Reprinted from LIGHT AND LIGHTING,
Vol. XLIV, No. 9, August, 1951

Electric Lamps—A Decade of Progress

by

J. N. ALDINGTON, B.Sc., Ph.D., F.R.I.C., F.Inst.P., A.M.I.E.E., F.I.E.S.

Director of Research, Siemens Electric Lamps and Supplies, Ltd.

Electric Lamps—
A Decade of Progress

This article reviews the development of lighting with special regard to the contributions made by British scientists.

By J. N. ALDINGTON,
B.Sc., Ph.D., F.R.I.C., F.Inst.P., A.M.I.E.E., F.I.E.S.*

There have been many misinterpretations of the meaning and purpose of the Festival of Britain. Whatever else is intended it does, however, seem certain that at this time the British people should pause a moment to look at the broad picture of their achievements in the varied fields of science, technology, and industrial design.

A visit to the South Bank Exhibition will teach us how innumerable are the facets through which one can glimpse the progress that has been made or the diversity of contributions which together comprise the whole story of British achievement. It is, therefore, not inappropriate that we should use the occasion of the Festival to record some aspects of light source developments to which British scientists have contributed in some measure, either great or small.

Development of the tiny lamps which enable the surgeon to examine deep into the human body or of the powerful sources which produce the lighthouse beam has not occurred by chance, but is the result of years of patient work. To trace the history of even a single development in the ever progressing field of lamp research would require more space than can be allotted to the present article—to do it justice would require a book. It is, therefore, intended to indicate only the broad lines along which progress has been made and success achieved in the constant search for new and better sources of light. This search stems and flows from the desire to render ever more efficient the process of conversion of electrical energy into light.

In surveying the course of development over the last decade and the remarkable progress which has been made in certain fields we can trace the influence of both pure and applied research. We can see how from time to time advantage has been taken of the general advance of knowledge to divert the course of an investigation and to enable a forward step to be made. We can see, too, how investigations into the properties of transparent materials such as glass and quartz, refractory metals such as molybdenum and tungsten, and the rare gases such as krypton and xenon have contributed to the evolutionary progress from which have emerged the many different forms of electric lamp upon which the industrial, domestic, and social life of our country so much depends.

Perhaps the most elementary way of transforming electrical energy into light is to make use of the heating effect of an electric current as it passes through a metallic conductor. This is the basis of the incandescent tungsten filament lamp. While it is true that there are several thousand different forms of tungsten filament lamp, common to them all are certain features such as the filament itself, which is always made from the element tungsten, the filament supports, which are practically always made from thin molybdenum wire, and the various types of glass used for the internal construction of the lamp and for its outer envelope. Nowadays most lamps, after exhaustion, are filled with an inert gas, that is to say, with a gas which does not chemically react with tungsten even at the high temperature at which the filament is caused to operate.

It is true that no major development in the field of incandescent tungsten filament

*Director of Research, Siemens Electric Lamps and Supplies, Ltd.

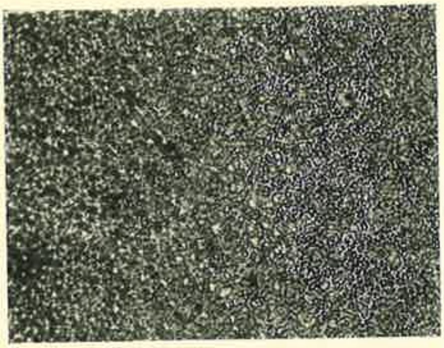

Fig. 1. Close-up of etched pits on the inner surface of a pearl lamp.

lamps has occurred during the past 10 years. It must not be assumed, however, that there has not been most active development and research into many aspects of lamp design and manufacture.

Miner's Lamp Bulbs

Noteworthy contributions have been made by British lamp designers to the present range of miner's lamp bulbs. Two main types of portable lamp are used by the coal-miner, both of which require special highly efficient electric lamp bulbs. In the so-called cap lamp the bulb is mounted in a headpiece worn on the miner's cap, and in the result a beam of light is produced directly in front of the miner and illuminates his particular working area. The miner's hand lamp, on the other hand, gives an all-round flood of light for general purposes. Both of these lamp bulbs are powered by a small portable battery, which may be either of the lead-acid or nickel-alkaline type. Obviously any improvement which enables the production of more light for a given consumption of power from the portable battery would be a step forward of major importance.

A notable advance in this direction was made by the large-scale introduction of krypton-filled miners' bulbs developed in the lamp research laboratories of this country. Approximately 20 per cent. more light is produced from a krypton-filled bulb than from the earlier argon-filled types. The development was made prior to 1939, but the war hindered progress, although many krypton bulbs were in use when war broke out. Since hostilities ended, however, new types of krypton-filled bulbs have been developed and a substantial contribution has been made to assisting the miner in his difficult task.

To bring about this result industrial plant had to be developed to extract krypton from the atmosphere in which it is present to the extent of only five parts in 1,000,000, and new techniques of lamp manufacture had to be evolved to enable the employment of smaller lamp bulbs and brighter filaments. It is tempting to digress and write of the work on air liquefaction and fractional distillation which enabled adequate quantities of krypton to be made available for this purpose, but this is a subject beyond the scope of the present article.

Silica-coated Lamps

When the gasfilled lamp was first developed it was soon appreciated that particularly for lighting purposes in which the lamp was required to operate within the field of view of the observer means should be sought to reduce the brightness of the source without of course reducing the luminous output. It is not possible to achieve this result in entirety, but the introduction of the pearl or inside-frosted lamp some 20 years or so ago was a material contribution to this end. Recently a further step forward of considerable importance has been effected by the development of lamps in which a very high degree of diffusion was obtained with low light absorption by the deposit of finely divided silica on to the inner surface of the lamp bulb.

It is an obvious truism that the required degree of diffusion to make the lamp bulb the virtual light source instead of the filament within the bulb could be obtained by coating the bulb with a white material. It is a matter of considerable difficulty, however, to produce and apply a white material in such a way that virtually the whole of the luminous output of the filament is emitted from the bulb surface. In the case of the pearl lamp, which provided a partial solution to this problem, etched pits were produced on the inner surface of the bulb by special chemical processes and these pits were shaped to be of lenticular form as shown in Fig. 1. The degree of light scattering was, however, governed by the average size of the pits. This grain size was itself related both to the chemical composition of the glass bulb and to the nature and composition of the chemical fluids used to roughen the surface. To achieve a higher degree of diffusion it was obviously necessary to employ an entirely different technique.

In the silica coated lamps which are now available use is made of a technique which allows of the deposit on the inner surface of the lamp bulb, prior to lamp manufacture, of a fume of chemically produced extremely finely divided silica. The high degree of transparency of the individual particles, notwithstanding their extremely small size, allows of at least 95 per cent. of the light emitted from the filament to pass through the bulb which then glows evenly and becomes the virtual light source. It is interesting to record that this development, like that of the pearl lamp, has been made effective in most of the countries producing incandescent tungsten filament lamps while a great deal of the pioneer work originated from our American cousins.

Projection Lamps

In the field of projection lamps increased attention has been paid to the more accurate control of the emitted light by the optical system for which it is designed. An illustration of this is the British pre-focus headlamp. A number of different types of these headlamp bulbs are now available, but they have the common feature that the filament of each bulb is accurately pre-focussed in relation to the lamp cap. The lamp cap carries a disc which locks into a seating on the headlamp of the car thereby ensuring automatically the correct relationship of the lamp filament to the reflector system. This development is an undoubted contribution to road safety as the light from the car headlamp is directed at the proper angle and with the correct beam candle power on to the road surface.

Discharge Lamps

It is appropriate at this point to pay tribute to the co-operation which exists in this as in many other branches of human endeavour and to the way in which as a result of that co-operation when an advance is made its benefits are rapidly disseminated in every country. Nowhere has this been more true than in the development of the various forms of electric discharge lamp, with which may be included the low and high pressure mercury vapour lamps, the sodium lamp, rare gas discharge lamps of various forms and the fluorescent lamp.

In this connection it is surely of interest to remember that the first electric discharge

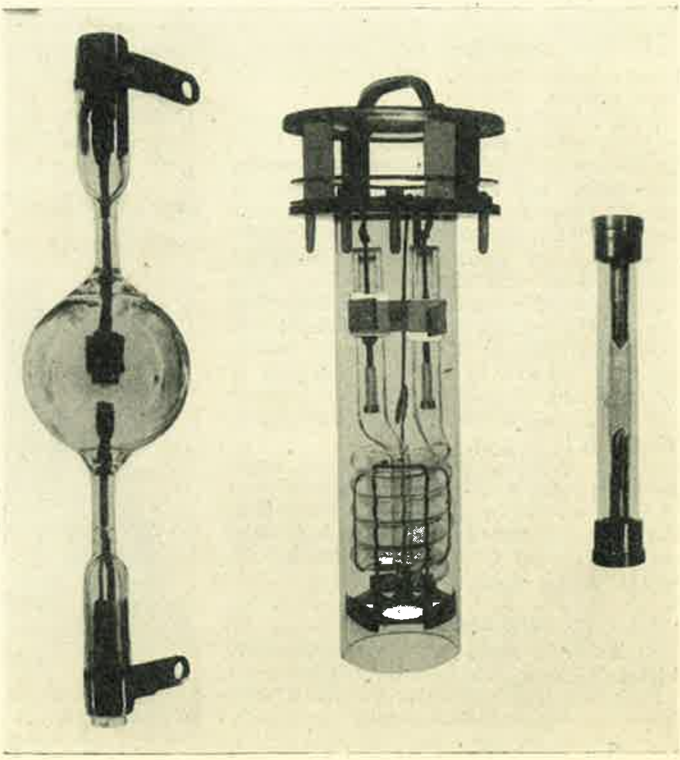

Fig. 2. Comparison of a 10-kw. high-pressure mercury compact source lamp with a 5-w. water-cooled gas arc and a xenon-filled flash tube.

arc was produced by Davy at the Royal Institution when he touched together two pieces of charcoal connected to a powerful battery. Davy's own notes read as follows:

"The charcoal became ignited to whiteness and by withdrawing the points from each other a constant discharge took place through the heated air, in a space at least equal to four inches, producing a most brilliant ascending arch of light, broad and conical in form in the middle."

Modern forms of the carbon arc still find important uses both in war and peace. They are still the principal light sources employed for motion-picture production and projection. The carbon arc is however, mentioned in this review primarily because it was the forerunner of the electric discharge lamp.

Parallel with developments in other light sources, investigations into the properties of glow and arc discharges through various gases and metallic vapours are still being vigorously pursued. To-day in Great Britain alone there are several major groups of research workers continuously engaged in the study of electric discharge phenomena. Their discoveries have not only enriched contemporary science and furthered man's knowledge of the structure of matter, but they have produced new types of lamps of great importance in the search for improved light sources.

The story of the high-pressure mercury vapour and the sodium lamp belongs to an earlier period than the one at present being considered, but their importance can be judged from the effect they have had on street lighting techniques and by the principal uses for which they are employed, mainly street and highway lighting. Discoveries made in the course of their development led to the high-brightness, high-pressure mercury discharge lamp and its colour-modified variants in which an amalgam of mercury and cadmium with zinc produces the vapour within which the high brightness discharge is formed.

These so-called compact source lamps have been used as photographic light sources in films studios in the last few years both for black and white and for Technicolor film production, and Great Britain has led the world in this field.

New Light Sources

It is felt by some that the high-pressure, high-brightness mercury vapour lamp is a transitional type and that new forms with improved characteristics will eventually emerge from the lamp research laboratories. It is too early to say whether this prediction will prove true, but it is not too early to record that the investigations which led to the achievement of this type of lamp with its pure quartz envelope and its high-current direct metallic seals through quartz has opened up the way to several new and interesting types of light source.

In Fig. 2 a 10-kw. high-pressure mercury compact source lamp is shown compared with a 5-kw. water-cooled gas arc and a xenon-filled flash-tube capable of dissipating 16 kw. seconds in a single flash. In the development of these rare gas lamps use was made of the earlier pioneer work on high-pressure metallic discharges and particularly the high-current hermetic seals through quartz.

Of the two the xenon flash tube was historically the earliest. It was brought to fruition as a high-power light source during the war years for military purposes, and has since been produced in a variety of forms for commercial and industrial use. A particularly interesting form is that shown in Fig. 3 in which the flash tube proper, consisting of a quartz tube fitted with special electrodes, is mounted at the focus of an internally mirrored glass bulb of parabolic contour. This tube has been designed to operate in conjunction with apparatus which will produce a sequence of flashes at the rate of up to 4,000 per second, the duration of each flash being of the order of only five millionths of a second.

With the aid of this powerful investigatory tool not only has it been found possible to examine photographically rapidly

Fig. 3. Showing a flash tube mounted at the focus of an internally mirrored glass bulb.

Fig. 4. Example of high-speed photography by use of the Schlieren technique, showing convection currents rising from the warmth of the hand.

occurring events such as the cavitation phenomena exhibited by high-speed moving parts in water, but such phenomena as the convection currents rising in the atmosphere from the warmth of the hand can be portrayed by the use of Schlieren techniques. (See Fig. 4.)

The continuously burning xenon arc has been investigated by workers on the continent of Europe, in America, and in this country. The British contributions have included the provision of practical light sources such as the 5-kw. water-cooled gas arc, a 1,000-watt air-cooled xenon arc, and experimentally a number of high brightness types. It has been found that under certain conditions the high current density discharge through xenon can result in a source giving white light of daylight quality and at the relatively high efficiency of 25 to 35 lm/w. Valuable properties of all these xenon lamps are their ability to give full light output immediately the arc is ignited, and the fact that visible light has a spectral distribution not dissimilar from that of daylight.

The xenon arc is also a powerful source of infra red radiation as well as a valuable radiator of a continuous spectrum in the ultra violet region. It is as yet too early to predict what further forms of rare gas discharge lamp will eventually emerge, but there can be no doubt that British lamp research engineers are in the forefront of developments in this field.

The position with regard to fluorescent lamp developments is perhaps a little more definite. From the engineering aspect the fluorescent lamp is a well defined entity and is now available in a range of sizes which cover virtually every lighting need for which its properties make it suitable.

Fluorescent Lamps

It is difficult to overestimate the value of British contributions in a field in which so much is owed to the pioneer contributions of British scientists. One of the most outstanding aspects, however, is probably that of phosphor development. Many of the phosphors used in the first fluorescent lamps were the products of British research and the calcium halo-phosphate powders which were developed in Great Britain and introduced into fluorescent lamps some three or four years ago are now being used by manufacturers in many other countries. The life of the fluorescent lamp has been constantly improved by developments in both manufacturing techniques and in the design of electrode systems and circuits. It is probable that the service life of the fluorescent lamp to-day is three or more times the life of the first lamps which were marketed. In this connection it should be emphasised that in considering the life of any electric discharge lamp, either of the pure discharge type or of the fluorescent type, account must be taken of the lumen maintenance of the source. In this way the fluorescent lamp is sharply distinguished from the tungsten filament lamp. In the latter case the life is determined by the operating temperature of the filament, but the life of the fluorescent lamp is more appropriately considered as related to its lumen maintenance and to its particular usage. In other words, the average life of a group of fluorescent lamps must be assessed in relation to the efficiency of the fluorescent lighting system as a whole.

With this in mind, developments have been made to improve the uniformity of fluorescent lamps and their lumen maintenance. The calcium halo-phosphate phospor mentioned above has proved particularly useful in this respect, as it has inherently a higher maintenance than the mixed powders hitherto used. It is probable that in the future development will be along the lines of still further improvements in the maintenance of light output over life and in the development of lamps with improved colour rendition.

British lamps makers have already made major contributions in this field and have progressively introduced new lamps such as the Natural and Mellow types as occasion demanded, and they are playing a major part in international discussions in connection with the specification and measurement of the colour and colour rendering properties of light sources.

In addition to the various standard types of fluorescent lamp of white or near white colours, the range has been recently increased by the introduction of four new fluorescent lamps with relatively saturated colours, namely, blue, green, yellow and red. It is interesting to note in conclusion the way in which these highly coloured yet efficient lamps have been used to produce special display effects in connection with the celebrations of the Festival of Britain.

ARGUS PRESS, LTD., London, E.C.4.—5375