselves together in order to make the general lighting of their street as attractive as possible.

In some cases extra posts were actually erected, but the authorities were inclined to take exception to these, on account of obstruction to traffic. In other cases the plan of arranging brackets carrying lamps on the sides of the houses of the tenants acting together was adopted.

Passers-by involuntarily select a brilliantly lighted street in preference to a comparatively gloomy one, especially when indulging in shopping by night. It is therefore contended that the cost of such exceptional lighting is amply compensated for by the amount of business done.

The Use of Flame and other Arc Lamps for Exterior Illumination.

By Prof. E. W. Marchant, D.Sc.

As a comparatively small number of results of test made on the modern flame arc-lamps have been published, the figures obtained in some fairly complete trials on these lamps, with a view to determining their suitability for street illumination, may be of interest. These tests were carried out with a view to determining the actual gain in efficiency obtained by using a modern yellow or white flame carbon arc-lamp in place of one of the older pattern lamps. The first point of distinction between a flame lamp with inclined carbons and the ordinary arc is the light distribution. In the ordinary vertical carbon arc the maximum illumination occurs at an angle of from 40 degrees to 60 degrees below the horizontal, the exact angle for maximum illumination depending on the length of arc used. In the inclined carbon lamp the maximum intensity of illumination is in a direction vertically underneath the arc. Curves obtained for two typical lamps are shown in Fig. 1, *a* and *b*.

This alteration in distribution of light is a disadvantage for exterior illumination, since it gives maximum effect immediately below the lamp, *i.e.*, on the ground which lies nearest to the source of light, with the result that the surface illumination obtained with such lamps is patchy, being very bright directly under the lamp, and rapidly falling off the farther one goes from it. Although in most of these lamps when the globes are in position the vertical light is almost entirely cut off, there is still a tendency

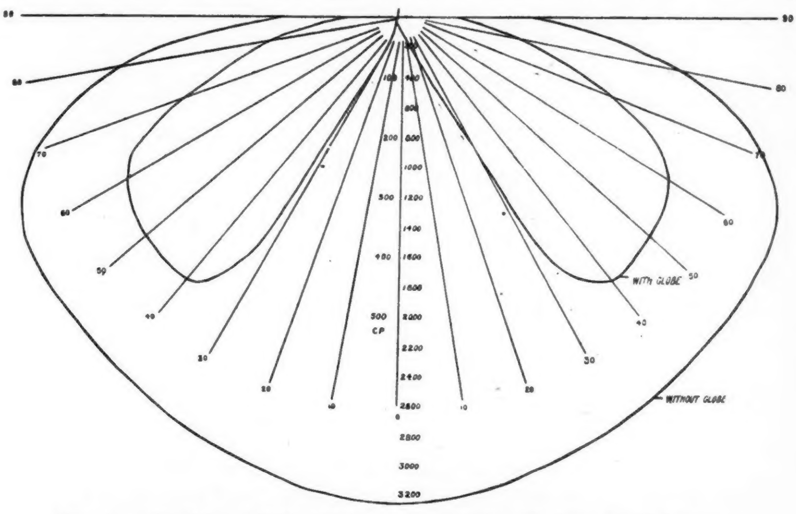


FIG. 1A.—Flame Lamp Yellow Light. Average Volts=38, Current=10 Amperes.
Mean Hemispherical Candle-Power=2,650 (without Globe).
" " " =360 (with Globe).

for the illumination to reach its maximum at an angle considerably nearer to the vertical than with the older type of lamp. It may be of interest to compare the illumination curves given with one which has been drawn—Fig. 2—to show the candle-power curve that would be required to give uniform horizontal illumination over a limited area.

The illumination curve has been drawn so that the source of light gives 0·5 candle-feet horizontal illumination over an area 60 ft. in radius, with the lamps supported 40 ft. above the ground at the centre. This curve approximates much more closely to the illu-

	Mean Hemispherical Candle Power.	Watts per M.H.S.C.P.
Yellow Flame Lamp	2,650	·144
White Flame Lamp	1,270	·338
Ordinary Arc ...	620	·69

These measurements were made without globes, the arc taking a current of 10 amperes at a pressure of about 45 volts in each case.

These figures are comparative, the actual values of the candle-power in the flame lamps vary within wide limits for a given lamp, according to the quality of the carbons employed.

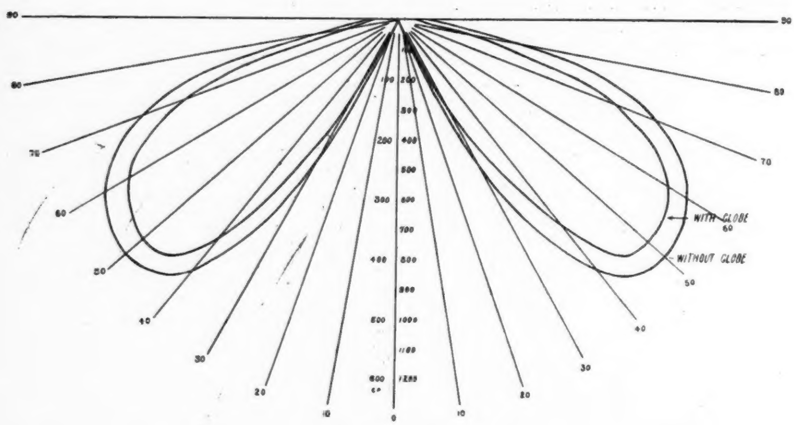


FIG. 1B.—Ordinary Arc double Carbon Lamp. Average Volts=47, Current=10 Amperes. Mean Hemispherical Candle-Power=745 (without Globe).

mination curve given by an ordinary arc-lamp than to that given by the flame arc-lamp with inclined carbons, and shows clearly that a lamp with vertical carbons is much more suitable for street illumination.

The increase of efficiency with the flame lamps is well known, but some of the figures obtained may be of interest. For the sake of comparison, the mean hemispherical candle-power has been determined, although the magnitude of the mean hemispherical candle-power is far from being an adequate criterion of the suitability of a lamp for general illumination.

Some of the flame lamps tested, however, burnt with remarkable steadiness, particularly those giving a yellow flame; in this respect they are now not at all inferior to the older ordinary carbon lamps.

Besides testing these lamps without globes, a number of observations were made with the globes in position. The "globe" tests are liable to a certain amount of inaccuracy, since, with a globe, the source of light becomes scattered, and the square law by which the candle-power was estimated does not hold, except at great distances from the lamp. With the globes used on the flame lamps the light was usually reduced to about one-sixth of its former value, though in some cases the absorption of the globe was even greater, the light emerging being only one-tenth of that actually produced by the lamp. Making a corresponding comparison with globes in position the figures are :—

	Mean Hemispherical Candle Power.	Watts per M.H.S.C.P.
Yellow Flame Lamp	360	1·05
White Flame Lamp	200	2·15
Ordinary Arc ..	190	2·25

It will be seen that the flame lamps under these conditions are very little better than ordinary arc-lamps, and have hardly as high an efficiency as some of the modern metallic filament glow-lamps

It may at first sight appear remarkable that the makers of flame lamps should use globes which practically neutralize the gain in candle-power obtained by using the flame arc. These globes, however, are very brilliant and conspicuous objects when the lamp is burning, and where a lamp is used (as it is in many cases) for

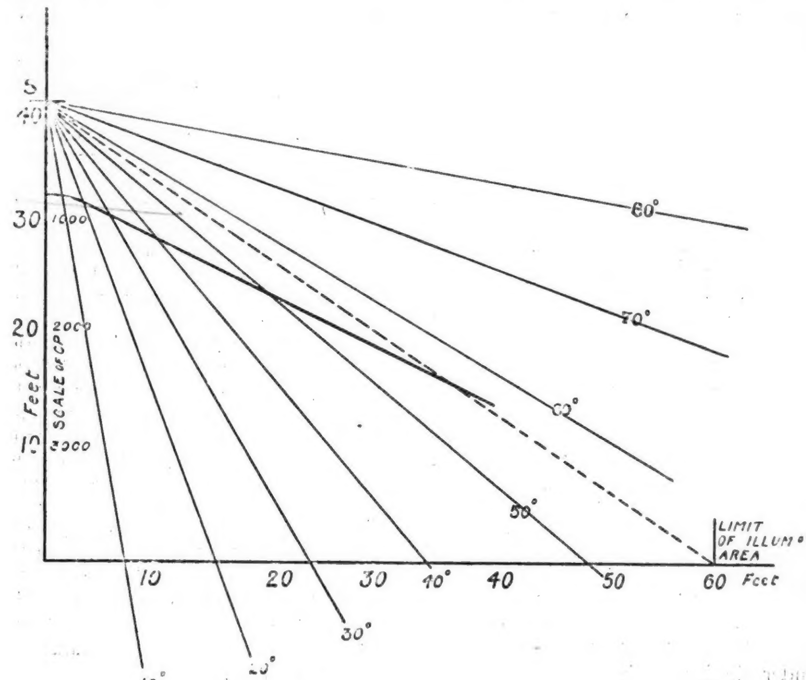


FIG. 2.—Polar Curve showing Candle-Power required to give Uniform Horizontal Illumination of ·5 Candle Foot over a Limited Area from a Single Source (S).

spectacular purposes the brilliance of the globe becomes of practical utility. At the same time where illumination is wanted it is obvious that a comparatively clear globe should be used. For street lighting, where the lamps are placed high and well out of the direct line of vision of a person in the street, a slightly obscured or even a clear globe might well be employed. If the lamps are low the glare from an arc in a clear globe is, of course, very dazzling, and a dense globe becomes a necessity. Under most conditions it is clearly of no advantage for the electrical engineer to attempt by every means in his power to give, let us say, 10 per cent. more light for a given supply of energy to his arc-lamps, when the illuminating engineer absorbs 90 per cent. of the total that is produced in the globe.

A point of some importance in connexion with street illumination is the colour of the light used. It is a well-known fact that, on the whole, a reddish coloured light has far greater penetrating power in a fog than one of a white colour. This point may be very clearly seen by a casual observer noticing the distance at which yellow flame lamps and ordinary arc-lamps remain visible in foggy weather. Yellow lamps are visible at a distinctly greater distance than those giving a white light. It is exceedingly difficult to get any actual comparisons between the penetrability of different coloured lights on account of the variations that are liable to occur from time to time in the amount of light that a lamp gives, but there can be no doubt of the greater effectiveness of yellow flame lamps burning under these conditions. This point is one which deserves further consideration from illuminating engineers. In some rough tests made in Liverpool it appeared that the effective illuminating power of a yellow flame lamp in a fairly dense fog was about 30 per cent. greater than that of a white light lamp burning under similar conditions.

It is to be hoped that flame lamps will lead to the more extended use of electric light for street illumination; many lamps of this kind have already been erected. Unfortunately, in lamps intended for street illumination, in which it is essential that the time of burning without retrimming shall be as long as possible, very little care appears to have been taken to avoid losses by absorption, due to auxiliary appliances inside the globe. Lamps of this description are now fairly common, and many of them are of great ingenuity in design, and are admirably constructed; but it cannot be too strongly urged that the essential quality of a lamp is to produce as much light for a given expenditure of energy as possible, and though long burning is of equal (possibly of even greater) importance than efficiency care should be taken that long burning is not obtained at too great a cost.

The development of the flame lamp has been most remarkable, and the operation of these lamps reflects great credit on those who have been responsible for their development; the modern flame arc, when compared with the unsteady flame arc used in the laboratory ten or more years ago shows a wonderful advance, but the limit of efficiency is very far from being reached. and it is to be hoped that lamps of this type will continue to progress until they hold an indisputable position as the most efficient means of illumination that we have.

A High-Pressure Flame Arc.

A RECENT number of the *Journal für Gasbeleuchtung* contains a description of a new form of carbon arc-lamp. The article refers to the fact that the spectrum of the lamp closely resembles daylight, and the results of some recent tests at Charlottenburg are given. The most interesting feature of the lamp, however, is the high P.D. across the arc, which approaches 80 to 90 volts.

The Production and Utilization of Light.

Luminous Efficiency and the Mechanical Equivalent of Light.

By DR. C. V. DRYSDALE.

(*Continued from p.* 379.)

C. *Spectrum Integration Method.*—As before stated, this method was introduced by Tyndall, who employed it to estimate the radiant efficiency of the electric arc. A spectrum was formed of the source under test and the distribution of energy obtained by moving a line thermopile from end to end of this spectrum. In this way a curve such as is shown in Fig. 2 is

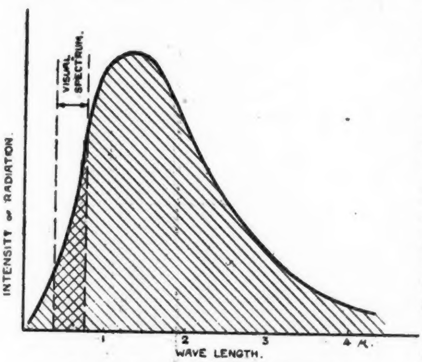


Fig. 2.—Total and Visible Radiation.

obtained. It is then only necessary to find the area of the curve between the two visual limits ·38μ and ·76μ, and to divide this by the total area of the curve from end to end, to obtain the radiant efficiency. The chief precaution nece sary in this case is to form the spectrum by a device which gives no absorption or anomalous dispersion, and this is best satisfied by rock salt or carbon bisulphide. In this way Tyndall found a radiant efficiency of 7·7 per cent for the arc, as against 10 to 11 per cent by the absorbing screen method.

The only accurate measurements that have been made by this method are those of Langley* in 1881 and later. In this case the spectrum was formed by a reflecting grating, which eliminated any difficulties as to absorption, &c., and the radiation was measured by the bolometer, which, although discovered in principle by Svanberg in 1851, was first developed by Langley into an accurate measuring instrument. Langley does not, however, appear to have determined the radiant efficiencies from his curves, but Prof. Kapp has recently done this,† and found a value of about 4·5 per cent for the arc.

The method above described is extremely tedious and difficult to carry out, but it may be considerably simplified by forming the spectrum, and recombining either the whole of it or the luminous portion only, on the thermopile. This procedure was adopted by Angström in determining the mechanical equivalent of the Hefner lamp, as described below.

Table I. is a collection of the values of the luminous efficiencies obtained by various experimenters.

Mechanical Equivalent of Light.—For the determination of this quantity three methods have been employed :—

1. Measurement of total power per unit of light and total efficiency.
2. Measurement of total radiation per unit of light and radiant efficiency.
3. Measurement of power and luminosity of a beam of definite composition.

* 'The Bolometer and Radiant Energy,' *Proc. Am. Acad. of Arts and Science*, Jan. 12th, 1881; 'The Actinic Balance,' *American Journal of Science*, xxi., p. 187, 1881; 'On the Selective Absorption of Solar Energy,' *Phil. Mag.*, 1883, p. 153; Langley and Very on 'The Cheapest form of Light,' *Phil. Mag.*, 1890, p. 260.

† Discussion on 'New Incandescent Lamps,' *Proc. I.E.E.*, Jan. 10th, 1907, p. 232.

TABLE I.—LUMINOUS EFFICIENCIES, COLLECTED VALUES.

Source.	Observer.	Date.	Method.	Total Efficiency. Per cent.	Radiant Efficiency. Per cent.
Candle	Thomsen ...	1863	A	0·3	2·1
Oil Flame ...	Melloni	1833	A		10
	Thomsen ...	1863	A		2·06 to 2·11
	Wedding ...	1905	A		0·029
	Lux...	1907	A	0·25	1·23
Hefner Lamp ...	Lux...	1907	A	0·103	0·89
Gas Flame ...	Tyndall	1862	A		4
	Thomsen ...	1863	A		1·84 to 2·11
Incandescent Gas	Lux...	1907	A	0·46 to 0·51	2·03 to 2·97
Acetylene Flame	Angstrom ...	1902	A		5·6
	Nichols & Coblentz ...	1903	C		3·3 to 4
	G. W. Stewart	1902	C		4
	Lux...	1907	A	0·65	6·36
Glow Lamp ...					
Incandescent ...	Melloni	1833	A		2
Platinum	Tyndall	1862	A		4·17
Carbon Filament	Merritt	1889	B	·5 to 7·2	
	Russner	1907	B	·58 to ·61	
	Wedding ...	1905	A		0·34
	Lux...	1907	A	2·07	2·7 to 3·2
Nernst	Ingersoll ...	1903	C		4·7 falling to 3·6
	Wedding ...	1905	A		0·85
	Lux...	1907	A	3·85 to 4·21	5·7
Tantalum... ...	Russner	1907	B	2·2	
	Lux...	1907	A	4·87	8·5
Osmium	Russner	1907	B	2·3	
	Wedding ...	1905	A		0·62
Osram	Russner	1907	B	2·46	
	Lux...	1907	A	5·36	9·1
Arc Lamp ...	Tyndall	1862	A		10 to 11
	Tyndall	1862	C		7·7
	Nakano	1889	A		1·48 to 8·1 various angles
	Marks				2·3 to 16·2
	Wedding ...	1905	A		0·318
D.C. Arc	Lux...	1907	A	5·6	8·1
D.C. enclosed Arc	Lux...	1907	A	1·16	2·0
Flame Arc, yellow	Lux...	1907	A	13·20	15·7
Flame Arc, white	Lux...	1907	A	6·66	7·6
A.C. Arc	Lux...	1907	A	1·9	3·7
Mercury Arc ...	Geer	1903	A		40·8 to 47·9
Uviol Mercury Vapour... ...	Lux...	1907	A	2·24	5·8
Quartz Lamp ...	Lux...	1907	A	6·00	17·6
Vacuum Tube...	Drew	1903	A		23·4 to 48·6

It is evident that whenever observations have been made, accompanied by measurement of the power consumption of the source, a value for the mechanical equivalent of light can be deduced. Thomsen* thus obtained values of about ·3 watt per candle-power for the mechanical equivalent of the light from candles and other flames. Tumlirz and Krug—from the results of two experiments on the total radiation and radiant efficiency of incandescent platinum wire—gave ·17

* *Loc. cit. ante.*

and ·19 watt for the mechanical equivalent of the light of the hefner lamp.

The most scientific attempt hitherto at the determination of the mechanical equivalent is that of Angström,* who used the apparatus shown in Figs. 3

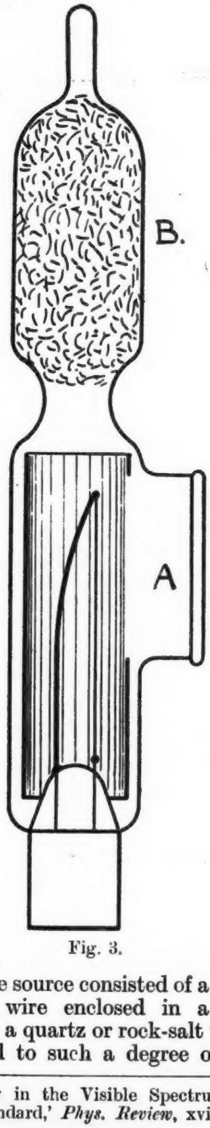


Fig. 3.

and 4. The source consisted of a straight platinum wire enclosed in a special bulb, with a quartz or rock-salt window, and raised to such a degree of incandescence as to match the colour of the Hefner lamp. This source was used in conjunction with the mirrors and prism, and absorbing trough A to form a spectrum at E, where a sharp edge could be traversed by the screw V so as to cut off any given portion of the spectrum. The remainder was recombined by the cylindrical lens C on to the radiometer B or wedge photometer F, which could be introduced into the main body of the apparatus, a Hefner lamp H being employed as standard in measuring the intensity of the beam. The radiometer consisted of the "pyrheliometer," an instrument devised by Angström for absolute measurement of radiation, which will be described elsewhere.

In making the determinations the edge E was set so as to cut off the whole of the radiation of greater wave length than ·76μ, and measurements were successively made of the intensity of radiation, and of luminosity of the beam, resulting in a value of ·1085 watts per Hefner, or ·121 watt per candle. Until quite recently these were the only attempts at obtaining a value of the mechanical equivalent of light, although Merritt has included values of the light power per candle-power in his tables. At normal efficiency this appears to be of the order of ·2 watts per candle, although values in some cases as low as ·14 watt per candle-power were obtained.

It will be noted that in all the previously quoted work, the mechanical equivalent has declined from about ·3 to ·12 watt per candle, as greater care in the cutting of the "dark heat" has been employed. Recently, however, in Germany three workers—Prof. W. Wedding,* J. Russner,† and Dr. H. Lux‡—have obtained values which are extraordinarily low in comparison with all the earlier workers. Wedding

* 'Energy in the Visible Spectrum of the Hefner Standard,' *Phys. Review*, xvii. p. 302, 1903.

* 'Uber den Wirkungsgrad und die praktische Bedeutung gebräuchlichsten Lichtquellen,' *Jour. für Gasbeleuchtung und Wasserversorgung*, 1905.

† 'Luminous Efficiency of Incandescent Lamps,' *Phys. Zeitschrift*, viii. p. 120, Feb. 15th, 1907.

‡ On the 'Efficiency of the most Common Sources of Light,' *Illuminating Engineer*, No. 2, p. 98.

has given values as low as ·0011, or about one-hundredth part of Angström's result; Russner's lowest value is ·02; and that of Dr. Lux ·014. It seems impossible to account for, or to reconcile these values with the earlier ones; and the discrepancies can only be ascribed to the uncertainty which Prof. Nichols has pointed out as attending all absorption methods.

As a correct determination of the mechanical equivalent is evidently of the greatest importance, Mr. Jolley and the writer attempted in the spring of last year to make a direct determination. At the time of doing so we were absolutely unaware of any previous attempt, as nothing appears to have been written on the subject here; and a method was at once devised, which appears to be correct in principle, and which will probably be admitted as the basis on which all such determinations should be made; whether the results obtained are finally accepted or not. The principal object was to determine the mechanical equivalent of the monochromatic yellow-green light suggested by Guilleaume, and thus to be independent of the source or of the properties of any absorbing media whatever.

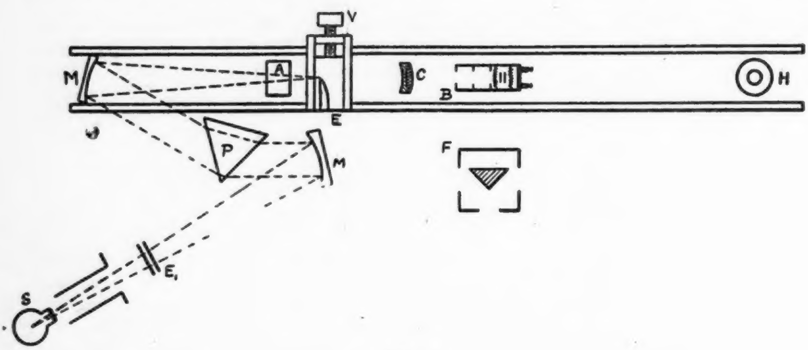


Fig. 4.

(*To be continued.*)

Obituary.

It is with great regret that we learn of the death of Mr. F. H. Leeds, F.I.C., who was well known both for his general work on photometry and as joint author of a standard text-book on acetylene. Mr. Leeds was among the first contributors to this magazine, and his comprehensive article on 'The Present State of Acetylene Lighting' was one of the last he wrote.

The Development and Prospects of the Metallic Filament Glow-Lamps.

BY DR. FELIX JACOBSOHN.

(*Continued from* p. 399.)

BESIDES the patents of Just and Hanaman, there also exist a large number of others dealing with the application of wolfram for the manufacture of glow-lamp filaments. Actually, the use of wolfram for this object is open to anybody, for the first patents bearing on the subject date back as far as the eighties of the last century, and have therefore long since expired (J. G. Willcox, Aldridge, August 11th, 1886, and J. B. Tibbits, October 11th, 1890). The same holds good for the paste process. Consequently all the newer patents are directed to the improvement of existing defects or improved methods of preparing metallic wolfram.

For instance, the wolfram lamp Aktiengesellschaft of Augsburg (German Patents 182,766 of 1904) modify the original substitution process by employing carbon filaments containing wolfram or molybdenum in place of filaments of pure carbon. According to their patent of 1905 (No. 184,379) this firm prepare extremely fine carbon filaments—or, according to the supplementary patent (191,883), filaments containing wolfram and molybdenum —of 0·02 to 0·06 mm. in diameter, which are coated with a layer of molybdenum or wolfram.

Finally, carbides are produced by incandescence in an atmosphere of rarified hydrogen, and these in turn may be either subjected to reduction in water vapour, the carbonaceous material existing in the filaments being thus removed, or the filament may be embedded in wolfram—or molybdenum-dioxide, and heated to 1,600 degrees —to attain which temperature the flame of a blow-pipe suffices. In the last case the process of reduction follows a course which may be expressed by the following relation—

$$WO_2 + 2C = 2CO + W$$

In the supplementary patent No. 193,221, the creation of the carbide and its subsequent reduction are united in a single process involving incandescence in an atmosphere of hydrogen and water vapour. The German patent 185,585 of 1905, taken out by the same company, abandons the use of carbon entirely, the filaments being composed of an aqueous paste of the oxides of wolfram and molybdenum; or the metals, mixed with sulphur or carbon-di-sulphide embedded in clay or magnesia, are reduced in the blow-pipe flame.

The Auergesellschaft of Berlin likewise employ a *small* quantity of water vapour in the reduced atmosphere of hydrogen in order to remove carbonaceous constituents in the filament (German patent 182,683 of 1905). In a more recent patent, however (German patent 194,653), the carbon is no longer removed by the oxidizing action of water vapour, but by the use of nitrogen and water vapour or ammonia; the operation is said to be simpler in this case. The same company (German patent 193,292 of 1906) prepares hollow filaments by rapidly heating the wolfram filaments containing carbon to a white heat. The channel formed in the interior of the filament as a result is proportional to the rapidity with which this temperature is arrived at. One advantage of such a hollow filament is that for a given P.D. a smaller filament is necessary than if it were solid.

The A.E.G., of Berlin, utilized an iron series-resistance in order to compensate for the falling resistance of the filament as it loses its carbon (German patent 188,908 of 1906).

Johannes Lux, of Vienna (German patent 182,967 of 1906), employs an "equalization process" for filaments of wolfram and molybdenum, according to which the prepared filament is heated in an atmosphere of rarified halogens at a pressure of 0·1 to 1 mm. As a result volatile halogen compounds are formed, which again deposit on the hottest, *i.e.*, the thinner portions of the filament, a cycle of operations which eventually results in the production of an extremely homogeneous filament. In the subsequent patent (German patent 188,509 of 1905) Lux seeks to exhilarate the reduction of a filament composed of a paste of carbon, wolfram, or molybdenum, by the addition of about 0·1 to 0·5 per cent. of aluminium or magnesium. Yet another patent (189,637 of 1906) of Lux advocates the application of aluminium in the form of an alloy of the oxide, in order to improve the ductility of the ensuing product of reduction. According to patents 193,920 of 1905 and 194,894, Lux attempts the production of very fine filaments composed of a paste of wolfram with zinc oxide or sulphide together with an organic binding material. The processes taking place are best represented by the following two equations—

I. $W + ZnO + C = WZn + CO$.

II. $WZn = W + Zn$.

These reactions are accompanied by marked shrinkage on the part of the filament. Cadmium compounds have the same effect.

In the German patent 194,171 of 1906 Lux employs as a binding material completely volatile substances such as camphor.

These processes cannot easily be expected to lead to successful results because, by volatization of the binding material before the melting together of the filament the consistency of the latter is seriously prejudiced.

Francois Jean Planchon, of Paris (German patent 194,896), has the same object in view in employing the albumenoids of molybdenum, wolfram, titanium, and tantalum, which yield gelatinous precipitates with wolfram trioxide, &c.; these in turn can be pressed into absolutely homogeneous filaments.

Siemens and Halske (German patent 194,468 of 1906) heat ammonium wolframate to a temperature of 300 degrees. As a result the ammonia escapes, but a product remains behind which is insoluble in water; it can, however, be worked into a thick paste, which permits of the manufacture of very homogeneous filaments. According to the German patent 195,030 wolfram trioxyhydrate is heated in ammonium until glittering crystals separate out. After heating to 250 degrees these filaments can be worked into a plastic paste with water. In addition the same company (169,928 of 1904) protect the process involving the drawing out of molybdenum, wolfram, &c., into fine wire. In order to secure absolute purity and durability on the part of the metal, and to reduce its inclination to volatize, they advocate the preheating of the same either in vacuuo or in an atmosphere of inert gases, and also describe the preparation of the metal by fusing the oxide, nitride, or hydride. According to the method proposed in their patent number 173,134 they also avoid the consequences of the natural brittleness of wolfram by depositing these metals upon iron. In this ductile condition it can be drawn out into wires, and the iron subsequently removed.

According to German patents 194,349 and 194,682 the brittleness of wolfram and molybdenum can be improved by coating with a layer of ductile metal, this being subsequently removed from the finished filament. Finally, in their patent 181,050 of 1904 they mention the value of alloying tantalum with osmium, wolfram, or molybdenum, the brittle metals being deposited on a tantalum wire, and the want of ductility being thus provided for.

This last patent leads us naturally to discussion of the metal tantalum and its homologues, vanadium, and niobium. Before considering this patent literature in detail, however, which is almost entirely confined to the patents of Messrs. Siemens and Halske, let us briefly pass in review the scientific progress that has been made in the reduction of these refractory metals.

Berzelius* accomplished the reduction

* Poggendorff's 'Annalen,' **22**, 1, 1831.

of metallic vanadium by reduction of the acid with potassium, and also by treatment of the oxychloride $VOCL_3$ by means of ammonia. As Roscoe* had shown, as far back as 1867, only the oxide VO and other lower oxides of vanadium, or else the nitride VN, were obtained by this method. Roscoe therefore endeavoured to accomplish the reduction of this nitride by means of a stream of hydrogen, but achieved no satisfactory results. He therefore turned his attention to new methods, according to which chlorides such as VCl_2, free from oxygen, were treated with hydrogen, or else reduced at a bright red heat with metallic sodium. The resulting product, however, still contained about 1·3 per cent. of hydrogen, and also traces of oxygen; at a white heat yet more marked oxidization occurred.

Moissan's† researches in the electrical furnace only led to the production of the vanadium group, or to the production of the metal containing carbon, which, even under the most favourable conditions, amounted to 4·4 or 5·3 per cent. The aluminium thermal process of Goldschmidt proved quite ineffective for the purpose in view. Somewhat better results were obtained by Weiss and Aichel‡ with the so-called "mixed" metal, aluminium being replaced by an alloy of certain metals of the cerium and yttrium group. Owing to the great reducing power of such an alloy, the vanadium is obtained in the form of a molten metallic regulus of silver-white metal. According to Cowper-Coles§ silver-white vanadium can be obtained by electrolysis of a mixture of 1·75 parts of vanadium pentoxide and 2 parts of sodium hydroxide, with the addition of 32 parts of hydrochloric acid, with a cathode current-density of 0·018 to 0·02 amperes. Gin‖ subjected molten calcium fluoride, placed between a steel cathode and an anode composed of carbon and vanadium tri-oxide, to electrolysis. Vanadium fluoride was then formed on the anode, and metallic vanadium separated out therefrom at the cathode.

Finally, Werner von Bolton* heated rods of vanadium tri-oxide to a white heat by means of a current of 1·8 amperes at a pressure of 42 volts in an evacuated glass vessel. By this means the element was deposited, the recombination of vanadium with oxygen being avoided by the use of a permanent vacuum. By this means the small rods of the oxide were gradually converted into grey, metallic vanadium. As regards the properties of this metal, it may be mentioned that it crystallizes in hexagonal, rhomboid crystals, is white in colour, and is capable of a brilliant polish. It is exceptionally hard, and cannot be scratched, either by steel or force. According to Smith, the metal melts at about 2,000 degrees. Moissan found it more difficult to melt in the electrical furnace than other metals, while von Bolton estimated its melting-point, by the photometrical method of Lummer, to be about 1680 degrees. At ordinary times vanadium is quite stable when exposed to the atmosphere.

It is also exceedingly difficult to isolate niobium from its compounds for it unites very readily with oxygen, and also combines with the substances used in its attempted reduction. The first efforts in this direction may be attributed to Rose,† who succeeded in obtaining the oxide NbO, by the action, under heat, of sodium upon potassium-fluoroxiniobate. Roscoe,‡ by reduction of the vapour of niobium chloride by means of hydrogen, obtained a product which still, however, contained about 0·27 per cent. of hydrogen, and also traces of the oxide and chloride. According to the process of Goldschmidt§ the compound $Nb_2 Al_3$ is formed, while that arrived at by Moissan‖ in the electric furnace contained 2·5 to 3·4 per cent. of carbon.

* Liebig's 'Annalen. Suppl.,' **7**, 70; **8**, 95. *Phil. Trans.*, **159**, 11, 689; **160**, 11, 317.

† *Compt. Rend.*, **116**, 1225, 1893, **122**, 1297, 1896.

‡ Liebig's 'Annalen.,' **377**, 380, 1904.

§ *Eng. a. Mining Journal*, **67**, 744.

‖ *L'Electricien*, **25**, 5, 1904.

* *Zeitschrift für Elektrochemie*, ii. 45, 1905.

† *An. Chim. Phys.*, **54**, 426. *Pog. An.*, **104**, 310, 1858.

‡ *Chem. News*, **37**, 25, 1878.

§ *Phys. Zeitschr.*, 166 and 195.

‖ *Compt. Rend.*, **133**, 20, 1901.

The regulus obtained through the mixed metal by Weiss and Aichel* was, as von Bolton showed, rendered impure by the presence of Nb_2O_5 and the metal referred to. Werner von Bolton, last year, first obtained pure niobium.† He compressed a paste of niobium pentoxide with paraffin into small rods. These were heated to about 1,700 degrees by means of an electric current, the tetroxide of niobium being formed in the process; this in turn was reduced to the metallic state by additional heating in vacuo. The resultant product was extremely pure.

Niobium is of a dull grey colour. Its specific gravity is given as 12·7 to 12·75, and its melting-point is in the neighbourhood of 1,950 degrees. It is fairly ductile, and may be drawn out into wires as thin as 0·05 mm. At a red glow portions of it may be welded together with the hammer. The pure metal is not so hard as soft steel; when traces of aluminium, carbon, or oxygen are present, however, the metal is much harder—almost as hard as vanadium. The electrical specific resistance of niobium, in the form of pressed sheet, is 0·187 (1 m., 1 sq. mm.), but increases with rising temperature in the case of the pure metal. From this standpoint niobium would appear well adapted for the manufacture of glow-lamp filaments. Unfortunately for its application to this purpose, however, the metal has the undesirable property of volatilizing somewhat rapidly in vacuo. As regards the chemical properties of niobium, it is only necessary to add that it forms a refractory oxide and easily volatile chlorides.

Tantalum, the atomic weight of which is given as 181·4, is by far the most important element of this group for the purpose of the manufacture of glow-lamps. As in the case of its homologues, Moissan's researches‡ with the electric furnace only led to a product which contained carbon as an impurity. Goldschmidt and Vautier likewise obtained a product which contained aluminium.*

The researches of Weiss and Aichel† again led to no good results, for the temperature of reaction did not suffice for the production of a satisfactory regulus. Other means of reduction, such as those involving the use of magnesium and zinc, also proved unsatisfactory. The preparation of tantalum in the pure state is also due to Werner von Bolton.‡ Messrs. Siemens and Halske have protected his results in a large number of patents (German patents, Class 49i, 152,848, 152,870, 153,826, Class 40a, 153,548, 1903).

The process of reduction is similar to that described in the case of niobium. Tantalum pentoxide and paraffin are pressed into the form of filaments, embedded in the dioxide, and then reduced to the metallic state, by the so-called pulsating electrolysis, the process taking place in an evacuated vessel which is also subjected to continuous exhaustion in order to remove completely all oxygen. To Werner von Bolton is also due the method of purification involving a modification of the Berzelius-Rose process, in which tantalum powder, obtained from potassium fluortantalate, is employed; on account of its great affinity for all elements in a vacuum, the metal is melted in the electric arc. As a result a shining regulus of platinum-grey metal is obtained. In the truly pure state the metal is so ductile that it can be drawn into wires of only 0·03 mm. in diameter. Tantalum containing 1 per cent. of impurities is still malleable, but already very brittle.

The specific weight of tantalum is about 16·5. It melts near 2,250 to 2,300 degrees. Its modulus of elasticity resembles that of steel. The specific electrical resistance of a length of 1 meter, 1 sq. mm. in cross section, is 0·165, but at a temperature of 1,700 degrees has already risen to 0·855.

* *Lieb. An.*, 337, 384, 1904.

† *Zeitschr. f. Elektrochemie*, **11**, 45, 1905; **13**, 145, 1907.

‡ *Compt. Rend.*, **134**, 212, 1902.

* *Chem. Soc. Ind.*, **17**, 543, 1898.

† *Lieb. An.*, 337, 386, 1904.

‡ *Zeitschr. f. Elektrochemie*, **11**, 45 and 722, 1905.

According to their first patent (154,527, 1902) Siemens & Halske form filaments from tantalum by the paste process, and derive the metal from the oxides. In supplementary patents, 158,570, 158,571, 164,357, they also utilize the nitrides, sulphides, and carbides. According to another patent (156,714) they increase the resistance of the metal, and reduce the tendency towards volatilization, by previously purifying the filament by the use of hydrochloric and sulphuric acids. In the German patent 159,811 they protect the drawing and forcing out of the electrolytically reduced metal, and in the supplementary patent 165,057 recommend the addition of a trace—no more than $\frac{1}{20}$ per cent.—of carbon, hydrogen, oxygen, silicon, aluminium, tin, or titanium, in order to improve the hardness and durability of the filament. Any addition above this amount must at all costs be avoided, for it leads to great brittleness.

Hitherto the tantalum lamps have proved themselves by far the most durable of the metallic filament lamps. The diameter of the filaments lies between 0·035 and 0·05 mm.; a filament, 0·05 mm. in diameter, intended for a 110 volt 25 candle-power lamp, must have a length of 650 mm., and involves the use of 0·022 grams of the metal. Consequently the horseshoe form filament, characteristic of carbon filament lamps, cannot be utilized. Siemens & Halske have protected the process of winding the filament upon a suitable frame in the German patents 153,328, 159,096, and 168,973.

Tantalum lamps are built by this firm in three distinct types—types A and B being intended for 1·5 to 1·7 watts per H.K., and type C for 2·1 to 2·3 watts per H.K. The temperature of a glowing filament running at 1·5 watts per H.K. lies in the neighbourhood of 1,700 degrees. The increase in temperature above this value, necessitated by the attempt at a higher efficiency, would cause the metal to assume a crystalline form and become brittle very rapidly. In the case of the more durable forms A and B, the useful life, during which the light falls off by 20 per cent., reaches about 800 hours; but the actual life before the filament breaks is considerably higher—often double the above value. Reckoning the initial cost of the lamp at 2·50 marks, the maintenance-cost of the lamp thus approaches 0·2 to 0·3 pfennigs per hour of life. On account of the durability of tantalum filaments, which unlike those of the other more fragile metallic filament lamps, can be burnt in any position, it appears that the great shipping companies have now decided to utilize tantalum lamps on their steamboats.*

Let us now refer to the efforts that have been made to utilize the tetravalent metals, zirconium, titanium, and thorium, for the manufacture of filaments. In the first place it may be remarked that, in spite of many experiments, no very practical results have yet been arrived at as regards the use of either titanium and thorium. In addition efforts to obtain zirconium in a pure condition have, up to the present, proved fruitless. For progress in this direction science is greatly indebted to the work of E. Wedekind and his colleagues at Tübingen, whose results have been published in countless communications to the *Berichten der deutschen chemischen Gesellschaft* and in the *Chemiker Zeitung* since the year 1903. Although very many different methods of reduction were attempted the zirconium invariably proved to be impure, and to contain traces of the substances used in the process. In one case, however, Wedekind certainly succeeded in producing an aqueous solution of colloidal zirconium, to which we will refer later.

The most important patents relating to the preparation of and application of zirconium to glow-lamp manufacture are those of Sander of Berlin. Naturally, however, there are many patents in which the use of zirconium is referred to, but the wideness of the claims usually put forward by patentees makes any rigid system of chemical classification of these very difficult. According to a German patent (140,323 of 1901) Sander reduces zirconium or thorium oxide by the use of magne-

* *Chemiker Zeitung*, 1908. 26, p. 336.

sium in a stream of hydrogen. During this process volatile compounds with hydrogen are formed which can be caused to deposit the metal upon a suitable conducting "carrier," when the latter is heated to incandescence in vacuo. Also when zirconium and magnesium are heated together in the electric furnace the resulting product can be treated with dilute nitric acid so as to form a volatile zirconium hydride. The following additional method for the production of this volatile hydride is also given :—

$$ZrCl_4 + 4NaOC_2H_5 = 4NaCl + Zr(OC_2H_5)_4$$

On heating, the volatile hydride is derived from the zirconium alcoholate so produced. The zirconium ethyl obtained by means of the relation—

$$ZrCl_4 + 2Zn(C_2H_5)_2 = Zr(C_2H_5)_4 + 2ZnCl_2$$

also yields the hydride when treated with sodium fluoride.

The other patents of Sander (133,701, 137,568, 137,569, 140,378, 141,353, 146,555, 147,223, 147,316) enable us to perceive that the volatile zirconium compounds cannot be reduced to the metal by the use of carbon with heat, for the essential feature of these patents is the description of processes for the production of carbides. The mechanical portion of the manufacture of glow-lamp filaments from these materials is accomplished by the paste process.

The technical utilization of Sander's patents for Germany was taken up by Dr. Hollefreund & Co. of Berlin. In the case of the carbide lamps so manufactured the diameter of the filament approaches 0·6 mm. and a length of 5 mm. per volt is necessary. Therefore on all ordinary pressures it was necessary to run several of these lamps in series. At a consumption of 1 watt per candle-power they burned for about 100 hours only, and thus exhibited but little mechanical durability. The technical difficulties in the way of the improvement of these lamps proved to be so serious that Hollefreund & Co. finally abandoned the utilization of zirconium entirely, and the so-called "Zircon" lamps practically manufactured by this firm to-day are incorrectly named, for they consist of pure wolfram.

Mention may also be made of the patents of Carl Pieper of Berlin (116,141 of 1898 and 138,468). According to this process filaments of thorium, titanium, &c., are manufactured from titanium, nitride, or graphite of density 2·25, in conjunction with the oxide of thorium, with or without the addition of cerium oxide. By the addition of chromium or wolfram to these metals the melting-point is said to be raised and the general mechanical qualities of the material improved.

The patents of Siemens & Halske (140,088, 140,503, 140,832, 169,565, 169,928, 194,349) relating to this group of metals and also various rare earth metals have already been referred to. When these patents are compared with one another many contradictions become evident. For whereas in the first three patents it is the carbide of thorium that is specially recommended for the manufacture of glow-lamp filaments, the fourth dilates on the advantages of the pure metal; the last patent, however, speaks of thorium filaments containing oxygen, which suggests that the preparation of the metal in a pure state has not yet been accomplished. A great variety of patents relating to the utilization of the carbides of the rare earths for glow-lamp filaments have also been taken out by W. L. Voelker, H. Jehrlant, Konsortium für elektrochemische Industrie, Nürnberg, Dr. W. Nernst, &c., but the discussion of these would carry us outside the scope of the present article.

There exist but a few patents referring to the construction of glow-lamp filaments from boron and silicon either in the form of the pure metal or the carbide. Boron oxide, however, has been added to carbon filaments, with the object of increasing their durability and electrical resistance. André Blondel, of Paris, manufactured filaments from boron and silicon by the aid of the paste process as in 1899 (German patent 115,708). In their patent 195,504 of 1907, the A.E.G. describe a process of fusion in order to improve the conductivity of boron.

The electrical resistance of boron is very high—nearly a hundred times that of carbon; on the other hand, its decided tendency to volatilize in a vacuum militates against its use for glow-lamp filaments, and its mechanical strength also leaves something to be desired. The boron carbide, on account of its low conductivity, can be added to zirconium carbide with advantage. Too high a percentage of boron carbide, however, results in the filament becoming very brittle, while a filament containing 10 per cent. of boron carbide and 7 per cent. of carbon is mechanically strong, but inclined to volatilize.

Silicon and its carbides exhibit much more promising qualities. Thus a lamp in which the filament is composed of silicon, the so-called "Helion" lamp, has recently been put upon the market, and tests on these filaments have given very favourable results. The filament is prepared by the deposition of silicon from volatile compounds upon a carbon core. Lamps intended for 110 volts consume 1 watt per candle-power, the temperature of incandescence of the filament being given as 1,750 degrees. The life, it is said, often extends as long as 1,270 hours, and invariably over 700 hours.

Finally, reference must be made to the Kuzel process of constructing metallic filaments. This method is protected by the German patents 194,348, 194,890, 194,891, 194,893, and covers the use of all the metals under consideration. The method is really essentially a paste process, but differs from others in the fact that the pure metal is reduced to a gelatinous colloidal condition, thus obviating the necessity for any foreign binding material.

In order to prepare metals in a colloidal state—*i.e.*, simply explained, an exceedingly finely divided condition, in which the surface exhibited is very great—Kuzel utilizes neither the vaporization of a metal by electrical means, nor the primary creation of the desired state by suitably guided processes of reduction. He prefers rather to rely upon chemical methods, according to which metals, already reduced to a finely divided condition by mechanical means, are subjected to alternate treatment with acid and alkali aqueous solutions, and during the process of washing a small quantity enters into solution in the water as a "hydrosol." Wedekind,* for instance, by utilizing a reducing process of this nature, was able to prepare a hydrosol of zirconium by treatment of the zirconium-potassium-fluoride with metallic potassium. By careful evaporation of such "sols" we are able to obtain "gels" of varying consistency which can afterwards be pressed out into exceedingly homogeneous filaments, and can be forced through much narrower apertures than in the case of any other variety of paste.

In consequence of the absolute uniformity in diameter of these filaments, which burn at a consumption of 1 watt per H.K., they can bear an enormous degree of over-running, even as far as 0·31 watts per H.K., without burning out; their useful life approaches 1,000 hours. The practical working of the Kuzel patents is in the hands of Messrs. Pintsch in Germany, and Joh. Kremenezky in Austria-Hungary.

When we reflect upon the evidence of energy and painstaking labour embodied in the array of patents to which reference has been made in this article, and survey the progress that has already taken place in the development both of electric lighting and in the manufacture of incandescent mantles, we cannot doubt but that we are on the eve of a complete solution of the problems that have arisen in the manufacture of metallic filament lamps, formidable as many of them now appear.

* *Chemiker-Zeitung*, 1906, 1,264.

The Photometry of Street Lamps.

By Haydn T. Harrison, M.I.E.E.

The close competition which now exists between the gas and electricity supply undertakings for street lighting is so keen that the respective merits of the competitors can only be judged by actual photometric tests made on the lamps in position. Therefore a few hints as to the ways and means of carrying these out expeditiously and accurately may be of value to the readers of this journal.

Before actually describing the best method of procedure, it would be well to consider the conditions under which the measurements are generally made, and the figures which it is required to know.

Street illumination consists in nearly all cases of a row of lamps supported by posts, generally erected on alternate sides of the road, but sometimes on one side only or down the centre. Therefore the degree of illumination will depend on three factors :—

(1) The candle-power of the useful rays of the lamps. (C.P.)

(2) The distance apart of the lamps. (D.)

(3) The height of the lamps. (H.)

These three factors can be included in one figure, viz., minimum illumination, by the following simple formula :

Minimum illumination in Candle Ft. =

$$\frac{\text{C.P.}}{d^2 + H^2}$$

d^2 being the distance half-way between the lamps, and therefore the furthest distance from any lamp.

$d^2 + H^2$ giving the slant distance from the lamp squared, this figure when divided into the c.-p. of the lamp at that point gives the minimum illumination which combines all the factors it is required to know.

From this it would appear that it is only necessary to make a measurement in the position (P) shown in the sketch —Fig. 1 of which represents an elevation of the street and Fig. 2 a plan—but, unfortunately, in ninety-nine cases out of a hundred it is impossible to make this measurement, as the illumination at that point is generally lower than any photometer can record accurately.

Take, for example, a street lighted by incandescent gas lamps of 50 candle-power, erected on posts 12 ft. high and 120 ft. apart (diagonally). The direct illumination on a photometer screen 4 ft. from the ground at a distance of 60 ft. from any lamp would be :

$$\frac{50}{3600 + 64} = {\cdot}014 \text{ C.F.}$$

Or if a horizontal screen photometer were used, thus deriving illumination from both lamps, but at an angle which reduces the degree of illumination in proportion to the cosine of the angle of incidence (which in this example is between 11 and 12 degrees, of which the cosine is ·193) the illumination on the screen would be :—

$$\text{C.F.} = {\cdot}193({\cdot}014 + {\cdot}014)$$
$$= {\cdot}0054$$

As no photometer can be used with any degree of accuracy below ·02 of a candle foot, it is obvious that, even when measuring the illumination direct, it would be unwise to do so at the point of minimum illumination; and in most cases it is a waste of time to attempt it.

My method of procedure is as follows :

I first make careful notes of the height and distance apart of the lamps. It is sometimes difficult to measure the height of the lamps with a tape measure, and therefore the better class of portable photometer is generally provided with some means of ascertaining the angle at which the rays from the lamp strike the photometer—such as a lens or sector. These can be used to calculate the height by placing the photometer at a measured distance from the post, levelling it, and ascertaining the angle of the rays; then the height will be equal to the distance multiplied by the tangent of the angle.

Having made these notes, the next proceeding is to measure the illumination at the greatest distance from the post that it can conveniently be measured, and calculate the candle-power at that particular angle. This will give very approximately the candle-power of the rays which will strike the point of minimum illumination.

After this, all measurements on that type of lamp can be made at the point most suitable for obtaining accurate readings and rapidity of working.

Taking, for example, the beforementioned case of incandescent gas will occur at any part of the street, provided the distance apart of the various posts is known.

It will be noted that in the above method, which I have found to be by far the most easy and accurate way of surveying the illumination of a street, the actual measurements are made in direct illumination; that is to say, the photometer is pointed so as to receive the rays of the lamp under test at an angle nearly approaching a right angle to the surface of the measuring screen. It is for this reason that a photometer with a screen at forty-five degrees lends itself to rapid and accurate work in practice.

In the above example, when making measurements at 12 ft. from the post, the light from the lamp would fall on

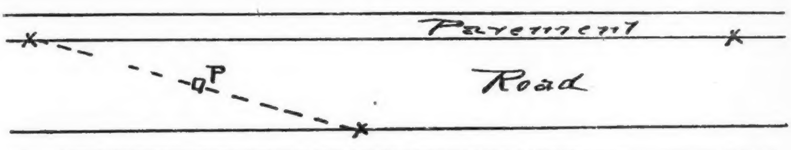


FIG. 1.

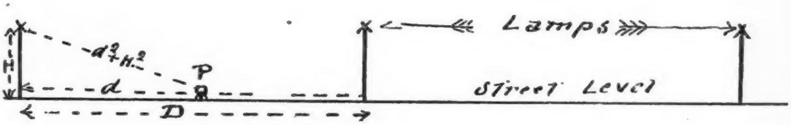


FIG. 2.

lamps 12 ft. from the ground and 8 ft. above the photometer screen: the height squared is 64. Therefore, a distance such as 12 ft. from the post, which, when squared and added to 64 equals 208, would prove a good position at which to make the tests on the lamps. Let us suppose that the direct illumination proved to be ·22 candle-feet, which when multiplied by 208 shows that the candle-power is 45·76, or at that position 8·5 per cent lower than it was found to be at the position nearest the minimum, which was higher owing to the horizontal candle-power being greater. This difference being known, measurements can be rapidly made at 12 ft. from the various posts in the street, and the results reduced to the minimum which the forty-five-degree screen at an angle of which the cosine is ·98; thus the error due to this would only be 2 per cent. Even at a distance of 40 ft. from the post, where the illumination is as low as ·03 c.-f., the angle of incidence would be only thirty-four degrees, which means a correction of 17 per cent; whereas if a horizontal screen is used, the angle at the latter distance would be seventy-nine degrees, and the illumination as low as ·005 c.-f. In this case, an error of one degree in levelling would cause an error of 8·5 per cent in the reading; whilst in the case of the forty-five-degree screen it would only be 1·2 per cent.

When measurements are being made in more important thoroughfares, where lamps of greater candle-power erected on higher posts are used, it is sometimes possible to make horizontal measurements at the point of minimum illumination; but these cases are so rare that the use of a horizontal screen is generally impossible if it is required to know the illumination throughout a street.

On the other hand, the use of a horizontal screen is sometimes preferable when testing the illumination of an open space containing large candle-power lamps irregularly spaced; but even then the candle-power of each lamp cannot be calculated from the results—which is sometimes a serious drawback.

As regards the best type of photometer to use: this does not come within the scope of the present article; but for the benefit of those who have had little experience in photometric work, I would strongly advise the use of a photometer which has a flicker head. This type of photometer can be used to measure the illumination from any kind of lamp, and, moreover, it is possible for any one, however inexperienced, to obtain a balance by eliminating the flicker.

In street photometry the following sources of error should be carefully guarded against:—

1. *Errors due to variation in standard lamps.*—Any other form of standard than an incandescent electric lamp requires the careful attention of an expert, and cannot be used with success except in calm weather. An electric standard can be relied upon, provided all connexions between it and the battery are permanently made; and the necessary switch or plug key which is inserted in the circuit in order to disconnect the lamp is of the most substantial design. It must be obvious to all that these precautions are most important when it is borne in mind that a four-volt battery is used; therefore, the varying of the pressure of a terminal, due to connecting and disconnecting, might easily introduce resistance which varies the P.D. across the lamp by ·05 of a volt—this means over 1 per cent, or often 7 per cent, variation in the candle-power of the standard.

The safest way, therefore, is to use a type of photometer in which the battery is contained in the instrument, and thus the connexions, with the exception of the switch or key, are permanent. After charging the cells the lamp should be connected for at least fifteen minutes; the photometer can then be checked against a lamp of known candle-power. After measurements have been made in the street, the photometer can again be checked against the same lamp to see if any variation has occurred.

2. *Errors due to observation.*—These are often caused by the operator placing his eye too close to the screens, and thus not getting a general view. I find that when using a photometer 4 ft. from the ground, the best results can be obtained by leaning over so that the eye is about a foot above the screens.

When using a flicker head, let it revolve as slowly as is possible, with the object of eliminating the flicker. The speed has to be increased if the spectrum of the lamps vary considerably, but when they are similar the speed can be low. Measurements should not be taken if the eye is fatigued.

3. *Errors due to angular uncertainties.*—These have been touched on before, and are not, as a rule, serious except when a photometer having a horizontal screen is used, when the greatest care must be taken in levelling the instrument.

In conclusion I would endorse the advice so often given to amateur photographers: never be in a hurry. Always make ready before going out, so that as little work as possible need be done in the open. Note-books should be prepared, with columns ruled under headings of the details required, such as distance, height, reading in C.P., angle, type of lamp, position, and general notes. These columns can be filled in by an assistant while the measurements are being made.

With a suitable instrument and ordinary care, the candle-power of the lamps or the illumination of a large number of points in several streets can be measured in a few hours, and from the results all the data required can be calculated and curves prepared if necessary

The New "Radium" Illuminated Sign.

BY W. BIEGON V. CZUDNOCHOWSKI.

ILLUMINATING signs used for advertisements and other purposes in the streets by night are now beginning to receive a considerable amount of attention. Naturally such signs attract the attention of the passer-by much more readily than a daylight advertisement would do. During the daytime people are engaged in business, and have little leisure to study their surroundings in the streets. In the evening, on the other hand, their attention is free to wander, and the greater brilliancy of the illuminated sign more readily attracts attention.

Hence it comes about that many forms of illuminated signs are now being devised, and the amount of energy actually consumed in this way is already far from trivial.

It occurred to the author that a description of an ingenious and effective arrangement recently shown at the "Augur" display in Berlin—an exhibition devoted to recent devices for shop-lighting, &c.—might be of interest. The general construction of this "Radium" sign is shown in Fig. 1.

L is a small glow lamp mounted on the end of a horizontal tube, and surrounded by the conical reflector R; in the case of very large signs several lamps may be used. The conducting wires D are passed through to the glow lamp at a right-angle bend in the tube at K. There is a thread on the outer surface of the tube on which are mounted two metal plates P, provided with nuts as shown. These two plates serve to clamp and hold in position the curved metallic framework GG.

This surface GG is a zone of a sphere made up of a network of strips of metal. The glow lamp is placed at the focal length of this spherical framework, so that the beam of light from the reflector R is cast on to the strips of which it is composed.

Under ordinary circumstances emblems or mottoes are cut out of some suitable light-reflecting material. and mounted on this skeleton framework, the usual plan being to place the emblem or trade mark in the centre, and the motto surrounding it. When the lamp is turned on these letters, &c., appear brilliantly illuminated, the surrounding surface appearing dead black in comparison. In order that the signs may be visible from different angles, a substance which diffuses the light in all directions, but yet, at the same time, absorbs very little of it, is employed.

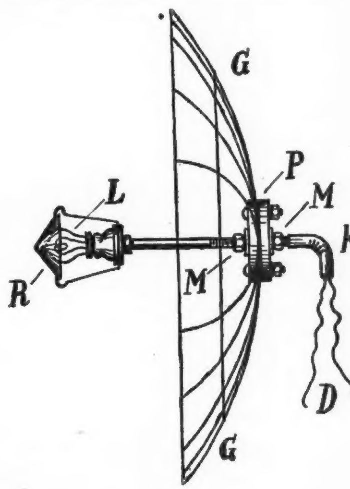


FIG. 1.

In general, such surfaces present a silver-like appearance, but, of course, trade marks, &c., can be made up in various colours as required.

The effect is to cause the illuminated device to appear as if floating in the air unsupported; the source of light being of small dimensions and, of course, screened from the eye, is not noticeable at the distance. The general effect of such an arrangement is shown in Fig. 2.

Such a sign is simple and ingenious, and consumes comparatively little energy. Hitherto illuminated signs require a considerable amount of energy.

Secondly, signs may take the form of illuminated transparencies, lanterns, &c., fitted with opal glass or other diffusing surfaces, but these signs commonly absorb a great deal of light.

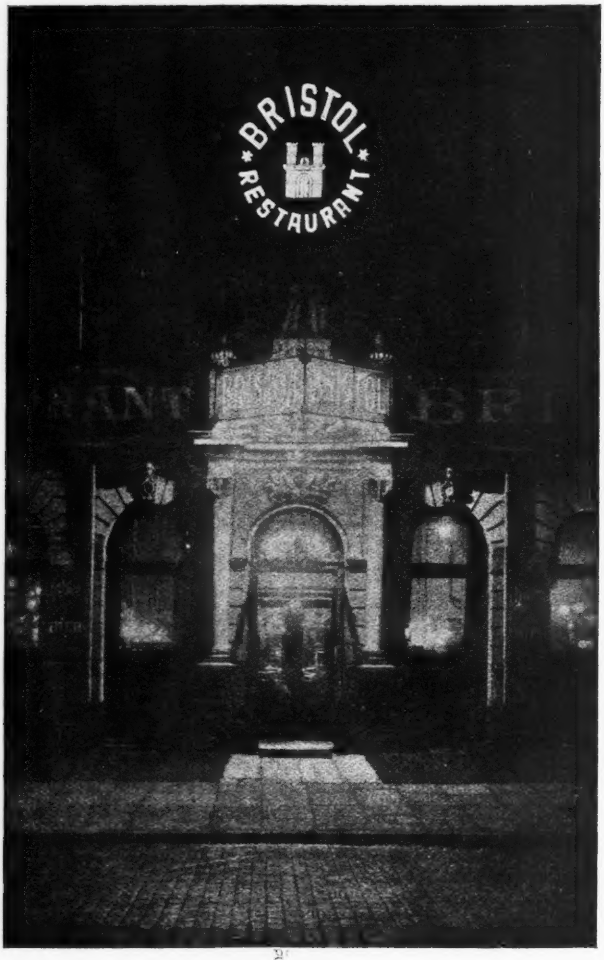


FIG. 2.

have been divisible into two main classes. There is firstly the type of signs outlined in incandescent lamps, which are frequently turned on and off at intervals by a special mechanical contrivance. Such signs, however, The newly patented "Radium" sign certainly seems to produce very effective results, and consumes a relatively small amount of energy, while the loss of light by absorption is reduced to a minimum.

Gas-Lighting at the Scottish National Exhibition, Edinburgh.

By W. R. Herring,

Chief Engineer to the Edinburgh and Leith Corporation's Gas Commissioners.

Gas-lighting plays an important part in the illumination of the Scottish National Exhibition, which was opened on May 1st by H.R.H. Prince Arthur of Connaught, and it will no doubt be of some interest to briefly state what has been done to demonstrate the efficiency and economy of coal gas for both exterior and interior illumination for such and similar purposes. To simplify the description the subject is sub-divided into the following headings, viz., Exterior Illumination, Interior Illumination.

Exterior Illumination.

The main entrance is approached by a bridge spanning a river. The bridge is lighted by means of eight Vesta-Graetzin inverted self-intensifying lamps with three burners and mantles in each, supplied by Messrs. Falk, Stadelmann & Company, Ltd., London.

These lamps were found to give, when photometrically tested, their best results when regulated to a consumpt of 10·6 cubic feet per hour each at thirty tenths pressure, and gave a total of 396 candles per lamp or 37·4 candles per foot of gas consumed, with a clear glass globe. The lamps are suspended within a harp-shaped attachment surmounted upon a dwarf column supported upon the pedestals of the entablature of the bridge, the centre of the light being 14 ft. above the carriage-way. The area of the roadway lighted is not great, measuring in all 3,546 superficial feet. The total illumination given by the lamps is 3,168 candles or ·89 candles per square foot of area illuminated for a consumpt of 84·8 cubic feet of gas, costing $2\frac{3}{4}d.$ per hour and yielding 1,132 candles per pennyworth of gas consumed.

A. Vesta-Graetzin—3-Light Lamp (Clear Globe).

Pressure on Burner. Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	15 0	17 9	45	1·17	9·8	368	37·44
„	„	„	„	1·19	10·2	374	36·7
„	„	„	„	1·21	10·2	382	37·4
„	„	„	„	1·13	15·9	357	22·5
30	15 0	17 9	45	1·26	10·6	396	37·4
„	„	„	„	1·11	11·4	349	30·6
25	4 0	15 1	4	1·17	10·2	266	26·0
„	„	16 2	3½	1·11	15·9	289	18·2

Remarks.—At 25 tenths the consumpt was reduced to 8·8 cubic feet per hour, but no photometric test was taken on account of the loud noise made by the lamp. Similar conditions prevailed at 30 tenths on reducing the consumpt below 10·6 cubic feet per hour.

The last two tests (viz., at angles of 4° and 3½°) are as near horizontal as possible without cutting off part of the light with the lamp shade.

The statement of our tests of these lamps in Table A conveys some interesting information.

The entrance gateway, offices, and turnstiles, &c., are lighted by means of incandescent gas lamps supplied by Messrs. J. & W. B. Smith and Messrs. Moffats, Limited.

Each central archway is fitted with a Nero-Graetzin five-light inverted lamp supplied by Messrs. J. & W. B. Smith, some of these lamps being also in use in other parts of the exhibition not specifically mentioned. When subjected to photometrical investigation they were found to give their best results when regulated to a consumpt of 14·1 cubic feet at thirty tenths pressure, and gave a total of 580 candles per lamp, or 41·1 candles per cubic foot of gas consumed, with a clear glass globe. The maximum candle-power obtained from these lamps was 607 candles at a consumpt of 15·25 at twenty-five tenths pressure, but the efficiency per foot is only 39·8 at this consumption. (See Table B.)

B. NERO-GRAETZIN—5-LIGHT LAMP (CLEAR GLOBE).

Pressure. Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	15 0	17 8	45	1·75	13·9	543	39·0
,,	,,	,,	,,	1·81	14·3	567	39·6
,,	,,	,,	,,	1·94	15·25	607	39·8
30	,,	,,	,,	1·87	14·1	580	41·1
,,	,,	,,	,,	1·90	15·2	594	39·1
25	3 6	16 1	3	1·56	15·25	404	26·5
30	3 5	16 0	,,	1·50	14·2	386	27·2

Remarks.—At 30 tenths with a less consumpt than 14·1 cubic feet per hour the light decreased, and no photometrical test was taken.

The last two tests (viz., at angle of 3°) were taken as nearly horizontal as possible without cutting off part of the light with the lamp shade.

The Stanley inverted lamps supplied by Messrs. Moffats, Ltd., are of their well-known type, and used at the entrance gateways and offices, and also in the kitchen of the first-class restaurant, and gave, when photometrically tested and the gas pressure regulated to twenty-five tenths at a consumpt of 8·3 cubic feet per hour, 338 candles or 40·7 candles per foot of gas consumed, and the data (Table C) regarding these will be interesting.

Immediately upon passing the entrance portico to the exhibition one has access to the main avenue leading to the Grand Promenade.

The lighting of these areas has been entrusted to Messrs. James Keith & Blackman Company, Ltd., who have installed one of their well-known high-pressure plants. The engines and compressor plant are situated in a small building to the left of the entrance portico. Messrs. James Keith & Blackman Company, Ltd., have introduced for this purpose for the first time their new single burner inverted lamp of a guaranteed candle-power of 1,500 candles. Along the avenue placed alternately on either side twenty-four single lamps are erected, spaced from 29 to 70 ft. apart, the breadth of the avenue being 40 ft., and there are twenty-one three-cluster lamps surrounding the grand promenade, which

C. STANLEY 3-LIGHT LAMP.

Pressure Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	15 0	17 2	45	1·12	10·0	332	33·2
,,	,,	,,	,,	1·2	9·3	350	37·6
,,	15 1	17 4	,,	1·12	8·3	338	40·7
,,	15 2	17 5	,,	1·0	8·2	310	37·8
,,	15 2	17 5	,,	0·86	8·2	262	32·0

Remarks.—The first three tests were made with a clear globe and reflecting shade.

The fourth test with clear globe, without reflecting shade, and the last with opal globe without reflecting shade. The loss of light with the opal globe is therefore 15·5 per cent.

measures 580 ft. long by 300 ft. wide. It may be stated that the principal exhibition buildings are placed around the Grand Promenade, thus forming a quadrangle. There is a further number of forty-one single-burner lamps on the same system lighting other avenues and areas within the exhibition grounds. The lamps are suspended from a swan-neck attachment secured to the top of the column. The mantle, it may be interesting to note, measures 3⅝ in. long by 1½ in. diameter. One of these lamps tested in the first instance yielded 1,630 candle-power for a consumption of 24·5 cubic feet of gas per hour, which is equal to 66·5 candles per cubic foot. As on this occasion, however, the mantle was not found to be suitable for the size and shape of the flame, and the test was purposely carried out in order to enable the makers to adjust both the nipple of the lamp and get a properly shaped mantle for the particular purpose; further tests were made at a later date when the lamps were delivered for the exhibition proper. These results are set out in Tables D and Dᴀ.

The area of the avenue along which some twenty-four single lamps are placed measures 45,527 square feet, and the total candle-power emitted is 40,440 candles; this is equal to an illumination of ·88 candles per superficial foot of area dealt with. The twenty-one three-cluster lamps around the grand promenade are of an exactly similar type to those already described. The total area of the quadrangle is 174,000 square feet, and the total candle-power 106,155. This illumination is equal to ·61 candles per square foot of area lighted, and yields 2,230 candles per pennyworth of gas consumed.

D. Photometrical Tests on Keith's New High Pressure Inverted Lamp—1 Mantle Light, Mantle 3⅝ inches long by 1½ inches diameter, slight bulb shape.

The normal quality of the gas would be 20 to 21 candles when burnt in a No. 2 Metropolitan Argand Burner, and the calorific power of the gas at Granton 648·3 gross, 598·9 net, and at the Testing Station 560 net.

The test was taken by a Simmance & Abady's Street Photometer, which had been previously verified by testing a given lamp simultaneously on a 100 inch Bar Photometer and the Portable Photometer in the same room and under like conditions.

29th April, 1908.

Pressure Inches.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
61	4 6	40 0	2½	1·05	24·6	1,683	68·4
61	16 0	42 4	20	0·95	24·6	1,705	69·3
61	20 0	29 9	37	1·81	24·8	1,609	64·9

Remarks.—Clear globe. Slight leak in the meter, which did not affect the index when the burner was shut off, but which may have affected the consumpt.

Band-Stand.

The band-stand in the centre of the quadrangle is illuminated by means of twelve Nero-Graetzin two-light lamps supplied by Messrs. J. & W. B. Smith. Each lamp is controlled to work at twenty-five tenths pressure by a service governor, and when photometrically tested was found to give its best results when regulated to consume 6·2 cubic feet of gas, yielding 218 candles, or 35·2 candles per cubic foot of gas consumed, with *a frosted globe,* and the following statement of tests convey some interesting information. With all lamps burning 74½ cubic feet of gas per hour is consumed, costing about 2½*d.*, and giving 2,616 candles or 1,066 candles for one pennyworth of gas consumed. (See Table E.)

It may be interesting to note that Messrs. Rosie & McKelvie's automatic lighting and extinguishing device has been introduced experimentally into the band-stand installation.

The device is one that is actuated by a change of pressure, the lighting and extinguishing being brought about by a momentary reduction of pressure, and is capable of adjustment to a considerable extent. One leading feature of the arrangement is the means by which the bye-pass flame is extinguished during the period that the lamp is burning, this being accomplished in a very ingenious way. The apparatus is in process of being patented, and therefore a more definite description cannot at the moment be given.

Grounds around Old Hall.

The lighting of the grounds around the Old Mansion House south of the main exhibition buildings is accomplished by means of ordinary lamp-posts fitted with swan-neck connexions, to which are suspended five-light inverted Pharos lamps, supplied by Messrs. W. Anderson & Co., Ltd., Edinburgh. They are supplied with gas from the ordinary town main at a pressure of thirty to thirty-five tenths. There are in all twenty-eight of these lamps.

These lamps photometrically tested gave their best results when regulated to twenty-five tenths pressure and a consumpt of 15·4 cubic feet, yielding 560 candle-power, or 36·3 candles per foot of gas consumed, with a clear glass globe. It must, however, be pointed out that these lamps are still deficient in that perfection of method of regulating which applies to some of the other lamps referred to, and that the results vary when testing different lamps. This point is worthy of the makers' attention. (See Table F.)

Da. Photometrical Tests on Keith's New High Pressure Inverted Lamp—1 Mantle Light, Mantle $3\frac{5}{8}$ inches long by $1\frac{1}{2}$ inches diameter, slight bulb shape.

30th April, 1908.

Pressure Inches.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
61	4 9	40 0	4	1·04	22·9	1,655	72·2
61	16 0	42 1	20	0·95	22·9	1,685	73·6
61	20 0	28 9	37	1·9	22·9	1,572	68·6

Remarks.—Clear globe. A slight leakage in the pipe amounting to 0·09 feet per hour, which has been allowed for.

E. Nero-Graetzin—2-Light Lamp (Frosted Globe).

Pressure Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	10 0	10 4	45	1·43	5·4	153	28·3
,,	,,	,,	,,	2·04	6·2	218	35·2
,,	,,	,,	,,	2·04	7·7	218	28·3
30	,,	,,	,,	1·94	6 1	208	34·1
,,	,,	,,	,,	2·13	6·8	228	33·5
25	4 0	15 11	5	0·62	6·2	156	25·2
,,	,,	,,	,,	0·60	7·6	151	19·9

Remarks.—All the above tests were taken with a ground glass globe.

At 30 tenths on reading the consumpt below 6·1 there was a marked decrease of light, and therefore no photometrical test was taken.

The last two tests (viz., at angle of 5°) are as near horizontal as possible without cutting off part of the light with the lamp shade.

Interior Lighting.

At the outset gas-lighting appeared to have a poor chance at the exhibition for any purpose. Fortunately for both the authorities and also for the industry wiser councils prevailed, and a reasonably fair share of lighting has been allocated to the gas commissioners. Although at one time it had been definitely arranged that the whole of the interiors were to be electrically lighted, negotiations resulted in gas being adopted somewhat largely. It was, however, only on the basis of competitive estimating, and these remarks apply to the whole of the succeeding lighting installations, for each of which competitive estimates were submitted by both the gas commissioners and the electrical contractors; the cheaper estimates were for gas, the estimates in all cases being based on candle-power and cost per hour for illumination as well as equipment.

The principal feature of the interior lighting is the illumination of the Fine Art Section.

F. PHAROS—5-LIGHT LAMP (CLEAR GLOBE).

Pressure Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	15 0	17 9	45	1·6	14·7	502	34·1
,,	,,	,,	,,	1·78	15·4	560	36·3
,,	,,	,,	,,	1·86	16·3	586	35·9
,,	,,	,,	,,	2·10	18·5	658	35·5
,,	3 9	13 4	4	2·10	16·0	372	23·2

Remarks.—Tests taken with clear globe.

The last test (viz., at angle of 4°) is as near horizontal as possible without cutting off part of the light with the lamp shade.

One of the mantles showed signs of sooting after about one hour's burning.

There is no means of regulating the air supply.

This consists of nine galleries, which the gas commissioners took under their especial care. The lamps selected for the lighting of these galleries is the three-light "Empire" inverted lamp of Messrs. J. & W. B. Smith fitted with frosted globes and arranged as follows:—

In each gallery a double line of pipes is laid upon the roof structure, each line being placed 8 ft. 6 in. from the wall upon which the pictures are hung. Depending from this pipe lamps are suspended 11 ft. apart, this method being applied to all nine galleries, with the addition that in the central gallery three additional lamps are suspended, as the same is of much higher pitch, and is intended for statuary as well as pictures. The double line of lamps in each gallery is shielded on the outer side with a curved-shaped screen so as to prevent the light from one side of the room reflecting in the pictures on the opposite side. The central gallery, in addition to the "Empire" lamp, is fitted in the centre with a thermopile Lucas lamp, which has been kindly lent by Messrs. Moffats, Ltd., London, for the purpose. This lamp has already been fully described in the technical press, and one need not, therefore, say more than that this, like others, was submitted to photometrical tests, and was found to give a candle-power of 1,814 candles, burning gas at the rate of 40 cubic feet per hour, and 45·3 candles per cubic foot, with a clear glass globe, the lamp being upright in form with a single mantle measuring about 6 in. by 1½ in. A note of the tests taken upon this lamp is given in Table G.

On either side of the thermopile lamp a five-light Pharos inverted lamp is fitted, supplied by Messrs. Anderson, and similar in every way to those erected by the same firm in the gardens.

The lighting and extinguishing of the lamps in the art section is under central control. Each lamp is fitted with one of Messrs. Alder & Mackay's automatic distance lighters. This device is actuated both for lighting and extinguishing by momentarily raising the pressure, or, so to speak, sending forward a pressure-wave of from eight to ten tenths in excess of the normal. The gas supply is controlled by means of a Peebles governor, and the lamps adjusted to give their highest efficiency at a pressure of twenty-five tenths, the pressure in the district mains ranging from thirty-two to thirty-five tenths. A bye-pass is introduced between the inlet and the outlet of the Peebles governor controlling the entire building, and the lighting and extinguishing of the entire installation is accomplished by opening the bye-pass stopcock for a period of from one to two minutes and then closing it again. The extinguishing is brought about by an exactly similar operation.

This system of lighting and extinguishing has been found to answer admirably, and is peculiarly well adapted to installations where the control is desirable or can be established from one or more centralized positions, and the pressure-wave impulse made to reach all points, either from a station governor or from a localized governor on small gasholder.

with a clear glass globe. The particulars in Table H of our tests on this burner will give some useful information.

Regret may be here expressed that circumstances prevented our testing all of the lamps with clear glass shades. Attention may, however, be directed to the paragraph beneath the statement of tests of the "Empire" lamps where it is brought out that the loss of light by photometrical test consequent upon using a frosted globe instead of a clear glass amounted to 15½ per cent. As a matter of fact, I am of opinion that the frosted or satin finish globe is by far the most satisfactory for interior lighting, and that, whilst there is an apparent loss photometrically observed, it is a question whether the diffusion and more equal distribution does not more than compensate for the apparent loss of light. The softness of the light and the slightly yellow tone resulting from the use of ground glass is much more pleasing, and on the whole better appreciated by the public.

G. Lucas—Thermopile—1-Light Lamp (Clear Globe).

Pressure Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	5 1	33 0	4	1·66	40·0	1,814	45·3
,,	,,	,,	,,	1·33	35·0	1,450	41·4
,,	,,	,,	,,	1·05	30·0	1,145	38·1
,,	15 0	29 7	25	1·63	35·0	1,426	40·7
,,	20 0	24 6	45	1·94	35·0	1,168	33·3

Remarks.—Tests taken with clear globe. This burner makes a whirring noise.

H. Empire—3-Light Lamp.

Pressure. Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
25	15 0	17 6	45	1·16	7·75	355	45·8
,,	,,	,,	,,	0·96	7·10	294	41·4
,,	,,	,,	,,	0·98	7·75	300	38·7

Remarks.—With the Gas Regulator fully open the consumpt was 7·75, so no test with a higher consumpt could be taken.

The first two tests were taken with a *clear globe*, the last test being taken with a ground glass globe causing a loss of light equal to *15·5 per cent.*

The "Empire" lamps, when photometrically tested gave their best results when regulated at twenty-five tenths pressure to pass 7·75 cubic feet of gas per hour, yielding 355 candles, or 45·8 candles per foot of gas consumed,

The floor area of the galleries lighted (taking one gallery as an example) is 2,640 square feet, and there are sixteen three-light "Empire" lamps fitted in each, giving a total illuminating power of 4,800 candles, with frosted globes, which is equal to 1·8 candles per square foot of floor area illuminated. The total illumination in the whole of the galleries works out at 47,934 candles, with frosted globes, and the consumpt of gas at 1,233 cubic feet per hour, which at 2*s.* 9*d.* per 1,000 cubic feet equals 3*s.* 4½*d.* per hour, or equal to nearly 1,178 candles per one pennyworth of gas consumed, or by using clear glass about 1,400 candles per one pennyworth of gas consumed could have been obtained.

PRINCE'S RESTAURANT AND WELCOME CLUB.

The Prince's Restaurant and Welcome Club, consisting of reception-room, dining-hall, smoking and retiring rooms, and verandah are also lighted by gas at low pressure, controlled by means of a Peebles governor to twenty-five tenths pressure at the outlet, the lamps employed being adjusted to give their maximum efficiency at this pressure.

In this building Messrs. J. & W. B. Smith's two- and three-light "Empire" lamps and their single burner "Nulite" lamp are installed. Here the lamps are fitted in pairs and actuated by means of pneumatic distance lighters so that they may be switched on and off at will.

The test of some of the lamps installed have already been referred to, but the following statement relating to the "Nulite" burner contains a

I. NULITE—1-LIGHT LAMP (CLEAR GLOBE).

Pressure.	Consumpt.	Candle-power.	C.P. per foot.	Remarks.
15	2·56	67·00	26·17	
"	2·46	67·00	27·23	
"	2·35	61·50	26·17	
"	2·68	70·00	26·12	
"	3·19	65·00	20·38	Regulator fully open, special test at 3½ ft. consumpt.
20	3·06	79·00	25·82	
"	2·85	79	27·72	
"	2·69	74	27·51	
"	2·50	66	26·40	
"	3·54	74	20·90	Special test at 3½ ft. consumpt.
25	2·80	74	27·14	
"	2·96	81	27·37	
"	3·15	84	26·66	
"	3·59	81	22·56	Special test at 3½ ft. consumpt.
30	3·16	88	27·85	
"	3·03	87	28·71	
"	2·94	82	27·89	
"	3·53	90	25·49	Special test at 3½ ft. consumpt.
35	3·12	88	28·20	
"	2·96	84	28·38	
"	2·86	77	26·92	
"	3·54	92	26·00	Special test at 3½ ft. consumpt.
15	3·54	78	22·03	
20	4·00	76	19·00	
25	4·02	80	19·90	
30	4·03	78	19·35	
35	4·04	83	20·54	Regulator fully open.

Remarks.—This lamp is in appearance similar to the Graetzin, but unlike the latter *has no means of regulating the air supply.* The gas regulating nipple *is not* placed immediately over the centre of the lamp as is usual, but is at the side, the gas being conducted over the "Crown" of the lamp, down the side, and thence to the burner. The lamp is fitted with a chimney contained within the globe as in the Graetzin.

good deal of information. This lamp, when photometrically tested, was found to give its best results when the gas was regulated to a consumption of 3·03 cubic feet per hour at thirty tenths pressure, yielding 87 candles, with clear glass, or 28·71 candles per foot of gas consumed. It may be remarked that this lamp does not contain the regenerative or pre-air heating device which most of the other lamps already dealt with embody. It does ensure a fresh or unvitiated air supply by a bunsen tube; its results are not however, so good as where the air supply is not only unvitiated, but pre-heated in its access to the mixing chamber, and furthermore it is a lamp that requires a greater pressure for its highest efficiency. (See Table I.)

The area of the principal rooms lighted is about 5,578 square feet, and a total of 3,128 candles is provided; this is equal to ·56 candles per square foot of area. The gas consumption per hour amounts to 97 cubic feet, which at 2*s.* 9*d.* per 1,000 cubic feet works out at about 3¼*d.* per hour or 977 candles per one pennyworth of gas consumed

General Dining Room and Restaurant.

The above restaurant, &c., situated to the south of the Industrial Hall, consists of large dining-hall, side wings, kitchen, service rooms, &c. This establishment is lighted by "Pharos" lamps supplied by Messrs. W. Anderson & Co., Ltd., Edinburgh, similar to those already referred to. The dining-hall is lighted along the centre by means of four five-light "Pharos" lamps, and along the two sides by twelve one-light "Pharos" lamps, the latter actuated by pneumatic switches. The total area of the hall is 4,620 square feet, and the total candle-power 3,752 candles, giving an illumination of ·81 candles per square foot of area. The gas consumption per hour for this section is 104 cubic feet, costing under 3½*d.* per hour, or 1,093 candles per one pennyworth of gas consumed.

The single burner "Pharos" lamp gives a high efficiency, but considerable variation on testing different burners. This arises primarily from the want of means of adjustment in the inner chamber where the gas and air meet. The following tests, however, of this particular lamp when carefully adjusted by ourselves will show that it is of a promising character. (See Table K.)

K. Pharos—1-Light Lamp.

Pressure. Tenths.	Height of Lamp from Floor.	Distance of Lamp from Photometer Disc.	Angle.	Foot Candles at Photometer Disc.	Consumpt Cub. Ft. per Hour.	Candle-power.	C.P. per Cub. Ft.
	ft. in.	ft. in.	°				
30	—	7 6	Horizontal.	2·25	3·52	126	35·7
30	11 1	10 0½	45	—	3·52	125	35·5

Remarks.—These tests were taken with white porcelain cone in position. The lamp will *no* burn *without* this cone.

The make of these lamps is not yet quite satisfactory, as the means of adjustment are not as easy as will be necessary to ensure the lamp the success that it deserves on the market, as in testing other lamps of the same class considerable variations are discovered in the quality of the mixture at the burner. The makers will do well to give these points their serious attention.

Industrial Hall, Restaurant, and Bar.

The above restaurant and bar, situated on either side of the main entrance to the Industrial Hall are also lighted by incandescent gas on the low pressure system controlled to a pressure of twenty-five tenths by a Peebles governor. These lamps are of the "Nulite" pattern by Messrs. J. & W. B. Smith.

The total area of the restaurants amounts to 5,050 square feet, and the total candle-power is 2,523. This gives an illumination of ·50 candles per square foot of area, and a gas consumpt of 88 cubic feet per hour, or less than 3*d.* per hour, or 870 candles per one pennyworth of gas consumed.

There are other minor sections of the exhibition where gas has also been installed as well as to a number of the stall-holders. They are mostly, however, fitted with lamps of the classes already dealt with, and need not be further referred to.

SAUGHTON HALL.

Saughton Hall, an old mansion house which forms part of the exhibition, is used as an administrative block, and for exhibits of the artisan section, wherein specimens of handicraft of all trades and the work done by the technical schools of Scotland are exhibited in various rooms, as well as a section in connexion with the Japanese Education Department.

This Hall was previously lighted by means of coal gas in the old-fashioned manner, but has been refitted throughout for lighting by means of incandescent burners of the inverted type, viz., two- and three-light "Empire" lamps, and single burner lamps supplied by Messrs. J. & W. B. Smith.

Altogether some ninety-four lamps have been fitted in the various rooms, yielding 12,427 candles of illumination for a consumption of 323 cubic feet, or at 2*s.* 9*d.* per 1,000 cubic feet, costing a little more than 10½*d.* per hour for the entire illumination of this building, which is equal to 1,170 candles of illumination per one pennyworth of gas consumed.

Taking one of the principal rooms as an illustration the area lighted is 1,122 square feet, and the candle-power 1,370 candles, which is equal to 1·22 candles per square foot of area lighted.

MEMORANDA.

The preceding statements of tests need a few words of explanation in order that a true value may be put upon the results obtained.

In the first place, the gas used would read 20 to 21 candle gas when tested on a No. 2 Argand burner, and would have a calorific value of 560 net. The tests were taken in a large workshop, and the lamps to be tested were screened on three sides by a large black painted framed screen which completely cut off light rays from the walls of the building, which were by no means white, and the roof, which was black. There might be some slight reflection from the floor, but no more than would result from the ordinary ground surface, where the lamps are normally installed.

The apparatus employed was one of Simmance & Abady's street photometers, adjusted and verified by testing a known lamp simultaneously on a 100-inch bar photometer, and also on the Street photometer situated in the same room at the same time.

The general scheme of lighting was devised by Mr. A. C. Freeman, C.E., Chief Engineer to the Exhibition Committee, and in planning it he has provided for an ample flood of light, both as regards electricity and gas, believing that brilliant lighting is a source of attraction to the public, and adds a charm and fascination for the purposes in view.

The lighting generally was placed in charge of the Machinery and Lighting Committee, of which Mr. James T. R. Wilson, the Convener of the Lighting Committee of the Edinburgh Corporation (who it will be remembered has done so much to bring Edinburgh into the front rank so far as its street lighting is concerned), is also chairman, and the following gentlemen members: Prof. Beare; Prof. Barr, Glasgow; Mr. Douglas; Mr. Alexander Gracie, Govan; Mr. C. N. Kemp, B.Sc.; Mr. W. H. Massie; Mr. McMichael; Mr. Newington, City Electrical Engineer; Mr. Hugh Reid, Glasgow; Mr. Simon Slater; Mr. George A. Scott; Prof. Stanfield; Mr. James Thomson, C.E.; Mr. W. B. Walker; Councillor J. T. R. Wilson, Convener; Mr. W. R. Herring; and upon an official inspection of the lighting the day previous to the opening of the exhibition all expressed their admiration of what had been accomplished.

Table L, giving the candles per square foot of area illuminated and the number of candles per pennyworth of gas consumed at 2*s.* 9*d.* per 1,000 cubic feet, is rather interesting when taken comparatively.

It will be observed that the principal restaurants are allocated one-half candle per superficial foot of floor area dealt with, and it may be remarked that this is an ample amount of light in such places and in dwelling-houses and offices. It is, however, a little remarkable to find the whole of the exterior illuminated with a greater degree of light than the interiors, excepting, of course, in this instance the art galleries. I have found from experience that the half-candle of illumination per superficial foot of area covered in an ordinary-sized room is ample, lighted from the centre. The inverted lamp invariably gives its best results at an angle of at or about 45 degrees. Taking an ordinary room, say 18 ft. square, centrally lighted, the height at which the fitting would be placed would throw the greatest degree of light on the floor at the skirtings, and ensures the most perfect distribution and illumination. The cost per 1,000 candles of illumination also referred to on the same table is of interest, and is a most striking instance of the enormous advance that has been made from the days when three candles per foot of gas consumed burned in the best type of then known burner, viz., the Metropolitan Argand, and which is still the standard by which coal gas illumination is officially measured.

L. Statement giving the degree of Illumination in Candles per Square Foot of Area dealt with and the Number of Candles of Illumination per One Pennyworth of Gas consumed.

Area Lighted.	Candles per Square Foot.	Candles for One Pennyworth of Gas.	
Entrance Bridge	0·89	1,132	Clear Glass
Royal Avenue	0·88	2,230	"
Grand Promenade	0·61	2,230	"
Fine Art Gallery	1·95	1,178	Frosted Glass
		1,400	Clear Glass
Industrial Hall Restaurant ...	0·50	870	"
Prince's Restaurant	0·56	977	"
General Dining-Room	0·81	1,093	"

Some Important Forthcoming Events.

At the meeting of the Verband Deutscher Elektrotechniker at Erfurt on June 11th, 12th, and 13th, several papers of special interest relating to electric lighting and illumination are to be read. Among these we notice that of *Prof. W. Wedding* dealing with recent progress in electric illumination, and two papers by *Herr Remané* on the effect of overrunning on metallic filament glow-lamps, and a comparison between the upkeep of small arc lamps and high candle-power osram lamps. *Drs. Schanz* and *Stockhausen* will contribute a paper dealing with the effects of light on the eye.

The meeting of the Institution of Gas Engineers in this country will be held from June 16th to 18th: subsequently, by the invitation of the Deutsche Verein von Gas-und Wasserfachmännern, the English members will pay a visit to Berlin, returning to England on June 24th.

We note that the annual meeting of the Dutch Gas Association will take place at Breda on July 8th.

The fifth International Acetylene Congress is being held in London on May 28th, 29th, and 30th, when delegates from the various countries will attend, and addresses will be delivered by Sir Wm. Ramsay, Mr. F. S. Thorn, and others, and will be followed by visits to various installations of acetylene lighting.

Artificial Illumination and the Education of Those Concerned in its Production.

By Charles W. Hastings.

(*Continued from* p. 206.)

Although it is not absolutely essential that the student should have served his articles in the office of a gas engineer, or his apprenticeship in a gasworks, a knowledge of the theory and practice of gas manufacture is imperative. We do not premise that the illuminating engineer shall be a maker of gas, but that he should be able to employ the illuminant (which is brought to the door of the house) in the best and most economical manner.

It will, of course, be necessary that he should be able to make the usual tests for illuminating power, calorific value, and specific gravity; also to test the purity of the gas which he is going to use for illuminating purposes. Therefore practical photometry must be one of his earliest studies. If the illuminating engineer is to be anything more than a glorified gas-fitter he must also be able to measure light, *in situ*, and so arrive at a definite idea of the requirements for buildings of varying propertions (heights and areas). He should be able to make photometrical tests of burners of all kinds, and to this end it will be necessary to thoroughly grasp the notifications of the Metropolitan Gas Referees, to which we called attention in a previous number.

A slight knowledge of the chemical constituents of coal gas will probably have been acquired; if not, we recommend the close study of Butterfield's 'Chemistry of Gas Manufacture.'

Flame temperature must have careful attention; we know of no treatise upon the subject, but a very admirable lecture was delivered, in June, 1905, before the members of the Institution of Gas Engineers, by Prof. Arthur Smithells, B.Sc., F.R.S., on 'The Temperature of Flames.' We commend this lecture to the consideration of all interested in illuminating engineering.

Another branch for inquiry and research is air supply to burners, and the best point at which it shall mix with the gas. Opinions differ much: some makers of burners go so far as to bring an independent high pressure air supply to the point of ignition; generally burners of the bunsen type—be they upright or inverted—have a mixing chamber. The regulation of the quantity of both air and gas are matters of economical consideration, both in the intensity of illumination and the consumption of gas. Very carefully constructed regulators are attached to many incandescent burners. In the writer's opinion those made upon the needle governer principle are the best. Here, again, the aid of the illuminating engineer is needed by the consumer; these admirable helps to the better use of gas are purchased by the public, but their practical application not being understood, the beautiful mechanism of the regulator is soon put out of gear, and the last state is worse than the first.

An establishment, large or small, lighted with gas should have the supply pressure regulated on the street-main side of the meter, and the pressure of the gas supplied to the house standardized; in such a case all difficulties of gas and air supply could be overcome, the regulators set, and uniformity of illumination ensured.

A standard pressure is desirable, and a service from the main of a sufficient diameter to supply the maximum quantity of gas needed; this should be attached to a governor or regulator, and then coupled up to a meter of the size necessary to measure the maximum quantity of gas consumed. It is no unusual thing for twelve or fourteen "points" to be fitted with burners, with gas passing through a five-light meter—this should never be permitted. Service pipes are very commonly too small to permit of the necessary flow of gas. Interior pipes and fittings are often ridiculously small. An establishment to be lighted with gas should have a rising main from the meter to the top floor, and trunk mains should be taken from it to supply the fittings on each floor.

In Walter Hole's book, 'The Distribution of Gas,' we find the following table, which gives the size of service pipes usually laid for the number of lights specified :—

$\frac{3}{4}$ in.	Service	up to		10	Lights
1 ,,	,,	for		10	,,
$1\frac{1}{4}$,,	,,	,,		20	,,
$1\frac{1}{2}$,,	,,	,,		50	,,
2 ,,	,,	,,		80	,,
3 ,,	,,	,,		150	,,

It will be noted that no pipe of less dimension than $\frac{3}{4}$ in. is scheduled; the author assumes that the services should not exceed 100 ft. in length.

Some useful instructions upon the point under consideration will be found in the last edition (1904) of Newbigging's 'Handbook for Gas Engineers.' In the section devoted to 'Internal Fittings' Mr. Newbigging suggests a series of regulations to be issued, by gas companies and others, to those undertaking the fitting up of houses or other buildings for gas, and gives the sizes of meters and their measuring capacity, &c. :—

Size of Meters.	Size of Inlet and Outlet.	Measuring Capacity per Revolution.	Measuring Capacity per Hour.
Light.	In.	Cub. ft.	Cub. ft.
2	$\frac{1}{2}$	$\frac{1}{12}$	12
3	$\frac{5}{8}$	$\frac{1}{8}$	18
5	$\frac{3}{4}$	$\frac{1}{4}$	30
10	1	$\frac{1}{2}$	60
15	1	$\frac{3}{4}$	90
20	$1\frac{1}{4}$	1	120
30	$1\frac{3}{8}$	$1\frac{1}{2}$	180
50	$1\frac{1}{2}$	$2\frac{1}{2}$	300
60	$1\frac{1}{2}$	3	360
80	$1\frac{3}{4}$	4	480
100	2	5	600
150	3	$7\frac{1}{2}$	900 .

To ascertain the number of lights which any size of meter will supply, divide the measuring capacity per hour by the quantity of gas per hour which each jet is estimated to consume. Example: What number of lights, consuming 4 cubic feet of gas per hour, will a 20 light-meter supply ?

$$\text{Then } \frac{120}{4} = 30 \text{ lights.}$$

With regard to the sizes and lengths of pipes to be used for ordinary house lights Mr. Newbigging gives the following table :—

Internal Diameter.	Greatest Length allowed.	Greatest No. of Burners allowed.
In.	Ft.	Number.
$\frac{3}{8}$	20	3
$\frac{1}{2}$	30	6
$\frac{5}{8}$	40	12
$\frac{3}{4}$	50	20
1	70	35
$1\frac{1}{4}$	100	60
$1\frac{1}{2}$	150	100
2	200	200

It has now become general to fit up with iron pipes, but the illuminating engineer will be probably consulted with reference to the gas-lighting of houses or premises that have been fitted up for many years; in such a case it is quite certain that he will discover a network of small lead or composition pipes with strange elbow joints and T unions. His first work should be to strip them all out. Instances have been met with, in our own experience, of a five-light chandelier, each burner consuming at least 5 cubic feet per hour, being supplied with gas through a $\frac{1}{4}$ in. composition pipe.

We have touched upon several matters more or less relevant to the education of the illuminating engineer, viz. :—

1. That some knowledge of gas-making and the chemistry of coal-gas is desirable.
2. A study of the temperature of flame, air supply, &c., is necessary.
3. A knowledge of the science and practice of photometry, the estimating of consumption of burners and intensity of illumination under varying conditions is imperative.
4. That attention be given to the size of service pipes, flow of gas, pressure regulation, capacity of meters, and dimensions of internal pipes and fittings.

(To be continued.)

SPECIAL SECTION.

Illumination at the First Municipal Exhibition.

THE first Municipal, Building, and Public Health Exhibition was opened on the 1st and closed on the 12th of May this year. During the exhibition a series of lectures dealing with various subjects of interest to municipal authorities were given, and the Editor of *The Illuminating Engineer* was invited to assist in bringing the subject of illumination before the public notice. Two lectures dealing with this subject were delivered by Mr. Leon Gaster and Mr. J. S. Dow respectively, and were followed by actual demonstrations of the measurement of illumination.

The object of these lectures, which we reproduce in this section, and the demonstration by which they were followed, was to show that this subject is really of vital importance to the general public, and that methods of actually measuring light and illumination are now available, which are quite sufficiently accurate to justify the more general reliance upon actual systematic measurement instead of mere ocular demonstration.

For the purpose of the demonstrations referred to a lofty room at the Agricultural Hall was illuminated by Messrs. The New Inverted Incandescent Light Co., Ltd., and the Agricultural Hall Co., Ltd., who kindly fitted up a series of the latest flame arc-lamps and incandescent gas-lamps. The illumination was then measured at various points in the room, experts being present to explain the action of the various illuminometers shown working. Those present were extremely interested in the use of these instruments, and to many of them it came as a surprise to discover how comparatively simple measurements of illumination have now become.

We take this opportunity of thanking all those who came forward at such short notice to assist in the display of apparatus. Thanks are due firstly to those mentioned above for kindly arranging for the illumination of the King Edward Hall by means of incandescent gas-lamps and flame arc-lamps respectively. Mr. Haydn Harrison and Mr. Kenelm Edgcumbe kindly undertook to be present at the demonstration of the use of the illuminometers with which they are connected.

We have also to express our acknowledgment of the courtesy of Mr. Lancelot Wild and Messrs. Sugg for arranging for the exhibition of the Wild flicker photometer, and also to Messrs. Sugg for lending an example of the Harcourt 10 candle-power pentane standard for exhibition. Also to Messrs. Elliott, Ltd., and Messrs. Everett, Edgecumbe & Co., Ltd., who kindly sent representatives to demonstrate the working of the Harrison and Trotter illuminometers. Messrs. Franz, Schmidt, and Haenseh, of Berlin, also kindly sent an interesting collection of instruments for exhibition, including the Martens illuminometer, two types of Bechstein contrast and flicker photometers, the Thorner apparatus for testing daylight illumination, the most recent form of Lummer-Brodhun photometer head, &c. Dr. C. H. Williams, of Boston, also kindly sent an example of the Simplex illumination - photometer. Thanks are also due to Mr. C. C. Patterson and Mr. J. W. Blakey for lending a number of lantern slides.

Among the many others who expressed their interest in the exhibition and indirectly contributed to its success we may mention the names of Dr. Biegon von Czudnochowski, Dr. Krüss, Dr. Martens, Prof. Ulbricht, and Dr. W. Voege in Germany, and Dr. Louis Bell, Dr. Hyde, and Mr. P. S. Millar in the United States.

Some Lighting Exhibits at the Municipal Exhibition.

Among the various exhibits relating to lighting by gas and oil, we may mention that of the Praed Safety Gas Light Co. The gas in question consists mainly of air, containing a very small admixture of petrol-vapour, and is prepared by means of the plant shown in Fig. 1. The hot-air motor A, worked by a burner using the safety gas, actuates the small petrol pump C and the air-propeller B, and thus forces the air into the chamber D; here it comes in contact with a very fine spray of petrol, and becomes mixed with the vapour. E is the tank holding the required amount of petrol.

It is claimed that the petrol-air gas so produced burns with an intensely hot flame, which suffices to bring an incandescent mantle to bright incandescence and to enable the gas to be used for heating and cooking. It is also stated that the gas is non-poisonous, non-explosive, and, owing to the fact that it contains practically all the air necessary to support combustion, uses a negligible amount of the air of the room it is used to illuminate. We are also given to understand that it is possible to secure a light of 75 C.P. for one hour, with a consumption of petrol only costing about one-fourteenth of a penny, *i.e.*, at the rate of about one penny per candle-power hour.

Messrs. R. Stephens & Sons, of Clevedon, exhibited their automatic light controller, an example of which is shown in Fig. 2. In order to save the waste of labour involved in the constant turning on and off of street-lamps by hand, it is now becoming customary to utilize a change of pressure at the gasworks in order to control automatic lighting-up devices of the nature attached to individual lights. It may often be desired, for instance, to extinguish at a certain hour at night all but certain lights at definite intervals down the streets. The exact behaviour of this controller can be modified considerably; it can be adjusted either to light up with a given increase in pressure, and, independently, to extinguish at a specified diminution in pressure, or to light up with a certain increase in pressure, and then to extinguish by the next subsequent increase of the same nature.

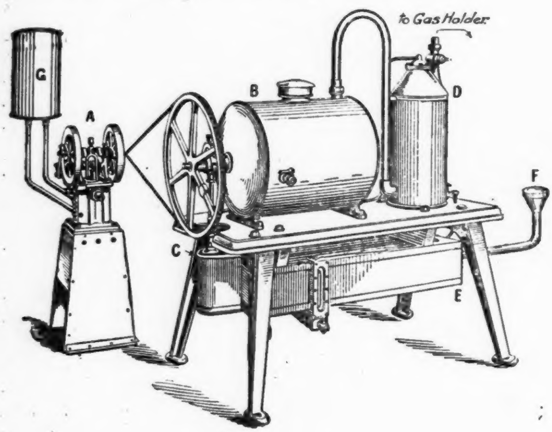


Fig. 1.


Fig. 2.

Another light-controlling automatic device exhibited was the time-switch of the Automatic Light Controlling Co. of Bristol. This can be applied to extinguish automatically the arc-lamps used in street-lighting at any predetermined time.

Messrs. Parkinson and W. Cowan, Ltd., of Birmingham, also exhibited a number of examples of lanterns for street-lighting, lamp-columns, brackets, &c., as well as their special anti-vibrator, which, it is claimed, provides for both lateral and vertical vibration, and is now extensively used.

Among other exhibits mention may be made of the exhibit of the "Ironclad" mantles made by Messrs. Curtis & Harvey, Ltd., of Deptford, for which special durability and strength is claimed, and the petrol-air gas plant of the De Laitte Gas Co., Ltd.

Efficient Illumination and Municipal Requirements.

(Lecture delivered by Leon Gaster at the Municipal, Building, and Public Health Exhibition on May 6th.)

THERE are a number of aspects of the subject of illumination which are of vital importance to the public at large and to those interested in municipal affairs in particular. Immense sums of money are spent annually in the illumination of streets and public buildings of various descriptions in which the ratepayers are directly interested. There are countless public halls, libraries, hospitals, asylums, &c., where the need for good and efficient illumination make itself manifest.

My object to-night is to impress upon those responsible the urgent need for paying due attention to the need for better illumination in municipal affairs. I firmly believe that neglect of this matter, either in the direction of useless extravagance or mistaken and false economy, has a wide and far-reaching effect upon our national welfare, and, as I shall endeavour to show later, may well be responsible in many cases for injury to health to an extent that is not generally realized.

This leads me to allude firstly to one question which has been giving grave concern to the medical profession, and which will readily be admitted to be, at any rate, of the greatest national importance. I refer to the question of the eyesight of the children in our schools. It seems to be placed beyond doubt by the researches of authorities in this country, on the Continent, and in the United States, that a very serious deterioration in eyesight makes its appearance in children during their passage through the school-life. I do not doubt that improvements in our system of education might effect a partial remedy of the existing conditions, but I wish to emphasize the stress that has been laid by all those in the medical profession who have recently taken up the subject upon the value of *good illumination.* In this connexion I may quote a few results on the subject which were recently summarized in a special section of *The Illuminating Engineer* (Jan. and March, 1908).

Dr. Kerr, Medical Officer to the L.C.C., has recently issued a report which deals with the lighting of schools in London, and the eyesight of school-children at work therein. He particularly emphasized the need for a good illumination in the case of children who are called upon to make special mental efforts at a critical period in their physiological development.

"A normal person of middle age," he says, "will distinguish characters on paper in a poor light with greater readiness than a small child, because the characters are more familiar to the adult, and so much more easily recognized. Conversely a child requires a better light to learn to read by than does an adult, to whom reading is second nature. From a large number of experiments the least illumination permissible on the school-desk of a child has been found to be equal to 10 candle-metres."

Dr. Kerr lays down simple rules of illumination which, he says, ought to be insisted upon in schoolrooms, and quotes the results of a number of tests, according to which it appears that of 163 schools visited, the artificial lighting of 20 per cent. were classed as only fair, while 29 per cent. were classed as really bad. The daylight illumination was likewise condemned in many cases, 27 per cent. of the schools visited being described as fair, and 25 per cent. as bad.

Miss Sayer, also an Assistant Officer to the L.C.C., has likewise pointed out how school life does, in some way, interfere with the salutary development of eyesight. In the London schools alone there are nearly a million children, and of these at least 25,000 are actually seriously handicapped by defective vision.

Lastly I may refer—only selecting two among the many authorities who have made consistent statements on this point—to the work of Prof. Scott in the United States and Dr. Hubert Biss, who recently contributed an article to *The Illuminating Engineer* on this very subject. Prof. Scott traces the development of eyesight in the schools in America since the alarming figures published by the United States Bureau in 1881. He is convinced that the evils referred to are partially due to defects in illumination which might easily be avoided, and winds up with the following conclusion :—

"Because of the lack of attention which is paid to the light actually present in the school-rooms, and because of the great difficulty in adjusting our windows and shades to the varying intensities of the external sources of light, it is not surprising that we should find in our school-rooms conditions of light so bad that during many hours and days reading of ordinary printed matter without undue strain upon the eyes is impossible."

Dr. Biss fully confirms the significance of the deterioration in eyesight in school life, and points out how essential not only good, but *very good* illumination in our schools must be.

In the face of this consistent evidence I do not think that I can be accused of attaching undue importance to the matter. Many different authorities have reported on the subject, and all tell the same tale. We know that the eyesight of school children does suffer. We know that the illumination in schools is often put down as inadequate. And we are, therefore, justified in feeling that this defective illumination is at least a partial cause of the existing trouble and ought to be remedied. It also stands to reason that even where defects of eyesight do not make their appearance, the effort and strain of working under a bad illumination must leave its effect on the general health and well-being of the worker. I have dwelt specially on this section of my lecture, because I think it is of special importance to municipal authorities. I wish to advocate the establishment of a really systematic testing of not only the eyesight of children in schools, but also of the conditions of illumination which are prevalent. The present moment is particularly opportune. For the first time this year the Board of Education directly concerns itself with the medical inspection of school-children. This inspection will include the examination of eyesight. Let it be also extended to include a critical examination of the illumination. I am convinced that the data accumulated in this way would be of inestimable value, and would enable us to determine in what exactly the present defective conditions consist and how they are to be remedied. It must also be remembered, too, that even when the illumination in a school is excellent the parents or guardians must be interested in order that the illumination at home may be equally good.

The question of eyesight leads me to speak next of the illumination of our public libraries. Here again the constant strain to which the eyes of readers are necessarily put in close reading serves to emphasize the importance of really good illumination. The lighting of libraries certainly deserves special study. Any one who has passed much of his time in reading under these conditions must have been struck by the fact that the lighting is rarely all that it should be. The illumination of the reading-tables may be defective, owing to improper location of lights and other causes. Lights are also frequently placed so as to offend the eye of the reader as he glances up from his book, or so as to get into his line of vision as he is looking for a book on the shelves.

I should like to point out, too, that this is emphatically a case in which cheeseparing economy in the matter of lighting is out of place. It is manifestly absurd to spend large sums of money on books and buildings and then to grudge the small additional expenditure necessary to enable both to be put to the purpose for which they were intended. Naturally it is only by means of the *illumination* we produce that we are able to use either.

The same considerations apply, as I have previously pointed out, to factory lighting The output and character of the work turned out in a factory depends very largely on the comfort of the workers, and it is false economy indeed to grudge the cost of the necessary illumination -- an expense which is usually a mere fraction of the money spent on tools and skilled labour. My remarks on the desirability of testing the illumination of school buildings are at least equally applicable to factories. Children are still employed in factories at a comparatively early age, and it is recognized that a carefully organized system of inspection is desirable in order to secure their physical well-being. The point to which I wish to draw attention is as follows. Why should it be considered necessary to test the conditions of ventilation, the water supply, and the general sanitary conditions, and yet to pay no attention to the method of lighting employed? Surely it must be evident that the strain of working by means of defective illumination may lead to equally serious consequences! Here again I may venture to suggest that the existing system of inspection should be extended so as to include the illumination of factories. Very excellent machinery for this purpose is already in existence. Why not utilize it for the purpose of gathering data which, in addition to improving the conditions of work of employees, might be very beneficial in furnishing data from which to draw conclusions as to existing defects in illumination and the means of remedying them.

I feel that the importance of the matter justifies the appointment of a special commission, consisting of a fully representative collection of impartial and accredited experts to deal with the whole question of lighting schools, libraries, &c. We have had many commissions in the past, created for the purpose of studying matters of relatively lesser importance to the nation as a whole.

Finally, I should like to say something upon the subject of street lighting—a problem of exceedingly great interest to municipal authorities. Here there is still ample room for improvement.

It must be recognized that the illumination in many cases is only too frequently very far from what the situation demands. The illumination of the streets of a district, for instance, has hitherto been in the hands of the local engineer, who is responsible for so many different matters that often he has hardly the opportunity to make himself as efficient as is rendered desirable by the introduction of new illuminants and the recent strides that have been made in modern methods of lighting.

Even granted, however, that the engineer is a man who is really impressed with the need for better illumination, and has gone out of his way to study the intricacies of the subject, he is often allowed but a small measure of freedom in carrying out his ideas, and is subjected to hindrance, which is attributed to outside circumstances by which the street-lighting committee of the district are influenced.

One cannot but be struck by the fact that although so much money is expended annually in the lighting of streets, there are no adequate tests and specifications in general use which would enable the authorities to at once determine whether the illumination in a street is up to the prescribed value or no.

I, of course, realize that the problem appears to be a complicated one, and that many different issues are involved. No doubt, for instance, the conditions to be prescribed in the case of streets differing in character, streets lined with shops, busy thoroughfares, and side streets, &c., differ considerably. But I feel confident that a full inquiry into the subject by a commission of experts representing the various systems of illumination involved would lead to very valuable results, and might, at least, enable us to decide upon some definite working basis on which the illumination in our streets is to be measured. I also feel that there is a great need for greater co-operation between those responsible for the lighting of adjacent districts. Only the other day I had the privilege of conducting a visitor from the United States, who was interested in street lighting, on a circular tour lying well within the five-mile radius. He was amazed to find that no less than twelve distinct methods of illumination were in evidence.

Another matter on which co-operation is desirable is the making of frequent tests on new systems of illumination. The perpetual experiments in adjacent districts which are continually taking place not infrequently lead to a considerable waste of energy and money. On the other hand, it must be recognized that it is hopeless to place reliance on data obtained only a few years ago. The conditions are constantly changing. New illuminants and new methods of utilizing them to the best advantage are constantly making their appearance.

Bearing these facts in mind, I wish to amplify a suggestion which I made two years ago in an article on 'The Need for the Illuminating Engineer' (April, 1906). I mean the establishment of a joint municipal testing laboratory, a permanent home of experiment in illumination, conducted on strictly impartial lines, and on a sufficiently large scale to enable practical conditions to be genuinely reproducible. Consider the advantage to municipal bodies of having an accredited testing laboratory of this description, in which experiments on a sufficiently extensive scale could be carried out by a recognized experts, at their disposal. The results of such experiments might be utilized by all the authorities participating, and the requisite annual contribution of each body to the total expenses would certainly be trifling in comparison with the saving effected. Moreover the series of experiments undertaken at the laboratory would be always carried out by the same experts, under known and specified conditions, and this is certainly no small advantage. In such an establishment a collection of all the most recent illuminants and the most recent methods and instruments for testing illumination should find a place. Of recent years, since the practical importance of testing illumination has come to be fully realized, great strides have been made in the measurement of light and illumination. It is becoming increasingly difficult for any one to keep pace with the most recent developments, and an easily accessible building, where all the newest instruments would be on show, would be of very great value to manufacturers and engineers, and municipal councillors interested.

I have dealt with all these points in some detail because of their great importance, both from the standpoint of municipal authorities with whom rests the responsibility of providing the illumination in our streets and public buildings, and also from the point of view of the public for whose benefit such illumination is intended. I know that those who undertake such responsibilities are frequently busy men, who can ill spare the time that they devote to the public service, and cannot fairly be expected to be experts in the subject of illumination themselves.

Good and efficient illumination is as essential to the welfare of the general public as good ventilation, good food, or good drainage, and ought to receive the same consideration that is bestowed on these quantities.

The Measurement of Light and Illumination.

By J. S. Dow.

(Lecture delivered at the Municipal Building and Public Health Exhibition, May 11th, 1908.)

In his lecture last Wednesday Mr. Gaster dealt with the importance of illumination and the measurement thereof, both to the municipal authorities — who are responsible for the lighting of our streets and public buildings—and to the general public for whose benefit this illumination is intended.

The possibility of studying illumination in the manner referred to depends primarily upon our ability actually to test and measure our illuminants, and to estimate the effect they produce in a commericial way. In my lecture to-night I shall try to describe briefly some of the recent developments in the subject of light - measurement. Naturally, in the time at my disposal, I can only hope to touch in a general fashion upon a few of the most important aspects of the subject, and I must ask your indulgence if I occasionally pass over points on which you may wish to hear fuller details, or dwell upon others with which some of you feel yourselves sufficiently familiar.

In the first place, I should like to point out how great is the alteration in the general outlook on the subject of photometry compared with what it was a few years ago. Only a few years ago the whole question of light-measurement was regarded as an interesting scientific study; but the vital practical bearing of the matter was hardly generally realized. There were, indeed, a few pioneering workers in the subject, the benefit of whose efforts we reap to-day; but such researches as were carried out in this country were almost invariably purely scientific in their scope and aim.

This indifference may be partly explained by the fact that our available illuminants were then few in number.

Possibly those of you who have not followed this matter closely will hardly realize the extraordinary progress—and more, the extraordinary increase in our rate of progress—that is now taking place in our ideas. Mr. Swinburne, in his Presidential Address to the Institution of Electrical Engineers in 1902, summed up the situation as follows :—

"Our chief work, until lately, has been producing light. Here the inefficiency and waste is prodigious, and though it is mostly unavoidable, there is still great room for improvement. We take great care over our stations, watching every penny from the coal shovel or mechanical stoker to the station meter. We quarrel over 1 per cent. in the generators. When we get to the mains we care less, and once we get to the consumers' meters we care nothing at all."

Since the date of Mr. Swinburne's address we have seen a wonderful development in illuminants. We have seen great progress in flame-arcs, the metallic filament glow-lamps, the inverted gas mantle, and the development of high-pressure gas-lighting and petrol-air lighting, not to mention the mercury arc-lamp, the Moore vapour tube, and many other lamps which are still not very generally familiar to the general public. Naturally this progress has had the effect of drawing attention to the necessity for studying the best methods of *using* light.

After all, what the consumer wants is illumination, *i.e.*, light usefully applied. Therefore, we must have means of ascertaining, firstly, whether a source of light is really giving the light it is supposed to do, and, secondly, whether, having obtained the light, we are distributing it to the best advantage. Let us therefore now pass to the main subject of my lecture, and consider exactly what is wanted in order to describe the "power of creating brightness"—the illuminating power of a light.

It will be evident in the first place that we cannot, at least at the present time, readily expect to measure this quantity *directly* by the movement of a pointer or by any mechanical means, as in the case of electricity, for instance. We must, in fact, necessarily form our conclusions as to what lights can do by comparing their capability to make a surface *bright*. With this object in view we say that if we place either of two lights at a given distance from a white screen, and if, under exactly the same conditions, they both cause this surface to appear equally bright, the two lights have the same illuminating power. Given two sources of unequal intensity we can then adjust their distances from the screen so as to secure this condition, and calculate their relative effects by noting their relative distance. Or we can alter *the angle* at which the rays from one of the sources strike the surface. There are, of course, other methods of adjusting the illumination from two lights to equal brilliancy, according to some known relation; but into these I will not enter at present.

Our chief need, therefore, is some means of telling accurately when two portions of an illuminated surface, or two exactly similar surfaces, are equally illuminated. One of the very first methods and devices for this purpose was that of Count Rumford, who erected a rod in front of the white surface and judged the relative brightness of the two shadows. A modification of this device is used by the gas referees to-day, and the method has, indeed, certain signal advantages. Afterwards the plan suggested itself of placing the two sources of light on either side of a sheet of white paper and comparing the appearance of the two sides. The judgment in this case was rendered more accurate by the use of a "grease spot" on the paper, and this type of photometer, too, while very simple in construction, is still regarded as an excellent one at the present time. A modification of this instrument was effected in the Lummer-Brodhun photometer by means of an ingenious optical device. There have, of course, been many other types of photometers perfected, some of them exceedingly sensitive. An interesting instrument of recent date is a form of "contrast" photometer due to Dr. Bechstein, an example of which, by the kindness of the makers, Messrs. Franz, Schmidt & Haensch, I am able to show this evening.

To sum up, it may be said that we have to-day many very perfect instruments which enable this proceeding of judging the brightness of two surfaces to be accomplished with as great an accuracy as is commercially desirable—for lights of the same colour. A practised worker in photometry, for instance, would probably consider himself able to form a judgment of equality of brightness under these conditions to within ½ per cent., while Dr. Clayton Sharp has recently estimated the total accuracy of general photometrical testing at about 2 per cent, which is certainly ample accuracy for practical purposes.

An additional question that has commanded the attention of those engaged in photometry of late years has been the introduction of sources of light, such as the incandescent mantle, the flame arc, and the mercury vapour lamp, which differ considerably in colour. Naturally it is very much more difficult to tell when two surfaces illuminated by such diversely coloured lights are equally bright. To meet this difficulty a new form of photometer, in which the two surfaces are exposed to the eye in rapid succession, has been devised. Most of you, in going home in the trams or tubes by night, have experienced the unpleasant flickering effect on the eye which arises through the light from brilliant sources streaming into the tram or train as you pass by, and then being replaced by darkness. Just in the same way a throbbing, flickering sensation is caused when the two surfaces in the photometer, exhibited to the eye in succession as described, are unequally illuminated. But when we reach a point at which the apparent brightness of the surfaces is the same the effect ceases. On the slide which I now throw upon the screen you will notice a few of the devices which have been constructed for this purpose by Rood, Whitman, Krüss, Simmance and Abady, and others. A modification of the Rood method is exemplified in the Bechstein photometer, an example of which has likewise been kindly loaned to *The Illuminating Engineer* for demonstration purposes, and which I have again the privilege of showing to-night. Though primarily intended to facilitate the comparison of lights of different colour, flicker instruments can, of course, also be utilized for lights of the same colour, and a high degree of accuracy may be reached by such means. Before leaving this subject I must mention the simple and ingenious form of flicker-photometer due to Mr. Wild, who merely rotates a disc, half of which is greased and half plain.

You will see, therefore, that there are a number of excellent photometers available to-day. As far as the mere judgment of illuminated surfaces goes, we can carry out photometric operations with an accuracy well within practical requirements. At the same time, there is no reason why we should not reach still more excellent results in the future, and, indeed, ultimately render judgment of the equality of brightness of two surfaces as certain an operation as observing the position of a pointer on a scale.

Let us now turn to another most important matter in photometry. We cannot be content with merely comparing the brightness of two lamps which we happen to have by us. We want some standard of reference to which all such lamps can be referred. We want to be able to express the illuminating power of any lamp in terms of such a standard. This need was early realized, and it was proposed that the light from a candle, "1 candle-power," should be adopted as this standard. It was, however, soon realized that different candles, even burning under apparently the same conditions, gave very different results. Ultimately the whole question was considered of such importance that a Royal Commission was appointed and reported very unfavourably on the value of the candle as a standard. One interesting point, which illustrates the indifference that had seemingly been previously displayed to the illuminating powers of sources of light, was that according to the statement of certain witnesses, though great attention was paid to the conditions affecting general durability and reliability of candles, no tests of their illuminating power appeared to have been previously carried out or even contemplated.

Since the date of that Commission various suggestions have been made as to possible standards of light. A number of standard lamps have been developed in England, France, Germany, and the United States, some of which are shown upon the slides kindly lent for the occasion by Mr. Patterson, of the National Physical Laboratory, which I now throw upon the screen. While speaking on this point I must mention the incalculable benefit to the subject of light-measurement which has followed the efforts towards co-operation on the part of different countries. Appointed laboratories in this and the other countries mentioned are in constant communication; standardized glow-lamps are now exchanged and tested by the various laboratories in order that the standard of light in each country may be retained constant, and the ratios between the units adopted by different countries are now accurately known. It is now impossible for any serious misunderstanding as to the value of these standards to occur. One by one the small discrepancies still existing are being removed. One result much to be desired, which we hope to see achieved very shortly, is the establishment of an international unit of candle-power.

I may next mention one point which, though seemingly evident, has been the subject of considerable misunderstanding in the past. Naturally the light from any source of light differs very greatly in different directions. A glow-lamp, for instance, gives its highest candle-power in a direction at right angles to the filament, and its lowest in the direction of the cap of the bulb. An inverted mantle similarly gives its highest value immediately beneath the lamp and its lowest in an upward direction, where the burner obstructs the light. Strictly, therefore, in order to compare different sources, we ought to take into account *all* the light from a source in all directions. We may accomplish this somewhat laboriously by studying the distribution-curve of light from the source. A distribution-curve of this nature is naturally of considerable use in other respects. But the process referred to is greatly simplified by the arrangements which have recently been introduced in order to concentrate the net effect of all the light on the photometer.

The Matthews "integrating photometer," and the Ulbricht "globe photometer" exhibited in the slides which I will now describe, are examples of such devices. The important point to which I wish to draw attention, however, is that the possibility of uncertainty in this respect is now generally realized and guarded against in photometry.

Hitherto I have referred to the measurement of the light from the *source* employed, without reference to the conditions under which it is afterwards used. Naturally it is important that all such sources should be tested, for we want in the first place a guarantee that the lamp is capable of producing certain results. But, even if our sources of light are all that is desired, we may fail to *illuminate* our premises because we fail to use our lights correctly. If, for instance, we place our lamps in such a position as not to throw light where it is wanted, or if we lose all their light by surrounding them with absurdly dense shades, our illumination must suffer. Again, the light needed for any building depends very greatly upon the general scheme of decoration—upon the colour of wall-papers, for instance.

All this suggests the desirability of having some method of testing the actual illumination at the place where it is needed, and many types of portable photometers have been developed of recent years specially to meet this necessity. In such instruments the comparison source of light is placed, with the photometer, in one piece of apparatus. This source may take the form of a small oil-lamp, and small electric lamps are found very convenient; their use has been considerably simplified by the introduction of the osram and other metallic filaments.

Such an instrument can be carried about to any desired locality. It may be used to test the illumination in the street or at a table in a building. The construction of the "illuminometer," as this type of photometer is called, has been taken up with great energy during recent years, and there already exists a number of thoroughly practical instruments of this nature. Nevertheless there is every reason to suppose that much progress will be made in their manufacture in the near future, and that such defects as yet exist will be removed very shortly. I now propose to show some slides, exhibiting, among others, the instruments due to Mr. Trotter and Mr. Harrison in this country, Dr. Clayton Sharp and Mr. P. S. Millar in the United States, and Dr. Martens in Germany. Naturally these are only a few among the many existing instruments, but they will serve to show that really serviceable and practical results have been already achieved. I have also two other very interesting and simple forms of instruments on the table, that of Dr. Thorner intended for the purpose of testing whether the daylight-illumination in a room is adequate, and the "Simplex" photometer kindly sent from the United States by the inventor, Dr. C. H. Williams.

In conclusion, therefore, I wish to again emphasize my statements at the commencement of this lecture, as to the feasibility of measuring both the illuminating power of a source and the actual illumination in practical conditions. Illuminometers are so simple in operation that, even in the hands of a novice, they may furnish an indication whether the illumination enjoyed by the consumer is adequate or otherwise. I think, however, that it must be realized that, in order to determine exact values, and to suggest a remedy for the defective conditions thus brought to light, the services of an expert in illumination are required. Therefore when, as Mr. Gaster suggests, illumination in streets and public buildings is subjected to careful specification and constantly tested by actual measurement, we may expect that such measurements will be conducted under the direction of an expert in illumination, who will be a municipal inspector, and will discharge duties every whit as essential as those undertaken by sanitary engineers and other municipal engineers of the present day. I look forward to the time when illumination will be specified and measured in the exact and precise manner that is now considered essential in the case of other commodities, such as food, water, and air, in which the general public is vitally interested, and it will be considered as reprehensible for the illumination of a street, public building, or conveyance to be manifestly deficient and below that legally enacted as for a tradesman to sell short weight or adulterated foods.

And, lastly, I wish to emphasize the importance of co-operation both on the part of those in the same country, but representing different systems and aspects of illumination, and on the part of different nationalities. The time has now come when it must be realized that there are many questions which affect the general public very closely which cannot be adequately settled by individual effort, while even questions of purely scientific interest often suffer through lack of suitable co-operation of workers in the same field, and their consequent ignorance of what is being done in other quarters.

In particular I should like to draw attention to Mr. Gaster's proposal, now two years old, that a permanent home of experiment in matters of illumination, including a museum where the ever-increasing collection of recent instruments for photometry and the measurement of illumination could be gathered together and rendered accessible to those generally interested.

It is a platitude in these days to remark upon the growing internationalism of science, but the work of the International Photometrical Commission and the concerted effort between the laboratories of the nations interested is an excellent example of what is possible by this means. In reality all the nations have contributed their share in assisting the progress of the movement towards better illumination. The United States, in establishing an Illuminating Engineering Society, have proved their appreciation of the need for mutual assistance in this matter; we ourselves have now a journal devoted solely to illumination, regarded from an impartial and international standpoint, and we have also every reason to be proud of the work of the many pioneers in the subject in this country, such as Sir Wm. Preece, Mr. Trotter, Mr. Dibdin, Mr. Vernon Harcourt, Sir Wm. Abney, to mention only a few of the names that occur in this connexion. To these early efforts the apparently sudden growth of interest in the subject of illumination is largely due. One may, indeed, sum up the situation in the memorable lines :—

For while the tired waves, vainly beating,
  Seem but a painful inch to gain,
Far back, by creeks and inlets making,
  Comes, silent, flooding in, the main.
And not by eastern windows only,
  When daylight dawns, comes in the light.
In front the sun climbs slow, how slowly!
  But westward look! the land is bright!

Some Recent Photometers and Illuminometers.

THE instruments exhibited at the Municipal Exhibition may be classified as photometers and illuminometers respectively, *i.e.*, instruments intended for the measurement of the light-giving capacity of sources and instruments for the measurement of illumination. Attention may first be concentrated on the various photometers exhibited at the exhibition. Nearly all the photometers in practical use at the present day may be included in the divisions of "equality of brightness," "contrast," and "flicker" photometers, and examples of all these three classes were shown.

In Figs. 1 and 2 is shown a recent type of Bechstein instrument, which can be used either as a contrast photometer or on the equality of brightness principle.

The plaster of Paris prism G is illuminated by the rays from the two sources J_1 and J_2, to be tested. The rays from the illuminated photometrical surfaces then traverse first the lens O, then the two biprisms Z_1 and Z_2, and finally the lens L on their way to the eye of the observer at A. The dividing lines of the prisms Z_1 and Z_2 are perpendicular to one another. Thus in the diagram the edge of the prism Z_1 is visible in Fig. 1 and the edge of the prism Z_2 is not, while in Fig. 2 the reverse is the case. The angles of the prisms are so adjusted that the prism with its dividing edge vertical, Z_1, divides the field of view into two equal portions, the left region being illuminated by rays from the left side of the ritchie wedge G, and the right region in the same manner by rays from the right side. The second prism Z_2 exerts a similar action, its dividing edge being, however, horizontal. As a result the field of view is divided into four quadrants which appear equally bright when the photometer

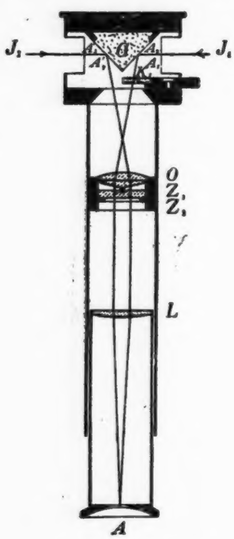


FIG. 1.

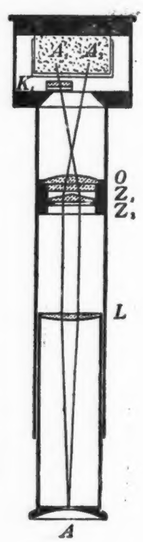


FIG. 2.

THE BECHSTEIN PHOTOMETER.

is in balance as an "equality of brightness" photometer.

The contrast element may, however, be introduced by merely inserting two thin squares of glass K_1K_2 in the path of the rays illuminating two opposite quadrants, as shown in Fig. 3. A small percentage of light is absorbed in this way. Fig. 4a indicates the appearance the field of view will now assume the photometer is in balance, and Figs. 4b and 4c show its appearance when slightly disturbed from this position in either direction.

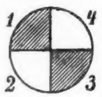


FIG. 4a.

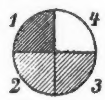


FIG. 4b.

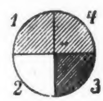


FIG. 4c.

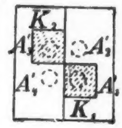


FIG. 3.

BECHSTEIN CONTRAST PHOTOMETER.

Many different forms of flicker photometers are now available. Two of the most recent types, those due to Dr. Bechstein and Mr. Wild respectively, were shown at the exhibition. The earliest flicker photometers may be divided into two classes, those in which the photometrical surfaces themselves were moved, as occurred in the Whitman sector photometer, and those in which a lens or prism was oscillated in front of the dividing lines between the illuminated surfaces in the photometer, as in the instrument devised by Prof. O. Rood.

The Bechstein flicker photometer utilizes a modification of the Rood device. The optical arrangements are shown diagrammatically in Fig. 5. The two sides of the wedge G are illuminated by means of the two sources to be compared, J_1 and J_2. The path of the rays from the photometric surfaces to the eye is then as follows: The rays pass through the lens L_1, then through the prismatic arrangement Kk to the eye-piece lens L_2, and ultimately to the eye at A. The prismatic arrangement Kk consists of a prismatic annulus K, the angle of which is so chosen that in the position shown only the rays from the right side of the wedge are brought to the eye-piece. Within the annulus K is fixed the disc k, which is likewise prismatic, having an angle of inclination equal to, but in the reverse direction to that of the annulus. Consequently only the rays from the *left* side of the prism passing through this disc are brought to the eyepiece. The result is that the eye sees a field of view similar to that shown in Fig. 6a, the centre of the circle being illuminated only by rays from the left hand source and the outer ring only by

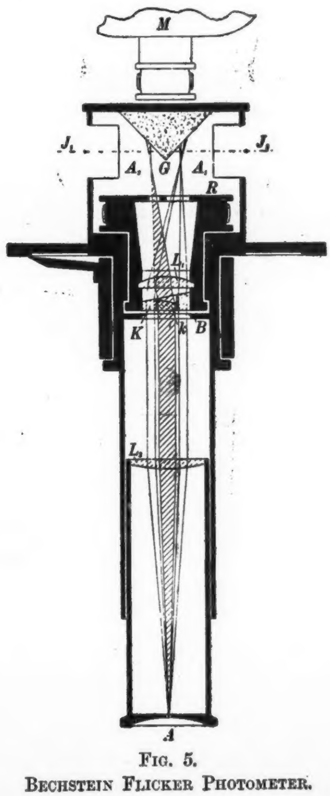


FIG. 5.

BECHSTEIN FLICKER PHOTOMETER.

means of rays from the right-hand source.

If the prismatic arrangement Kk is kept stationary we can employ the photometer on the "equality of brightness" principle, and obtain balance by judging when ring and centre appear equally illuminated.

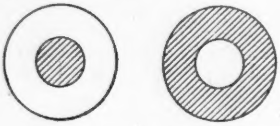


FIG. 6a. FIG. 6b.
FIELD OF VIEW, BECHSTEIN FLICKER PHOTOMETER.

In order to obtain the flicker the prismatic disc Kk is rotated about a horizontal axis by means of a band from a small motor passing over the pulley R. It will now be observed that, when the disc has rotated through 180 degrees, the rays of light which formerly illuminated the centre now illuminated the ring, and vice versa; the field of view is therefore now that shown in Fig. 6b. Hence when the disc is rotated at a suitable speed, *both* ring and centre will appear alternately dark and bright, and a flicker will be seen which only disappears when centre and ring are equally bright.

A very simple modification of the Whitman method is due to Mr. Wild, who merely rotates a paper disc, half of which is greased and half plain, as shown in Fig. 8, illuminated on each side by the two sources of light to be tested in the ordinary way. The observer looking down a telescope sees,

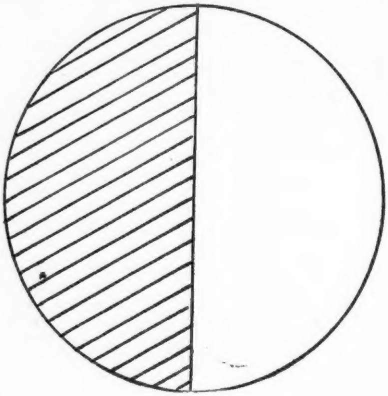


FIG. 8.

in rapid succession, first the greased and then the plain portion reflected in the inclined mirror M, as shown in Fig. 9. The photometer is thus extremely simple in construction, and it is said that very great sensitiveness

FIG. 7.—BECHSTEIN FLICKER PHOTOMETER.

In the model shown in Fig. 7 the motor is arranged in such a way that the whole instrument can be easily reversed without the observer being required to change his position at the bench.

can be obtained when a suitable grease-spot screen is employed. Another advantage claimed for the instrument is that the rays from the two sources of light to be tested strike the surfaces of the disc vertically,

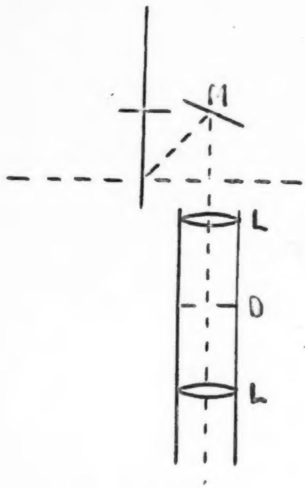


Fig. 9.
Diagram of Wild Flicker Photometer.

Fig. 11.
Trotter Universal Photometer.

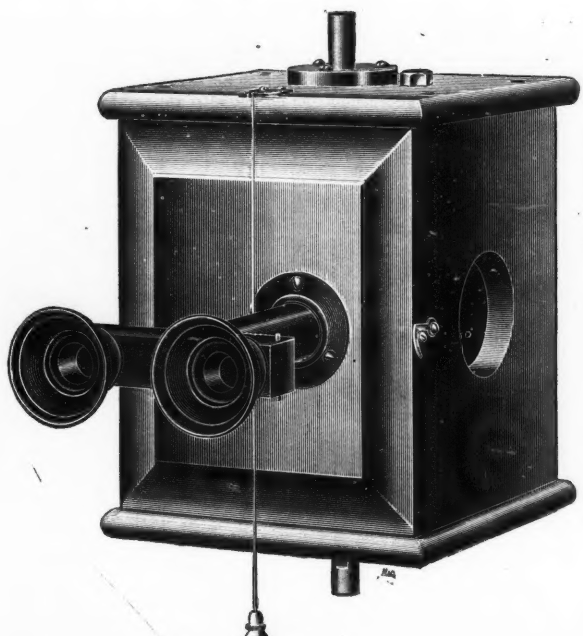


Fig. 10.—The Wild Flicker Photometer.

as is the case with most photometers of the equality of brightness or contrast photometers, and that therefore the possibility of "angle-errors" is much reduced. Fig. 10 shows a general view of the most recent type.

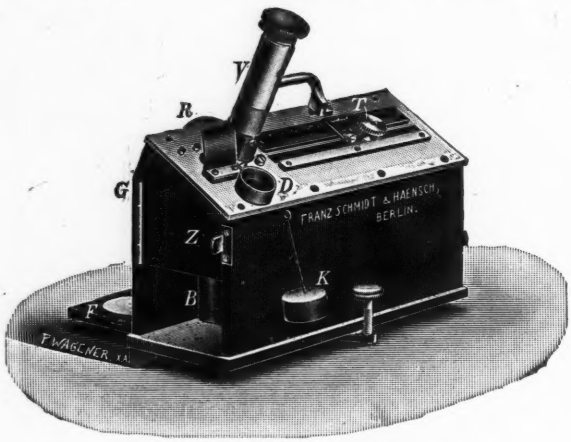


FIG. 13.—MARTEN'S ILLUMINOMETER.

Some description may now be given of the various instruments for the measurement of illumination exhibited. The Trotter Universal Photometer is shown in Figs. 11 and 12. The comparison-source of light is in this case a small glow-lamp L, the rays of light emitted by which strike the mirror M, and are thus reflected on to the white diffusing screen S_1, receiving the illumination it is desired to measure. The observer looks at the white diffusing screen S_2; in this is cut a small aperture with very sharp edges. The observer is thus able to compare the brightness of the actual illumination of the surface S_2 with that of the screen S_1. The latter can be rotated so that the light strikes it at various inclinations, and the illumination is thus altered through a definite and convenient range from zero to 2 candle-feet. The actual value in candle-feet is obtained by observation

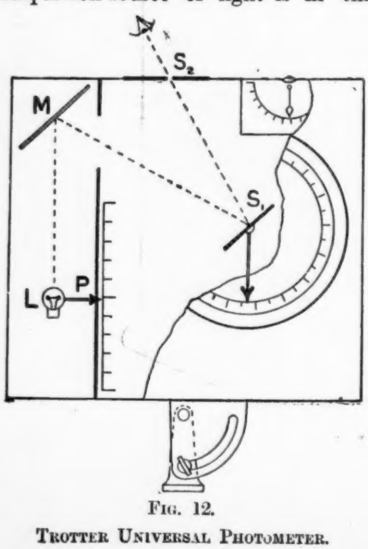


FIG. 12.
TROTTER UNIVERSAL PHOTOMETER.

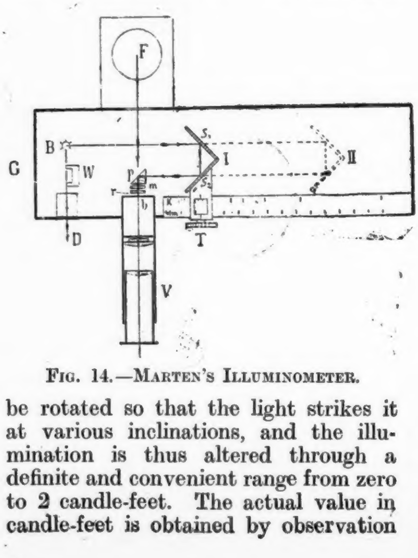


FIG. 14.—MARTEN'S ILLUMINOMETER.

of a pointer attached to the screen S_1, moving on a scale on the outside of the box containing the photometer, as shown in the diagram.

The small glow-lamp is carefully aged and standardized, and, in addition, is run at such an efficiency as to give a light intermediate in colour between

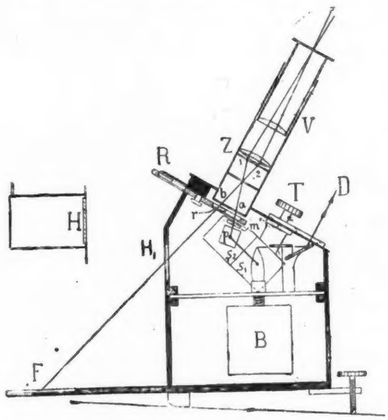


FIG. 15.—MARTEN'S ILLUMINOMETER.

that of an underrun glow-lamp and the whiter light of the arc. As a result no very serious difficulty is experienced by a practised operator in using the instrument with the range of colour occurring in the case of the ordinary illuminants in use for street lighting. In order to facilitate the comparison of such sources, however, a modification to the conditions suggested by Crova is obtained by using yellow screens of varying depth of colour, the percentage of light absorbed by which has been previously ascertained. If, for instance, the light striking S_2 is yellower in character than that striking S_1, S_1 may be slightly yellower than S_2, so that the two screens appear very nearly the same colour. After making the measurement we should then allow for the fact that the coefficient of reflection of the yellower screen S_1 is less than S_2, the necessary correction being marked on the screen used.

In order to use the small glow-lamp no more than is actually necessary, and thus at once to reduce the gradual fall in candle-power of the lamp with use to a minimum, and to economize the use of the small accumulator supplying current to it, a small spring-key is provided; by this means the lamp is lighted just as long as may be necessary in order to get a reading. Owing to the small length of time for which the lamp is in use its candle-power only varies very gradually. However, the possibility of such a change, or of the pressure of the battery falling below the correct value of 4 volts, is provided for by means of the scale at P, which enables the lamp to be brought nearer or further from the screen S.

The general working of the Martens illuminometer will be understood from Fig. 13, which shows a general view of the instrument, and Figs. 14 and 15, which represent a sectional plan and elevation.

The plaster of paris surface F receives the general illumination the intensity of which it is desired to measure. The rays from this surface pass into the telescope of the instrument at *b*: its brightness is compared with that of the frosted glass *m*, illuminated by the small benzine lamp B, the rays from which enter at *a*. The flame-height of this lamp is regulated to exactly 20 mm., this height being controlled by observations through the window at D. The rays from the benzine lamp, before proceeding to illuminate the plate *m*, must suffer reflection from the pair of mirrors S_1, S_2, as shown in Fig. 14. By moving these mirrors to and fro by means of a rack and pinion arrangement we can weaken or strengthen the brightness of the illuminated plate *m*, and can determine the relative values of the intensity of illumination, corresponding to equality of brightness in the field of view, by means of a scale calibrated direct in lux.

This alone, however, would only enable the comparatively small range of illumination of 15 to 1 to be measured, and therefore a disc *r* is inserted in front of the plate *m*. This disc contains a series of graduated smoked glasses, the densities of which are such that the illumination read upon the scale must be multiplied by 0·01, 0·1, 1, 10, and 100 respectively. Special provision is made for the measurement of the intensity of unknown sources by means of the cap shown in the diagram containing the diffusing semi-transparent screen H. This cap can be fitted on in front of the aperture H_1.

Another accessory, specially intended to facilitate the comparison of lights differing in colour, is the introduction of a pair of red and green glasses, either of which may be inserted in the eyepiece of the telescope. The observer then takes a reading, firstly, looking through the red glass, and, secondly, through the green glass.

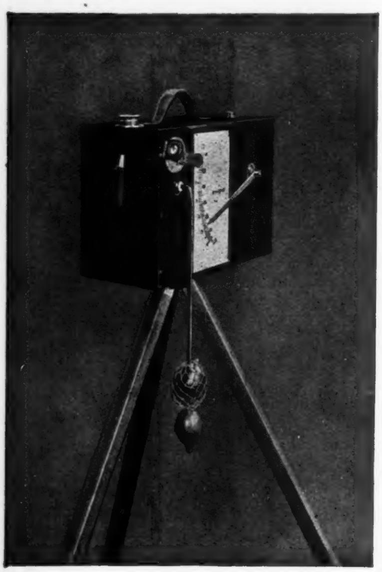


Fig. 16.
Harrison Street Photometer.

The mean of these two results is then assumed to be a measure of the relative total intensities of the two illuminations compared.

In Figs. 16 and 17 will be seen the general arrangement of the Harrison street photometer. The standard of light is again a small glow-lamp L, which receives current from a small accumulator within the instrument, and which illuminates the moveable screen S_1. S_2 represents a white sector-disc (*i.e.*, a disc from which two symmetrical sectors are cut out) which is driven by means of a small air-blast at any desired speed; on this screen is received the illumination which it is desired to measure.

The eye of the observer at E sees, in rapid succession, first the illuminated white surface of the sector S_2, and then, in the mirror M, the illuminated surface of the screen S_1. All that is necessary, therefore, is to alter the inclination of the screen S_1 until no flicker can be perceived by the eye. The surfaces S_1 and S_2 then appear equally bright. The actual illumination at the screen S_2 can be read off by the reading of a pointer attached to S_1, and moving on a scale graduated in candle-feet. In the position shown in the diagram the photometer is arranged to measure the intensity at an angle of 45 degrees to the vertical, but, by tilting the photometer, the intensity at any measured angle may also be obtained.

The method of producing the air blast, by the action of which the rotating

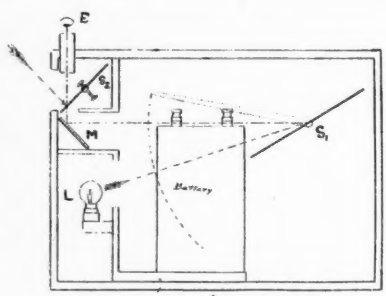


Fig. 17.—Harrison Photometer.

sector is driven, is shown in Fig. 17. The apparatus merely consists of a rubber tube terminating in two balls which are controlled with the hand. The upper one of these serves to maintain the requisite pressure, and retains the speed constant while a reading is taken, the lower one being pressed in the hand in such a way as to accelerate or retard the speed as may be required. The small glow-lamp in the photometer is put in circuit by inserting a plug-key into a socket on the outside of the instrument. When measurements are not actually being made, this plug is removed and the connexion broken. In order to secure a wider range of measurement two alternative lamps of different candle-power are usually provided, either of which can be lighted at will by the insertion of the key into one of two distinct sockets. Illuminations up to 5 candle-feet can be determined.

The ingenious little apparatus shown in Figs. 18 and 19 is intended to enable a rough idea to be formed as to whether the daylight-illumination in a room is satisfactory or not. The instrument really compares the brightness of an image of the sky with the actual illumination to be examined. The enclosed box shown in Fig. 18 contains a sheet of paper *fg* with a fine aperture at *a*. Vertically above this fine aperture *a* is to be found a convex lens *d* and an inclined plane mirror *e*, which can be rotated about both a horizontal and a vertical axis. The aperture *a* is situated at the focal length of the lens *d*. A second paper surface at *c* receives the available intensity of illumination to be examined.

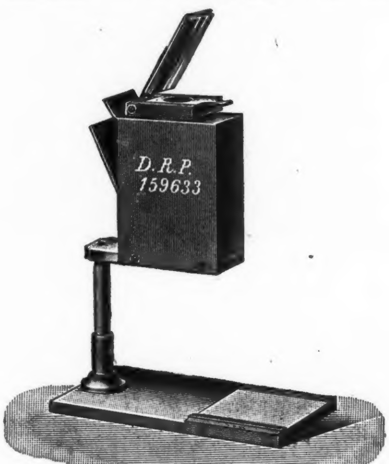


FIG. 18.—THORNER ILLUMINATION-TESTER.

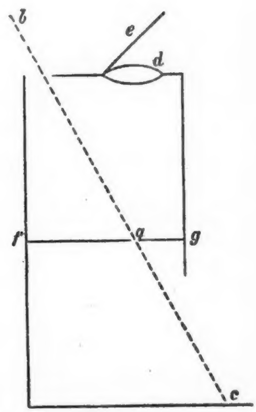


FIG. 19.

An observer, looking along the direction of the dotted line *bae*, sees the surface *fg* and this second surface through the aperture *a*. He then turns the mirror *e* in such a way that an image of a portion of the sky is formed on the region of the paper screen *fg*, adjacent to the aperture *a*. He now judges the value of the existing illumination by merely observing whether the surface illuminated at *c*, seen through the aperture, appears brighter than the image of the sky formed on *fg*, or vice versa. If it appears darker, as shown in Fig. 20a, we say that the illumination is too weak. If, on the other hand, the spot appears brighter, as in Fig. 20b, the illumination is judged to be sufficiently bright. Of course it may happen that *no* portion of the sky is visible from certain positions in a room. When this happens, however, we are safe in condemning the daylight-illumination in the room without further test.

As the standard brightness of the image of the sky is to some extent an arbitrary value, several stops are provided, which correspond to illuminations in the ratio 1, $\frac{4}{3}$, and 2. Determinations are best carried out in cloudy weather. Naturally precautions must be taken to avoid abnormal conditions. The effects of a heavy fall of snow, for instance, and the light reflected upwards as a result, would cause an abnormal distribution of illumination in the room tested. In the same way results obtained when the sun is streaming direct into the room will be too high, while, in the case of a clear sky, the process of testing is somewhat affected by the fact that the image of the sky appears a different colour to the aperture.

Finally, mention must be made of

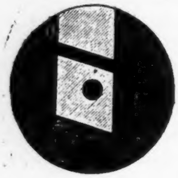


FIG. 20a.

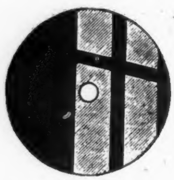


FIG. 20b.

the Williams Simplex photometer. The photometer is stated to be mainly intended to measure the relative brightness of distant sources of light, such as railway or marine signal lights, &c.

The method employed is merely that

FIG. 21.—SIMPLEX PHOTOMETER.

of extinction, and consists in passing a specially prepared photographic film, increasing gradually in intensity from one end to the other, before the eye until the source of light becomes indistinguishable. As shown in Fig. 21

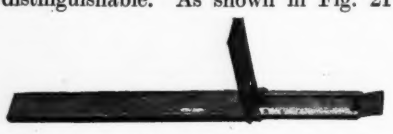


FIG. 22.—SIMPLEX PHOTOMETER.

it may be carried in the pocket. When in use the cap covering one end is removed and attached to the instrument in such a way as to screen the eye, which is applied to the small aperture which may be seen in Fig. 22. With the other hand the photographic film is then gradually removed from the instrument until the light is just cut off. Then, without moving the glass wedge, the instrument is removed from the eye, and the relative degree of obscurity of the film required to cause extinction inspected through the sight-hole, also shown in Fig. 22.

The numbers on the film correspond to stellar magnitudes, that is to say,

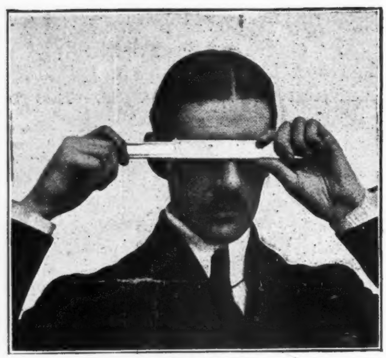


FIG. 23.

the relative values of the intensity increase in geometrical progression in a ratio of about 1 to 2·5, a difference of 5 magnitudes thus corresponding to a ratio of 1 to 100.

It must, of course, be understood that the readings are only intended to be *relative*. Thus the absolute brightness of the light depends upon the state of the atmosphere, while different people, whose eyes differ as regards sensibility to light, will naturally obtain different readings, though the *relative* results obtained by each person should be the same.

Light and Illumination at the Royal Institution.

THE great interest now felt in this subject is illustrated by several recent events of interest at the Royal Institution. Prof. Trouton, F.R.S., recently delivered two very interesting lectures on the theory of light, to which we mean to refer in detail in our next number.

At the Conversazione on Friday evening, May 22nd, *The Illuminating Engineer* was also invited to exhibit some of the instruments, described above, and previously shown at the Municipal Exhibition.

The exhibits, which included the Martens and Trotter illuminometers, the Bechstein contrast and flicker photometers, and the Thorner illumination-tester, proved to be of considerable interest to many of those present.

REVIEWS, ABSTRACTS, AND REPRODUCTIONS.

The Physiological Basis of Illumination.

By Dr. Louis Bell.

(From the *Proceedings* of the American Academy of Arts and Sciences, September, 1907, Vol. XLIII. No. 4.)

(*Concluded from p.* 418.)

Finally, one is nowadays often confronted by questions of colour. Until electric lighting in its more recent forms appeared there was a sufficient similarity in the colours of artificial illuminants to place them substantially on a parity. At present, strong colours are common, and are likely to be increasingly so, since, as I have noted in a previous paper (*loc. cit.*), selective radiation is necessary to high luminous efficiency. One has to deal with the yellow of the flaming arc, the yellowish-green of the Welsbach, the blue-green of the mercury tube, and the violet of the enclosed arc, all of which may have to be compared with the deep orange of the Hefner lamp.

Practically the question of suitable colour resolves itself into two parts—first, the effect of colour on the proper functioning of the visual apparatus, and second, its relation to our observation of coloured objects. I shall not take up here the theories of colour vision, save to note that many of their difficulties may now be charged to the existence of at least two kinds of independent visual elements, the rods and cones, differently distributed in the retina, and possessing two radically different types of visual sensitiveness. That the cones are highly evolved rods has been shown beyond much doubt by Cajal, and is in evidence in the simple rod structure found in the parietal eyes of some fishes and lizards and in lower organisms generally. Whether, as Mrs. Franklin* surmised, there are definite intermediate phases of sensitiveness between the achromatic vision of the rods and the full chromatic vision of the cones, is an important topic for research.

May I venture to suggest that there are some reasons for thinking that there may even be a difference in kind between a simple photochemical rod stimulation and the strongly selective stimulation of the highly specialized cones? Selective activity does not necessarily connote chemical instability. They may coexist, as in some organic dye-stuffs, or may be entirely independent, as in the fluorescence of heavy paraffin oils. The presence of strong pigmentation at the rods and its absence at the cones, coupled with the absence of visual purple in some nocturnal creatures whose eyes are presumably specialized for very weak light, suggests that the evolution of the retinal elements may have proceeded along more than one line. In fact, the Young-Helmholtz and Hering doctrines may find in a heterogeneous retina a certain amount of common ground. Be this as it may, mankind certainly has superimposed a very sensitive but achromatic rod vision, and a much less sensitive but chromatic cone vision, the latter being mainly central and the former mainly peripheral. The passage from predominant rod vision to predominant cone vision is shown in the sharp flexure of the curves in Fig. 1. The exact point at which the colour sensitive cones begin to get into action undoubtedly varies greatly in different eyes, and in the same eye in different conditions of adaptation. As the illumination is progressively diminished, colour vision gets more and more imperfect and uncertain, especially toward the red end of the spectrum. The effect is shown very clearly in the variation of Fechner's fraction with colour as the intensity changes. Fig. 5 shows the change in $\frac{dI}{I}$ with λ for intensities of 15 meter-candles (a) and 0·75 meter-candles (b) respectively from the data obtained by König and Brodhun (*loc. cit.*). Looking at the latter, it is

* *Mind*, N.S., 2, 473 *et seq.*

evident that for the orange and red, vision must be very poor indeed, and in no part of the spectrum really good. In curve *a* colour vision is pretty well established, although there are still traces of the point of inflection, which, as we shall presently see, falls near the point of maximum sensitiveness in very weak light, as if the superimposed rod vision were still helping out at this moderate intensity.

The Purkinje phenomenon, now well known to depend on the progressive failure of cone vision, also gives valuable evidence along the same line. It was noticed more than twenty years ago by Prof. Stokes* that the phenomenon varied with the areas involved, and recently Dow* has found that for small areas (*i.e.*, nearly central and hence mainly pure cone vision) Purkinje's phenomenon appears only below about 0·2 meter-candle. This figure would quite certainly have been somewhat higher had he used instead of red and signal-green glass the primary red and green; but it is clear from his results that the superposition of rod vision has a very considerable effect at moderate illuminations.

Finally, one must consider the luminosity curves at various intensities. Fig. 6 gives in curve *a* the relative luminosities of the spectrum colours at fairly high intensity. The maximum is in the yellow, and the falling off, especially on the red side, is very rapid. This seems to be about the normal curve when the eye is fully in action. Curve *b* gives the luminosity curve for an intensity of about 0·0007 meter-candle. At this point colour sensation is practically extinguished, and the maximum luminosity is perceptible, in what would seem the pure green were the light brighter, very near the E line and at a point corresponding to the inflection in the curves of Fig. 5. This is practically the condition of pure rod vision. Curve *c*, Fig. 6, lends confirmatory evidence. It is the luminosity curve obtained by Abney* from a patient with pure monochromatic vision. He had apparently an absolute central scotoma (cones atrophied rather than replaced by rods ?), visual acuity greatly subnormal (central vision absent), and nyctalopia. This is a typical condition, nyctalopia being generally associated with central colour scotoma, leaving peripheral vision but slightly affected (Fick). The patient apparently had no colour perception, and his lumino-

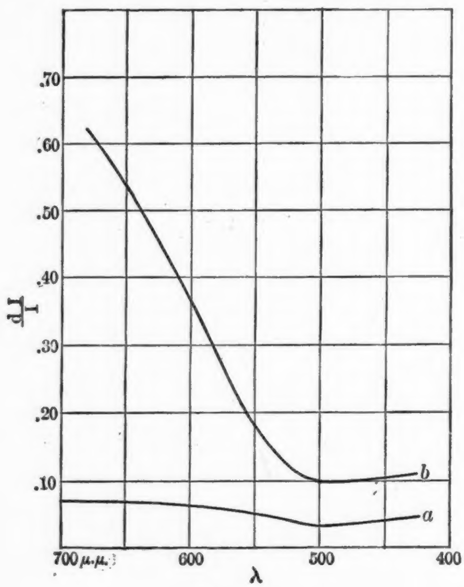


FIGURE 5

* *Nature*, 32, 537.
† *Phil. Mag.*, Aug., 1906.

* *Proc.* Roy. Soc., 66, 179.

sity curve was practically identical with *b*, the normal curve for very weak light.

It would be most interesting to get proper tests for luminosity in one of the rare cases of congenital hemeralopia which would present the reverse condition of rods inactive and cones nearly normal. A comparison of such a case with luminosity in the hemeralopia associated with *retinitis pigmentosa*, in which peripheral vision is progressively contracted, might give valuable evidence as to the existence of retinal elements intermediate in function between rods and cones.

To sum up this phase of the matter, rod vision seems to be predominant from the very threshold of illumination up to several tenths of a meter-candle, and to continue in force to all ordinary intensities, although rather easily exhausted. It gives low visual acuity and shade-perception perhaps of the order of a tenth normal, but, such as it is, it is our main nocturnal reliance. Cone vision begins to come perceptibly into play at a few thousandths of a meter-candle, and at a few tenths is pretty well established, but does not become normal over the visual area below 5 or 10 meter-candles, and gains materially even beyond that, especially in acuity, which is weak at the lower intensities.

Acuity in practical degree is chiefly an attribute of cone vision. The general theory of optical resolution requires acuity inversely as the wave-length of the light concerned. In practice this difference is in great measure masked by other and larger causes of variation. Chief among these is the very low luminosity of the shorter wave-lengths on the one hand and of the very long ones on the other. For example, in comparing acuity at $\lambda = 500\ \mu\mu$ and $\lambda = 650\ \mu\mu$ there is a proportional difference really due to colour, but a ratio of 2·5 : 1 in luminosity in further favour of the green. Violet light favours acuity, if one can get enough of it, but a luminosity of ·02 of the maximum in the yellow stands in the way.

Certain strongly coloured lights, like the flaming calcium fluoride arc and the mercury arc, give apparently extremely sharp definition in black and white objects. In general this is not due to any advantage in colour as such, but to improvement in the conditions of chromatic aberration in the eye. At rest for distant vision, the normal eye is in focus for the rays of maximum luminosity, and the focus for blue lies perhaps 0·4 mm. in front of the retina. That is, the eye is short-sighted for short rays. In near vision the rear conjugate focus moves backwards and the eye finds focus on the blue with less accommodation than usual. Thus Dow* finds that, while the mercury arc gives easy and sharp definition for near vision, at a distance of twenty feet or even less it becomes difficult to get focus. Lord Rayleigh† noticed some years ago that in very weak light he became myopic and required a glass of —1 diopter to restore normal vision. This effect is of the order of magnitude required by the shift of maxi-

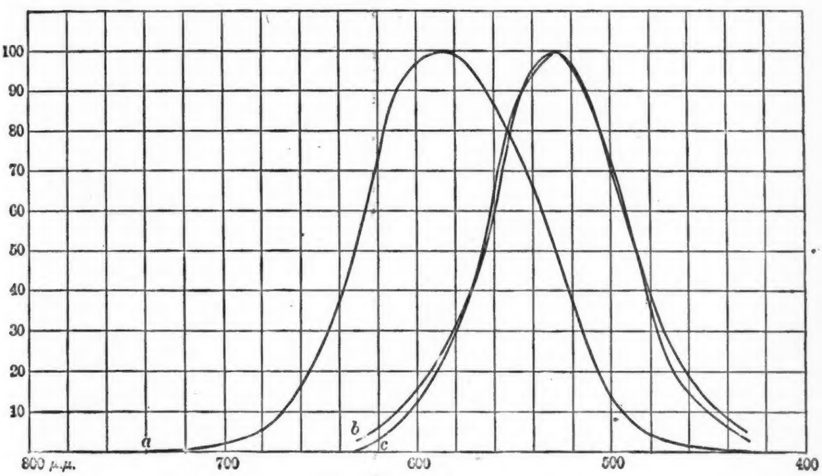


FIGURE 6.

* *The Illuminating Engineer*, 2, 26 *et seq.*

† *Nature*, 31, 340.

mum luminosity into the green at very low intensities. Another phase of chromatic aberration is even more important. Were it not for the existence of a very high maximum in the luminosity curve, distinct vision would be impossible, since the difference of focus between the red and violet in the eye is something like 0·6 mm. and were these extreme colours highly luminous, there would be no focal surface to which the eye could adjust itself. Only the great predominance of the central colours in luminosity gives the chance for a fairly sharp image.

It is easy to show the difficulties into which equal luminosity throughout the spectrum would plunge us. If one forms a grid of certain purples by cutting strips of tissue paper of the required colour perhaps 5 mm. wide and 100 mm. long, and pasting them upon a dark neutral background spaced about their width apart, one readily finds the practical effect of chromatic aberration. From a distance of a couple of meters sharp definition of the grid is quite impossible. The purple chosen should give considerable absorption of the green, yellow, and orange, leaving strong red and blue evenly balanced in luminosity, and the background should be of not greatly different luminosity, so that the eye must rely mainly upon colour effects. The rays from the grid are then of two widely different colours, for which the focal length of the eye differs. There are therefore two image surfaces of about equal intensity, perhaps half a millimeter apart, and the effect is a curious blur, the eye hunting in vain for something definite upon which to focus.

Interposing now a deep red screen (concentrated saffronine is good), or a suitable blue screen, the image of the grid becomes nearly monochromatic, and appears sharply defined. This is an extreme case, but any monochromatic light has an advantage in definition if other conditions are at all favourable. It seems highly probable that the well-known trouble found at twilight in trying to work by a mixture of natural and artificial light is due to a similar cause. The predominant hue of diffused sky light is strongly blue, while that of gas flames, incandescent lamps, and like sources is strongly yellowish. At a certain point in the fading of daylight the luminosities of these widely different colours should balance closely enough to produce something of the effect just described, although the usual difference of direction in the two superimposed illuminations may play a part in the general unpleasant effect.

There is, however, an inherent danger in using monochromatic or strongly coloured light for general purposes. Whatever may be the nature of colour vision, a strongly coloured light utilizes only a part of the visual apparatus. If of high intensity to make up for inherently low luminosity, it rapidly exhausts that part, and produces, as is well known, a temporary colour blindness. There is, at least, a serious chance that long continued use of coloured light would produce persistent and perhaps permanent damage to colour perception. A light nearly white, with its maximum luminosity near the normal wave-length, runs the least chance of imposing abnormal strains on the visual apparatus.

In colour discrimination the same rule holds good, for any considerable departure from white leads to entirely false colour values. In closing, I may mention an interesting question which arises with reference to obtaining a light of high efficiency by building it up from the monochromatic primary components. Would the eye see clearly by such a light, and could it discriminate colours properly? The answer is probably, "yes." The equation for white is roughly

$$W = \cdot 20R + \cdot 30G + \cdot 50B.$$

These are quantities as determined by slit width in the spectrum or a like process. There is sufficient predominance of luminosity in the green to avoid trouble from chomatic aberration, and the actual working of the combination in giving photographs in natural colours is such as to indicate proper colour vision. As yet, however, no means are available for producing all three primary colours efficiently, and for white artificial light we are compelled to rely on what is in effect building up a nearly continuous spectrum from heterogeneous components, unless, as usual, we employ the continuous spectrum of an incandescent solid.

Electric Supply Prospects and Charges as Affected by Metallic Filament Lamps and Electric Heating.

By H. W. Handcock and A. H. Dykes, Members.

(Paper read before the Institution of Electrical Engineers, April 8th.)

(*Continued from p.* 429.)

DISCUSSION (Abstracted).

Mr. Arthur Wright remarked that the position of the industry as regards the new lamps needed careful consideration and handling. He thought, however, that the consumer ought to recognize that he was now in a position to use light more liberally than formerly. He could, in fact, have three times the light for the same power. He also hoped that the new lamps would enable the companies to reach many consumers at present not available. For this reason it was essential to do all that was possible to make things easy for the consumer, to avoid complexities, and to try to imitate the simplicity of the dealings of gas companies with the public. In the past the electrical industry had rather suffered through trying to provide for perfect safety at the cost of simplicity.

Increase of output was extremely valuable to the supply authorities. The high charges for house connexion were also a great drawback, and it seemed very desirable that engineers should turn their attention to the cheapening of this branch. At present it actually cost nearly as much per kilowatt to connect up as to build a power station.

Mr. Hugo Hirst mentioned that he had just handed in a paper to the Institution dealing with recent progress in metallic filament lamp manufacture; he thought that if the authors of the present paper had had an opportunity of studying this they would have modified some of their conclusions as to the effect of metallic lamps on the electrical industry.

He urged that there was a wide field for the extension of electrical supply. At present there was only about £6,000,000 invested in electrical works as compared with £27,000,000 invested in gas undertakings. Mr. Hirst also mentioned that he had recently proposed to fifteen central station engineers that they should combine to supply metallic filament lamps to the contractors, and thus be in a position to regulate their introduction.

Mr. W. R. Rawlings spoke from the contractor's view. He had no hesitation in condemning the maximum demand system, as regards its effect on the consumer. In fact he had never yet met a consumer who had thoroughly understood it. As a rule the consumer seemed to think that, in some mysterious way, the wiring was responsible for his high bills, and he sent for the contractor in consequence. What was wanted was greater simplicity.

In the same way consumers certainly would not be induced to use electric kettles and so on, if they found that this necessitated a separate meter. In Knightsbridge there were actually many triple systems of supply, involving three meters, three main-switches, &c., in the same house.

Mr. F. M. Long, of Norwich, explained the system of charging recently adopted by him. The present system consisted in merely charging 12 per cent. of the rateable value of a consumer per annum, and a uniform rate of 1*d*. per unit. Actually 10 per cent. of the rateable value would have served to enable the company to obtain the same revenue as previously, but the higher rate mentioned provided a margin. The system had worked excellently, and there had been no grievances or complaints. During the fifteen months for which it had been in use the number of customers supplied by the system had increased from 400 to over 800. The system also favoured the use of heating devices, and there had been about 100 radiators put in. In the case of business houses, &c., special terms were given, usually a charge of £10 per K.W. required, and 1*d.* per unit. In the case of sign and advertisement lighting the initial charge might be reduced to £5. He also recommended that extra meters should be avoided as far as possible.

Mr. C. P. Sparks described the advent of the metallic filament lamp as the greatest thing that had happened for the benefit of the lighting industry for twenty years. The industry must ultimately benefit by their introduction, and in any case their adoption would come only gradually. The advent of the incandescent mantle had proved to have done the gas industry no harm. Yet the field was in this case much more fully covered than in the case of electricity.

He thought that the maximum demand system had proved to have grave disadvantages, in spite of its scientific nature, and felt that the industry rather owed Mr. Wright a grudge for being the inventor of it. Yet he had some doubts as to the practicability of the system adopted at Norwich. It might work very well in a small provincial town, but nevertheless prove unsatisfactory in the case of a big London company.

Mr. C. H. Stearn referred to the value of small local transformers utilized to reduce the P.D. at the consumers' terminals. When direct current-supply only was available it must be recognized that the present means of utilizing the metallic lamps were very imperfect. By using large units we obtained an undesirably great concentration of light. We could, of course, subdivide units by putting filaments in series, and the question arises whether it is best to do what is necessary in this way in a single big bulb, or to run a number of separate lamps in series. He favoured the latter plan, lamps so arranged being each provided with a compensating resistance which cut into circuit and replaced a filament in the case of a lamp failing. (The working of such an arrangement was exhibited by the speaker.)

Mr. P. Still thought that the system proposed by the authors entailed some difficulties, among which he might specify the really arbitrary nature of the fixing of the contract demand of the consumer. In this connexion an application form did not form a reliable guide. The consumer would very often modify his previously estimated demand, and introduce 16 candle-power lamps in the place of 8's, and so forth. The method would be of very much easier application to factories and business houses where, of course, different conditions prevailed.

Mr. L. Andrews maintained that the influence of the new lamps on the supply company's business must ultimately be good. He thought it was most essential that a system of charging should be adopted which the consumer could understand. A flat rate, though simple, was not equitable. A system introduced at Hastings which had been found to give very great satisfaction had been as follows. The consumer was charged 10*s.* per 8 c.-p. lamp put in (as determined by the maximum demand indicator) annually, and also 1½d. per unit.

Mr. S. F. C. Snell took an optimistic view of the situation. He considered that with the new lamps electricity was able to compete with the gas mantle, as soon as the cost per unit fell below 3½*d.* Many companies were now in a position to supply at this figure. Transformers were only to be regarded as a temporary makeshift.

Mr. Robert Hammond thought that it was unfortunate that the discussion had turned mainly upon tariffs. Now at last, thanks to the new lamps, electricity was again in a position to compete with gas on equal terms, and results abroad had often showed that electricity could displace gas for lighting purposes by their aid. He was not sanguine as to the possibility of the consumer being induced to raise his standard of illumination. In many cases the use of metallic lamps led to too much "glare" as it was.

Mr. Hammond endorsed what had been said as regards the inadvisability of installing separate meters in private houses to measure the power supplied to the lighting circuit and to electric kettles and the like. He considered the flat rate inequitable, and thought that Mr. Long's method of charging might be of great benefit in avoiding the unpleasantness accompanying the maximum demand system. To this end he hoped that the Board of Trade might be induced to allow the insertion of such provisions in the next electrical supply bill as would enable every company to make a fixed charge.

Mr. Leon Gaster congratulated the authors on their opportune paper. Many people seemed to think that the new lamps would merely result in more light being used, while there were others who feared that the consumer would now obtain the amount of light he desired at about a third of the energy previously taken. He himself thought that some compromise between these conditions was necessary; meantime the gradual development of the lamps from high candle-power and low voltage to, ultimately, low candle-power and high voltage would enable supply companies to adjust their methods to meet the new conditions.

He was also glad to see that the point of view of the consumer was receiving attention, and thought that the chief necessity was to simplify the present system so that the consumer really understood the method on which he was charged. The plan suggested by the authors seemed a desirable compromise. Meantime he thought that, in cases in which the flat rate was offered as an alternative to the maximum demand system, a consumer who elected to be charged on the latter plan ought not to suffer as a result. He ought, therefore, to be assured that his bill could not come to more than that of his neighbour who paid a flat rate, but might come to less.

Mr. Gaster also advocated closer co-operation and mutual tolerance between gas and electricity supply companies. In particular he urged that an industry that employed such an immense capital as that invested in gas would not readily give way unless it was able to perceive possibilities of remunerative extension in other directions.

MR. F. GILL agreed that the maximum demand system was productive of much misunderstanding. He felt that greater simplicity was needed, and urged the possibility of adopting a sliding scale method of charging on similar lines to that often offered in connexion with telephone service.

MR. R. B. MATTHEWS thought that the consumer must be educated to a higher standard of illumination. He also indicated the advisability of inducing customers to utilize electricity for heating and cooking purposes, of increasing the number of consumers, and of trying to decrease the cost of house-service. He, too, thought that the maximum demand system was not understood, and a cause of trouble with consumers.

MR. W. M. MORDAY said that the maximum demand system had proved undesirable in practice. Three years ago there were three times as many M.D. systems in use as flat rates. Now the condition of things was reversed. He advocated an attempt to approach nearer to the broad, free methods of dealing with the consumer employed by the gas companies.

COL. CROMPTON remarked upon the different condition of things to be met with in different districts. Naturally the effect of the new lamp depended very greatly on whether the ground had been already very fully covered or whether there was room for much further extension. This was partially responsible for the different points of view, pessimistic or otherwise, as to the influence of metallic lamps on revenue. We had, however, now arrived at a condition of affairs such that it was almost impossible to reduce the first cost of electricity very much, except by securing an enormous output or splendid load-factors. He thought that the Norwich system of charging introduced by Mr. Long at Norwich was one of the most important points in the paper, and regretted that it had not received fuller discussion. It resembled the ordinary water-rate, and would be largely instrumental in getting over the injustice done to the small consumer.

MR. A. H. DYKES, in reply, stated that some present thought that they had taken an unduly pessimistic view of the situation, but that this was not really so. He showed several load-curves to illustrate the falling off in energy supplied during the present year. As a whole the curve for 1907 fell below that for 1906, and, occasionally, even below the corresponding value for 1905. On the whole, however, he thought that the discussion endorsed his view that the metallic filament lamps might lead to considerable reduction in revenue unless some efforts were made to put things on a more satisfactory footing. Certainly even their immediate effect was very serious in the case of large consumers using perhaps £2,000 per year. Mr. Wright had suggested that the public ought to be educated to use more light, but had we any solid reason to hope that they could be induced to do so ?

He was glad to see that the disadvantage of the maximum demand system, and also the inequality of the flat rates were widely recognized, and that modifications of the system which the authors proposed had been adopted by Mr. Long and others. As a matter of fact, a very similar system had been advocated by Messrs. Tate and Bowden in 1906.

Some scheme of the kind he felt to be very desirable, and thought that the Board of Trade would sympathetically consider any suggestions that the Institution might put before them on the subject.

Recent Progress in Tungsten Metallic Filament Lamps.

By H. Hirst, Member.

(Paper read before the Institution of Electrical Engineers, May 21st, 1908.)

In the first part of the paper the author deals briefly with the early work of Swan, Edison, and others on metallic filaments. He explains the immediate success of carbon applied to the manufacture of glow-lamp filaments, and traces the subsequent attempts to employ rare metals which culminated in the invention of the osmium lamp by Auer von Welsbach. These steps have been so comprehensively described in *The Illuminating Engineer*, in the recent articles by Dr. Weber and Dr. Jacobsohn, that it is unnecessary to do more than mention a few of the developments on which the author lays stress.

Mr. Hirst, however, goes on to mention the work of von Bolton on the tantalum lamp, which was put on the market in 1905. Afterwards attention was turned to tungsten, and Siemens and Halske attempted to apply their drawing process, which had been successful in the case of tantalum, to tungsten; they failed, on account of the brittleness of the latter metal.

The well-known patent of Just and Hanaman was obtained in 1904. The patents of the Deutsche Gasglühlicht Aktiengesellschaft were worked out independently. Both deal with the manufacture of filaments from pure tungsten. These two fundamental patents refer to the paste-process. Other patents have been taken out by:—

Heany (American patent No. 839,585), who proposes to use an alloy of tungsten with titanium.

Kuzel (British patent No. 28,154 of 1904) suggests the manufacture of glowing bodies from colloidal metals.

British Thomson-Houston Company, (British patent No. 18,749 of 1906 and subsequent patents) describes the manufacture of filaments of tungsten with the help of volatile metals or alloys, chiefly amalgams, which could be drawn into wire. It will be interesting to watch the progress of this suggestion

Zerning (British patent No. 2,554 of 1906) claims the use of hydrogen and nitrogen compounds of tungsten as the materials from which to construct tungsten filaments.

Mr. Hirst, however, contends that only the two original patents referred to above have yet been successful in producing commercial lamps. All metallic filaments burning at a consumption of 1 watt per candle have been made with tungsten filaments. If ever so small percentages of other substances are added to the tungsten, the economy and useful life of lamps with such filaments suffer immediately.

The osram lamp is manufactured by the "paste" process, the principle of which consists in preparing from solid substances, such as the metals themselves, in the most finely divided form, a paste with binding or stiffening agents such as the gums, dextrine, and other similar bodies. Such a mass has the consistency of putty, and is then squirted through a very fine orifice in a diamond, with a pressure of several tons per square inch. The result of the squirting operation is that one obtains a somewhat moist thread, which, however, has enough coherence to be formed into filaments that do not break while being dried.

The filaments are first heated under exclusion of air and then possess sufficient strength to be held in metal clamps. They are then subjected to the passage of an electric current which raises them to a high temperature, causing the filaments to sinter. The filament so obtained is dense and homogeneous, but being obtained by a sintering process it is different in structure from the still denser metal which would be obtained from a melted mass.

Auer von Welsbach describes a method for the manufacture of an electrical illuminating body of osmium by sintering the most finely divided metal at such a high temperature that platinum would evaporate, which temperature destroys the binding material which had been used in the manufacture of the threads. The filament so obtained withstands a very high temperature, but it is still of a more or less spongy or porous constitution; very metallic, but nearly solid. During the process there is a considerable shrinking in the material of the filament amounting in all to about 55 per cent.

The other method of constructing tungsten filaments was developed by Drs. Just and Hanaman simultaneously with, but quite independently of, the Deutsche Gasglühlicht Aktiengesellschaft. Their lamp was introduced commercially under the name "Just-Wolfram." This process is carried out as follows: Ordinary carbon filaments of very small diameter, 0·02 to 0·06 mm., are raised to a bright red heat by means of an electric current in an atmosphere of volatile tungsten compounds in the presence of hydrogen.

The heat of the filament causes the hydrogen to reduce the volatile metallic compounds, depositing the metal in homogeneous condition on the carbon filament.

The filaments are next submitted to the action of an electric current in an atmosphere of highly rarified inert gas, such as, for example, hydrogen at a pressure of about 20 mm., until they show the clearest white incandescence. This process causes the carbon to combine with the tungsten surrounding it, forming a carbide.

Finally, they are raised to a high temperature through the passage of an electric current while surrounded by a mixture of hydrogen and a little steam. This causes the carbon to be oxidized by the same reactions which go on in the water-gas process.

Drs. Just and Hanaman have also obtained patents protecting the process of *mounting* their tungsten filaments to the leading-in wires. This is effected by means of a paste consisting of finely divided tungsten metal mixed with coal tar or gum. These paste mounts are dried and finally made red-hot by any suitable means before the filament is heated in the bulb.

The supports used in these lamps are made of suitable metal.

Exhausting is done in a manner similar to that employed for carbon lamps.

Though this process is entirely different from the "paste" process, the final result in each case is a pure, sintered filament of tungsten metal. The sole difference is that the filament made by the Just and Hanaman process is tubular.

It has been proved that these lamps will burn for from 1,000 to 2,000 hours with a consumption of about 1 watt per candle-power, without any appreciable falling off in the candle-power. Of all the metals which have been experimented with up to now, only pure tungsten has such a life.

In economy, the result is also better than has been obtained with other filaments, thus:—

The osmium filament takes 1·5 watts and the tantalum 1·7 watts for direct current, and somewhat more for alternating.

The results of some recent life tests are shown in Table 1.

TABLE I.—LIFE TEST RESULTS.

No. of Test	Type.	Cost per Lamp.	Tested by	Starting.		Efficiency in W./C.P.	Number of Lamps.	Duration of Test.	Average Useful Life.	Mean Efficiency.	Average C.P. Hours.	Cost per 1000 C.P. hours.		
				Watts.	C.P.							Renewals.	Energy at 4*d.* per Unit.	Total.
	Low Voltage.	*d.*						Hrs.	Hrs.	W./C.P.		*d.*	*d.*	*d.*
I.	Osram	48	Faraday House ...	35·7	36.3	0·99	12	2,000	1,520	1·12	48,700	0·98	4·48	5·46
II.	Osram	48	Westminster Testing Laboratory	35·8	29·7	1·22	12	1,500	1.360	1·29	36,600	1·31	5·16	6·47
II.A*	Osram	48					12	3,350	2,850	1·42	70,800	0·67	5·68	6·35
III.	Osram	48	T. R. Charlottenburg	34·7	1·0	1·12	?	1,000	1,000	1·11	31,100	1·54	4·44	5·98
IV.	Osram	48	Robertson, E. L., Ltd.	35·0	27·7	1.26	6	1,800	1,720	1·36	45,600	1.06	5· 4	6·50
V.	Wolfram	48	Robertson, E. L., Ltd.	38·0	30·7	1·24	2	1,000	1,000	1·27	28,900	1·66	5·08	6·74
VI.	Tantalum	33	Westminster T. L. ...	39·1	22·0	1·78	6	1,000	700	1·84	15,000	2·19	7·36	9 55
VII.	Carbon	12	—	59·0	18·7	3·15	10	1,000	1,000	3·25	18,000	0·67	13·00	13·67
	High Voltage.													
VIII.	Wolfram	90	Robertson, E. L., Ltd.	63·4	53·7	1·18	10	880	720	1·12	42,500	2·12	4·48	6·60
IX.	Carbon	12	—	68·0	18·9	3·6	10	1,000	1,000	3·95	18,200	0.66	15·80	16·46

NOTE.—For the purpose of comparison *all* the above results have been expressed in terms of the "Hefner" unit of candle-power.

* This is a continuation of Test II. to 3,350 hours to show that it pays to burn osram lamps to the limit of life.

The author next refers to the curious fact that whereas the osram filament appears to radiate only 87 per cent. of the energy radiated by an equal surface of a carbon filament, yet it gives about 275 her cent. more light. The author attributes this to the selective radiation exercised by the metallic filament, in virtue of which the temperature of an osram lamp may be about 100 degrees lower than that of a carbon filament lamp of the same efficiency; otherwise it would have to be burnt at an efficiency of 1·5 to 1·6 watts per candle-power in order to have the life which it actually enjoys at 1·1 watts per candle-power. Mr. Hirst also refers to the well-known fact that metallic filament lamps are very much less affected by alterations in P.D. than the carbon ones. In this connexion he gives the curves shown in Fig. 1.

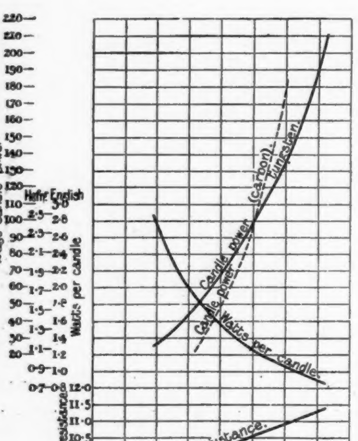


FIG. 1.

The candle-power of a carbon filament lamp, due to a 6 per cent. change in P.D., is as much as 34 per cent.; in the case of the osram lamp the corresponding change in candle-power is only 21 per cent.

HIGH-VOLTAGE LAMPS.

High-voltage metallic filaments of the osram type have recently been put upon the market, manufactured both by the D.G.A. and the Just-Hanaman processes. The average life of a 1 watt 1 candle-power lamp seems to be between 800 and 1,000 hours. During this period there is no appreciable drop in candle-power, and the lamps have shown themselves to be equally good as the low-voltage osram or Just lamps. These high-voltage lamps, made for from 200 to 250 volts, require double the number of filaments used in the low voltage lamps. It is evident, therefore, that they cannot be produced for small candle-power. Up to the present 40 to 50 candle-power is about the lowest unit that has been obtained in a commercial lamp, and some extraordinary development or discovery will have to be made before that candle-power can be largely reduced.

THE USE OF 110 VOLT LAMPS ON 220 VOLT CIRCUITS.

In so far as the lamp is different from the carbon lamp, it will, therefore, always be necessary to rely on series running whenever low units of light are required on high-voltage circuits; thus, for public lighting (especially for the lighting of large spaces), the convenience of one lamp will be apparent, and people will stretch a point to use 50 candle-power for such purposes whenever they can; but for the use of private houses and confined spaces it will always be necessary to revert to lamps burning in series.

This running of osram lamps in series can be avoided to a very large extent in those areas where the supply is given on the alternate-current system.

These tungsten filament lamps burn equally well on either continuous or alternating current, and are quite independent of both frequency and wave form.

THE EFFECT OF METALLIC FILAMENT LAMPS ON SUPPLY SYSTEMS.

Fears have been expressed by some electrical engineers that the introduction of these osram lamps will seriously affect the finances of supply undertakings. Exactly the same fears were expressed by gas engineers when Welsbach mantles were introduced, which enabled the gas required to produce a given quantity of light to be reduced to one-third of that previously used. These fears proved groundless, and the demand for gas increased instead of decreased. The same result will probably follow the commercial use of the metallic filament lamp. It seems likely that the introduction of these lamps will mean an increase of 100 per cent. in the unit adopted for electric light. 16 candle-power carbon lamps will be replaced by 25 to 35 watt tungsten lamps, and those places in which a low illumination is desired will still be supplied with carbon filament lamps of 2½, 5, and perhaps 8 candle-power. As it is not practicable at present to make osram lamps for 110 volts circuits of a lower candle-power than 25, it is likely that in small rooms greater illumination will have to be used.

Amongst the disadvantages of the lamp is the *burning in vertical position*, which up to now has been insisted upon by the manufacturers. This problem is already solved in different ways, and lamps can now be supplied to burn in any position.

The price of these lamps is for the moment a trifle higher, but before many months I believe they will be supplied at the same price as the others.

The *price* itself is naturally held up as a disadvantage, especially when a consumer is displacing old lamps for new ones. The outlay then appears serious, but the saving in current for given illumination rapidly wipes off this expenditure.

Much has been made of the brittleness of the metallic filament and of the percentage of *breakage* in certain instances. small changes in vacuum. Other theories exist as to the cause of this, but what for the moment mainly interests the users is that if a lamp is going to blacken it usually happens at a very early period of its life, when the makers are prepared to deal with the matter generously. It is quite different in this respect to a carbon lamp, in which a blackened bulb means as a rule that the lamp has been kept on circuit for an indefinite period, far exceeding its useful life.

TABLE II.

DETAILS OF IRON LOSSES OF SMALL TRANSFORMERS.

Output of Transformer in Watts.	Number of 16-c.p. Osram Lamps Alight at one Time.	No Load.	Iron Losses.	Units taken per Year.	Cost per Year at 4*d*. per Unit.
		Watts.	Per Cent.		£ s. d.
300	19	5	1·67	44	0 14 8
750	47	10	1·33	88	1 9 4
1,500	94	17	1·13	149	2 9 8

The cost per year at 4*d*. per unit is given in the last column.

TABLE III.

ANNUAL COSTS FOR CURRENT ON AN INSTALLATION OF 25 16-C.P. LAMPS, OF WHICH 19 ARE BURNING AT ONE TIME.

(16-watt Osram Lamp *v*. 60-watt Carbon Lamp.)

No. of Hours per Annum at Maximum Load.	Maximum Load in Watts.		Units used per Annum with Osram Lamps.			Units used for Carbon Lamps.	Cost of Current at 4*d*. per Unit.								
	Osram Lamps.	Carbon Lamps.	Osram Lamps.	Trans-former.	Total.		Osram Lamps.			Carbon Lamps.			Saving.		
							£	s.	d.	£	s.	d.	£	s.	d.
300	304	1,140	91	44	135	342	2	5	0	5	14	0	3	9	0
400	304	1,140	122	44	166	456	2	15	3	7	12	0	4	16	9
500	304	1,140	152	44	196	570	3	5	3	9	10	0	6	4	9
600	304	1,140	182	44	226	684	3	15	3	11	8	0	7	12	9
700	304	1,140	213	44	257	798	4	6	6	13	8	0	9	1	
800	304	1,140	243	44	287	812	4	15	6	15	4	0	10	8	

Table IV. shows the complete balance sheet obtained by adding the cost of current to the lamp renewal charges for both carbon and osram lamps.

From the moment it was understood how to pack the osram lamp the breakage in bulk has been a negligible quantity. It now only affects the supply of the lamps in small parcels of one half-dozen to one dozen. This problem is now being dealt with, with every prospect of an early success.

Another point about which there has been considerable outcry is the *blackening* of individual bulbs which occasionally occurs. It is at present thought that this blackening is due to some extent to the great sensitiveness of the filament to

Finally the author discusses a few special applications of metallic filament lamps. He points out the value and special merits of low pressure 25-volt lamps, used in connexion with a transformer. He refers to the general impression that the iron loses in such small transformers, which, unless special precautions are adopted, go on continuously, are so serious as to nullify the gain in efficiency from the lamps. In the table shown below the iron loss on a transformer taking 3,000 watts is assumed to be 5 watts.

The copper losses in these transformers are not large, and only occur when the lamps are being used.

The following table shows the financial results from the use of these 25-volt 16-c.-p. osram lamps in a private house requiring 25 lamps. It is assumed that the smallest size of transformer in the preceding table will suffice, as 19 lamps alight at one time is about the extreme maximum load in such a house.

houses, workshops, &c. Where small units of light are quite sufficient, the cost of the generating plant can be reduced very largely as the output required falls in the ratio of the efficiency of the filaments used in the lamps.

The same reduction in the cost of generating plant in mains can be realized when designing electric lighting equipment for the numerous small towns and villages within the United Kingdom yet to be supplied with electrical energy. In such undertakings the capital burden to be borne by the relatively few consumers obtainable is the chief deterrent.

While the saving from the use of the metallic filament lamp may not bring the capital down quite in the above ratio, it will make many schemes feasible which hitherto have been passed by.

TABLE IV.

No. of Hours per Annum of Maximum Load.	Osram Lamps.		Carbon Lamps.		Total.		Total Saving with Osram.	
	Current.	Lamp Renewals.	Current.	Lamp Renewals.	Osram Lamps.	Carbon Lamps.		
	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.	Per cent.
300	2 5 0	1 10 0	5 14 0	7 1	3 15 0	6 1 1	2 6 1	38
400	2 15 3	2 0 0	7 12 0	9 6	4 15 3	8 1 6	3 6 3	41
500	3 5 3	2 10 0	9 10 0	11 10	5 15 3	10 1 10	4 6 7	43
600	3 15 3	3 0 0	11 8 0	13 3	6 15 3	12 1 3	5 6 0	44
700	4 5 6	3 10 0	13 6 0	16 7	7 15 6	12 2 7	6 7 1	45
800	4 15 6	4 0 0	15 4 0	19 0	8 15 6	16 3 0	7 7 6	45½

These tables show that private houses in those areas over which electricity is distributed in the form of alternating current can at once realize to the full the exceptional radiating properties of the tungsten filament.

There is another large field for these low voltage lamps in connexion with isolated plants for the supply of country

Publications Received.

The Annual Report of the Lighthouse Board, Washington, U.S.A.

A REPORT giving exhaustive particulars of the various lighthouses, beacons, buoys, &c., in use in the United States.

It contains a series of maps referring to the sixteen districts dealt with, is excellently arranged and indexed, and should be found of great value by all interested in the subject of lighthouse illumination.

Die Revision elektrischer Starkstromanlagen. By Paul Stern. (Mk. 3.60., Hannover, Max Jänecke.)

This little book describes the inspection of heavy current installations. In the first section the author classifies the various kinds of inspection to which electrical installations are subjected; in the second and third sections he reviews the possibilities of injury to men and things, either accidental or arising from imperfect electrical conditions. In the third and longest section he gives a summary of the existing legislation, regulations, and statistical data in Germany bearing on the subject.

Isolationsmessung und Fehlerortsbestimmung in elektrischen Starkstromanlagen. By Paul Stern. (Mk. 1.60., Hannover, Dr. Max Jänecke.)

In this little book the author deals in a condensed manner with the existing methods of testing insulation, and locating faults in electrical installations.

The arrangement of the book is such as to present the available data in a readily accessible form, and the numerous and clear illustrations provided constitute an important and excellent feature in a book devoted to this subject.

Working Standards of Light and their Use in the Photometry of Gas.

By Chas. A. Bond.

(Abstracted from the *Journal* of the Franklin Institute, March, 1908.)

In this paper the author describes and reviews the various standards of light utilized in the United States for gas-testing. Among these standards occur some of those which have recently been described by Mr. Trotter in *The Illuminating Engineer*, but also some others which are exclusively used in America. In particular the experiences of the United States as regards our own standard, the 10 candle-power pentane lamp, are of interest.

The Vernon Harcourt lamp was legally adopted by the Gas Referees in this country about ten years ago. Since that date as many as 150 of these lamps, or reproductions of them, have found their way into use in the United States, and have given very satisfactory results. In order that a lamp may serve as a standard, the luminosity may be maintained constant, (1) by securing a uniform consumption of fuel, and (2) by the maintenance of a constant height of flame. In spite of the greatest care in specifying the construction and opacity of lamps, however, it is impossible to secure the reproduceability of the light to within a few per cent.

The Reichsanstalt in Germany, for instance, certify Hefner lamps, the candle-power of which falls within ± 2 per cent of the standard.

Of the sixty-four pentane lamps that have been standardized by the photometrical department of the Philadelphia gasworks, by comparison with an imported English lamp certified by the Gas Referees, eight have differed more than 1½ per cent from the standard value. Three of these did so owing to errors in construction.

As an instance of the great constancy in the light of a given lamp that is possible the author quotes the following experience. An English lamp (No. 51) was imported from London in January, 1900, and certified to give a value of 10 candles. In 1904, as a mean of sixty readings, an American lamp (No. 2) proved to have a value of 10·04 candle-power, expressed in terms of this English lamp.

In 1905 a second American lamp (No. 89) was compared with No. 2, and found to have 10·02 candle-power, as the mean of a hundred readings.

In 1907 this last lamp (No. 89) was taken to London, and, tested by the Gas Referees against their own standard, proved to have a value of 9·99 candles, which represents a discrepancy of only 0·3 per cent as compared with the American value. From the point of view of gas-testing, therefore, the pentane lamp appears to possess the desired constancy as a unit of light.

The author then proceeds to mention the requirements of a good working standard, which are as follows :—

1. That it should be readily portable, of simple construction and operation, and of unvarying dimensions.

2. It should have an independent fuel, reasonable in price and readily procurable, of definite chemical composition, with a fixed boiling point.

3. The flame should be of the same order of luminosity as the test flame; of a similar colour; fed without a wick; at a constant pressure, through a constant opening; and no chimney should intervene between it and the photometer disc.

4. The lamp should be burnt in a quiet, adequately ventilated room of uniform temperature, and be supplied with pure air of the same temperature. After reaching thermal equilibrium its flame height should be set, and, all the conditions named above having been complied with, the flame height and flame value will remain unchanged for that particular atmospheric condition.

5. It is known that all flames, being supported in combustion by atmospheric oxygen, are influenced by the condition of that atmosphere as regards carbonic acid content and water vapour content. It is desirable, therefore, that the luminosity of the standard used should, as far as possible, be influenced in the same direction and to the same extent as the

test flame. In this way the correction in value is automatic.

Common Working Standards.

Reports were received by the American Gas Institute from the gas companies in about eighty of the largest cities of the United States, showing the following working standards to be in use :—

A.—British candles of several importations. Used by 31 of the 40 municipal and State inspectors, and by 41 gas companies.

B.—Edgerton Standard, used by 18 gas companies; no municipal or State inspectors.

C.—Hefner lamps, used by 1 municipal inspector; 5 gas companies.

D.—Electric incandescent lamps, used by 2 municipal inspectors; no gas companies.

E.—Elliott lamp, used by 11 gas companies.

F.—Pentane lamp, used by 31 gas companies and three municipal inspectors.

G.—Jet photometers, variously manipulated, used by 28 gas companies, 20 of which also use bar photometers.

Of these working standards we may eliminate from consideration D (electric incandescent lamps) and G (jet photometers); D because no companies use it, and for the reason that it is unaffected by atmospheric changes, and so is unsuited for testing gas flames which are so affected; G for the reason that while by flame phenomena it serves to indicate the direction of change in candle-power, and can be calibrated fairly well, yet in the true sense it is not a photometer, and makes no use of the light standards under discussion. In justice to the electric incandescent lamp it should be said that it is to-day the most trustworthy custodian of the unit of light, and is employed at the Bureau of Standards for that purpose.

A. *Candles.*—Candles have the weight of long usage behind them, are mentioned in many contracts, and are simple and easily set up. They also yield a light of a convenient colour.

Otherwise (though still frequently employed) they are now recognized as being very irregular and unsatisfactory standards, even when carefully used. Thus the Dutch Photometrical Commission found the average deviation to be 2·87 per cent, and the individual variation as much as 9 per cent from the normal. In order to secure standard conditions attention must be paid to a very large number of different factors. The last specification issued in 1894 contains such minute directions as to be rarely complied with by manufacturers. Then again the performances of candles are very much affected by atmospheric conditions, and under certain climatic conditions it may be impossible to secure the standard burning rate at all. Candles imported from different sources also vary among themselves very greatly. The number of threads per strand, the melting point of the wax, and the curvature of the wick during burning, all affect the luminosity of the flame. The author has found variations as high as 11·5 per cent above and 7·5 per cent below the standard candle-power.

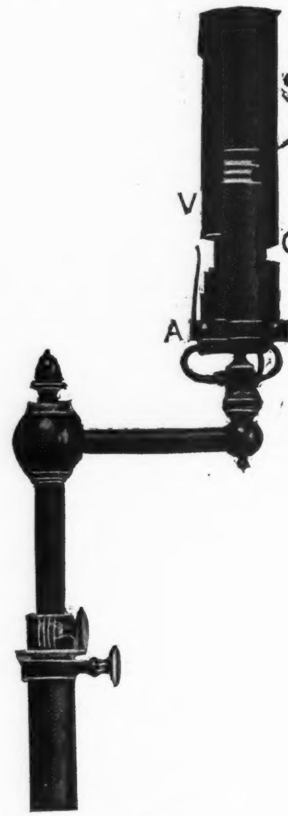


Fig. 1.
Edgerton Standard.

Lastly, the actual manipulation of the candle as a standard presents many inconveniences.

B. *The Edgerton Standard.*—This standard, which is shown in Fig. 1, appears to be a modification of the Methven screen, long used in England as a standard lamp.

The standard consists of a Sugg D argand burner with a 7 in. × $1\frac{3}{4}$ in. chimney, surrounded by a blackened brass sleeve. In the front of this sleeve, with its lower edge $\frac{7}{8}$ in. above the top of the steatite ring of the burner, there is cut a slot $\frac{11}{32}$ in. high and of such width as to include the entire diameter of the flame.

Theoretically, if the flame be adjusted to a height of 3 in., the portion visible through the slot will remain practically constant in intensity, for ordinary variations in the illuminating power of the gas fed into it. Actually with coal-gas of candle-power varying from 13 to 17, its value alters from about 4·20 to 4·6.

A number of tests by Mr. Rollin Norris, published in 1899, led him to conclude that the standard could be relied upon to give results, the error of which would not exceed $1\frac{1}{2}$ candles, while most observations would be correct to within one candle of the true illuminating value of the gas.

This standard is, however, said to give good results if carefully used, and is frequently employed as a substandard in connexion with the pentane lamp.

C. *The Hefner Lamp.*—(This standard has been previously described in *The Illuminating Engineer*, by Mr. A. P. Trotter, January, 1908, p. 10.)

D. *The Elliott Lamp.*—The general nature of this standard will be gathered from Fig. 2. A high grade of petroleum oil is burnt by means of a flat wick, the glass chimney being large and bulbous in order to allow of a screen within. The screen being relatively near to the flat flame, does not call for a correction of the position of the radiant centre as in the case of the Edgerton standard.

The lamp is painted black, and has an acorn-shaped reservoir, capable of holding about 500 cc. of oil, the normal rate of consumption being 1 cc. per minute.

The trimming of the wick is a very essential operation, and must be carefully looked to. After burning twenty minutes, so as to gain thermal equilibrium, the lamp is ready for standardization and subsequent use. After this it should not be touched again, and, it is said, yields a very constant light until the reservoir is depleted. It is also claimed that a wick will last about 200 hours before capillarity is impaired; but it is desirable to standardize the lamp frequently. The mean intensity of the lamp approaches 10 candle-power very closely. Thus the mean value of 550 readings from April 17th to April 23rd was found to be 9·957, the lowest value being 9·76, and the highest 10·21.

Like other flame-sources the lamp is affected by atmospheric conditions, though, it is said, to a very similar extent to the pentane lamp.

F. *The Pentane Lamp.*—(This lamp has already been described in *The Illuminating Engineer*, Trotter, January, 1908, p. 9).

It is to be noted that although the dimensions of the lamps are the same, there are several details in construction that differ. For instance, a metal tube is used to convey the pentane vapour to the burner in preference to a rubber one. Again, what seems a rather essential difference, the position of the cross-bar in the mica window is lower, it being customary in America to regulate the top of the flame to this bar, instead of maintaining it half-way between the bar and the base of the window. It is interesting to note that the author considers that of all the standards mentioned, the pentane lamp is far the best both as regards convenience and reliability.

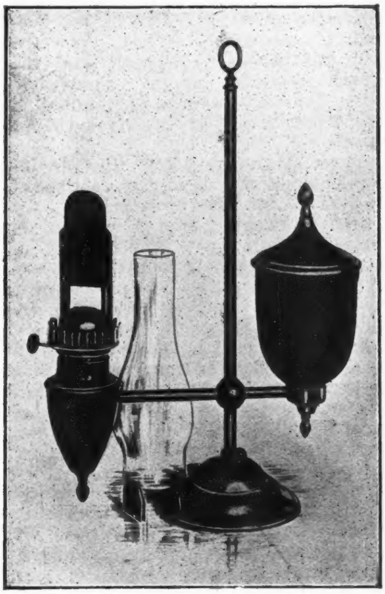


FIG. 2.
ELLIOTT STANDARD.

Review of the Technical Press.

ILLUMINATION AND PHOTOMETRY.

THE æsthetic and physiological aspects of illumination are still receiving a considerable amount of attention in the United States. Mention has already been made of the recent papers of G. L. Hunter and E. L. Elliott dealing with the former aspect, and that of Dr. Seabrook on the effect of light upon the eye: the two former papers and the ensuing discussion are now published in the *Transactions* of the Illuminating Engineering Society for March and April respectively.

Among other papers from the physiological standpoint we may note that of Dr. J. T. Krall. He considers that the superior illuminating power of modern sources is no drawback from the physiological point of view—is, indeed, necessary for the arduous work of the present day, provided such sources are properly shaded. He suggests that the main injury caused by artificial light arises through too great intrinsic brilliancy rather than any peculiarity in colour. He recognizes, however, the indisputably evil effect of excess of ultra-violet rays, and gives a resumé of the recent literature on the subject.

Dr. Miles Standish likewise insists upon the importance of avoiding intrinsic brilliancy, and in addition makes the suggestion that light coming from unusual angles must be considered bad; our eyes are naturally adapted to receive light from above.

L. W. Marsh describes the Luxfer system of utilizing daylight to the best advantage by means of prismatic glass, the object being to prevent the production of inconvenient shadows from light coming at a certain angle, and to distribute it in any desired direction.

H. W. Castor discusses illumination from the architect's standpoint. He dwells upon the value of artificial illumination in order to accentuate certain architectural features of a building, and quotes particulars of the illumination in a number of churches; in this connexion he points out that, from the æsthetic standpoint, the main illumination should be distributed over the chancel in order to give this part of the church special prominence.

F. C. Dickey states the point of view of the fixture manufacturer, who is really anxious to adopt efficient and artistic types of fixtures, but who is naturally forced to compromise his ideals owing to the necessity of satisfying the prevalent taste which, unfortunately, often elects to admire showy fixtures rather than artistic and efficient ones.

Among other recent articles on problems of illumination we may mention that of A. R. Dennington (*Illuminating Engineer*, N.Y., May), who discusses the illumination of streets lined with trees, the foliage of which is found to interfere with ordinary methods of illumination. The author considers that this variety of street is best illuminated by a number of small units, distributed at frequent intervals, rather than concentrated sources of high candle-power.

Niemann and Du Bois (*J.f.G.*, April 18) contribute a continuation of their reecnt historical study of illumination. The present instalment deals with methods of lighting in the Middle Ages, and is illustrated by means of a number of drawings and photographs showing the nature of the huge fixtures used at that time for the lighting of large halls and churches, &c.

Weinbeer (*Elek. Anz.*, April 21) continues his previously published series of articles on the production of uniform illumination by means of various types of artificial illuminants. These he divides into four main classes, according to the nature of their polar curves of distribution of light, and, in the article to which reference is now made, illustrates his previously determined results by several concrete examples.

Schilling (*J.f.G.*, April 18) gives some examples of the degree of illumination found necessary in the *Technische Hochschule* at Münich. Originally 40 lux was provided, but complaints of the poverty of illumination caused a value of 80 lux to be afterwards specified. Ultimately it was found desirable to increase this value to about 112 to 115 lux; under these conditions even one of the lamps failing to work entirely would only reduce the illumination to about 70 lux.

The author shows that the number of lamps required to produce such an illumination is in fair agreement with the computed value suggested by his own tables.

The Electrical Review (New York), in a recent editorial, lays stress on the necessity of precision in using scientific terms, and makes special reference to the innumerable terms in use to denote intensity of illumination (see also Monasch, abstracted *Illuminating Engineer*, Feb., 1908). Attention is drawn to the convenient and precise terminology sanctioned by the International Photometrical Congress, and particularly the term "lux," which, though somewhat differently used by different nations at present, has certain evident advantages as an international unit.

Among articles of a more strictly photometrical nature reference may again be made to the new graphic method of Dr. Kenelly for determining mean spherical candle-power, which now appears in the *Transactions* of the Illuminating Engineering Society for April.

Schuchardt (*J.f.G.*, May 2) describes the photometrical laboratory of Messrs. Ehrich and Graetz.

The *Sweizerische Elektrotechnische Zeitschrift* (April 25) describes a new portable and enclosed form of photometer produced by Messrs. Siemens and Halske. In this instrument the "angle-mirror" method, sanctioned by the Verband Deutscher Elektrotechniker, is used for the determination of mean horizontal candle-power. One point of interest is the use of a special form of "grease-spot" screen composed of two frosted glass plates, between which is placed a silvered spot.

Electric Lighting.

The number of papers dealing with the metallic filament lamps is this month greater than ever. Chief among these may be mentioned the paper by Mr. Hirst before the Institution of Electrical Engineers in London on May 21st. The author dealt mainly with the tungsten lamps, though he prefaced his subject proper with a short historical introduction. Of the many existing processes for the manufacture of tungsten filaments, he contended that only those of Just and Hanaman and the Deutsche Gasglühlicht Aktiengesellschaft have led to the manufacture of really commercially successful lamps. The author next describes the exact method of manufacture of osram and Just-Wolfram lamps, and alludes to the curious behaviour of the metallic filament lamp in apparently radiating only 87 per cent. of the energy per unit surface that the carbon filament lamp does, and yet giving 275 per cent. more light; this is to be ascribed to some form of selective radiation. Reference is made to the behaviour of osram lamps in actual practice and their probable influence on the lighting industry; some interesting particulars of the loss in small transformers are given.

There are also a number of articles dealing with the more technical side of the question. The *Zeitschrift für Beleuchtungswesen* continues a very comprehensive review of recent patents on the subject, and also contains a more popular article, in which the writer points out the tendency in all kinds of electric lighting to adopt metallic conductors in place of carbon; this is exemplified by the flame arcs, the metallic filament lamps, and the mercury vapour arc.

Duschnitz (*Elek. Anz.*, April 30, May 14) continues his valuable resumé of patents bearing on the details of manufacture, such as the various devices for the attachment of the filaments to the leading in wires.

Lottermoser (*Chem. Zeitung*, No. 25, 25, 3, 1908, also *Elek. u. Masch.*, April 19) reviews the work of the earlier students of colloidal processes—Bredig, Billitzer, Wedekind, &c., and describes the modern methods of producing metals in a colloidal state, as applied to the manufacture of the Kuzel lamps.

Pécheux (*Lumière Electrique*, May 16) contributes the results of some tests on the characteristic properties of the tungsten and other lamps, including details of their alteration in resistance with temperature and consequent relative sensitiveness to fluctuations in P.D., &c.

J. B. Taylor (*Elec. World*, April 25) describes a curious phenomenon exhibited by tungsten lamps. One result of the relatively low heat-capacity of metallic lamps as compared with carbon filament ones, is the rapidity with which they light up. In the case of the ordinary carbon lamps, the eye can usually distinctly perceive the building up of the light, but in the case of the metallic lamps, no such effect is clearly visible. But the author goes further. He himself, when viewing a tungsten lamp lighting up, is conscious of a distinct impression that the lamp exceeds its normal brilliancy for a short time—overshoots the mark, in fact.

Such an impression, which was shared by other observers, might possibly be attributed to purely physiological causes. The author, however, states that he has actually secured photographic demonstration of the effect. At present, there seems no very plausible explanation.

It is interesting to learn that the Edison

Electric Illuminating Co. have come to a decision as regards the question of free renewal of tungsten lamps (*Elec. Rev.*, New York, May 9). The company state that the conditions of manufacture of metallic lamps at present militate against the possibility of giving such lamps free. In future, however, lamps will be supplied at cost, deducting an allowance covering cost of carbon lamps to free renewal customers; thus the 40 or 50 watt tantalum lamps will be supplied at 25 cents. each, subject to the burned-out lamps being returned. This point is also mentioned by Willcox, in a recent lecture (*Elec. Rev.*, N.Y., May 16).

There have also been several articles of interest bearing on arc lighting. Dyott (*Elec. World*, April 25th) describes some experiments upon the magnetite arc. He gives some curves illustrating the relation between current and P.D., and deals at some length with the nature of the spectrum of the arc and the effect of certain impurities, notably chromium, on the colour of the light emitted.

Ladoff (*Illum. Eng.*, New York, April and May) contributes a general review of recent patent literature on the subject of arc-lamps.

Vollhardt (*J.f.G.*, May 20) describes the most recent form of Carbone high-pressure arc. The general advantages of the lamp—its efficiency and the resemblance of its spectrum to daylight, &c., are pointed out, and the results of some recent tests at Charlottenburg given. The chief point of interest, however, is the fact that it seems to be possible to secure, with inclined carbons, a pressure of more than 80 to 90 volts across the arc.

GASLIGHTING, &c.

The most interesting event in gas-lighting during the past month has been the publication of the tests by Mr. Herring of the lighting at the National Scottish Exhibition, including those on the new Keith high-pressure lamp. According to these tests, which receive detailed comment in the *Gas World* and the *Journal of Gaslighting*, it is now possible, in the Keith lamp, to secure the exceedingly high efficiency of from 60 to 70 candle-power per cubic foot of gas. Yet the result seems to have been achieved without the introduction of any very novel device, and to be attributable merely to the exceptionally perfect conditions secured by the combined effects of high-pressure and heating the combustible mixture. The mantle used is also exceptionally long and narrow, the length being given as $3\frac{5}{8}$ in. and the width as $1\frac{1}{2}$ in. in the case of a 1,500 candle-power lamp. Four of these lamps are now erected in Kingsway, London.

Among other articles we may mention the review of existing patents on inverted burners and mantles to be found in the *Zeitschrift für Beleuchtungswesen* (May 10).

A. Granjon (*Rev. des Eclairages*, May 15) discusses the value of different combustibles as a means of rendering mantles, &c., incandescent. He points out the distinction between the heat of combustion and flame-temperature. The former is a constant quantity for the same combustible; the latter, on the other hand, depends upon the exact conditions of use. Thus acetylene yields about 14,000 calories, but its flame-temperature may vary from 2,500 to 4,000 degrees, according to the burner used and other conditions.

The *Zeitschrift für Beleuchtungswesen* (May 20) contains a discussion of the relative merits of high-pressure gas systems and systems in which the air and gas in the burner are brought into intimate mixture by being churned together or other mechanical means. Our only object in either case is to enable the gas to get as much contact with the air in which it burns so as to cause it to burn quickly and reach a high flame-temperature; for it is on the value of this temperature that the efficiency of an incandescent solid mainly depends. We may accomplish this result by injecting gas at a high pressure. In practice pressures greater than about $\frac{1}{10}$ to $\frac{1}{8}$ of an atmosphere are rarely used. In the Salzenburg lamp, it is true, as high a pressure as 1·1 atmospheres was actually used; but this lamp does not seem to have found its way into practical use in this form as yet.

The author, however, evidently prefers the method of causing a mixture of gas and air by some arrangement not involving the supply of high-pressure gas.

Lastly, mention must be made of a recent article by Schäfer (*J.f.G.*, April 25) dealing with the illumination of interiors by means of gas. The author lays stress upon the necessity for studying the distribution of light in such cases, and the value of the inverted lamps, which may be arranged to throw the light just where it is needed.

The article is accompanied by a series of photographs showing the fixtures employed and their position for the illumination of various types of rooms.

List of References:—

ILLUMINATION AND PHOTOMETRY.

Castor, H. W. Modern Methods of Illumination from the Architect's Standpoint (T. I. E. S., April).
Dennington, A. R. The Illumination of Shady Streets (*Illum. Engineer*, N.Y., May).
Dickey, F. C. Lighting Fixtures from the Manufacturer's Standpoint (T. I. E. S., April).
Dow, J. S. Some Physiological Effects of Light (*Illum. Engineer*, N.Y., April).
Editorials. The Careless Use of Scientific Terms (*Elec. Rev.*, N.Y. May 9).
Illumination and the Municipal Councillor (J. G. L., May 12).
Illumination Contracts and Tests (J. G. L., May 19).
Elliott, E. L. The Relation of Illuminating Engineering to Architecture from the Engineer's Point of View (T. I. E. S., April).
Hunter, G. L. Light and Colour in Decoration (T. I. E. S., March).
Kenelly, A. E. A Graphical Construction for the Spherical Reduction-Factor of a Lamp (T. I. E. S. May).
Krall, J. T. Eyesight and Artificial Illumination (T. I. E. S., March).
Lux, H. The Efficiency of Artificial Illuminants (J. G. L., April 28, March 12, translated).
Marsh, L. W. Daylight Illumination (T. I. E. S., March).
Nieman and Du Bois. Zur Geschichte des Beleuchtungswesens (J. f. G., April 18).
Schilling. Bemessung der Stärke der Lichtquellen für indirekte Beleuchtung mit Gasglühlicht (J. f. G., April 18).
Schuchardt, G. Lichtmessung in der Praxis der Gasbrennerfabrikation (J. f. G., May 2).
Standish, M. Artificial Illumination from a Physiological Point of View (T. I. E. S., April).
Weinbeer, W. Reflektoren für konstante Bodenbeleuchtung (*Elek. Anz.*, May 21).
Neue tragbare Photometriereinrichtungen (Schweiz. E. T. Z. April 25).

ELECTRIC LIGHTING.

Canning, J. H. Some Notes on New Electric Lamps (Discussion). (J. G. L., May 12).
Duschnitz. Die Verbindung der Glühfäden mit den Elektroden (*Elek. Anz.*, April 30, May 14).
Dyott, G. M. The Magnetite Arc (*Elec. World*, April 25).
Handcock, H. W. and Dykes, A. H. Electric Supply Prospects and Charges as Affected by Metallic Filament Lamps (Discussion). (See Elec. Press of Current Date.)
Hirst, H. Recent Progress in Tungsten Metallic Filament Lamps (Paper read before Institution of Electrical Engineers in London, May 21).
Huguenin, P. A. La Lampe à vapeur de mercure (*Lumière Electrique*, April 25).
Ladoff, I. Recent Progress in the Voltaic Arc (*Illum. Engineer*, N.Y., April and May).
Lottermoser, A. Einige Bemerkungen über die Herstellung von Metallfäden für elektrische Glühlampen, besonders aus kolloiden Metallen (*Chem. Zeitung*, No. 25, 25, 3, 1908; also *Elek. u. Masch.*, April 19).
Pécheux, H. Du Regime de Fonctionnement Electrique des Lampes à Incandescence à Filaments Metalliques (*Lumière Electrique*, May 16).
Taylor, J. B. The Overshooting of Tungsten Lamps (*Elec. World*, April 25).
Vollhardt, E. Die Carbone-Hochspannungbogenlampe (J. f. G., May 23).
Wilcox, F. W. The New Incandescent Lamps (Paper read before Iowa Electrical Association, *Elec. Rev.*, N.Y., May 16).
The Stearn Metallic Filament Lamp (*Elec. Engineering*, April 30).
Small Transformers for Metallic Filament Lamps (*Elec. Engineering*, May 7).
Two Recent Patents Referring to Metallic Filament Manufacture (*Elec. Engineering*, May 14).
Metallic Filament Lamps for Street-Lighting (*Elec. Engineering*, May 14 and 21).
Fortschritte in der Glühlampen-Industrie (*Z. f. Bel.*, May 20).
Die Wanderung des Elektrischen Lichtes von der Kohle zum Metall (*Z. f. Bel.*, May 20).
Fortschritte, &c., Elektrische Beleuchtung, Bogenlampen, Glühlampen, Quecksilberdampfbogen (*Elek. u. Masch.*, April 19, 26).

GAS LIGHTING, OIL LIGHTING, ACETYLENE, &c.,

Editorial, A Big Increase in Efficiency (J. G. L., May 5, G. W., May 9).
Granjon, A. Les différents modes d'éclairage par l'incandescence (*Rev. des Eclairages*, May 15).
Schäfer, F. Das Gasbeleuchtung von Innenräumen (J. f. G., April 25).
Thomson, G. W. Extension of Gas for Illumination (T. I. E. S., March).
Gaslighting at the Franco-British Exhibition (G. W., May 9).
The New Keith Lamp (G. W., May 9).
Sixty to Seventy C.P. per Cubic Foot of Gas (J. G. L., May 5).
Neue Invertbrenner (*Z. f. Bel.*, May 10).
Pressgas oder Pressluft (*Z. f. Bel.*, May 20).

CONTRACTIONS USED.

E. T. Z.—*Elektrotechnische Zeitschrift.*
Elek. Anz.—*Elektrotechnischer Anzeiger.*
Elektrot. u. Masch.—*Elektrotechnik und Maschinenbau.*
G. W.—*Gas World.*
J. G. L.—*Journal of Gaslighting.*
J. f. G.—*Journal für Gasbeleuchtung und Wasserversorgung*
Z. f. Bel.—*Zeitschrift für Beleuchtungswesen.*
T. I. E. S.—*Transactions of the Illuminating Engineering Society.*

PATENT LIST.

PATENTS APPLIED FOR, 1908.

I.—ELECTRIC LIGHTING.

8,298. Choking coils for arc lamps (C.S.). April 14. L. O. Langworthy, 53, Chancery Lane, London.
8,308. Arc lamps. April 14. W. J. Davy, 40, Chancery Lane, London.
8,375. Arc lamps. April 15. A. D. Jones, Hartham Works, Hartham Road, Holloway.
8,421. Filaments for incandescent lamps (C.S.). April 15. (I.C. May 13, 1907, Germany.) Wolfram-Lampen Akt.-Ges., 7, Southampton Buildings, London.
8,494. Luminous signs, &c., for advertising. April 16. E. V. Gratze, 44, Whitfield Street, London.
8,737. Filaments or bodies for incandescent lamps (C.S.). April 21. C. A. W. Hopton, 4, South Street, Finsbury.
8,746. Incandescent filaments (C.S.). April 21. G. Auger, 18, Southampton Buildings, London.
8,773. Electric lamps. April 22. E. Böhm, 45, Hillmartin Road, London.
8,848. Incandescent lamps. April 23. W. K. Dickson and H. J. G. Reeser, 61, Strand, London.
8,991. Arc lamps. April 24. The Electrical Co., Ltd., and F. Schaefer, 83, Cannon Street, London.
9,097. Holders for tungsten filaments in lamps (C.S.). April 27. (I.C. Feb. 13, 1908, Germany.) Deutsche Gasglühlicht Akt.-Ges. (Auerges.), 55, Chancery Lane, London.
9,222. Arc lamps. April 28. C. A. Carpenter and O. T. Banks, 49, Mortimer Street, London.
9,241. Arc lamps. April 29. A. D. Jones, Hartham Works, Hartham Road, Holloway. (Addition to 3,060/07.)
9,257. Incandescent lamps. April 29. J. Cochran, 17, St. Ann's Square, Manchester.
9,501. Arc lamps (C.S.). May 1. H. Baggett, 88, Chancery Lane, London.
9,636. Fittings for glow lamps (C.S.). May 4. (I.C. June 25, 1907, Germany.) Siemens-Schuckertwerke G. m. b. H., Queen Anne's Chambers, Broadway, Westminster.
9,654. Miners lamps. May 4. P. M. Justice, 55, Chancery Lane, London. (From Deutsche Gasglühlicht Akt.-Ges. (Auerges.), Germany.)
9,862. Arc lamps. May 6. W. J. Davy, 40, Chancery Lane, London.
9,972. Increasing or decreasing the light of arc or incandescent lamps for theatrical purposes, &c. May 7. L. Sunderland and G. C. Pillinger, 165, Queen Victoria Street, London.
10,098. Filament for glow lamps. May 9. J. W. Ward and R. H. Stevens, 11, Southampton Buildings, London.
10,128. Portable lamps. May 9. J. Bein, 205A, Pentonville Road, London.
10,269. Arc lamp (C.S.). May 12. F. Ruzicka, 115, Cannon Street, London.
10,339. Electrode for arc lamps. May 12. F. M. Lewis, Norfolk House, Norfolk Street, Strand.
10,341. Incandescent lamps. May 12. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From Allgemeine Elektricitäts-Ges., Germany.)

II.—GAS LIGHTING.

8,172. Inverted incandescent lamps. April 13. G. Hands and F. Breeden, 77, Chancery Lane, London.
8,473. Gas pendants (C.S.). April 16. C. W. Kemp, 11, Burlington Chambers, New Street, Birmingham.
8,573. Incandescent burners. April 16. H. R. Prosser, 5, Corporation Street, Birmingham.
8,639. Anti-vibrator for suspended fittings. April 18. S. Jones and A. H. Bennett, 70, Chancery Lane, London.
8,730. Automatic gas-ignition and control (C.S.). April 21. P. Jensen, 77, Chancery Lane, London. (From L. G. Bartlett, U.S.A.)
9,276. Inverted incandescent lamps (C.S.). April 29. M. Graetz, 18, Southampton Buildings, London.
9,286. Nozzles for inverted incandescent burners (C.S.) April 29. (I.C. Nov. 19, 1907, Germany.) Deutsche Gasglühlicht Akt.-Ges. (Auerges.), 1, Great James Street, Bedford Row, London.
9,306. Incandescent mantles (C.S.). April 29. J. Stubbers, 31, Bedford Street, Strand.
9,760. Lighting devices for street lamps, &c. (C.S.). May 5. O. Schubert, 18, Southampton Buildings, London.
9,892. Pressure-controlled igniters (C.S.) May 6. E. Zickwolff, 31, Bedford Street, Strand.
9,907. Anti-vibrators for incandescent lamps. May 7. R. O. Tweedie, 65, Chancery Lane, London.
9,945. Incandescent lighting. May 7. C. Scott-Snell and C. H. Stuart, 25, Victoria Street, Westminster.
9,996. Lighting appliance. May 8. W. Thomson, Royal Institution Laboratory, Manchester.
10,029. Shades or globe-holders for inverted incandescent burners. May 8. A. E. Smithdale, 88, Chancery Lane, London.
10,105. Gas burners. May 9. G. N. Sperryn, 77, Colmore Row, Birmingham.
10,223. Regulating nozzles for inverted incandescent lamps (C.S.). May 11. M. Graetz, 1, Broad Street Buildings, Liverpool Street, London.
10,233. Incandescent mantles (C.S.). May 11. A. Simonini, 332, High Holborn, London.
10,284. Inverted incandescent burners. May 12. E. J. Shaw, 60, Queen Victoria Street, London.
10,295. Gas burners (C.S.). May 12. (I.C. June 3, 1907, U.S.A.), W. O. D. Kelly, 55, Chancery Lane, London.
10,321. Inverted incandescent lamps. May 12. L. Zechnall, 70, Chancery Lane, London.
10,380. Holders for incandescent mantles (C.S.). May 13. J. Bernheimer, A. Gut and A. Melder, 20, High Holborn, London.

III.—MISCELLANEOUS

(including lighting by unspecified means, and inventions of general applicability).

8,138. Burners for lamps (C.S.). April 13. C. Jahnke and R. Jahnke, 345, St. John Street, London.
8,427. Reflectors for lamps. April 15. F. J. B. Collis, 4. South Street, Finsbury.
8,509. Lighting of billiard tables, &c. April 16. J. H. Faulkner, 111, Hatton Garden, London.
8,565. Automatic acetylene lamps and torches. April 16. E. Grube and A. C. Wells, 7, Southampton Buildings, London.
8,586. Acetylene lamps for cycles, &c. April 18. F. J. Miller, 24, Temple Row, Birmingham.
8,687. Vapour lamp (C.S.). April 21. A. F. Chiesanova, 100, Wellington Street, Glasgow.
9,362. Suspending device for gas, electric, or other lamps. April 30. W. H. Chipperfield, 149, Strand, London.
9,376. Lamps for burning carburetted air, &c. April 30. W. G. Potter, 14, Ingleton Street, Brixton Road, London.
9,971. Inverted vapour burners. May 7. H. Brooper and C. Wilkinson, 1 Broad Street Buildings, Liverpool Street, London.
10,344. Incandescent vapour burners. May 13. F. C. Lynde, 51, Deansgate Arcade, Manchester.

COMPLETE SPECIFICATIONS ACCEPTED OR OPEN TO PUBLIC INSPECTION.

I.—ELECTRIC LIGHTING.

8,841. Incandescence bodies (C.S.). I.C. April 17, 1906, Germany. Accepted April 23, 1908. Allgemeine Elektricitäts-Ges., 83, Cannon Street, London.
10,513. Arc lamps with laterally supported electrodes (C.S.). I.C. May 5, 1906. Accepted May 13, 1908. H. Beck and Deutsche Beck-Bogenlampen Ges. m. b. H., 231, Strand, London.
10,662. Arc lamp (C.S.). May 7, 1907. Accepted May 13, 1908. C. C. Winther-Hansen and P. Bouchsein, 40, Chancery Lane, London.
12,139. Filaments for lamps. May 25, 1907. Accepted April 29, 1908. F. J. Planchon, 7, Southampton Buildings, London.
13,882. Incandescent lamps. June 15, 1907. Accepted May 6, 1908. T. W. Lowden and The Westinghouse Metal Filament Lamp Co., Ltd., Norfolk Street, Strand.
15,451. Refractory conductors for incandescent lamps. July 4, 1907. Accepted May 13, 1908. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From General Electric Co., U.S.A.)
16,503. Attaching tungsten filaments in glow lamps (C.S.). I.C. May 6, 1907, Germany. Deutsche Gasglühlicht Akt.-Ges. (Auerges.), 55, Chancery Lane, London.
16,530. Refractory materials. July 18, 1907. Accepted April 23, 1908. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From General Electric Co., U.S.A.)
16,531. Supports for filaments of incandescent lamps. July 18, 1907. Accepted April 29, 1908. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From General Electric Co., U.S.A.)
16,956. Arc lamps. July 24, 1907. Accepted April 23, 1908. H. E. Angold and The Maxim Electrical Co., Ltd., 18, Southampton Buildings, London.
19,562. Incandescence lamps having holders or suspenders for the filaments (C.S.). I.C. April 15, 1907, Germany. Deutsche Gasglühlicht Akt.-Ges. (Auerges.), 55, Chancery Lane, London.
21,476. Incandescent lamps with metal filaments (C.S.). Sept. 27, 1907. Accepted April 23, 1908. A. G. Bloxam, Birkbeck Bank Chambers, London. (From Siemens and Halske Akt.-Ges., Germany.)
23,199. Arc lamps (C.S.). I.C. Sept. 4, 1907. Accepted April 29, 1908. D. Timar and K. von Dreger, 7, Southampton Buildings, London.
3,465. Clutch for arc lamps (C.S.). I.C. Feb. 18, 1907, Sweden. Accepted April 23, 1908. L. S. Andersson, 65, Chancery Lane, London.
3,700. Arc apparatus for photography (C.S.) Feb. 18, 1908. Accepted May 13, 1908. J. Schmidt, 31, Bedford Street, Strand. (Addition to 9,574/07.)
8,416. Filaments for incandescent lamps (C.S.). I.C. April 26, 1907, Germany. Wolfram-Lampen Akt.-Ges., 7, Southampton Buildings, London.
9,479. Supporting hooks for lamp filaments (C.S.). I.C. May 3, 1907, Germany. W. Schäffer, 31, Bedford Street, Strand, London.
9,502. Arc lamps (C.S.). I.C. May 2, 1907, Germany. Allgemeine Elektricitäts Ges., 83, Cannon Street, London.

II.—GAS LIGHTING.

9,973. Inverted burners. April 30, 1907. Accepted April 23, 1908. J. H. McLean, F. Phelps, and A. Raybould, 19, Sandon Road, Edgbaston, Birmingham.
14,162. Igniting gas electrically. June 19, 1907. Accepted April 29, 1908. E. Plumstead and Newton & Lawrence, Ltd., 6, Bream's Buildings, Chancery Lane, London.
19,478. Street gas lanterns. Aug. 30, 1907. Accepted May 6, 1908. W. Sugg & Co., Ltd., and E. S. Wright, 6, Bream's Buildings, Chancery Lane, London.
20,109. Automatically turning on and off lights from a distance. Sept. 9, 1907. Accepted April 29, 1908. G. Robson, 18, Southampton Buildings, London.
20,153. Inverted incandescent burners. Sept. 10, 1907. Accepted May 13, 1908. A. Turner, Gas Works, Amersham, Bucks.
25,637. Carriers for incandescence mantles (C.S.). I.C. June 13, 1907, Germany. Accepted May 6, 1908. Julius Pintsch Akt.-Ges., Birkbeck Bank Chambers, London.

1,844. Inverted regenerative incandescent lamps (C.S.). Jan. 27, 1908. Accepted May 13, 1908. L. Zechnall and J. Altman, 70, Chancery Lane, London.
2,300. Systems of lighting. (C.S.). Feb. 1, 1908. Accepted May 13, 1908. R. E. Andrews, 37, Oakhurst Grove, East Dulwich, London.
3,785. Filaments for incandescent mantles (C.S.). I.C. Oct. 11, 1907, France. Accepted May 13, 1908. R. Laigle, 6, Lord Street, Liverpool.
4,549. Inverted incandescent lamps (C.S.). I.C. May 1, 1907, Germany. M. Graetz and A. Graetz, trading as Ehrich & Graetz, 18, Southampton Buildings, London.
9,622. Filaments for incandescent mantles (C.S.). May 4, 1908. Accepted May 13, 1908. R. Laigle, 18, Southampton Buildings, London. (Addition to 3785/08.)

III.—MISCELLANEOUS.

(including lighting by unspecified means, and inventions of general applicability).

9,663. Petrol lighting. April 25, 1907. Accepted April 29, 1908. H. Harsant and J. Chalk, Birkbeck Bank Chambers, London.
13,300. Suspending apparatus for lamps for high buildings. June 8, 1907. Accepted May 13, 1908. C. Rees, 20, Hewitt Street, Warrington, Lancs.
23,048. Light modifiers (C.S.). Oct. 18, 1907. Accepted May 13, 1908. F. Monpillard, 111, Hatton Garden, London.
24,871. Vapour lamps (C.S.). Nov. 9, 1907. Accepted May 13, 1908. M. F. P. Oialard Goudon, 111, Hatton Garden, London.
27,022. Oil lamps (C.S.). Dec. 6, 1907. Accepted May 6, 1908. E. R. Schreiber, 111, Hatton Garden London.
3,696. Pendants, &c. (C.S.) Feb. 18, 1908. Accepted May 6, 1908. H. W. Hanwell, 111, Hatton Garden, London.

EXPLANATORY NOTES.

(C.S.) Application accompanied by a Complete Specification.

(I.C.) Date applied for under the International Convention, being the date of application in the country mentioned.

(D.A.) Divided application; date applied for under Rule 13.

Accepted.—Date of advertisement of acceptance.

In the case of inventions communicated from abroad, the name of the communicator is given after that of the applicant.

Printed copies of accepted Specifications may be obtained at the Patent Office, price 8d.

Specifications filed under the International Convention may be inspected at the Patent Office at the expiration of twelve months from the date applied for, whether accepted or not, on payment of the prescribed fee of 1s.

N.B.—The titles are abbreviated. This list is not exhaustive, but comprises those Patents which appear to be most closely connected with illumination.

TRADE NOTES.

Messrs. Siemens Bros. inform us that all tantalum lamps are now specially tested previous to delivery, and that in future those which fail prematurely on circuit, owing to faulty workmanship, will be replaced; for this reason, the allowance of 2½ per cent. to cover such failures will be discontinued. This alteration came into force from May 1st onwards. We are also given to understand that the tantalum lamps are now finding extensive use for side-street lighting, the Brighton Corporation having placed an order with the above firm for 15,000 16 c.-p. lamps for this purpose.

The *Sun Electrical Co.* send us a catalogue describing the 'Kalkos' wiring system. Briefly, the system involves the use of tinned brass tubes in place of the iron and steel conduits previously employed, and it is stated that defects due to oxidation and corrosion are thus practically avoided.

Messrs. Moffat & Co. send us a catalogue describing their well-known form of thermopile lamp, a *speciality* of which is the driving of small fan, which in turn drives into the burner the requisite amounts of air and gas, by means of a small electrical current generated by a thermopile.

Messrs. The Union Electrical Co. draw our attention to a list of automatic motor-starting switches both for direct and polyphase currents, and intended for use with motor-driven pumps, air-compressors, &c., which require automatic control when starting.

The *Frister Aktiengesellschaft* (Berlin) draw our attention to the 'Tubus' form of burner, which enables the mantle to be burned in a horizontal position, so that the highest illumination is secured in a downward direction.

Among other matter received, we have also to acknowledge the receipt of a number of well got-up pamphlets relating to the Osram lamps and inverted burners, issued by the *Deutsche Gasglühlicht Aktiengesellschaft*, some interesting particulars of the 'Pharos' inverted gas-lighting system, and a description of the 'Regina' arc lamps, the Weinert lamps, &c.