Lamps and Lighting—
A Vision of the Future

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IT IS practically always unwise to try to forecast the future. This is true of human affairs, of the relations between nations and it is true in science and the arts. I therefore want to make it clear that in selecting the title "Lamps and Lighting — a Vision of the Future," I shall be attempting to draw conclusions from the present state of the art rather than to predict possible developments from premises which must be at the best uncertain.

Let me first of all ask you to look with me at the incandescent electric lamp. Developments in this field have ceased to be dramatic. This can be due to one of two factors, either we are approaching an upper limit of efficiency for a given designed life for each of the normal types of lamp, or we have become hide-bound in our thinking, and because we are travelling along well worn tracks, have failed to strike out in fresh directions which may lead us to hitherto unsuspected possibilities in the production of incandescent light. Let us look at each of these possibilities in turn.

The filaments of our incandescent lamps are made from tungsten, an element with a melting point of 3655K. For each type of lamp whether it be of vacuum coil design for traction purposes or a single or a coiled-coil gas-filled lamp, or whether it be one of the many different designs of high brightness projection lamps, there is a maximum average efficiency obtainable by the best manufacturers for a given designed average life. Developments in the last two or three decades have proceeded in the direction of reducing the spread between individual lamps and the spread between batches of lamps made by different manufacturers. As a result the average quality of this class of lamp has gradually but steadily been improved. In this connection it is worthy of note that lamp manufacturers all over the world at an early stage in the evolution of the industry recognized their separate and joint responsibilities for promoting the production and development of the best possible sources of light.

Exchange of information among the lamp companies has therefore proceeded freely for many years and the main differences which still remain in the quality of tungsten filament lamps as between different manufacturers are not generally those due to differences in "know-how" but are due to differences in the extent to which local circumstances make it possible to take advantage of the optimum conditions of manufacture which alone can lead to the highest quality. Developments in stable glasses, in the production of pure gases, in vacuum physics, and in the metallurgy of tungsten, have all contributed to this end.

Having in mind these things, it is good to be able to reflect and record that in the electric lamp industry the endeavour of all reputable manufacturers has always been to strive after the optimum performance. It is recognized that this optimum performance in the case of tungsten filament lamps is governed by the nature of the materials with which we have to deal and with the physical factors involved in the construction of the lamp. It is a function of the vapour pressure characteristics of tungsten under the conditions which obtain inside the lamp. It is a function to a lesser degree of the unavoidable losses due to conduction through the leading-in wires of the lamp and the filament supports, losses due to conduction and convection in the gas-filling and the slight loss due to absorption and total internal reflection at the face of the glass bulb and that due to the solid angle subtended by the cap. The evaporation characteristics are also to some degree affected by the surface condition of the tungsten wire used for making the filament and hence by the composition of the wire itself, its crystalline structure and its surface condition. The thermal losses due to the gas-filling are influenced by the gas pressure and the percentage of argon to nitrogen used in the filling. The maximum obtainable gas-filling pressure is generally always desirable and here the practical limitation is due to the need for pipping off the exhaust stem of the lamp at a pressure not greater than atmospheric or not very much higher. The higher the ratio of argon to nitrogen in the gas-filling, the higher the quality of the finished lamp, but with too high a ratio there is a liability to an increase in the gas current in parallel with the filament and to explosive rupture

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due to arcing at the instant of failure. This is of course a problem which exists to a greater extent in Great Britain and Europe than in your country due to our use of 200- to 250-volt mains. The use of fused-in lead constructions for both single and coiled-coil lamps to enable higher argon ratios to be used is now being extended in various countries.

All these factors, however, are as mentioned at the beginning factors which can influence the final result by only a small amount assuming that the general lamp manufacturing technique is good and the technical control of the lamp making process is adequate at all stages.

Let us now turn to some considerations of the second of my two premises, namely, the possibility that by treading well worn paths, we may be missing some new avenue along which lies the means to produce a very material increase in the efficiency of the incandescent lamp. There can be no doubt that in the case of the comparatively low-wattage type of ordinary gas-filled lamp of either single or coiled-coil construction, an immediate improvement would result from the substitution of krypton for argon. This is of course well known. While supplies of krypton are now freely available from liquid air plants in various parts of the world the cost is generally prohibitive compared with the magnitude of the possible improvement in luminous efficiency for a given life.

A still greater benefit would result from the use of fillings of xenon. Here, however, the matter does not appear to even be remotely within the bounds of practical possibilities in view of the extreme rarity of this constituent of the earth's atmosphere. For special high-power high-brightness tungsten filament projection lamps, mercury vapour at high pressure either with or without xenon or other monatomic gas has definite possibilities and has been used in experimental designs with gratifying results. There is, however, no likelihood whatever that mercury vapour could be used as a gas-filling in anything other than very special projection lamps and the other design features which are simultaneously necessary makes this type of development very expensive.

Figure 1. Experimental mercury-filled high brightness tungsten filament lamp.

It seems unlikely that much further progress can be made in developing alternative filament designs such as triple coils for the tungsten filament gas-filled lamp nor is there much scope for still further reducing thermal losses at the filament supports and electrodes. It would appear, therefore, that the tungsten filament lamp will remain in its present form and will continue to be one of the principal light sources of the future in very many lighting fields for it must be remembered that in a very large range of lighting applications there is as yet no alternative source with anything like the desirable characteristics of the tungsten lamp.

We are forced therefore to look at the incandescent radiator itself. There is no metallic element likely to supersede tungsten as a filament material. We may, however, ask ourselves whether selective radiators of the type used in the original Nernst glower or of other types yet to be studied offer any possibilities. If we cannot obtain a higher filament temperature and therefore a more effective transformation of electrical energy into visible radiation by temperature alone can we either coat the filament with a material which emits preferentially in the visible region or can we produce a new type of filament made from oxides, carbides or other compounds of high melting point and low volatility or with selective radiation properties. It is easy to say that this field has already been investigated. It is perhaps more true, however, to reflect that the remarkable advances which have been made in the tungsten filament lamp have prevented serious work on these other possibilities which did not appear to offer such immediate reward for effort as continued studies of existing designs. If our thinking is to remain vigorous and fresh, we must not fail to re-examine methods which have been discarded long since — for now, and in the future, we have more powerful means at our disposal for investigation and research than were available to the pioneers of the decades that have passed.

Discharge Lamps

When we consider the electric discharge lamp we are on much less sure ground. Only in certain specific directions are we limited by the properties of matter. In other directions the free play of research, development and invention will undoubtedly result in material advances in the efficiency, performance characteristics and life of electric discharge lamps.

Sodium Lamps. — The most fundamental limitation yet recorded in a practical lamp is probably that imposed in the case of the sodium lamp by the fact that the resonance doublet of the sodium atom is produced at optimum efficiency at a very low vapour pressure.

Movement in lamp design from the optimum condition in the direction of lower or higher vapour pressure or higher current density results in each case in a decrease in the luminous efficiency. There is thus set a limit to the maximum attainable efficiency of the order of 70 to 80 lpw for a lamp design in which the temperature of the containing vessel necessary to give the requisite sodium vapour pressure is obtained by heat absorbed from the discharge itself.

If one separates the heating effect of the discharge from the total power consumed by the lamp and thinks in terms of maintaining the requisite vapour pressure by external means, then still higher efficiencies can be obtained by suitable choice of the tube parameters including current density. So far, however, no practical lamp forms more efficient than existing designs which give initial efficiencies of more than 70 lpw have emerged from such considerations and it is unlikely that they will do so. In any case no practical modification of the sodium lamp has so far been conceived which can result in other than the emission of the practically monochromatic yellow radiation so well known to all of us without a serious loss in efficiency.

Mercury Vapour Lamps. — When we turn, however, to the range of mercury vapour lamps we see at once that the possibilities have by no means been exhausted. The low pressure mercury vapour discharge is a most efficient source of ultraviolet radiation in the region of 2537A, a characteristic utilized so notably in connection with the fluorescent lamp. When the mercury lamp is designed to operate at a pressure of between one atmosphere and ten atmospheres quite high efficiencies can be obtained and there are many designs of long life mercury vapour lamp on the market which operate at initial efficiencies between 40 and 60 lpw. Experimentally lamps have been made with initial efficiencies greater than 70 lpw but these are of types which at the present time have certain features which make them unsuitable for commercial exploitation.

Studies of tube design and particularly of electrode design have progressively resulted in better maintenance of luminous flux over life and in longer lives. There is no indication that the possibilities in these directions are exhausted. We can therefore look forward with confidence to continuous developments in the field of high pressure mercury vapour lamps for general lighting purposes as well as to continued development of special purpose high brightness mercury lamps.

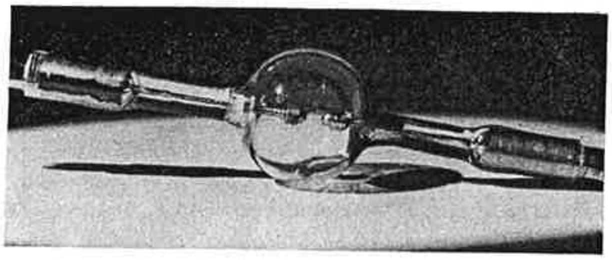

Figure 2. Air-cooled short arc mercury vapour lamp

The association of highly efficient phosphors with high pressure mercury vapour lamps has been practiced for many years. Developments are still taking place in this field and many improved phosphors capable of materially increasing the red and blue radiation from the mercury vapour lamp have been developed and their properties are being examined. Some of them have already found their way into mercury vapour lamps of improved colour and other characteristics. It is anticipated that there will be further material progress and that further new mercury vapour lamps with the colour modified both by the addition of other metals such as cadmium and zinc to the vapour phase and by the modifying effect of fluorescent powders on the inner surface of the outer bulb containing the discharge tube proper will emerge from the lamp research laboratories of the world. There is no indication of finality.

In view of the theoretical and practical developments in mercury vapour arcs as brightness sources, I propose to mention one or two points very briefly. The theoretical possibilities have been examined over a wide range of operating conditions and quite an extensive practical survey has been made of short arc high pressure air-cooled mercury vapour lamps from about 100 watts up to 50 kw loading. Brightnesses of the order of 1.5×10^5 candles per square centimetre have been obtained with a type M.E. lamp of 10 mm arc length loaded to 30 kw. With a similar lamp with the arc length reduced to 5 mm the brightness would exceed 4×10^5 candles per square centimetre which is more than twice the brightness of the sun's disc as viewed from the earth. It is necessary to emphasize that these are extreme conditions which lie somewhat outside the region of practical lamp engineering at the present time. They indicate, however, the remarkable flexibility of the mercury vapour arc as a light source and its potentialities. At the other extreme, a 100-watt M.E. lamp with a 1 mm arc can be made with a centre arc brightness of 5×10^4 candles per square centimetre, a remarkably high figure for so small a lamp.

As far as I am aware there is no alternative discharge lamp offering so many design possibilities as the high pressure mercury vapour arc. It has been established that both the centre brightness *Bc* and the arc width '*w*' at half *Bc* may be expressed by simple relationships in which the only terms involved are:

L = arc length in cm
V = arc voltage
A = arc current

These approximate relationships are:

$$Bc \text{ (stilbs)} = 3.0 \times \left(\frac{V}{L}\right)^{1.5} \times A^{0.7}$$

and

$$W \text{ (cms)} = \frac{1.4 \times A^{0.3}}{\left(\frac{V}{L}\right)^{0.5}}$$

There are associated properties, however, which restrict the field of usefulness of these very high brightness sources. A restriction in particular is the requirement that the high mercury vapour pressure condition can only be developed by operating the lamp bulb at a high and even wall temperature. The bulbs are therefore made from quartz and a time measured in minutes is required before full brightness is attained. While this time can be reduced to a very short order by bulb preheating and by other means, the inconveniences of such additional arrangements have so far prevented many large scale installations of high brightness air-cooled mercury vapour lamps. The applications which have been found in a variety of optical instruments and for which the lower wattages of air-cooled M.E. type lamps are eminently suitable, however, point the way to further developments in the future.

The Gas Arc.—An interesting newcomer to the field of high brightness sources is the high current density xenon or gas arc. This type of lamp has two principal advantages over its forerunner the high pressure mercury vapour arc, namely, that full light output is obtained immediately the arc is initiated and, secondly, that the gas arc gives light of daylight quality which thus makes it suitable for both the projection and the taking of colour photographs. A disadvantage is the relatively low arc voltage drop. There can be no doubt that very few of the possibilities and potentialities of the gas arc have been so far examined. It is therefore reasonable to expect that the field of usefulness of such lamps will be extended in the future.

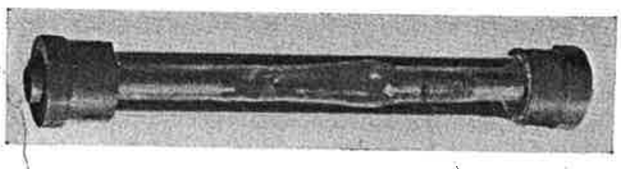

Figure 3. Original 5 kw gas arc lamp.

Fluorescent Lamps

In any continuous series of developments such as those which gave to the world the mains voltage fluorescent lamp in 1938, it is necessary at some stage to make decisions which rightly taken will influence the whole course of an industry for many years to come and it is a good thing if when that time arrives there are men with sufficient knowledge, experience and courage to make these decisions and abide by them.

By 1938 all the factors necessary for the production of successful mains voltage fluorescent lamps were known. Several suitable phosphors were available. Experience for a decade with alkaline earth oxide activated cathodes had shown the direction in which low current electrodes could be developed and the critical parameters of tube voltage and current were known from studies of the optimum conditions for the production of the ultraviolet resonance radiation from the excited mercury atom.

As a result, certain dimensions of fluorescent lamps were decided upon and while the range of lamps has increased since 1938 there has been no change in the principles which were then used to govern the decisions. There have been improvements — marked improvements — new phosphors have emerged, new phosphors are still being developed, electrodes have been improved with consequent improvement in lamp life and general lamp performance. Such changes as have occurred therefore, have been in quality and not in type. They have been evolutionary and not revolutionary. The fluorescent lamp has taken its place as one of the major lighting developments of the century. In cases of this sort we do well therefore, from time to time, to re-examine the position, to re-affirm the earlier decisions if an examination supports that attitude, or to determine alternatvely if there are new avenues which our preoccupation with the continued evolution of the present range of fluorescent lamps has so far prevented us from exploring.

It is not my purpose to suggest what these avenues might be. My thesis is directed as much to myself as it is to all other members of our Society. The fluorescent lamp has opened up such vast potentialities for good in the field of lighting that we would not be true to our heritage in the lighting world if we failed to re-examine from time to time

Figure 4. Interior view showing illumination of vertical surface.

the whole phenomena of fluorescence and our practical lamp forms, for while standardization is essential to the commercial engineer, absolute freedom is vital to the fertility of research.

Lighting

The remarks I have made in connection with lamp developments in the fluorescent field can be repeated with even greater force in connection with the application of light. From the oil lamps of the ancients, through the flickering flame of the gas burner, to that remarkable invention the incandescent gas mantle and on to the modern tungsten filament lamp, we see employed a principle which apparently enunciated that an artificial light source should be mounted in the region of the ceiling space and arranged to cast its light in a downward direction.

With the advent of the conception of brightness engineering, which after all is but a new description of a particular aspect of illuminating engineering, increased attention is being paid to the surface brightnesses produced by the lighting system and the lighting system is more and more being engineered to give desirable surface brightness and brightness ratios once the criteria for promoting efficient seeing and comfortable and pleasing lighting conditions have been determined. We are therefore branching away, I believe, from the continous line of development which I have referred to, along a new avenue and towards a new goal which I am convinced will result not only in more efficient illumination but in a greater appreciation by the general public of the material benefits which result from the proper application of artificial light. I can see no limit to the development possibilities in this field.

In this connection I would ask you for a moment to reflect on the visual scene under natural conditions. We tend to think of the sky as a source of overhead lighting and one object in very many lighting installations has been to simulate this conception by the regular placement of lighting fittings to produce a pattern of relatively bright sources over the entire ceiling areas. But if we look again at the visual scene outdoors we realize that in fact the illuminated area has the effect of the projection of a vertical surface at right angles to the plane of vision and that because of the curved surface of the sky enclosing the earth and the upward cut-off of the visual mechanism due to the bony structure of the forehead, we are not indeed conscious of overhead illumination at all, although it of course makes its appropriate contribution to the overall effect.

If now we turn our view indoors and contemplate the brightnesses of the surfaces inside a room provided with adequate daylighting from vertical windows in the wall surfaces, we find that it is the walls and not the ceiling which provides the bulk of the reflected light. The illumination from the ceiling is of a secondary order and the ceiling brightness derives its intensity from the walls, the floor areas and the room contents, if those are sufficiently light to contribute materially to the diffusion of the incident flux.

It therefore seems to me that our thinking should be directed towards a more positive approach to the production of illuminated vertical wall surfaces in those cases where the room geometry allows. We need to stress more the horizontal component of our illumination systems rather than the vertical component. For such purposes one could hardly wish for a more desirable light source form than that of the fluorescent lamp. Such experiments as I have personally been concerned with in this type of development have led to most pleasing lighting effects. Not only is the result of producing room illumination by the illumination of vertical surfaces efficient from the point of view of reducing objectionable shadows, it is also pleasing in giving a sense of space and openness to the illuminated interior which is surely a desirable objective for the illuminating engineer. By the production of adequate vertical surface illumination, ease of seeing is promoted and at the same time the lighting has the valuable aesthetic quality of producing good modelling of form and feature. I realize that in the Americas, the approach to this problem of home lighting has evolved in the direction of the extensive use of table and floor standard lamps. But I am unrepentant in advocating the radically different approach illustrated.

As we return to the outdoor scene and re-stud

Figure 5. Outdoor scene showing partial silhouette and brightness contrast. Distant objects are seen in partial silhouette whereas near objects are seen as a result of their own detail in brightness and colour contrast.

it with the thought in mind that the major sky area appears to consist of an illuminated vertical surface, we realize that distant objects are seen in partial silhouette whereas near objects are seen as a result of their own detail in brightness and colour contrast. It is this property of the outdoor scene which gives to it its character and beauty and which has become so familiar to us as to pass almost unobserved. We do not reproduce this effect or simulate its beauty by merely directing light from ceiling-mounted lighting fittings or from standard lamps or isolated points. It is only when we realize the importance of the vertical surface, and indeed its dominating influence as a low brightness source, that our illuminating engineering comes truly into its own. I believe that this is a factor which has long been recognized in connection with theatre stage lighting. The transformation from the gloomy effects produced by overhead lights to the modern practice of using a very high component of horizontal illumination results in the vertical surface illumination characteristic of the best stage lighting practice and to the charm and beauty of the lighted theatre scene.

Outdoor Illumination

The most important single outdoor lighting application is that of street lighting. It is an aspect of illuminating engineering which is of the first importance not only on account of road safety but also because good public lighting materially increases the amenity aspects of our towns and cities at night.

We have moved a considerable way from the conception that isolated points of light constitute good lighting although it should be noted that in many parts of the world little practical progress has been made from this early conception except in isolated instances. In the best practice at the present time as much as possible of the available luminous flux is directed on to the road surface at angles which will produce in the eye of either the pedestrian or the driver of the motor vehicle a luminous background against which objects are revealed in silhouette. In this way it is considered that the best utilization of the power available for street lighting can be effected. We have thus moved through three principal stages in the history of man's endeavours to conquer the night in his nocturnal wanderings.

The first stage was the one in which torches or other illuminants were carried by the travellers themselves to reveal otherwise hidden pitfalls in their path. The second stage, which still exists very largely in many parts of the world, is the one in which relatively isolated sources of light produce pools of illumination in otherwise dark roadways. The third stage represented by the best practice is the one in which the highway is lighted in such a way as to produce in the eye of the observer a brightness pattern sufficient to allow the safe movement of traffic even at high speeds. I am not now concerned with the various means by which this desirable objective is achieved.

It seems to me that there is a fourth possibility and one which may come within the realms of practical politics in the future due to the advent of high-power highly efficient light sources. It is the possibility of generally illuminating a town from light sources mounted at much greater heights than are commonly used today. Already in Great Britain one or two interesting preliminary experiments have been carried out. Under conditions in which the light source is outside the normal field of view of the observer, good visibility results from much lower illumination levels than are necessary where the eye has to contend not only with the brightness of the road surface, but also with the brightness of the sources producing the road illumination. This is of course a phenomena well known to those who have travelled in open country by clear moon light only. It is an aspect which I commend for further study on a practical scale.

Within the lifetime of most of us, the mounting height of lamps used for public lighting has been increased from 10 feet or so, up to about 25 feet, which is a figure used in Great Britain for Class A public lighting installations. The benefits which resulted from this change were most noteworthy in the production of better and safer road lighting conditions. There is, in the author's view, however, nothing sacred about the decision to use a 25-foot or 30-foot lantern mounting height. The policy was no doubt dictated by the practical difficulties of mounting at materially greater heights. With much greater heights for the light sources the spacing between sources would be increased very materially and much higher wattage lamps could be utilized at each point.

I will conclude, therefore, by making the plea that particularly where new public lighting is to be installed and especially in connection with the planning of new towns or urban areas, consideration should be given to the concept of general town illumination by light sources of high power, mounted at considerably greater heights than is common practice today and that the town planning itself should take into account of the lighting needs just as it has learned to take account of the needs for such other essential matters as drainage, water supply, electricity and all those other public amenities which we accept today as of right. The public has the right to the best lighting that we can at present provide and to all the developments which await us in the future. We are on the threshold, I believe, of a new era in the application of artificial light and of a new impetus in the furtherance of these broad humanitarian principles which underlie and should stimulate the work of every member of our Society.

I appreciate the opportunity which has been afforded to me of expressing my mature convictions on a number of matters affecting the future of lamps and lighting. I have spoken of what I truly believe to be the possibilities which lie immediately ahead of us. They are possibilities evolving from the practices of the present day. Beyond that, no man can say.

DISCUSSION

WARD HARRISON*: It is indeed a pleasant thing to listen to a really informing paper by one of our good friends, and a distinguished authority, from overseas, and not only do such interchanges make their contribution, large or small, to closer relations with other lands but, also as in this case we have an opportunity to learn much more than by just continuing to listen to ourselves talking to ourselves.

Dr. Aldington's statement that we may be missing new avenues in incandescent lamp development by retreading well worn paths is certainly an intriguing one. For example, has the Nernst-glower principle really been sufficiently re-examined? Dr. Aldington reminds us too that the maximum obtainable gas pressure is generally desirable in a tungsten lamp but is kept down by the need for pipping off the exhaust stem. I would like to ask how much would be gained by doubling the customary pressure. It seems to me that the industry has surmounted greater problems than this one of pipping off the stem.

Dr. Aldington mentions that no alternative light source seems to him to offer so many possibilities as the high pressure mercury. This is certainly true for special applications but I would like to ask whether for general lighting the efficiencies obtainable are likely to exceed that of the fluorescent lamp.

The author makes the most effective case that I have heard for having the predominate light flux horizontal in direction so as to accent vertical rather than horizontal surfaces. I rather question the success of this proposal as applied to strictly utilitarian lighting but certainly from the aesthetic view there is much in its favor. For example, can you visualize a room with an open fire suspended in a basket just beneath the ceiling with, of course, a flue directly above it? Such a fire would retain the interest of the living flame but it would lose much of the charm of our present fireplaces which is due, in large measure, to the direction of light and the long, interesting shadows which are cast.

I should like to propose that at the conclusion of the discussion a formal vote of thanks be given to Dr. Aldington for his most interesting paper.

M. N. WATERMAN**: Dr. Aldington's plea, in his very stimulating paper, for a more positive approach to illuminated vertical wall surfaces is congenial to what I noted in a very brief visit to England and the Continent this spring. I noted a strong interest in what I would call the "acceptability" of lighting as a criterion in addition to simple conformity to certain specifications as to footcandles and brightness ratios. By "acceptability" I mean an effect which is comfortable in the sense of giving aesthetic pleasure in addition to lack of pain. For example, many of you are familiar with the studies by Mr. Kalff in Holland of the most acceptable pattern of color and brightness on a wall panel in front of a jury of observers. As I recall it, the observers are given opportunity to adjust both color and brightness of surroundings to a visual task before them and to vote for their preference from the standpoint of their

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feeling of well being. In Europe I saw installations of the so-called "cut-off" system of street lighting in which the street lights are shielded to a much lower angle below the horizontal than is usual in the United States. While I realize that this "cut-off" lighting is more costly and less efficient in an engineering sense, nevertheless I found it very comfortable and pleasing. I think this approach to street lighting is another instance of experimentation toward comfort in the meaning I have described.

I, for one, am grateful to Dr. Aldington for the recommendation he has given us for more active thought about the lighting of vertical surfaces for greater comfort and pleasure.

R. G. SLAUER*: It is almost impossible to discuss objectively a philosophical paper such as Dr. Aldington's — if one really knew the trend of future scientific progress, he would be a very important man indeed. However, I have on specific comment to make — the suggestion that we who spend our time in applying light share with Dr. Aldington and other laboratories the burden of future lighting effectiveness. Efficiency is in some cases not as important as application utilization. This seems to be recognized by the author in that the second half of the paper does not mention efficiency at all while the first half is based on it.

Dr. Aldington does not paint too hopeful a picture of the future of incandescent lamps. Yet so many billions are in use that even small increments in efficiency are important. England's utilization of 230 volts instead of 115 is a discarding of over 10 per cent efficiency, more than the overall development advance in 15 years. If we in the U. S. should suddenly shift to 230 volts, it would cost us at least 70 million dollars per year in power costs alone. One is constrained to ask if progress can be isolated from practices which have grown around the product.

The thought is emphasized by an incandescent-fluorescent comparison. The latter is only three times as efficient — less if ballast losses are considered. But in utilization efficiency it is 5-10 times as effective. Here one has the feeling that, relatively at least, the goal of better lighting through improved patterns of brightness, through spectral control, and so on, makes lamp efficiency improvement only half of a team.

New light sources such as the panelescent lamp also may be considered as an example of this thinking. For this source, incandescent efficiencies seem a terrific challenge, fluorescent efficiencies extremely remote. But its inherent characteristic of a large area source suggests that the direct production of 25-100 footlamberts may be a better way of reaching certain illumination goals than the modification of 2000- and 100,000-footlambert sources.

We are happy that the laboratories of England are working strenuously toward newer and better light sources. It gives us all a feeling that the limits of our profession lie wholly within our own power; as we learn more and more about what the eye needs and how, we will have the source tools for our goals.

JAMES M. MCCULLOCH**: Would you please enlarge a bit upon whether your suggestion for the lighting of vertical surfaces is offered in lieu of, or in addition to, the lighting of horizontal surfaces? I realize that you will probably want to make a distinction between various applications.

None of the several books on stage lighting with which I am familiar advocate specifically the lighting of vertical surfaces. They are, in fact, much more likely to emphasize the avoidance of lighting the back wall. While it is true that the audience sees the vertical surfaces of the actors' face and figure, I believe that the actors are made more visible in space by lighting from a diagonal, rather than by horizontal lighting flux. Might it not be well to emphasize an increase in flux other than vertical, allowing spilling on vertical surfaces, rather than emphasizing the lighting of vertical surfaces which might be interpreted by many as recommending the use of horizontal flux?

I thoroughly enjoyed this address and thank the author for it.

J. N. ALDINGTON*: May I first of all express the pleasure which has been mine in being asked to address this Conference. I have enjoyed every minute of it and particularly the contributions made to the discussion.

Many of the comments could no doubt be debated at considerable length with benefit to us all if time and space permitted. I will confine myself under the circumstances to dealing with the queries that have been raised.

I was most interested in the comments of Dr. Ward Harrison. A gain of the order of 10 per cent would be possible if we were to double the customary gas pressure in a gas-filled lamp. There is, however, an upper limit to the pressure which could be allowed as obviously a lamp with a cold filling pressure greater than 1 atmosphere would have an explosive potential when accidentally broken which would increase with increased pressure above that point.

With regard to Dr. Harrison's question on the high pressure mercury lamp, it was my intention to relate the design possibilities with this class of lamp to alternative plain discharge lamps and it occurs to me from the question that I must not have made this point clear. However, in reply to the question relating mercury lamp possibilities to those of the fluorescent lamp I am of the opinion that for general lighting mercury lamp efficiencies while of the same order are not likely to exceed fluorescent lamp efficiencies. For comparable wattage lamps they are likely to remain somewhat lower.

I am very grateful for the support of both Dr. Harrison and Mr. Marshall Waterman for my plea for a more positive approach to the accenting of vertical wall surfaces in appropriate surroundings.

Mr. Waterman mentions the European work on the acceptability of lighting systems. We in Europe, of course, for street lighting have what we consider very acceptable systems of street lighting employing the two extremes of cut-off on the one hand and non-cut-off on the other. The general thought on street lighting in your country, if I have understood discussions with your engineers aright, is to work somewhere between these two systems. Of one thing I am sure, we shall all benefit by the interplay and interchange of ideas on these matters between members of your Society and the sister Society in England.

Mr. Slauer's comment on the use in England of 230-volt supply instead of the 115-volt used in your country misses I feel an important governing factor and that is the cost of the transmission lines and energy convertors for the lower voltage. This is such an overriding factor that it has recently been decided that the final objective voltage in Great Britain shall be 240 volts when it is ultimately found pos-

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*Author.

sible to have a standard voltage throughout the country. The choice of 240 rather than 230 was I believe in part governed by the further saving in copper obtained by choice of the higher voltage. While therefore I appreciate Mr. Slauer's point of view regarding lamp efficiency, in our view the other considerations far outweigh the one he has brought up.

The utilization factor that he mentions is to my mind much more important, so often is the improved efficiency produced by years of work on lamp development brought to nought by poor utilization!

Mr. McCulloch has drawn attention to a lack of clarity in my presentation which came from the need to make a very broad survey in the short delivery time which was required by the organization of your Conference. Most certainly one has to distinguish between various applications in considering the relative weight to be attached to the vertical component of illumination and the horizontal. This point is of course brought out also in Dr. Harrison's contribution. What I have pointed out is that undue emphasis has been placed historically on the downward component of illumination presumably due to the consideration that the sky was overhead and therefore produced downward illumination. I have sought to show that it is the horizontal component of the sky's illumination which is by far the most important in producing the illuminated visual scene both outdoors and for the daylighting of interiors.

In general the practical factors involved in producing adequate illumination of vertical surfaces will ensure the simultaneous illumination of the horizontal surface — at least such has been by experience and I illustrated this point by mentioning stage lighting. I profess no special knowledge of this field. I would remind ourselves, however, that the quality of the visual scene on the theatre stage as viewed from the audience results from the colour and brightness contrasts produced by the horizontal component of whatever illumination is used. I entirely agree with Mr. McCulloch's statement of the case in regard to stage lighting that it would be well to emphasize and increase any flux other than vertical. This is of course a special example of the general case which I have sought to present to your Conference.