

**THE TRANSACTIONS OF  
THE FIRST WORLD POWER CONFERENCE**

THE TRANSACTIONS OF  
THE FIRST WORLD POWER  
CONFERENCE

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VOL III

INTERNAL COMBUSTION ENGINES  
GAS AND FUEL SECTION  
POWER FROM OTHER SOURCES  
POWER TRANSMISSION AND DISTRIBUTION  
STANDARDISATION AND RESEARCH  
ILLUMINATION

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### INTRODUCTION.

The use of electricity for illumination lies at the very root of the electrical industry. Both directly and indirectly it has stimulated electrical development more than any other application. It accounted for the establishment on a commercial basis of the dynamo, the high-speed steam engine, the water tube boiler, and it led to the improvement of the various auxiliaries used to-day in the efficient generation of electrical energy. It brought about the transmission of electricity, both overhead and underground; and it was by means of the circuits established for lighting purposes that the original promoters of electric power transmission were able to put their schemes into effect. To-day, in spite of the rapid growth in the applications of electricity for other purposes, the consumption of electricity for lighting purposes alone is relatively, as well as absolutely, immense. It has been estimated that the figures for the year 1920 in the chief countries of the world were as follows :—

United States .. .. .	6,870	million	units
Japan .. .. .	2,010	,,	,,
Germany .. .. .	1,100	,,	,,
United Kingdom .. .. .	830	,,	,,
France .. .. .	652	,,	,,
Italy .. .. .	612	,,	,,
Canada .. .. .	581	,,	,,
Belgium .. .. .	240	,,	,,
Switzerland .. .. .	200	,,	,,
Sweden .. .. .	167	,,	,,
Norway .. .. .	100	,,	,,
Australasia .. .. .	100	,,	,,
Total for 12 countries	13,462	,,	,,

A similar impression of the magnitude of the existing electric lighting field is conveyed by the figures relating to the number of electric lamps sold. The following table gives the figures for various countries during the year 1922 :—

## ILLUMINATION

Country.	Population.	No. of Lamps	
		Sold.	Per Capita.
	Millions.	Millions	
U.S.A.	118	205	1.74
United Kingdom	47	20	.42
Hungary	7.25	2.75	.38
Austria	6	4	.67
France	41.5	30	.72
Italy	40	15	.38
Germany	57	50	.88
Switzerland	4	6.5	1.62
Total	320.75	233.25	.73

A striking feature of the progress of illumination in the United Kingdom is revealed by the following :—

In 1912 the average wattage of lamps used was 36.1 watts.

In 1917 „ „ „ „ „ 48.8 „

In 1922 „ „ „ „ „ 57.4 „

These figures show that the average wattage of metal filament lamps used has materially increased in spite of the simultaneous improvement in the efficiency of the lamps, thus clearly indicating the public demand for a higher standard of illumination.

### SECTION I.

#### EVOLUTION OF THE ELECTRIC INCANDESCENT LAMP.

During recent years the evolution of electrical illumination has been so rapid that radical improvements have succeeded each other before the general public have become accustomed to or even aware of them.

It will, therefore, be useful to recapitulate the main stages in the development of the incandescent electric lamp.

1841. *Platinum Filament.* The earliest record of any attempt to make a practical incandescent electric lamp is contained in a patent dated 1841, which mentions the use of a fine spiral of platinum raised to incandescence by an electric current.

1879. *Carbonised Cotton Filament.* This lamp, which was produced after several years of experiment, formed the first real step towards a commercial product, although its life was only about forty hours and its efficiency about 1.4 lumens per watt.

1880. *Carbonised Bamboo Filament.* The bamboo filament was selected after exhaustive tests of about 6,000 specimens of vegetable fibre gathered from many parts of the world. It would frequently burn as long as 3,000 hours, but its useful life was much shorter,

### SULLY: ILLUMINATION

owing to early blackening of the bulb. Its efficiency was about 1.6 lumens per watt.

1883. *Squirted Cellulose Filament*. The filament of this lamp was made from cotton, dissolved and treated by a special process which gave a greater uniformity of diameter than had previously been attained. The lamp had a longer useful life and was more uniform in quality than its predecessors. Its efficiency was about 2.5 lumens per watt.

1892. *Treated Cellulose Filament*. This development involved a process by which the filament was heated for a moment in hydro-carbon vapours to make it more uniform and to improve its radiating properties. These lamps were made in relatively large quantities, they had a longer useful life, and their efficiency was about 3.3 lumens per watt.

1902. *Osmium Filament*. This lamp had a filament which was made by squirting a paste consisting of finely divided osmium, soot and a binder such as sugar, through dies. The lamp was extremely fragile and could only be burnt in a vertical position. Its efficiency was about  $5\frac{1}{2}$  lumens per watt.

1905. *Metallised Carbon Filament*. By coating the carbon filament with graphite it acquired some of the characteristics of a metal. Filaments so "metallised" could be run at a slightly higher temperature than was possible with the ordinary carbon filament. The efficiency was thereby improved—to about 4 lumens per watt—but the metallised lamp was found to be too fragile to take the place of the treated cellulose filament lamp.

1905. *Tantalum Wire*. Tantalum was the first metal to be used successfully as a filament material. This metal was drawn into a wire and the lamp had a very satisfactory life. Its efficiency was about 6 lumens per watt.

1907. *Squirted Tungsten Filament*. Although this development represented a tremendous advance in the efficient production of light, the fragility of the filament, formed by reducing tungsten to a paste and squirting it through diamond dies, was a serious drawback. The efficiency of the pressed tungsten lamp was about 8 lumens per watt.

1909. *Drawn Tungsten Wire*. The introduction of the process of drawing tungsten into a ductile wire made it possible to combine strength with increased efficiency. Successive improvements made since 1909 have brought the maximum efficiency of drawn tungsten vacuum lamps up to about 10 lumens per watt.

1913. *Gasfilled Lamps*. By the introduction of an inert gas into



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the bulb it was found possible to operate the tungsten filament at a higher temperature. This, together with the coiled construction of the filament, has made possible efficiencies up to 20 lumens per watt in the larger sizes of lamps.

The following table summarises the improvement in lamp efficiency from 1896 to the present day :—

Date of Introduction Commercially.	Type of Lamp.	Average Efficiency in Lumens per watt.	Total cost per 1,000 Candle/hours* with current at 6d. per unit excluding cost of lamp.
1896	Carbon	3.3	22.8d.
1905	Tantalum	6.0	12.5d.
1908	Tungsten (Vacuum)	8.0	9.6d.
1913	Tungsten (Gasfilled)	12.5	6.0d.

\* Equivalent to 12570 lumen hours.

A simple calculation will reveal the extent of the benefit thus conferred on the general public. England's electric lighting bill in 1922 was about £19,000,000. If the lamps in use less than twenty years ago had not been improved by continuous research, that amount would have been £72,000,000. The difference of £53,000,000 approximates to the total net annual income of all the railways in Great Britain.

## SECTION II.

### ECONOMICS.

The cost of obtaining electric light depends upon three factors,

- (1) The efficiency of the lamp.
- (2) The price of the lamp.
- (3) The price of electricity.

To take a definite case, let us consider a 100-watt gasfilled lamp of 1,000 hours rated life and 1,100 initial lumens output, with electricity at 6d. per unit and lamps at 5/- each. The effect of a variation in one of the above factors (the others remaining fixed) on the lumen hours obtained for one penny is set out in the following table :—

	<i>Lumen hours for one penny.</i>
All factors normal . . . . .	1652
12 per cent. reduction in the price of lamps . . . . .	1670
7 per cent. improvement in lamp efficiency . . . . .	1673
1.2 per cent. decrease in the price of electricity . . . . .	1670

These figures show that, in order to produce effects of the same

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order of magnitude, the change in lamp price must be several times greater than the change in either lamp efficiency or the cost of electricity. In other words, the price of energy and the efficiency of the lamp are the predominating factors in the cost of light. Where the price of current is high the efficiency of the lamp becomes of

LUMEN CHARACTERISTIC

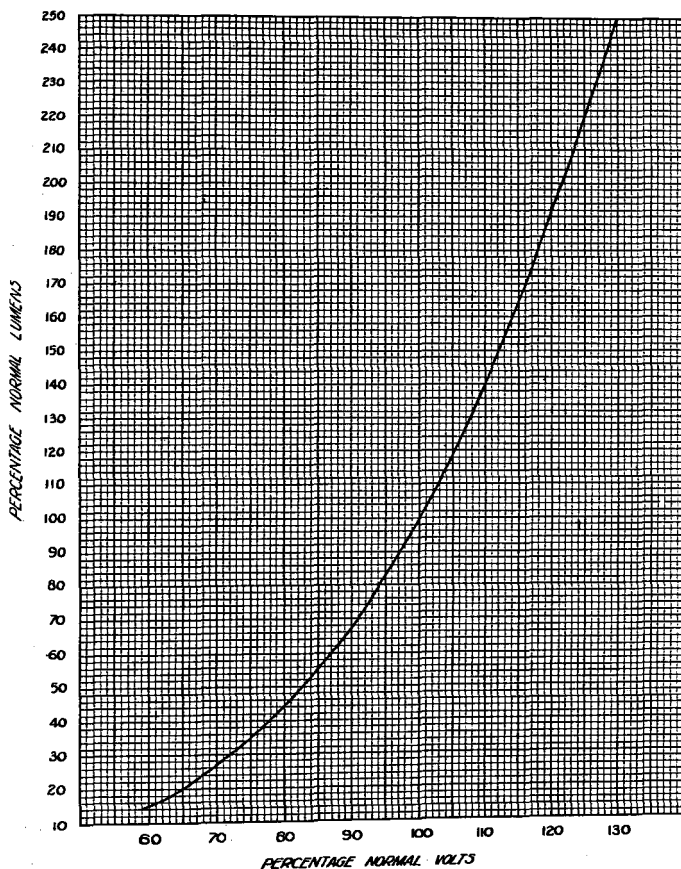


Fig. 1

paramount importance ; under such conditions the most economical operation is obtained with lamps of high efficiency and moderate life.

The amount of energy required to produce a given amount of light

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depends upon the efficiency of the lamp. This in turn is dependent on the temperature at which the filament is operated. The improved efficiency of the modern lamp is due to the filament being operated at higher temperatures. In order that lamps should realise in practice their true efficiency it is essential that they should be operated at the precise voltage for which they were designed. A fall of 1 per cent. in the temperature of the filament reduces the light output by 11 per cent.

An example will make this important point clear. A modern 100-watt 230-volt lamp, costing 5/-, gives an average of about 935 lumens throughout its life of about 1,000 hours. Where electricity costs 6d. per unit, the cost of supplying 935 lumens for 1,000 hours is 50/-, thus making, with the cost of the lamp, a total of 55/-.

If the same lamp is operated at 10 per cent. below its rated voltage, its light output will be reduced by 33 per cent., and it will then emit only 636 lumens. This relationship between volts and lumens is illustrated in Fig. 1.

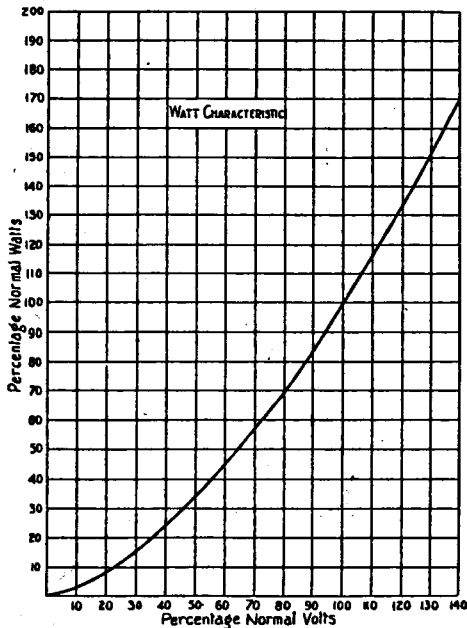


Fig. 2.

Fig. 2 shows the relation of watts to volts for tungsten filaments, and from it we deduce that a 10 per cent. reduction in applied

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voltage lowers the watts consumed by 15.5 per cent. That is to say, our 100-watt lamp now takes only 84.5 watts. Assuming that the reduction of voltage will double the life of the lamp—a generous assumption—the cost of supplying 636 lumens throughout this life 2,000 hours will be 84/6 for current and 5/- for the lamp, making a total of 89/6. At this rate the cost of supplying 935 lumens for 1,000 hours would be 66/-, as compared with 55/- in the first case. In other words, the light emitted actually costs 20 per cent. more when a 230-volt 100-watt lamp is operated on a circuit voltage 10 per cent. below the rated voltage of the lamp.

It is therefore extremely important that lamps should be operated at their rated voltage. The more efficient the lamp, the more important this point becomes. It is equally necessary that supply voltages should be as definite and constant as possible, in order that lamp manufacturers may rate their lamps at the most economical efficiency.

### SECTION III:

#### PRINCIPLES OF ILLUMINATION.

Investigations carried out by expert authorities show that much higher intensities of illumination than at present prevail should be adopted for industrial operations if maximum efficiency in performing such operations is to be acquired, and in this connection scientific tests indicative of the effect of light on vision have been carried out, with results shown in the following curves.

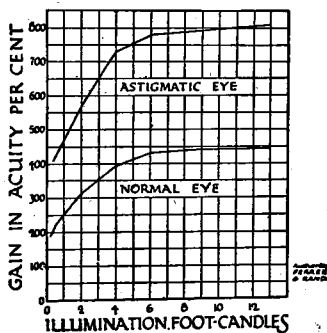


Fig. 3.

Fig. 3 deals with acuity of vision or the ability of the eye to distinguish fine details. In this test a condition most favourable to high acuity at low levels of illumination was taken—the extreme

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contrast of a black object on a white ground. Results show that acuity rapidly improves with increase of illumination and that the improvement is more rapid and of greater extent when the eyes are astigmatic. In this connection it might be mentioned that an examination of over 10,000 employees in factories and commercial houses showed that 53 per cent. had uncorrected faulty vision. The flattening of the curves on reaching 6 f.c., may be attributed to the effect of reflected light from the white surface tending to blur the sharp outlines of the black object.

Fig. 4 deals with speed of discrimination or the rapidity with which the eyes can identify a difference in objects. For this test advantage was taken of the fact that in most industrial processes the degree of contrast encountered is ordinarily low, therefore to approximate to

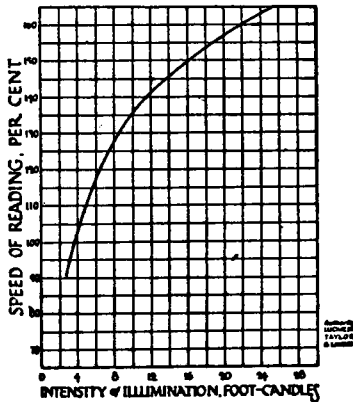


Fig. 4.

this condition, black letters on a fogged paper ground having a reflection factor of 22.5 per cent. was taken. Increasing the illumination resulted in very rapid acceleration of perception with but small tendency to retardation even at 26 f.c., where the curve ceases.

Fig. 5 deals with sustained vision or the ability of the eyes to maintain a clear view of details in an object over a protracted period of time. The observer under this test was required to gaze at an object for periods of three minutes under each increasing degree of illumination and in each period the proportion of time during which the object appeared clear to that in which it appeared blurred was taken as the measure of sustained vision. An extreme contrast of black on white was used for the purpose of this test. In this instance

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also the effect of increased illumination on astigmatic eyes is more marked than in the case of normal eyes and very material improvement is shown up to 12 f.c., beyond which the curves continue to rise.

Fig. 6 deals with speed of accommodation or the ability of the eyes to distinguish clearly objects at different distances. Extreme contrast of black and white was again employed. The curves show the effect of increased illumination and its advantage to the astigmatic eye as compared with the normal eye. The tendency to flatten out at 6 f.c., may be attributed to the causes assigned under Fig. 3.

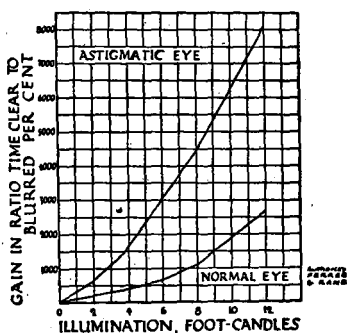


Fig. 5.

There is no doubt that if artificial illumination was obtainable without cost, far higher levels of illumination than those at present in use would speedily be adopted in order to secure the advantages

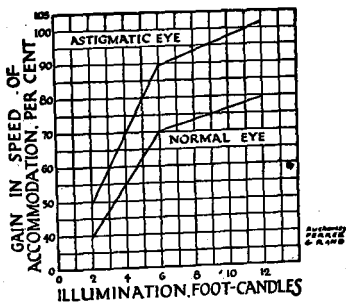


Fig. 6.

that would accrue from improved visibility. In the vast majority of cases to-day artificial lighting conditions might be described in terms reminiscent of war days as "visibility low."

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The ideal state is that in which artificial illumination should in degree approximate to that given through a northern skylight on a clear day in May, and illumination experts are at present engaged in ascertaining to within what degree that ideal is attainable when all economic and other factors are taken into consideration.

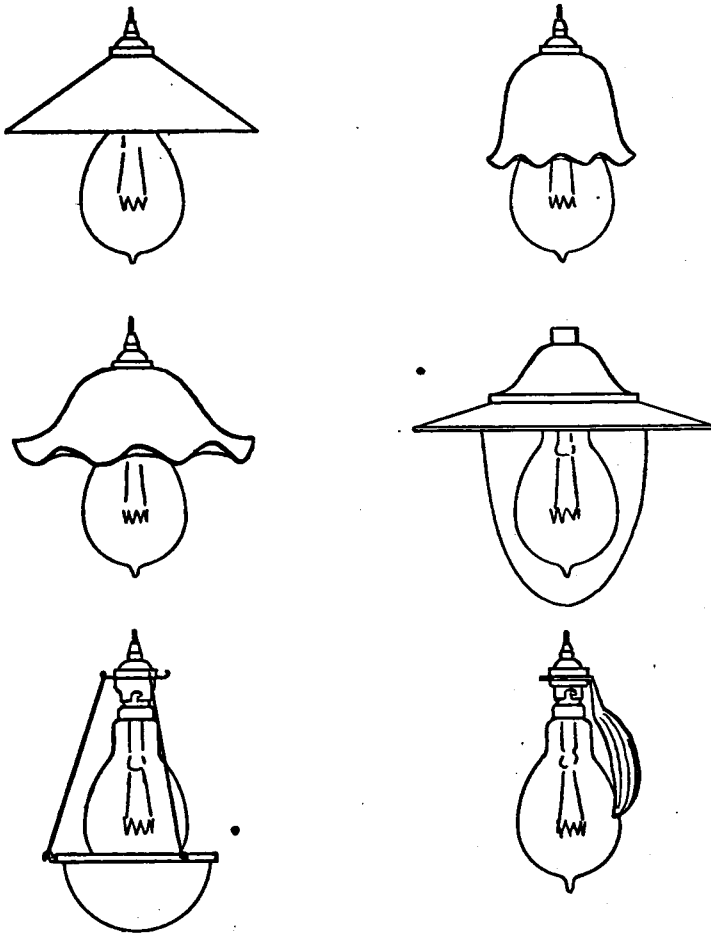


Fig. 7.

### SECTION IV.—A.

#### APPLICATION TO FITTINGS.

The evolution of the electric lamp, accompanied by changes in its dimensions, and a steady increase in filament brilliancy, has

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progressed much more rapidly than the adoption of fittings and accessories appropriate to the new forms.

When a big improvement is made, such as the introduction of the gas-filled lamp, the new lamps come into service gradually as the old lamps are used up. Fittings, however, have an indefinite life, so that there is a natural tendency for them to become out-of-date in relation to the lamps generally in use. Many shades and reflectors











LIGHTING UNIT.	EFFICIENCY.	GLARE.	SHADOWS.	MAIN-TENANCE.	LIGHTING UNIT.	EFFICIENCY.	GLARE.	SHADOWS.	MAIN-TENANCE.
 ENAMELLED STEEL REFLECTOR.	A	B	B	A	 WHITE GLASS REFLECTOR BOWL.	B	A	A	C
 ENAMELLED STEEL DOME REFLECTOR.	B	B	C	A	 ENCLOSED UNIT.	B	A	A	A
 WHITE GLASS REFLECTOR.	A	B	B	B	 OPAL BOWL.	B	A	A	C
 MIRRORED GLASS REFLECTOR.	A	C	C	B	 INDIRECT BOWL.	C	A	A	D
 WHITE GLASS GLOBE.	B	B	A	B	 ENAMELLED IRON OR OPAL REFLECTOR.	D	D	D	C

Fig. 8.

A = Excellent.  
B = Good.

C = Fair.  
D = Bad.

which were quite suitable for carbon or vacuum lamps are still used with gas-filled lamps, for which they are totally unsuited.

The prevalence of glare, incorrect light distribution and inefficient illumination is largely due to this cause.

Examples of obsolete fittings used with modern gas-filled lamps are shown in Fig. 7. The combination most commonly met is a 10-inch conical opal shade with a 100-watt lamp—a unit which has no recommendation.



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Fig. 8 shows the main types of fittings and tabulates their main characteristics for comparison. The column headed "Efficiency" indicates the degree to which the unit usefully redirects the light emitted by the lamp used in conjunction with it. In this connection light distribution must be considered as well as light absorption. The "Glare" column shows the relative brilliancy of the units and is an indication of their liability to injure the eye. Under "Shadows" it is assumed that hard, sharp shadows are undesirable, as is the case in most work. The factors taken into account under "Maintenance" are permanency of the reflecting surface, ease in cleaning, and liability to collect dust.

The advantages of adopting higher efficiency lamps as they become available are obvious. It is not, however, so generally realised that the increase in illumination which should be obtained with high efficiency lamps can be to a great extent negatived by inefficient accessories. As an example, the following results were obtained with a reflector when two different lamps were used. The reflector was of a concentrating type, designed for use with a 100-watt gas-filled lamp, and comparative tests were conducted to ascertain the effect when the above mentioned reflector was equipped with a 100-watt and a 200-watt lamp.

In the first case the 100-watt lamp gave an average horizontal illumination of 3.73 foot candles at floor level. The substitution of a 200-watt lamp did not, as might reasonably be expected, increase the illumination intensity, but actually reduced it to 3.5 foot candles.

This is rather an extreme case, but it serves to emphasise the desirability of increasing the useful light output of a lamp by adopting accessories specially designed on scientific lines for that particular lamp.

### SECTION IV.—B.

#### APPLICATION TO DOMESTIC LIGHTING.

The lighting of the home does not usually receive the attention it deserves, owing to the fact that the average consumer of electricity does not fully realise either the importance or the artistic possibilities of artificial light in daily life.

The cost of equipping a house with electric light represents a relatively trifling amount—approximately 4 per cent. to 5 per cent. of the total investment on the house. If this proportion were increased to 6 per cent. or 7 per cent., the added comfort, convenience and beauty of the lighting would amply justify the extra outlay.

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The average middle class family spend about 6d. a day on lighting. Economy in current is, therefore, not a serious consideration.

There is, in fact, no economic reason why the general standard of domestic illumination should not be raised far above the present level. All that is needed is the clear appreciation and the intelligent application of a few fundamental principles.

In the case of a new house, the plan should be carefully studied, and the location of furniture, etc., should be settled as far as possible in advance. It will then be possible to decide on convenient positions for ceiling points, brackets, and wall plugs. The convenience of an adequate number of wall plugs outweighs the extra outlay on wiring and enables the lighting effects in a room to be varied at will.

Fittings for the home should be chosen, not merely on account of their intrinsic beauty, but because of their lighting utility, their suitability for particular rooms, and their harmony with the general scheme of decoration.

The following suggestions may serve as a general guide in selecting suitable fittings for the different rooms in a house :—

*Hall and Staircase.* The hall should be well illuminated in order that a bright entrance may announce a warm welcome. As a rule a pendant or wall bracket will be found most suitable. A pendant or wall bracket may be used on each landing. It is convenient and economical to arrange these fittings with two-way switches so that the lamps may be controlled from either the bottom or the top of the stairs.

*Drawing Room.* As this room will be used for a variety of purposes, the lighting system should be as flexible as possible, both as regards location and intensity of light. The arrangement likely to prove satisfactory in the great majority of cases is a centre point or wall brackets giving adequate and well diffused illumination, supplemented by one or two table lamps and a floor standard.

*Dining Room.* In a dining room the chief consideration is that the table should be brightly lighted without any glare, and the remainder of the room need be no more than moderately illuminated by reflected light. A large silk shade, suspended centrally over the table on a rise and fall pendant, is a popular fitting which is correct in principle. A very beautiful effect can be obtained by using an orange or red silk shade in conjunction with daylight-glass lamps. The daylight lamps have the effect of making the linen appear perfectly white ; the silver shows up well, and flowers and other coloured objects appear in their natural tints. The light

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filtering through the orange shade illuminates the remainder of the room with a pleasant toned light. Wall brackets may be added for increased decorative effect.

*Bedroom.* In bedrooms local lighting is the chief requirement. Pendants or brackets should be placed over the dressing table, and a bracket should be fitted in a position convenient for reading in bed. It will generally be possible to arrange the location of these points accurately beforehand in accordance with the position of the furniture. In cases where it is possible that the furniture will be rearranged an ideal method is to attach the lighting fitting to the furniture and to provide a suitable number of wall plugs.

*Kitchen.* In the kitchen, which may be described as the "workshop of the house," well diffused light is required. Harsh shadows should be avoided, and the table, the dresser and the cooking stove well illuminated. A satisfactory arrangement for the majority of cases will be a totally enclosed diffusing unit fixed close to the ceiling.

### SECTION IV.—C.

#### APPLICATION TO OFFICE LIGHTING.

The main requirements are sufficient illumination, even distribution, the absence of harsh shadows and both direct and reflected glare.

A survey which was made of office lighting showed an average of about 3 foot candles, with extremes of 0.4 and 14 foot candles. Although this average value is being adopted in many new installations, a higher intensity (up to 10 foot candles, and never less than 5 foot candles) is recommended to ensure the conditions best suited for efficient work.

General lighting in offices has much to recommend it. Fewer points are required; installation costs are reduced to the minimum; the units can be located well above the normal field of vision; and maintenance is simplified.

The effects of glare are exceptionally important in offices. Artificial light is often necessary during the greater part of the day and the work is so close that inefficient lighting soon has a serious effect on the eyesight of the staff. The most common cause of glare is the placing of naked filaments directly in the field of vision. In its normal position the eye, when at rest, looks horizontally; consequently exposed sources of light should as a general rule be placed at a minimum of from 25° to 30° above the line of sight, unless they are fifty feet or more away.

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Another form of glare is produced when the total volume of light entering the eye is too great, as for example when a low room is lit by large units, even if they be of the diffusing type.

The practice recommended for office lighting is the installation of totally enclosed units. In addition to providing excellent diffusion and distribution, these units have the merit of being dust-proof and, therefore, easily maintained at a high level of efficiency.

#### SECTION IV.—D.

##### APPLICATION TO SHOP LIGHTING.

Probably there is no branch of the lighting industry where there is greater opportunity for progress than in shop window lighting.

Data has been collected on approximately 10,000 shop windows throughout the United Kingdom in order to emphasise the need of a campaign for better and more efficient shop window lighting. Only 34 per cent. of those examined could be considered as satisfactory. The remaining 66 per cent. were badly illuminated. Naked filaments were exposed within the field of vision; the reflectors were generally unsuitable for the lamps used; and very little thought seemed to have been given to either efficiency or effect.

On the assumption that there are 200,000 shops in England, of which the windows could be rearranged for reasonably good illumination at an average cost of £6, inclusive of minor alterations to wiring, the potential business in this field amounts to over a million pounds. This estimate does not take into account the large number of unwired premises which offer a promising field for electrical illumination.

The average shopkeeper fails to appreciate the advertising value of his windows, or the important part they play in building up his goodwill. At present gas-filled lamps are so badly and unscientifically used that he has no idea of the possibilities of effective and decorative lighting. On the other hand, large stores have realised the value of intense window lighting, and during the last few years the average intensity used has been doubled.

A well lighted shop window stands out from its surroundings, attracts attention, and displays to the best advantage the goods which the shopkeeper has to sell.

The desirable intensity for windows cannot be definitely stated, as it depends on several factors, such as the lighting of neighbouring shops, the street lighting and the class of goods displayed.

Modern practice in shop window lighting for large stores is to

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provide approximately 100 watts per foot run of window, with trough fittings or individual reflector units. For shops of medium size 50 watts per foot run of window is often used. The range of intensities obtained is from 10 to 100 foot candles.

The use of coloured lamps or coloured screens supplemented by reflectors is an effective method of attracting attention to the window and enables a large variety of beautiful effects to be produced.

As regards shop interiors, where the main object is of course to illuminate the goods displayed, the choice of fittings depends on the character and arrangement of the goods. In the case of music shops, chemists, and booksellers, the illumination of the walls is chiefly required; in drapery establishments and general stores the horizontal plane must be considered; and in the case of jewellers, etc., the lighting of show cases needs most attention; these should be illuminated to at least twice the intensity of the shop interior.

Illumination readings taken in a large number of shops, covering all sorts of trades, give an average of 4.8 foot candles; but here again, as in the case of window lighting, the tendency is towards higher intensities.

As has been pointed out, it is difficult to make a definite recommendation as to the desirable intensities which should be used, but the following table gives the main considerations governing the choice.

- 2-3 foot candles. General illumination, which should be supplemented by table or standard lamps, where a restful subdued atmosphere is required. Suitable for restaurants, buffets, etc.
- 4-6 foot candles. Suitable for small shops in suburban districts or for localities where the surroundings and street lighting are not very bright.
- 6-10 foot candles. Satisfactory from the standpoint of selecting goods and where advertising value and appearance are considered.
- 10-15 foot candles. Brilliant lighting. Desirable in tailors' and milliners' shops and in departments where dark goods are displayed.

It has been found from experience that the drawing power of windows is very materially increased when the lighting intensity is raised, that more people enter a well lighted shop and that the value of individual purchases is greater. Light properly installed is an efficient salesman, producing results out of all proportion to its cost.

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### SECTION IV.—E.

#### APPLICATION TO FACTORY LIGHTING.

Compared with the best modern practice, the existing standard of artificial illumination for industrial interiors is of a very low order.

Although rapid changes have been made both in factory equipment and electric lamps during the last fifteen years, very few changes have been made in lighting practice. The principle reason for this slow progress is the retention of the obsolete system of local lighting, it having been common practice to bring a light source close to the work—a practice inherited from the days of the candle and confirmed by the open-flame gas jet.

While the carbon filament lamp opened a new era in lighting, it was still necessary, owing to the small quantity of light emitted by each lamp, to place the light source as close to the work as possible.

The introduction of tungsten lamps should have led to a corresponding improvement in illumination. The new lamps, however, with their larger dimensions and more brilliant filaments, were used indiscriminately with the old fittings; reflectors which were more or less satisfactory with the carbon lamp were retained with the tungsten lamp. The result was that, in almost every industrial interior, the workers were handicapped by excessive glare from the exposed filaments.

With the growth of electricity supply from about 1890 onwards, electric lighting was rapidly adopted in factories, and by 1914 hundreds of thousands of electric lamps were installed, nearly all of them being attached to flexible pendants on the traditional local lighting system. So firmly had this system established itself that when gas-filled lamps were introduced in sizes of 1,000 and 1,500 watts, the new units were used only for the illumination of open spaces of large area such as goods yards. They were not adopted to any extent for industrial lighting. Industry had become so accustomed to the use of local lighting that no other form of illumination was considered practicable.

The development of the new light source was, however, as swift as it was revolutionary. Before lighting engineers had time to exploit its uses, the lamp manufacturers were producing gas-filled lamps in smaller sizes. Thus it soon became the general practice to install the new gas-filled lamps in the existing drop pendants which were designed for the early carbon filament lamp.

An example of this practice is illustrated in Fig. 9, which shows types of units which are still frequently seen in factories.

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Thus it has come about that the introduction of a more economical light source has accentuated the evils of glare. Light is more misused to-day than at any other period of history. *If the invention of the first large gas-filled lamps had coincided with the application of electricity to illumination, local lighting would never have been adopted to any extent for industrial use.*

From the earliest days, light has been considered merely as a utility or convenience. It is only during recent years that, as a

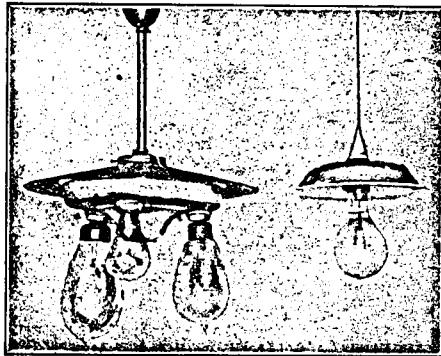


Fig. 9.

result of research carried out by manufacturers of lighting equipment, illumination is being considered from other aspects.

Light has been taken too much for granted. Many people assume that, as electric light is so obviously the best form of illumination, it needs no recommendation and admits of no improvement. To the majority of factory executives, electric lighting and good lighting are synonymous terms; and the difference between a bad installation and a good one is, therefore, not appreciated. In spite of the publicity given to the progress of illuminating engineering during recent years, factory managers remain strangely ignorant of the advantages of good lighting. This is proved by the fact that present standards are little in advance of those of the past, and much below the standards which are justifiable from humanitarian and economic points of view.

During the year 1922, 97,986 accidents (843 of which were fatal) occurred in factories and workshops in this country. Considered in terms of pounds, shillings and pence, this loss is tremendous. Anything that can be done to reduce the risk or eliminate the causes of accidents is worthy of careful consideration.

### SULLY: ILLUMINATION

Although no searching enquiry has been made to determine the relation of artificial lighting to accidents, there is sufficient evidence from official sources to indicate that more accidents occur during hours when artificial lighting is used than during the daylight period. The following graph, Fig. 10, plotted from figures issued by the Home Office prior to the war, shows that the accident rate is higher during the winter months.

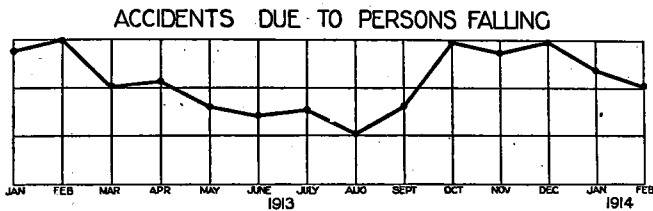


Fig. 10.

In some factories insufficient light is tolerated on the ground of economy. Instructions are given to leave this or that light off, on the assumption that while "one or two lamps less will make no difference" to the illumination, the saving effected through economy in current consumption will be considerable. Economy is at all times desirable, but it should not be sought at the expense of life and limb. A factory may have an excellent lighting system, but ill-considered economy in its use at once makes it a bad one.

In the First Interim Report of the Departmental Committee on Lighting in Factories and Workshops, the excess of night accidents over day accidents is given as 29 per cent. As the "night accidents" are those which occurred during the hours of darkness of the ordinary working day, the excess on an equal time basis is really much higher than 29 per cent. Of the total number of accidents 71 per cent. were due to employees falling.

In some works, supposed to be well lighted, many employees are injured, not as a result of insufficient illumination, but because of poor light distribution. In one shop a certain work bench was well illuminated by local lights with a good type of reflector. The bench however, cast a shadow, which the general illumination was not sufficient to overcome, and the result was that frequent accidents occurred. When a good system of general lighting was installed, the shadows were eliminated and the accidents stopped.

There is no reason to suppose that accidents would be more numerous during hours of artificial lighting than during daylight hours, if the artificial illumination were in all respects up to the



## ILLUMINATION

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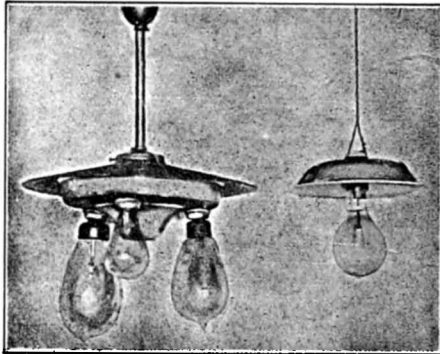


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## ILLUMINATION

standard of daylight. The higher accident rate associated with bad artificial lighting is considered by experts to be due mainly to inadequate intensity of illumination, harsh shadows and glare resulting from the use of improper equipment.

With the object of securing data for this paper a few investigations have been made on the lighting practice adopted in various industries. It is impossible, owing to the variations of illumination found in different factories of the same class, to state an exact figure for any given industry, but the following figures are believed to represent a fair average :—

		<i>Foot candles.</i>
ENGINEERING	<i>Foundries</i> .. ..	0·5 to 3
	<i>Machine Shops</i> .. ..	1 to 3
	<i>Assembly Shops</i> .. ..	1 to 3
	<i>Drawing Offices</i> .. ..	2 to 6
PRINTING	<i>Compositors' Room</i> ..	5 to 10
	<i>Machine Rooms</i> .. ..	2 to 4
	<i>Sorting and Packing</i> ..	2 to 3
TEXTILE	<i>Spinning and Warping</i> ..	1·25 to 2
	<i>Weaving</i> .. ..	1·25 to 1·5
BOOT AND SHOE	<i>All processes</i> .. ..	1·25 to 7·5

Generally speaking, the average illumination approximates to the lower figure. It should be pointed out that the illumination provided by local units is very uneven, frequently varying from 50 foot candles immediately beneath the lamp to 0·5 a few feet away.

The science of illumination is not sufficiently advanced to enable exact specifications of intensity to be laid down for particular industries. In order, however, to afford a working guide to the public, provisional standards are set from time to time by experts who, through constant study of the requirements of various industries, are able to indicate, with a fair degree of accuracy, the lighting practice which will give the best service to the consumer. The intensities tabulated below, which are the latest recommendations for the industries previously listed, are well in advance of present day practice. Nevertheless, as the public become better educated in the advantages of more light, and as the knowledge gained from research increases, it is possible that these figures will require revision in an upward direction :—

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		<i>Minimum foot candles.</i>
<b>ENGINEERING.</b>		
<i>Foundries.</i>	All processes other than fine moulding and core making ..	5
	Fine moulding and core making	10
<i>Machine Shops.</i>	For all Rough operations ..	6
	.. .. Medium ..	9
	.. .. Fine ..	12
<i>Fitting Shops.</i>	For all Rough operations ..	5
	.. .. Medium ..	8
	.. .. Fine ..	10
<i>Drawing Office</i>	.. .. .. .	10
<b>PRINTING WORKS—</b>		
<i>Compositors' Room</i>	.. .. .. .	12
<i>Machine Room</i> ..	.. .. .. .	8
<i>Sorting and Packing</i>	.. .. .. .	5
<b>TEXTILE.</b>	Spinning, Warping and Weaving	8
<b>BOOT AND SHOE.</b>	For all processes .. ..	10

There is every indication that the intensities of illumination now being recommended are justifiable on a strict commercial basis. During recent years it has been proved that illumination has a distinct effect on output.

Efficiency in production is the primary aim of every manufacturer. The broad practical question always confronting him is, "Upon what factors does efficient production depend, and how can these factors be secured?" The main factors controlling quantity of production are:—

- (1) The extent of the facilities available in the way of buildings, machinery, and other equipment, and the number of employees ; that is to say the size of the plant.
- (2) The efficiency of the entire organisation, including that of the employees and of the various processes carried out by human labour or by mechanical means.

Therefore the output of a plant can be improved by increasing its effective size, or by increasing its internal efficiency. The most economical method, however, is that which secures increased output at a minimum increase of cost. This means that any improvement in the efficiency of the employees or of any essential element of the plant, is much more remunerative than a plant extension and the increased output thus obtained is secured at the

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lowest unit cost. The improvement of artificial lighting is a simple means of increasing the efficiency of the operatives and of the plant as a whole. It stimulates production, yielding results of a value far in excess of its modest cost. There are many recorded instances where output has been considerably increased when a modern system of lighting superseded an antiquated installation. In addition, proof is available that poor artificial illumination results in decreased production. Evidence of the latter result was collected by the Industrial Fatigue Research Board, formed under the auspices of the Medical Research Council. The report on *Study of Output in Silk Weaving during the Winter months*, published in 1920, contains some interesting data on the lighting of silk weaving sheds. In addition to many other studies an investigation was made on the effect of artificial light upon output. After careful study it was found that production was reduced by 10 per cent. during the hours when artificial lighting was used. Other reports by the same Board : *A Study of efficiency in Fine Linen Weaving 1922* and *Variations in efficiency in Cotton Weaving 1923*—contain similar data on the effect of artificial light. The tests were conducted in sheds where the illumination was provided by local drop lights. In the former case, (fine linen) production was reduced under artificial light by 11 per cent., and in the latter case (cotton weaving) by 5 per cent. in certain sheds.

In all three cases the artificial lighting equipment is clearly described and the illumination intensities given. As is inevitable with local lighting, there is a big diversity in the figures. The intensities recorded for electric lighting are as follows :—

		<i>Foot Candles.</i>	
		<i>Max. under</i>	<i>Min.</i>
		<i>Lamp.</i>	<i>on Cloth.</i>
Silk Weaving	.. .. .	35	3.0
Linen Weaving	.. .. .	8	1.5

Cotton Weaving. Average, 1.5 foot candles.

It is not surprising to find that production falls off with artificial lighting of so irregular and inadequate a character.

Had these factories been equipped with lighting installations based on modern recommendations, production would have been maintained at a constant level throughout the working day. Further, in sheds where structural features prevent an adequate supply of daylight, good artificial illumination at night will actually cause an increase in production as compared with the daylight standard.

In many factories where there is not an adequate supply of daylight,

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improved production would result from the use of high intensity artificial lighting throughout the whole period of the day.

The results of the investigation emphasise the desirability of further research on this important subject.

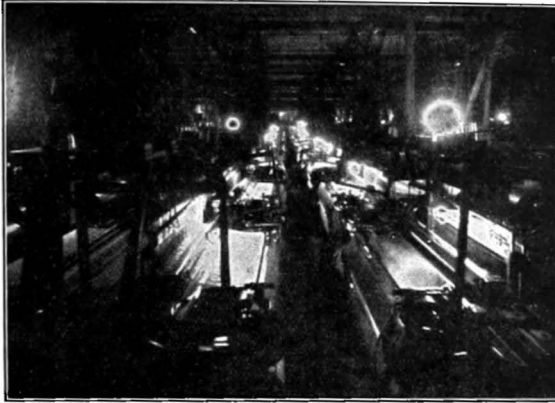


Fig. 11

Fig. 11 illustrates an example of local lighting in a weaving shed. The unit over each machine consists of a 30-watt lamp in a shallow enamelled iron shade. It will be noticed that the lighting on the cloth is very uneven, and the intensity of illumination inadequate.



Fig. 12.

There is practically no light underneath the machine, and the aisles and the upper part of the shed are badly lighted. The whole effect

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is depressing and gloomy ; and under such conditions it is small wonder that production lags when night-time arrives.

Fig. 12 shows a section of the same shed when the old equipment was replaced by a modern system of high intensity lighting, employing efficient reflectors and lamps (see Fig. 13).

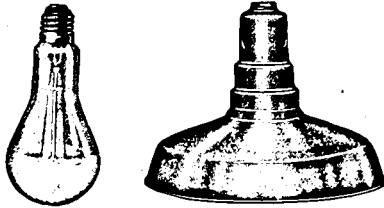


Fig. 13.

Here the light is perfectly even and well diffused ; all parts of the moving machinery can be easily seen, the average intensity being 16 foot candles. With this method of lighting the aspect of the whole shed is changed. It is now cheerful ; and the employees produce more cloth under more satisfactory conditions.

The results recorded by the Industrial Fatigue Research Board are amplified and confirmed by tests made in the United States on the effect of improved illumination upon output. The results of these tests are summarised in the following table :—

Shop.	Average foot candles with old system.	Average foot candles with new system.	Increase in production with new system.	Additional Lighting cost in per cent of Payroll.
(a) Pulley Finishing	0·2	4·8	35%	5%
(b) Soft Metal Bearing	4·6	12·7	15%	1·2%
(c) Heavy Steel Machine	3	11·5	10%	1·2%
(d) Carburetter Assembly	2·1	12·3	12%	0·9
(e) Jute Spinning	1·5	9·0	17%	No data
(f) Factory Mfg. Elec. and Gas Irons	0·7	13·5	12·2%	2·5%
	(4·0 at tool point).			
(g) Semi-Automatic Buffing Brass Shell Sockets	3·8	11·4	8·5%	1·8%
(h) Mfg. Piston Rings	1·2	18·0	25·8%	2%
(i) Letter Sorting	3·6	8·0	4·4%	0·6%
Average	2·3	11·2	15·5%	1·9%

It will be seen from the above that in every case where the intensity of illumination was raised, increases in production were recorded. If an average of these nine tests is taken, it will be found that an increase in illumination from about 2 to 11 foot candles results in an

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average increase in production of over 15 per cent. at an additional cost of less than 2 per cent. of the wages bill. Taken together, this group of tests in widely separated industries firmly establishes the fact that—in addition to its value in preventing accidents, lessening eyestrain, raising shop morale, and bettering conditions generally—good lighting has a definite production value which can be expressed in terms of pounds, shillings and pence.

Special interest attaches to (i) which relates to investigations conducted by the Office of Industrial Hygiene of the United States Public Health Service into the work of letter sorters. It was definitely ascertained that when 8 foot candles of illumination replaced the installation giving 3.6 foot candles, there resulted an average increase of 4.4 per cent in the work of the sorters. In the large office where the test was made it was estimated that, after the extra cost of the increased lighting had been allowed for, there was a net annual saving to the State of approximately £22,000, due to the speeding up of work.

Another recent investigation is described in the proceedings of the Illuminating Engineering Society of America. A test was carried out over a period of ten weeks, and throughout the whole of that period it was observed that the amount of work produced consistently increased or decreased as the level of illumination was raised or lowered. The work of the department under observation consists of inspecting material "in the green"—that is to say, just as it is turned out by automatic screw machines and before heat

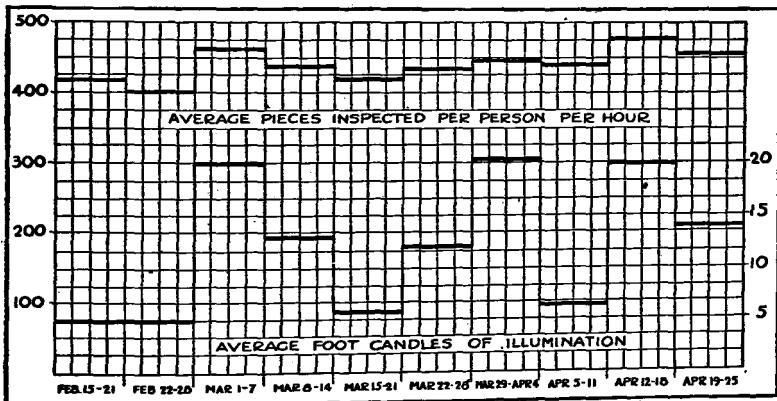


Fig. 14.

*Figures on the left denote number of pieces, and on the right, foot candles.*

### ILLUMINATION

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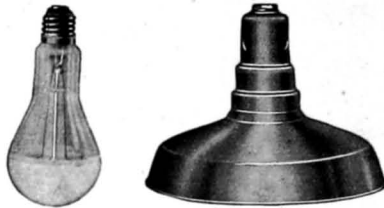


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*SULLY: ILLUMINATION*

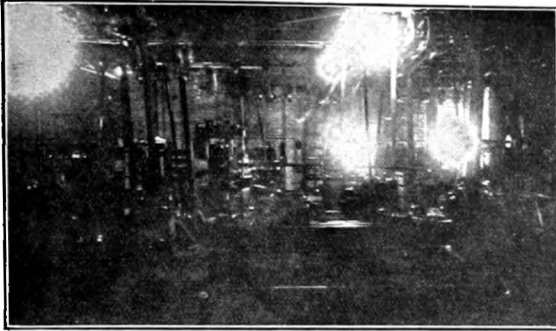


Fig. 17.

chamfer ; and the third for imperfections in the thread on the inside of the cones, bad milling, and inadequate burnishing.

At the beginning of the test the personnel of this department consisted of a foreman, a clerk, and thirty-eight inspectors. The number varied each week, the average during the test being forty-four. The production results, which cover 7,313,323 pieces inspected, are recorded (Fig. 14) in terms of results per man. They furnish apparently conclusive proof that, for the class of work carried on in the green inspection department, production is materially affected by the character of the illumination. To sum up the results in a sentence "it was found that by increasing and improving the illumination of an inspection department from an average of 5 foot candles to one of 20 the production of that department was increased 12.5 per cent."

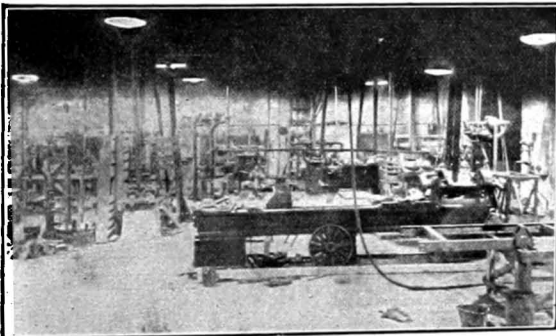


Fig. 18.

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Fig. 15.

treatment. The material inspected consists of various sizes of cups, cones, and threaded cones which form parts of roller bearings.

The work is conducted by three groups of inspectors. The first gauges the material for diameter and depth ; the second inspects for defects such as chatter, tool marks, ingot breaks, thin ribs, and bad

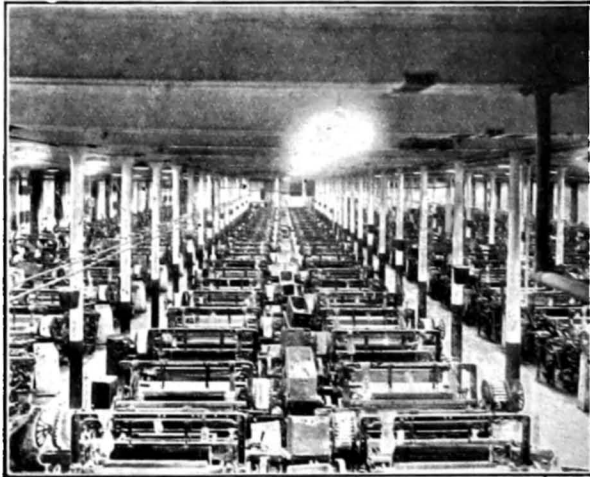


Fig. 16.

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Figs. 15, 16, 17 and 18 indicate the appearance of two factories before and after good lighting was installed.

Modern systems of general illumination have a marked psychological effect on employees in factories; and further research on this matter is shortly to be undertaken. Improved lighting is not put forward as a means of sweating the worker in order to stimulate production. The beneficial effect produced is due to improved visibility, cheerful atmosphere, and the saving of time.

In view of the international aspect of the World Power Conference, it is desirable to emphasise the influence which good lighting practice in England must have on the Overseas Dominions. Numbers of British engineers migrate to all quarters of the British Empire, and the practice familiar to them at home is the practice which they will recommend abroad, as is proved by information collected in various parts of the Empire. It is vitally important, therefore, that engineers who will become responsible for the lighting of factories overseas should be acquainted with the latest developments in illuminating engineering in order that the benefits of good lighting may be enjoyed in all quarters of our vast Empire.

### SECTION IV.—F.

#### APPLICATION TO STREET LIGHTING.

The efficient lighting of streets and other public places has a direct influence in reducing the number of accidents, in preventing crime, and in improving the amenities of town life. It is indeed time that the question of street lighting received much more thorough attention than has yet been given to it. In the first place it is necessary to form an adequate definition of "good" lighting for this purpose. While the measurement of street illumination in a horizontal plane is undoubtedly helpful, the only final test is the ability to distinguish objects readily at a distance. It is possible to light a roadway uniformly without rendering much aid to vision; vertical illumination helps considerably in the definition of objects and obstructions.

The solution of the problem appears to be the provision of high power units mounted 20 to 25 feet above the ground and spaced a fair distance apart. With this equipment distant vision is assisted, since the object ahead and the light source do not lie in approximately the same line of sight, as is the case when short standards are used. The sensitiveness of the eye is thus materially increased,

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as the glare of a bright light source in the immediate field of vision impairs the acuity of sight.

It is exceedingly difficult to obtain any reliable figures covering the relation of street accidents to bad lighting. Such figures as are available, however, do show that many accidents can be attributed directly to defective illumination. A survey taken recently in a certain city in U.S.A. illustrates the connection very clearly. In one instance it was found that between the hours of 5 and 9 p.m. in the months of June and July (when daylight is available) there were 157 accidents; and in the months of December and January, when it is dark during these hours, there were 193 accidents, an increase of 23 per cent. Other factors, of course, enter into the problem. There are probably fewer vehicles in the streets during the winter evenings; consequently the accident liability is reduced. On the other hand, this factor is counterbalanced by the streets being more slippery and the vehicles more likely to skid.

It was also found that in districts where additional light was available from brilliantly illuminated signs the accidents during winter and summer were approximately the same and were less numerous than in other parts where only normal street lighting was available. These results indicate that there were more accidents during the periods of artificial light than during daylight, except in places where the illumination reached a very high degree. It is clear, therefore, that the higher the standard of illumination and the nearer the approach to daylight conditions, the fewer will be the accidents.

From another and entirely different point of view—that of crime—it is essential that streets and open spaces should be well lighted. Darkness always forms a cover for burglary, assault and other crimes. "Daylight robberies" are so rare that they always receive exceptional publicity. Efficient and well-distributed lighting will do much to reduce the volume of nocturnal crime and assist the police in maintaining order.

During the war darkened streets and dismal alleys were universal, but fortunately, on account of the considerably reduced amount of traffic, both vehicular and pedestrian, accidents attributable to lack of lighting were comparatively few. To-day, however, with fast moving traffic so seriously congested, a badly lighted street may well be responsible for more accidents than one completely darkened under war conditions.

*ILLUMINATION*  
SECTION IV.—G.

APPLICATION TO RAILWAYS AND TRANSPORT SERVICES.

With the ever-increasing demand for improved travelling facilities, the efficient lighting of railway stations and vehicles becomes more and more essential. As services are speeded up, better lighting arrangements become imperative for the benefit of both employees and the travelling public.

Interesting tests recently conducted by the Underground Railway at intersecting stations of their system clearly showed one of the effects produced by increased illumination. The lighting intensity in subways, etc., was practically doubled and as passengers were better able to see their way they moved more quickly, and any tendency towards congestion was materially reduced. In specific cases the lighting intensity was increased from 1.3 f.c. to 2.1 f.c. under the lamp and from .3 f.c. to .5 f.c. at midway between points.

From the point of view of safety, consideration must be given first to railway stations, particularly the crowded terminal stations of large cities. Statistics taken from the Board of Trade railway returns show that accidents are very much higher in winter than in summer. Taking the figures over a period of years, it appears that there were 18 per cent. more accidents during the winter than during the summer.

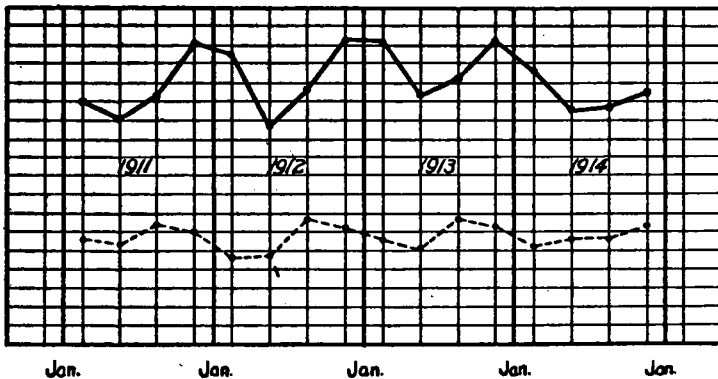


Fig. 19.

Fig. 19 shows the relation between accidents and the period of year on British railways, the upper curve referring to employees and the lower curve to passengers. In the case of passengers, the increase

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in the third quarter of the year is explained by the fact that holiday traffic is included.

Several accidents have occurred recently in which a railway passenger has opened a carriage door in the darkness, thinking the train had stopped at a station. If darkness can thus be mistaken for a platform it must follow that railway stations are, as a class, so badly lighted that the platform cannot be distinguished. It is necessary then, that platforms should be well lighted, not merely by "beacon lighting," but by properly designed units distributing the light over the ground and especially on the edge of the platform.

Sufficient light should also be provided to show up the name of the station. On the other hand, care must be taken not to dazzle the eyes of the drivers by glare, or to confuse the signals. Frequently, too, at terminal stations brighter local lighting is required in parts where customs examination is carried out.

A series of tests taken recently at twelve of the London railway termini shows the following results:—

Average illumination in foot candles—

Booking halls	..	..	..	..	..	..	..	1·19
Platforms	..	..	..	..	..	..	..	·74
Highest average illumination in any Booking Hall	..	..	..	..	..	..	..	3·39
Lowest	..	..	..	..	..	..	..	·27
Highest average illumination on any Platform	..	..	..	..	..	..	..	2·63
Lowest	..	..	..	..	..	..	..	·27

These figures indicate that some of the companies have realised the importance of good illumination and have accordingly increased the intensity of their station lighting.

It is recommended that the minimum intensity on platforms in main stations should not fall below 2 foot candles; in suburban stations 1 foot candle should be the minimum. For booking halls the corresponding figures should be 5 foot candles in main stations and 3 in smaller stations.

Where luggage is handled the light should be even, though not of a very high intensity. Shadows should be avoided, as they tend to cause many little accidents and reduce the speed of working.

In goods yards, sidings, and sheds there should be adequate general illumination, not less than 1 foot candle, to distinguish the markings on the trucks, etc. Here again care must be taken to avoid glare in the eyes of the drivers.

Inside vehicles the same remarks apply, whether they be trains, trams, omnibuses, or motor cars. The light required should be

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adequate for comfortable reading, but there is no need to make it stronger, as fine work cannot very well be done in a moving vehicle. Something of the order of 3 foot candles is recommended. Precaution should again be taken not to let any light shine forward on the driver, especially if he has glass in front of him which would reflect the light and dazzle him. There seems no reason, on the other hand, why the driver's cabin should not be provided with carefully concealed lighting to show up the controls.

As regards marine lighting, there is ample scope for improved illumination. A ship carries its own generating plant, which can quite well be large enough for all requirements, and there is no difficulty in obtaining lamps to withstand the vibration of the engines.

The standard of illumination in each part of the ship should be the same as for a similar place on land. In the saloon the standard should be that of a restaurant; in the cabin that of a bedroom; in the engine room that of a power station or machine shop. It is important, however, that no illumination should be visible from the bridge, as it is essential for those on watch to be able to see any faint light at sea and to distinguish other ships. Any stray light on deck would seriously impair their vision. Concealed lights can be provided for charts, compass and indicators.

Fairly strong well-diffused illumination is also required for the hatches when cargo is being loaded or unloaded. Shadows must be avoided here, as they are always a great source of danger with heavy moving objects.

## SECTION IV.—H.

### APPLICATION TO ADVERTISING.

As far as Great Britain is concerned, electrical advertising is a field which needs a great deal of development. This development would undoubtedly be more rapid if the advertiser could be made to realise the many advantages which electrical advertising has over other forms of propaganda. By the use of the electric sign, it is possible to introduce features which are unattainable in other forms of publicity.

*Brightness.* Instinctively all eyes turn towards the brightest object in view. Electric lamps provide the easiest means of attaining this object.

*Motion.* By means of controllers and other devices this feature is easily introduced into electric signs.

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*Originality.* Any form of advertisement which possesses distinction or individuality attracts attention and becomes the subject of after comment. The electric sign gives full scope to the inventive genius of the publicity expert.

*Beauty.* With the aid of the skilled designer, electric signs can produce beautiful effects of form, colour, and movement which are not possible with other forms of advertising.

*Colour.* An infinite variety, richness, and charm of colour is possible with electrical advertising. Frequent changes can be easily and quickly made, thus making the display of continuous interest.

*Position.* Electric signs may be fixed in such positions that they cannot fail to be seen by thousands of observers.

In addition to the development of the large flashing sign, there is an unlimited field for increasing the value of poster hoardings by means of electric light. The use of enclosed box signs, although fairly general in Great Britain, can still be greatly increased.

It is interesting to observe the rapid development of electrical advertising in the United States. In the Spring of 1922, there were in use a quarter of a million display signs, illuminated posters, and box signs of all kinds, using a total of fifteen million lamps, with a connected load of 185,000 kilowatts. The normal rate of increase is about 15 per cent. per year, indicating that the business should double itself every six years. In America, the average sign has seventy lamp holders, each consuming 25 kilowatt hours per year. The average sign costs £1 per lamp holder. The principal users of electrical advertising in U.S.A. are as follows:—

Automobile Trade and Garages .. .. .	29,500
Restaurants .. .. .	27,000
Hotels .. .. .	15,500
Chemists, etc. .. .. .	14,700
Theatres .. .. .	13,700
Clothiers .. .. .	11,200
Shoes .. .. .	7,500
Confectioners .. .. .	6,300

## SECTION IV.—J.

### APPLICATION TO FLOOD LIGHTING.

Flood lighting is a term used to cover the illumination of the exteriors of buildings and other large areas by means of light projected in wide beams from concealed lanterns. The flood light projector holds an intermediate position between the searchlight and



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the interior lighting unit, as it throws the light only where required and gives even illumination over a wide area.

Properly treated, this form of lighting has great possibilities both from the utilitarian and the artistic points of view. Every day new uses for it are suggested. A few of the more general uses are :—

1. Advertising, *i.e.*, the illumination of hoardings and the exterior of large shops, hotels, theatres, etc.
2. For showing up at night notable public buildings and statues.
3. Illuminating (a) Railway Goods stations.  
(b) Aerodromes.  
(c) Quarries.
4. Facilitating night work on the unloading of steamers, repairs to bridges and roads and constructional work generally.

The best method of flood lighting a building is to arrange the projectors at some distance from the frontage. Distortion of the architectural features must be carefully avoided, and collaboration between the architect and the illuminating engineer cannot be too strongly recommended when flood lighting is proposed. Examples of flood lighting are shown in Figs. 20, 21, 22 and 23.



Fig. 20.  
Flood light illumination of hoarding.

Special attention should be given to the design and construction of the projectors. Owing to the exposed positions in which they are mounted, they must thoroughly enclose the lamp and be robust and rigid. As the heat of the lamp is confined, the unit must be carefully ventilated to avoid early failure of the lamp and discoloration of the mirror.

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SECTION V.—A.

APPLICATION OF ANTI-GLARE LAMPS.

Although tungsten lamps have been before the public for at least seventeen years, and gasfilled lamps for more than half as long, users are not yet educated to the necessity of protecting the eye from glare in view of the exceptionally high intrinsic brilliancy of the filament. Although diffusing reflectors and other fittings afford this protection, they have not been generally adopted, and the prevalence of glare, therefore, inspired the attempt to make the bulb itself an efficient diffuser. The principle followed is that of breaking up the light in its passage through the bulb, so that the bulb becomes,



Fig. 21.  
Flood light illumination of cinema facade.

so far as the eye is concerned, the light source. Owing to the surface of the bulb being vastly greater than that of the filament itself the intrinsic brilliancy of a unit of this type is correspondingly lower than that of a clear lamp.

This result can be achieved by making the bulb of opal glass.

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effective. It is, however, in interior decorative lighting that they will find their most extensive and important use. Whereas the bolder, cruder, colours are most effective in public signs, there are delicate tints available which, judiciously used, enhance the beauty of interior decorations to an extent which can be appreciated only after actual demonstration.



Fig. 23.  
Flood light illumination of London stores facade.

### SECTION V.—B.

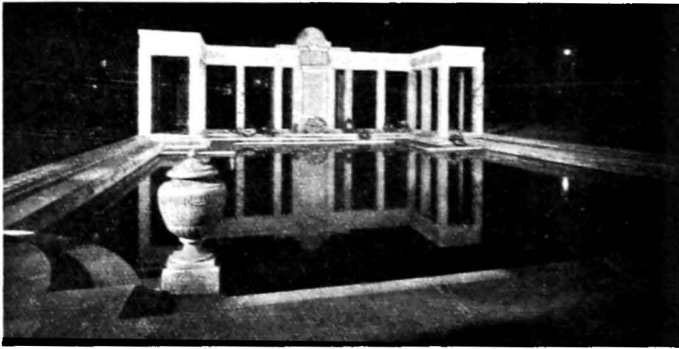
#### APPLICATION OF DAYLIGHT LAMPS.

Apart from intensity, the principal difference between artificial light and daylight is that of colour. Both are composed of mixtures of wave lengths, and the light of any particular wave length received by the eye produces the sensation of a pure colour. In the mixtures

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The opal bulb is not, of course, a new invention. Opal lamps are, in fact, almost as old as the art of lamp making itself, but whereas they were originally employed for their decorative effect, their use has been revived for the prevention of glare. Further, a new phase has been attained in which the opal forms merely a filmy covering to what is otherwise a clear glass bulb.

In white sprayed lamps the glass bulb has a thin coating of a colloidal solution of china clay and sodium silicate sprayed on to the exterior surface. This coating is subsequently dried and is fixed with ammonium chloride. These methods of eliminating glare accomplish their purpose with a minimum of loss by absorption.



*Photo. by G. W. King, Brighton Corporation*

Fig. 22.

Flood light illumination of war memorial.

As the actual position of the incandescent filament cannot be detected, they can be truly described as anti-glare lamps.

A development arising naturally from the white sprayed lamp is the colour sprayed lamp. Preparations somewhat similar to that already described are mixed with various pigments, which impart distinctive tints to the light transmitted through the coated bulbs. The colouring matter used is always mineral, with one or two exceptions where suitable inorganic colours are not available; consequently the colours are very resistant to atmospheric action or heat and outlast the life of the lamp. Colour sprayed lamps have only lately been introduced and should have a big future. In signs they produce quite novel, attractive and striking effects, especially when used in conjunction with the sign blue lamps described below, the contrast between the brilliance of the blue lamps and the smooth diffused glow of the colour sprayed lamps being most

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individual colours cannot be distinguished by the eye, but the whole produces a composite sensation with a definite character according to the proportions in which the wave lengths are mixed. The sun radiates energy at a much higher temperature than any source of illumination available on the earth, consequently a spectroscopic analysis of daylight shows a much larger proportion of short wave length energy than in any kind of artificial light. Short wave lengths (within the visible range) produce on the human eye a sensation of colder colours than long wave lengths, that is to say, the spectrum of sunlight contains a larger proportion of blue than is included in any form of artificial light.

Among incandescent electric lamps, the gasfilled tungsten lamp operates at the highest temperature, and its light, therefore, contains the largest proportion of short wave length energy. Even so, it is very far from matching sunlight, and to the eye appears much warmer or yellower. For ordinary purposes, this feature is by no means a drawback, since a warm tint in artificial light is actually desirable for aesthetic reasons. There are, however, certain directions in which artificial light can be useful only if it is of the same quality as daylight. For example, in the manufacture, inspection and sale of coloured fabrics or other goods, the matching of materials to be made into garments, colour printing, paint making and so forth, it is important that coloured objects should appear in the same scale as in daylight. A great deal of investigation has been directed towards producing the requisite artificial daylight, and until recently the most successful results were obtained by passing light from an incandescent lamp or other source through colour filters which, by absorbing suitable proportions of the long wave lengths, produce a balance between the various light components comparable to that which exists in normal daylight. In such apparatus it is necessary to enclose the light source in some kind of fitting or lantern. Such units, however, are relatively expensive.

To America belongs the credit of producing the first incandescent lamp forming a self-contained unit for producing artificial daylight. Nevertheless the British lamp makers were not far behind in developing lamps on the same lines. These are gasfilled lamps, having bulbs of special glass which, when the lamp is unlit, appears brilliantly blue.

A lengthy research has been made on this subject in this country with the result that highly satisfactory lamps are now produced. Since, as explained, a large part of the long wave length light must be absorbed to give the desired effect, the illuminating efficiency of

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such lamps, if they are to be accurate, is comparatively low—about 40 per cent. of that of clear lamps. This loss of efficiency is unavoidable unless the temperature of the light giving filament can be very greatly increased, which at present is impracticable. Notwithstanding this drawback, the daylight lamp is invaluable for the purposes indicated, and enables workers dependent hitherto on daylight to carry on irrespective of time or season.

When absolutely true colour values are not essential, similar daylight lamps can be used for general illumination with very distinctive effect, notably in shop windows. Under such conditions lamp bulbs absorbing a far smaller proportion of light can be used. Although the spectroscope or a colour-matching test would show that true daylight value has not been attained, the unaided eye is not able to perceive the difference, and the impression made is that of a window flooded with daylight. Such effects can be produced with the absorption of only about 40 per cent. of the light—that is to say at about 60 per cent. of normal efficiency.

A further use of similar glass is made in sign lamps. Signs equipped with such lamps are very distinctive and appear much whiter and more brilliant than those fitted only with clear lamps. Numerous examples may be seen in the London streets.

### SECTION V.—C.

#### APPLICATION OF PROJECTOR LAMPS.

Owing to the intensity of the light emitted the gasfilled lamp can be used with excellent results in light projection systems by suitable arrangements of the shape and position of the filament.

Amongst the uses of such systems the following may be cited :—

- Cinematograph and magic lantern projection.
- Theatrical "spot" lighting.
- Photographic enlarging.
- Long range signalling.
- Floodlighting.
- Aircraft headlights.
- Lighthouses.

For such purposes the lamps have to be specially made to suit the requirements of the apparatus employed. Such requirements react upon the shape and dimensions of both bulb and filament, and in some cases they necessitate the use of special heat resisting glass.

Projector type lamps are now made from 6 to 3,000 watts and their use is rapidly extending for various purposes owing to the following

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inherent advantages they possess over other means of illumination :

1. Absence of fumes and freedom from fire risk.
2. Facility of operation and replacement.
3. Uniformity and high intensity of illumination.

## SECTION VI.

### POSSIBILITIES OF EXPANSION.

In compiling this paper we have attempted to set out the vast difference between existing conditions and recommended practice in the principal fields of electric lighting. From the data given, it will be appreciated that the problem confronting the electrical industry is to convey to the community at large the knowledge gained by the engineer on the value of illumination and the correct application of lighting equipment. It is felt, therefore, that this paper would be incomplete if it did not give an estimate of the potential market and offer suggestions as to the means by which the public may be brought to enjoy the full benefit of a service regarding which they are as yet strangely ignorant.

So rapid has been the development of lighting practice during recent years, and so constantly is research discovering new advantages in the use of higher standards of illumination, that we feel we are only at the beginning of the possibilities. In attempting, therefore, to estimate the value of the potential market for electric lighting, we can do no more than indicate figures which are consistent with our present knowledge of the art. Estimates which at present imply saturation point may, owing to improved knowledge on the part of the lighting industry, and better appreciation on the part of the public, prove to be merely the starting point of a new development.

The following series of estimates covers the five principal fields of lighting :—factories, offices, shops, public buildings, and the home. In each case the numbers have been obtained from directories, and are, we believe, sufficiently accurate for the purpose in view. In each case, also, the cost has been estimated of modernising existing electric lighting installations and of wiring and equipping, in accordance with recommended lighting practice, all buildings not at present electrically lighted.

In considering the figures, it should be remembered that each unit is assumed to be a separate installation. For example, a factory may be either a single workshop or an establishment employing several thousand employees. The estimated cost of £100 for modernising the equipment, although high for the former type, would



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be low for the latter. Our estimates are, we consider, made on a conservative basis, and the possibilities for business development they reveal are sufficiently striking.

*Factories and Workshops (265,500).*

On the assumption that 50 per cent. require to be modernised at a cost of £100 each, the total estimated business amounts to .. .. .	£13,275,000
On the assumption that 50 per cent. must be completely wired and equipped at a cost of £200 each, the total estimated business amounts to .. .. .	£25,550,000
	£38,825,000

*Offices (758,650).*

On the assumption that 50 per cent. require to be modernised at a cost of £30 each, the total estimated business amounts to .. .. .	£11,380,000
On the assumption that 50 per cent. must be completely wired and equipped at a cost of £70 each, the total estimated business amounts to .. .. .	£26,552,000
	£37,932,000

*Shops and Stores (574,360).*

On the assumption that 30 per cent. require to be modernised at a cost of £30 each, the total estimated business amounts to .. .. .	£5,160,000
On the assumption that 70 per cent. require to be completely wired and equipped at a cost of £75 each, the total estimated business amounts to .. .. .	£30,200,000
	£35,360,000

*Public Buildings (86,870).*

On the assumption that 40 per cent. require to be modernised at a cost of £150 each, the total estimated business amounts to .. .. .	£5,220,000
On the assumption that 60 per cent. require to be completely wired and equipped at a cost of £300 each, the total estimated business amounts to .. .. .	£15,660,000
	£20,880,000

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Homes (9,440,000).

On the assumption that 13·75 per cent. require to be modernised at a cost of £10 each, the total estimated business amounts to .. .. .	£12,940,000
On the assumption that 86·25 per cent. require to be completely wired and equipped at a cost of £30 each, the total estimated business amounts to .. .. .	£244,380,000
	£257,320,000

*Summary.*

In re-equipping to modern recommendations .. .. .	£47,975,000
In the equipment of unwired buildings .. .. .	£343,340,000
	Grand total     £391,315,000

These figures take no account of the annual revenue to be derived from the sale of energy or of the business to be done in providing additional generating equipment, switchgear, cables, and the numerous mechanical devices such as automatic stokers, coal conveyors, etc., which form an integral part of the modern generating station.

To sum up, the intensive development of electric lighting, which would be of inestimable value to the general public, would at the same time stimulate trade in all directions. The first step which is necessary in order to set in motion a scheme of development is the education of the public. The achievements of the engineer must be presented to the consumer in the most speedy and effective way. Well organised and intensive campaigns through the proper channels should be conducted in order to induce existing electric light users to improve their installations. The ideas of prospective consumers should be moulded so that new installations will be equipped in accordance with modern practice. We attach great importance to the latter category because the practice adopted for the majority of new electric light installations is little in advance of the methods employed twenty years ago.

In our opinion the quickest and most convincing means of education in illumination matters is actual demonstration of lighting effects. Descriptions of lighting effects are seldom convincing; the "atmosphere" created by adequate well-diffused illumination must be experienced in order to be appreciated. Fittings showrooms, in which a mass of ornamental metal is submitted for inspection, help

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little in improving standards of illumination. Accordingly we suggest the establishment throughout the country of well-equipped demonstration rooms where correct principles of electrical illumination, supported by convincing data, can be presented to selected classified groups of light users. Such an enterprise must of necessity be organised by electrical retailers and supply undertakings, since they represent the only sections of the electrical industry in direct contact with the public. In order to encourage this essential process of public education the Electric Lamp Manufacturers' Association has acquired premises in London fully equipped for the demonstration of various forms of illumination and for illustrating the benefits of improved methods and higher standards in the art of lighting.

In conclusion, we maintain that good lighting implies much more than mere utility or decorative effect. It is a matter of national importance. It has a direct bearing on the safety, well-being, and temper of the people. On the domestic side it means brighter and more cheerful homes, increasing the comfort and happiness of social and family life. On the industrial side it means greater safety, increased production, and less strain upon the operatives. On the public side it increases the amenities of life in cities, towns and villages, rendering our streets safer and more effective, and combating the depressing effect of our winter climate. The movement towards more light and better light is, therefore, one to which statesmen, public health authorities, industrial and social reformers, and all others concerned in the betterment of the conditions of life should give sympathetic study and every possible encouragement.

### RÉSUMÉ.

Le sujet a été traité au point de vue pratique et ces conclusions sont applicables à ces parties de l'Empire Britannique qui adoptent dans l'ensemble la pratique Anglaise actuelle.

Des chiffres indiquent l'énergie électrique utilisée pour l'éclairage dans les différentes parties du monde et résument l'augmentation du rendement des lampes depuis 1896.

L'Auteur discute la durée économique d'une lampe moderne et insiste sur l'importance de faire fonctionner les lampes à leur voltage exact et de fournir au public du courant ayant des voltages définis et constants.

Le besoin de plus fortes intensités d'illumination est préconisé. Des tableaux indiquent l'influence des intensités d'illumination sur l'acuité visuelle, sur la vitesse de discernement, sur la vision soutenue et la vitesse d'accomodement.

Le rendement de l'éclairage dépend de facteurs autres que la source de lumière elle-même et différentes indications sont données sur la perte de rendement des lampes modernes qui sont souvent placées dans des armatures qui



# INTERNATIONAL CO-ORDINATION IN ILLUMINATION

J. W. T. WALSH, M.A., M.Sc.

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## 1. HISTORICAL.

The urgent necessity for the formation of an organisation to promote international agreement on such matters as standards of light, and to unify the photometric work done in the principal civilised countries of the world was first realised at the International Congress of the Gas Industry, held in Paris during the Exposition of 1900. The outcome of this realisation was the formation of the International Photometric Commission, which held its first session at Zurich, in 1903, when the representatives of nine nations were present. Other sessions were held in 1907 and 1911, under the presidency of Prof. Th. Vautier, of the University of Lyons. The papers presented at these sessions and the discussions which took place were mainly concerned with the problems of photometry, and with the properties and behaviour of light sources. A feeling that the basis of the Commission should be broadened so as to include all aspects of the subject of illumination resulted in a decision to reorganise it as an International Commission on Illumination, and a meeting of the delegates of nine nations was held in Berlin in 1913 to discuss the details of the reorganisation and to draw up the statutes. The outbreak of war stopped the activities of the Commission almost at the outset, but a fresh start was made in 1921, when a technical session was held in Paris and much valuable work was done, as will be seen from the account given in later sections of this paper. The next meeting will take place in Geneva from the 21st to 25th of July, 1924, and it is expected that illuminating engineers and photometric experts from at least ten countries will be present.

## 2. CONSTITUTION.

The Commission is constituted, according to the Statutes drawn up in 1913, by the co-operation of National Illumination Committees formed in each of the countries participating in the work of the

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Commission. Each national committee consists of members appointed by the technical societies representing gas and electricity and other methods of lighting, and includes representatives of the national laboratory if there be one. For example, the British National Committee consists of seventeen members, five appointed by the Illuminating Engineering Society, five by the Institution of Electrical Engineers, five by the Institution of Gas Engineers, and two by the National Physical Laboratory.

Each national committee deals with problems of illumination as they present themselves to that committee. Sometimes these are problems mainly of national importance, but more often they concern matters on which some degree of international agreement, or at least an exchange of views between the various national committees, is felt to be desirable. This exchange of views may take place at any time, and in certain cases it paves the way for definite international agreement at the next session of the whole Commission.

These sessions are normally held every three years and every national committee is entitled to send ten delegates to represent it at the meetings. Examples of agreements which have been arrived at by this means will be found in the following sections of this paper.

The general policy of the Commission is directed by an Executive Committee which is composed of two members from each of the participating countries, and of the officers of the Commission. The officers are a President, one or more Honorary Presidents, three Vice-Presidents, an Honorary Treasurer and Honorary Secretary. The office of President is now filled by Dr. E. P. Hyde, of the United States of America, while Mr. C. C. Paterson, director of the G.E.C. Research Laboratories, Wembley, is Hon. Treasurer and Secretary. The central bureau of the Commission is located at the National Physical Laboratory in this country.

It has been ruled that the self-governing Dominions of the British Empire may be admitted to participation in the work of the Commission on exactly the same terms as other countries, and one, the Union of South Africa, has been so admitted, and will be represented at the forthcoming session in Geneva.

### 3. THE WORK OF THE COMMISSION.

(a) *The Standard of Light*: As stated in the first section of the paper, the work of the original International Commission on

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Photometry was mainly photometric in character, and although the scope of the present commission has been extended to include other aspects of illuminating engineering, photometry still remains an important item in the Commission's work. Probably the most important matter calling for international agreement in every branch of science or engineering is the unification of its fundamental standards. Until the year 1909 no agreement whatever had been attained in the matter of an international standard of light, although a considerable amount of work had been done by way of intercomparison between the diverse national standards. It was through the efforts of the members of the International Photometric Commission that an agreement was made in 1909 between the national standardising laboratories of France, Great Britain and the United States of America, establishing a common unit of candle-power for these three countries and defining a simple ratio between this common unit and the Hefner unit used in Germany and some other countries. This most important piece of work was carried a step further at the 1921 meeting of the International Commission on Illumination, when the common unit previously agreed upon was adopted by all the nations there represented and termed the "international candle."

In Fig. 1 are shown the four principal units which have been adopted at various times by the principal different countries. These are:—(a) the carcel lamp (France) burning colza oil at a specified rate and agreed to have a luminous intensity of 10·4 international candles; (b) the Vernon-Harcourt pentane lamp (Great Britain, U.S.A.) burning pentane vapour ( $C_5 H_{12}$ ) from a wickless burner and agreed to have, under specified atmospheric conditions, a luminous intensity of 10 international candles; (c) the Hefner lamp burning amyl-acetate ( $C_7 H_{14} O_2$ ) from a wick contained in a tube of specified dimensions and agreed to have, under specified atmospheric conditions, a luminous intensity of 0·90 international candles; (d) the Violle standard consisting of a surface of molten platinum 1 sq. cm. in area which, at the temperature of solidification, is agreed to have a luminous intensity of 20 times the bougie décimale, *i.e.*, 20 international candles.

Unfortunately none of the standards just described was found to be reproducible to the accuracy attainable in precision photometry, so that it was found necessary to maintain the unit of luminous intensity by means of electric incandescent glow lamps, which when suitably prepared had been proved to be of very great constancy. The lamps used for the purpose in this country

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were of the design employed by Prof. Fleming and manufactured by the Ediswan Company. A specimen is shown on the right of Fig. 2, and it will be seen that it consists of a single "hairpin" filament of carbon in an unusually large cylindrical bulb. Lamps of this type were carefully aged and their candle-power was compared with that of other lamps at the Laboratoire Central d'Electricité at Paris, the Physikalisch-Technische Reichsanstalt at Charlottenburg-Berlin, and the Bureau of Standards at Washington.

The value of the unit of candle-power adopted in the 1909 agreement was, as nearly as possible, one-tenth of the candle-power of the pentane standard lamp, so that no discontinuity was intro-

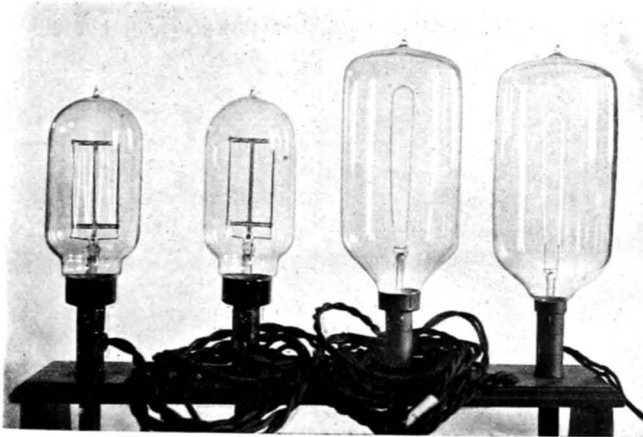


Fig. 2

duced into the values of candle-power determined in this country. The French unit was declared by them as being already the same as this unit, and the American unit was lowered by them by 1.6 per cent. in order to obtain agreement between the three countries. Thus, from 1st July, 1909, only one unit was in use in the three countries, and that unit was maintained by means of electric glow lamps. Since 1909, other international comparisons have been carried out by exchange of lamps between the laboratories concerned, and a fresh intercomparison is being made during the present year. This comparison is being carried out by means of tungsten filament lamps operating at two efficiencies, *viz.* :



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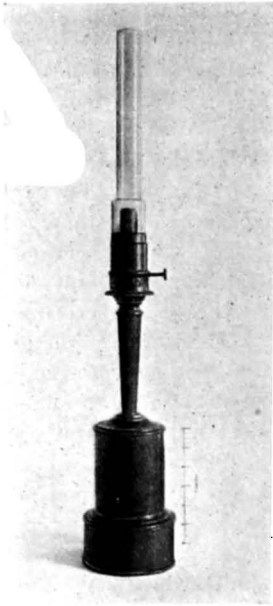


Fig. 1(a)

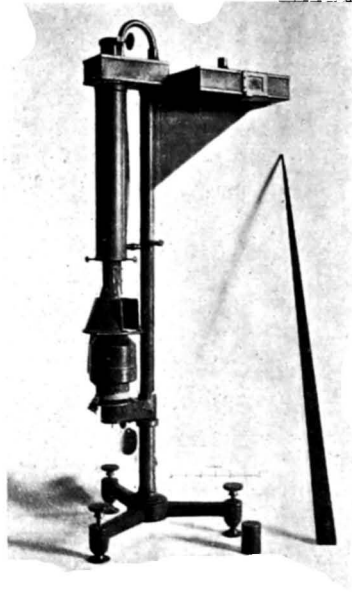


Fig. 1(b)

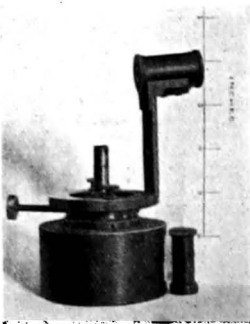


Fig. 1(c)

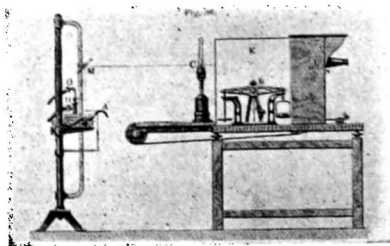


Fig. 1(d)

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approximately three and seven lumens per watt<sup>1</sup>. When run at the latter efficiency the lamps give light which is nearly of the same colour as that of the ordinary vacuum tungsten lamp. A lamp of the type used for this comparison is shown on the left of Fig. 2.

(b) *Photometric Definitions*: Of importance secondary only to the establishment of an international standard of light and of considerable assistance in facilitating exchange of data and promoting uniformity of practice, is the production of an agreed set of definitions and a common nomenclature for use in the literature of illumination. Several reports on this subject were presented at early sessions of the Photometric Commission, but the first definite progress in international agreement was made in 1921 when definitions were adopted for three of the four principal photometric quantities, *viz.*: "luminous intensity" (candle-power), "luminous flux," and "illumination." The units of each of these quantities were defined at the same time and these definitions in their definitive form (French) will be found in the appendix to this paper. It is hoped that further progress will be made in this direction at the forthcoming session of the Commission. An international committee appointed at the 1921 session has been carefully considering the whole subject and will present a report which, it is hoped, may lead to the international adoption of definitions of other quantities such as brightness, efficiency, etc. Progress is necessarily slow, but it is very important that every effort should be made to ensure that what is adopted at the general session will be acceptable to all the interests concerned in all the countries forming the Commission. Nothing is gained by hasty and ill-considered decisions which have, in all probability, no chance whatever of general adoption and only lead to confusion and the retardation of agreed practice rather than its promotion.

(c) *Lighting Legislation*: One of the first fruits resulting from the extension of the Commission's work is the consideration it has given to the subject of industrial and school lighting. The importance of adequate and suitable lighting in industrial establishments is now being realised more and more in the different countries of the world, and the problem of setting up certain minima as statutory requirements is receiving much attention. The first

<sup>1</sup> Specimens of the Fleming-Ediswan, and of the tungsten filament standard lamps were shown as part of the exhibit from the National Physical Laboratory (Photometry Division) in the Royal Society's Stand (Government Building, Stand No. 11), British Empire Exhibition.

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considerable step in this direction was taken in this country when a Home Office Committee on Lighting in Factories and Workshops was set up shortly before the war, to consider the whole question of factory lighting from the point of view of ensuring the safety and health of the workers. This committee issued its first report in 1915, and its second and third reports in 1921 and 1922. Meanwhile the subject had been receiving much attention in the United States of America, where the Illuminating Engineering Society of New York drew up a code of industrial lighting which was adopted in slightly varying forms by a number of different states. A committee on the subject is now studying the question in France. It is clearly of the utmost importance that each country should be fully cognisant of what is being done abroad so that the results of any investigations carried out may be made full use of, not only in the country in which they are made, but also in each of the other countries interested in the subject. To the furtherance of this end the International Commission on Illumination set up in 1921 a committee, having representatives from each of the countries participating in the Commission's work, and charged with the duty of keeping in touch with the developments taking place in the matter of lighting legislation in those countries. One very considerable obstacle to uniformity of action in the various countries is the diversity in the machinery adopted by different states, for putting into operation any legislative requirements made with respect to industrial establishments. On the other hand it is clearly desirable that as much uniformity as possible should be secured in these requirements, and it is to this end that the International Commission on Illumination is working through its international committee on the subject. It is too early yet to say what will be the result of the Commission's work, but the report of the committee, to be presented at Geneva, will probably indicate the directions in which international agreement appears to be most practicable in the future.

(d) *Automobile Headlights* : The subject of preventing or restricting the use of glaring automobile headlamps is, again, a subject of growing importance in every civilised country of the world. Regulations having legal support are in force in the majority of the United States of America, and similar regulations have just come into force in France. A committee appointed by the Ministry of Transport in this country has issued two reports on the subject and has made certain recommendations. The difficulty of securing uniformity of practice in the different countries is in this case

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intensified by the exceptional nature of the problem and the probability, amounting almost to certainty, that a solution satisfactory both to the motor driver and to the other users of the road does not exist. On this subject the International Commission on Illumination has taken the same action as in the case of lighting legislation, feeling that some form of liaison between the lighting experts of the different countries was likely to be of the utmost value, at least in preventing the adoption of mutually contradictory requirements in different countries. Again it is too early to prophesy as to the value of the work in this direction. Much depends on the recognition accorded to the Commission by the government departments dealing with the matter in the different countries.

### 4. THE FUTURE.

It cannot be too strongly insisted that the International Commission on Illumination is as yet only in the early stages of its existence. International agreement in matters scientific or technological is generally of slow growth, and attempts to force a more rapid progress than popular technical opinion will allow, can only lead to failure and possibly even retrogression. The work of such a body as the International Commission on Illumination must rest on the broad basis of a desire for co-operation between the various lighting interests in the different countries of the world. It cannot force that co-operation, but it can and does provide the machinery by means of which such a desire for co-operation may express itself by common agreement and by unity of action. The existence of this machinery at the early stages in the development of the science and technics of illumination will, it is to be hoped, assist the industries concerned and help to avoid the crystallisation of national practice on lines peculiar to each country, a state of affairs which past experience has proved to be so detrimental to progress in any branch of pure or applied science.

It must be remembered, however, that progress in good illumination is not confined to standardisation and international agreement. It depends also on a thorough interchange of knowledge and experience gained in different countries. The Commission affords opportunities for this interchange in the readiest and most effective manner and it also provides a platform from which the illumination experts of the world may, with a united voice, preach the benefits to be derived from an intelligent and scientific application of power to the production of that most important commodity in modern life, illumination.

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### APPENDIX.

Photometric Definitions Officially adopted by the International Commission on Illumination.

*Flux Lumineux* : C'est le débit d'énergie rayonnante évalué d'après la sensation lumineuse qu'il produit.

Quoique le flux lumineux doive être regardé strictement comme le débit de rayonnement tel qu'il vient d'être défini, il peut cependant être admis comme une entité pour les besoins de la photométrie pratique, étant donné que, dans ces conditions, le débit peut être considéré comme constant.

*L'unité de flux lumineux est le Lumen.* Il est égal au flux émis dans l'angle solide unité par une source ponctuelle uniforme d'une bougie internationale.

*Eclairement* : L'éclairement en un point d'une surface est la densité de flux lumineux en ce point, ou le quotient du flux par l'aire de la surface lorsqu'elle est uniformément éclairée.

*L'Unité pratique d'éclairement est le Lux.* C'est l'éclairement d'une surface de un mètre carré recevant un flux de un Lumen uniformément réparti, ou l'éclairement produit sur la surface d'une sphère de un mètre de rayon par une source ponctuelle uniforme d'une bougie internationale placée à son centre.

Par suite de certains usages reconnus, on peut aussi exprimer l'éclairement au moyen des unités suivantes :—

Si l'on prend pour unité de longueur le centimètre, l'unité d'éclairement est le lumen par centimètre carré appelé Phot. Si l'on prend pour unité de longueur le pied, l'unité d'éclairement est le Lumen par pied carré, appelé "Foot-Candle."

1 "Foot-Candle" = 10,764 Lux = 1,0764 milli-phot.

*Intensité Lumineuse.* L'intensité lumineuse d'une source ponctuelle dans une direction quelconque est le flux lumineux par unité d'angle solide émis par cette source dans cette direction. (Tout flux émanant d'une source de dimensions négligeables par rapport à la distance à laquelle on l'observe peut être considéré comme provenant d'un point).

*L'unité d'intensité lumineuse est la Bougie Internationale* telle qu'elle résulte des accords intervenus entre les trois laboratoires nationaux d'étalonnage de France, de Grande-Bretagne et des Etats-Unis en 1909<sup>1</sup>. Cette unité a été conservée depuis lors au moyen de lampes à incandescence électriques, dans ces laboratoires qui restent chargés de sa conservation.

### RÉSUMÉ.

Ce rapport décrit l'organisation de la Commission Internationale de l'Eclairage, groupement ayant pour but la coordination des travaux des Comités Nationaux de l'Eclairage établis dans chacun des pays participants. Ces comités sont constitués par les membres nommés par les principaux intéressés dans les questions d'éclairage (gaz et électricité) et par le laboratoire nationale où il y en a un.

La commission a réussi à établir un étalon international, d'intensité lumineuse la bougie internationale, et prépare actuellement une série de définitions

<sup>1</sup> Ces laboratoires sont : le Laboratoire Central d'Electricité, à Paris, le National Physical Laboratory, à Teddington, et le Bureau of Standards, à Washington.

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internationales des principales unités utilisées en illumination et en photométrie. La Commission a établi des Comités internationaux pour étudier la question de la photométrie hétérochromatique, l'éclairage industriel et celui des écoles, ainsi que les phares d'automobiles. Ces Comités s'efforcent, par le Comité National, de renseigner exactement chaque pays sur ce qui se fait ailleurs en ce qui concerne les travaux de recherche, la législation projetée et tout autre aspect de leur branche particulière d'éclairage.

La Commission fournit le moyen d'un échange rapide de l'expérience acquise dans les problèmes d'illumination et une plateforme parmi les pays participants où les experts en éclairage de tous les pays peuvent se réunir pour insister sur les avantages que l'on peut retirer d'une étude scientifique et intelligente des sources d'illumination qui sont maintenant à la disposition de l'humanité.

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## DISCUSSION

Chairman: DR. A. RUSSELL (GREAT BRITAIN)

Friday, July 4th. *Afternoon Session*

THE CHAIRMAN, opened the session by calling on the authors to give a brief résumé of their papers, after which he declared the session open for general discussion.

DR. CLAYTON H. SHARP (*U.S.A.*), suggested that the utilisation of light was not carried out anything like so well or in such a good way as it should be; furthermore, illumination as ordinarily carried out was not nearly on so high a standard as it could advantageously be. Statistical studies in the United States had shown that about 25 per cent. of the current that was supplied to residences was used in the various appliances, and about 75 per cent. or even 80 per cent. was used in lighting.

Illumination levels were too low everywhere. The effort which should be made towards increasing the central station loads looked primarily to increasing the lamp load, and it was the lamp load with which the central station started.

It had been fairly well understood for some time that an increase in the standard of illumination in a workshop would result, in a general way, in increased production and in decreased spoilage, as well as in increased contentment of the workers. They had not been entirely satisfied with the conclusiveness of the numerical results showing how much this increase was. Consequently, at the suggestion of the Research Committee of the Illuminating Engineering Society, the National Research Council had undertaken to carry out an investigation of the question. Suitable committee organisation for that purpose had been effected, and it was expected that during the coming winter they would be able to supplement the present data with additions which would be of a more authoritative character, obtained in an entirely impartial way. The cost of light represented a very small percentage of the cost of production, and if by doubling or quadrupling it or going further with it, the productiveness of labour could be increased a little bit, it was a very clear and evident gain. Here, again, it was to the interest of those who were selling and distributing current for lighting to get behind and push ahead a movement of this kind. The great thing to do was to get the idea to the man in the street, to the man who was paying no attention to questions of lighting. Propaganda towards this end by such bodies as the Illuminating Engineering Society in the various countries was something that should be welcomed.

He suggested that insufficient attention had been devoted to the question of illumination at this First World Power Conference.

MR. C. C. PATERSON (*Great Britain*), said that, though the International Illumination Commission gave an opportunity for individuals to meet, it had not up to now had sufficient of the influence of the manufacturers and those interested actually in the technical side of the industry, taking part in its proceedings. They needed the co-operation of the manufacturing sections of all countries on the various National Committees, in order to ensure that their deliberations and decisions should be of practical as well as academic value. He urged engineers who were engaged on the industrial side and the manufacturing side of the illumination industry, to take real steps to acquire

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an interest in the work of their National Illumination Committee, through which they might take part in the proceedings of the International Commission.

He emphasised the necessity for the production of a unit of light or a standard of light, much whiter than they could get at the present time. He hoped they would hear what had been done in other countries towards getting a photometric unit or standard for a whiter light than the Tungsten lamp.

He thought that Mr. Sully, in his paper, passed a little lightly over the question of cost, and the serious effect of the cost of power and installation in connection with the application of electricity generally, and the use of more illumination. First of all, he reminded the audience that the chief consumer of electric power in Great Britain and the chief prospective consumer, was the private individual in his private house. It seemed a slow business to get that individual to appreciate the advantages of the use of electric power generally and of higher illumination at home. First, the question of cost both of installation and power was regarded as a serious one by the ordinary householder. Also, the private individual was not even yet being made aware adequately of the real advantages which came from the extensive use of electricity in his private house. There was much inertia to be overcome in getting the private householder to make any change in his house. Electricity was a strange thing which he did not understand. They had to force the advantages of improved illumination right under the nose of the domestic consumer, and he himself felt that if that were done in a more organised manner, in a limited number of neighbourhoods in the first place, they would achieve their object more rapidly than seemed likely at the present time.

A DELEGATE, said that as one in touch with the consumer in Great Britain all the time, he felt that it was not entirely cost that was stopping the progress of illumination; it was rather education, and the British manufacturers and associations of British manufacturers were doing a very great deal in this country. He was convinced that they were on the threshold of a new era in electric lighting.

Mr. J. S. Dow (*Great Britain*), referred to the comprehensive data contained in Mr. Sully's paper and urged the need for exhaustive experiments, conducted by committees on an impartial and authoritative basis, illustrating the benefits of good illumination. What was needed was not so much the expression of views—for with regard to the benefits of good lighting, all experts were agreed—but the presentation of facts that would carry conviction to the public. In regard to street lighting, it would be useful to be able to compare one city with another in terms of candle power furnished or expenditure per capita on public lighting. An understanding as to the requirements of different classes of streets was needed. The values specified in the Report of the Joint Committee concerned with the Standard Specification for Street Lighting, indicated what was actually to be found in streets, rather than what was desirable. He would like to see a complete survey of the streets of London, and a considered estimate of the improvements necessary, and the areas which were under-lighted. In approaching the manager of a factory, there were many arguments based on self-interest—for example, the saving in time of operators and higher production consequent on improved lighting. In the case of streets, the direct benefit was less manifest, and was more widely distributed, so that improvements in street lighting were dependent on the education of public opinion. If ratepayers could be made to feel a pride in the lighting of their city, municipalities would readily respond to public opinion and spend more generously. In regard to industrial lighting, the distinction between legal minima and values recommended in the interests of more efficient production was obvious. Manufacturers would do well to accept the Home Office recommendations with gratitude, as a valuable expression of official opinion; it was quite open to them to suggest higher values as a good investment commercially. But it was not possible to insist on people being efficient by legislation, which was naturally based primarily on danger to health or safety. The great educational value of official lighting



## DISCUSSION

requirements, however moderate, should be recognised. Such recommendations should be on broad lines, supplemented by detailed data similar to that incorporated in the American codes as a supplement. Probably the chief value of these American codes was educational, and, for the present, any form of legislation on lighting should be applied in a very tolerant manner, so that it would be willingly accepted by management and workers alike.

Mr. P. GOOD (*Great Britain*), said that speaking as the man in the street, he thought more progress would have been made if they had really pressed forward the use of higher standards of illumination generally, each one of them in their own circle. People would very quickly imitate those standards. He had been interested to notice that many who had been actively interested in illumination work still maintained very much the old standards in their own homes and offices, and he felt that some of them might begin at home and they would soon find that the disease would spread.

Mr. B. P. DUDDING (*Great Britain*), referred to four curves given under the main principles of illumination in Mr. Sully's paper, which were concerned with the ability of the eye to discriminate details, the speed with which it would work, the sustaining of good vision and ability to accommodate. A cursory study showed that these factors were to some extent fighting against one another. Most industrial operations brought into play nearly all four factors, so that what was wanted was data from the factory people who actually tried various types of illumination, with regard to the best conditions for various manufacturing operations. For example, there was some evidence already that very high general illumination for certain operations was detrimental, whilst very high local illumination for that work was extremely good. For other operations the reverse was true.

Mr. L. E. BUCKELL (*Great Britain*), suggested that as 1,500 or 2,000 foot candles was not an abnormal standard of day lighting, it seemed strange to hear of hopes that the standard of artificial light in certain circumstances might be raised from 3 to 6 foot candles. He thought that a realization of the large figure by which artificial light standards lagged behind daylight must have a considerable bearing upon the question of bringing the idea of more light home to the user. In the past, artificial light had been a difficult and expensive thing to get, and those using it, possibly those applying it, had not quite realised that to-day conditions had changed so much. With regard to the question of cost of installation and the cost of current, it was quite likely that those costs could be reduced, but even with those costs as they were, they were surely very low relative to the cost of many other things, which were taken as a matter of course and whose cost was not considered to the same extent by the domestic user. It was safe to say that there were very few who spent 2½ per cent. of their income on light. That was a very small amount. Light could be shown to be at least as important to the well-being of the community as such things as cleanliness, fresh air and clean water, to obtain which enormous sums were spent.

Mr. R. W. HUGHMAN (*Great Britain*), reminded them that there was such a thing in life as joy, and people would pay for joy. One of the things which helped to give joy in private houses, in restaurants and in life generally, was light. The public would pay for more light, if that aspect could be brought home to them. He did not think that in Great Britain the cost of illumination was a serious drawback. Light was distinctly cheap, and if station engineers, manufacturers and contractors would all put their shoulders to the wheel and try to double and treble the standard of illumination, very much extra current could be sold, and the health of people and the amenities of living would be greatly increased. He advocated a regular "better lighting" campaign on a national scale. The advent of electric light had been followed by heating and cooking and power, etc. These other uses were important; they filled up the load curve and helped to bring down costs, but in pursuing many of them, they had lost sight of the enormous field for light which still remained uncultivated. Even amongst the minority who already used electric light, it

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would be possible by proper handling to double their consumption of electric energy for lighting purposes.

Mr. G. CHELIOTTI (*Great Britain*), confessed that as lamp manufacturers they had not until comparatively recently given the attention that might have been expected from them, to the lighting of their shops. The average value of the illumination would have been probably from 1 to 3 foot candles, with a bias on the low side; the local illumination would have been anything from 10 to 50 foot candles. They had tried, in various departments, the experiment of putting up the general illumination to anything from 10 to 35 or 40 foot candles, and he did not think that it would be fair to say that in any of those cases they had produced a general illumination which was excessive. The average industrial worker was extremely conservative on the subject of light. Although he might use many hundreds of foot candles in the day time, as soon as a new installation was switched on to give him 10 foot candles at night he was dazzled out of his wits, but he soon grew used to it. Some of the operations were very delicate, because they had to work on wires as fine as 1/5th of a human hair, and they had found that it was imperative to have, in addition to a good standard of general illumination, some local illumination. If they did not get high lights with these small parts, they could not see to handle them.

Mr. J. W. T. WALSH (*Great Britain*), referring to the practice in the United States for the large Supply Companies to deal with their customers on the basis of free lamp renewals, said that that system must have been adopted for a very good reason, and it seemed as though it should have a very marked value in eliminating the inefficient lamp and in encouraging the consumer to use what was generally regarded as a high level of illumination; it would avoid in fact many of the wasteful practices to which the uninstructed consumer was liable.

A DELEGATE, suggested that the general idea of the ordinary person was that the International Commission concerned itself wholly and solely with such matters as the settling of definitions and units and other very useful spheres of work, but spheres into which the ordinary manufacturer or consumer or user or supplier did not feel that they could rightfully enter. If it was a fact that they were prepared to consider and were considering more practical questions, it was most desirable that it should be made more widely known than it was at present.

Mr. W. G. BUSH (*Great Britain*), said that although the service of electricity for lighting purposes had been available for some forty years, it was only of recent years that a serious effort had been made by manufacturers and other bodies to develop its correct application. The greatest evil which they had to combat was the evil of glare. An outstanding example of that was shop window lighting. In seven out of ten shop windows they would see a glaring lamp. If equipment were properly used and higher intensities were adopted, more people would be attracted to the windows of the shops. The same applied to factories, offices, shops and all interiors where electric light was used. In this connection it would be desirable if the Industrial Fatigue Research Board and other bodies would make further investigations, because it appeared that they themselves were not yet at all familiar with the value of good illumination. For example, he referred to the Home Office welfare pamphlet No. 7.\* If the Government were sending round information of that character it made the task doubly hard.

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\* "The Lighting of Factories and Workshops."  
" . . . some recent studies of output in relation to industrial fatigue have afforded evidence that under artificial illumination production falls off even if electric light of sufficient intensity is provided. Every unnecessary hour under artificial light means a direct loss of production and makes the task of the worker more difficult than it need be."

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## DISCUSSION

Of all the services made available to mankind by the use of electricity, electric light was one of the greatest, and Mr. Sully's paper should do much to stimulate its progress.

MR. L. GASTER (*Great Britain*), said that previous speakers had referred to the smallness of the audience, but he could recall instances in the early days of the Illuminating Engineering Movement, when the audience had been very much smaller. At that time, the importance of good illumination, and the principles on which it was based, were not properly appreciated. There had been a great change for the better in this respect, due to the steady propaganda work of the last fifteen or sixteen years.

There was a general recognition that the moment was ripe for propaganda on a much larger scale, in order that the rewards of the past effort might be gained, both by the lighting industry and by the public. Mr. Sully's paper had shown very clearly the great opportunities for remunerative business in the lighting field. It would be well worth while for firms in the lighting industry to encourage educational work, designed to bring home to the public the benefits of good illumination—especially work conducted by independent and impartial bodies, whose advice would be received with confidence.

These facts were now fully realised in the United States, where very extensive educational schemes had been developed.

Referring to the remarks on American methods of charging a consumer very low prices for wiring and supply of lighting appliances, Mr. Gaster said the wisdom of this procedure could be recognised in a country where lamp makers worked closely together. He quite agreed with the proposal, but in Great Britain this community of interests was not yet closely established. There was also the difficulty that many landlords had not been educated to take a personal interest in furnishing good lighting for their tenants, and that the latter were usually uncertain how long they would continue to occupy the premises. He would very much like to see a scheme developed to help forward the "Better Lighting Movement," now also initiated in this country. Credit was due to the organisers of the World Power Conference for having given the subject of Illumination a share in the programme of papers to be read, but no doubt great progress would be recorded at the next Conference on the recognition of the value of good lighting, and he hoped that the technical and daily press would give wide publicity to the work of this Conference.

MR. WALSH, dealing with the extension of the scope of the International Commission on Illumination, said he thought that the impression received as to the scope of the Commission's work was very largely due to the fact that it was the successor of the old International Commission of Photometry, in which naturally the field had been far more restricted. It was not until 1913, that the Commission had been reorganised to enable it to deal with the whole subject of illumination, theoretical, scientific and practical.

In 1921, a start had been made. At the second technical meeting to be held at Geneva in a fortnight's time, the programme of subjects to be dealt with by the Commission was very broad indeed. In addition to papers on factory lighting, automobile head-lighting and photometric subjects, they were having papers such as, for instance, one by Mr. Lieb on the work which central stations had done in America towards education in good lighting, and one by Mr. Merrill on demonstration methods of teaching good lighting practice. Then they had papers, from the French National Committee on the application of gas lighting to streets, and finally a striking paper by Mr. Harrison, the illuminating engineer responsible for the lighting of the British Empire Exhibition, on the Lighting of Highways. Such subjects as these were now being dealt with by the Commission, and its platform was as broad as illumination itself. He hoped that, as a result of meetings following on these lines, the International Commission on Illumination would become recognised as the International body to deal with illumination subjects of all kinds.

MR. C. W. SULLY (*Great Britain*), said that with reference to Mr. Paterson's suggestion that the International Commission on Illumination should receive more active assistance from the manufacturing industry, he felt sure that so

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far as the electric lamp manufacturers were concerned, they were only too willing to participate at once in any work that was being done by so valuable a Commission. With reference to the question of cost of light, which, as had been pointed out, had not been made a very serious point in the paper standing under his name, his only excuse was that by the time he had extended the paper to forty-five pages, it was felt necessary to end the subject.

Regarding the point that had been raised by Mr. Good, in which he advocated that they should literally put their own houses in order first of all, and show an example to the world of what electrical illumination really was, he concurred with that advice and at the same time advocated the necessity for striking out on very much broader lines. The three papers they had been discussing indicated that internationally and nationally, they had very good machinery for looking after the situation as far as illumination was concerned, but the point he had hoped would be discussed more thoroughly that afternoon, was the importance of the industry itself pushing this question of illumination in a far better way than it had in the past. As far as the Lamp Manufacturers' Association in Great Britain were concerned, they had recently started a special department in an endeavour to impress upon those interested the many important features in connection with good illumination. But there were other sections of the industry which were equally interested in such propaganda. What they must remember in connection with illumination was that they were dealing with a matter which needed to be developed by means of demonstration, rather than by written papers and debate.

When considering the erection of super power stations, the first thing that was necessary before deciding upon the most convenient spot for cheap fuel and an ample water supply, was to estimate correctly the total potential requirements of the whole country. If the Electricity Commissioners were working on those lines and were estimating the amount of electricity that would be needed in ten or fifteen years' time, were they considering a potential load on the basis of 0.42 lamps per capita as at present in use in Great Britain, or were they allowing for two lamps per capita, as were being used in the United States to-day? If those who were interested in illumination did not bestir themselves, they would find all those who were doing their best to visualise the future would fail sadly, unless it was impressed upon them that the appearances to-day were quite misleading and they must allow for something very much greater.

THE CHAIRMAN then closed the session.