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The ILLUMINATING ENGINEER

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ILLUMINATION

EDITED BY LEON GASTER

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DEVOTED TO
THE SCIENCE
AND ART OF
ILLUMINATION

THE
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ENGINEER

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ILLUMINATING ENGINEERING PUBLISHING COMPANY, LTD.

EDITORIAL.

THE recent important developments in our methods of producing light, and the growing interest taken in the subject of proper illumination, have convinced us of the necessity of issuing a special Magazine, devoted solely to the careful study and consideration of all aspects of the subject. Due attention will be paid to the requirements of the consumer and professionals by keeping them in touch with the most recent results obtained.

Apart from the inefficient nature of our present methods of converting electrical or any other variety of energy into light, a very large amount of the light actually produced is unnecessarily wasted. Too often the consumers pay comparatively little attention to the question of getting the best illuminating results from the method of lighting adopted. Many cases can be noticed in which recourse has been had to extravagant methods of illumination without due regard to expense, one half, or perhaps even two-thirds of the actual light produced remaining useless. In other cases the reverse has happened, too little light being used from motives of mistaken economy, and even that not always turned to the best advantage.

The amount of money expended in the production and use of light in this country is very large, and it seems safe to say that in no other department of modern commerce is there so much expended with so little knowledge of the best methods of obtaining the desired results. It is estimated that the expenditure for lighting in this country exceeds 36,000,000*l.* per annum. We believe that, by paying attention to the correct use of illumination, the possibility of reducing the waste to a minimum is well worth taking into consideration. It was therefore thought that the issue of a special Magazine devoted to the furtherance of the science and art of illumination would be cordially received by all classes.

It is not only the small consumer who may expect to secure great economies by the use of the most up-to-date methods of lighting, but there are many public and other buildings, such as factories, ware-houses, hotels, restaurants, clubs, theatres, &c., in which the methods of illumination adopted may be greatly improved, and considerable economies thereby effected.

The moment is therefore opportune for the issue of a Magazine devoted entirely to matters of illumination, and, realizing that the problem is one of international importance, we have endeavoured to give 'THE ILLUMINATING ENGINEER' an international character, and so shall include in our pages articles contributed by the British, Continental, and American authorities.

The Editor has recently visited the United States and the Continent, with the object of ascertaining the views, and securing the co-operation, of those connected with the various aspects of illuminating engineering. We are glad to say that, in addition to our British and American helpers, we have been promised the cordial co-operation of many of the leading continental authorities, amongst whom we may mention the following :—

Dr. Blau, Dr. Bloch, Dr. Blondel, Dr. Richard Böhm, Dr. Bunte, Dr. Grau, Mr. Guiselin, Dr. Herzog, Mr. Kremenetzky, Dr. Krüss, Dr. Lux, Dr. Monasch, Mr. Pihan, Mr. Predit, Mr. Remané, Dr. Rubens, Dr. Ruhmer, Dr. Wedding, &c.

We feel, therefore, that the response which has greeted our efforts fully justifies the conviction that the correct treatment of illumination is not only of national, but of international importance.

The variety of readers to whom our Magazine will appeal is very wide, and it has been thought advisable to make the contents of our first issue as representative as possible, in order to illustrate the general nature of the ground which we propose to cover. We shall, in turn, pay special attention to the different aspects of illuminating engineering, in order that all sides of the question will ultimately receive their due share of consideration.

In this issue we desire to draw attention to the articles dealing with the influence of light on eyesight. We also wish it to be understood that 'THE ILLUMINATING ENGINEER' is independent of any particular system of illumination, and therefore, in our editorial columns, we shall deal with all systems *impartially*. Our Magazine constituting neutral ground, we should like to mention that our columns are at the disposal of all authorities connected with the different aspects of illumination, in order that our readers may have the opportunity of drawing their own conclusions as to the relative merits of the different systems of illumination now in use. We shall also publish, for the benefit of the lay readers of the Magazine, a series of popular articles, in which technical data will be reduced to simple forms and expressions, so as to be readily understood.

The question of illumination concerns not only the lighting engineer and the consumer, but the points of view of, among others, the architect, the oculist, and the physiologist, also deserve great consideration. There is a need at the present time to bring together those who are interested in all these various sides of the question, and, until this can be done, we maintain that illumination cannot receive suitable recognition as a science or an art.

There are many cases in which special knowledge, of great value to the illuminating engineer, is not readily available in a form applicable to general problems of illumination. As an illustration of this point, we may draw attention to the fact that our conception of illumination and nearly all our methods of measuring light must rest upon the peculiarities of the eye. Naturally, therefore, those who have no knowledge of the physiology of this organ are constantly confronted with results, in photometrical testing and elsewhere, which they find themselves unable to explain.

Physiologists, for instance, have recently been devoting attention to the difference in the behaviour of the eye under the influence of strong and weak illuminations, and the peculiarities of the retina, as regards the perception of colour. Yet the requisite knowledge of this research is almost entirely confined to the physiologists themselves. It is our intention to keep our readers in touch with essential results of this nature, and to bring out the practical aspect of such researches of the specialist, which might otherwise escape the notice of the student in another field.

The need for a more scientific study of the requirements of illumination is now generally admitted. The only difficulty which some have found is the question of the means by which the improvement was to be secured and the different interested parties brought together. We believe that our Magazine will afford the necessary opportunity for those connected with the various aspects of the subject to express their respective views, and that, through our columns, the general public will gradually become familiarized with the merits and faults of the method of illumination they adopt. We trust, also, that 'THE ILLUMINATING ENGINEER' will be the means of ultimately bringing the exponents of various aspects of illumination into personal contact through the formation of a society devoted to the consideration of all illuminating engineering problems. With this subject we will, however, deal in another issue.

ILLUMINATION AND EYESIGHT.

WE have made special reference to this question in our first number, for one cannot read the views of Prof. Scott, Dr. Kerr, &c., without being impressed by the importance attached by them to good illumination, or without feeling that the deterioration in eyesight of school children recorded is, to some extent, attributable to the bad lighting conditions which they condemn.

It seems natural to suppose, too, that trying conditions of illumination, even when they do not appear to directly affect the eyesight, must enormously increase the strain experienced in carrying out a certain piece of work, and so indirectly influence the physical well-being of the worker.

As Dr. Kerr points out, if this is true of the adult, it is yet more applicable to the children in our schools, who are called upon to make what is to them a special effort, at the period of their life when they are most likely to suffer from undue strain.

We feel, therefore, that there is every reason to advocate a more complete investigation of these conditions by those who undertake the inspection of factories and schools and the testing of eyesight.

We know that the illumination by which work is executed is often too weak, that bright sources of light are often so placed that the rays of light fall directly upon the eye, and, so far from assisting the worker, render it difficult to see surrounding objects.

But there are many other questions which are as yet merely matters of conjecture, and can only be authoritatively settled by co-operation of the nature advocated.

An exhaustive system of medical inspection of factories and workshops is in existence, and has done excellent work in other departments. We should like to see these operations so extended as to include particulars of the conditions of lighting occurring in the works they visited.

By this means valuable and authoritative data as to the influence of various systems of illumination on sight and health might be gathered, which would eventually lead to the elucidation of many of the vexed questions of the present day.

The same considerations apply with even greater force to the inspection of schoolrooms, where the conditions of illumination have been shown to be, in many cases, defective. In this connexion it may be pointed out that the creation of a medical department of the Board of Education, and the presumable extension of the medical inspection of schools under their directions, affords an opportunity of organizing a more complete investigation of the nature we desire.

Much information might also be gained through the experience of the oculist and optician, and the recording of the conditions of illumination under which those who come to them for treatment have been working, especially any marked examples of the influence of any particular system of illumination.

The whole question is one with which the illuminating engineer, the architect and the oculist, are all concerned. Only through their mutual co-operation can we ensure that the various aspects of illumination shall each receive its due share of attention.

We therefore also invite architects to avail themselves of the opportunity given in our columns of exchanging views with others interested in the question of illumination, and bringing forward the aspects of illumination with which they are most intimately connected.

Shop-Window, Library, and Factory Lighting.

In a recent paper read before the Association of Engineers in Charge, the Editor had occasion to allude to the misuse of light as exemplified by the three cases mentioned above.

There can be no doubt that, even in the best streets of London, much of the light utilized for the illumination of shop-windows is not merely wastefully employed, but is actually so displayed as to defeat the object for which it is intended.

Brilliant lights are frequently distributed, either in the front of the window or among the contents of it, in such a way that the prospective customer cannot gaze into the window without discomfort. Everybody has experienced the temporary blindness which follows an attempt to look steadily at an intensely bright object, and has noticed how impossible it is to see into a background behind the light of this description. Whenever one looks at such an object the pupil orifice and retina of the eye adjust themselves in such a manner as to protect the eye from the excessively brilliant illumination, and in so doing cause all moderately illuminated objects to become almost indistinguishable.

The value of a well-lighted window as a means of attracting customers is well worth consideration. Only, let this increased illumination be tastefully and effectively distributed, and let us recognize that such illumination has two distinct objects in view, firstly, to attract the customer, and, secondly, to exhibit the contents of a window to him to the best advantage.

Attention may also be drawn to the unsatisfactory method of illumination employed in many libraries. The lights are sometimes so arranged as to brilliantly illuminate the gangways, where in reality we only require sufficient illumination to find our way about in comfort, while the illumination of the reading tables is often very inadequate. In a library light should serve three chief purposes. It should enable the worker to read, it should illuminate the shelves of books so that the titles are easily recognizable, and it should also illuminate the surroundings with a subdued illumination, sufficiently strong, however, to enable the reader to find his way about. Moreover, when we consider what a serious task for the eyes continuous reading of this description must frequently be, even under the best conditions, the importance of an adequate illumination and of the subdued restful surroundings for the reader will be readily admitted.

The same general conditions apply,

with perhaps even greater force, to the lighting of factories and workshops.

When we consider the very great amount of work carried out by artificial light, and the number of workers employed upon it, we must admit the importance of doing all that is possible to enable this work to be done in comfort. As a rule the cost of light in comparison with the cost of labour is trifling, and any additional expense incurred in providing a satisfactory method of illumination would be amply repaid, firstly, by an appreciable increase in the output and quality of work executed under artificial light, and, secondly, by the improvement in the general health of the workpeople.

The extent to which the workman is guided by the sense of sight in his work is apt to be overlooked. To furnish the most up-to-date machinery and tools, and to pay the present high prices for labour, and then to handicap the worker by insufficient or improperly placed lights, is false economy indeed. Take as an illustration the case of a skilled workman receiving 8s. to 10s. a day, and compare the cost of the energy consumed by an electric 16 C.P. lamp burning for the ten hours or so or a gas flame, and it will be found to be trifling.

Yet one sometimes notices not only that the methods of illumination employed are inadequate, but that even adequate installations are allowed to fall into a defective state because no particular precautions have been taken for their upkeep. The expense entailed by the regular renewal and inspection of these lamps would be trifling in comparison with the resulting saving of light and labour.

Illumination and the Measurement of Light.

The progress of the study of illumination is necessarily closely bound up with the study of its measurement. We are anxious to know exactly what order of illumination is necessary for each specified purpose, and we can only reproduce this order of illumination at will, by having at our disposal suitable methods of measurement, and by having come to an agreement as to what we want to be measured.

Now that the practical value of measuring illumination is becoming realized, it may safely be predicted that convenient and exact methods of measuring light will gradually be evolved.

We have already taken a great step in realizing the value of so-called "illuminometers"—portable instruments which enable us to measure the actual practical illumination in a street or building. Illumination is naturally influenced by many factors,—the reflected light from wall-papers and surroundings in a room for instance,—which are not taken into consideration by a mere measurement of the intensity of the source employed in a photometrical laboratory. The discrepancies so introduced have continually been a cause of no little confusion in the past.

The need for co-operation is very strikingly exemplified when we come to compare the various data obtainable with regard to the relative sensitiveness of different photometers and illuminometers.

One cannot help feeling that the individual efforts of the past—creditable and valuable in themselves as many of them were — were often restricted in value by the fact that the measurements of different observers were often made under different conditions, and frequently involved differences in nomenclature and definition.

At the present time it is very important that we should be able to agree as to what degree of accuracy can really be expected from photometrical measurements under certain specified conditions, and which of the instruments of the present day are the most sensitive and satisfactory. These questions could be definitely settled by the combined efforts of the various experts in photometry. At present much misconception undoubtedly exists, and can only be removed by the free interchange of views which we are advocating.

In 'THE ILLUMINATING ENGINEER' we propose to publish articles dealing with this important subject.

THE ILLUMINATING ENGINEER AND THE PRESS.

THE technical press in this country have shown interest in matters of illumination by publishing many important articles on this subject, and, in particular, have frequently reproduced or referred to articles published in *The Illuminating Engineer* of New York, or papers read before the Illuminating Engineering Society of New York.

We hope that the contents of our columns will likewise be regarded as of value, and we take this opportunity of expressing our desire of harmonious co-operation for the furtherance of the objects with which we are identified. At the present time too much cannot be done to make the fundamental principles of illuminating engineering more widely known.

We also wish to express our conviction that 'THE ILLUMINATING ENGINEER' covers a field of its own, and will in no way interfere with that occupied by other existing journals in this country.

CONCLUSION.

It may be urged that we have got on all right hitherto without troubling about the defects of our methods of illumination. This suggestion has always confronted any new movement. The truth of the matter is that we rarely realize how bad a thing is until we have something better, and until the question has been more carefully studied. We believe that the time will come when we shall wonder at the crudeness and inefficiency of many of the systems of illumination in use at the present day, and we hope that the work of 'THE ILLUMINATING ENGINEER' will receive due recognition and, being heartily supported, bring about the desired result.

LEON GASTER.

[The Editor of 'The Illuminating Engineer' does not necessarily identify himself in any way with the opinions expressed by his Contributors.]

Obituary Notice.

THE LATE LORD KELVIN.

IT is with deep regret that we chronicle the death of Lord Kelvin, whose long and unique record as a scientist has received world-wide recognition, and requires no comment from us. Lord Kelvin will long be remembered, not only for the greatness of his individual achievements, but also for the wideness of the ground covered by him. Up to the very last he worked indefatigably in the cause of science, with an energy which would have been remarkable in a younger man. This year he accepted once more the Presidency of the Institution of Electrical Engineers, a position which he had filled so illustriously in the past.

In Lord Kelvin the world loses a worker in the field of science who will be regretted indeed. His life should serve as an example to the younger generation of what a scientist's life should be, and supply them with an inspiration to further work in the future.

TECHNICAL SECTION.

Illumination, Its Distribution and Measurement.

By A. P. Trotter,

Electrical Adviser to the Board of Trade.

On May 10, 1892, a paper on 'The Distribution and Measurement of Illumination' was read before the Institution of Civil Engineers, and was subsequently awarded a Telford Medal and a Telford Premium. The paper was published in vol. cx. of the *Proceedings* of the Institution, and is now (with the permission of the Council of the Institution) revised, largely rewritten, and enlarged.

INTRODUCTORY.

Light being an expenditure of energy, "candle-power" is an accurate term, since it is the measure of the rate of expenditure of energy; and the art of illumination is therefore, in a very definite sense, a matter which comes within the province of civil engineers, since it is the art of directing this power for the use and convenience of man. The study of light, its nature and laws, belongs to the science of optics, but even to-day we may look to optical treatises in vain for any useful information on the present subject. Illumination, if alluded to at all, is passed over in a few lines, and it has remained for engineers to study and to work out the subject for themselves. Fortunately the geometrical laws of the distribution of illumination are very simple, and those of photometry are as easy. The physiological side of the question presents some puzzles, and these should receive attention from scientific men who are conversant with the practical difficulties of subjective investigations. Notwithstanding the attention which has been given to the matter during the last few years, the specification of a required illumination of a street or of a railway station would perplex most contractors, and the time has hardly yet arrived for it to be possible to express intelligently how much illumination is required, or, a specification being given, how to execute it.

The vocabularies of the French and English languages are remarkably rich in words connected with light, and such terms as illumination, brilliance, brightness, intensity, and luminosity are generally employed by different writers to express different ideas, and are often used in a confused and vague way. The terms force, power, work, energy, and efficiency have been used by the general public, and will continue to be used, in a very loose and inexact manner; it has been the business of engineers to attach precise meanings to them for their own purposes, to recognize these as the only proper meanings, and to regard a misuse of one of them as a mark of ignorance of the elements of engineering science.

DEFINITIONS AND UNITS.

Light for the present purposes means visible radiation emitted from a flame or incandescent surface, or reflected from a surface. The word "light" is often loosely used instead of intensity of light or quantity of light

In one sense, light is no more a physical quantity than dimness or darkness, it is a general term; in another sense it is luminous radiant energy. The particular terms which denote the chief physical quantities are intensity, commonly called candle-power; flux, or spherical candle-power; illumination; brightness, or intrinsic brilliancy; and quantity of light.

One of the difficulties of this subject is that the use of light and illumination is to satisfy the eye, and the eye is a very poor judge of the physical quantities in question. It is well known that even experts cannot make a tolerable estimate of the candle-power of a lamp by merely looking at it when alight. Electric glow lamps of 16 candle-power and of 8 candle-power or thereabouts are so common, that most people accustomed to use them can make a fairly satisfactory guess whether a single lamp or a number of the same lamps are of 8 or of 16 candle-power. An estimate of the "heft" of a letter, whether it is over or under 4 ounces, the temperature of the air, a length in inches or feet, or the contents of a vessel in pints or gallons can be made by most persons with greater accuracy than a guess at the candle-power of a lamp. Comparative estimates are not much better. It is easy to see that a 12-candle-power lamp gives less light than a 16-candle-power lamp, but it is very difficult to say how much less.

INTENSITY OR CANDLE-POWER.

Candle-power is measured as an intensity in any direction. It is also measured as a flux by the product of a solid angle into the candle-power.

A brief account will be given of the more important standards which have been proposed and used from time to time. Further information may be obtained from the writings of those who have given special attention to the subject.*

* Palaz, 'Traité de Photométrie Industrielle'; J. W. Dibdin, 'Practical Photometry'; W. M. Stine, 'Photometrical Measurements'; Dr. J. A. Fleming, *Journal Inst. Elec. Engrs.*, vol. xxxii.; C. C. Paterson, *Journal Inst. Elec. Engrs.*, vol. xxxviii. Dr. Fleming's paper is followed by a valuable bibliography.

At an unofficial congress at Geneva in 1896 the name "pyr" was suggested for a unit of intensity, and Dr. J. A. Fleming* has proposed the name "lamp" for a 10-candle standard, on the ground that the candle itself having been abandoned, the name need not be retained. It is unfortunate that the word candle-power has taken such a firm position in technical language, and it is curious that we seldom use the word intensity, and its use by the French in connexion with electric current appears to us redundant. If the word candle-power were not so well-established, there would be a better chance of agreeing on an international standard of intensity. If a "daniel" had been in extensive use as a unit of electromotive force there would have been more difficulty in introducing the volt.

The Carcel.—The earliest standard of light was the Carcel lamp, introduced in 1800, and used by Regnault and Dumas for testing gas, and is still employed officially for that purpose in France. It is a colza oil lamp containing a clock-work pump, and has an Argand burner and glass chimney of certain specified dimensions.†

The value in British candle-power was determined by Mr. Sugg in 1870 as 9·6; in 1885 Mr. W. J. Dibdin made it 9·4; while Mr. C. C. Paterson, at the National Physical Laboratory, gave 9·82; and at a photometric meeting held at Zurich in July, 1907, this last value was confirmed. The discrepancies may be accounted for by the many sources of error in the use of this standard, the charring of the wick, the irregular consumption of oil, and the use of a glass chimney. Even in the hands of a single observer successive measurements vary widely.

The British Candle.—The so-called English Parliamentary candle was not more scientific, and hardly more accurate, than the barley-corn, of which three went to the inch. That candle, six going to the pound (but neither

* *Journal Inst. Elec. Engrs.*, vol. xxxii. p. 164.

† See 'Traité de Photométrie Industrielle,' A. Palaz, p. 101.

length nor diameter being specified), and intended to burn 120 grains of sperm per hour, was set up under the Metropolis Gas Act of 1860 as an official standard, only for the purpose of testing London gas.

The German Candle.—In 1868 a carefully specified candle of paraffin was officially adopted by the German Association of Gas and Water Industries, and was called the *Vereinskerze.*

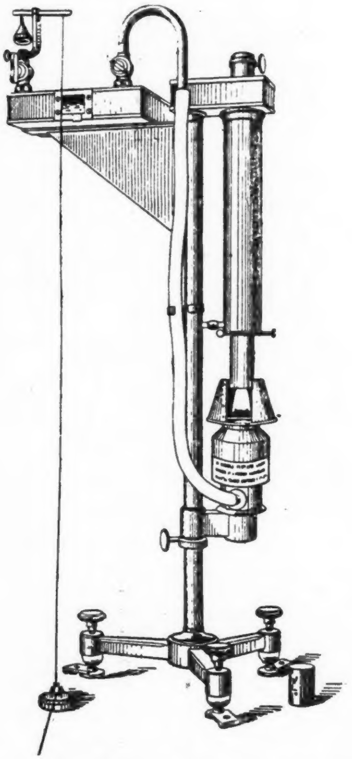


FIG. 1.—THE VERNON HARCOURT PENTANE 10-CANDLE LAMP.*

The Harcourt.— In 1877 Mr. A. Vernon Harcourt described a lamp burning air saturated with the vapour of pentane, a volatile hydro-carbon distilled from petroleum. This has undergone several modifications, and the present pattern, intended to represent ten times the candle-power of the Parliamentary candle, is the official standard of the Metropolitan Gas Referees, and is doubtless an excellent one for their purpose. The liquid pentane is held in a flat tank, and air passing over it, becoming saturated with the vapour, falls by its own gravity through a siphon pipe to a steatite ring or argand burner; and the flow is regulated by a screw cock near the burner, or one on the inlet of air to the pentane saturator. No wick is needed. A tall chimney draws the flame up with a considerable draught, and ensures a steady light. A second outer chimney, concentric with the first, warms the air which is supplied to the flame. No glass chimney is required, but the flame may be inspected for adjustment through a mica window. The top of the flame is cut off in the direction of the photometer by a screen, giving a clear opening of 47 millimetres, but notwithstanding this, the height of the flame must be carefully adjusted. The total height of the apparatus is about 2 ft. 10 in.

The Hefner.—The amyl-acetate lamp, produced in 1884 by Hefner von Alteneck, was subjected to careful tests by Liebenthal, and after certain modifications, was declared to be the official standard in Germany. The pattern certificated by the Reichsanstalt has been adopted by the American Institute of Electrical Engineers, and, provisionally, by the Bureau of Standards of the United States, and was recommended as an international standard at the Chicago Congress of 1893, but was not adopted, for reasons which probably do not exist now. It has been widely recognized for scientific as well as for industrial work.

The container, made of brass, holds abou 4 ounces (115 cc.) of amyl-acetate. The ordinary commercial quality used as a solvent for celluloid is unsuitable, and even the commercially "pure" quality is apt to corrode the container. Unless this is well nickel-plated inside, a cock should be fitted for draining off the liquid after use. A thin German-silver tube, constructed to

* Reproduced by permission of the Gas Referees, from their official description.

the exact dimensions specified by the Reichsanstalt, holds the wick. Two toothed wheels, worked by worm gear, feed the wick, and give a fine adjustment for the height of the flame. A miniature camera with lens and ground glass is carried on a support at the side. A horizontal line is drawn on the ground glass, and the flame of the lamp is adjusted so that its inverted image just touches the line. The ordinary wick for spirit lamps may be used, but should be well dried; it should be carefully trimmed level with the top of the tube.

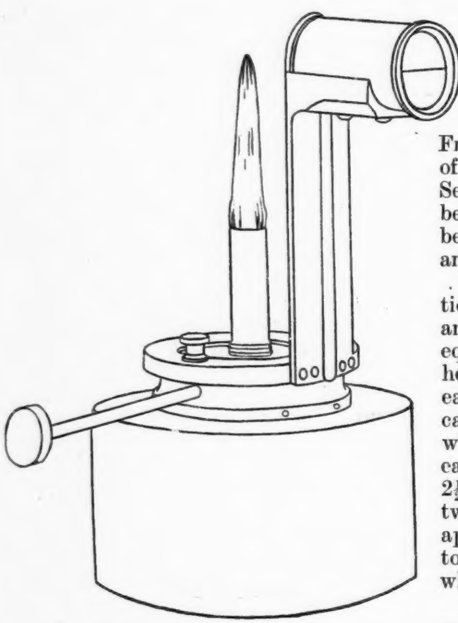


FIG. 2.—THE HEFNER LAMP.

The temperature of the flame, which is of an orange colour, is remarkably low, and owing to the feeble draught, the flame is sluggish and sensitive to very small currents of air. It is not difficult to screen it, and the screens which should always be used in photometric work for keeping the eyes in a sensitive condition may be arranged to protect the flame without causing an artificial upward draught.

Though the flickering of the flame sometimes makes it difficult to check its height on the gauge, it has not so much effect on the candle-power as might be supposed. The temperature of the room has no appreciable effect on the candle-power of the Hefner lamp, and with ordinary ventilation the effect of carbonic acid is negligible. A rise of an inch in the barometer increases the candle-power about $\frac{1}{4}$ of 1 per cent., a difference far beyond ordinary powers of observation, but the presence of moisture is of some importance, and it is unfortunately troublesome to measure. From Mr. C. C. Paterson's* investigations it may be deduced that the Hefner lamp gives its normal candle-power early in May and throughout October. Towards the end of May it begins to fall off, and 1 per cent. must be added. From the middle of June to the middle of August, add 2 per cent.; during September, 1 per cent.; during November, deduct 1 per cent.; during December, January, and February, 2 per cent.; and during April, 1 per cent.

Liebenthal's statement of the relation between the height of the flame and the luminous intensity is an equation which means that when the height of the flame is less than 40 mm., each millimetre change of height causes 3 per cent. change in light; and when the flame is more than 40 mm. each increase of a millimetre produces $2\frac{1}{2}$ per cent. change. No doubt these two linear relations are good tangent approximations, but it is not possible to imagine a change *per saltum* at 40, which is the most important point.

The relative Values of the Standards.—The generally accepted value of the Hefner unit (often written H.U.) has been 0·88 candle-power (or 1 c.-p. = 1·14 H.U.), but at the photometric meeting at Zurich in July, 1907, at which several laboratories were represented, the following values were declared:—

Carcel = $10{\cdot}7_5$ Hefner
Harcourt = $10{\cdot}9_5$ Hefner
Harcourt = $1{\cdot}02_0$ Carcel

* *Journal Inst. Elec. Engrs.*, vol. xxxviii. p. 276.

The results referred to may be conveniently expressed as follows, the subscript figures being approximate.

	Carcel	Harcourt	Hefner
Carcel	10	9·8	$10{\cdot}7^{5}$
Harcourt	$10{\cdot}_{2}$	10	$10{\cdot}9_{5}$
Hefner	$0{\cdot}93_{2}$	$0{\cdot}91_{3}$	1·0

The difference between 0·88 and 0·913 is rather surprising, being more than 3½ per cent., and may indicate that the Harcourt is somewhat less than ten times the value generally taken as the British candle, or that it has been used otherwise than according to the standard manner.

Assuming that a change of 1 mm. in the height of the Hefner flame changes the light by 2¾ per cent., a height of 43½ mm. will correspond with the value 0·913, and a height of 45 mm. will correspond with the value 0.88. These differences are too great to be marked as lines on the ground glass of the gauge, but an adapter can easily be made to raise the whole gauge. The flame burns equally well at this height, which gives one candle-power. Mr. J. W. Dibdin found that the height of an amyl-acetate flame had to be increased to 51 millimetres to give one candle-power. This, according to Liebenthal's formula would mean that one candle-power is equal to 1·275 Hefner units. It is difficult to account for this discrepancy.

The Violle.—More than one attempt has been made in France to set up the standard invented by Violle, and proposed for international adoption at the Electrical Congress at Paris in 1881. The standard is the light emitted in the normal direction by one square centimetre of the surface of molten platinum at the temperature of solidification. The cost of the apparatus is as formidable as the difficulty of using it. In the earlier patterns about one kilogramme of platinum was melted in a crucible of lime by an oxy-hydrogen blowpipe. When a quantity of water begins to freeze the temperature remains practically constant until it is all converted into ice. The same thing happens when a metal solidifies, and this condition must be seized upon for the photometric measurement. A considerable mass of metal is needed to delay the process for a period long enough to allow photometric observations to be made. The crucible was run out from below the blowpipe, and brought beneath a hollow water-cooled screen of copper in which a circular hole one square centimetre in area allowed the light to ascend to a mirror. Dust, scum on the molten surface, the ascending current of hot air, and other difficulties have not only prevented the Violle standard from coming into use, but have left its value in terms of other standards uncertain. It has been assumed that the Violle was equal to about 2 Carcels.

As long ago as 1844 Draper proposed the use of an incandescent platinum wire for a standard of light, and the idea was so attractive to electricians that Zoellner, Schwendler, Werner von Siemens, Liebenthal, Lummer, and Kurlbaum, and finally Petavel have spent much trouble but have produced little practical result. Mr. J. E. Petavel's researches* show the extreme difficulty of working with molten platinum. It has been left for many years to various International Congresses of Electricians to deal in a desultory fashion with the question of a standard of light, and like the mercury ohm, the Violle standard has been officially adopted again and again at International Congresses by people who had never tried to construct or even to use one, and who were unaware that far greater accuracy may be obtained by less academical methods.

The Bougie-Decimal.—The only other standard which need be mentioned is the bougie-decimal proposed at the Geneva Congress of 1896. It was considered to be approximately one-twentieth of the Violle, or one-tenth of the Carcel, but it was declared to be equal to the Hefner unit.

(*To be continued.*)

* *Proceedings* Royal Society, vol. lxv., 1899, p. 469.

The Present Status of Acetylene Lighting.

By F. H. Leeds, F.I.C.

For purposes of convenience, the methods employed for the production of artificial light may perhaps, according to the form of the matter or energy transformed, be divided into three classes: (1) The combustion of a gaseous or previously vaporized fuel; (2) the combustion of a non-gaseous fuel yielding light by vaporization and decomposition within the flame; and (3) the use of electricity. Similarly, the problem of producing artificial light may be divided into three phases: (*a*) choice of the actual illuminating agent, (*b*) selection of the method by which it is caused to develop light, and (*c*) adoption of a proper method for utilizing the light efficiently and economically.

During the past twenty years comparatively few changes have come over the processes whereby non-gaseous flame illuminants are made to yield light; and although great improvements have been effected in the use of electricity, the alterations have been rather in important matters of detail than in underlying principles. The employment of gaseous illuminants, however, has undergone so fundamental a change by the invention of the incandescent mantle as to deserve the term revolution. The solid illuminant, *i.e.*, the candle, remains in use as heretofore —inefficient, costly, troublesome, but frequently indispensable. Liquid illuminants survive principally in the form of lamp oil, which is burnt as in days gone by; for although heroic attempts have been made to couple paraffin and denatured alcohol with the Welsbach mantle, the results do not appear to have attained any considerable measure of success. With one exception the actual illuminants available fifteen or twenty years ago are all that are available to-day, but that one exception is so striking as to demand careful and minute attention.

The one exception to the rule just enunciated is formed by acetylene, a gaseous illuminant and fuel which is distributed through a house like any other gas, and consumed from fixed burners broadly resembling those employed for coal gas; but, unlike coal gas, made on the great majority of occasions by the consumer himself in a special piece of apparatus erected within an outbuilding at the back of his residence. Although acetylene has been known to chemists for nearly fifty years, it has only come under the cognizance of the illuminating engineer for ten or twelve, its appearance upon the scene of daily life being post-dated until a suitable method was discovered for preparing it at a low price in simple plant. During its brief life-time acetylene has made astonishingly rapid progress when all the obstacles it has had to encounter are duly borne in mind.

First and foremost amongst these obstacles has been its apparent ease of preparation, which has caused every tradesman and amateur suffering from unrestrained love of the soldering iron to essay the construction of a generator. It is not proposed on the present occasion to discuss in detail the various ways in which acetylene is generated, because the main points now under contemplation are the qualities of the gas as an illuminant, and the scope of its practical employment. Treatment of this character may perhaps appear a placing of the cart before the horse; but actually, however, a man will not care to study the methods of making a substance the utility of which seems questionable or is altogether unknown to him. Nevertheless the principles involved in preparing acetylene must be mentioned in order that misconceptions may be removed and the paradox uttered above be explained.

Acetylene is generated by bringing a solid body known as calcium carbide (usually referred to as carbide) into contact with water in an enclosed space, the gas evolved by a process akin to effervescence being then led to a storage receptacle or to the actual burner where it is consumed. The by-product of the chemical reaction that takes place between the carbide and the water is a solid body, slaked lime to wit, which, being but slightly soluble in water, remains undissolved even if what is termed by generator builders a large excess of water is present in the apparatus. The mere fact that the by-product is solid might at once have shown a chemical engineer that the process of acetylene generation is encompassed with difficulties, more particularly because the reaction between carbide and water is accompanied by the evolution of much heat, which heat is very liable to act prejudicially upon the operation and upon the resulting gas. If the by-product had been a liquid—if, for example, it had been feasible to decompose carbide with dilute hydrochloric acid—only a simple liquid would have been left, a solution of calcium chloride; and in these conditions the construction of a thoroughly satisfactory generating apparatus would have been perfectly simple. On these grounds a qualified engineer might have seen that much technical knowledge was called for in the design of a good apparatus, and might well have taken the subject up in the early days of the industry. Unfortunately, however, he did not; and it was largely left to men of little chemical and engineering knowledge to devise satisfactory generators by the tedious and expensive method of trial and error. At length the experiments have been brought to a successful issue, and acetylene is produced in most recognized apparatus under conditions and in a manner of which neither chemist nor engineer need be ashamed. A second reason for the comparatively slow progress made by acetylene as an illuminant for residential and larger premises has been and still is, curiously enough, its rapid spread amongst cyclists and motor-car owners.

It is a truism to say that the gas has already proved itself indispensable to the car owner who desires to travel far and fast at night. In this way acetylene has made itself known in almost every corner of the land; but it has done so in circumstances that have not by any means altogether recommended it to members of the general public as an indoor illuminant. As open-air instruments, some of the earlier and most of the later types of motor-lamps have proved satisfactory, their rays of light being, indeed, so powerful as to bring the gas they consume into unmerited disfavour amongst people who do not employ them. Another serious fault has been that unconsumed gas has frequently escaped from them—a matter of no consequence on the road, since motor-car owners are *ex hypothesi* rich, but one which has absurdly, though very naturally, left in the layman's mind the almost ineradicable impression that acetylene itself cannot be burned without the production of an unpleasant odour. The townsman is intellectually aware that coal gas has an obnoxious odour before combustion, though it yields none when burned; but his illogical habit of mind prevents him seeing that the same fact may be (as, indeed, it is) true of acetylene, or realizing that an odourless gas would be a most dangerous thing to introduce into a dwelling-house.

It is an unpleasant necessity to have to write thus unfavourably of vehicular lamps, because cyclists and motor car owners are so very numerous that, in spite of their small individual consumptions of carbide or purchases of ready-made acetylene, as a class they are most valuable supporters of the carbide industry. According to a recent estimate the present consumption of carbide in France is at the rate of about 20,000 tons per annum, one-tenth of which is decomposed in vehicular lamps. In the United Kingdom their relative consumption is undoubtedly much higher, although precise figures on the subject are not easily procurable.

While recognizing the vehicle owner as a strong supporter of the carbide trade, one cannot help regretting that road lamps often leave such powerful visual and olfactory impressions behind. To counteract all this very little has been done systematically by the trade. Only two or three years ago there was absolutely no co-operation on the part of acetylene engineers, and now there is but little.

An excellent scheme of common advertising was drawn up some time back, but the trade gave it no support. Indeed to this very day Tom usually hints to a possible customer that Dick's generator is very extravagant, and that Harry's is very dangerous, to which both Dick and Harry reply in suitable terms, until the would-be consumer is finally convinced that he had better go dark than employ the gas at all. It must be matter of common experience to all who are interested in the gas to find scarcely one person in a thousand, particularly in country places, which form the true field for acetylene, knows the gas by name or repute, except as the material that is burned in so many vehicular lamps by the members of a class who are not precisely beloved on all hands.

In very truth, however, when properly generated and properly burned, and when the light is properly utilized, acetylene is a most excellent indoor illuminant, possessing properties that render it unrivalled in many directions. Inasmuch as the gas is actually generated by the person who consumes it from a material which is neither bulky nor capable of catching fire, acetylene is available as a trustworthy illuminant in the most isolated country house. Hitherto the only forms of artificial light procurable in such a residence have been the candle and the paraffin lamp. The candle cannot be considered as a serious illuminant except where everything (including fresh air) is sacrificed to the elegant effect given by large numbers of low-power lighting units.

Acetylene has to be generated by the consumer just as paraffin lamps have to be cleaned by him, but whereas the existence of the least odour in a house lighted by acetylene is proof of bad gasfitting on the part of the erector, and is therefore absolutely unnecessary, absence of odour in a house lighted by paraffin lamps is so rare as to be practically non-existent. Again, the labour involved in attending to one or two paraffin lamps may appear trivial, but when, as in the houses of the upper middle class, there are some twenty or thirty lamps to be cleaned and made ready for service every day, the labour required may occupy one person for half that day or more; whereas the labour required by an acetylene plant of smaller, equal, or far greater capacity never exceeds one hour per day, and frequently demands but an hour once a week or so. Thirdly, the fact that a large store of highly inflammable material must be kept, if not actually within the residence, in a position close to it, renders the use of paraffin lamps fraught with very grave danger in respect of fire; and the danger occurs precisely in those neighbourhoods where facilities for extinction are the weakest.

It is not possible for the raw material used in generating acetylene to catch fire under any conditions whatever. Before arriving at an open burner the gas itself can only catch fire if it escapes from the apparatus; it cannot escape from the apparatus unless the plant is defective; if it does escape it cannot catch fire unless, in disobedience to all rules, a naked light is brought near the apparatus; if the escaping gas does catch fire or explode, the accident is limited to the special shed containing the plant, and does not harm the dwelling-house or its inhabitants.

Of course, as acetylene has to be generated (except in special circumstances, as where a public supply of the gas has been provided) by its actual consumer it is inevitably less convenient than any illuminant which is supplied ready for use to the very spot where the light is required. Hence acetylene, strictly speaking, is less convenient than either supplied coal gas or supplied electricity. (By coal gas throughout this article is meant true coal gas, carburetted water gas, or any mixture thereof.) In nearly every place where a supply of coal gas is to be found, a householder can obtain cheaper light from it than from acetylene, provided always some member of his household spends the time needed to keep the incandescent burners, their glass-ware, their mantles, and their shades in good condition; but in nearly every place he can obtain a better and cheaper light from acetylene than from coal gas if he retains flat-flame burners. In nearly every place, however, a householder can obtain cheaper heat from supplied coal gas than from acetylene, owing to the fact that the latter affords very much less heat in proportion to its light than coal gas per unit of volume.

In comparison with supplied electricity, acetylene has the advantage of yielding a cheaper light under domestic conditions, and of being consumed through a service and fittings which are cheaper to erect and safer in the matter of fire. It is also cheaper than supplied electricity in the matter of heat development.

Naturally, acetylene finds its most obvious and hopeful future in places where neither coal gas nor electricity is supplied. If the illuminant has to be made by the consumer, coal gas can hardly be considered a rival, as the requisite plant is most costly and unpleasant to manipulate. Similar remarks apply to oil gas; whilst the plant needed for the generation of current is also expensive and requires constant supervision by a man of technical knowledge, in place of the coachman or gardener, who is perfectly able to work an acetylene installation.

Although the statement made at the beginning of this article was true, that with the exception of acetylene no new illuminant had been discovered within the past fifteen or twenty years, the introduction of the incandescent mantle has wholly changed the conditions affecting another illuminant, which has always been put forward as peculiarly suitable for employment in country districts. This is the material known as air gas, made by partially saturating ordinary air with a certain proportion of a very volatile spirit in an apparatus where artificial heat, over and above manual or motive power, may or may not be required.

The liquid employed is gasoline, petrol, or something of the kind, which, undiluted, burns with a very smoky flame, and which therefore, if only diluted with a limited quantity of air, yields a luminous flame like non-incandescent coal gas. Owing to the extreme volatility indispensable in any liquid used for carburetting air by a cold process, the use of air gas connotes the presence in or about a house of a liquid which is much more readily inflammable and potentially explosive than paraffin lamp oil. For this and other reasons air gas, colloquially termed "greased air" in the States, made little or no progress before Welsbach produced his mantle, but since that date the material has become more popular.

There is a maximum proportion of air beyond which gasoline vapour cannot be diluted, if it is to be consumed in an open burner; but when it is required only to yield a non-luminous flame intended to bring a mantle to incandescence, the proportion of vapour may be much lower.

Recent improvements have, indeed, been effected in the construction of incandescent air gas burners, which allow the gas itself to be made with such a large proportion of air that the mixture contains a smaller quantity of combustible vapour than corresponds with what is known as its lower explosive limit. The consequence is that if modern air gas escapes very freely into a room, no danger of explosion arises, which, of course, is not true of acetylene or coal gas. Air gas, therefore, appears to be the one rival cf acetylene in country districts. As a source of heat it is doubtless equal, and perhaps superior, but as a source of light it exhibits four grave defects.

In the first place, in comparison with the solid incombustible raw material whence acetylene is generated, air gas is produced from a spirit, as already mentioned, whose fire and explosion risks it is impossible to exaggerate.

In the second place, being an extremely dilute fuel, all the service pipes and connexions for air gas must be as much larger than those used in the piping of a house for coal gas as the fittings used for coal gas are larger than those required for acetylene. This, of course, means a notable economy in the capital cost of installing acetylene. Thirdly, modern dilute air gas is so nearly devoid of odour that leakages are liable to remain undetected much longer than in the case of coal gas, whilst acetylene has an odour which renders an escape immediately noticeable. Certainly an escape of modern air gas is a matter of little importance so far as danger is concerned; but any escape involves waste of money.

In the fourth place, modern air gas cannot be burned so as to produce light, except in an incandescent burner, whereas acetylene can be consumed in an open burner without any serious sacrifice of economy; and, in contradistinction to incandescent burners, open burners can be turned down, or constructed in the smallest sizes desired.

The position occupied by the incandescent mantle to-day is somewhat peculiar. Its invention, as already stated, has effected a complete revolution in the methods used by the more intelligent sections of the populace for the development of light from coal gas. In the hands of a gas engineer, or even of a person who has some manual dexterity, coupled with the disposition which causes him to maintain his animate and inanimate dependents in the best possible condition, the incandescent burner and mantle is wholly satisfactory. A mantle lasts on an average three months. The burner can, if needed, be cleaned and put together without destroying the mantle upon it. The most modern inverted burners can be taken to pieces and assembled very frequently without causing the mantle to suffer in the least. Reports of the general behaviour of mantles and of the illuminating power they still possess when several hundred hours old are constantly being published in most favourable language, and no one can doubt that the figures quoted are perfectly correct. On the other hand, most householders (not excluding the lady members of their families) are too clumsy and careless to lock after the burners properly, while comparatively few of them care to take part in a scheme of "maintenance." Perhaps, too, very many lay householders still retain a dread of gas to such an extent that they scarcely venture to touch so complicated-looking an object as an incandescent burner, or so fragile an article as a mantle. The consequence is that the light given by many incandescent burners of established good quality in private houses, and even in shops, is deplorable, causing the consumer much discontent.

Again, although an incandescent burner adjusted so as to give the highest possible duty is affected slightly by the dirt present in an urban atmosphere and during a London fog, the interference with its functions is smaller than that it suffers when used in the country. During a dry spring and summer the mantles on the burners of all country houses situated near a main road are constantly being subjected to the deposition of coarse road grit raised by motors, which collects round the nipples and chokes the air supply.

For a certain period of the autumn winged creatures of all sorts, unrecognized by the photometrist and unknown to the Londoner, submit the mantles to impact stresses, and suffer for their temerity by obstructing the globes with their cremated remains. Other crawling insects, more cylindrical in shape and inquisitive in nature, enter the air inlets, and, apparently enjoying the warmth, remain alive to obstruct the entrance of primary air and to cause the burners to smoke.

All this will be brushed aside as nonsense or pure special pleading by the citizen gas engineer, but the records kept by the present writer relating to the consumption of mantles in a town as well as in a country residence prove that no fanciful picture has been drawn.

In circumstances such as these can there be any doubt that acetylene, which may be consumed economically in an open burner, may be regarded as superior to air gas, which can only be consumed under a mantle; more particularly when it is remembered that the open flame of acetylene is as steady as the incandescent light of coal gas, has a much more pleasing tint, and that it may be utilized without involving the wanton sacrifice of economy which occurs when coal gas is consumed in a flat-flame burner?

There is yet another point. Part of the advance made in the direction of producing artificial light during the past decade or more has consisted in the construction of illuminating units of ever-increasing strength and brilliancy. Only within the past two years or so has any attention been directed to the fact that there is a limit beyond which the illuminating power of a single unit employed for domestic purposes ought not to be pushed. Whatever illuminant is adopted, the efficiency of a single unit tends to rise with its illuminating power; and competition between paraffin oil, coal gas, and electricity has been such that the rival exponents have felt themselves compelled to exact the uttermost farthingsworth of light from the fuel.

Fortunately a reaction has recently set in, as is exemplified by the appearance of this journal in the United Kingdom, and, we hope, by the early formation of a Society of Illuminating Engineers. For the past two years or so voices in the wilderness have cried out against powerful sources of light, prophesying eyestrain and other diseases of the optical organs. They have endeavoured to proclaim that the evils arising from the use of excessive light are as imminent and disastrous as those accruing from inefficient illumination, and they have demonstrated that a room may be easily lighted satisfactorily and comfortably by the use of numerous small sources of light even at a lower outlay for fuel than by one central burner of enormous power. The term intrinsic brilliancy or specific intensity, as applied to a source of artificial light, is probably so new, that even now many lighting engineers and architects could be found who do not know its precise meaning, or the full significance of the facts that lie behind it. The tendency during the past ten years towards the production of ever more powerful sources of light has greatly increased the specific brilliancy of the illuminants, perhaps the greatest offender amongst such sources as are used for domestic purposes being the incandescent glow-lamp inside its bulb of plain glass.

Naturally a light exhibiting so high a degree of specific intensity as to be harmful to the eyesight can be rendered better in that respect by the application of suitable non-transparent globes, which also hold back the harmful ultra violet rays.

But inasmuch as some loss of light occurs in even the best piece of glass, that light is best for use in a dwelling room which requires the smallest amount of degradation from its original intensity.

The specific intensity of a glow-lamp appears to vary, according to the nature of its filament, from 200 to 1,000 or more C.P. per square inch; whereas a light ought not to be erected and used in such a position that its unshaded rays can enter the human eye if it has a much higher intrinsic brilliancy than some 5 or 6 candle-power per square inch. The incandescent upturned gas burner, in its smallest sizes, is usually stated to exhibit an intensity of 20 to 25 candle-power per square inch; but as the unit increases in size, and particularly when a system of so-called intensified lighting is adopted, the figures become a good deal higher, and may rise to 100 or more. The specific brilliancy of an inverted incandescent coal gas burner does not yet seem to have been examined by many authorities; but having regard to the general shape of inverted mantles, and the fact that such burners throw a very much larger proportion of the total light they yield in a downward direction than do upturned burners, the specific intensity must be higher (in all probability) than the intensity of an ordinary Welsbach. Bell has quoted the specific intensity of the ordinary acetylene flame as being from 75 to 100 candle-power per square inch, but this is undoubtedly incorrect. Woodwell quotes from 25 to 75 candle-power, which agrees a good deal better with measurements made by the present writer, who has found that the light of such an acetylene burner as is most likely to be employed for domestic purposes does not, or need not, exceed 20 candle-power per square inch. The specific brilliancy of an incandescent air gas flame does not appear to be on record, but it should be of the same order of magnitude as that of the open acetylene flame or the incandescent coal gas burner. Thus acetylene exhibits the advantage of being a light of reasonably low intensity, equal, roughly speaking, to air gas and incandescent coal gas, but having the great advantage of being economically capable of combustion in a non-incandescent burner.

One of the most important lessons to be drawn from a study of the new applied science of illumination has recently been taught by Dr. Krüss of Hamburg, who has ably argued that different lights can no longer be fairly compared one with another by measuring the horizontal candle-power they yield, or even by determining their mean spherical or mean lower hemispherical illuminating power, the proper method being to measure the illumination received from them by a surface lying at some stated distance below the light in a position resembling that of the writing-table or book used in everyday life.

At the present juncture it is impossible to say exactly how acetylene stands in comparison with other illuminants whose emissive powers have been carefully measured, because few determinations have been carried out on the capacities of the gas, except in the direction of measuring its horizontal illuminating power. Lansingh has given curves showing the spherical illuminating powers of various unshaded and shaded ordinary acetylene burners; but, to the best of the writer's belief, figures covering the illumination received on surfaces from such burners still remain to be collected.

At a guess, however, it may be said that the illumination afforded by an acetylene flame should be in proportion to its standard illuminating power, very similar to the illumination afforded by a flat-flame burner consuming coal gas.

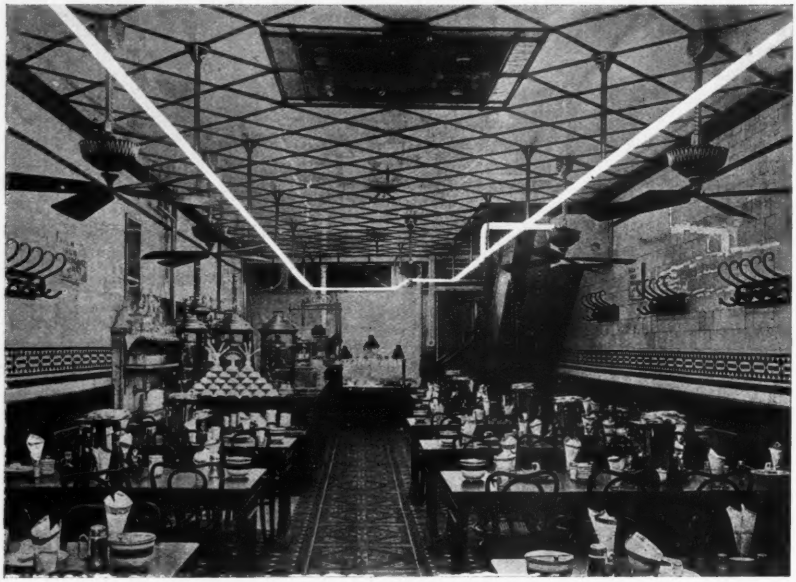
On Vacuum Tube Electric Lighting.

By Dr. J. A. Fleming, F.R.S.

From the time when inventors first turned their attention to electric lighting by incandescence the only line along which their efforts met with any reward, until quite recently, was by the employment of solids rendered incandescent by a current. But although Edison and other inventors nearly thirty years ago spent much time in trying to make use of refractory oxides and metals in the form of wire as the glowing material, no very great success attended their labours, and it was not until Edison and Swan in 1879 and 1880 gave us the completed carbon filament lamp that incandescent lighting started on its practical development. From that date for at least eighteen years the only substance employed as the incandescent material was carbon. The limitations attending the use of carbon were, however, well understood, and in the endeavour to produce a more efficient lamp, inventors went back again to refractory oxides and metals as the material to be heated. In the last eight or nine years much persevering work has resulted in the production of the Nernst lamp, using as the glower a mixture of oxides of earthy metals, the Tantalum wire lamp, and the later Osram or Tungsten lamp.

As in all other matters, no single invention has a monopoly of all the virtues. The above investigations have issued in the production of filaments of materials which can be heated without sensible evaporation to higher temperatures than a carbon filament in vacuo, and have a durability sufficiently great to permit of use in the manufacture of a practical glow lamp. The result has been a marked increase in the so-called efficiency reckoned in the usual unscientific manner in watts per candle; but the drawbacks are, first, the much greater intrinsic brilliancy of the glower, secondly, the inability so far to make lamps of small candle power—say 8 to 10 c.-p. —for working on 100 far less on 200 volt circuits, and thirdly the difficulty in making a high voltage lamp, at least with the materials so far used for metallic wire lamps. The inclusion of the intrinsically brilliant glower in a sand blasted or diffusing globe at once cuts down the useful flux of light per watt of power taken, although it obviates the painful effect produced on the eye by the use of intense point or linear sources of light. On the other hand, difficulties present themselves which detract considerably from the advantages of the improved efficiency. These are best seen by considering an example in detail.

Supposing, for instance, that a large room has to be lit which is to be used as a museum, showroom, drawing office, or workshop, where it is important to have a uniform diffused light and no hard shadows. The present method of procedure in nine cases out of ten would be to distribute about the room pendant carbon filament lamps, and if a sufficient number are employed under shades the desired effect can be obtained. The carbon filament lamp, hung apex downwards, gives, however, only about 60 per cent. of its mean horizontal candle power in a downward direction; and if the electric supply is, as usual, at 200 or 220 volts, the lamps will take 4 watts per nominal c.-p., or probably more. The so-called 16 c.-p. 220 volt carbon filament lamp will generally be found to take 60 to 70 watts or more, and give a light of 9 to 10 c.-p. in the direction of its axis. If then an attempt is made to take advantage of the higher efficiency of the new wire lamps, we



Moore Lighting Installation, Child's Restaurant, New York.

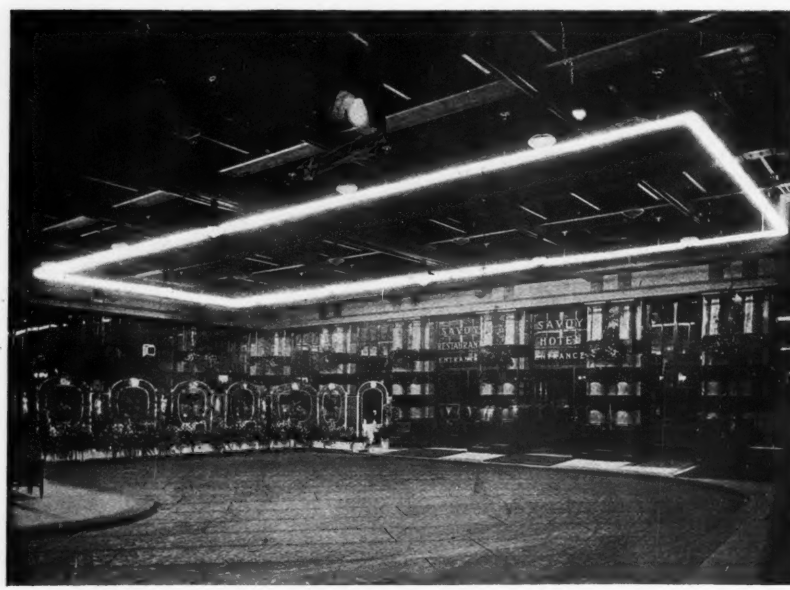


Fig. 4.—Moore Lighting Installation at the Savoy Hotel.

are met with the difficulty that 220 volt 16 c.-p. lamps of this type are not yet on the market.

Assuming we place two Osram 32 c.-p. 180 volt lamps in series, although these two together are not taking more power than one 16 c.-p. 220 carbon lamp, yet we should have at that point 64 c.-p. instead of 16 c.-p. Either, then, we have to use fewer points of lighting in the space to be lit, or sacrifice efficiency by diffusing globes, or spoil the uniformity of the lighting by increasing the distance of the sources, or else be unduly lavish of lighting, and so increase the total cost. It will be found that in no way can we obtain the advantage of the greater flux of light per watt spent in the newer illuminants without affecting the distribution of the lighting disadvantageously.

This is altogether apart from any questions as to the life and cost of the newer lamps themselves. So that whilst the unsophisticated householder is implored in the advertisements to adopt the new metallic wire lamp, and so save 70 per cent. of his bill for electric supply, a very little experience shows that there are serious obstacles in the way of this achievement. It is more and more realized that a scientific distribution and diffusion of light is required, and that the mere hanging up of glow lamps in conventional manners and positions is not the highest realization of the functions of the illuminating engineer.

The question then arises, Is there any solution of the problem of interior illumination which, whilst giving us the power of making a proper distribution and diffusion of light, enables us to take advantage of the higher voltages of electric supply now in use and gives an advantage over the widely used carbon filament in respect to the flux of light emitted per watt spent on it? An answer to this question has been given by the improved vacuum tube lighting of Mr. D. Macfarlane Moore, which has now been under test long enough to give proof of its value. Although it has been known in a general way for some time past that light could be obtained by passing a high tension current through rarefied gas, and although many inventors have patented or experimented with vacuum lamps in which the glowing material is a gas and not a solid, it has remained for Mr. Moore to make a forward step of a very remarkable kind in connexion with it.

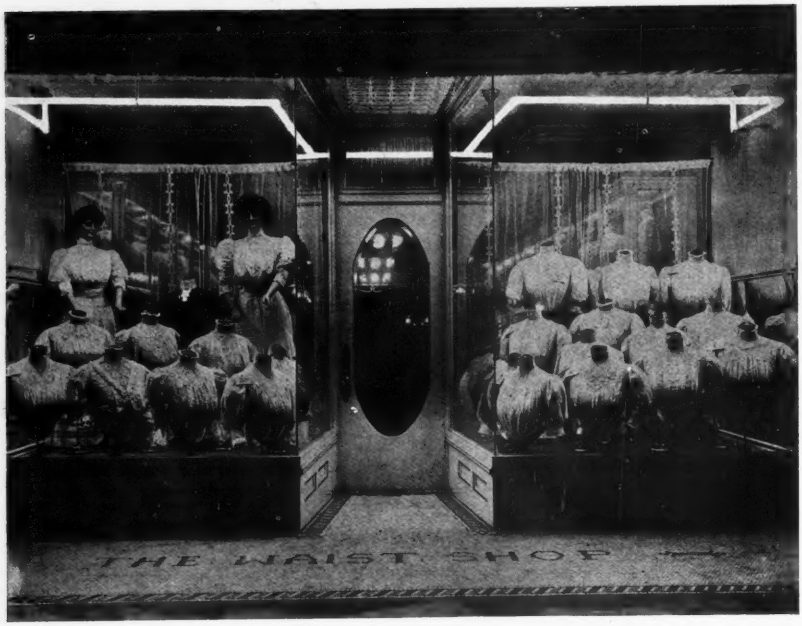
It has long been a familiar fact that when a high tension discharge is passed through a rarefied gas in a glass vessel the pressure in it very soon decreases; that is, the vacuum becomes higher, assuming no leak at the sealing-in of the electrodes.

The gas seems, as it were, to be absorbed. This fact is a familiar one in connexion with Röntgen bulbs, and many have been the devices for lowering the vacuum and making the tube "softer" by reducing the vacuum.

It is generally achieved by heating or sparking against a material contained in the bulb, which has gas occluded in it, whereby the gas is liberated and reduces the vacuum in the bulb. This, however, is not possible in the case of a vacuum tube to be employed in electric lighting. For the last named purpose the process of adjusting the rarefaction of the gas in the tube must be perfectly automatic, and the supply of new gas must not be limited merely by the small amount which can be occluded in, or supplied by, a material sealed up in the vacuum tube.

Mr. Moore has arrived at a practical solution of the problem by the invention of an extremely ingenious automatic valve, which enables the vacuum tube to replenish itself from an external reservoir, or from the unlimited reservoir of the atmosphere as often and as long as required. This valve is controlled by the pressure of the gas on the tube itself, or rather by the change of resistance which accompanies it.

If a tube full of air or other gas has a gradually increasing vacuum made in it the electric conductivity of the tube, for a high tension luminous glow discharge through it, increases as the pressure falls to a certain limit, and then decreases again, so that the gas column has a maximum conductivity corresponding to a certain gas pressure and electric voltage applied.



Moore Lighting Installation, Drapery Store, New York.

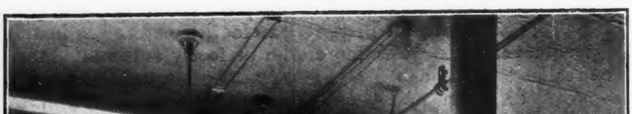


Fig. 2.

Suppose, then, that such a vacuum tube is attached to the secondary terminals of a high tension transformer which supplies a voltage sufficient to make a luminous discharge through the tube, and suppose that the pressure of the rarefied gas in it has been initially so adjusted that it is a little greater than that which corresponds to maximum conductivity, then as the gas is used up in the tube the conductivity will slightly increase. This will cause the transformer, assuming it to be a constant potential one, worked off electric supply circuits, to give out more current on its high tension side, and therefore take in more on its low tension side. This increase in current is then made to operate a valve which admits a small quantity more gas into the tube. The valve itself is shown in Fig. 1. From the vacuum tube a side tube is led off, and this is closed by a plug of porous carbon. A wider tube encloses the plug and end of the tube in which it is placed, and a small quantity of mercury, not sufficient to cover the plug, is placed round it. A hollow glass plunger dips into this mercury, and when it is depressed it forces the mercury up to cover the plug, and so seals the entrance to the vacuum tube. When this plunger is raised it lowers the mercury surface, and exposes the porous plug more or less, so that gas or air can diffuse through it into the vacuum tube. The raising and lowering of the plunger is accomplished by a solenoid, which embraces the outer tube of the valve. The upper part of the plunger contains a bundle of iron wire, and when the current through the solenoid increases it raises the plunger and exposes the end of the porous plug. Hence it will be seen that if this solenoid is included in the primary circuit of the transformer the arrangement for admitting air or gas to the vacuum tube can be made automatic. For as the gas in the vacuum tube is absorbed, so its conductivity is slightly increased, and this will increase the current through the high tension coil of the transformer, and therefore through the low tension and through the solenoid, which in turn will lift the plunger and let a little more gas diffuse through the plug into the vacuum tube. The actual arrangement of the Moore vacuum tube is therefore very simple. A long glass tube, 1¾ inches in dia-

Fig. 1.

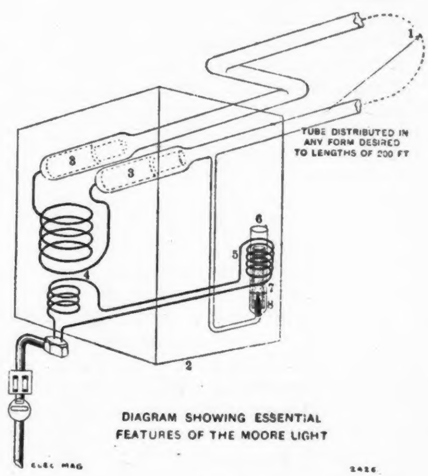


Fig. 3.

meter, is built up in lengths of 6 or 8 feet, the jointing being quickly effected by a special form of gas blowpipe. This tube can be bent as required, and is supported at some little distance from the ceiling or walls of the room by being passed through brass rings (see Fig. 2). It can be extended up to a total length of 200 feet or rather more. The closed ends of this tube are brought into a small iron box, and are equipped with graphite electrodes, which are carried on platinum wires sealed through the glass. To these ends are attached the high tension terminals of a small transformer stepping up the voltage of an ordinary public alternating current supply from say 220 or 440 volts to 10,000 or 12,000, depending on the length of the tube. For tubes from 40 to 70 feet long a 2 kilowatt transformer is required, and for greater lengths as follows :—

80 to 125 feet a 2·75 k.w. transformer.
130 to 180 feet a 3·50 k.w. transformer.
190 to 220 feet a 4·5 k.w. transformer.

The iron box also contains the above-described feeder valve and solenoid, and some arrangement for supplying the required gas. There are, therefore, no exposed high tension circuits, and in the room to be lit what is distributed is light, and not current, whilst in special cases the transformer box itself can be outside the building and the ends of the vacuum tube brought through the walls.

A very important factor in the illuminating value of the tube is the nature of the gas contained in it. According to Mr. Moore nitrogen is about twenty times better than hydrogen and about twice as good as carbonic dioxide for the same expenditure of electric power on it. Nitrogen is also better than atmospheric air. The light of a tube filled with nitrogen is a rich golden colour, and with carbonic dioxide a whitish-blue. The nitrogen required is easily prepared by aspirating air very slowly over phosphorus. Accordingly the most efficient material for the tube contents is easily drawn from the unlimited supply in the atmosphere. The pressure of the gas in the tube is about one-tenth of a millimetre of mercury, and is maintained at that within 0·01 of a millimetre by the valve.

When actuated by an alternating current of a frequency of 50 a tube filled with nitrogen 200 feet in length and 1·75 inches in diameter takes from 0·25 to 0·3 amperes at a pressure of 10,000 to 12,000 volts. The transformer, assuming it to have a step-up 50 : 1 ratio, will then take 25 or 30 amperes at 100 volts. The tube may therefore be said to have a resistance of 40,000 or 50,000 ohms.

The illuminating quality of the tube and its so-called efficiency are the next points of importance. Mr. Moore gives the illuminating power as 12 Hefners per foot run of the tube for the 1·75-inch diameter tube. The author made some measurements on a Moore tube installed in the courtyard of the Savoy Hotel, London. The tube is 176 feet long, and in the form of a rectangle 60 feet by 24 feet. (See Fig. 4.) It is suspended 30 inches below the ceiling, and 17 feet above the ground. By erecting a special photometer the candle power of 1 foot run of the tube was taken by comparison with a small carbon-filament lamp, itself standardized against Fleming large-bulb standard glow lamps known to be correct. The photometer used was as follows :—

A large wooden box or tube was constructed about 5 feet in length and 1 foot square, and lined throughout with dead black velvet. Both ends were open. At one end two semicircular nicks were cut out so that when the end of the box was held against the Moore tube and a flap of black velvet thrown over it, it was as if the section of 1 foot run of the tube was placed transversely through the box.

About 3 feet from the vacuum tube a Lummer-Brodhun prism photometer was fixed, the telescope projecting out through the side of the wood tube. On the other side of the Lummer-Brodhun was arranged a small carbon filament lamp attached to a socket sliding on a brass rod, so that on moving the glow lamp to and fro the illumination on one side of the photometer disc could be varied. This photometer was then calibrated by placing standardized glow lamps of known candle power at various distances from the photometer disc, and noting the position in which the small glow lamp traversed by a fixed and measured current had to be placed to obtain a photometric balance.

Then we have the following problem to consider. The section of the Moore tube 1 foot in length passing across the photometer box has a certain illuminating power per inch run which may be expressed in c.p. Each element of length sends its light to the photometer disc and makes a contribution to the total illumination, which depends upon its absolute distance from the disc and its distance from the centre point of the length of Moore tube intercepted. It is not a difficult mathematical problem to determine from the observed total illumination due to 1 foot run of the Moore tube produced on the photometer disc at a distance of 3 feet the absolute per inch and therefore per foot run of the tube. For if I is the illuminating power of a unit of length, say 1 inch run of the tube, and x is the distance of any small element of length dx of the tube from the centre line of the photometer box, and l is the distance of the photometer disc from the centre of the intercepted length of the Moore, then it is seen that the expression $\frac{I dx}{(l^2+x^2)^{\frac{3}{2}}}$ must be the contribution made to the illumination of the disc by that element. Hence the integral of the above expression equated to the value of the observed total illumination gives us the illuminating power per inch run of the tube. In the actual experiments the wooden photometer tube was erected on a stage 12 feet high, so that the end of the wood tube was just in contact with the Moore tube, and a flap of black velvet was thrown over it to prevent any light reaching the photometer disc except that coming from the intercepted length of the vacuum tube. The candle power was found to be 9·6 British candles per foot. If the ratio of Hefner to British candle is taken at 0·92 this gives nearly 10·5 Hefners per foot. The current supplied to the transformer of this tube on the low tension side was 20 amperes at 220 volts, and the frequency 60 volts. The actual power was measured by a correct wattmeter, and found to be 3,000 watts. Hence the total candle power of the tube is $176 \times 9{\cdot}6 = 1689{\cdot}6$ c.-p., and the efficiency 1.78 watts per candle. These candle-power measurements, however, give very little information as to the real illuminating power of the tube. For one thing the intensity of light from such a linear source, if very long, does not vary inversely as the square of the distance, but more nearly inversely as the distance, for the same reason that the magnetic field of a long, straight current varies inversely as the distance.

Any valid comparison with other illuminants must be based upon the cost of providing an exactly equal illumination in candle feet on a certain surface. This, however, is in some cases impossible. The cost of producing a certain comfortable illumination on a horizontal surface, say 3 feet above the ground, having a certain uniformity, may be taken as one measure of the value of the light for commercial purposes. In the case of the tube above mentioned the illumination in candle feet was taken by an illumination photometer of the Trotter type at 3 feet above the ground at six equidistant places in the space lit, and found to be respectively 1·05, 1·10, 1·00, 1·00, 1·00, 0·95 candle ft. Such a distribution affords a very pleasant shadowless illumination over an area of 4,800 square feet. Hence the total flux of light per watt is $4{,}800 \times 1 \div 3{,}000 = 1{\cdot}6$.

The courtyard can also be illuminated by thirty ordinary glow lamps of 30 c.-p. each, which are enclosed in glass diffusers. On extinguishing the tube and switching on twenty-four of the glow lamps, the illumination on the same level was found to have fallen to 0·1 candle-foot. In fact, to replace the Moore tube by equivalent glow lamps would require at least 100 16-c.-p. lamps uniformly distributed over the ceiling at the same height above the ground as the tube, and these of carbon filament lamps would absorb not less than 6 to 8 kilowatts in place of the 3 kilowatts taken by the tube and transformer.

The tube filled with carbon-dioxide, though not having the same efficiency as the nitrogen tube, has a remarkable power of revealing tinted surfaces in daylight colours, so that it is possible to carry on artistic work of all kinds by it as by day. The above figures as to efficiency are not to be taken as the absolute limit of economy. The intensity of the light from the tube can be regulated from 3 or 4 candle-power per foot of tube up to 18 or 20 c.-p. per foot, and the efficiency of long tubes in total candle-power per kilowatt is greater than that of short tubes. The heat produced is negligible, the tubes never rising above 50° or 60° C. in temperature. The character of the illumination given by the nitrogen tubes is remarkably restful to the eye, and from the perfect absence of shadows is an ideal light for museums and drawing offices, or works in which precision work of any kind is carried on.

There are many scientific problems connected with vacuum-tube lighting yet unsolved. Why, for instance, should nitrogen be so much more efficient than hydrogen or than carbon-dioxide ? The variation of resistance, with pressure, has also to be more fully investigated in the light of what is now known about conduction in gases. We may not yet have nearly reached the limits of possible efficiency by the use of suitable gaseous conductors. The gas required for inspiration is not large, and in most cases is generated as required. For example, carbon dioxide from marble and hydrochloric acid in a Knipp's apparatus, which stops generation of gas when the gas is no longer being drawn off. The nitrogen is obtained from the air by passing it slowly through an iron reservoir containing lumps of phosphorus.

The actuation of the tube of course requires alternating current, and any frequency above 25 volts can be used. If, however, the street supply is continuous current, then a small rotary transformer has to be interposed to convert the alternating to continuous current. The transformer used is one having a power factor of about 0·65, of special design, whereby changes in the primary current make larger changes in the secondary current than would be the case with an ordinary type of transformer. With, however, an improved valve a transformer with much less reactance can be employed making the tube as a whole have a power factor as high as 0·84.

One point of great importance in connexion with vacuum tube lighting is that the light intensity is directly proportional to the voltage, and not to the fourth or sixth power of the voltage, as in the case of metal wire or carbon filament lamps. Hence a variation of the supply voltage is not seen on the lamps to anything like the extent that it is seen in the case of carbon, or even metallic wire lamps.

The experience gained in the use of this new form of lighting in the United States is sufficient to show that this system of vacuum tube lighting can not only compete with, but surpass, incandescent lighting by glow lamps in the matter of economy. Moreover, in first cost it has the advantage. It does away with all costs of interior wiring, and is, in fact, a form of "wireless electric lighting." The cost of erection of a 200-foot tube and transformer is far less than the cost of installing its equivalent in the form of 100 16-c.-p. incandescent lamps, whilst the operating costs per equivalent candle-feet illumination on a table surface is about half that of carbon filament lamps. This type of vacuum tube lighting has not yet been put into operation to any great extent in Great Britain, but no one who has studied it in its commercial and scientific aspects can have doubts that it is destined to find a large field of utility in connexion with certain classes of public and private lighting.

The Production and Utilization of Light.

By Dr. C. V. Drysdale.

INTRODUCTORY.

A comprehensive survey of technical science at the present day throws into prominence the importance of greater attention to the production and utilization of light, as a subject in which there is the greatest need for and prospect of improvement. The progress of civilization has been largely dependent upon facility of locomotion and the conquering of darkness; and even now, when we are infinitely better off in both these respects than our ancestors of only one or two generations back, we feel more than ever the need of further progress. While, however, in locomotion great advances have been made on scientific lines, and the efficiency of our methods is in some cases fairly high, the production of light, until quite recently, has been almost empirical, and its efficiency extremely low. The proportion of useful light energy, for example, in the case of an ordinary candle to the total energy of combustion is probably only about one-tenth of 1 per cent., for an oil lamp or ordinary gas flame about 0·2 per cent., and incandescent gas not more than 1 per cent. Electric lamps are apparently much better, the efficiency of the ordinary glow lamp being 2·5 per cent., Nernst lamp 5 per cent., metallic filaments about 10 per cent., ordinary arc 10 per cent., flame arc 20 per cent., and vacuum tube possibly 40 to 60 per cent.* But it must not be forgotten that in electric lighting the electrical power is derived from the combustion of fuel through the agency of a heat engine, and only in few instances does the efficiency of conversion exceed 20 per cent. This, therefore, brings down the overall efficiency of electric lighting considerably, and the cost of the conversion from heat to electrical energy has also to be taken into account.

The prodigal wastefulness of our present methods of producing light has been forcibly put by Sir Oliver Lodge in his 'Modern Views of Electricity,'* in which he says that a boy turning a handle could, if his energy were properly directed, produce quite as much real light as is given by the furnaces and boilers of a great steam engine driving a group of dynamos. Although this is probably an exaggerated estimate, there is no doubt that the power of one man, if it could be all turned into light, would suffice for fifty 16-c.-p. lamps, and the total energy consumption of a single wax candle should be sufficient to light sixty such lamps, or to brilliantly light a large mansion.

CONVERSION OF ENERGY.

One of the chief functions of engineering is the conversion of energy from one form to another. Energy, as is well known, is indestructible, and it may exist in the static or potential form, as in a bent spring or lifted weight, a chemically active mixture, or an electrically charged body; or in the kinetic form, as in a moving train or bullet, a revolving flywheel, an

* The estimates of luminous efficiency given by various authorities differ widely. The numbers given here are based upon a determination of the mechanical equivalent of light by Mr. A. C. Jolley and the writer, and are probably fairly correct. This subject will be fully dealt with in a subsequent article.

* Second edition, p. 284, *et seq.*

electric current, or as heat or light.* From the point of view of practical conversion it is most convenient to distinguish five forms of energy: chemical, mechanical, electrical, heat, and light; sound being neglected, or considered as mechanical energy. As light and heat are associated together on account of their vibratory nature we may arrange our various forms of energy as in the diagram (Fig. 1), the transformations being represented by connecting lines. With the exception of the conversion of chemical to mechanical energy and *vice versa*, all these transformations can be effected in either direction, but with very varying degrees of ease and efficiency; and it will be seen that the most inefficient conversions are those from heat to either mechanical or electrical energy, or to light. These are therefore the directions in which there is the greatest scope for, and need of improvement.

In the conversion of heat to mechanical or electrical power, however, theory, while guiding us towards improvement, imposes a bar in the shape of the second law of thermodynamics, which leads to the conclusion that higher efficiencies are only to be gained by increasing the limits of temperature, a conclusion which makes the prospect of great improvement somewhat remote. So far as is known, there is no such bar to the production of a perfectly efficient light, in fact the glow-worm and fire-fly appear to have solved the problem; and we now have a mass of theory and of experimental data which, if thoroughly understood, should ere long enable us to make immense improvements. The recent great advances which have been made in both gas and electric lighting by incandescence have all been the result of a realization of the laws of radiation from heated bodies, and of working on scientific lines.

* Strictly speaking, light energy may be continually varying from the kinetic to the potential form, but it is, at any rate, associated with motion.

NATURE OF LIGHT.

It is obvious that for any such scientific investigation into light production it is necessary to have the clearest possible notion of what constitutes light itself. As is generally known now, the overwhelming balance of evidence is in favour of the undulatory or wave theory of light, which asserts that light consists of waves or vibrations in a medium known as the ether, and of such a rate as to excite the organs of vision. This rate must lie between 400 to 800 billions and vibrations per second, and the disturbance is propagated in free space at the rate of 186,000 miles or 300 million metres per second. Vibrations of lower frequency than 400 billions are only sensible to us as heat; between 400 and 800 billions we have light of colours ranging from red to yellow, green, blue, and violet; and above the latter rate they are known as ultra-violet light, and are instrumental in producing photographic and other chemical effects.

These vibrations in the ether are set up by the luminous source which must therefore itself be in a state of vibration. The kinetic theory of heat tells us that all bodies at ordinary temperatures are made up of particles or molecules in rapid agitation, and as the temperature is increased the rate of motion of the particles increases with it. When the temperature is raised sufficiently, the body, as should be expected, begins to glow with a dull red light, showing that some of the vibrations have at length reached the rate of 400 billions per second required to produce this light.* This would at first sight appear to be a sufficient explanation of the excitation of the vibrations in the ether, but since Maxwell's electromagnetic theory of light was propounded in 1865 the conviction has been gradually forced upon us that all radiation requires to be stimulated electrically, and that the

* As a matter of fact, at a temperature far below red heat the body will commence to emit a very faint greyish light, which is only visible if the observer has been for some time in the dark.

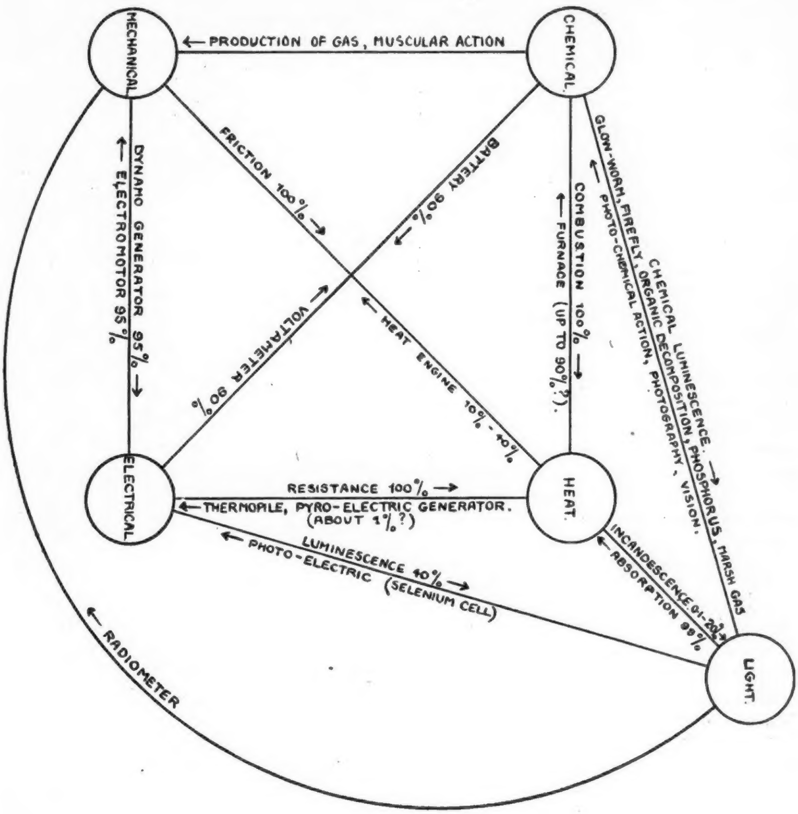


Fig. 1.

motion of uncharged particles is powerless to displace the ether. At the same time we have been aware that in incandescent gases, where the molecules are relatively free from each other's influence, the colour of the light does not depend upon the temperature, but is definitely fixed, as is evidenced by the absolutely fixed position of the bright lines in the spectrum of the gas. This immediately suggests that the vibrations communicated to the ether are not the result of the movements of the molecules as a whole, but rather of movements within themselves, and that the molecules of each gas have special rates of vibration like bells, which give the same note, however they are struck, so long as they are allowed to vibrate freely afterwards.

These two considerations taken together lead us finally to the conclusion that each molecule or particle consists of at least two other particles of opposite electrical charge (as is also indicated from the facts of electrochemistry), and that the collision of these molecules, or any stimulation of them, gives rise to vibrations or distorted orbital motions of these charges or ions, which therefore give rise to electro-magnetic waves in the ether. The positive charges appear always to be associated with the mass of the atom, while the negative charges may exist independently in the form of much smaller bodies termed electrons; and one way of picturing the ordinary atom is that it consists of a central mass of relatively large size surrounded by one or more smaller electrons, like the sun surrounded by planets. When the molecules are far apart, as in a gas, these vibrations or orbital motions take place with the natural frequency or frequencies of the particular molecule, and we have the ordinary line spectrum. On compressing the gas, however, until the molecules are brought nearer together the collisions are more frequent, and forced vibrations are given out of various rates. This should cause a broadening of the lines of the spectrum, as is found to be the case, while if the gas is condensed to a liquid or solid in which the molecules are not freed for any appreciable time from each other's influence, the vibrations are nearly all forced, and of irregular rates, giving rise to a continuous spectrum or mixed light, as is common in all lighting by incandescent solids.

To more clearly illustrate this theory we may conceive a model such as is illustrated in Fig. 2. It consists of a number of exactly similar tubular bells hung side by side in square order, as in Fig. 3, in such a way that by moving a plate at the top the distance between them can be varied. On the top of the apparatus is a comb of steel strips like those in a musical box, or in the now well-known Frahms speed indicators; each successive reed vibrating in unison with a musical note of higher pitch, like the successive strings of a piano. If now the bells are apart, as in Fig. 3, and they are agitated so as to strike against one another, they should give out an almost pure note, as the intervals during which they are in contact with or interfering with each other will be very short in comparison with the time they are swinging freely and vibrating with their natural frequency. This pure note corresponds to a single vibration or spectrum line of a gas in which the particles are far apart, and will cause one of the reeds only to vibrate.

On now bringing the bells up close together, as in Fig. 4, and again agitating them, it is evident that the number of times they come into contact with one another will be greatly increased, and that the free vibrations of the bells will be interfered with:

> "Like sweet bells jangled out of tune."

Other rates of vibrations will be produced, dulling the sound, and causing the reeds adjacent to the first one to be also affected. This corresponds to the broadening of the spectrum line in a compressed gas, or a liquid or solid substance, where the molecules are more tightly packed.

This being said, the problem of efficient lighting is of a perfectly definite character. We have to learn how to stimulate the molecules of a substance, either in the form of solid, liquid, or gas, in such a way as to make it give out electro-magnetic waves of from 400 to 800 billions of vibrations per second, without any outside these limits. The most efficient light, as will be seen later, would be obtained by producing vibrations of about 450 billions per second, which appear to have the greatest effect on the eye; but this would have much the same effect as employing a sodium flame as an illuminant, and all differences of colour would disappear. In order to see objects with natural colours it is necessary to have "white" light, which consists of a mixture of all the rates of vibration between the visual limits. Probably a sufficient approximation to white light would be afforded by light containing seven or eight lines, or, preferably bands, spaced evenly over its spectrum, and it is very probable that the light of the future will be one of this character, rather than one with a continuous spectrum.

(To be continued.)

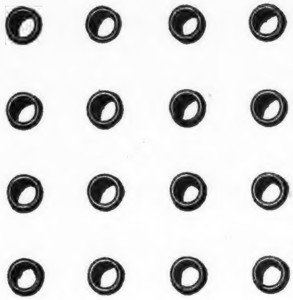


Fig. 3.

Fig. 4.

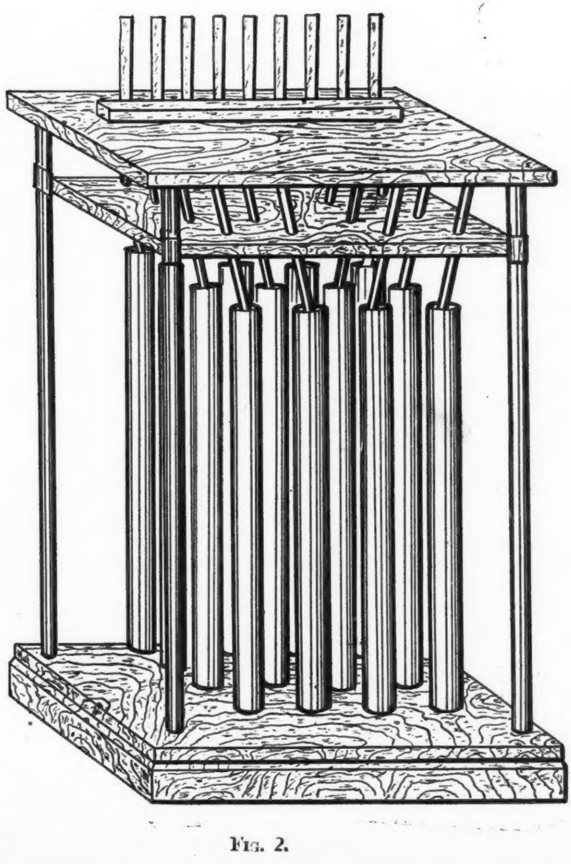


Fig. 2.

Street Illumination.

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

There is probably no branch of the important work of illumination where the knowledge of an expert is so urgently required as in the matter of lighting streets economically and efficiently. It is difficult to give any reason why this branch has been so neglected, affecting, as it does, both the pockets of the ratepayers and the comfort of the general public ; but I am inclined to believe that it is explained by the well-known proverb, "Everybody's business is nobody's business." Thus the nobodies have endeavoured to look after it, and in most cases failed conspicuously.

It is, therefore, very gratifying to me to note that at the recent Convention of the National Electric Light Association at Washington, a specification relating to this subject was drafted. Unfortunately, this only referred to electric lighting, and cannot be considered as a basis on which a general specification could be drawn. Nevertheless, as it indirectly endorses certain views laid down by me in a paper on this subject, read before the Institution of Electrical Engineers at Manchester in 1905, I propose to make certain suggestions, based on these views, which might be of value when drafting a general specification of street lighting.

In this paper I stated that, "In order to judge the lighting of a street, it is only necessary to know the minimum illumination at any point where light is required, because if that illumination is sufficient, it obviously follows that it will be ample elsewhere."

Comparing this statement with the specification above referred to, which states that, "With lamps spaced 200 to 600 ft. apart, the specification for street lamps should define the mean illumination thrown by the individual lamp, in position in the street, as measured at the height of the observer's eye, and perpendicular to the rays, at some point not less than 200 or more than 300 ft. distant, along a level street, from a position immediately below the lamp," it is noticeable that if my suggestion of minimum illumination had been specified, the point of measurement would have been fixed once and for all, namely, halfway between the posts; whereas, by leaving this indefinite, no standard can be arrived at.

The Committee state, as their reason for leaving the distance flexible, that a definitely specified distance "might be unsuitable for purpose of measurement." This I cannot agree with, for the simple reason that at 200 ft. with a ten-ampere arc lamp the illumination would only be about ·015 c.-f. at the most, which is not in any case a sufficiently high degree of illumination to measure with much accuracy. Therefore the photometerist would probably prefer to measure the candle-power of the lamp at that angle which lights the specified point, and calculate the illumination resulting. In other words, to place his photometer at, say, 40 ft. from the post, and at such a height as to intercept the rays to be measured.

This raises another point which the Committee might have considered, namely, that if the illumination at the distance mentioned is to be the basis on which to work, it would be better to specify it on the ground level, thus making it possible for the operator to make the measurement at a more convenient distance from the post and height from the ground.

It is noticeable that the Committee decided that the direct illumination derived from one source of light was the unit to be specified, and with this I am in absolute agreement. Mr. Trotter and others strongly uphold the unit of horizontal illumination, because the light derived from all sources is included therein ; but I contend that this unit is misleading, because in a street the illumination of the road and pavement, which are the only horizontal surfaces, is of comparatively little importance compared with the illumination of the faces of passers-by, numbers on vehicles, doorways, name-plates, &c. For example, a person who does not wish to be recognized stands directly under a lamp, knowing that the light from it will not fall on his face, and that the illumination from the adjacent lamps is too low to make recognition possible. If horizontal illumination were the criterion of good lighting, this would be the most dangerous spot for such a person to stand.

It might be argued from the above that it would be well to specify the direct illumination measured at a lamp-post, but derived from the adjacent lamps; but this would not be satisfactory if the lamps are unequally spaced. I therefore return to my original contention that the best illuminated street is that in which the direct illumination (measured halfway between the posts) is the highest; and I think that in drafting a specification, a clause to the effect that the direct illumination measured at a point halfway between any two sources of light shall not fall below a certain number of candle-feet (or other approved units of illumination) from either source, is all that is required to cover the question of illumination.

In cases of open spaces where lamps are situated in all directions, the point of measurement should be that which is the greatest distance from any source of light.

I would also like to see a clause relating to intrinsic brilliancy introduced into specifications. In the paper above mentioned, I suggested that both the maximum and minimum illumination should be considered, and a limit put on the diversity factor; but I am now inclined to think that something further is required. It is true that the use of large units of light spaced at considerable distances is bad practice, but it is possible to produce excellent results in this way, provided the source of light is reduced in brilliancy by increasing the apparent area. For instance, a 3,000 c.-p. flame arc is less trying to the eye than a 300 c.-p. gas mantle, provided the former is enclosed in an opalescent or other suitable globe. Therefore, if a clause limiting the candle-power per square centimetre of apparent source were inserted, this difficulty would be overcome.

Nevertheless, it would be well to limit the maximum illumination permissible, in order to ensure that, should large units of light be used, they would be erected at sufficient height from the ground to obtain as even illumination as possible.

I would, therefore, suggest that every specification relating to public lighting should contain the following clauses:—

(*a*) That the minimum direct illumination measured at a point halfway between each two sources of light, and at a stated height above the road level, shall not be below a stated figure.

(*b*) That the maximum direct illumination at any part of the street a stated distance above the road level shall not exceed a stated figure.

(*c*) That the candle-power per unit surface of apparent source of light visible from the street by any pedestrian, or person on an ordinary vehicle, shall not exceed a stated figure.

The figure stated will, of course, depend largely upon the class of street, road, or open space under consideration, and the sum which is available for expenditure on illuminating same. But in my opinion the fairest way to deal with a tender of this sort is to ask those tendering to state the actual figures which they guarantee under each clause, and to allot the contract to the tenderer who guarantees the highest minimum illumination, with the smallest diversity factor and the lowest candle-power per unit surface of apparent source of light, for the lowest cost per annum. It is, of course, essential that such guarantee be maintained, but this can generally be ensured, as all firms making genuine offers would be prepared to agree to a penalty clause in the event of non-fulfilment of contract.

Such considerations as the spectrum of the lamps, type of post, and ornamental details do not come within the scope of the illuminating engineer, and can well be left as a solace to those who will be loath to cast from his throne their favourite judge of such matters, namely, the mythical "man in the street."

The Petrol - Air Gas Light.

By W. H. Y. Webber.

It strikes one at first as an example of the irony of things, that after many years of strenuous apostleship of the vacuum incandescent electric light, which has been recommended largely on the score of its not being a light of combustion, and therefore incapable of using up or contaminating the air of enclosed interiors, a real novelty and considerable practical improvement of the world's resources for artificial lighting should arrive in the shape of another flame light.

It is, of course, impossible to order the course of mechanical invention; but one can easily understand that the appearance of the petrol-air "gas" light must arouse a sentiment nearly akin to disgust in the minds of those who had persuaded themselves that the artificial lighting of the future would exhibit some wholly different character. Facts, however, are stubborn; and there is no room for doubt in unprejudiced minds, that the so-called petrol-air "gas" light is something to be reckoned with among the resources of civilization in this kind.

For, after all is said and done, in the vain endeavour to establish for a particular method of supplying a want a reputation for being more "scientific" or "hygienic" than the others, the pressing needs of mankind, which have always an economic basis, will never fail to turn to the cheapest convenient means of obtaining satisfaction.

The necessity for good artificial light remains one of the most imperative calls of a progressive material civilization. Naturally, it is best satisfied in regard to the largest communities; and the flood of light which towns enjoy, while the country is plunged in darkness, is one of the most powerful of the attractions of town life. Consequently, those whose tastes or necessities constrain them to live in the country—which has been defined as "the region beyond the gas-lamps"—or in the less inhabited parts of the globe, miss the good lights of the town perhaps more than anything else. It is, therefore, good news for them that in the new petrol-air light they have at their disposal a really bright, convenient, and cheap means of lighting, competent to reduce very largely the disadvantage in this respect under which isolated houses, mills, churches, hospitals, and so forth, have hitherto lain as compared with town buildings.

I do not believe for a moment that there is any room worth mentioning for petrol-air lighting where either town gas or a public electricity supply can be had cheap. Nobody at this time of day is going to give himself unnecessary trouble over home-made gas, when he can have it laid on from the mains. Something very remarkable and considerable would have to be assured as compensation for undertaking any extra domestic or shop expense and responsibility of the kind in question; and this does not exist.

We see the working of this principle of cutting down individual pains and labour in the disuse of oil lamps and bedroom candles, for all their cheapness and æsthetic merits, by town dwellers. People simply will not be bothered with such things.

In the country and abroad, however, the appeal of the petrol-air light is to those who are eager to do or to pay anything in reason for a brilliant and systematic artificial light, by which people can work or play as they do in the town. It is not my business to discuss the drawbacks of older means of supplying this want. I am disposed to think that the once familiar branch of gas engineering, which laid itself out to provide gasworks for private mansions and country institutions, which was stunned for the time being by the electric light, may yet revive under the influence of the brilliancy and cheapness of incandescent gas lighting, and the convenience of gas cooking and warming.

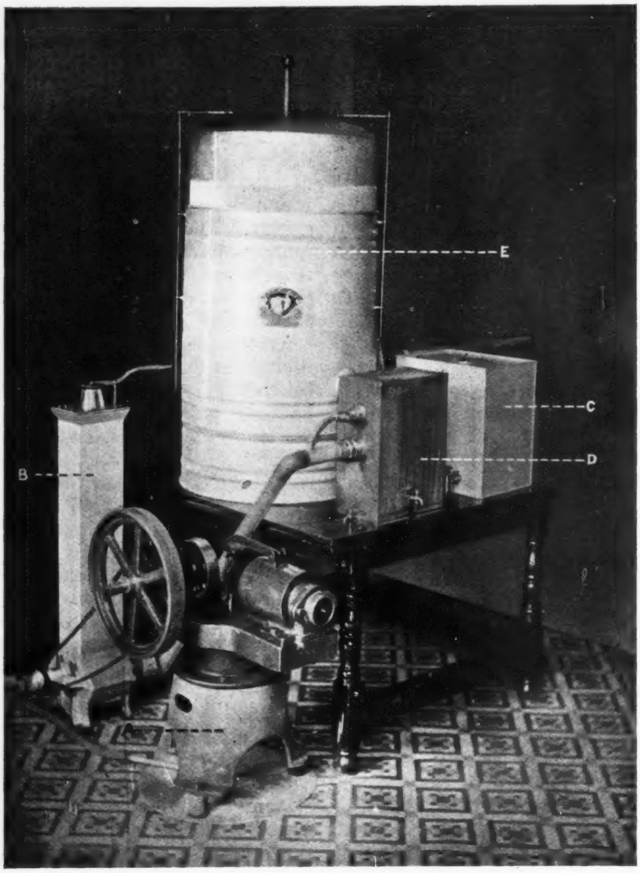
But, in the meantime, the petrol-air light is available for the purpose at a very small initial and running cost. To pipe a building for gas of any kind costs not more than one-fifth the expense of electric wiring; and the petrol-air "gas" generating apparatus is simplicity itself. It can be had in stock sizes ranging from 20 to 100 lights. The smallest size is naturally the dearest proportionately; but it only costs about 2*l.* per light capacity, and the larger sizes run to 1*l.* 10*s.* per light, or less.

The so-called petrol-air "gas" is not gas at all, but merely air very lightly carburetted with petrol vapour. There is in the system the incidental, but very real advantage, that there is sure to be about a country house or institution somebody who is familiar with the handling of petrol for motor-car work so that the simple rules relating to the carburetting of air for lighting are likely to present no strange difficulties. The most remarkable feature of the system is the extremely small proportion of petrol added to the air—not more than 1½ per cent. All the different makes of plant in the market adhere to this proportion of 98½ per cent. of air to 1½ per cent. of petrol vapour. The main thing to make sure of in selecting a plant of the kind is that it will constantly make this particular mixture, and no other.

Every plant comprises the elements of a vessel containing the petrol, the carburetter, the small relief gasholder and governor which ensures the automatic operation of production corresponding to the demand, and the hot-air engine for driving the air blower.

The process is necessarily a power one, since the air must be mechanically driven into the carburetter, and so onward. This is effected by the use of the combustible mixture itself, which is caused to burn under the engine. The process is started by pulling round the fly-wheel for a few revolutions by hand, by which the mixing is commenced. As soon as the engine burner begins to work, the rest goes on *ad lib.* The plant occupies a very small space. Of course the petrol tank wants taking care of, but the working parts of the plant are quite harmless. The "gas" is usually advertised as "non-explosive," which is not quite correct. Any gaseous mixture which will burn is also explosible under favourable conditions. This petrol-air blend, however, is so poor a combustible, that the moment it escapes into the air from a burner, or, say, from a leak in the piping, it becomes so diluted by the surrounding air—drowned, so to speak—that it ceases even to be combustible, and consequently cannot explode. This constitutes its safety. So long, therefore, as the machine cannot make a richer mixture, the system is safe enough. A much richer mixture would not burn properly in the burners; so that any mistake in this direction would be promptly indicated.

The cost of making the mixture is variously stated by different manufacturers of the plant; but it is agreed that a gallon of petrol may make about 1,500 cubic feet of it. If the retail price of petrol were to rise to 1*s.* 6*d.*, therefore (it is now 1*s.* 4*d.*), the prime cost of the "gas" would be only 1*s.* per 1,000 cubic feet for the raw material. The upkeep of the plant must be inconsiderable, and the labour cost might almost be neglected. For lighting the mixture is useless, except with suitable incandescent mantles, either upright or inverted. Obviously, as the mixture contains all the air for an illuminating power of about 47 candles. This makes a very convenient lighting unit for indoor use. Compared with ordinary town gas, light for light, petrol-air has an efficiency, as above, of 5 candle-power per cubic foot, as against 20 candle-



"GLOBE" PETROL-AIR GAS MACHINE: A, hot-air motor driving air drawn in through the drying chamber, B, into the carburetter D, on its way to the gasholder and regulator E. C is the petrol tank.

necessary for combustion, special burners, which do not increase the air supply, are needed for its combustion.

The consumption per burner is usually about 9 cubic feet per hour power per cubic foot for town gas burnt in the ordinary way at the pressure of the mains. The latter figure can be doubled at the cost of just such power plant as goes to the production of the petrol-air mixture, in which case the comparison stands at 1 to 8, that is to say, town gas at 4*s.* per 1,000 cubic feet is equivalent to petrol-air, when burnt in low-pressure Welsbach lamps of any pattern; or at 8*s.* per 1,000 cubic feet if burnt at high pressure, after the same fashion as the petrol-air mixture.

For fuel purposes the difference is also considerably in favour of town gas, because the calorific power of the petrol-air mixture is 90 B.Th.U. per cubic foot, as against 540 B.Th.U. for common town gas, which is therefore its equivalent at the high price of 6*s.* per 1,000 cubic feet. In point of fact, it is not very useful for cooking or heating purposes, as, although the flame-temperature is high, the bulk required to do any serious amount of heating work is excessive, rendering the management of the flames difficult.

It is claimed as an advantage that the petrol-air mixture has no odour; but clearly this character is not an unmixed benefit, as there is no indication to the senses of any amount of leakage. On the whole, I do not foresee any disabling degree of danger attaching to the proper use of the petrol-air light, although I certainly cannot certify that the plant is "fool-proof." The consent of the Fire Offices must be obtained for the introduction of the system into inhabited premises; and the usual precautions are required with regard to the rather considerable bulk of petrol to be stored. Not the least recommendation of a good plant of this kind is the absence of any evil-smelling residuum to get rid of. The business probably has a future, but should be disentangled from some of the absurd claims put forward by certain of the firms engaged in the trade—claims which, I regret to say, are backed up in some instances by individuals of some pretensions to rank as men of science who ought to know better.

Researches on Reflected and Transmitted Light.

By Dr. Hugo Krüss.

All portions of a luminous image, projected upon a screen, can never appear equally bright to the observer.

This arises, firstly, from the fact that the rays of light which strike the midpoint of the screen, do so vertically, whereas the rays striking the edges do so at some angle depending upon the dimensions of the screen and the distance away of the source of projection; and secondly, from the fact that the observer himself looks at the different portions of the screen at a different visual angle.

As regards reflected light, the variation in brightness is so slight as to be hardly perceptible, provided the screen consists of some good dull white material which is not shiny. But in the case of *transmitted* light it may be very considerable.

The diminution in brightness of a surface, illuminated from the front, follows Lambert's law up to angles of 30 degrees, varying as the cosine of the angle. For greater angles than this, the diminution in brightness is proportionally greater.

According to my experiments the brightness of an illuminated plaster of paris surface appears as follows, when viewed at the angles stated :—

Degrees.	*Brightness.*
0	100
30	87
45	64
60	40

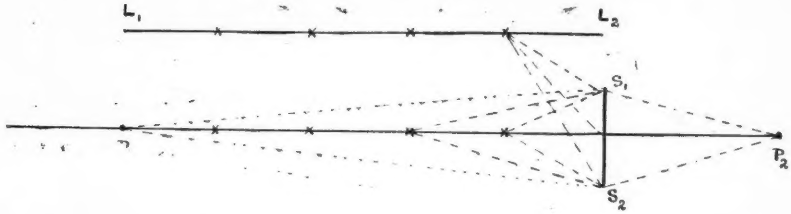
In the case of transmitted light the image is thrown upon the screen in a direction immediately opposite the observer. For this purpose tracing paper—linen, wetted, or soaked in wax—or, finally, a sheet of frosted glass, may be used. More recently it has become customary to use the latter almost exclusively for the purpose.

The transparency of such frosted glass sheets varies very greatly according to the nature of the frosting. In general, however, such plates allow a comparatively large amount of the light falling on them to pass through, so that the image appears very bright, if one looks at it in line with the rays striking the glass, but appears very much darker when observed from other directions. The finer the frosting the more marked is this difference.

In this connexion I have made comparisons between a finely etched and a coarsely frosted glass plate. If one takes the brightness of the image in the direction of the impinging rays as 100, the relative brightnesses corresponding to the angles specified below work out as follows :—

Angle between the direction of the rays striking the glass plate, and the direction of vision.	Finely etched plate.	Coarsely frosted plate.
0 Degrees	100	100
5 ,,	87	89
10 ,,	47	57
15 ,,	9·8	34
20 ,,	3·1	13
25 ,,	1·7	9·7
30 ,,	—	4·8
40 ,,	—	2·4
60 ,,	—	0·7

By the help of these data I have calculated out some figures which illustrate the variation in apparent brightness of the midpoint and right and left extremities of an illuminated screen when viewed from different positions in a room. For this purpose it is necessary to assume certain definite dimensions.



Let us suppose that the illuminated screen S_1 S_2 is 4 metres in breadth, and that the source of radiation P_1 is 25 metres from the screen S_1 S_2, when we are dealing with reflected light. In the case of transmitted light this distance will be chosen as small as possible. I will suppose that the source P_2 is placed 9 metres from the screen S_1 S_2; if the distance is reduced, the conditions are less favourable.

On these assumptions let us calculate the angles at which the rays from the two sources P_1 and P_2 strike the two extremities of the screen S_1 S_2.

This has been worked out in the case of an observer standing on the central line P_1 P_2, and also for one standing on the line to the side L_1 L_2, which is 5 metres distant from the central line P_1 P_2. We can next calculate the apparent brightness of the middle and extreme edges of the screen under these conditions, the distance of the observer being increased at intervals of 5 metres. These values of the brightness are shown in the table, the apparent brightness of the mid-point of the screen, as seen by an observer situated on the central line being again represented by 100. For the opaque screen a dull white plaster of paris surface is assumed, for the transparent screen a coarsely frosted diffusing glass plate.

In the case of reflected light the variation in the brightness of different regions of the illuminated screen are so minute, as to be only perceivable with difficulty by observers standing on the central line; and even in the case of an observer standing on the sideline, the difference is relatively small.

REFLECTED LIGHT.

Distance in Metres.		5	10	15	20
Observer on Central Line	Left edge	93	98	99	100
	Middle	100	100	100	100
	Right edge	93	98	99	100
Observer on Side Line	Left edge	85	95	98	99
	Middle	64	89	95	97
	Right edge	37	64	82	89

TRANSMITTED LIGHT.

Distance in Metres.		5	10	15	20
Observer on Central Line	Left edge	2	11	13	17
	Middle	100	100	100	100
	Right edge	2	11	13	17
Observer on Side Line	Left edge	17	92	97	92
	Middle	2	8	17	38
	Right edge	0	1	2	25

On the other hand, the variation in the apparent brightness of the screen illuminated by *transmitted* light, as seen by an observer in any position in the hall, is so irregular as to render this method of projection inadvisable. The figures quoted are naturally only applicable to the particular variety of frosted glass considered; but this was comparatively well adapted to the purpose for which it was intended, so that very much better results with some other kind of glass are not to be expected.

Finality Reached in Gas Testing.

By W. Grafton.

Uniformity can be secured by using burners which will only yield the maximum light of the gas; and it matters very little what burner is employed so long as this one great object is secured alike for testing the quality of the gas as for the consumer's use.

To secure the maximum light at all times is to obtain finality; but it is questionable whether the good result obtained with modern argands is at the same time the extreme possible for the consumption of 5 cubic feet an hour. Gas-testing law and method dates back a number of years, and therefore it will be well to consider some of the enactments that have been framed in order to secure universal and uniform testing of gas of average quality, but particularly that of from 14 to 16 candles, commonly supplied to the public.

The illuminating test is the best to apply, and far better than a calorific one, because gas is supplied to give light (without the use of a mantle), and it cannot yield light without heat, and consequently its illuminating power is an indirect measure of its heating value. By having the quality gauged only by a calorific test there is nothing to prevent a non-luminous gas being supplied; and besides being not only against the interests of the gas industry, it would entail far more trouble in working to a minimum number of calories per cubic foot than most people imagine.

Most Acts of Parliament relating to the supply of illuminating gas in England specify that the gas shall be burnt at a fixed or nominal 5 cubic feet per hour, also the type of burner, but not always the length of chimney to be employed.

Turning back the pages of history we find that Clause 25 of the Metropolis Gas Act, 1860, provides, so far as London was concerned, that

"the quality of the common gas supplied by any Gas Company shall be, with respect to its illuminating power......such as to produce from an argand burner having 15 holes and a 7-inch chimney consuming 5 cubic feet of gas an hour, a light equal in intensity"

to so many candles. Here specifically defined are the number of holes in the burner, the length of chimney to be employed, and the rate per hour at which the gas is to be consumed. Nothing is stated as to the kind of gas, and it appears as if it also did not matter how it was burnt, so long as these three requirements were satisfactorily complied with. To this vague description may be ascribed an enormous amount of error and dissatisfaction, for although there is no doubt it was the intention, express and implied, of the Legislature to give the companies the full benefit of the most suitable burner for displaying to the best advantage the quality of the gas supplied to the consumer, it is also quite evident that the worst burner was never contemplated by Parliament, as such would naturally depreciate the quality of the gas.

It is not a case of nominal candle value. The Statute states 13, 14, 15, 16, and the like value in candles, and means what these figures represent, not any approximate or depreciating value. Gas is not like an electric glow-lamp, having one value to-day and another to-morrow; it does not last but is consumed, and so the quality of succeeding supplies of gas must be of the same value as the first, or, in other words, the candle value must be maintained day by day. This being so, there is no such thing as nominal candle value for gas, nothing, aye nothing, else but the real value, and that must be the "greatest" obtainable by an argand burner, not a value attributed to it by the flat flame, any more than that by the thoria-ceria mantle.

In the Birmingham and Staffordshire Gas Act, 1864, the standard burner then was to have 15 holes and a 7 in. chimney for 14 candle gas. From want of more intimate knowledge of the subject, the Legislature was induced to select a burner which is far from being suitable as a standard. Suppose the gas to be not greater than 14 candles with this burner, a more carefully designed burner would show it to be more, and for which the gas company would gain no credit, because the burner might not be of the same description. The consent of Parliament must be obtained before a 24-hole burner can be employed.

Besides, in those days, and the same belief is held by very many to-day, if the gas be more than 14 candles, it is very probable, when tested by the standard, to be recorded as less than 14, because, if the rate of gas be maintained at 5 feet an hour, the burner will smoke, and consequently give less light. To obviate this, the examiner is compelled to neglect this regulation in the Act, reduce the consumption, and so increase the illuminating power as if read off from the photometer to the standard of 5 feet, by a rule of three calculation. This is a source of error that is increased as the rate of consumption of coal gas is reduced in the argand burner. The following tests show this:—

QUALITY OF GAS AT LESS RATES.

Quantity consumed.	Corrected to 5 ft.
5·0 cu. ft. per hour	14·30
4·9 " "	14·03
4·8 " "	13·90
4·5 " "	12·60

Even the No. 2 Metropolitan burner, with its form of air regulation, cannot avoid this loss of light in greater proportion to the reduced gas, clearly showing that the burner is not properly designed and constructed, for it is possible to make the gas smoke in this burner, and yet yield a higher value for the gas than when not smoking.

Now the rule of three is applicable for estimating the light given in proportion to the quantity consumed, within wide limits, in the Parliamentary Standard Argand (Fig. 1). This is proved by the fact that the results obtained at other rates than at 5 cubic feet are within a tenth of a candle of each other, and this is one degree in uniformity and finality.

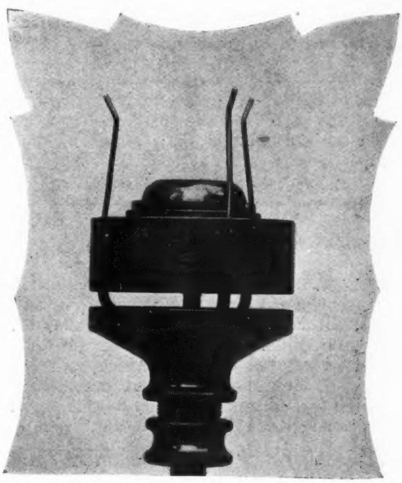


FIG. 1.—PARLIAMENTARY STANDARD 15-HOLE ARGAND.

The burner most generally in use as a standard for gas testing throughout Britain and the colonies is that known as Sugg's burner, the top of which is formed of steatite having 15 holes and requiring a 7 in. chimney. As previously stated, all Acts relating to the testing of gas distinctly state that the gas shall be consumed at a stipulated rate, and shall equal a given number of candles. Now, if the gas be richer than that required by the Act, and no proper provision made for recording its true value, it is, as shown in preceding experiments, very likely that a much less value may be given to it than it really possesses. Nevertheless, the consumer reaps no advantage by the increase in quality, because he is not bound to consume a specified quantity per hour, but requires only to obtain from each burner a certain amount of light, so that he gets the full quantity of light prescribed by the Act, and in addition, wastes his gas and pays more for it, by reason of its superior quality. These days are not bound up in flat-flame burners, but in incandescent mantle burners, and high quality gas disfigures such with carbon deposits.

The following are examples of Parliamentary testing clauses, dating back to 1867 and 1868, and which are still in force in very many towns :—

I. "All the gas supplied by the Local Board shall be of such lighting power at the place of testing the gas as to produce from an argand burner having 15 holes and a 7-inch chimney, and consuming 5 cubic feet of gas an hour, a light equal in intensity to the light produced by fourteen sperm candles of six to the pound burning 120 grains an hour."

II. Gas Act of 1868 :—

"All the gas supplied by the Company shall, after the 31st day of December, 1868, be of such quality as to produce from an argand burner, having 15 holes and a 7 inch chimney, and consuming 5 cubic feet of gas per hour, a light equal in intensity to 14 sperm candles."

III. Also in 1868 Parliament laid down this rule :—

"The burner for testing illuminating power shall be such as shall be most suitable for obtaining from the gas the greatest amount of light."

IV. Then again as if to emphasize this regulation modern enactments—*vide* The London Gas Act 1905, and in other Acts of more recent date—define the *burner and its use* to be such as to obtain from the gas at "5 cubic feet an hour the greatest amount of light."

The best standard burner for testing gas is, at the same time, the best self-luminous burner for the consumer, as the principles to be observed in the construction of both are identical, and may be stated thus :—

That the quantity of gas to be consumed shall arrive at the point of ignition by an easy and regular flow, and at such a velocity, that after passing through the holes in the top, the carbon particles or illuminants contained in the gas shall be wholly raised to the highest degree of incandescence, yet be fully consumed by the time the flame nearly reaches the top of the chimney.

That the quantity of air for the proper combustion of the gas shall be so regulated, that every portion of the flame shall receive a slow, steady, uniform, but ratioed supply, but not in excess as to destroy the particles so rapidly as to evolve heat without light.

The burner shall be capable of consuming to the greatest advantage in developing the illuminating power, a like volume of any illuminating gas, whether it be coal gas, carburetted water gas, or mixed gases.

The burner that complies with these requirements is the "Parliamentary Standard Argand having 15 holes and a 7 in. chimney." Fig. 2 represents the burner consuming gas without any air regulation, and in which the air drawn in by the chimney is in excess, and is not utilized except in distorting and bunsenizing the flame, so that it is robbed of light, but not of heat. Fig. 3 shows the effect of bringing the air under control by the "perfect regulator." The flame assumes its proper length, and emits the "greatest amount of light" when it "fits" the chimney. It is principally owing to this slow rate of flow of gas and air that argand burners yield, with ordinary illuminating gas, a better light per unit of gas consumed than is possible from flat-flame burners.

The regulator then is used to assist the gas examiner (or consumers) in representing justly the illuminating power, so that if the gas supplied to the public be better than that prescribed by Act of Parliament or agreement, it may be so recorded by the official, in the same manner as it would undoubtedly be if it were below the standard quality. If, however, the gas is so rich in quality that the flame is smoking at 5 feet, the rate may be reduced until the flame burns within the chimney, and with the air regulator

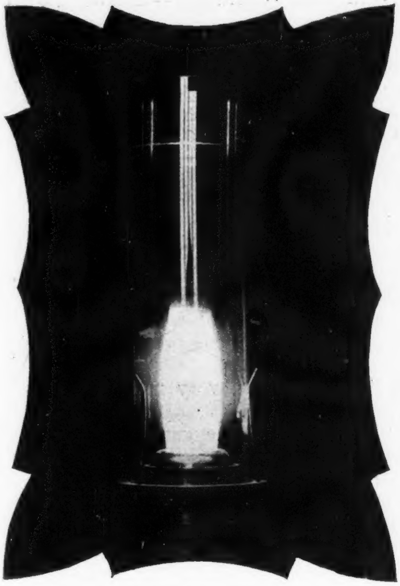


FIG. 2.—FLAME WITH EXCESS OF AIR IN 7-INCH CHIMNEY.

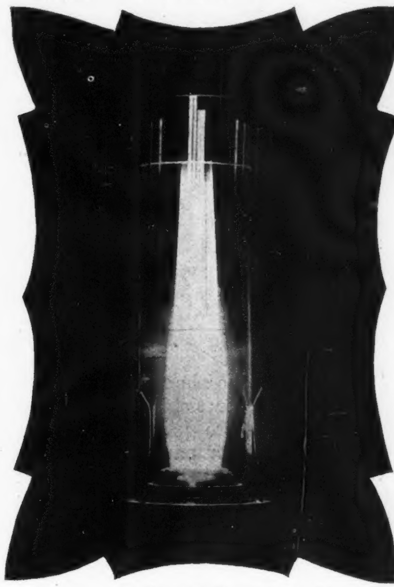


FIG. 3.—"PERFECT" SUPPLY OF AIR AND "GREATEST AMOUNT OF LIGHT."

full open the burner, unlike others, still developes the "greatest amount of light" from that quantity consumed. A simple calculation, based on the amount of light found and the rate of gas used, gives the true value for 5 cubic feet, just as if the 5 feet had been consumed; and so finality is reached by obtaining the "greatest amount of light" capable of being found and prescribed by the Act.

On this point of extra good gas, the London Gas Referees prescribe that

"if the gas is so rich that it cannot be made to burn at the prescribed rate without tailing above the chimney or smoking, or if the burner cannot be pushed far enough away to produce equality of illumination on the photoped, the rate must be reduced until the flame bu ns properly within the chimney."

The No. 2 Metropolitan burner, however, does not obtain for the gas "its greatest amount of light," although the result may be better than that obtainable by the No. 1 London argand using either the 5 cubic feet or 16 candle-flame method.

The following results clearly show the superiority of the Parliamentary Standard Argand, using a 7 in. chimney and 5 cubic feet of gas an hour, over the No. 2 Metropolitan burner, using a 6 in. chimney and similar rate of consumption, by the air regulation and prescribed method of testing.

Some results are also given with a 6 in. chimney on the former burner and a 7 in. one on the (No. 2 Metropolitan) latter, by way of showing a complete comparison, and a proof of uniformity.

COMPARISON TESTS WITH COAL GAS.

Parliamentary Standard Argand.	No. 2 Metropolitan Argand.	
7-in. Chimney. Candles.	6-in. Ch'y. Candles.	7-in. Ch'y. Candles.
14·75	13·87	13·10
14 94	14·28	13·74
15·21	14 70	—
17·07	15 76	—
18·50 (slightly smoking full air).	17·65	—

COMPARISON TESTS WITH CARBURETTED WATER GAS.

Parliamentary Standard Argand.		No. 2 Metropolitan Argand.	
7-in. Ch'ney Candles.	6-in. Ch'ney Candles.	6-in. Ch'ney Candles.	7-in. Ch'ney Candles.
23·95	—	**21·02**	19·46
23·46	—	**20·30**	18·90
21·37	—	**18·11**	17·32
21·10	21·15	**18·20**	—
20·20	20·25	**18·26**	19·11
20·07	20·05	**17·38**	18·90
18·11	—	**16·00**	13·40
16·00	—	**13·97**	13·05

COMPARISON TESTS WITH MIXED GASES.

Parliamentary Standard Argand.		No. 2 Metropolitan Argand.	
7-in. Ch'ney Candles.	6-in. Ch'ney Candles.	6-in. Ch'ney Candles.	7-in. Ch'ney Candles.
15·12	15·24	**14·10**	13·27
15·68	15·79	**14·56**	14·20
17·72	—	**16·27**	15·97
19·31	19·30*	**18·30**	—

* At 4·73 cu. ft. per hour.

The whole of the above figures speak for themselves, particularly the legal methods which are printed in black type to facilitate comparison.

One thing is certain, the Metropolitan burner cannot efficiently consume any gas in order to get "its greatest amount of light," but it can burn the gas, even up to 18 candles, very much as flat-flame burners do.

The future of the gas industry depends upon obtaining from the test burner the whole of the light the gas possesses, and nothing short of this should be accepted by gas authorities if they are to supply a low-priced gas.

The Artificial Illumination of Schools

By S. W. Cuttriss, M.I.E.E.

The question of the efficient illumination of schools is one which has been much neglected in the past, but the Education Authorities are now waking up to the importance of the subject in its bearing on the deterioration of eyesight seen in children of the present generation. The increased stress caused by the modern curriculum necessitates more work under conditions of artificial light, and if this is bad it must react on the nervous system, affecting more or less injuriously the general health as well as the eyesight of the student. The question is not one merely for the electrical engineer, but it is of equal, if not greater, importance when gas is the medium used, and there is undoubtedly ample opportunity for the *Illuminating Engineer* to make it a special study.

By efficient illumination is not meant solely the question of electrical efficiency (when electricity is used) to the illumination obtained, or the most light for the least cost, but, what is of more vital importance to the health of the scholar, the best distribution and intensity of illumination so as to cause no unnecessary strain on the eyes, at the same time giving a cheerful appearance to the room. It is not merely a question of the number and intensity of the light sources, but a consideration of illumination obtained—which means the value of the light reflected from the objects looked upon.

How often does one see a number of naked gas jets or incandescent electric lamps fixed at a height of 6½ or 7 feet above the floor, many of which are in the direct line of vision between the pupil and the teacher or blackboard. The unprotected light shines direct into the eye, which becomes dazzled; the sensitiveness is lost, and the object looked at is only indistinctly seen through the intervening glare. When the eye is cast down to the desk a sensible time elapses before readjustment takes place, the sight is indistinct, and a constant repetition of these violent changes results in an aching or pricking sensation in the eyeball, the effect of unnecessary strain on the optic nerve.

Seeing there is such an objection to having the light shine direct into the eyes, it might be thought that an ideal system would be one giving perfect diffusion with the light sources hidden from view, the light being reflected from the ceiling and walls. Perfect diffusion may be tolerated in some cases and under special conditions, but for class-room lighting it is not to be desired. The great objection is the absence of definite shadow, which is so essential in giving form and solidity to surrounding objects and the idea of perspective.

Further, it would be very inefficient and expensive in operation. The ceiling and walls forming the diffusing surfaces quickly lose their freshness, and the loss of light would be enormous. Experiments with indirect lighting, both by arc and incandescent lamps, have been made both on the Continent and in America, but, so far as the writer is aware, the results have not justified permanent installation. Diffusion is a very good thing, up to a certain point, but it should not be pushed to an extreme, so that the usual effects of moderate light and shade are lost.

In my experience the best, and at the same time most economical system, is to well subdivide the light, and arrange the lamps so that the preponderance of incident rays comes from a position behind the left of the worker. Suspend

Comparison Tests with Carburetted Water Gas.

Parliamentary Standard Argand.		No. 2 Metropolitan Argand.	
7-in. Ch'ney Candles.	6-in. Ch'ney Candles.	6-in. Ch'ney Candles.	7-in. Ch'ney Candles.
23·95	—	**20·02**	19·46
23·46	—	**20·30**	18·90
21·37	—	**18·11**	17·32
21·10	21·15	**18·20**	—
20·20	20·25	**18·26**	19·11
20·07	20·05	**17·38**	18·90
18·11	—	**16·00**	13·40
16·00	—	**13·97**	13·05

Comparison Tests with Mixed Gases.

Parliamentary Standard Argand.		No. 2 Metropolitan Argand.	
7-in. Ch'ney Candles.	6-in. Ch'ney Candles.	6-in. Ch'ney Candles.	7-in. Ch'ney Candles.
15·12	15·24	**14·10**	13·27
15·68	15·79	**14·56**	14·20
17·72	—	**16·27**	15·97
19·31	19·30*	**18·30**	—

* At 4·73 cu. ft. per hour.

The whole of the above figures speak for themselves, particularly the legal methods which are printed in black type to facilitate comparison.

One thing is certain, the Metropolitan burner cannot efficiently consume any gas in order to get "its greatest amount of light," but it can burn the gas, even up to 18 candles, very much as flat-flame burners do.

The future of the gas industry depends upon obtaining from the test burner the whole of the light the gas possesses, and nothing short of this should be accepted by gas authorities if they are to supply a low-priced gas.

The Artificial Illumination of Schools

By S. W. Cuttriss, M.I.E.E.

The question of the efficient illumination of schools is one which has been much neglected in the past, but the Education Authorities are now waking up to the importance of the subject in its bearing on the deterioration of eyesight seen in children of the present generation. The increased stress caused by the modern curriculum necessitates more work under conditions of artificial light, and if this is bad it must react on the nervous system, affecting more or less injuriously the general health as well as the eyesight of the student. The question is not one merely for the electrical engineer, but it is of equal, if not greater, importance when gas is the medium used, and there is undoubtedly ample opportunity for the *Illuminating Engineer* to make it a special study.

By efficient illumination is not meant solely the question of electrical efficiency (when electricity is used) to the illumination obtained, or the most light for the least cost, but, what is of more vital importance to the health of the scholar, the best distribution and intensity of illumination so as to cause no unnecessary strain on the eyes, at the same time giving a cheerful appearance to the room. It is not merely a question of the number and intensity of the light sources, but a consideration of illumination obtained—which means the value of the light reflected from the objects looked upon.

How often does one see a number of naked gas jets or incandescent electric lamps fixed at a height of 6½ or 7 feet above the floor, many of which are in the direct line of vision between the pupil and the teacher or blackboard. The unprotected light shines direct into the eye, which becomes dazzled; the sensitiveness is lost, and the object looked at is only indistinctly seen through the intervening glare. When the eye is cast down to the desk a sensible time elapses before readjustment takes place, the sight is indistinct, and a constant repetition of these violent changes results in an aching or pricking sensation in the eyeball, the effect of unnecessary strain on the optic nerve.

Seeing there is such an objection to having the light shine direct into the eyes, it might be thought that an ideal system would be one giving perfect diffusion with the light sources hidden from view, the light being reflected from the ceiling and walls. Perfect diffusion may be tolerated in some cases and under special conditions, but for class-room lighting it is not to be desired. The great objection is the absence of definite shadow, which is so essential in giving form and solidity to surrounding objects and the idea of perspective.

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In my experience the best, and at the same time most economical system, is to well subdivide the light, and arrange the lamps so that the preponderance of incident rays comes from a position behind the left of the worker. Suspend the lights at a considerable elevation, and protect the eyes from the direct glare of the light by partially obscured globes.

It is not possible toa dhere rigidly to the rule that the light should come from a position over the left shoulder; but there is no reason why a bias should not be given in that direction, so that the strongest shadows are thrown away from, instead of towards the sight. The effect of direct reflection from white paper is to produce eye strain. The sources of light may be shaded from the eye, and yet, owing to the slope of the desk and the angle at which the incident rays strike the paper, reflected rays pass direct to the eyes. Try the effect of this reflection when reading a newspaper, and it will be at once apparent how comfortable reading is interfered with.

The calculation of the number and candle-power of the lamps required to give the desired illumination is a subject which requires separate consideration, and I do not propose to deal with it in the present article. In an article on the 'Artificial Illumination of Interiors,' which appeared in *Electrical Engineering*, January 31st, 1907, the writer discussed the subject from a theoretical point of view. The results then arrived at are shown in Fig. 1.

In several of the schools with which the author is acquainted the general system of distribution is illustrated in Fig. 2.

Each class-room is fitted with four clusters, each of 3·16 c.-p. clear bulb incandescent lamps, hanging vertically about 7½ ft. above the floor, with 10 in. opal shades over each lamp. The clusters are controlled by independent switches fixed near the door. This gives an "Installation" candle-power of about ·33 per square foot of floor, and approximately 1·4 watts per square foot.

At the time these schools were fitted the plan adopted was considered satisfactory, but experience shows it to have serious defects. The illumination is uneven, being localized too much underneath the clusters; the lamps are not high enough to be out of the line of vision, and the clear globes allow the glare of the unprotected filaments to annoy the vision.

All the switches being near the door, it was found that there was great waste of current by the cleaners, who turned on all the lights when half at the most would have given ample illumination for their purpose.

With a view to improving the illumination, and at the same time reducing the waste of current, I was instructed to make experiments in one of the

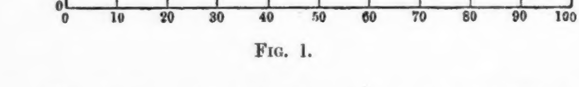

FIG. 1.

The curves indicate approximately the number of square feet of floor area which may be allowed per 1·16 c.-p. lamp, to give an average illumination of 1 candle foot on the floor, premising a white ceiling and various-coloured walls.

schools, as it was desired to adopt the most approved system in a large secondary school then in course of construction. The plan finally adopted is illustrated in Fig. 3. Instead of clusters, 10 single-light pendants are used. These are not distributed evenly over the ceiling, but mostly hang over the desks, and towards the left side of the room when looking at the black-board.

The lamps are the large bulb type, with half-frosted globes, taking 3·5 amperes at 200 volts. The small opal shades usually supplied with this type of lamp are used, and the bottoms of the globes are 9 ft. above the floor. The "Installation" candle-power is ·28 per square foot of floor, and the

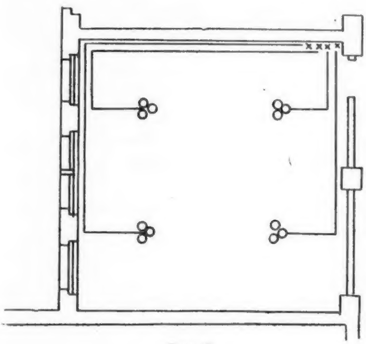

FIG. 2

consumption 1·2 watts per square foot. Although both these figures are less than in the first example, the general effect is much more satisfactory, and the teachers who have had experience of both systems are unanimous in its favour.

It will be observed that only the four centre lamps are controlled at the door, this number of lights giving ample illumination for cleaning purposes. The remaining lamps are controlled by switches near the teacher's desk—a great convenience to the teacher, and at the same time offering less temptation for unnecessary usage.

Class-rooms for special purposes have necessarily to receive individual treatment, but the general principles are very similar, viz., a bright, cheerful light, not too glaring, but yet of ample

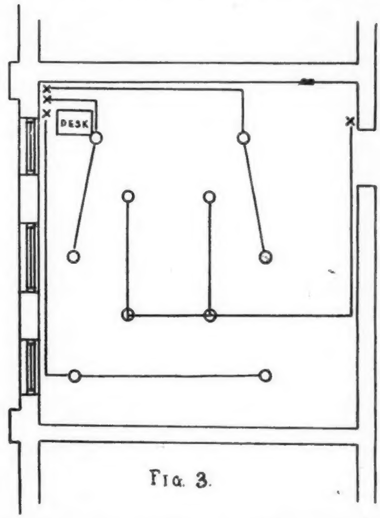

FIG. 3.

intensity for easy working. The sources of light to be well out of the direct line of vision, the lower portion of the globes being frosted, to prevent the eye seeing directly the incandescent filaments or mantle; the light, while being fairly well diffused, not to be subdivided to such a degree as to prevent the formation of definite shadows.

Gas as an Illuminating Agent.

By Norton H. Humphrys, *Assoc.M.Inst.C.E., F.C.S.*

An account of the various industries connected with the work of supplying the demand for artificial daylight would be incomplete without some reference to hydrocarbon gas, popularly known as "coal gas," or simply as "gas." It was the pioneer as regards the distribution of light energy from a central station, and on this account, as well as others, had to encounter special disadvantages. But the gas industry is a hardy plant that will flourish in almost any soil, and from the first it has steadily grown and advanced in public favour. The quantity used for lighting increases year by year.

Gas was introduced in England about one hundred years ago, and, in many respects, it had a premature birth to the extent of fifty years or more. The earliest gas companies had to design and, to a large extent, manufacture the necessary apparatus and plant.

We are now aware that a qualified manager of gas works must have some knowledge of civil engineering and also of chemistry. But in the beginning of the nineteenth century the chemical engineer was an unknown quantity. The chemist never came out of his laboratory, and the engineer never went into one if he could help it.

Under these circumstances the greater part of the pioneer work was carried out by managers who, without the slightest reflection, may be described as technically uneducated.

The intelligent working man—relying on his natural powers of observation, common sense, inventive faculties, and perseverance—made a successful showing, where the science and professional skill of the period was powerless. Such was the state of affairs at the gas-works, and it continued right away through to the burners, which consisted of little more than a suitably shaped orifice at the end of the pipe for the escape of the gas.

As a result, an impression was established to the effect that any intelligent artisan could run a gas-works, and no inducement was offered to attract the better class of engineering or chemical ability. Numerous defects, properly chargeable to ignorance as regards fitting up or the selection of appliances, were accepted as inseparable from the use of gas, and many of these prejudices survive to the present day, although the circumstances under which they originated have long since given way to a more competent and better-informed state of things.

In passing, one cannot but express admiration of the courage and perseverance exhibited by these early workers in laying a firm foundation for an industry of which they knew so little and had great difficulty in studying.

It is only recently that suitable laboratory apparatus for analyzing gas or the products of combustion, for ascertaining calorific value, &c., has been available for the use of the gas engineer. For a long time he had to be satisfied with a photometer and a slip of lead paper. The usual order of things was reversed. When a new manufacture is to be introduced to the public, the first thing to be done is to make some progress as regards a knowledge of its properties and the physical laws concerned.

But we find, even after 100 years' experience, that the leading gas companies are just beginning to organize lectures and classes for instructing their employees in the A B C of the physical laws concerned in the production, purification, and combustion of gas. The rank and file of the gas-works staff are absolutely without any inducement to increase their technical knowledge. The progress of the industry has been, and is being, hindered by no cause more than ignorance—ignorance in the board-room, on the works, and in dealing with the consumers.

With this state of affairs at the head, one cannot wonder if gas, as a rule, is ignorantly and wastefully used. There is a general tendency to think that anything is good enough for gas, and the only consideration in buying burners and appliances is to get the cheapest goods and labour. The question of efficiency is lost sight of entirely, and it is useless to point out that an accurately made substantial article, designed and constructed on proper lines, and costing, say, 10*s*., may prove cheaper after a twelvemonth's use than a flimsy imitation affair that can be supplied for 1*s*.

During the first half or more of its existence, the gas industry had the field to itself to such an extent that it came to be regarded as a monopoly. At that time there were only candles and lamps burning sperm or colza oil to reckon with, and from this cause the consumer was left to his own devices, the gas company considering that their work terminated in the delivery of the gas at the boundary of his premises or at the meter. And this position was forced upon them by the Legislature and by the popular opinion. There was a strong feeling that the gas companies' powers should cease at the meter, and that for the rest the consumer should do as he liked.

But the last forty years have witnessed developments that entirely altered the complexion of that position. With cheap petroleum and electricity in evidence, gas is no longer a monopoly, and it must stand or fall by its intrinsic value, just as any other commodity. One might reasonably suppose that the natural consequence would be a large falling-off of business. Looking at the extent to which electricity is used—the supply and distribution of electricity is not yet thirty years old—at the steady improvement in oil and petroleum lamps, the large reductions in the cost of those liquids, and at the advance in respect to candles, one may well express surprise at the inherent vitality which has enabled gas to more than maintain its position.

The explanation is very simple. The demand for artificial light has greatly increased. A brilliant light in the evening was formerly regarded as a luxury confined to the wealthy. Now it is a necessity to all but the destitute. Not only so, but there is a very large increase in the amount of candle power required to make up that very indefinite result which secures the approbation of the customer as being a "good" light. The demand is for a good light or for plenty of light, but looking at general ideas now prevalent on that point, it is amusing to go back 100 years and read the press reports on the introduction of gas light. A burner that would now be rejected for ordinary use was then likened to the "full splendour of noon-day sun."

Our grandparents read small print or did fine lacework under the glimmer of one or two candles. Our parents considered one or two flat-flame burners, giving possibly 10 candle-power each, to be excellent light for an ordinary living room. In the public street, one burner was considered quite enough for 100 yards run.

But the electric arc, the central-draught petroleum lamp, the regenerator gas-burner, and the Welsbach mantle have inaugurated larger ideas. The general demand for all purposes is in the neighbourhood of four to six times as much light as was considered sufficient within the recollection of middle-aged people.

Previous to 1880 the only burners available were the flat-flame and argand, the latter being used to so slight an extent that it may be neglected. The flat-flames in general use consumed 4 or 5 cubic feet of gas per hour, and gave a photometrical value of 8 to 12 candles. Larger burners in clusters, giving up to 500 candle-power, were introduced for public streets and large halls, and regenerator lamps of 50 to 200 candle-power were put on the market.

About ten years later came the Welsbach mantle, promising a duty of 20 to 40 candles per cubic foot of gas used per hour, and gradually pushed all other kinds of burners into a back seat. Some time before 1880, however, the possibility of having more light for less money had been made known, and burners giving a duty of 3 to 4 candles per cubic foot of gas, were introduced by Mr. W. Sugg, Messrs. G. Bray & Co., and others.

The first endeavours to increase the latent resources of gas as a producer of artificial light were in the direction of checking or regulating the pressure at the point of combustion. For obvious reasons the pressure applied at the gas-works to carry the gas to the various burners must be excessive, so far as the greater part of the district is concerned. With the flat-flame burner the quantity of gas passed follows the well-known laws governing the flow of fluids through apertures, and varies inversely as the square root of the pressure behind it. It is usual to express this pressure in terms of an inch of water, and about $\frac{7}{10}$-in., as shown on an ordinary U gauge, is sufficient to give the best result; and if increased appreciably beyond that point, there is not only a larger consumption of gas, but an actual loss of light and steadiness.

A rough-and-ready way of illustrating this point was to stuff a loose plug of wool into the base of the burner, and appliances on this principle, containing gauze, or a second and smaller orifice below the outlet proper, found very general favour, especially the cheaper varieties. But they were simply checks, not regulators, and therefore were far inferior to the governor or regulator burner, which, as its name implies, could be adjusted to give any desired pressure at the point of combustion, quite independently of the inlet pressure, so long, of course, as the same was in excess.

Two very important points were overlooked, or, at any rate, not properly appreciated, at this period.

One was the question of a proper air supply to the flame, especially with regard to the avoidance of draughts or cross currents. At a fairly high pressure the flame would be stiff, but the nearer the adjustment approached the best lighting results, the greater the liability of the flame to flutter and smoke under a draught of air.

And the second was the fact that a globe or shade is something more than a mere artistic appendage. Check or regulator burners were used in offices or public buildings without any protection, and the light was frequently unsteady. This was not only a nuisance in itself, but a flickering flame means soot and other objectionable products of incomplete combustion. It was a long time before relation of the shade or globe to a satisfactory steady flame and complete oxidization of the gas was considered by the makers, who put upon the market all sorts and shapes, colours, and patterns that might be expected to catch on with the public, quite regardless of the fact that many of them tended to increase the troubles just instanced rather than to reduce them. But the general idea is now in favour of simplicity, both as to pattern and colour. The plain clear or opal shade is generally called for, and gaudy colours, elaborate engine-turned patterns, or attempts at high art designing, are things of the past.

The introduction of the Welsbach incandescent burner ushered in a new era, apart from the large economy as compared with the flat-flame. The duty per cubic foot was increased from 2 candles to 20 or more; but that was not all. A great deal has been said about the fragile nature of the mantle; but such was not an unmixed evil either to the consumer or the gas company. It was a blessing in disguise. It necessitated the use of chimneys and other means of guarding the flame from draught, incidentally bringing out the point which the public had hitherto failed to appreciate, that a gas flame need not necessarily be flickering and smoky. It necessitated a periodical cleaning of the burner, whereas many flat-flame burners were born and died without having experienced contact with a duster or brush, and the lighting effect was largely discounted by dirt.

Under improved conditions of combustion discoloured ceilings and stuffy atmospheres become things of the past. The largely reduced consumption of gas secured by introducing the Welsbach burner of course carries a proportionate reduction as regards heat and products of combustion; but in addition, the protection of the flame from draught is of equal importance as regards securing these desirable conditions. A point that was a matter of some moment under the old system becomes a neglible quantity under the new. Any room so insufficiently ventilated that one or two incandescent gas-burners show an appreciable effect on its atmosphere, is unfitted for human habitation under any circumstances. The ventilation that is necessary, on account of hygienic considerations, apart from our subject, will take proper care of the products of combustion.

A natural result of ignorant and extravagant usage was not only low efficiency, but high bills. The public did not trouble much about the first-named. They were satisfied to walk the streets or to sit at home in what we should now call "darkness visible" if they could save money by the process. Especially in regard to public lighting, the price was a very big first and the quality a small second. One or two astute individuals set themselves up as promoters of gas-consumers' protection or defence associations. The managers of gas-works endeavoured to meet the popular demand by straining every nerve to reduce the price of gas, and their ability came to be measured by their success in this direction.

But while the pence were being taken care of at the works, the cost of manufacture and purification being worked out to the second decimal, the pounds were *not* taking care of themselves at the consumers' burners. The quarterly issue of accounts was always regarded as the opening up of a lively time at the gas-office, in the shape of more or less unpleasant and protracted interviews with indignant consumers.

But very little is now heard in the shape of a cry from the purse. Complaints of the kind are few and far between, partly because with increased sales the gas can be supplied at lower prices, but chiefly because of the improvement in respect to the old wasteful methods, in which direction, however, much yet remains to be done. The cry is now for better service, without regard to expense, and people are willing to pay more, provided they can get better attention, prompt attention to defects, and competent advice as to their requirements.

Under these circumstances there is need for a closer study of the problems connected with illumination, which are complicated by the fact that every room requires a degree of light proportioned to the prevalent colour of the walls and furniture. Certain rules as to so much candle-power per cubic foot of space are useful as a rough guide, but only touch the fringe of successful lighting. In this connexion it is just as well to look over the wall from time to time and see what others are doing. So there is ample scope for a publication devoted to the science and practice of illumination, wherein all parties interested in any branch of this very extensive subject may meet on common ground to consider and discuss the problems and difficulties that have to be encountered.

The Development and Present Position of Gas and Electricity for Lighting.

By Sydney F. Walker.

The keen struggle that is taking place at the present time between gas and electricity for the custom of users of light, recalls the struggle which was also in progress in 1882, when the first Electrical Exhibition was held. At that time there was a very strong feeling indeed against gas, and very strong hopes on the part of the general public that electricity was going to be the light of the immediate future, and that it was going to be very good and very cheap.

Gas had held the field for a number of years previously, and though the electric light had been known and in use to a limited extent for at least thirty years, practically nothing had been done with it until the years immediately preceding the Exhibition. Numerous inventors had been working at the problem of the division of the electric light, and so strong were the hopes in connexion with it, that when Mr. Edison cabled over from New York, a year or two before the Exhibition, that he had solved the problem, gas shares declined some thirty points in value.

At the time of the Exhibition the incandescent lamp had only recently been put upon the market. Mr. (now Sir) Joseph Swan in this country; Mr. Edison in America; Mr. (now Sir) Hiram Maxim, Mr. Lane Fox, and others had been working at the problem, and there were at least four incandescent lamps upon the market, the inventions of those four gentlemen. At the present time the carbon filament lamp which holds the field is made by a process which is practically a modification of that adopted by Mr. Swan at an early date. The Brush arc lighting system had been brought over to this country just previously, and had taught British electrical engineers one method of dividing the electric light. In those days, those of us who were engaged in the struggle could see the numerous faults of the Brush system; but looking back now, we can see what an enormous advance Mr. Brush made by the bold design which he worked out. The date of the actual first advance of electric light would properly be the Paris Exhibition of 1878, when the Jablochoff candle was shown illuminating the Avenue de l'Opera.

But it was the advent of the Brush system in this country which gave the first important impetus to street lighting by arcs. English electrical engineers had been working around the problem of producing a steady arc, but they had found themselves obliged usually to employ one, and sometimes two machines for each arc. Mr. Brush produced forty lamps from each machine, and though the lamps flickered a good deal, they were steadier than the lamps furnished by one or two machines. Mr. Brockie was in the field with his early commutating arc lamp immediately afterwards, and his lamp solved the problem of the lighting of open spaces, such as railway sidings, iron works, and colliery yards, and so on, practically as well as the Brush lamp. The present writer fitted up two collieries in the Rhondda Valley, in the year 1881, with Brockie commutating arc lamps. But the wink produced by the feed of the Brockie lamp was too irritating for indoor work. The Brush arc lamp, a number of other arc lamps that were on the market at the time, and all the incandescent lamps that were on the market, were exhibited in large quantities at the Crystal Palace Exhibition of 1882, and the public were asked to subscribe for the purpose of laying down electricity generating stations for supplying towns using some of the lamps exhibited.

The public subscribed some twelve millions sterling, but the lighting of towns by electric light, as we know it now, did not come to pass for a number of years afterwards. Enormous sums were paid for the right to use certain systems in certain districts, and very large sums passed into the hands of company promoters. Companies were established in nearly every district, to exploit different systems, but all have gone the way of all flesh many years ago, and the whole of the lamps that were exhibited at that time, and that were on the market, have long since ceased to exist. Gas was supposed then to be about to receive its death blow, and there were many amusing references to the subject. *The City Press* had a coloured cartoon, labelled 'The Gas Director's Dream,' in which a gas director is supposed to be haunted by the faces of the men who were leading the attack on the side of electricity.

But gas was by no means in a dying condition, and did not receive anything approaching a death blow. Careful observers noted a few years after, even when electricity had overcome some of the difficulties it met with, and was making great headway, that the consumption of gas also was steadily increasing. In fact it may be said that, from the time of the Electrical Exhibition in 1882, gas has steadily progressed, both in quality and in the quantity consumed. Gas engineers had previously had the easy time which comes from the absence of competition. Parliament had provided that gas companies should not pay more than 10 per cent. without giving a proportional reduction in the price of gas to its consumers. It was much easier to keep the price of gas up, and to pay dividends at the 10 per cent. with which every one was satisfied, and to spend any money that might be over in building handsome offices, and so on, than to bother with improvements.

From the time, however, of the really active competition of electricity, gas engineers put their shoulders to the wheel, and have been steadily improving their product ever since. In 1882 the price of gas was very high. Five shillings a thousand cubic feet was a very common figure, and six shillings, and seven and sixpence were to be found in small towns. The quality of the gas also was very bad. It burned with a smoky, yellow flame, and numerous gas engineers were at work trying to whiten it.

Further, though it had been known since the discovery of the late Sir William Perkin in 1856, that the impurities of gas contained valuable products, very few gas engineers had made much use of them. After the competition of electricity set in, they turned their attention to that, and though the profits supposed to be available from by-products were not always realized, the gas was more thoroughly cleaned, and gas engineers were able to provide a better article, and to steadily reduce the price.

The competition of electric light, as explained above, increased the consumption of gas. One tradesman perhaps lighted the front of his shop with arc lights, and his neighbour endeavoured to produce an equally brilliant illumination by means of gas, and the gas company reaped more from the neighbour than they lost from the man who adopted electricity. With the advent of the Welsbach mantle in 1893, the tradesman who employed gas was able to make quite as brilliant a display with gas as his neighbour could with electricity, and at much less cost.

The Welsbach mantle only became practical in 1893, and at the third time of trial. In 1886, and again a few years later, it was introduced to the public with the usual flourish of trumpets, and was supposed to have given the gas companies the weapon they were wanting to enable them to compete with electricity, but in both cases it disappeared shortly after from the market. In 1893 it became a practical success, and gas has not looked back since.

The mantle became successful just in the nick of time. At the moment electricity was going ahead by leaps and bounds. Nearly every town was laying down an electric lighting plant, and there was great enthusiasm for the electric light, while the difficulties in the way of economical production and of distribution had not been thoroughly realized. It may be mentioned incidentally that the Electric Lighting Act of 1882 is blamed for the want of progress between that year and 1888. The real reason was, the problems involved in economical distribution, and even the problem of the dynamo itself, had not been worked out. It was not until 1884, when the late Dr. Hopkinson and Mr. (now Prof.) Kapp worked out the law of the dynamo, that electrical engineers were able to design dynamos with any certainty that they would accomplish what their designers intended them to. From 1884 the progress of electricity has been continuous. There were also difficulties in connexion with electrical distribution, that hardly have a place in this article, but which retarded the progress of electric lighting.

Further, when electricity generating stations were more or less in full swing, it was found that they were very seriously handicapped in competition with gas by the fact that light was only required for a very short portion of the twenty-four hours, by the bulk of those who were disposed to use electricity, even in the winter months, and hardly at all during the summer months. A number of the towns also had handicapped themselves by the adoption of the alternating current, which cut them out of the motor load and prevented the use of storage batteries.

Meanwhile gas was not idle. What is known as high pressure gas was introduced in about 1898 or 1899, the development of the gas mantle enabling this to be done. The principle of high pressure gas may be taken approximately to be the same as that of forced draught. A more perfect combustion is obtained, with an economy in gas and better light. At the Glasgow Exhibition in 1901, portions of the grounds were illuminated by different forms of high pressure gas, and other portions by different forms of arc lamps, and though the arc lamps gave more light individually, when measured photometrically, than the high pressure gas, for practical purposes the grounds illuminated by gas were just as well lighted as those illuminated by the arc light. Since then high pressure gas has steadily advanced, and is in use in a great many towns of the United Kingdom, its use enabling street lighting to be carried out quite as efficiently as by arc lighting, and at a lower cost.

The improvement of the gas mantle also has enabled the gas companies to practically secure the lighting of the side streets, surburban roads, &c., with gas mantles under ordinary pressure. The gas mantle itself has been enormously improved, and the using public have learned to know how to get the best results from it. Later forms are made very much stronger than those of a few years back, so that they can be handled with impunity, and the fittings can be taken down, the dust cleared away from them, and the mantle when relighted is nearly as good as when new.

Against all this, electricity has produced the flame arc lamp, the mercury vapour lamp, the Nernst lamp, the metallized carbon filament lamps, and the metallic filament lamps, and the real struggle is now to commence.

The flame arc lamp gives a very much larger amount of light for the same expenditure of electricity than the ordinary arc, but it is difficult, under a large number of the conditions ruling, to make effective use of the increase.

The mercury vapour lamp has not "caught on" yet to any great extent, on account of its weird colour, though its efficiency is high, and it appears to be of use for a good many purposes, such as the lighting of offices, printing works, &c. Probably the prejudice against it will be overcome in time, and the public will get used to it, just as they have done to the arc lamp.

The real struggle is between the Nernst lamp, the later forms of carbon filament lamp, the metallic filament lamps, and the later forms of Welsbach mantle. At the present time, in the writer's view, gas is winning, and still holds winning cards. The great advantage possessed by electricity in the matter of convenience is still a very strong card, but gas engineers have learned to copy electricity in a great many respects, and have succeeded in arranging their lights, in many cases, quite as conveniently as electric lights, the pilot light of the gas mantle providing a means of turning lights in and out at a distance. The very high efficiency of the metallic and later forms of carbon incandescent electric lamps give electricity a very strong card, which, if the corporations use it wisely, will enable them to make a good fight with the gas companies.

In the writer's view, there is no question of either light extinguishing the other. Both will go on side by side, the healthy competition between the two leading to continual improvement and continual lessening of cost.

The great danger is the possibility that both may be extinguished by the discovery by some savant of the secret of the light emitted by the firefly. This may seem far-fetched, yet when we remember the enormous number of men and women who are constantly asking nature to surrender her secrets, and the enormously improved instruments with which they are working, also the number of secrets that have been wrested from her during the past twenty years, we should hardly be surprised if the secret mentioned should be discovered at any moment.

Artificial Illumination, and the Education of those concerned in its Production.

By Charles W. Hastings.

The history of gas-lighting has been much before the public during the last few months and almost all that can be said upon the subject has appeared in the technical journals or published in book form; without doubt the best 'History of Gas-Lighting,' is that written by Mr. Charles Hunt, M.Inst.C.E., and published a few months back in commemoration of the centenary of gas-lighting.

The first object of this article is to endeavour to set out the distinct disadvantages under which the gas-maker has laboured for want of a practical and theoretical education; it is no slight upon the intelligence or the industry of the managers of gas-works, of, say, even forty years ago, that they then knew practically nothing about the science of gas-making and were—with but few exceptions—completely ignorant of the most rudimentary laws governing illumination, as such.

The carbonization of coal and the production of gas was carried out by rule of thumb, the Standard of Illuminating Power—which in some cases was fixed by Act of Parliament—was low, the tests for purity and freedom from sulphur compounds were only enforced in the larger cities, lime only was used for purification, ammoniacal liquor, and even tar was allowed to run to waste, and coke itself was often a drug in the market. The gas-maker considered his work complete when the gas was passed into the gas-holder.

Up to perhaps the "sixties" no attention whatever had been given to the improvement of the burner; the first burners—and even those used at this date—were made of iron, and, so far as the writer knows, no attempt had then been made to gauge the size of the aperture from which the gas issued, and certainly no knowledge existed of the rate of flow of gas through pipes. If it was desired to have a quantity of light a six or seven inch bat's-wing burner was recommended. To those whose recollection will not take them back so far, we may mention that the flame from such a burner measured from 6 to 7 inches across, and as the name of the burner implies, was in the shape of the wings of a bat, when fully spread. Pressure was not checked, burners were not governed, and the gas-maker, if he had plenty of gas, was liberal with the pressure; if, on the other hand, he had little gas, he worked at as light a pressure as would travel the gas to the point of ignition.

The engineers and managers of the larger gas companies were very conservative; they met one another upon but very rare occasions, and the provincial men were practically isolated. Up to the "sixties" the bulk of the men in charge of gas-works were drawn from the shops of engineers and contractors who made a business of erecting gas-works, and the best of them were generally mechanics with no more education than that class of artisan acquired, at best, at the local grammar school or otherwise at what were known in those days as the National Schools.

There were, of course, some exceptions, but they were very few, and we venture to say that the Institution of Civil Engineers could not claim as many as might be counted on the ten fingers, even as Associates, and the Members' class was practically unrepresented in gas-works management. Chemical science was quite neglected, laboratories did exist in connexion with the London gas-works and a few of the larger cities, but we do not remember any one being in charge of them who was either a Fellow of the Chemical Society or the Institute of Chemistry.

In 1864 the first real step was taken to improve the educational position of the gas-maker, for in that year the British Association of Gas Managers was formed, and the first meeting was held under the presidency of the late Thomas Hawksley, who was then, we believe, a member of the Institution of Civil Engineers. He held the office for four years in succession, and was followed by Thos. G. Barlow, the then editor and proprietor of the *Journal of Gas-Lighting*, a very capable man, who made considerable reputation in the Committee Rooms of the House of Commons, and had a large Parliamentary practice in connexion with the promotion of gas and water companies Bills in Parliament.

The starting of the Association, of course, resulted in the gathering together of gas engineers and managers, but the reading of papers, and the discussions upon them, was carried on by only a very limited number of members; some are still living, but the most of them have "crossed the bar."

The great International Exhibition of 1862 gave some impetus to the gas industry; the buildings were of course lighted with gas, and some few new inventions were exhibited. Improvements had been made in the testing and measurement of gas; Messrs. Geo. Glover & Sons, if we remember rightly, exhibited for the first time the cubic foot bottle, also a full range of apparatus for testing meters, &c. Attention was also given to the improvement of gas burners, but still the class of men managing gas-works remained the same.

Directly associated with illumination, it should be noted that in 1869 the late William Sugg described the London Argand burner, which all readers of this magazine will know was the standard burner for illuminating power until the adoption in 1905 of Mr. C. C. Carpenter's "No. 2 Metropolitan London Argand Burner," and even now the old "London Argand" is in general use.

In the matter of gas illumination for the million, the name of George Bray (who died a short time back) stands out as marking an epoch. Mr. Bray was engaged in the cloth trade in Leeds, and in the course of his occupation had recourse to the use of gas in the preparation of fine faced cloth, and it was through this employment that he turned his attention to the manufacture of gas burners; for many years he only made a nipple burner with steatite tip, tested to consume 1, 2, 3, 4, 5, and 6 cubic feet of gas per hour; these burners had, under the steatite cap, a screen of fine wire gauze, and burned with a good-shaped, steady flame, so much so that the gas supplied to public lamps was very generally paid for at the rate of feet per hour, which these burners were sold to pass, no regulators of any kind being used. In later years Mr. Bray made great advances in the construction of gas burners, especially for street lighting, and pioneered the flat-flame system, which was at its zenith in the early "eighties," when both Sugg and Bray were rivals in the field and the electric light made its first bow for public favour.

(*To be continued.*)

SPECIAL SECTION.

Illumination and Eyesight.

THE last century has seen a great development in our means of producing artificial light, and the progress of the last few years has been exceptionally rapid. We have learnt to turn night into day with an ease undreamed of by our forefathers. This improvement has naturally not been without influence on our mode of life. We are able to utilize the hours of darkness more effectually for pleasure, and the ease with which light can now be produced is also a temptation to work longer than in the past, so that the amount of work carried out by artificial light continually tends to increase.

Simultaneously with this improvement in artificial light we may note the ever-increasing supply of printed matter, and the development of education. Far more books and magazines are read than was formerly the case. Not only do more people find their pleasure in reading, but the increase in the number of excellent textbooks is an indication of a certain tendency to replace oral by written instruction, a matter in which we already differ notably from the great nations of the past.

The net result, therefore, is that we use our eyes more than formerly, and also in a different way. At the same time there is every reason to suppose that the increasing use of artificial light will continue, and it is therefore essential to do all we can to realize the most perfect physiological conditions of illumination. For some time past oculists, inspectors of schools, and the medical profession have been calling attention to this subject, and have almost invariably agreed that the evils referred to were at least partially due to bad illumination.

When we consider that all our impressions of the brightness of surrounding objects—the very basis of illumination—are received through the eyes, and depend upon its physiological peculiarities, the need for the advice and co-operation of the physiologist and oculist is evident.

There are, indeed, a vast number of questions connected with illumination which deserve immediate attention. The most evident defect of present day lighting is, perhaps, insufficient illumination. Prof. Scott and Dr. Kerr (Medical Officer to the L.C.C.) have fixed the minimum permissible illumination in schools at about one candle-foot. Higher illuminations, however, are frequently advocated in America, and it is probable that for reading very fine print, in drawing offices, and for work which is especially trying to the eyes, one candle-foot may be profitably exceeded. In any case it is certain that the degree of illumination met with in offices, reading-rooms, &c., is occasionally so inadequate that reading cannot be accomplished without painful effort, which, in the long run, cannot be without influence on our eyes and general physical well-being.

Yet much remains to be learnt as to the exact order of illumination requisite for special classes of work, and the upper limit, where the illumination becomes strong enough to fatigue and strain the eyes through sheer over-brilliancy is very undecided.

This consideration naturally leads to the mention of one recognized bad feature in modern lighting. Every one is familiar with the disagreeable dazzling effect of very bright sources of light placed so that the rays of light can strike the eye directly. Extreme exposure may seriously injure the eye, and it is highly probable that the constant reception of images of naked glow lamps, plants, &c., on the retina, which is an unfortunate result of our present methods of light, is, in a great measure, responsible for the undoubtedly fatiguing effect of working by artificial light.

The ever-increasing brilliancy of our sources of light, the introduction of high-pressure incandescent gas lights, flame-arcs, and metallic filament lamps, has had the effect of drawing public attention to the question.

Yet here, again, expert physiological advice is needed to determine the order of brightness per unit area which must be considered permissible, and, if possible, to provide us with a ready test by which the injurious character of any installation can be readily recognized.

Certainly the brilliancy of the unshaded arc-lamp, and even of the glow lamp, is far above what is physiologically accepted as safe.

Prof. Basquin has estimated that the average brightness of the sky in the northern part of the United States is in the neighbourhood of 2·5 C.-P. per square inch, and this may perhaps afford some indication of the permissible brightness per unit area of a source of light. Dr. Louis Bell ('The Art of Illumination,' p. 308), reasoning from the brightness of a white surface illuminated by bright daylight, has given 5 C.-P. as the maximum permissible limit, and Dr. Karl Stockhausen has mentioned a result not far removed from this figure (*Zeit. für Beleuchtungswesen*, Oct. 10, 1907). Yet one would like to feel that any such universally accepted determination rested on actual physiological evidence. Possibly the study of the contraction of the pupil orifice, and the "after-image" of the fatigued retina might furnish valuable information on this point.

Violent contrasts of light and shade, and "flickering" sources of light, are also undeniably trying to the eyes, and deserve the authoritative condemnation of the oculist. Again, the use of glossy and highly calendered paper, which reflects the light regularly and directly into the eyes, is believed to lead to bad results, and some have ascribed this to the fact that the light comes from an unusual direction, and so impinges upon a part of the retina which is not usually exposed to light. Whatever the reason, however, there can be no doubt that paper of this description is very trying to the eyes of clerks, book-keepers, and those who are continually bending over shiny-paged books. Dr. Louis Bell, indeed, in commenting on this danger, recently stated that he had been in counting rooms where every clerk bore signs of bad eyes (Proc. Am. Acad. of Arts and Sciences, vol. xliii., No. 4, Sept., 1907, p. 88).

A word or two may next be said on the subject of the physiological action of light of different colours. There is perhaps no question in illumination on which so little authoritative information is available, and on which such divergent views are expressed. Yet the introduction of modern sources of light differing considerably in colour, and our growing control over the spectral composition of illuminants, renders such knowledge very desirable. It is not only that the luminous quality of the light yielded by such sources of light differs. We must remember that in most cases the *visible* light is, unfortunately, but a small fraction of the total radiation of a source, and that even when the colour of the light yielded by two sources appears similar, the nature of the radiation, as a whole, yielded by them may be very different.

The effect of the *visible* rays of different colours, and of the heat rays of great wave length, seems to be very imperfectly understood. Physiologists have told us that the chemical action of light upon the retina becomes more pronounced the shorter the wave-length, and it has therefore been suggested that the blue and violet rays exert a fatiguing action on the retina, similar to that of the ultra-violet rays, but less pronounced. On the other hand, it has also been frequently maintained that the red end of the spectrum is exciting and irritating, while the blue end is soothing, and there seems to be definite physiological evidence of the existence of a second effect of this nature.

One point on which not the remotest doubt can exist is the dangerous character of the influence on the eye of an excess of ultra-violet energy. This question is the more important because we have now at our command sources of light, such as the Heraeus quartz lamp and the Schott "Uviol" lamp, which are far more powerful in such rays than any known a few years ago. It is even possible that the comparatively small quantity of energy of this description radiated by the sources of light utilized for ordinary purposes of illumination, is not without influence.

Yet very few authoritative data are available as to the practical aspect of these questions, and it remains to be seen to what extent they actually influence our daily life. There is a general and apparently well-grounded impression that artificial light is more trying to the eyes and more fatiguing to the worker than daylight illumination, but how far this is due to the spectrum of artificial light, and how far to the method in which this light is utilized, cannot be said with certainty at present.

Amidst these perplexities, however, one point seems clear. Our eyes have certainly been developed so as to utilize *natural* light—daylight—to the best advantage. Our wisest course would, therefore, seem to be to imitate the spectrum of daylight as closely as possible, and, in the present state of our knowledge, to avoid working for any length of time under any untried light of very peculiar spectral composition.

The differences of opinion expressed points to the need for co-operation on the part of the oculist and the physiologist in order that we may receive definite information as to which features of modern lighting are really seriously injurious, and which are of only secondary importance. As we have seen, there are certain obvious defects of many modern systems of lighting on which there is fairly general agreement, and the recent statements of the medical profession make it clear that they, too, consider the lighting conditions frequently met with very unsatisfactory.

The question has recently received special attention in its application to the lighting of school buildings, and it is a striking fact that those who have investigated this subject have almost invariably commented on the need for improvement in the lighting of school premises.

Prof. Scott reported (*Illum. Engineer* of New York, Oct., 1907) very unfavourably on the lighting of a number of American schools very exhaustively examined by him. He mentions the unsatisfactory eyesight possessed by the children in these schools, and goes on to point out that the daylight and artificial lighting frequently did not come up to a reasonable standard of efficiency. In most of the rooms examined there were dark regions where the illumination did not come up even to the minimum permissible illumination of one candle foot. He concludes :—

> "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."

That these remarks are, in some measure at least, applicable to our own schools is shown by some recent remarks of Dr. Kerr, Medical Officer to the Educational Department of the London County Council. In his report for the present year Dr. Kerr likewise lays stress upon the necessity for adequate lighting arrangements, above all in the case of children.

"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."

He then proceeds to describe methods of securing a satisfactory and uniformly good illumination over school-room desks, and also points out that the children's and teachers' portions of the school-room require separate and special attention, especially the satisfactory illumination of black-boards and diagrams, &c.

The British Medical Journal of 1905, in an article on 'Eyestrain and Brain-strain,' drew attention to the same subject, and quoted the results of Dr. Kerr's previous researches on the lighting of different schools. As a mean of all the figures given it appears that of 163 schools visited, the artificial illumination of 31 (or 20 per cent.) was classed as fair, while 29 (or 18 per cent.) were classed as really bad. The window illumination was less satisfactory, for in 43 schools (or 27 per cent.) it was only considered fair, and 40 (or 25 per cent.) it was bad.

It must be noted, however, that these results were obtained in 1903, and that during the last four years the arrival of illuminating engineering has given rise to a very different standard of illumination, so that the lighting of many buildings, which was then considered adequate, might now be condemned.

The whole question of school-room illumination seems to have come into prominence by reason of the unsatisfactory nature of the recent eyesight returns. The deterioration of the eyesight of children during school life has given cause for grave concern, and that the gravity of this question is not exaggerated the following instances show.

The first investigations on this subject seem to have been undertaken in Germany, probably because this country was one of the earliest to institute a wide educational system, and possibly, too, because the German letters are, admittedly, exceptionally trying to the eyes. We may note, for instance, the investigations of Dr. Herman Cohn, of Breslau, referred to in Prof. Scott's recent article on this subject (reported in American *Illuminating Engineer*, Oct., 1907), that short sight hardly existed in village schools, but became more prevalent with the increasing tax on the eyes entailed by more severe school work, until, of the pupils who remained at school the full fourteen years, 63 per cent. were found to have defective sight. Subsequent investigations have led to similar results. The German Government have been making strenuous efforts to remove the cause of this evil, and it is stated that they now intend to create a commission of architects and engineers to decide how the lighting of school-buildings is to be conducted in future, so that the question will receive attention as new schools are built. (Dr. Wendell Reher, *Transactions* of the Illuminating Engineering Society, Feb., 1907, p. 125.)

The report of Dr. Maximilian Bondi, of Vienna, supplies similar high figures (*British Medical Journal*, February 4th, 1905, p. 258).

Dr. Bondi examined 949 pupils, varying in age from 8 to 19 years. In the Realschule, 22 per cent. of the children in the upper school were short-sighted, but only about half this percentage in the lower school. In the Gymnasium, on the other hand, 31·5 per cent. of the elder pupils were short-sighted, and of the younger 14 per cent.

In America the conditions seem to be likewise unsatisfactory. The Vermont State Legislature began to study the eyesight of children at the schools in 1905. Mr. Lansingh has recently stated that 34 per cent. of these children were found to have defective vision.

In New York, of 58,948 children recently examined, 17,938, or about 30 per cent., are stated to have defective vision (*Illuminating Engineer*, April, 1902, p. 149).

Prof. W. D. Scott (*ref. cit.*) has quoted even higher figures. The circular issued by the United States Bureau of information in 1881 led to the irresistible conclusion that near-sightedness steadily increased from class to class until, in the highest grades of school attendance, as many as 60 to 70 per cent. of the children had defective vision. Yet, in these tests, children were only regarded as short-sighted if their visual acuity in one or both eyes was ⅔ or less than that of a normal eye.

One deplorable fact, brought out by more recent investigations, on which Prof. Scott lays stress, is the fact that the children of the present day seem to be becoming short-sighted at an even earlier stage in their school career.

Lastly, some references may be quoted to indicate that the condition of things which is deplored on the Continent and America are, unfortunately, also to be met with in our country.

Attention may be drawn first to some statistics quoted by Miss Sayer, Medical Officer to the London Educational Committee (Int. Congress of School Hygiene, 1904, *B.M.J.*, 1904, vol. i. p. 418).

In the London schools alone there are nearly a million children. At least 25,000 of these were found to be actually seriously handicapped by defective vision. Of children of 6 years of age and under, only 3 per cent. had seriously bad vision, and 88 per cent. perfect sight. But at 11 years of age the percentage of children having really bad sight had risen to 11, while only 58 per cent. had perfect vision. Here, again, the influence of the strain of schoolwork seems clearly traceable.

In the same way Dr. H. Wright Thompson, oculist to the School Board of Glasgow, has stated that of 52,493 children distributed between 67 schools, 35 per cent. were found to have defective vision in one or both eyes (*British Medical Journal*, Sept. 14th, 1907).

Dr. Inglis Pollock, again, found that among the children in certain schools in Glasgow, only 1·7 per cent. of those below 5 years of age had defective vision. This percentage rose steadily until, at 13 years, 8·4 per cent. of the children had defective vision. At 18 years of age 25 per cent. of the pupils were similarly afflicted (*British Medical Journal*, Dec 23rd, 1905).

The situation, indeed, is summed up in an article in *The British Medical Journal* commenting on Dr. Bondi's results (*ref. cit.*) as follows :—

"Investigations in the schools in France, Germany, and in this country put it beyond doubt that the proportion of children suffering from myopia steadily increases as we pass from the lower to the upper classes,"

and attributes these defects to

"young people attempting to do fine work and read badly printed books in ill-lighted schools."

The author has dealt with these figures at some length in order to show that the general recognition of the importance of this evil seems to be well grounded, and that the conditions producing it are clearly not confined to any locality, and are found alike in the schools of the European nations and in America; the question is one of international importance.

The exact nature of these adverse conditions requires further study. It seems to be generally accepted that the main cause of *short sight* is the strain thrown upon the eyes of young children by too much close work.

Prof. Scott points out that our eyes were primarily adapted for distant vision, and that it is only quite recently that we have thrown upon them the constant strain of accommodation for near objects. He explains further that the developing child's eye is exceptionally easily injured by such effort, and advocates that such work as reading and writing should be entirely omitted in the first few years of a child's education.

What, however, we are chiefly anxious to learn is how far bad methods of illumination are responsible for these defects.

The figures here hitherto quoted have referred chiefly to "short sight," and it seems to be generally admitted that poor illumination, by tempting the worker to bring his eyes close to his work in order to make out the print, hastens short sight.

But there is also every reason to suppose that unsatisfactory illumination is very often responsible for the variety of eye troubles classed as "Eyestrain," and that further, the mental effort involved in attempting to work under bad lighting conditions is frequently indirectly responsible for headache, ill-health, and general breakdown. Dr. Kerr, for instance, mentions in his recent report that, in the Paddington Technical School and the Hackney Downs Secondary School, many pupils, quite apart from vision tests, showed signs of eyestrain—headaches, blinking or smarting of the eyes, and the like.

The same authority stated in his evidence before the recent Royal Commission on Physical Degeneration in 1903, that "the real harm of defective vision and schoolwork not adapted to the usual capacity in the young, lies in the strain thrown upon the developing nervous system." Miss Sayer has laid stress on the distinction between defective visual acuity and want of perception by the brain centres among school children (*ref. cit.*) and a number of cases of general ill-health that have been recently described in the columns of *The Lancet* and *The British Medical Journal* which were attributed to the indirect influence of eyestrain.

While, therefore, the present data do not seem sufficient to enable us to state definitely how far the defective eyesight existing is directly traceable to bad illumination, it is contended that the connection is sufficiently evident to emphasize the necessity for close supervision of our present methods of lighting.

We know that the eyesight of school-children—regarding whose sight exceptionally complete data are available—gives cause for grave concern. We know that the illumination of such schools as have been examined has been pronounced unsatisfactory. And there is therefore every reason to advocate a closer investigation of the connexion existing between the two. By a proper study of the scientific principles of illumination we may be able to reduce the troubles mentioned above, to a minimum.

The Sacrifice of the Eyes of School Children.

By Prof. Walter D. Scott,

NORTH-WESTERN UNIVERSITY.

(*From The Popular Science Monthly.*)

In the evolution of the animal organism the sense of touch has served the purpose of informing the individual of objects with which it came in contact. The sense of taste likewise gave information concerning objects upon contact, but of a more specialized form. The sense of smell and that of hearing gave knowledge of objects in the vicinity, and in certain instances of objects in the distance. The sense of sight seems to have been pre-eminently the sense by means of which the individual was enabled to adjust himself to objects at a distance. The enemy to the leeward might approach noiselessly, and so could not be smelt or heard. When knowledge of approach was revealed by the sense of touch it was too late for escape. The preservation of the individual and of the species thus depended upon the ability to see the enemy in the distance. Inasmuch as the function of the eyes has been to perceive objects at a distance rather than at close range, we are not at all surprised to find that the eyes are well adapted for distant vision, but poorly constructed for close work.

When our eyes are at perfect rest, when all the muscles which control them are relaxed, they are then adjusted for distant vision. When, on the other hand, the ciliary muscles and the muscles which move the eyeballs are at a maximum of contraction, then and then only are the eyes adjusted for close vision. Such a structure was admirably adapted to the needs of the primitive organism. The eyes were the sentinels which must always be on guard, and when employed in the appropriate way there was no strain. It was, of course, essential that the individual should be able at times to see objects close at hand. This could be accomplished by means of contractions of delicate muscles, and as soon as the contractions were relieved the eyes were again adjusted for the more important duty of distant vision.

The strain upon the eyes is in adjusting for objects closer than at about four feet, but for all greater distances there is a minimum of strain. Hence we may speak of all objects as being *distant* which are removed as much as four feet. With this definition of the term distant it is evident that distant vision was the most common form of vision for all our ancestors, from the most primitive forms of life to the most highly civilized races, till the last few centuries. With the invention of writing, and then with the invention of the printing-press, a new element was introduced, and one evidently not provided for by the process of evolution. The human eye which had been evolved for distant vision is being forced to perform a new part, one for which it had not been evolved and for which it is poorly adapted. The difficulty is being daily augmented. The invention of printing-presses has been followed by an increasing number of books, magazines, and daily papers. The rural population has given place to the urban. The long days of manual labour have given way to the eight-hour system with abundant time for reading. Labour-saving devices of all sorts have added to our sedentary habits. All things seem to be conspiring to make us use our eyes more and more for the very thing for which they are the most poorly adapted. It requires no prophet to foresee that such a perversion in the use of an organ will surely result in a great sacrifice of energy, if not of health and of general efficiency.

The Amount of Light required for Reading.

The eye has thus far been spoken of as though it consisted merely of delicate muscles, when in reality these are not the most significant part of it. In thinking of the eye we should never disregard the eye-muscles, but primarily the eye is a live camera, consisting of a lens, dark-box, and sensitive plate. The retina in the back part of the eyeball is the sensitive plate, and is the most vital part of the eye. It is affected by every ray of light falling upon it. Fortunately it responds to a weak light, and still is not injured by a moderately strong one. In speaking of the quantity of light it is well to have a standard. For this purpose the most convenient standard is the amount of light cast by a standard candle upon any point in the horizontal direction one foot from the candle. A light of twice this intensity is spoken of as a two-candle power, a light ten times the first is of course a ten-candle power. The light cast by a candle upon a printed page at a distance of one foot is sufficient for legibility at the normal reading distance. If the light is less than this the retina is not adequately stimulated and the reading is accomplished only after a strain more or less intense. If the light falling upon the page exceeds ten candle-power the stimulation of the retina is so great that it is displeasing to some people and is condemned by our best authorities as injurious to the retina. All are agreed that less than a single candle-power is injurious for reading, and during the present state of our knowledge it is at least safe to avoid an illumination of more than ten candle-power.

The iris may be blue, brown, or grey, and is that which determines the colour of our eyes. It is an adjustable shutter which reflexly regulates the amount of light which enters the eye. In the presence of a bright light the iris diaphragm contracts, reducing the size of the pupil, and cutting out much of the light which would otherwise enter the eye. In the presence of a dull light the pupil enlarges, allowing a great amount of the light, such as that falling upon a book, to enter the eye and to stimulate the retina. The iris is a wonderful device, but cannot in diverse illuminations perfectly equalize the amount of light entering the eye. The pupil expands inversely as the square root of the illumination. Thus if the actual illumination of the book increases ten-fold, the amount of light falling upon the retina is increased but little over three-fold. Even a twenty-five candle light sends but five-fold as much light into the eye as a single candle-power. A single candle-power seems sufficient, and ten candle-power is not too much. This ability of the retina and of the iris to deal successfully with lights of such different intensities is a most useful and necessary characteristic. Unfortunately, however, the actual diversities of intensities of lights used for reading are far beyond any for which the eye can adapt itself.

Variations in the Amount of Daylight.

We are in the habit of thinking of the light received from the sky—the daylight—as almost a fixed quantity during the hours from 9 in the morning till about 4 in the afternoon. The darkness preceding a storm and the occasional dark days are of course not forgotten, but, in general, daylight for the hours mentioned is thought of as at least fairly constant. To test this point observations were made at 9 A.M., 12.30 P.M., and 4.30 P.M., daily for five and a half days a week for twenty-two months. These tests were made in the Chicago laboratory of the American Luxfer Prism Co., and under the direction of Prof. Olin H. Basquin, of the Department of Physics of North-Western University. Inasmuch as the amount of sunshine and general illumination in Chicago is almost exactly the average for the United States, these results may be regarded as typical for the whole country, with the exception of such dark cities as Seattle or such light ones as Phœnix. Measurements were made of the amount of light coming through a square foot of clear glass placed horizontally in the roof of the observation building. The illuminometer was placed so far below the opening in the ceiling that the direct rays of the sun could never reach any part of the recording apparatus. The light thus measured was diffuse daylight received from the zenith of the sky. Taking the average illumination for the twenty-two months at 12.30 as the standard, it was found that the illumination at 9 A.M. was but 67 per cent. as great as that of mid-day. Again the illumination at 4.30 P.M. was but 27 per cent. as great as that at 12.30. Expressed in other terms, we see that the available light at 4.30 is approximately but one-fourth that of noon, and the light at 9 o'clock but two-thirds that of noon. These figures are the average for the school days of twenty-two months in one city, and although observations for a longer period and in other cities might change the results somewhat, it is safe to assume that our figures are not far from the actual conditions in a majority of our schoolrooms in the United States. In general a room which is barely adequately lighted at 12.30 will be 33 per cent. under-illuminated at 9 o'clock, and at 4 o'clock its illumination will be but 27 per cent. of the necessary amount.

Our difficulties are further complicated by the fact that the variations in illumination of daylight are as great between the months of the school year as between the hours of the school day. The illumination is best in the months of June, July, August, and September. Then follow in order May, April, March, October, February, November, January, and lastly December. Comparing the illumination of the four bright months (June, July, August, and September) with the four dark months (November, December, January, and February) we find that for the twenty-two months observed the illumination of the dark months is but 28 per cent. of that of the bright ones. This figure is found by averaging the three daily readings for each day for all the months concerned. December, the darkest month, has but 18 per cent. as great illumination as June, the brightest month.

When to these variations as between months or seasons we add the variations between mid-day and morning and evening, the results are most astounding. The light at noonday in June averages almost tenfold as much as that at 9 A.M. in December. If it is injurious to read with a light less than one or more than ten candle-power, a schoolroom that furnishes this maximum in June will be reduced to the minimum in December mornings and evenings on average days. Such deviations in the external source of light put most restricting conditions upon school architecture. How have we met the conditions, and how might we construct our schoolrooms to meet the situation satisfactorily ?

Rules for Lighting a Schoolroom.

In our climate it is almost impossible to over-light a schoolroom if the two following conditions are observed: (1) Never allow the direct rays of the sun to fall upon any surface within the field of vision of any pupil. (2) Avoid all glossy or shiny surfaces which reflect the light directly into the eyes of the pupils. A dead white surface is not injurious, while a darker surface may be shiny and hence injurious.

For securing adequate light the following rules are important: (1) The window space should be as much as one-fifth of the total floor space, and the height of the window two-thirds of the width of the room. (2) The walls, ceiling, woodwork, furniture, &c., should be a colour which reflects a large amount of well-diffused light. Perhaps the best colours for this purpose, in the order of their efficiency, are white, light yellow, light grey, light green, light blue, and light pink. (3) The schoolroom should be narrow and the windows facing an unobstructed area, so that from any seat in the room a large amount of sky is visible. (4) The windows should be provided with white holland screens, or others of a similar sort, which obstruct the direct rays of the sun, but which, when drawn down, emit into the room a maximum of diffused light. (5) There should be at hand light-coloured curtains which may be used to cover up all black-boards as soon as the darker parts of the room are inadequately lighted.

It is apparent to all that the construction of our schoolrooms has not conformed to these five simple rules. There are many rooms in which the window space is one-fifth of the floor space, but certainly not a majority of all schoolrooms in America. The second rule, concerning the reflecting surfaces within the schoolroom, is broken by the extensive surfaces of black-boards and by the dingy colour of the walls. Walls soon fade and become dirty, and need frequent attention to keep their reflecting power approximately at its maximum. The third rule is broken by constructing rooms so large that they will accommodate fifty pupils, and by placing school buildings too close to adjoining buildings. The fourth rule is broken by the use of opaque shades, which, when drawn to escape the brilliancy of the sun, leave the room darker than it would otherwise be on a dark and cloudy day. Because of this fact the schoolrooms with a southern exposure are perhaps our most poorly lighted rooms. The fifth rule, concerning the use of white screens for the black-boards, is never observed, and to many may seem insignificant. The justification of the rule is found in the following facts.

Dark Corners in Schoolrooms.

The ordinary schoolroom has the light from one side. The five rows of desks are so arranged that one row is next to the windows, and the last row next to the black-board on the side of the room opposite the windows. It is well known that the desks next to the black-board and furthest from the windows receive less light than the desks next the windows. That the difference between the first and fifth rows is great enough to occasion any alarm seems not to have been suspected. In the ordinary schoolroom the light reflected from the pupil's book on the first row is eight times as great as the light reflected from the book of the pupil who is so unfortunate as to sit in the row next to the black-board. The decrease of the light as the distance from the window increases is different in each room. The law of the square of the distance is not even approximately correct, but it is safe to say that in the great majority of schoolrooms in the United States the row of desks next to the windows has many-fold more light than the rows next the black-boards. Prof. Basquin and I tested schoolrooms having windows on but one side. In these rooms the variation between the first and fifth rows was from seven-fold to ten-fold. By the introduction of screens over the black-boards in the same rooms, the light at the darkest seat was increased as much as 50 per cent. That an increase of 50 per cent. in the light in the dark corners of our schoolrooms is important is apparent to all. Furthermore, this result can be secured with little or no cost. Most schools possess white screens, light-coloured advertising maps, charts printed on white paper, &c. They may be used to cover the black-boards, and when thus used they will reflect the light to the very parts of the rooms which need it most.

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

Unwise Demands made upon the Eyes of Young Children.

Until within a very few decades reading was taught by a slow and cumbrous method. The effort of reading was so great that few children enjoyed the reading of a book until after they had completed the third school year. Interesting books for children were few in number and not available for the vast majority of them. To-day this is all changed. Our methods of teaching reading are so improved that before the child has been in school a full year he begins to read books at home forhis own pleasure. Our printing-presses are teeming with children's books. Andrew Carnegie, or rather the movement which he so ably supports, has filled city and country with free books available for even the youngest. During the last twelve months I have tested the eyes of some 700 children. I have asked of each child an estmate of the number of books read in the preceding twelve months. One room of 31 pupils for the twelve months preceding the middle of the second school year, gave the following figures. The average number of books read by each pupil was 22. Some had read but few, while others had read many more than 22. One-half of the pupils had read 20 books or more. It should be observed that this record of the number of books covers the period from the middle of the first school year to the middle of the second school year. After the second school year many pupils read regularly a book a week. In several of the grade rooms tested, the pupils of the room read on the average as many as 50 books a year. In the first three years after reaching the legal school age not a few pupils in our best city schools read 100 books. This figure is certainly far above the average, but there is a tendency to increase the number of books read during these first three years of school. We should but deprecate the tendency, and do all we can to stop it. During these three years the pupils are growing faster than during the following years. At this time there is a decrease in the nervous energy of the child. In recent studies of the order of development of motor adjustments and co-ordinations, it has been found that the individual first acquires control over the larger muscles and later over the finer ones. The normal activity of the child exercises mainly the larger muscles. The plays of children give the widest scope to the exercises of such muscles. The coarser movements are most predominant. while the finer adjustments and the use of the smaller muscles are of secondary importance.

By our improved forms of modern education all this is changed. We put the six-year-old child to the task of reading and writing. These acts involve the use of the smaller muscles of the organism, and are dependent upon more exact control of these muscles than any other act the individual is ever likely to be called upon to execute in later life. If an adult is out of practise in the use of the pen, a single hour's work is sufficient to exhaust the hand. The extreme exertion which the child puts forth to guide the pen or to follow line upon line with the eyes is so far in excess of the amount of energy required by an adult that we are not in a position to appreciate the severity of the child's task. Children upon entering school have better control of movements involving the whole arm and the wrist than of those involving the wrist and fingers. The muscular control of the eyes is adequate for all free movements of the eyes, but not sufficient to warrant the finer adjustments of continuous reading. The loss of nervous energy, necessitated by reading and writing, at the ages of from five to eight years is an unwarranted drain upon the health of the child. At this age the child needs free and vigorous movements rather than the constrained and finer ones required in reading and writing. At a later age the control over the finer muscles is adequate for the task, but in this age of rush we are crowding our little ones and inverting the order of nature. Furthermore, the tissues of the globes of the eyes are still soft, and the strain of the ciliary and other eye muscles is likely to cause short-sightedness by increasing the anterior-posterior axis of the eyeballs. If the child's eyes do thus lengthen under the excessive strain, the eyes are not only weakened for vision, but they become diseased organs.

We have thus far attempted to establish the following four propositions. (1) The human eye was evolved for distant vision, and the perversion incident to reading and writing would lead us to expect some great injury to the organism. (2) Although the eye may easily adjust itself to a light changing from one to ten candle-power, the diversities of daylight during the hours of the school day and the months of the school year are so great that the minimum and maximum extremes are frequently exceeded. (3) The necessary rules for lighting buildings are not adhered to, thus placing an unnecessary strain upon the eyes of all attempting to read and write. (4) There is a growing tendency to use the eyes at a period of life which is in every way ill fitted to the task. If these four propositions had been established, and if the pessimistic forebodings are justified, then investigations of the eyes should discover a general destruction of the eyes of civilized countries, and an increasing number of eyes injured during the age of from six to nine.

Investigating the Eyes of School Children.

Systematic investigations of eyes upon a wide scale were not begun till 1865. At that date Dr. Herman Cohn commenced his investigations of the eyes of school children in Breslau. After having examined ten thousand children, he summarized his results as follows :—

Short-sightedness hardly exists in the village schools; the number of cases increases steadily with the increasing demands which the schools make upon the eyes, and reaches the highest point in the gymnasia.

The number of short-sighted scholars rises regularly from the lowest to the highest classes in all institutions.

The average degree of myopia increases from class to class, that is, the short-sighted become more so.

The circular of information of the United States Bureau of Information, No. 6, 1881, in speaking of the many investigations which had been made in this and other countries, said : —

All, without a single exception, prove beyond a doubt that near-sightedness, beginning, perhaps, at nothing in the lower classes in the school and first year of school life, steadily increases from class to class in the school until in the highest grades or in the last years of school attendance it has actually developed itself in as many as 60 or 70 per cent. of all the pupils.

In all these tests children were not regarded as near-sighted unless their visual acuity in one or both eyes was but two-thirds of normal vision or less. Think of the significance of these statements, which are entirely authoritative. Pupils entering our schools come to us with good eyes, but if they stay with us till the end of the course, 60 to 70 per cent. of them will leave us with but two-thirds normal visual acuity or less. Most of this loss of vision is caused directly by the strain put upon the eyes in reading, writing, and drawing.

The Sacrifices Caused by Premature Strain.

The picture drawn by the investigators during the two decades following 1865 was dark indeed. The only ray of hope was found in the fact that the destruction of the eyes did not begin during the first few years of school, so that pupils dropping out before the eighth or tenth year would probably escape with good eyes. Thus Cohn found that in the case of pupils eight and a half years old there were but 5 per cent. myopic, while of the pupils remaining the full fourteen years, 63·6 per cent. were myopic. Investigations of the pupils of other cities of Germany resulted in similar findings. Investigations in America were not so numerous as those in Germany, but in general the results were the same until recent years.

Investigations carried on in Worcester, Massachusetts, in 1891, showed that in the second and third grades from 50 to 60 per cent. of the pupils possessed less than normal visual acuity. Investigations upon over 3,700 pupils of the Chicago public schools, in 1899, showed that the maximum of defective eyes was reached with pupils nine years old. No one seems to have remarked upon this change in the grade at which the maximum destruction of the eyes is found. In fact, the results seemed to have been looked upon as rather accidental and of no special significance.

Some months ago I asked myself these two questions. Is the maximum destruction of the eyes of the school children reached earlier than formerly ? Secondly, if such is the case, what is the cause of it ? In attempting to answer these questions I have tried to learn what recent investigators have found concerning eyes, and I have attempted personally to examine the eyes of children in schools which were significant. The data which I have secured lead me to conclude that the excessive destruction of the eyes begins several years earlier than was formerly the case in America, and earlier than is still the case in Germany and other foreign countries. As to the cause of the early injury of the eyes the results of my investigations are most significant. The highest per cent. of defective visual acuity I have thus far discovered was found in a room in which the pupils had been in school but one and a half years. This is the room referred to above, in which the average number of books read by each pupil during the preceding twelve months was twenty-two. It may not surprise you when I tell you that 84 per cent. of these little innocents had defective vision. The schoolroom in which they were seated was unusually well provided with windows and had a south exposure. Unfortunately their teacher preferred a rather dimly lighted room, and made generous use of opaque shades with which the windows were provided. The light by which the pupils read in school was in most cases certainly better than the light which they had for their reading of books at home. Some of these children in their childish ignorance took books to bed with them, and upon awakening in the morning read before breakfast. It is probable that in most cases the children at home read during the evening twilight tlll it was too dark to tell one word from another. Then they would retire to some dark corner of a dimly lighted room and continue the reading till supper-time or bedtime. Young children have no regard for their eyes, and parents are not likely to interfere with them as long as they are quiet.

The pessimistic forebodings expressed in the first part of this article are more than justified by the figures just presented. The eyes of our school children are being destroyed, and worse than that, the destruction is now taking place at the age of from seven to nine years, which makes the matter so serious that we should bestir ourselves to lessen the evil as far as possible. In the palmy days of Greece the Athenian boy was not taught to read till he was ten years old. By our modern improved form of education we injure the eyes of our children so that one-half of them have defective vision before the age at which the Greek boy learned his alphabet.

The gravity of the situation is so great that I venture to offer in conclusion the following suggestions :—

1. We should recognize the fact that human eyes are ill adapted for reading, writing, and drawing for a long period at a time.

2. We should recognize the fact that the normal daily deviation of daylight is so great that any method of adjusting the window shades from mere habit is inadequate.

3. In constructing schoolhouses the window space should be as large as that described above.

4. The interior walls and ceilings should be light.

5. The amount of sky visible from each seat should be large.

6. The windows should be provided with white holland screens or their equivalents.

7. Every schoolroom should be provided with light shades, and they should be placed over the black-boards as soon as there are dark corners in the room.

8. School children's eyes should be tested annually, and parents notified that an oculist should be employed in the case of all defective eyes.

9. Children should not be taught even the elements of reading or writing during the first year of school. For the ordinary reading and writing should be substituted more oral instruction in language, number work, nature study, history, singings physical training, play, and other form, of training suited to the needs of the pupil.

How are we to Protect our Eyes from the Ultra-Violet Rays yielded by Artificial Sources of Light?

By Dr. Fritz Schanz (*Oculist*) and Dr. Carl Stockhausen (*Engineer*).

(Abstracted from the *Zeitschrift für Beleuchtungswesen*, Oct. 10, 1907.)

Dr. Schanz refers to the experience of his collaborator (Dr. Stockhausen), who experienced severe inflammation of the eyes after working with an electric arc lamp. Many experiments have proved that this effect is caused by the ultra-violet rays. These rays are invisible to the human eye, but produce powerful chemical effects, and are easily recognizable by their action on a photographic plate.

Hitherto a glass plate, placed between the eyes of the observer and the source, has been considered adequate protection, but this did not suffice in the case to which reference has been made. Dr. Stockhausen wore his spectacles while making these experiments, but nevertheless suffered severely. This circumstance induced the authors to undertake an investigation, with the object of determining to what extent glass really does absorb ultra-violet rays. It was found that the usual glass lamp-shade and the glass used in spectacles only absorbs rays of shorter wave-length than about 300 $\mu\mu$, and these are known to be just those rays which possess the least "penetrating power," and are, therefore, least deep-seated in their action on the human organism.

The most powerfully active rays are those between 300 and 400 $\mu\mu$, and these are transmitted by the glasses referred to. The so-called "blue" glasses, in fact, so far from affording additional protection, allow these rays to pass through with special ease. Smoked glasses weaken these rays, just as they do the visible spectrum, without completely suppressing them, however.

The authors have also investigated the richness in ultra-violet rays of many artificial sources of light, ranging from the torch-light and oil-lamp to the new quartz-glass mercury lamp. Briefly, the intensity of the ultra-violet element became more and more marked with rising temperature. Yet no general attempt has been made to suppress these rays, which are quite useless from the point of view of illumination.

Every one must have noticed how quickly the eyes tire when we attempt to execute a piece of work by artificial light, which we are only just able to get through in daylight. The light "strains" the eyes. When the eyes are already subject to a slight inflammation, the effect is more marked still.

Diffused sunlight is not very rich in ultra-violet rays, because our atmosphere absorbs them very markedly, and also because a very large proportion of such light is lost by multiple reflection, before the light reaches our work-table and eventually our eyes.

There is a piece of apparatus in the eye which protects the retina from the influence of ultra-violet rays, namely the lens. When strongly illuminated by ultra-violet rays, the lens becomes fluorescent. The ultra-violet light has, therefore, been converted into visible light.

This naturally raises the question whether the energy continually striking the eye may not, in time, effect appreciable alterations in the organ.

Widmark, Schuleck, and other workers have detected a cloudy formation in the lens under the influence of ultra-violet rays.

The authors therefore suggest that the various forms of cataract might be initiated in this way. It is not easy to prove, definitely, that this cloudiness of the lens of the eye is more prevalent than previously, when we had no sources of light which were rich in ultra-violet rays. Yet this possibility must be borne in mind.

We ought, therefore, to seek to protect our eyes from ultra-violet light, not only because of its irritating effect on the anterior portions of the eye, but also because of the possibility that the cataract of old age may be appreciably accelerated thereby.

It is desirable, therefore, to utilize a variety of glass which absorbs these rays more completely than the glass in general use.

The authors have succeeded in producing such a glass, which they hope will be put on the market very shortly.

The Illumination of Work-places and Workrooms.

BY DR. KARL STOCKHAUSEN.

(From the *Zeitschrift für Beleuchtungswesen*, Oct. 10, 1907.)

DR. STOCKHAUSEN remarked that a distinction must be drawn between the influence of the visible and the invisible rays upon the eye. But the dazzling effect of visible light of too great intensity is also injurious. From a hygienic point of view the brightness per unit area of an illuminant should not, the author thinks, exceed 0·75 candle-power (Hefner) per square centimetre of radiating surface.

The author traces the continually increasing surface brightness of modern illuminants, and compiles a table giving details of forty different sources of light, ranging from the ancient pine-torches and oil-lamps up to the inverted incandescent mantles and the newest metallic-filament glow-lamps of the present day. With the exception of the torches, candles, open oil-lamps, and flat-flame gas-flames, all these sources exceed the limit mentioned above, and should therefore be enclosed in suitable diffusing globes and reflectors.

The continually increasing brightness per unit area of gas-lights reaches a maximum in the acetylene flame and the inverted gas-burner.

The new metallic-filament lamps, and especially the Nernst lamp, with a surface-brightness of 460 c.-p. per square centimetre, are examples of a similar tendency in glow-lamp manufacture.

The brightness per unit area of the petroleum lamp is five times the safe value, and, similarly, the surface-brightness of the incandescent gas-light is eight times, the carbon-filament glow-lamp about 100 times, the metallic glow-lamp up to 270 times, and the Nernst lamp may be as high as 550 times the above value. Worst of all is the electric arc, the brightness per unit area of which is no less than 4,000 times that which the hygienic aspects of illumination demand.

The fact is emphasized, therefore, that all such sources of light, when intended for the illumination of workrooms, ought to be screened by the use of more or less dense diffusing shades. The most satisfactory system of all would seem to be inverted lighting, for in this case the dazzling effects are avoided, and the injurious ultra-violet rays are, for the most part, absorbed by successive reflection from the walls and ceiling.

The author points out, further, that, owing to the faulty construction and use of diffusing globes, brightly illuminated spots are often met with which exceed the permissible brightness per unit area by two to three times.

Finally, he remarks that, during the competition between gas and electricity for lighting purposes, it has become customary to aim at mere brilliancy of illumination, and either to omit the requisite diffusing shades entirely, or to place them in such a way as to throw the light downwards, instead of screening the eyes of the worker.

The author closes his paper with the following recommendations:—

1. All sources of light should be screened by diffusing shades, placed in such a position that the eye is unable to perceive any light-radiating surface of a brightness exceeding 0·75 C.-P. per square centimetre.
2. Chimneys or globes should be made of some variety of glass which absorbs ultra-violet light.
3. Globes must be sufficiently dense, and constructed in such a way as to enclose the source, and to present an evenly and weakly illuminated surface to the eye.
4. Glow-lamps with clear globes should be rejected for the illumination of schoolrooms and workrooms.
5. Inverted illumination is preferable (from a hygienic standpoint) to all other methods of illumination.

REVIEWS, ABSTRACTS, AND REPRODUCTIONS.

Coefficients of Diffuse Reflection.

By Dr. Louis Bell.

(The Transactions of the Illuminating Engineering Society, "Convention Issue," October, 1907.)

In all problems which have to do with practical indoor lighting, the coefficient of diffuse reflection of the walls plays an important part. In lighting such as we have here in the convention room, the coefficient of diffuse reflection is the permanent factor in determining whether the lighting shall be good or bad; and in all cases there is the more or less uncertain factor of wall reflection with which we have to deal.

It, therefore, seems desirable to add somewhat to the meagre data which are at the disposal of the illuminating engineer by measuring the coefficient of diffuse reflection of wall finishes, chiefly papers, in various colours, both by daylight illumination and by illumination from incandescent lamps. The coefficients of diffuse reflection, of course, vary both according to the colour of the finish and according to the colour of the incident light, the two mutually intersecting. I, therefore, started to determine a series of coefficients of diffuse reflection varying both these conditions.

The material was chiefly wall-paper of various finishes and of various colours. The method adopted was to compare each sample with a piece of white cardboard, taken merely for the purpose of a working standard, using the Munsell photometer for the purpose. This photometer gives fairly consistent readings, with a reasonable degree of accuracy, subject only to the condition which affects all photometers, that surfaces of widely different colours are somewhat difficult to compare. Then the coefficient of the standard cardboard which had served for reference, was determined in absolute measure by comparing the incident and the reflected flux of light.

The results of this comparison I have expressed in the accompanying table. The sum and substance of the matter s this: that nearly all the colours, certainly all the strong colours, give somewhat lower coefficients than we have been tempted at times to estimate for them. The absolute coefficient of the standard cardboard was ·74. The highest coefficient obtained with any wall paper was ·64, and that was with a very light cream tint, scarcely perceptibly different from white. That gave a coefficient of ·64 with the incandescent lamp, and ·53 with diffused daylight from a north window and a clear sky, which was the uniform condition under which the daylight measurements were made. The coefficients of the various colours, which ranged all the way from those nearly white in tint to deep greens and deep reds, ranged downwards from ·64 to ·05, the latter figure applying to dark greens and dark reds.

The various results from the papers divide themselves somewhat as follows: Far and away the best, incomparably better than any of the deeply coloured finishes, came the very light creams and yellows. These have coefficients of the order of magnitude of ·4 to ·6; next come the medium papers of grey, yellow, bright red, very light red, pink, and lilac. The coefficients of these run roughly from ·20 to ·40. Finally, last in the line, come some of the present fashionable papers in dark tones, which run down from say ·15 to ·05, winding up with the deep reds and deep greens, which are nearly equally bad.

As respects the differences existing between the coefficients for sky light and those for incandescent electric light, in most cases the incandescent lamp gives a little less satisfactory coefficient by a few per cent. In a few instances, and specially in the light creams and very light yellows, the reverse is the case, these showing up distinctly better by incandescent lamp light than by the light of the north sky, which is strongly bluish.

A particular point of interest is the very deceptive character of some apparently light finishes, greys in particular, and what the decorators are pleased to call "warm" greys more especially. These colours kill the light in a way that is perfectly astonishing to one who is not familiar with them. The coefficients, for example, for a light grey green drop to a little over 20 per cent. in either light, and the light brownish greys are similarly bad. Grey generally contains a more or less strong mixture of black, and frequently a little tint of red; both of these tend to destroy its colour-reflecting value.

As between the textures of the papers, except for the silk finishes, which in certain directions tend to absorb light very strongly, there seems to be very little difference, the crepe, the cartridge, and plain papers of similar colours having coefficients which are remarkably similar.

A few experiments were made with striped papers, and the difference between the several stripes of the papers found in practice was, as a rule, remarkably small.

TABLE OF COEFFICIENTS OF DIFFUSE REFLECTION.

Kind.	Colour.	Coefficients for Skylight.	Inc. lamps.	Remarks.
Plain Ceiling	Faint Greenish	·50	·53	
,, ,,	Light Ecru	·27	·26	
,, ,,	Very Faint Grey Cream	·53	·64	
,, ,,	Light Grey Green	·26	·23	
,, ,,	Light Yellow	·53	·49	
,, ,,	Faint Ecru	·47	·55	
,, ,,	Faint Pinkish	·41	·43	
,, ,,	Pale Bluish White	·42	·31	
Crepe	Medium Green	·25	·19	
,,	Darkish Coffee Brown	·08	·06	
,,	Deep Green	·05	·06	
,,	Deep Yellow Buff	·41	·41	
,,	Full Green	·06	·06	
,,	Deep Red	·05	·05	
,,	Medium Red	·06	·08	
Cartridge	Medium Green	·15	·11	
,,	Dull Green	·11	·07	
,,	Dull Yellowish Green	·09	·07	
,,	Light Pinkish Brown	·21	·26	
,,	Light Green	·23	·18	
,,	Light Blue	·21	·20	
,,	Pale Grey	·35	·27	
,,	Faint Yellowish Green Grey	·43	·33	
,,	Salmon Buff	·31	·33	
,,	Medium Light Buff	·44	·44	
,,	Medium Full Green	·11	·07	
,,	Medium Dull Red	·06	·07	Grey Red
,,	Light Red	·10	·10	
,,	Very Deep Ecru	·18	·15	
,,	Pale Pink	·25	·19	
,,	Deep Yellow Grey	·18	·15	
Silky Finish	Medium Crimson	·08	·12	Across Grain
,, ,,	Medium Grey Green	·17	·12	
Stripes	Deep Cream	·56	·60	
,,	Deep Cream Silvery	·56	·57	
,,	Yellow Medium	·50	·53	
,,	Deep Buff	·53	·58	
,,	Medium Red	·06	·08	

Kind.	Colour.	Coefficients for Skylight.	Inc. lamps.	Remarks.
Stripes	Medium Red Satin	·07	·11	
,,	Light Strawberry Pink	·43	·43	
,,	Light Strawberry Silvery	·51	·49	
,,	Light and Dark Green	·06	·07	Heavily streaked deep green
,,	Silvery Light Green	·13	·14	
,,	Light Green	·36	·26	Plain
,,	Silvery Light Green	·36	·23	Corded
Miscellaneous	Dark Green and Gold	·24	·19	Minute figuring with much gold
,,	Light Green and Gold	·31	·28	
,,	Deep and Light Red	·12	·20	
Pique	Light Bluish	·46	·47	
,,	Light Grey	·38	·38	

In closing I should say that these figures, so far as lights are concerned, refer to light from the north sky on the one hand and light from the ordinary incandescent electric lamp on the other hand.

As regards the angles of incidence, which are a very important feature in determining the coefficients of diffused reflection, in all cases the figures apply to medium angles of incidence, say from 35 degrees to 45 degrees. They do not apply in any sense to grazing incidence, but they will be approximately true for the moderate angles.

It would be almost impossible, even if it were desirable, to make a detailed investigation of the angular distribution of coefficients of reflection for a large series of papers. It would not be sufficiently instructive, even if made, and these figures will be sufficient to give a fairly clear idea as to the coefficients found with the finishes which are in common use and of which the coefficients do not always bear their values on the face of the paper. The data are for diffusion from a surface where there are no questions of either grazing incidence or grazing reflection coming in, and where there is no element of specular reflection.

Primary, Secondary, and Working Standards of Light.

By Edward P. Hyde.

Taken from *Transactions* of the Illuminating Engineering Society, October, 1907, "Convention Issue."

We are living in an age of exact measurement. With what profound wonder would our forefathers have contemplated the marvellous precision of modern physical science. We compare resistances to parts in a million, we weigh weights to parts in a billion: indeed, if it were not for photometry and a few kindred sciences, I am afraid that the term "per cent.," which for so many years has been the common unit in expressing accuracy, would soon become obsolete in that sense.

What, we ask ourselves, is the cause of this tardy development of photometry? Is it because our instruments are insufficient, or our standards inadequate, or is there some inherent difficulty that cannot be overcome? To be sure we shall always have the limitations of the human eye to contend with, because "light" by definition is subjective, but oftentimes the eye is made the scapegoat for faulty methods or inaccurate measurements. The accuracy of comparison of two luminous sources of the same colour is well beyond that with which the intensity of either can be expressed in terms of our standards. The fault then lies ultimately with our standards.

It is not my intention in this paper to present to you a history of primary standards of light, or to make a study of the relative merits of the various standards in use at present. It is my purpose, rather, to ask your consideration of a few very practical questions in connexion with the relationship of primary, secondary, and working standards of light. By a "primary" standard is meant any standard that can be set up from written specifications, such as the Violle platinum standard, or the Hefner lamp, or the Vernon-Harcourt pentane lamp. By a "secondary" standard is meant a standard which, though not reproducible, will remain constant after having once been calibrated. The well-seasoned incandescent lamp is the best example of this. By a "working" standard is meant any lamp that is used as a standard in ordinary photometric measurements. It may be a secondary standard or even a primary standard, but it is not necessarily either. Though the three classes of standards are quite separate in principle, they overlap in practice.

There is one quality which all standards must possess in common. They must have a suitable colour. This requirement is very indefinite, but it must needs be so. We cannot specify the actual spectral distribution, but we can exclude monochromatic sources. In other words, we can immediately eliminate some sources as being impracticable, whereas we cannot assign values of relative merit to those which fall within the wide range of acceptability. In addition to this common property there are special properties which each class of standards must possess.

A primary standard is good or bad accordingly as it is or is not reproducible. Its fitness as a primary standard depends upon the degree of accuracy with which it can be reproduced. It is not necessary that it should remain constant over a long period of use; the time at which the measurements are to be made can be specified, as is done in the case of the Violle platinum standard. It is not even necessary that it should be particularly inexpensive or simple, as it is sufficient that it should be set up from time to time in one or several of the various national standardizing laboratories now in existence. The only absolutely necessary qualification of a primary standard is, that in case all the secondary and working standards should be destroyed, the unit could be re-established. Of course if a lamp can at the same time serve as a primary standard and also as a secondary or working standard, it is the more valuable. If it is simple and inexpensive, so much the better, but these are not necessary qualities of a primary standard.

In a secondary standard we desire other qualities. These are best seen by keeping in mind an example—the well-seasoned incandescent lamp. A secondary standard need not be reproducible—we cannot make two incandescent lamps exactly alike; but it must remain constant after having once been calibrated in terms of the primary standard. It should be portable, simple, and inexpensive. Every standardizing laboratory should have a number of secondary standards against which to measure the working standards of lamp manufacturers and testing laboratories.

The working standards should be adapted to the particular kind of testing in which they are to be used. In testing incandescent lamps, we want as working standards other incandescent lamps; in testing gas or oil, we want flame standards. Working standards should be portable, simple, and inexpensive, easy to manipulate, and of suitable intensity, but they need not be reproducible. Having been standardized in terms of secondary standards, they should remain constant over a reasonably long period before having to be recalibrated or replaced.

With this brief statement of the requirements of primary, secondary, and working standards of light, let us inquire into the present conditions regarding these three classes of standards. First, Is there a satisfactory primary standard of light? I think you will all agree with me that there is not. Many such standards have been proposed from time to time, and at present there are three or four such standards in actual use. This last fact in itself indicates that there is no one standard sufficiently superior to the others to warrant its general adoption. And if we look over the tables of relative values of these different standards and compare the values found at one laboratory with those found at another, or those obtained in recent determinations with those accepted as the best of previous determinations, it is evident that there is an uncertainty in the ratios well beyond the limit of the error of measurement.

(*To be continued.*)

A Form of Cosine Flicker Photometer.

By J. S. Dow.

(*Phil. Mag.*, November, 1907.)

In this paper the author describes a form of photometer in which the cosine law is utilized in such a way, that it is possible to keep both photometer and sources of light stationary. The photometrical surfaces consist of the two sides of a Ritchie wedge rotated about their line of intersection, and the relative brightness of the two sources compared is ascertained by the indication of a pointer attached to the moveable wedge.

This type of instrument is stated by the author to be very convenient for certain purposes, but care is necessary to avoid the possibility of "angle errors," *i.e.*, errors introduced by any uncertainty as to the exact angle at which the rays of light strike the photometrical sources. To avoid this possibility the sources of light should preferably not be brought within about a distance of 1 metre from the photometer, and wherever possible the "double-comparon" method of photometrical measurement, which eliminates any want of symmetry in the photometer, should be used.

The instrument may be used on the "equality of brightness" principle, or, by utilizing an oscillatory lens on the rood system, as a flicker photometer. The author quotes some results as showing that good agreement, from a practical point of view, between the two methods was obtained in this case, but intimates that this might not be true for all regions of the retina, or in the case of very marked colour-differences.

Finally, some experiments on the application of Crova's principle to the comparison of lights of different colours are described. According to the principle of Crova, the integral luminosity of the spectrum of an incandescent source can be expressed in terms, if the luminosity is near $\lambda = 0{\cdot}582\mu$. Crova, therefore, proposed to view the two illuminated surfaces in a photometer through a special solution absorbing all rays but those in this neighbourhood.

The author employs this plan in connexion with both the methods of "equality of brightness" and "flicker," and finds that, though somewhat difficult to apply, the method gives fairly correct results when comparing the most commonly occurring sources of light. The general conclusion, is emphasized, however, that while Crova's method may be applicable to sources of light which yield a continuous spectrum, it assuredly is not so in the case of spectra broken up into isolated groups of lines, such as that yielded by the mercury vapour lamp.

The Nomenclature of Photometrical Quantities and Units.

(From the *Jour. für Gasbeleuchtung und Wasserversorgung*, Sept. 21, 1907.)

ADOPTING the recommendations of the International Electrical Congress in Geneva in 1896, and subsequently of their own congress in 1897, the 'Deutsche Verein von Gas- und Wasserfachmännern' and the 'Elektrotechniker Verein' have decided on the following description and nomenclature of the various photometrical quantities :—

1. The unit of light is the "Candle," and is defined in terms of the horizontal intensity of the Hefner lamp.

2. The following terms and symbols are to indicate the photometrical quantities and units :—

Quantities.		Units.	
Term.	Symbol.	Term.	Symbol.
Light Intensity (Lichtstärke) ...	J	Candle (Hefnerkerze)	HK
Light-flux (Lichtström)	$\phi = J\omega = \frac{J.S.}{r^2}$	Lumen	Lm
Intensity of Illumination (Beleuchtung)	$E = \frac{\phi}{S} = \frac{J}{r^2}$	Lux or Candle-metre (Metrekerze)	Lx
Surface-brightness (Flächenhelle)	"e" $= \frac{J}{S}$	Candles per squ. cms. (Kerze auf 1 q. cm.)	—
Output of Light (Lichtabgabe) ...	$Q = \phi.T.$	Lumen-hour (Lumen-stunde) ...	—

Where ω denotes a solid angle ; S, a surface in square metres ; s, a surface in square centimetres, both perpendicular to the direction of the rays of light striking them ; r, a distance in metres ; T, a time in hours.

Dr. Hugo Krüss gave the following explanations of these terms at the annual congress at Leipsic in 1897 :—

"By 'flux of light' is meant the total quantity of light radiated from a source of light within a solid angle (ω), or the total amount of light which a surface (S) receives, which is a distance (r) from the light-source.

"If one takes for this surface (S) the inner-surface of a sphere of radius (r) the flux of light becomes the total amount of light radiated by the light-source in question. The unit flux of light may therefore be defined as that quantity of light which will be radiated by a source of intensity 1 H.K., within a unit solid angle, or upon a unit surface of 1 square metre, distant 1 metre from the source of light. This unit flux we term '1 Lumen,' and designate by 'Lm.'

"The intensity of the illumination of a surface (E) is measured in lux (Lx), a quantity which has the same meaning and magnitude as the quantity hitherto known as the 'candle-metre.' This quantity is defined as the ratio of the light-flux to the area of the surface illuminated by it, in square metres, or, as the ratio of the intensity of the source of light to the square of its distance away from the surface it illuminates.

"On the other hand, by the 'surface-brightness,' 'e,' is understood, the brightness of a surface, expressed in candles per square centimetre. One understands by an 'intensity of illumination' of 1 candle-metre, that illumination to which a surface distant 1 metre from a source of 1 candle-power, will be subjected.

"But in the case of surface-brightness, we take as our unit the brightness of that surface, each square centimetre of which radiates with an intensity of 1 candle-power. The surface-brightness is, therefore, as far as the surface derives its brightness from an external source, not dependent upon the brightness of the illuminating source, and its distance away from the illuminated surface alone, but also upon the *nature* of the surface illuminated.

"The term 'surface-brightness' is also specially applicable to bodies which themselves radiate light, such as the carbon filament of the electrical glow-lamp or the incandescent surface of the incandescent mantle, &c. In view of this application of the term we select one square centimetre as our unit surface and not one square metre."

The last term of the series, "the output of light," refers to the product of the total amount of light emitted by a source of light by the period of time during which the light is emitted.

There remains only the conception of "intensity of light" and the consideration of the recommendations of the second congress of the International Photometrical Commission in Zürich in 1907, which refer chiefly to the designation of the total flux of light from a source, as determined by the newer photometrical apparatus designed for this purpose.

The intensity of light is to be designated by the symbol "J_2," provided with an index which shall signify, under what conditions the measurement of intensity was carried out (*i.e.*, whether horizontal, spherical, or hemispherical values).

The following signs are to be utilized:

I_h, horizontal intensity.

$I_{\alpha s}$, intensity at an angle α to the horizontal in the upper hemisphere.

$I_{\alpha i}$, intensity at an angle α to the horizontal in the lower hemisphere.

I_o, mean spherical candle-power.

$I_{\smile}$, mean hemispherical candle-power, lower hemisphere.

$I_{\frown}$, mean hemispherical candle-power, upper hemisphere.

$I_{m\alpha s}$, $I_{m\alpha i}$, maximum intensities at an angle α to the horizontal in the upper (s), and lower (i), hemispheres respectively.

The Tantalum Lamp with High Resistance Filament.

By L. H. Walter.

Electrician, November 22nd.

In this article the author comments on the fact that the great difficulty in the case of tantalum lamps is the low resistance of the filament, which admits of not less than 25 c.-p. on 110 volts. The recent B.T.H. Patent (B.P. 21,511 of 1906) is mentioned, according to which the resistance of the filament can be raised by a special process to about four times its original value. The filament is heated by passing a current through it for fifteen minutes at a pressure of 15 m.m. of mercury in an atmosphere of nitrogen. During this process the resistance (cold) of the filament changed from 65 to about 240 ohms. The author has tried treating tantalum lamps in the same way, and succeeded in producing a very similar alteration of resistance from 51 to 190 ohms. To the naked eye, the wire, after treatment, did not appear to have changed very perceptibly, except that the metallic lustre was less marked. On trying to take out the filament, however, it was found to be no longer strong, flexible, and springy, but so brittle, that pieces longer than one inch in length could only be obtained with difficulty.

The tensile strength was also found to be very small, compared with Dr. von Bolton's value. The general qualities of the filament, in its two states, are as exhibited below.

	Untreated.	*Treated.*
Appearance of Surface.	Metallic lustre.	Bright and dull.
	Uniform surface.	Irregular patches.
,, Fracture.	Fine, granular.	Coarsely crystallize.

The author suggests, therefore, that this method is apparently not directly applicable to the glow lamp industry, because it is just this very springiness of the tantalum lamp which enables it to compete with the highly efficient but more brittle metallic filament lamps. He also remarks that more attention might be paid to the Siemens and Halske patent (No. 9,109, 1906), according to which a metallic filament is put in series with a carbon filament in the same bulb. It is then possible to use quite a short length of metallic filament, and the efficiency may still be fairly high, especially if the metallized carbon filament is employed.

Oil-Lighting at the International Petroleum Congress, Bucharest, 1907.

At the recent International Petroleum Congress in Roumania the question of illumination received consideration, attention being chiefly directed to the necessity of devising some practical method of testing the illuminating power of oil intended for lighting purposes.

The contributions to the discussion of the question included the report of the French section, and papers by M. Aug. Pihan, Herr Curt Proessdorf, and Mr. Leon Gaster.

It was pointed out that the petroleum products intended for lighting purposes had not been hitherto uniformly tested with a view to their subsequent value in this respect.

Such oil was merely defined as the distallate passing over between 150 and 300 degrees Cent., and tests were carried out on the basis of density, inflammability, calorific value, and so forth, but little or no attention was paid to *illuminating power*—in this case the most essential quality of all. The purchaser of oil intended for domestic lighting was thus often unable to obtain any information on the very point with which he was most concerned.

It was further pointed out that different varieties of petrol require to be burnt under different conditions in order to secure the best lighting effect, and that a type of burner designed to burn Roumanian oil will not answer in the case of the American or Russian product.

Herr Proessdorf, in his communication, further lays stress on the fact that such data as have been published on this subject are very incomplete, and their value is often restricted by the fact that essential details of the variety of oil burnt, the nature of the burner and chimney, &c., are omitted. In order to illustrate the variety of burners, &c., existing, he mentions that he has recently had 150 different lamps submitted to him for examination, and gives a broad classification of the different types of burners and chimneys examined. He also discusses the designs of such burners and chimneys from the point of view of securing good illumination, and smokeless and steady flames, and points out how their design is affected by the character of the petroleum burned. Finally, he suggests a method of photometrical testing of oil lamps on similar general lines to that prescribed by the French section, but differing in several essential details.

The French section proposes to specify two standard burners, and also suitable wicks and chimneys for use with them, and the standard dimensions of them are given in detail in M. Pihan's communication.

The "Kosmos" burner is intended for use with oils of the American variety, poor in carbon, commonly used for domestic lighting. The "Luchaire" type, on the other hand, is specially designed to allow complete combustion of the richer oils.

Recommendations are also given to M. Pihan's paper as to the method of testing, including details as to the setting up of the lamps and preparation of the wick previous to test.

In the absence of the much to be desired international standard of light, M. Pihan advocates the use of the Carcel lamp.

The tests are to be carried out on three lamps simultaneously. At the expiration of one hour's burning the flame of each lamp is so regulated as to produce 1 C.P. (Carcel).

Each lamp is then weighed, and the exact time at which the weighing is carried out noted. The lamps are then allowed to burn for ten hours continuously without the initial regulation being altered in any way, either by adjusting the wick or substituting a new chimney. Measurements of the candle-power are made at intervals of 2, 6, and 10 hours after the commencement of the tests; the lamps are re-weighed at the end of the ten hours.

From these data the mean luminous intensity of the flame, and the mean consumption of oil per hour, and, finally, the consumption of oil per C.P.-hour during this period can be calculated.

The " duration of useful illumination "

is defined by the French section as the time which must elapse before the C.P. of the lamp has fallen to 20 per cent. of its mean value. It is conveniently determined graphically by observing the point at which the curve connecting the C.P. of the lamp, and the timse, cut the horizontal line, representing the mean C.P.

These foregoing regulations refer to the "Kosmos" type of burner. In the event of the "Luchaire" burner being used similar methods of test are prescribed, except that the C.P. is now regulated initially to 0·6 Carcels only, and that tests of C.P. are now made after the duration of 5, 10, and 14 hours.

Apart from the desirability of testing the illuminating power of lamps burning petroleum, the conditions governing the safe use of lamps of this description are also important, and the oil lamp has suffered in the past through want of authoritative ruling on this point.

The value of this question from an industrial point of view was urged by Mr. Leon Gaster, who, at the conclusion of a paper on 'The Petroleum Lamp,' moved a resolution, which was adopted, that the Bureau of the Congress should study and fix upon a type of domestic lamp offering the conditions of greatest safety and highest efficiency.

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Shop Lighting.

From *The Electrical World.*

IN a note referring to the recent paper of Mr. Pearson on 'Shop-Lighting,' the writer describes the method employed in the lighting of certain premises in New York as follows:—

"Those who have visited the store, during the progress of these tests, know full well that the improvement in general appearance, and the good impression on the public, is fully as marked as the improvement and efficiency shown by the illumination designs. Roughly speaking, almost any of the well-designed modern systems tried in this store gave better illumination on the counters than the old system, with one half the power used in the latter, and this, too, with an immense improvement in the general appearance of the store. Can anything more strikingly illustrate the practical importance of good illuminating design?"

Light and Cleanliness.

IN his presidential address to the Association of Engineers in Charge on November 13th on 'Economic Considerations on the Management of Plant,' Mr. Patchell emphasized one point of great interest to those responsible for the management of plant.

"Good lighting," he said, "is conducive to economy in both engine and boiler rooms, as plant in a badly lighted room never gets properly looked after or cleaned. Why should it? It is no credit to the cleaner if it cannot be seen. Dirt is about the worst disease a plant can suffer from, as it invariably means neglect of small indications and warnings, timely attention to which would prevent the otherwise inevitable breakdown. Not only is the plant better cared for, but men all work better in cheerful surroundings, and lose less time through sickness."

The Küch Mercury Lamp.

By O. Bussmann.

(Abstracted from the *Electrotechnische Zeitschrift*, 1907, vol. xxxviii.)

The essential features of this lamp consist in the facts that the pressure of the mercury vapour in the lamp is very much higher than in the older mercury lamps, that the power consumed by a lamp of given dimensions is increased, and that the consequent high temperature is favourable to greater efficiency.

The mercury vapour tubes hitherto available, which were intended for 110 volts, were nearly 1 metre in length and about 3 to 4 centimetres in diameter. The Küch quartz tube, intended for 110 volts, is only about 8 centimetres long and 1 to 1½ centimetres in diameter.

The study of the best conditions in the tubes formerly employed showed that the curve of "inefficiency" reaches a minimum near 0·6 watts per H.K. If more energy is given to the lamp the efficiency continues to fall off until the glass tube begins to soften.

Dr. Küch, however, has utilized a tube made of quartz glass, which permits of a much greater energy-consumption and higher temperature.

He finds that after reaching a maximum near 1·2 watt per H.K. the inefficiency begins to fall again, and eventually an inefficiency as low as 1·6 watt per H.K. is obtained.

The author also quotes some recent tests of the Reichsanstalt, according to which 3,000 H.K. (mean spherical), and an inefficiency of 0·27 watt per mean spherical C.P. was obtained.

Under these conditions the colour of the light yielded by the lamp is also much improved, the ordinary discontinuous spectrum of mercury being partially replaced by a continuous one, and a distinct red element thereby introduced.

Yet the colour of the light seems to be still such as to render the lamp chiefly useful for the illumination of outdoor spaces, parks, and gardens, station-platforms, and the like.

There is one feature of the lamp which must certainly be regarded as a partial drawback to its use for ordinary purposes of illumination, namely, the transparency of quartz-glass to ultra-violet light. In the older mercury lamps the glass tube almost completely absorbed these ultra-violet rays, but the quartz tube lamp is so powerful in energy of this description that an exposure of only a few seconds causes an inflammation of the skin lasting for several days, while the subsequent "browning" of the skin is visible months afterwards.

The dangerous action of ultra-violet light on the eyes is well known, and to avoid injury of this kind the lamp is surrounded by a suitable dense glass globe. This precaution might prove hardly adequate when one remembers that the globes surrounding arc lights in the streets are occasionally broken. Stringent precautions are also necessary to provide against the possibility of a careless or ignorant user of the lamp removing the protecting globe. This very richness in ultra-violet light, however, is said to render the lamp valuable for special purposes, such as the treatment of skin diseases and the sterilization of drinking water, photography, &c.

In the discussion of Dr. Bussmann's paper some difference of opinion was expressed as to how far exact photometry of the mercury lamp is possible. Hahn insisted that the spectrum of the mercury lamp differed so greatly from the other common sources as to render its photometrical comparison with them out of the question. L. Bloch, O. Bussmann, and others, however, had found no serious practical difficulty.

Two possible methods of improving the spectrum of the light were also suggested. Dr. Gehrcke mentioned the value of adding certain metals, the spectrum of which contains lines in the red, to the mercury used in the lamp. Wangemann suggested the possibility of utilizing the high temperature of the mercury lamp to render some refractory material incandescent, thus obtaining a continuous spectrum.

Heraeus stated that these methods had been tried. The amalgam method failed, because the added metal tended to gradually separate out at one pole. He had also investigated the second method, utilizing Nernst materials and metallic oxides, but without satisfactory practical results. All impurities—and metallic oxides must here be so considered—affect the durability of the lamp.

REVIEWS OF BOOKS.

A HANDBOOK OF PRACTICAL GASFITTING.

By Walter Grafton.

Published by B. T. Batsford, London, 7s. 6d. net.

Although, as the title of Mr. Grafton's book implies, its contents are mainly devoted to the subject of gas-fittings, yet there are certain portions of this work which contain information of practical value to those connected with illumination. Besides dealing broadly with the practice of running mains, meter fixing, &c., the author refers to special departments of gas-lighting, such as street-lighting, switch-gas-lighting, the illumination of workshops, &c. We are fully in agreement with Mr. Grafton when, in this connexion, he recommends the consumer to insist upon a high standard of work, as being invariably cheapest in the long run.

The appendix of the book also contains a quantity of interesting and useful information. The work, as a whole, appears to be of a thoroughly practical manner, and being, in addition, excellently written and well illustrated, deserves the attention of all those connected with gas-lighting.

TOWN GAS AND ITS USES.

By W. H. Y. Webber.

Published by A. Constable & Co., Ltd., London, 6s.

In this book the reader will find much interesting information on the subject of gas-lighting. The first three chapters are devoted to a description of the nature, manufacture, and historical development of ordinary "town" gas. Mr. Webber then proceeds to deal with the theory and mechanism of both flat-flame and incandescent gas lights, mentioning the recent developments of the inverted burner, and also briefly touching on the merits of high-pressure gas-lighting.

The scientific side of illumination is also insisted upon by the author, under the heading of 'Practical Gas-Lighting.' After stating what he considers to be the essential qualities of successful gas-lighting, he touches on certain important practical cases of illumination, such as shop-lighting, railway-yard lighting, church-lighting, and so forth, and winds up by giving a few sound and simple rules, which are, nevertheless, unfortunately, not infrequently ignored by those responsible for the lighting installations of the present day. Not the least interesting section of this work is that devoted to the legal aspect of gas supply, and a feature of Mr. Webber's book, which deserves special recommendation, is the simple and attractive way in which the subject is presented; this will, doubtless, render it of special value to many who are not personally connected with the technicalities of gas-lighting.

GRUNDZÜGE DER BELEUCHTUNGSTECHNIK.

By Dr. L. Bloch.

Published by Julius Springer, Berlin.

This little book is devoted to an exposition of the fundamental principles underlying illumination, and their practical application. The chief photometrical definitions and units are simply and clearly explained, and the writer uses the now generally accepted notation to designate the various quantities dealt with.

The author next turns to the theoretical aspect of light measurement. He explains the nature of mean spherical and hemispherical candle-power, and describes graphically methods by means of which they can be calculated from the polar curves of light-distribution of sources. All this is illustrated by figures and diagrams of actual results with different sources of light, and various types of enclosing globes, &c.

Attention is also paid to the application of these data to the practical lighting of streets and buildings, illustrated by records of practical experience, such as the illumination of Friedrichstrasse, Berlin, which render the treatment of this subject especially valuable.

A special chapter is given up to indirect lighting; the influence of the diffusion of light from ceilings, wall-papers, and so forth, is mentioned, and some tables of recent determinations of the coefficients of reflection from various materials are included.

Dr. Bloch has dealt with his subject with great care and thoroughness, and we have no doubt that the book will form a valuable addition to the technical literature bearing on the scientific aspects of illumination.

Review of the Technical Press.

General Illumination.

The growing interest in illumination in this country has recently found expression in the columns of our technical journals.

Mr. Gaster's paper on 'The Province of the Illuminating Engineer,' before the Society of Engineers in Charge, has also given rise to the discussion of this subject.

Attention has been drawn to the very vital distinction between the mere production of light—however efficiently—and the successful utilization of the light which we have produced. The subject of illumination is rendered specially difficult by the fact that the physical side of the question—the problem of choosing our light-giving substances, and marshalling the atoms at our disposal so as to secure efficient light-production—is complicated by the physiological peculiarities of the eye. Our eyes behave very differently in their perception of strong and weak illumination. Possibly the light which is good for reading purposes may not be the best for other purposes, &c. And, as one of the writers on this subject remarks:

"This point of view is far away from that of the average man with a photometer, who makes simple tests of 16 c.-p. lamps. It shows that it will be probably years before the amount of knowledge concerning illuminating engineering will be sufficient to render operations in this field at all commensurate with the development in other spheres of engineering activity."

On the other hand, some fear has been expressed lest the scientific side of illumination may be so strongly put forward that the ordinary man may be scared into the belief that illuminating engineering is too complex for him to understand. It has likewise been maintained that the rules of good lighting are few and simple, and that there is no need for the existence of a new expert in illuminating matters to deal with them.

These different views are especially interesting at the present time, when the formation of an illuminating engineering society is being proposed in this country. It is certain that the study of lighting and illumination cannot be at once as simple and as complicated as these differing opinions would suggest.

It will, however, be readily admitted that the most immediate and urgent needs of illumination can be met by considerations of a simple, commonsense character, and that much good work can and will be done by those who, for instance, have little knowledge of physiological optics or the theory of the radiation from incandescent materials. For the moment these urgent needs must be kept in view. Yet the scientific considerations cannot be shelved indefinitely if illumination is ever to become an exact science.

And the very existence of this difficult scientific background only proves the need for a body of men willing to give their attention to its complexities.

In *The Gas World* Mr. S. F. Walker deals chiefly with the limitations of the "candle-foot" as a standard of intensity of illumination (*Gas World*, Dec. 7). He rightly draws attention to the necessity for taking into account the angle at which the rays strike the illuminated surface and the amount of light reflected by the illuminated surface. Many, however, will agree with the editorial comments on Mr. Walker's article in deprecating the proposal of a new system of nomenclature involving such terms as 10,000 "rays" per square inch, &c., when we have already a carefully defined and selected set of photometrical quantities decided on at the international photometrical conventions.

Mr. Haydn Harrison (*Elec. Review*, Dec. 6) gives the results of a series of tests carried out in Cannon Street, Holborn Viaduct, Queen Victoria Street, and Farringdon Street. Cannon Street proved to be the best lighted street of the four, and Farringdon Street the worst. Some curves are also given illustrating the extremely low value of the minimum illumination which was found to occur, and the important conclusion is arrived at that the superiority of the lighting in Cannon Street is due to the better spacing of the sources of light, and not to additional expense.

Photometry.

A recent report to the American Gas Institute, on 'Methods of Testing the C.-P. of Gas,' contains many points of general interest from the point of view of photometry, and especially as regards the use of flame-standards of light. The dimensions of the photometer room are fully discussed, and the necessity of careful provision to avoid the possibility of draughts in accurate testing is also insisted upon, even to the point of recommending the introduction of previously warmed air from an adjacent room.

The well-known and marked influence of bad ventilation, barometric pressure, and humidity on the C.-P. of flame standards of light are also referred to.

Finally, the existing standards of light are reviewed, and the need for a generally accepted international standard emphasized.

A most interesting and valuable report.

Wild (*Electrician*, Nov. 8, 1907) deals with the sensitiveness of various photometers, which include the Lummer-Brodhun, the grease-spot, the Simmance-Abady, and his own type of grease-spot flicker photometer. He finds that two of the types of photometers examined exceed the flicker-types in sensitiveness when the two lamps compared yield light of exactly the same colour.

On the other hand, the flicker-photometer gave the best results when the two sources compared differed in colour and their superiority became more pronounced as the colour-difference became more marked.

Such experiments are useful, yet one cannot help feeling that the value is in this case restricted by the fact that the results quoted depend upon the author's experience alone. It is certain that many observers would conscientiously obtain quite different results from some of those here given, and only a series of experiments by a large number of observers, carried out under exactly the same conditions, can really definitely decide which is the best of the modern types of photometers. Now that a number of new photometers are finding their way into use, the desirability of an authoritative and impartial series of tests of this description is evident.

Dow (*Electrical World*, Nov. 30, 1907) contributes an article on 'The Problem of Colour-Photometry.' The author remarks that until recently our sources of light were very similar in colour, but the use of "selective radiation" enables us to obtain light of very varying colour, and we may eventually hope to gain greater control over the spectrum of illuminants. The point is insisted that it is naturally impossible to obtain all the desired information about the capabilities of a source of light by any mere photometrical test, especially in the case of light of different colours. Therefore the suggested method of comparing lights which differ in colour by a method involving visual acuity, is not, strictly, a photometric one, and cannot be applied to general questions of illumination. It is also pointed out that such methods are complicated by the fact that the eye is not achromatic, and that whereas the red portion of the spectrum is the best for distant vision, the contrary is the case if the detail is to be viewed at very close quarters.

The physiological complexity of the eye and its influence on colour-photometry is also dealt with, the Purkinje effect and the "Yellow-spot" effect being mentioned in connexion with the recent theory of the action of the "rods" and "cones" in the eye. Finally the author gives a brief *résumé* of the various methods which have been proposed to facilitate colour-photometry, the natural conclusion being reached that the difficulties of the subject are only postponed, and not avoided by such methods.

Krüss (*Jour. für Gas*, &c., Nov. 2) describes a form of apparatus specially intended for the study of the distribution of light from inverted mantles.

In the *Journal of Gas Lighting* (Dec. 10) another recent article by Dr. Hugo Krüss comparing the merits of the upright and inverted types of mantle lighting is reproduced. The author gives a number of curves illustrating the distribution of light in the two cases, both with clear and opal globes, and emphasizes the point that mere measurement of the M.S.C.P. of the two sources does not constitute a comparison of their merits for general purposes of illumination. His results also proved unfavourable to the inverted mantle, but Drehschmidt, in a recent letter to the *Journal für Gas*, &c., states that Krüss's results do not apply to the most modern form of inverted incandescent mantle, which he considers to be undoubtedly more efficient than the upright form.

Electric Lighting.

Prof. Teichmuller, in a recent article (*E.T.Z.*, Oct. 17, 1907), compares the standard specifications for glow-lamps enforced in Germany, Austria, Switzerland, and England respectively. The conditions enforced in Switzerland and Austria naturally resemble those contained in the earlier German specification. The English specification — the most recently issued—deviates somewhat further, but this, too, is founded on the same general considerations.

The latitude of variation in watts per C.P., allowed in the different specifications differs somewhat, Austria allowing only 4 per cent., while in England a latitude of 8 per cent. is allowed in the case of individual lamps, and an average of 5 per cent.

Fortunately, all countries are in agreement as to the definition of "useful life," namely, the time elapsing before the C.P. of the lamps in use has fallen 20 per cent. At present, life tests are to be carried out at the P.D. on which the lamp is intended to run. The German, Swiss, and English specifications do not definitely propose "overrunning life-tests," though the two former nations refer to this method.

Austria-Hungary proposes to test lamps by running them for twenty-four hours at 20 per cent. above normal pressure. Recent experiments are said to confirm the value of this test. Manufacturers, however, point out that the method would have to be applied with caution to the comparison of different makes of lamps, owing to the different qualities of the carbon used.

It may be noted that, in the case of England and Switzerland the conditions imposed by the specification are always applicable, while in Germany and Austria they only apply when the number of lamps ordered exceeds a certain value.

There is a general impression that the specifications are too severe to be rigidly enforced. Yet their educational value to the consumer is not to be despised.

The Electrical Engineer (Dec. 6) contains an article by "A lamp maker," discussing the influence of the new metallic filaments on central station revenue. He takes a rather sombre view of the situation, contending that neither the presumable increase in the number of consumers nor their supposed increased consumption of light can make up for the direct loss of revenue arising from the greater efficiency of the new lamps. The only solution he sees lies in the adoption of some radically different method of connecting and charging.

Recent issues of the *Zeitschrift für Beleuchtungswesen* contain notes on further processes connected with the manufacture of glow-lamps; for instance, a new method of exhausting the bulb by means of a small tube let into the base of the lamp. The exhaustion of the bulb and sealing in of the filament are thus carried out in one operation, and the production of the "pip"—a fruitful source of breakage—is avoided.

The scientific principles underlying the new metallic glow-lamps have been the subject of a recent paper by Stark (*E.T.Z.*, Oct. 24, 1907), who contends that these lamps owe their high efficiency to their high temperature of incandescence.

The same conclusion is reached in an article on the tungsten lamps in the *Revue Electrique* (Nov. 15, 1907).

Walters (*Electrician*, Nov. 22, 1907) describes a B.T.H. method of increasing the resistance of tantalum filaments.

Gas Lighting.

Attention may be drawn to two recent papers on gas lighting, by H. Kendrick and H. Burgess.

The former deals chiefly with the maintenance and adjustment of incandescent burners. The latter describes the high-pressure system of lighting on the Midland Railway.

Two interesting special appliances for the study of incandescent mantles have recently been devised. The first of these is intended to test the vibration and "shock-resisting" power of mantles, and is so arranged that, as a handle is turned, the mantle is alternately lighted and extinguished, and simultaneously receives a series of shocks.

The second is an optical device by means of which the change in shape of a mantle during its life can be accurately studied.

A rightly designed burner provides a flame of such a shape that the mantle utilized with it is completely encircled by the hot outer region of the flame. Therefore, as the mantle changes its shape, portions of it are withdrawn from this hottest region of the flame, and do not glow as brightly as they should do.

In increasing the life of incandescent mantles, our object should therefore be to devise a mantle which retains not only its exact original chemical proportions, but also its original correct shape.

The Journal of Gas Lighting for Dec. 3 contains an abstract of a recent paper by Winkler (*Jour. für Gas*, &c., Oct. 5, 1907) on the application of inverted burners to street lighting. Among other questions the author discusses the distribution of light from the inverted mantle, and the shape which ought to be given to the reflectors placed above them so as to secure the best distribution of light. Other interesting papers, which space does not allow us to deal with, are included in the following table :—

ILLUMINATION.

Editorial Notes. *Electrical Review* (Oct. 4, Oct. 25, Nov. 8).
Gaster, L. The Province of the Illuminating Engineer (The Society of Engineers in Charge, Dec. 11).
Harrison, H. T. The City Lighting (*Electrical Review*, Dec. 6).
"Multipolaris," Freaks and Fallacies in Illumination (*Am. Illuminating Engineer*, Nov.).
Walker, S. F. The Science of Illumination (*Gas World*, Dec. 7).

PHOTOMETRY.

Dow, J. S. The Problem of Colour-Photometry (*Elec. World*, Nov. 30).
Krüss, H. Photometrierstative für hängendes Gasglühlicht (*Jour. für Gas*, &c., Nov. 2).
Krüss, H. A Comparison between Inverted and Upright Incandescent Gas Lights (*J. G. L.*, Dec. 10).
Wild, L. The Sensitiveness of Photometers (*Electrician*, Nov. 8).

ELECTRIC LIGHTING.

'A Lamp Maker." Metallic Filament Lamps—How will they affect Electricity Undertakings? (*Elec. Engineer*, Dec. 6).
Guye and Zebrikoff. Experiments on the Electric Arc (*E. T. Z.*, Dec. 5, p. 1177).
Niethammer. Metalfadenlampen (*Elektrot. u. Masch.*, Nov. 24).
Patents. Bogenlichtkohle zur Erzeugung hochactinischen Lichtes, Dr. Marquart, D.R.P. 176419 (*Zeit. für Beleuchtungswesen*, Nov. 20).
Filaments for Gas and Electric Lighting (*J. G. L.*, Nov. 5).
Verfahren zur Betriebe von Quecksilberdampflampen (*Zeit. für Bel.*, Nov. 30).
Verfahren zur Herstellung elektrischen Glühlampen (*Zeit. für Bel.*, Nov. 10).
Stark. Prinzipien der neuen Verbesserungen der Okonomie elektrischen Lichtquellen (*E. T. Z.* Oct. 17).
Teichmuller, J. Technische Bedingungen für die Lieferung von Glühlampen (*E. T. Z.*, Oct. 17).
Upson, W. L. Observations on the Electric Arc (Paper read before the Physical Society, *Electrician*, Oct. 25 and Nov. 1).
Voss and Zinck. Mitteilungen über elektrischen Metallfadenglühlampen und hängendes Gasglühlicht (*Jour. für Gas*, &c.).
Walters, H. L. The Tantalum Lamp with High Resistance Filament (*Electrician*, Nov. 22).
Lampes au Tungsten (*Rev. Electrique*, Nov. 15).
The Crompton-Blondel Arc Lamp (*Electrician and Electrical Review*, Nov. 29).

GAS, OIL, AND ACETYLENE LIGHTING.

Brearley, J. H. Gas Hygiene and Ventilation (*Gas World*, Nov. 21).
Burgess. High-pressure Lighting on the Midland Railway (*Jour. of Gaslighting*, Oct. 15).
Fischer. Zur Theorie des Auerlichtes (*Zeit. für Bel.*, Nov. 30).
Goodenough, F. W., and Wallis Jones, R. J. The Advantages of Gas and Electric Lighting (*Jour. of Gaslighting*, Oct. 29).
Kendrick, H. The Maintenance and Adjustment of Incandescent Burners (*Jour. of Gaslighting*, Nov. 5).
Webber, W. H. Y. The Puzzle of Petrol Air Gas (*Gas World*, Nov. 2).
Winkler. Inverted Burners for Street Lighting (from the *Jour. für Gas*, &c., see *Jour. of Gaslighting*, Dec. 3).
Eine einfache Vorrichtung um Deformationen von Glühkörpern zu bestimmen (*Jour. für Gas*, &c., Nov. 2).
A New Mantle-testing Machine (*Jour. of Gaslighting*, Oct. 22).

PATENT LIST.

PATENTS APPLIED FOR, 1907.

I.—ELECTRIC LIGHTING.

24,635. Arc lamps. Nov. 7. W. A. Legge, 65, Chancery Lane, London.
24,706. Arc lamps (C.S.). Nov. 7. Johnson & Phillips, Ltd., and C. F. Tubbs, Birkbeck Bank Chambers, Southampton Buildings, London.
24,813. Filament for glow lamps. Nov. 9. J. W. Ward and R. H. Stevens, 140, High Rd., Ilford, Essex.
25,117. Arc lamps. Nov. 12. The British Thomson-Houston Co., Ltd., and W. H. Dalton, 83, Cannon Street, London.
25,304. Incandescent test or like lamps. Nov. 14. H. Brough, 18, Southampton Buildings, London.
25,355. Arc lamps. Nov. 15. P. M. Capitaine, 43, Boulevarde Voltaire, Paris.
25,881. Arc lamps. Nov. 22. D. Suchostawer, 33, Chancery Lane, London.
26,135. Enclosed arc lamps. Nov. 26. G. W. Farthing and T. K. Steanes, 77, Chancery Lane, London.
26,179. Manufacture of hollow metal filaments for incandescent lamps. Nov. 26. F. W. le Tall, 2, Norfolk Street, Strand, London. From A. Lederer, Austria.
26,294. Means of supporting filaments in incandescent lamps. Nov. 28. F. Harrison, 16, Ossian Road, Stroud Green, London.
26,838. Lamp filaments from metals and metallic oxides of high fusing point (C.S.). Dec. 4. H. P. R. L. Pörscke, 31, Bedford Street, Strand, London.
26,839. Lamp filaments from metals and metallic oxides of high fusing point (C.S.). Dec. 4. H. P. R. L. Pörscke, 31, Bedford Street, Strand, London.
26,840. Manufacture of lamp filaments, and securing same to leads (C.S.). Dec. 4. H. P. R. L. Pörscke, 31, Bedford Street, Strand, London.
26,841. Manufacturing filaments of non-fusible metals (C.S.). Dec. 4. H. P. R. L. Pörscke, 31, Bedford Street, Strand, London.
26,846. Arc lamps (C.S.). Dec. 4 (I.C. Dec. 5, 1906, Germany). Allgemeine Elektricitäts-Ges., 83, Cannon Street, London.
27,034. Arc lamps. Dec. 6. W. J. Davy, 40, Chancery Lane, London.

II.—GAS LIGHTING.

25,240. Inverted incandescent burners. Nov. 14. Sunlight and Safety Co., Ltd., and T. B. Smith, 5, Corporation Street, Birmingham.
25,657. Manufacture of incandescent mantles. Nov. 19. J. T. Robin, 7, Southampton Buildings, London. From S. Salomon, Germany.
25,846. Electrical gas lighting and extinguishing device. Nov. 22. J. M. Stewart and A. G. Rendall, 100, Wellington Street, Glasgow.
26,046. Inverted incandescent burner. Nov. 25. H. J. Ball, 1, Whymark Avenue, Wood Green, Middlesex.
26,286. Inverted gas lamps and burners. Nov. 28. G. Helps, Izons Croft, Ansley, Atherstone.
26,373. Upright incandescent mantles. Nov. 29. F. H. Mitchell, J. Lomax, and A. Millward, trading as Lomax & Co., 41, Corporation Street, Manchester.

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

24,871. Burners for lamps (C.S.). Nov. 9. M. F. P. Vialard-Goudon, 111, Hatton Garden, London.
25,277. Lamps (C.S.). Nov. 14. F. W. Kearsey, 111, Hatton Garden, London.
25,600. Acetylene storm-proof hand lamps. Nov. 19. T. P. Gandell, 46, Bedford Row, London. From J. Margreth, Germany.
25,695. Illuminated advertising devices (C.S.). Nov. 20. Radium-Licht-Reklame Co. m. b. H. and F. Stern, 6, Bank Street, Manchester.
25,715. Illuminated signs, facias, or the like. Nov. 20. R. F. Venner, 20, High Holborn, London.
25,874. Burners. Nov. 22. P. O. Rowlands, 8, Quality Court, Chancery Lane, London.
25,884. Vapour burning apparatus. Nov. 22. J. H. Miess, Birkbeck Bank Chambers, Southampton Buildings, London.
26,504. Illuminating bodies (C.S.). Nov. 30 (I.C. Dec. 1, 1906, Germany). O. Mannesmann, trading as Sparlicht-Ges. m. b. H., 53, Graben-trasse, Essen-on-the-Ruhr, Germany.
26,752. Devices for illuminating and examining the orifices or organs of the human body (C.S.). Dec. 3. F. E. Griswold, 6, Lord Street, Liverpool.
27,022. Oil lamps (C.S.). Dec. 6. E. R. Schreiber, 111, Hatton Garden, London.

COMPLETE SPECIFICATIONS ACCEPTED OR OPEN TO PUBLIC INSPECTION.

I.—ELECTRIC LIGHTING.

23,286. Arc lamps. Oct. 20, 1906. Accepted Dec. 4, 1907. A. D. Jones, 39, Hartham Rd., Holloway.
23,334. Conductors for use as incandescing bodies for lamps (C.S.). I.C. May 9, 1906, U.S.A. Accepted Nov. 27, 1907. W. D. Coolidge, 83, Cannon Street, London.
23,335. Conductors for use as incandescing bodies for lamps (C.S.). I.C. May 9, 1906, U.S.A. Accepted Nov. 27, 1907. W. C. Arsem, 83, Cannon Street, London.
23,336. Conductors for use as incandescing bodies for lamps (C.S.). I.C. May 9, 1906, U.S.A. Accepted Nov. 27, 1907. W. D. Coolidge, 83, Cannon Street, London.
26,620. Arc lamps. Nov. 23, 1906. Accepted Nov. 27, 1907. H. W. Headland and F. Plutte, 77, Chancery Lane, London.

27,569. Arc lamps. Dec. 4, 1906. Accepted Dec. 4, 1907. O. Gross, 5, John Dalton St., Manchester.
27,726. Arc lamps with mutually inclined carbon-holders. Dec. 5, 1906. Accepted Nov. 27, 1907. J. Brockie, Birkbeck Bank Chambers, Southampton Buildings, London.
28,680. Manufacture of incandescence lamps. Dec. 15, 1906. Accepted Dec. 4, 1907. C. H. Stearn and C. F. Topham, 47, Lincoln's Inn Fields, London.
29,423. Electric lighting of trains. Dec. 24, 1906. Accepted Nov. 13, 1907. W. R. Preston, C. Roe, and C. H. Roe, 77, Chancery Lane, London.
4,931. Arc lamps. Feb. 28, 1907. Accepted Nov. 13. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From General Electric Co., U.S.A.)
5,576. Apparatus for treating conductors, especially applicable in manufacture of lamp filaments. March 7, 1907. Accepted Nov. 20. The British Thomson-Houston Co., Ltd., 83, Cannon Street, London. (From General Electric Co., U.S.A.)
8,761. Arrangement of filament of high-voltage lamp of small energy consumption (C.S.). April 15, 1907. Accepted Dec. 4. C. Glogan, 27, Chancery Lane, London.
16,301. Electric lighting of lighthouses, beacons, or buoys (C.S.). July 16, 1907. Accepted Nov. 27. C. A. Stevenson, 28, Douglas Crescent, Edinburgh.
18,922. Production of Tungsten dioxide (C.S.). Nov. 27. Germany, I.C. Nov. 23, 1906. The Westinghouse Metal Filament Lamp Co., Ltd., Westinghouse Buildings, Norfolk Street, Strand, London.
18,923. Incandescent lamps (C.S.). I.C. Nov. 23, 1906, Germany. The Westinghouse Metal Filament Lamp Co., Ltd., Westinghouse Building, Norfolk Street, Strand, London.
19,808. Incandescent lamps (C.S.). Sept. 4, 1907. Accepted Nov. 13. W. E. Barnas and G. Weddell, 24, Southampton Buildings, London.
23,098. Manufacture of incandescent lamps (C.S.). I.C. Nov. 5, 1906, Germany. Schott & Gen, Jena, Germany.
23,351. Electric search-lights (C.S.). I.C. Nov. 6, 1906, Germany. Accepted Nov. 20, 1907. Gebrüder Siemens & Co., Birkbeck Bank Chambers, Southampton Buildings, London.

II.—GAS, OIL, ACETYLENE, AND INCANDESCENT LIGHTING.

23,116. Petroleum incandescent burners (C.S.). I.C. Oct. 20, 1905, Sweden. Accepted Nov. 27, 1907. E. H. M. Paerén, 7, Southampton Buildings, London.
29,123. Electrical apparatus for lighting gas. Dec. 21, 1906. Accepted Nov. 20, 1907. H. Nehmer, 36, Clifton Street, Finsbury Square, London.
29,155. Manufacture of incandescent mantles. Dec. 21, 1906. Accepted Dec. 4, 1907. J. Norden, 1, Great James Street, Bedford Row, London. (From C. Bartel, Germany.)
651. Testing incandescent mantles. Jan. 10, 1907. Accepted Nov. 27. H. W. Woodall and P. G. G. Moon, the Gas Works, Bournemouth.
1,349. Incandescent burners. Jan. 18, 1907. Accepted Dec. 4. T. Terrell, New Court, Temple, London.
6,179. Pilot lighting device for incandescent gas lamps. March 14, 1907. Accepted Nov. 27. R. Macfarlane, 41, Reform Street, Dundee.
8,744. Inverted incandescent burners (C.S.). April 15, 1907. Accepted Dec. 4. M. Graetz, 1, Queen Victoria Street, London.
8,972. Bunsen tubes of inverted incandescent burners. April 18, 1907. Accepted Nov. 13. A. Bray, Sunbridge Chambers, Bradford, Yorks.
15,544. Incandescent burner (C.S.). I.C. Nov. 14, 1906, France. Accepted Nov. 13, 1907. R. M. Vieu, 65, Chancery Lane, London.
19,555. Incandescent burners (C.S.). Aug. 31, 1907. Accepted Nov. 13. H. Cole, 77, Colmore Row, Birmingham.

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

27,187. Acetylene lamp (C.S.). Nov. 29, 1906. Accepted Dec. 4, 1907. H. V. Neukirch and E. M. Freytag, 65, Chancery Lane, London.
28,696. Oil lamp burners. Dec. 19, 1906. Accepted Nov. 13, 1907. W. H. I. Welch, Birkbeck Bank Chambers, Southampton Buildings, London.
5,777. Hanging oil lamps. March 11, 1907. Accepted Nov. 13. J. W. B. Wright and J. H. Woodroffe, 24, Temple Row, Birmingham.
6,879. Water-drip acetylene lamps. March 22, 1907. Accepted Dec. 4. M. W. Skelton and J. Todd, 20, Dumbarton Street, Liverpool.

EXPLANATORY NOTES.

The following apply to both lists :—

(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 5 of the Patents Rules, 1905. In the case of inventions communicated from abroad, the name of the communicator is given after that of the applicant.

The following apply only to the list of Complete Specifications accepted, &c. :—

Printed copies of accepted Specifications may be obtained at the Patent Office, price 8*d*., fifteen days after the date of advertisement of acceptance.

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 1*s*.

N.B.—Some of the titles are abbreviated. This list is not exhaustive, but contains a list of Patents which appear to be most closely connected with illumination.

AUTHORS' INDEX.

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