ENGINEERING SUPPLEMENT

TO THE

SIEMENS MAGAZINE

No. 201 FEBRUARY, 1942

TECHNICAL DEVELOPMENTS AND RESEARCH AT PRESTON LAMP WORKS

Introduction

A number of earlier *Engineering Supplements* have given some indication of the work carried out at Preston Works during recent years on the development of various types of electric discharge lamps, but no attempt has been made previously to review the wider field of technical developments and research in both filament lamps and discharge lamps.

The general trend in the lamp industry during recent years has been towards the production of more efficient light sources, and greater attention to the idea of fitness for purpose in the design of the ever growing range of tungsten filament and electric discharge lamps. Simultaneously, there has been much activity on the illuminating engineering side so that the newer light sources are more effectively used. The Preston Lamp Works is concerned with the actual light sources, but frequently has to face problems of design arising from developments in illuminating engineering practice. There are also a number of devices akin to lamps which may be regarded as off-shoots of the lamp making industry.

In order to provide some perspective for the discussion of particular technical developments, it may be helpful to indicate the main features of the organisation at Preston Works, which are :—

(*a*) Tungsten wire manufacture.
(*b*) Filament coiling.
(*c*) Joining of leading-in wires.
(*d*) Lamp manufacture.
  (i) Vacuum and gasfilled lamps up to 150 watts.
  (ii) Large gasfilled lamps 200-1500 watts.
  (iii) Motor car, bus, train, miners, signalling, and other small lamps for special purposes.
  (iv) Projector lamps.
  (v) Electric discharge lamps.
  (vi) Special devices, such as Vacuum Protectors, Impulse Valves, Ballast Resistors, etc.

The Laboratory has responsibilities in connection with every section as regards the control of processes, the maintenance of a high standard of quality, and the carrying out of a continuous policy of improvement. The research side of the Laboratory has been progressively developed over recent years with specific objectives in mind, so that the achievement of desired results and the improvement of existing methods are its main preoccupations. It naturally follows that the emphasis shifts from one section to another according to the needs of the time.

A few years ago the Laboratory was largely concerned with making improvements in the non-sag properties of tungsten wire, the elucidation of problems relating to lamp exhaust, and the development of the technique of manufacturing coiled-coil lamps having efficiencies 10 per cent. to 20 per cent. better than those of the old single-coil lamps. The Company is also justly proud of its high reputation for the performance of its "rough service" lamps which success is largely due to research on tungsten manufacture. Although these developments belong to an earlier phase and have reached a point at which outstanding further advances cannot be expected, continuous efforts are necessary in order to maintain the standard. The omission of specific reference to some sections must be interpreted in this light.

Tungsten Production

During the past year the production of tungsten powder has been reorganised, mainly with the object of increasing output owing to the very much greater demands for heavy sizes of tungsten wire used in projector lamp and discharge lamp manufacture.

Preparation of Internal Lamp Mirrors

Certain types of battery operated lamps and also some very large projector lamps require the provision of a spherical mirror, the function of which is to increase the amount of light in a given direction by superimposing on the filament an image of itself. This result is very conveniently achieved by placing a concentrated filament at the centre of a spherical bulb which is partly mirrored. Hitherto it has been general practice to manufacture the lamps in clear bulbs and then to silver the bulb externally over the required area. Obviously, such mirrors are liable to become damaged in use with resultant falling off in efficiency. Recently a technique has been developed for producing internal mirrors which give a higher reflecting power than externally silvered mirrors, and also have the advantage that once the lamps have been made the mirrors are not liable to

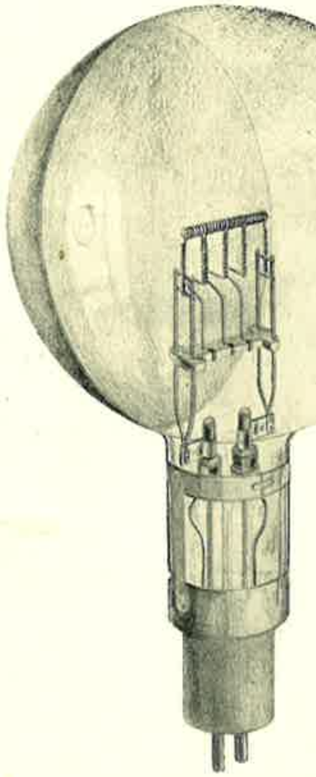


Fig. 1. 60 Volt, 5.8 kW. Lamp.

damage by mishandling of the lamps. Provided the necessary precautions are observed in manufacture, the mirrors retain a very high reflection factor throughout the life of the lamps. As one example of the way in which this technique has been applied there may be taken the 60 volt 5·8 kW. lamps used for mobile floodlights. The lamp is illustrated in Fig. 1 and incorporates a number of interesting features apart from the mirror, these will be referred to later.

The mirror is produced on the bulb before lamp assembly. In brief, the process consists in washing and drying the bulb so as to obtain a perfectly clean internal surface, and then evaporating in high vacuo sufficient aluminium to form an opaque mirror of high reflectivity on the bulb surface. The shape and size of the mirror is determined by a dissolving process that completely removes the aluminium deposit from those portions of the bulb which require to be clear. By this method internal mirrors, inclined at any angle to the bulb axis, may be produced in lamp bulbs of a whole range of sizes according to the purpose for which the final lamp is intended. In Fig. 1 it will be seen that the mirror covers the major portion of one side of the bulb. It actually subtends a solid angle of 160° to the filament centre.

The same technique is applied to certain small lamps required for special purposes.

Projector Lamp Filament Design

Improvements have been effected in the filaments for projector lamps, attention being particularly directed to filament design and treatment so as to obtain the maximum stability and, therefore, continued effectiveness of the light source during the life of the lamp. The result of this work will be exemplified by a few typical examples with special reference to improvements in manufacturing procedure.

Projector Lamps with Stable Filament Sections. A word of explanation is perhaps necessary in introducing this subject. In most types of tungsten lamps the filament is supported at one or more points in addition to the electrode current carrying leads, by hooks or loops of refractory metal wire, such as molybdenum or tungsten. These supports reduce filament sag during life, and also in the case of lamps with long thin filaments position the latter correctly and resist the effects of normal vibration and transit shock. Improvements have been effected in the stability of Siemens tungsten wire and in the filaments made therefrom to such an extent that in some types of projector lamps the number of supports which are necessary can be reduced, and in other cases dispensed with altogether. The 24 volt 1,000 watt tubular projector lamp is a typical example. Formerly, the filament of this lamp was held by three supports in addition to the electrode connections, while in the new design illustrated in Fig. 2 no supports other than the electrodes are used. The filament remains accurately positioned during the life of the lamp.

An extension of this principle led to the design of an improved 100 volt 5 kW. aerodrome floodlight lamp. Earlier designs employed two grid shaped filaments mounted parallel to one another, and giving a projected area of 9 sq. cm. In the improved design, self-supporting sections of coiled-coil filament are used as units for building up a complete filament which has a projected area of only 5 sq. cm. The efficiency and light output

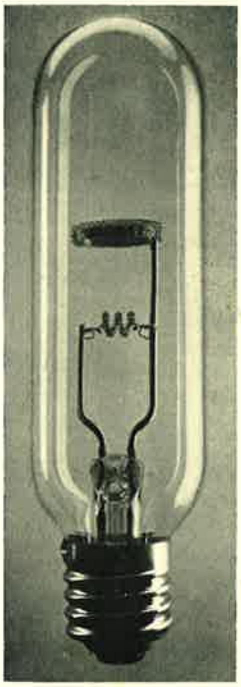


Fig. 2. 24 Volt, 1,000 Watt Tubular Projector Lamp.

are the same as for the double grid, but the beam candle power is greatly increased as it rises inversely to the projected area of the filament.

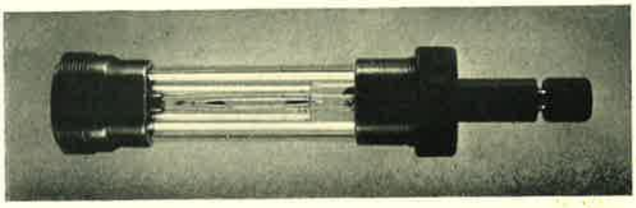
Another interesting new lamp which has recently been developed is the 60 volt 5·8 kW. projector lamp which was referred to above in the section on internal mirrors. It will have been seen from Fig. 1 that the filament is built up from several self-supporting sections, actually four in number. The usual filament supporting arrangements are unnecessary and have been dispensed with, the four filament units being assembled together by arc welding in a protective atmosphere of nitrogen and hydrogen mixture. The current carrying leads of heavy section nickel are also arc welded to the filament connections. A special type of lamp foot was designed for this lamp and consists of two copper thimbles directly sealed into glass tubes assembled on to a flanged tube of much larger diameter, this flanged tube in turn being sealed into the neck of the bulb. The filament structure is carried from electrodes bolted on to the copper thimbles.

HORIZON TYPE LAMPS. The general design of a horizon lamp consists of a line filament in the form of a single helix which is mounted along the axis of a tubular bulb. To obtain the maximum utilization from the floodlight fittings in which these lamps are employed the filament should be, both initially and throughout life, perfectly straight. For use with the most modern type of mirror it is also desirable to have a filament of the maximum possible brightness. To meet these needs the Company has produced a new design of horizon lamp in which, by paying attention to filament data and heat treatment, greater stability over life has been achieved, with resultant improvement in the maintenance of beam candle power from the fitting. A further advance has been the fitting of a collector grid situated vertically above the filament. This grid, which consists of nickel gauze, is raised to a dull red heat by the high temperature convection stream from the filament. It has the effect of allowing the gas with which the lamp is filled to pass through in the normal convection flow, but it collects tungsten evaporated from the filament, a tungsten nickel alloy forming on the wire gauze. It will be appreciated that in the absence of the grid, normal evaporation from a filament of this type causes the gradual development of a black deposit along the whole length of the upper portion of the lamp. The grid has the effect of materially reducing the density of this deposit and gives an improvement of some 10 per cent. in efficiency maintenance throughout life, and a somewhat greater increase in the beam candle power maintenance.

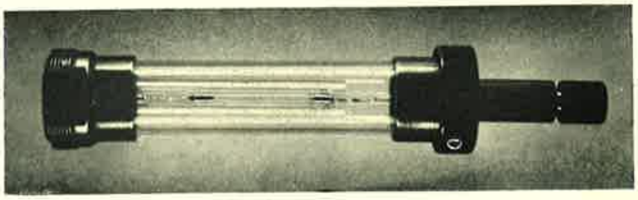
Experimental work is still being carried out on the application of suitable grids to various other projector lamps where improvement of their horizontal candle power maintenance is a desideratum.

Electric Discharge Lamps

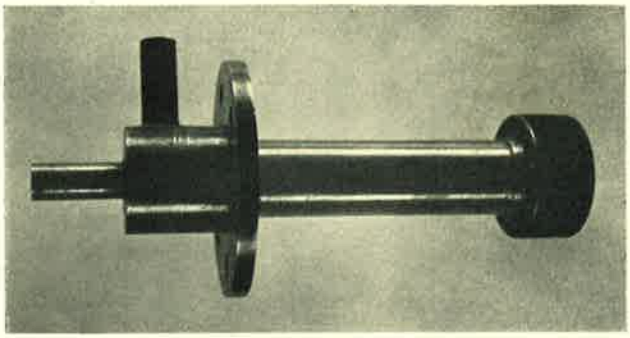
In the opening paragraphs of this review reference was made to earlier *Engineering Supplements* in which from time to time descriptions of various electric discharge lamps have appeared. In particular, *Engineering Supplement* No. 178, of March, 1940, contains on page 2 a table in which is set out the main types of mercury vapour lamp upon which development work has been carried out at Preston Works. A fairly long list of these lamps could be given and would include such well known types as the Sieray 80, 125, 250, 400 and 650 watt mercury lamps, the 300 and 500 watt Sieray-Dual lamps, and the 80, 125 and 400 watt fluorescent high-pressure lamps. Space does not allow of more than a brief description of the principal lines along which development has proceeded in the last year or two. Reference will, therefore, only be made to three types of mercury vapour lamp which will serve to indicate the variety of problems involved in this fascinating work.



500 Watt



1,000 Watt.



Water Union.

Fig. 3. 500 and 1,000 Watt, Water-Cooled Lamp Type MD/H with holder and water union.

(1) *Water-cooled HPMV Lamps, Type MD/H.*

Lamps of 500, 1,000 and 2,000 watt ratings have been developed and applications have been found for the 500 and 1,000 watt sizes. It will be remembered that in this type of lamp the discharge takes place in a quartz capillary tube of approximately 2 mm. bore.

The arc current is approximately the same for each of the three wattages, the length of the arc being made proportional to the wattage as shown by the following table of characteristics :—

	500 Watts.	*1,000 Watts.*
Supply	A.C.	A.C.
Open circuit volts ..	600	1,200
Lamp operating volts ..	450	840
Lamp operating current ..	1·35 amps.	1·4 amps.
Starting current	2·6 amps.	2·6 amps.
Maximum initial brightness	30,000 stilb.	30,000 stilb
Initial efficiency ..	60 L/W.	62·5 L/W.
Operating position ..	Horizontal.	Horizontal.
Arc length	13 mm.	25 mm.
Life	100 hours.	100 hours.

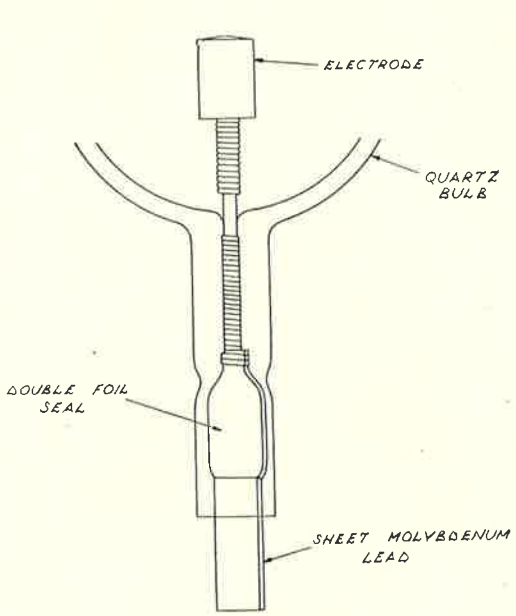


Fig. 4. 100 Ampere Seal.

Recent work has been carried out on the design of special seals and electrode arrangements for these lamps, and on methods of exhaust and processing during manufacture in order to obtain a good life and life uniformity. In collaboration with other Laboratories a standard type of concentric flow water jacket has been designed which has entailed a number of separate investigations on such widely different subjects as :—

(*a*) Glass to metal joints and seals ;
(*b*) Watertight cements capable of withstanding intense ultra-violet radiation.
(*c*) Watertight connections which are readily demountable and which are not subject to attack by organic solvents.

Fig. 3 illustrates lamps of 500 watt and 1,000 watt ratings, together with one type of holder and water union. The water enters through the inner tube of the outer jacket and returns through the annular space between the inner and outer tubes. The Siemens lamp has a demountable quartz burner (the actual light source) while the jacket may also be taken down for cleaning or other purposes. The whole design has been worked out so as to secure an important pre-requisite for successful operation, namely, the correct positioning of the various parts in respect to one another. These lamps are finding a variety of uses where very high intensities are required, and where it is important for the amount of heat to be kept down to a minimum.

(2) *Type ME Lamps.*

Research on air-cooled high-brightness mercury vapour lamps has been vigorously pursued during the past five years. Work on the general lines indicated in the *Engineering Supplement* No. 178 has been continued, and experimental lamps of very high power suitable for projection purposes have been successfully developed. Particular attention has been paid to two main aspects of the problem, namely :—

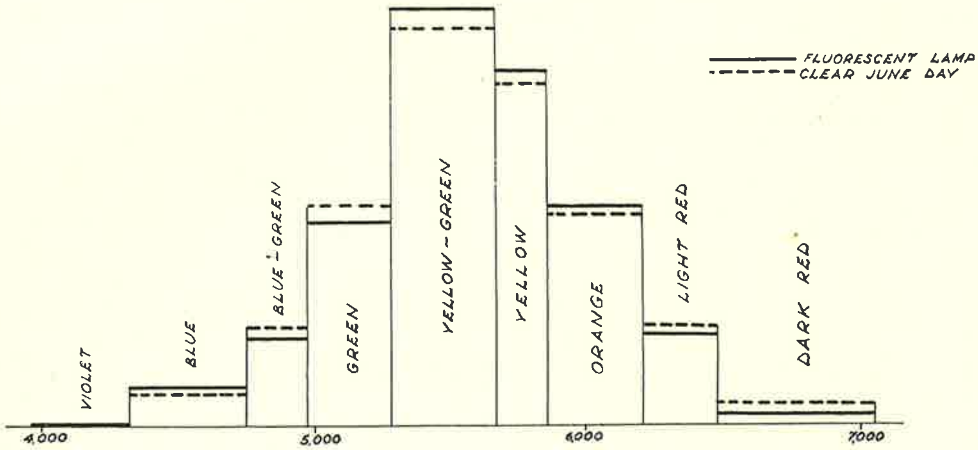
(*a*) The development of high-current hermetic seals through quartz ;
(*b*) The development of methods for procuring the instantaneous ignition of these lamps under full vapour pressure conditions.

Seals. One very difficult problem has been the devising of means by which molybdenum leads could be sealed into quartz in such a way that the hermeticity of the union is not impaired under extreme conditions of temperature and pressure. It has been known for a number of years that thin molybdenum sheets, the maximum thickness of which is not greater than about 30 microns, can by special methods be sealed directly into quartz to effect a vacuum tight union. By multiplying the number of such single seals it is possible to arrange for much heavier currents to be carried, but these methods are complicated and the seals are expensive to produce. Systematic experiment on fundamental lines and study of the conditions requisite for the production of these seals has enabled foil sections of 20 times greater current carrying capacity to be sealed directly into quartz.

In its present form the latest type of Siemens high-current hermetic seal through quartz works in air at a current density of 10,000 amperes per sq. cm. Fig. 4 shows one of these seals capable of carrying continuously a current of 100 amperes.

Methods of Ignition. Since the advent some nine years ago of the high-pressure mercury vapour lamp, one of its fundamental characteristics has been the fact that due to the high operating vapour pressure some minutes must elapse after the lamp has been switched out of circuit before it can be re-ignited. This characteristic is typical of all high-pressure mercury vapour lamps, the time period which must be allowed before re-ignition can occur being dependent on the pressure of the mercury vapour in the running condition, the temperature of the lamp bulb and surrounding atmosphere, and the rate of cooling which can be effected.

For certain purposes it is very desirable that a temporary cessation of the current supply to the lamp, whether occurring accidentally or as a normal phase of operation, should not prevent the lamp from being re-ignited instantaneously when the current is restored. Much progress has been made at Preston in the solution of this problem, but details cannot yet be published.



WAVELENGTH IN ANGSTROM UNITS ($1A° = 10^{-8}$ CM.)

Fig. 5. Spectral luminosity distribution of the Sieray Fluorescent Tube compared with that of noon sunlight on a clear June day.

In connection with the development of these lamps, methods have been worked out and equipment has been built at Preston Works for measuring the arc brightness, and for exploring changes in the brightness at various positions in the inter-electrode space.

Some idea of the intensity of this type of lamp may be gathered from the fact that in one type of lamp over 300,000 lumens are radiated from an arc space approximately 5 mm. diameter by 5 mm. long. The average 100 watt gasfilled household type lamp gives about 1,300 lumens.

(3) *Fluorescent Lamps Type MCF/U.*

These lamps are tubular in form and operate by a discharge through mercury vapour at low pressure, the abundant ultra-violet radiation so produced being converted to visible radiation by fluorescent powders coated on the inside of the tube.

Development has been limited by war conditions to a type of lamp which is highly suitable for the lighting of factories and large rooms in which general illumination of high intensity and good colour is required. The "Sieray" 80 watt 5 ft. Type MCF/U lamp has the following characteristics :—

Nomenclature	MCF/U.
Lamp watts	80
Supply voltage	200/250
Luminous efficiency—initial	35 L/W.
Luminous efficiency— average throughout life ..	26 L/W.
Overall length	60 in. ± 0·5 inch.
Bulb diameter	38 mm. ± 1·5 mm.
Lamp operating current	0·75 amps.
Cap	B. 22/25 × 26 (Standard B.C.)
Colour	Cold White
Life	2000 hours

The Siemens Lamp Laboratories at Preston are engaged on the production of the various types of fluorescent powder with which the inner surface of the tubular lamp is coated, the development and improvement of methods for quantity production of the lamps, and also work on the necessary auxiliary equipment and control gear.

Fluorescent Powder Production. In the future, fluorescent powder is likely to prove as important a material in the electric lamp industry, as tungsten has been hitherto. The realisation of this fact led to the decision to carry out development work on fluorescent powders and their production. In general, it may be said that no single fluorescent powder has yet been developed which, in association with the low pressure mercury discharge, will produce light which is substantially white. This result may, however, be achieved by mixture of powders, but each of the components must be of the highest possible efficiency and of a reproducible colour so that control of the colour rendering properties of the finished lamps can be readily achieved. At Preston Works, powders which have their peak fluorescent effect in the blue, orange and red portions of the visible spectrum are prepared, and their colour and efficiency is assessed before they are mixed with the binder which serves to fix them on the inner surface of the glass tube on to which they are coated.

The production of bulk supplies of these powders has involved the development of new manufacturing chemical processes, and the installation of various types of special equipment. Investigation and development are still proceeding.

Assessment of the colour of the individual powders and of the completed tubular lamps is carried out by measurement of the luminosity of the tubes in eight bands covering the whole of the visible spectrum. For this purpose a simple type of spectro-photometer has been developed, and routine measurements for the control of the product are carried out. A typical block diagram produced by this apparatus is shown in Fig. 5 in which the colour of the standard "cold white" tube

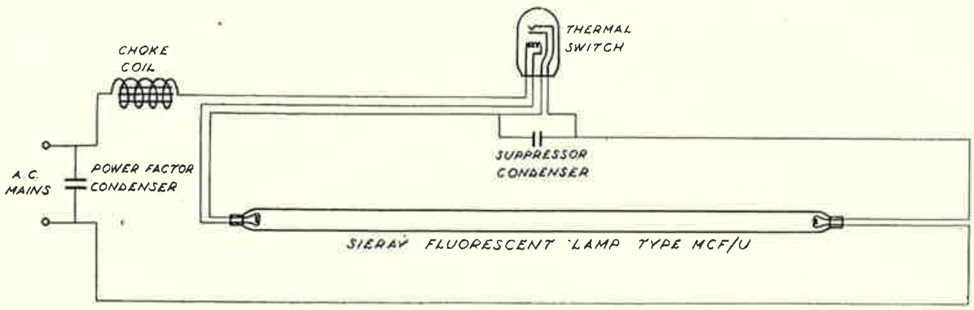


Fig. 6. Circuit for operation of Sieray Fluorescent Lamp, Type MCF/U.

is compared with that of daylight. It will be seen that in most of the eight bands into which the spectrum is divided a very close approximation of noon daylight has been achieved.

Manufacturing Equipment. The manufacture of low-pressure fluorescent tubes on a commercial scale necessitated the development of plant and equipment which for some of the processes was novel, as an entirely new field of discharge lamp design has been entered. The process of coating the powder on the inner surface of the glass tubing in such a way that the resultant grain is imperceptible at the working distance has received special attention. Another departure from traditional technique concerns the exhaust operation, involving as it does the simultaneous processing of a number of tubes 5 ft. in length which require a thorough baking of the powder coating and also de-gassing and bombardment of the activated electrodes. These requirements have led to the development of special types of exhaust equipment, and the experience so far gained has shown the way to further improvements which will shortly be put into effect.

Auxiliary Equipment. It will be appreciated from earlier articles in this supplement that every electric discharge lamp must operate in conjunction with some form of current limiting device. The 5 ft. 80 watt fluorescent tube Type MCF/U is, of course, no exception, but in this case in addition to the usual current limiting choke a special switch is required to enable the electrodes of the lamp to be pre-heated prior to ignition, and to produce a voltage surge of sufficient magnitude to strike the arc in the tube. These results are achieved by means of the circuit shown in Fig. 6 in which the switch illustrated in Fig. 7 is a necessary piece of equipment. This switch is of the bimetal type, deflection of the bimetal elements carrying the switch contacts being obtained by a small heater coil connected in series with the current limiting choke. The switch contacts which are normally closed are connected across one end of each of the filamentary electrodes of the lamp. On connecting the circuit to the supply mains, the heater coil X causes the switch to open in about two to three seconds by which time the electrodes have reached an emitting temperature. Opening of the switch contacts causes an inductive surge of some 500 to 1,000 volts which is sufficient to strike the tube. Although in the normal operating condition the current through the heater coil of the switch is lower than the starting current, the switch contacts are designed to remain open while current flows through the tube. Within about two to three seconds after the lamp has been switched off the switch contacts re-close enabling the above cycle of operations to be repeated as required. Development work on a magnetic type of switch is being carried out in conjunction with the Woolwich Works.

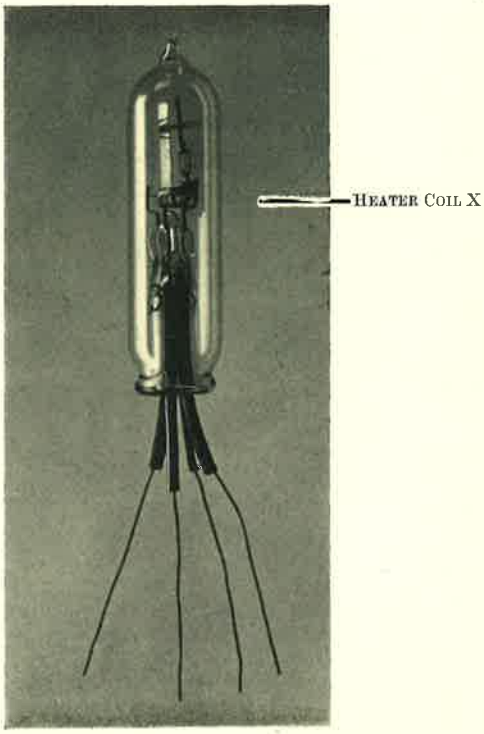


Fig. 7. Thermal Switch for Type MCF/U Fluorescent Tube.

FIG. 8.—SIEMENS IMPULSE VALVES AND VOLTAGE STABILIZERS.

Siemens Nomenclature.	Electrical Characteristics when Employed as an Impulse Valve.			Electrical Characteristics when Employed as a Voltage Stabilizer.		
	Striking Voltage.	Running Voltage.	Minimum Conductivity.	Maximum Current Recommended.	Current Range.	Stabilizing Voltage expressed as a percentage of R.V.
Impulse Valve Type 1 ..	253-277 v. D.C.	80-95 v. D.C.	25 m/a. through 4,000 ohms series resistance.	40 m/a.	2·5–40 m/a.	100±5%
Impulse Valve Type 2 ..	140-154 v. D.C.	80-95 v. D.C.	8 m/a. through 4,000 ohms series resistance.	25 m/a.	2·5–25 m/a.	100±5%
Impulse Valve Type 3 ..	Gp. 1 155-165 v. D.C. Gp. 2 166-200 v. D.C.	80-95 v. D.C.	11 m/a. through 4,000 ohms series resistance.	40 m/a.	2·5–40 m/a.	100±5%
Impulse Valve Type 3 ..	170±7 v. D.C.	80-95 v. D.C.	8 m/a. through 4,000 ohms series resistance.	40 m/a.	2·5–40 m/a.	100±5%
Impulse Valve Type 4 ..	357±17 v. D.C.	—	25 m/a. through 4,000 ohms series resistance.	—	—	—
Impulse Valve Type 5 ..	200 v. D.C.	120-150 v. D.C. at 50 m/a.	—	40 m/a.	2·5–40 m/a.	100±5%
Impulse Valve Type L. 7A	80–110 v. D.C.			—	—	—
Indicator Type I. 8 ..	180 v. A.C.	In series with 1 megohm working voltage 200-250 v. A.C.		—	—	—

Special Devices

GENERAL. It will be appreciated that the methods and processes of the electric lamp industry are eminently suitable for the production of various types of electrical devices which require similar constructional methods to those employed in electric lamps, and which can be built up on lamp making machinery. A wide variety of such devices form part of the regular manufacture of the Preston Lamp Works. Some of them are the products of quite recent developments while others have been in regular production for many years. Brief mention will be made of a selection of such devices.

(1) *Low Voltage Tubes.*

Progress has been made on the development of tubes of both the cathode glow and arc discharge types which can be operated from low-voltage D.C. supplies. The L. 7A Impulse Valve is an example of a cathode glow device which has a D.C. striking potential of the order of 90 volts, while a mercury vapour discharge tube has been developed which will operate directly from a 24 volt D.C. supply.

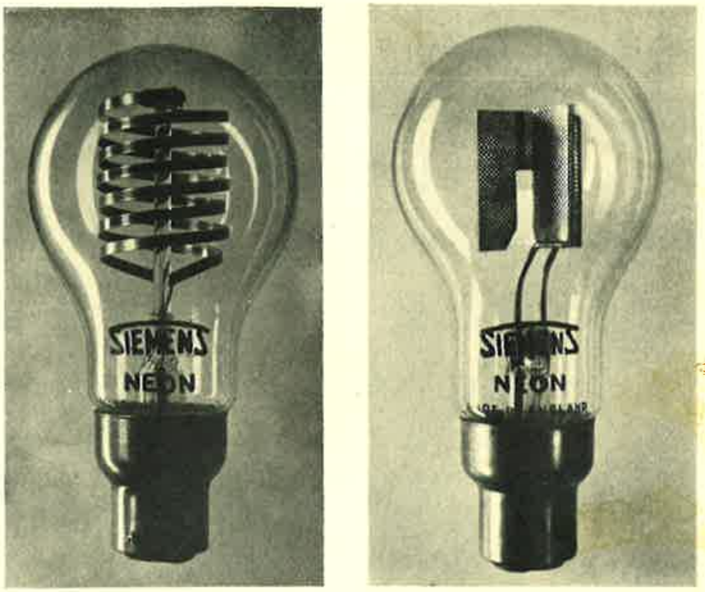
(2) *Impulse Valves and Voltage Stabilizers.*

Some of the standard types of Siemens impulse valves have proved to have characteristics very suitable for voltage stabilization, and have been employed in a number of cases for that purpose. Fig. 8 shows the characteristics of a range of these impulse valves and indicates the values of current over which good voltage stabilization can be effected. Siemens impulse valves are now being used for such widely different purposes as timing of traffic control equipment, switching of lighting circuits at dawn and dusk, and timing of grinding machinery.

(3) *Cathode Glow Devices.*

Among other devices of the cathode glow type which have received attention during the last year may be mentioned the Siemens glimmer lamp, and in Fig. 9 the old and new designs are compared. It will be seen that the older design was a two-start helix made from strip metal, while the new design consists of two sheet electrodes mounted in the form of a cross. A very much improved maintenance of light output is obtained with the new design, with a corresponding marked increase in the effective life.

A somewhat kindred device is the argon/nitrogen filled cathode glow tube which is used for the emission of near ultra-violet radiation. Some very interesting studies have been made in connection with the development of devices of this type which have a high factor of maintenance of U.V. output. Fluorescent powders have been applied successfully to bulbs and tubes within which various types of cathode glow are taking place, and some useful effects can be produced in this way. Some of these developments may possibly find an extended use after the war.



Old design New design

Fig. 9. Glimmer Lamp.

(4) *Ballast Resistances.*

The Siemens "tungsten-in-hydrogen" ballast resistance which was developed originally for use in automatic telephone exchanges, has been the subject of further study and new types of ballast resistances of both the tungsten/hydrogen and iron/hydrogen types have been developed recently. The characteristics of some typical Siemens barretters are given in Fig. 10.

Conclusion

The foregoing outline indicates some of the interesting work on which development has taken place and is still proceeding. Detailed technical discussions have been avoided deliberately in the desire to indicate broadly the type of problems with which the Preston Lamp Factory is at present concerned.

P. D. Oakley
J. N. Aldington.

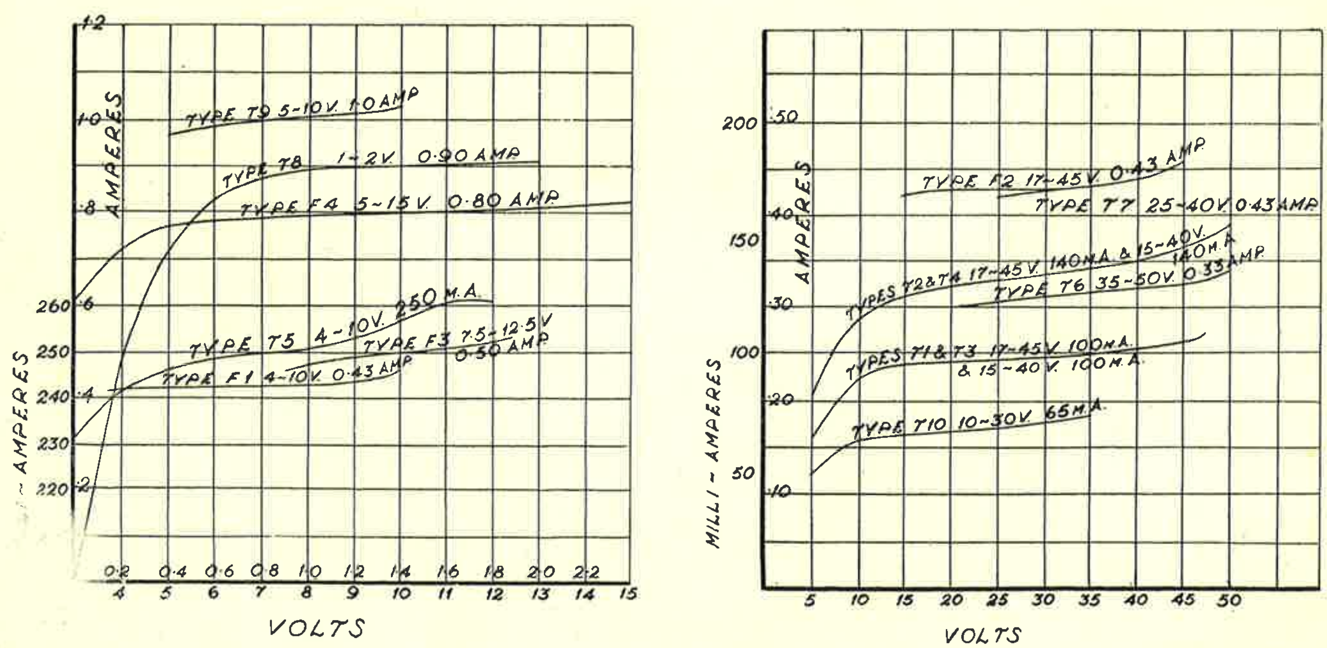


Fig. 10. Characteristics of Siemens Barretters.