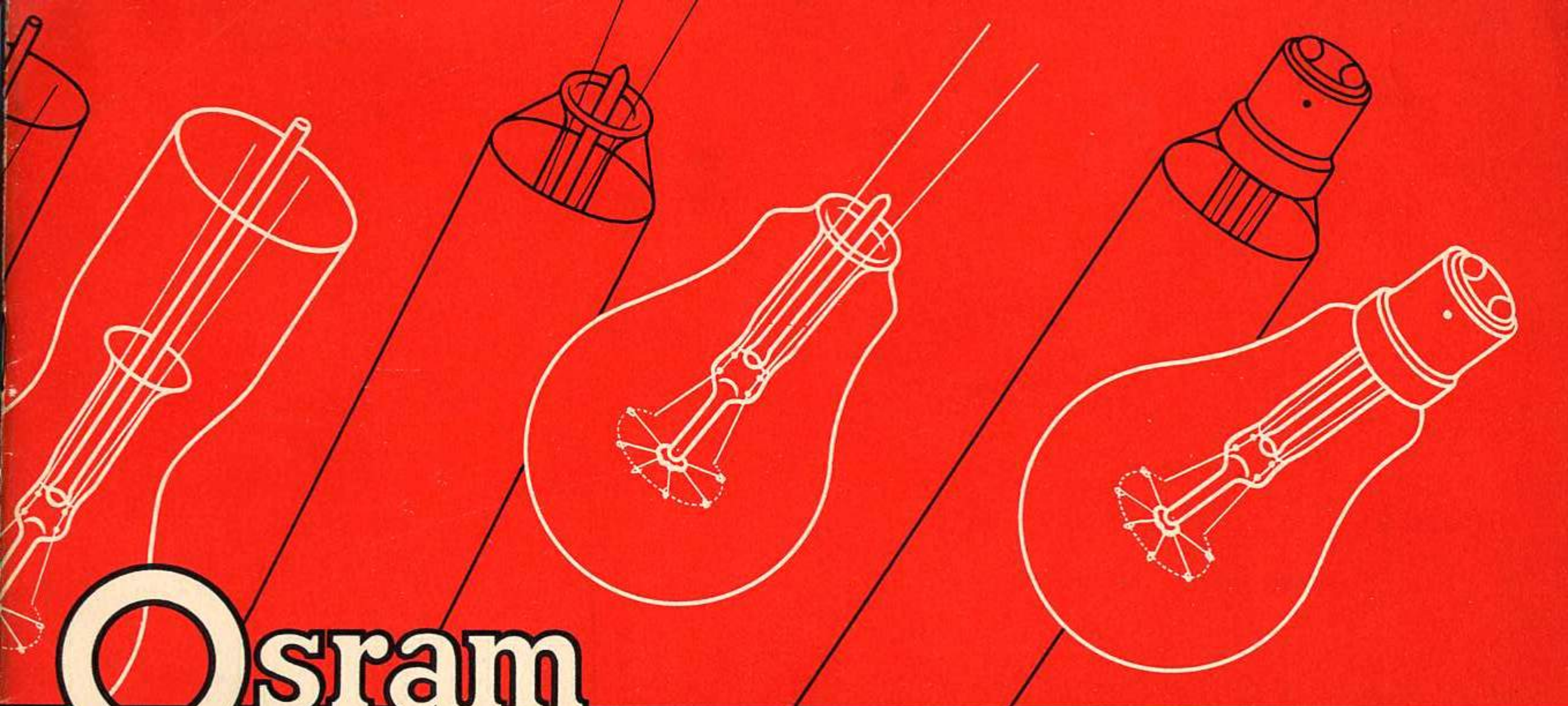


Osram lamps in the making

The Osram Lamp Works, Wembley, which has a floor area of two-and-a-half acres.

Osram LAMPS IN THE MAKING

The main gates of the G.E.C. Wembley Estate. The Osram Lamp Works, Wembley, are at the end of the main drive.

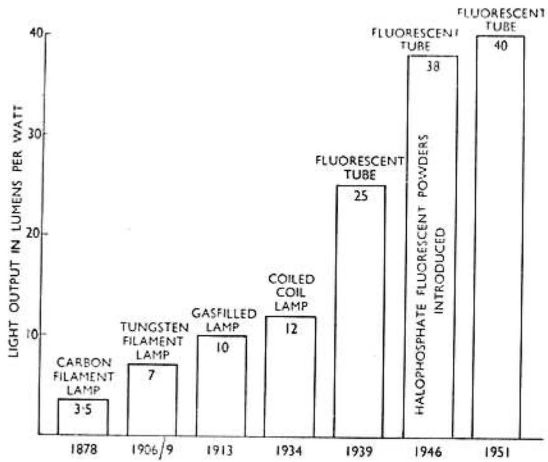
OSRAM LAMPS are made at the following OSRAM-G.E.C. factories:

TUNGSTEN FILAMENTS	Hammersmith, Wembley and Shaw (Manchester)
MOLYBDENUM SUPPORTS	Hammersmith, Wembley and Shaw (Manchester)
GLASS BULBS TUBING AND STEM RODS	Wembley, Lemington-on-Tyne and at the G.E.C. allied works, Glass Bulbs Ltd, Haworth, Yorks.
LEAD-IN WIRES	Shaw (Manchester) and Wembley
CAPS	At the G.E.C. allied works, Lamp Caps Ltd, Chesterfield
ARGON GAS	Hammersmith
FLUORESCENT POWDERS	Lumifax Ltd, Wembley, a subsidiary company of the G.E.C.

The G.E.C. Research Laboratories, responsible for all Osram Lamp development and constant testing of finished products are at Wembley, Middlesex.

LAMPS IN THE MAKING

Erratum
The words and Tantalum *should be deleted from page 3, para 2.*



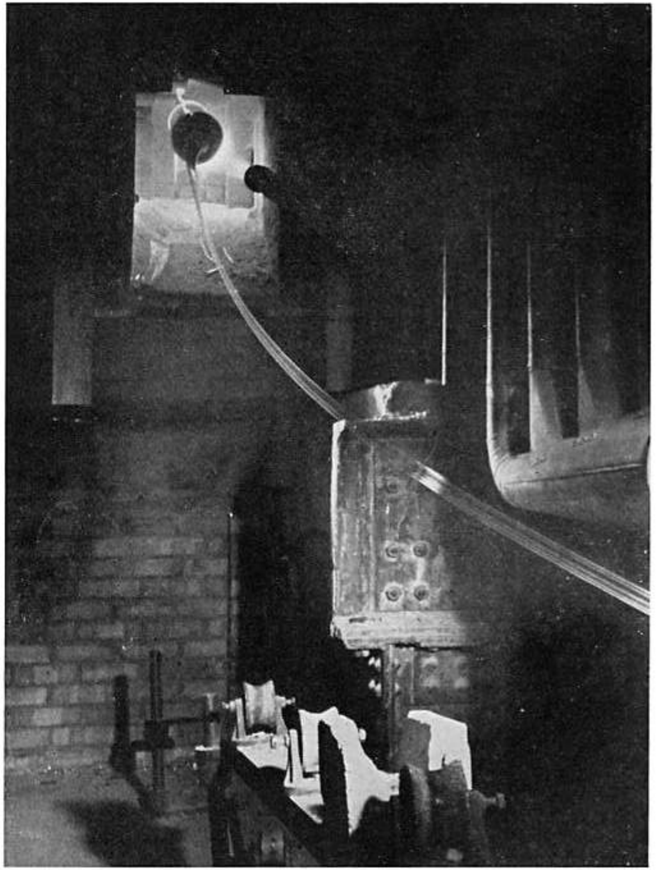
This graph illustrates the growth in efficiency (average through life) of the electric lamp since 1878.

At the end of the nineteenth century the forerunner of the present Osram-G.E.C. organization, Robertson Electric Lamps Ltd., Brook Green, Hammersmith, was producing only one type of electric lamp, the carbon-filament lamp. Although the modern 60-watt lamp lasts twice as long and is four times as efficient, the early carbon lamp should not be despised, for in its day it represented an important advance on previous means of artificial illumination.

By 1905 the G.E.C. was one of the major producers of electric lamps in this country, and was playing a prominent part in lamp improvement and development. The Company had already introduced into the country the Osmium and Tantalum lamps with metal filaments.

The appearance two years later of the first commercial tungsten lamp marked the opening of a new era in lamp-making, and 1907 saw a new factory rising alongside the Robertson Carbon Filament Lamp Works at Hammersmith. Forty-five years' experience in tungsten lamp manufacture has seen not only the evolution of better production techniques and a steady increase in lamp efficiency, but such major advances as gasfilling, the pearl bulb and the invention of the coiled-coil filament, which in 1934 at one stride improved a lamp's performance by some twenty per cent.

Since the early 1930's, when the introduction of the low-voltage emissive cathode made the commercial production of short discharge lamps operated from the ordinary supply mains a practical possibility, the G.E.C. has been a leading manufacturer of mercury and sodium lamps, and later, fluorescent tubes which were developed in the G.E.C. Research Laboratories. In fact the Osram factories form a completely self-



Molten glass from a 1,400°C furnace is drawn into tubing for foot tubes and exhaust tubes as well as for the bulbs of ordinary fluorescent lamps.

sufficient organization for the production of all varieties of electric lamps, able to draw not only on a reservoir of manufacturing experience accumulated over half a century, but also on the vast resources in scientific apparatus and manpower of the G.E.C. Research Laboratories at Wembley.

Today the Osram lamp brightens our offices and factories, lights our homeward steps and extends our hours of leisure. Its applications range from car headlamps and airfield beacons to studio lighting and miners' lamps. Health, welfare and comfort all come within its beneficial orbit.

The production of Osram lamps and tubes is a fascinating story. The filament lamp, for instance, which seems at a casual glance little more than a wire in a glass bulb, is a complicated scientific device, many components of which are made within dimensional limits too fine for the unaided human eye to discern. Nevertheless, effective quality control must be imposed at every stage of manufacture, for the degree of quality control determines the performance of the completed lamp. How this is carried out in the Osram factories is described in the pages which follow.

WHAT'S IN A LAMP

What's in a lamp, and how does it work? Filament lamps and fluorescent tubes obviously differ in appearance. How do they differ in operation?

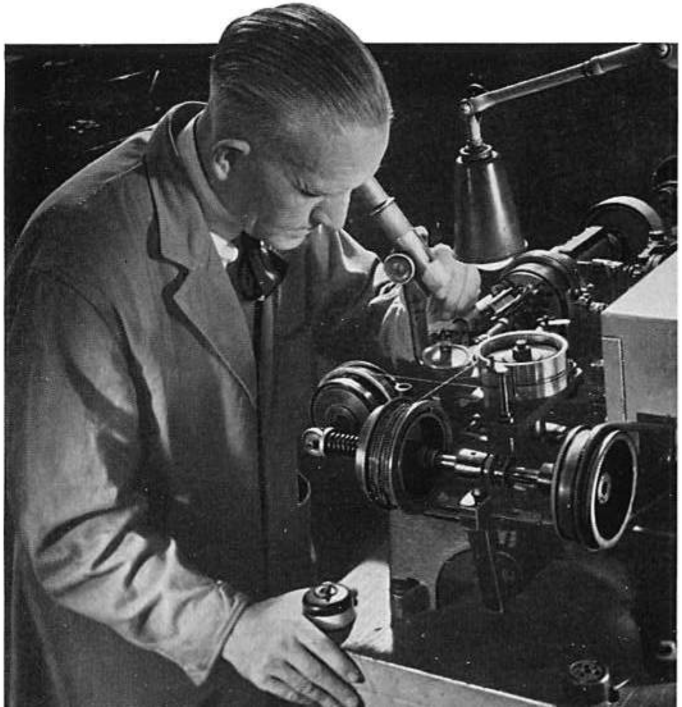
Let us take a look at the Osram filament lamp first. This consists generally of a gas-filled glass bulb containing a tungsten filament. Electric current passing through the filament must overcome its resistance, and the power consumed heats it to incandescence. The

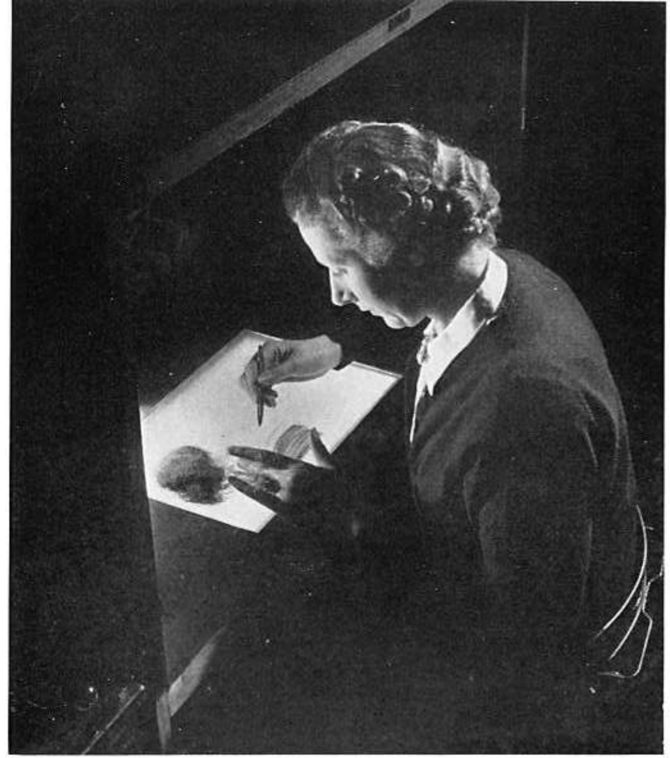
SINTERING TUNGSTEN

A heavy electric current passed through a bar of compressed tungsten powder raises its temperature to approximately 3,000°C and converts it to a solid crystalline structure.

The bar is then pushed through a series of swaging hammers which change its shape from square to round at 1,500°C and reduce its diameter to one-eighth of the original.

WHAT'S IN A LAMP?





Although the G.E.C. manufactures some two million filaments every week, they are all individually inspected.

COILING THE FILAMENT

Although the gap between adjacent turns of wire may be no more than $\frac{1}{4000}$ in., it is not allowed to err in either direction by more than $\frac{1}{50000}$ in.

filament is supported by molybdenum wires mounted on a glass support rod, and is supplied with electric current through lead-in wires sealed into the glass and soldered to a metal cap.

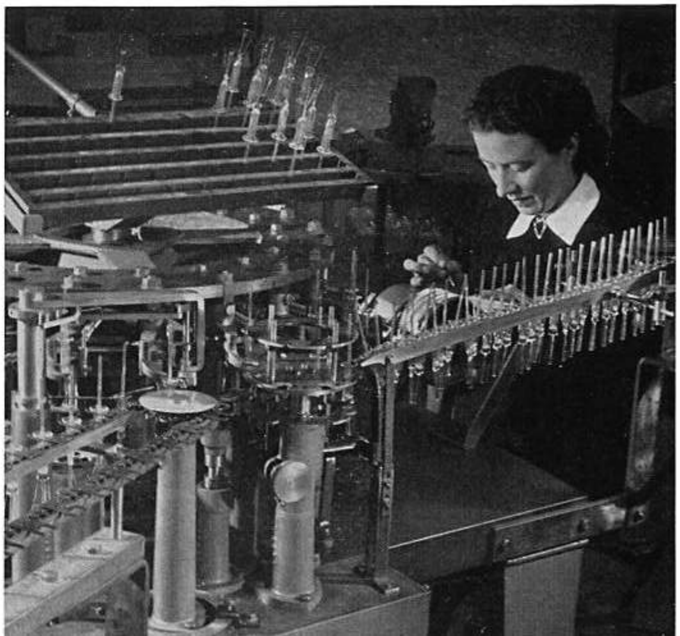
The Osram fluorescent tube is basically a long glass tube with a coating of fluorescent powder on its inner surface. Tungsten filament cathodes with an emissive coating are mounted at each end of the tube inside which are minute quantities of argon gas and mercury. When an electric discharge is set up between the two cathodes through the mercury vapour, ultra-violet light is emitted and causes the powder coating to 'fluoresce'. No ultra-violet light passes through the glass tube. It is the design of the cathodes which determines for how long the tube will continue to light up, but the light output is controlled by the fluorescent powder.

GLASS

It is clear even from this simplified explanation that there are many components which are common both to filament and to fluorescent lamps. Obviously neither would be a practical possibility without glass, which provides both the transparent envelope inside which light is generated and the structural base for wires and filament. Glass of an assured high quality is therefore a fundamental prerequisite of good lighting. In the Osram-G.E.C. Glass Works, sand, limestone and soda ash, which have first been analysed for purity and accurately weighed, are melted in gas or oil-fired furnaces operating at temperatures ranging from 1,400°C to 1,450°C, the resultant molten glass being then drawn into tubes or blown into bulbs by fully automatic processes. The flow and setting of the glass to specified dimensions calls for accurate thermostatic temperature control of the furnaces as well as mechanical control of the speed of draw and the air pressures used in blowing. Bulbs intended for Osram pearl lamps are then internally etched, a process which in no way impairs their strength, to produce an improved light-diffusing surface. In the Osram Silverlight lamp an additional inner coating of fine silica powder is deposited on the bulb by a patented process to give even more diffusion with very little loss of light.

The annual amount of glass tubing produced at Wembley is more than enough to throw a girdle of glass round the earth at the equator. In lamp manufacture it is used for the foot tube, through which the lead-in wires pass from the cap into the bulb of a lamp, and for the exhaust tube by means of which it is evacuated after assembly, as well as for the envelope of the ordinary fluorescent tube.

TUNGSTEN FILAMENTS

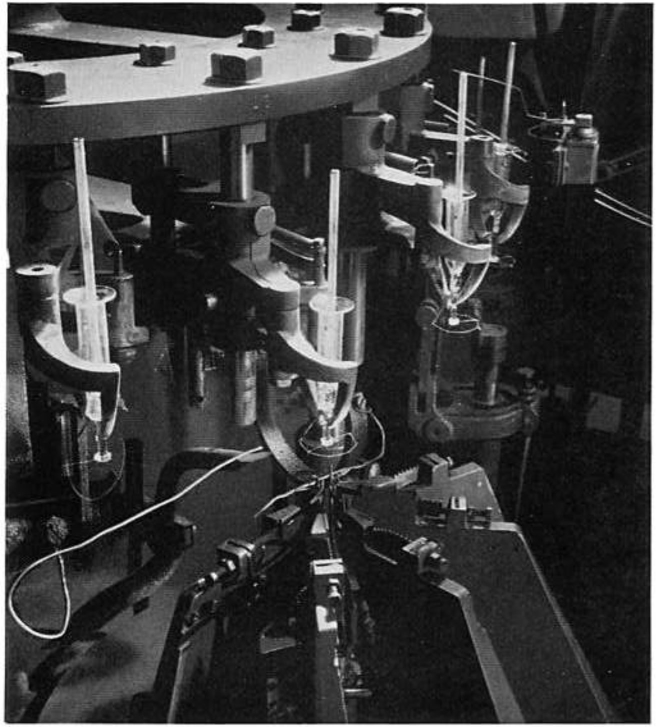


So much, for the time being, for the glass constituents of the Osram lamp. We have yet to describe its working elements, the most important of which is the tungsten filament (which is also used as a cathode in fluorescent tubes). The preparation of tungsten from crude ore and its subsequent sintering, swaging, drawing and coiling demands machinery so accurate that even a minute variation in a filament, which is in some cases finer than a human hair, is not permitted. Initially, tungsten, as it comes from the tungsten oxide plant, is a fine powder the grain size of which is controlled at a diameter varying between one- and two-thousand ths ofa millimetre; in the final product it is a slender wire which, although as fine as $\frac{1}{2000}$ in. in diameter, must retain its strength and rigidity at temperatures as high as 2,500°C.

FILAMENT MOUNTING

Filaments from the drum beneath the operator's right hand are mounted on the 'pinch' assemblies seen being conveyor-fed into the machine.

Components are assembled on the machine on the left, and pass to the support and filament-mounting machine (left foreground). After lamps have been exhausted and filled with gas (right foreground) they are capped on the finishing machine (right centre), inspected and packed.



The most sensitive operation in lamp-making, the filament being blown into position by compressed air.

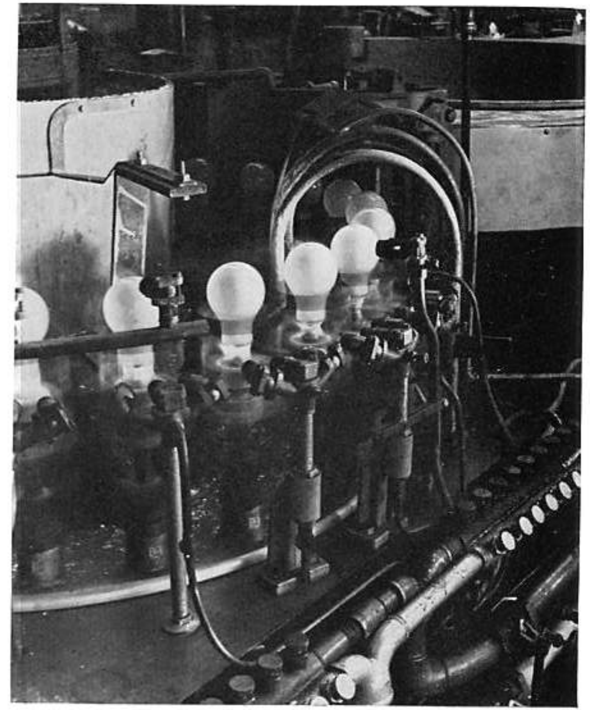
SEALING IN MACHINE

Bulbs and 'pinch' assembly come together for the first time.

Single-coil filaments are made by coiling this slender wire on an iron wire mandrel. 'Coiled-coil' filaments are made by coiling the primary coil together with its molybdenum mandrel around another molybdenum mandrel in the same way. Although the gap between adjacent turns of wire may be no more than $\frac{1}{4000}$ in., it is not allowed to err in either direction by more than $\frac{1}{50000}$ in. The diameter of the wire mandrels is controlled with equal vigilance. Both mandrels are ultimately removed by dissolving them in acid after the coils have been annealed and cut to appropriate lengths. Although the G.E.C. manufactures some two million filaments every week, they are individually inspected for dimensional accuracy, regularity of coil pitch and imperfections in the wire. In addition, forced life tests are carried out on lamps made from sample filaments taken from each batch which must be approved before they are released for normal production. It is this precision and attention to detail which, although quite imperceptible to the user, determines the quality of the finished product.

LEAD-IN WIRES

Nothing is easy in lamp-making. One would imagine that a pair of simple copper wires would suffice to carry current to a lamp filament. In fact each lead-in wire has three components, nickel, copper-clad nickel iron, and copper—joined together. It is the copper-clad nickel iron portion which is actually sealed into the glass envelope. With many filament lamps there is a further complication, in that a length of constantan fuse wire is inserted between the copper-clad nickel iron and the copper wires to avoid possible disruptive arcing and blowing of circuit fuses when a lamp fails. The fuse wire is sealed in a tiny glass tube to contain the metal vapours emitted when the fuse operates.



MAKING THE SEAL

The bulb neck is melted down to meet the flange on the 'pinch' assembly and form an air-tight seal.

THE FILAMENT LAMP

Having described the preparation of most of the components (unfortunately there is not the space here to describe the production of the caps or to explain in detail the elaborate process whereby molybdenum wire is produced), we now come to the assembly of the lamp itself.

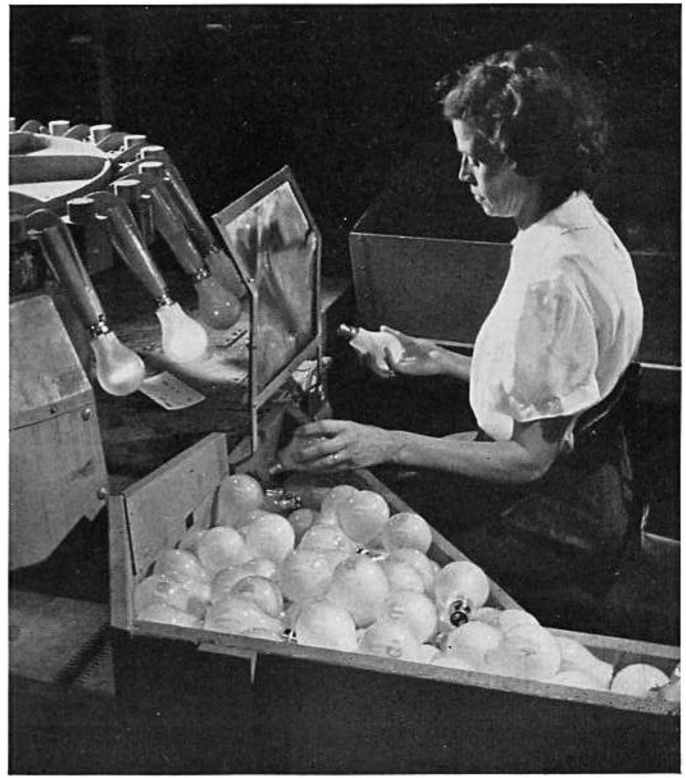
This involves the joining together of various components made of glass, and as this substance is only malleable when heated, the most satisfactory means of localising the application of heat are accurately directed jets of burning gas. The Osram Lamp Works at Wembley consume over a million cubic feet of gas each week. It cannot of course be used at the pressure to which the domestic consumer is accustomed, but is first compressed, passed through a series of gas regulators and mixed with compressed air. Without this pressure regulation it would be impossible to maintain the force, direction and temperature of the countless gas gurners employed to fuse a lamp's components and mould them to their final contours.

PUTTING THE FILAMENT INTO POSITION

The various rotary machines on which the lamp is assembled all operate on the same general principle, picking up the glass components one by one and moving them past a series of gas burners, each of which carries the shaping and assembly process a short stage further forward. The first of these machines

Metal caps are secured to the glass bulb by a special cement, the 'curing' cycle of which is controlled to ensure a bond which resists rigorous climatic conditions.

Every lamp is visually inspected and its brightness on circuit compared with a reference lamp.



takes the glass exhaust stem, rod and flange and two lead-in wires and 'pinches' them into a single unit. The second takes this 'pinch', as it is called, and successively flattens and hooks the ends of the nickel wires, clamps on a filament, forms a glass button and inserts molybdenum support wires (only 0·10 mm. thick) in it, loops the supports around the filament and shapes the finished "mount".

Putting the filament in position is the most delicate operation in the whole field of lamp-making and warrants some explanation. To avoid any possibility of the minute turns being damaged it is picked up by suction before being clamped to the lead-in wires. The looping operation which follows demands a mechanism even more watch-like in its precision. The filament is blown into a horizontal position by compressed air and the loops on the molybdenum support arms are formed around it. Only when the loops have been formed is there any contact between the filament and its supports. After the filament's tension has been adjusted it is coated with a phosphorous 'Getter' which on a lamp's first lighting ignites and burns away any lingering traces of oxygen.

Packers ensure that every carton is correctly labelled with voltage and other relevant details.

A proportion of Osram lamps is tested independently by the Inspection Department in accordance with the provisions of British Standard 161 (1952).

ASSEMBLING THE LAMP

The lamp has now reached the moment in its career at which the filament is embodied in the bulb. The neck of the bulb is first melted down to meet the flange on the 'pinch' assembly and form an air-tight seal, and the base is moulded so that it will fit snugly into the brass lamp cap. Air, gas, vapours and impurities are now removed through the exhaust stem by a succession of pumping operations to create a vacuum of less than $\frac{1}{40000}$ atmosphere. Any faulty bulbs are automatically detected and isolated from the pumping system. The bulb is then filled with argon gas and the exhaust stem finally sealed off to isolate the interior of the envelope.

The lamp is completed on the next machine, which cements on the metal cap. The time and temperature cycle for 'curing' the special cement is carefully controlled to ensure a bond which resists the most rigorous climatic conditions, including the wide fluctuations in temperature and humidity encountered in the tropics. The lead-in wires are then firmly soldered to the cap and the lamp is lit for the first time.

PACKING

It now passes to the packing table, where it is inspected on circuit and the brightness compared with a reference lamp. It is also checked for misplaced filament, supports or lead-in wires, bulb blemishes, the legibility of the 'Osram' stamp, a crooked or defective cap or imperfect soldering. The lamps are then packed.

INSPECTION — A four-fold check on quality

Altogether there is a four-fold check on the quality of Osram lamps. In addition to the routine examinations applied to them in the course of production, some of which have been described, a proportion of lamps are tested independently by the Inspection Department in accordance with the stringent provisions of the British Standard Specification (BS.161) dealing with tungsten filament lamps. In some respects, for instance in the test applied to the cement bond between cap and bulb, the Osram organization sets a standard appreciably higher than that demanded by the British Standard.

A further periodic process inspection is made of samples taken out of the production run at every stage of manufacture. This includes spot checks on the dimensions of all components and prefabricated parts, on the purity of argon gas, on the efficiency of the capping cement in each batch and on the hour-to-hour quality of lamps coming from the pumping machines.

This is not all: members of the staff of the G.E.C. Research Laboratories select quantities of lamps at random for exhaustive laboratory tests on their life performance and quality. The lamps are burnt to extinction to determine their life at rated voltage, photometric readings being taken at regular intervals throughout their life to check the maintenance of their light output. These tests, undertaken by a scientific staff completely outside the Osram factory organization, are the final buttress of Osram quality.

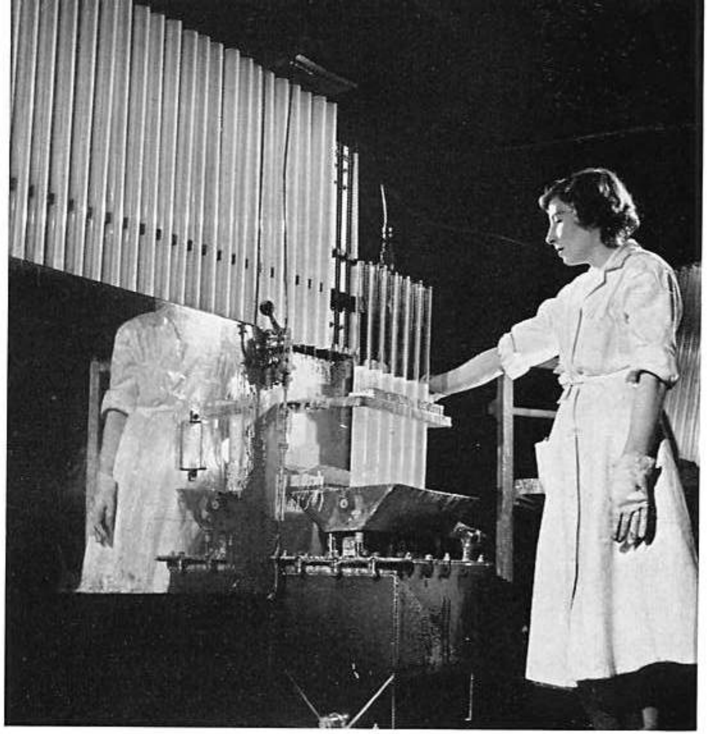
THE FLUORESCENT TUBE

FLUORESCENT POWDERS

The natural starting point for an account of the fluorescent tube is the powder used to coat the inside of the glass tube. On this powder, as much as on any other constituent, does a tube's performance depend, for as the agent which converts the invisible ultra-violet radiation inside the tube into visible light, its quality determines its light output, both initially and through life.

Before the powders reach the tubes, they have been subjected to a series of tests, ranging from chemical and physical analysis of the original ingredients to the production of sample tubes from each batch of finished powders to check their colour appearance and colour-rendering properties. Many hours' milling under controlled conditions is required before the powders are reduced to the optimum particle size. They are then mixed with a nitro-cellulose binder and a solvent until the suspension of powder forms a thin cream. The quantities of powder and binder are accurately weighed to ensure uniformity of coating thickness and correct viscosity, and the suspension is tested for colour.

Every tube is washed with hot water to remove chemical impurities.



A thin cream of fluorescent powder mixed with a binder and a solvent is forced up the tubes by compressed air. Tubes are then placed on the conveyor behind and the solvent evaporated.

The coating at the end of the tube has just been buffed off by a rotating brush under the cowl. The operator is looking out for blemishes on the next tube she will take from the oven.

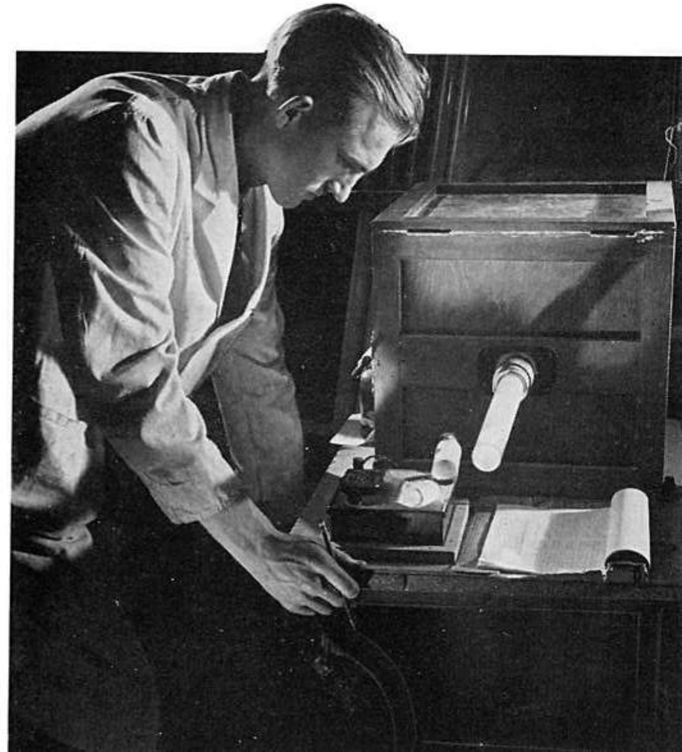
GLASS ENVELOPES

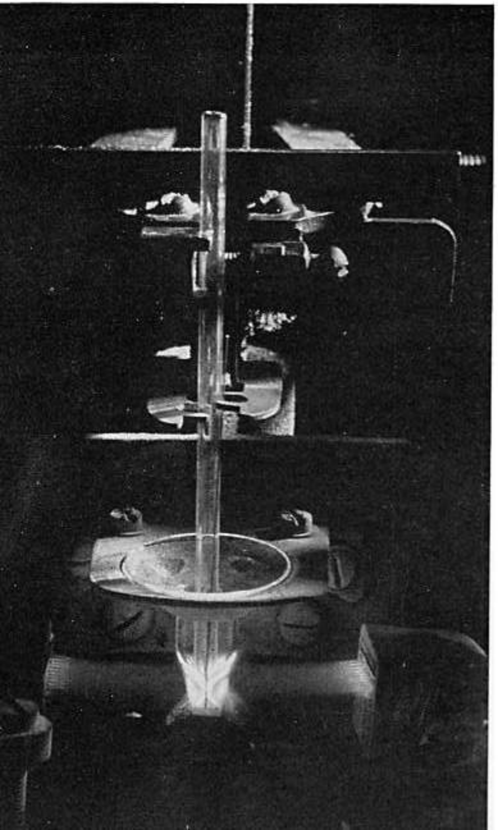
The glass tubes which pass through the Osram fluorescent tube works at Shaw each week are numbered in tens of thousands, every one of which is visually inspected for cracks and blemishes on arrival at the factory. Every tube is also washed with hot water before use to remove the film of chemicals left after drawing.

COATING THE TUBES

Compressed air is used to force the suspension of powder up the tubes, which, after a short interval for draining, are passed on a conveyor through a drying chamber which removes the solvent. The timing of the coating and drying cycle is critical, for premature drying would affect the coating's texture and hence the performance of the completed tube. The tubes are then passed through a tunnel oven where the nitrocellulose binder is baked away. At the far end of this oven the quality of the coating is visually inspected, free powder is extracted by a vacuum, and the coating is buffed off for a short distance at the end of each tube. The visual inspection of the coating which is applied to every tube is supplemented by a more exacting quality control test on a proportion of the tubes. It is

The thickness and dispersal of the powder coating is checked in an apparatus which measures its light transmission photometrically.





possible by weighing a tube before and after coating to determine the thickness of the coating. A variation of more than 0·05 gramme per foot is sufficient to cause the rejection of the whole batch from which the sample is taken. The thickness and dispersal of the powder coating is further checked in an apparatus in which a photocell connected to a microammeter measures the light transmission of the coated against the uncoated tube.

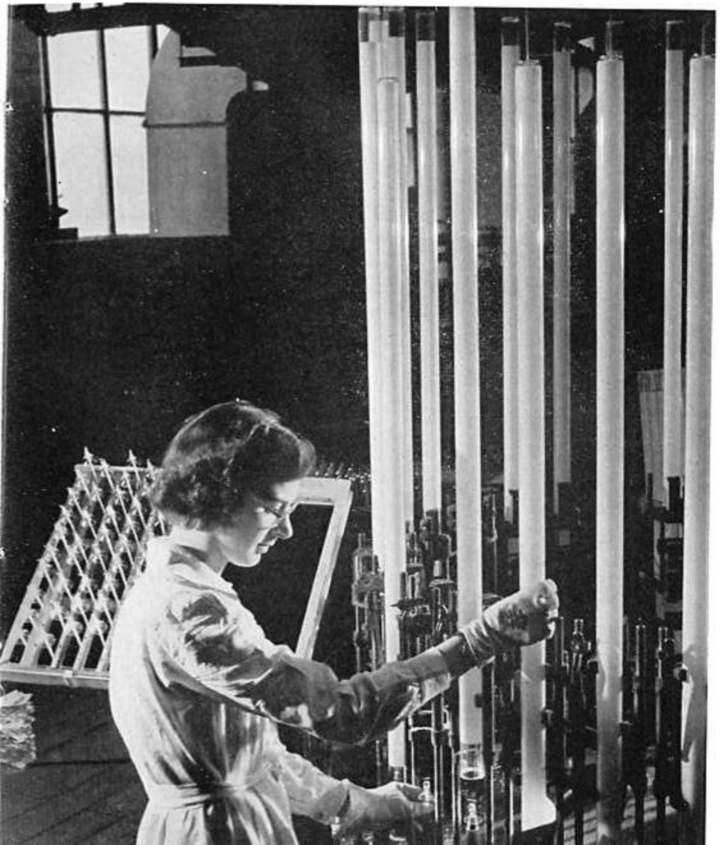
If this threefold check on the depth of the phosphor coating seems over-fussy, it must not be forgotten that it makes or mars a tube's performance. The light in a fluorescent tube originates *inside* the phosphor coating. If the coating is too thick it acts as a barrier to the transmission of light; if it is too thin there is a risk of discoloration through salts in the glass forming an amalgam with mercury inside the tube.

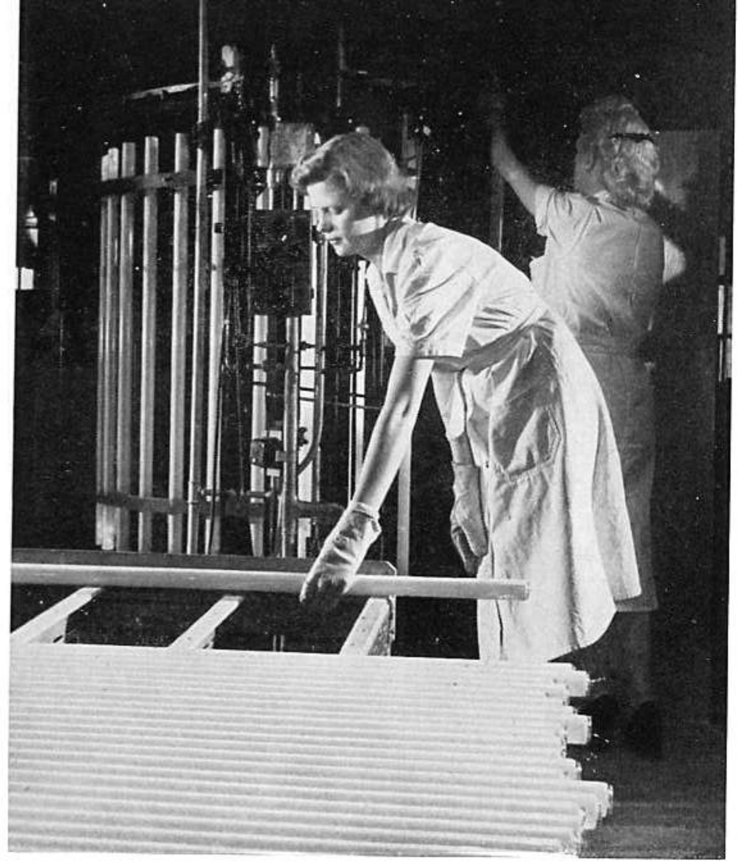
THE CATHODES

The fixing of the tungsten filament cathodes to the glass seals resembles so closely the assembly of the 'pinch' in filament lamps that a complete description here would be superfluous. One interesting difference is that the fluorescent tube cathode is coated with an emissive material. The temperature of operation is considerably lower than that associated with the tungsten lamp. This lengthens

The glass exhaust stem, rod and flange and the lead-in wires are 'pinched' into a single unit by accurately directed gas burners.

The 'pinch' assembly is placed ready for sealing into the fluorescent tube.





Air, gas and vapour are evacuated from the tubes and mercury and argon gas introduced into them.

The Cathodes (continued)

the life of the cathode, so that failure is caused by loss of emissive material rather than 'burning out' of the filament such as occurs with an ordinary filament lamp. Finally, two completed 'pinch' assemblies are sealed into each fluorescent tube and the seals are inspected to make sure they are gas-tight.

PUMPING

The tubes now pass to the 'exhaust' machine. 'Not too little, not too much, but just right' is a rule which applies as much to this operation as to any other in fluorescent tube production. The glass and phosphors are degassed, and the cathodes are burnt to degas the emissive material. A small quantity of mercury is introduced into the tube, and argon to a pressure of $\frac{1}{200}$ atmosphere. The tubes are then sealed off. Too little argon gas would result in short life. Too much would make starting difficult. The mercury content is also crucial, since some mercury is absorbed during the life of the tube and an inadequate amount would result in starvation. Too much would cause staining of the tube.

After leaking tubes have been located by the high frequency oscillator behind the tubes on the left, sound tubes are placed on a revolving ageing rack where they are run under normal conditions.

Before tubes are packed and labelled one last examination is carried out of their general quality and electrical characteristics.

CAPPING AND AGEING

At this stage the caps are applied, in the same manner as with filament lamps. One would imagine that when this had been completed nothing remained to be done, but the end is not yet in sight. The tubes are given an ageing period on a large and slowly revolving rack, any leaky tubes having already been eliminated by subjection to a high frequency test. During ageing the tube is run under normal conditions and at the end of this ageing schedule is examined visually for its general quality. Before they are packed and labelled one last examination is carried out of their general quality and electrical characteristics.

INSPECTION

All the various independent quality control tests applied to filament lamps are applied with equal thoroughness to fluorescent tubes. Although these may differ in detail they are all directed to the same end, the preservation of a reputation for quality in lamp manufacture which has been the pride of the G.E.C. for over fifty years.

The Inspection department test a proportion of tubes for the insulation resistance of their caps, normal resistance of the cathode, and many other characteristics.

World wide confidence in the quality of Osram lamps springs partly from the ability of the G.E.C. to control the manufacture of all materials and components from which they are made. Behind every completed lamp lies a carefully co-ordinated network of factories, each a specialist in its particular product, and each a contributor to the Osram lamp's reputation for reliability. Glass works at Wembley and Lemington-on-Tyne, lamp works at Hammersmith, Wembley, Shaw (near Oldham), and Team Valley (near Newcastle), a factory for fluorescent powders at Wembley, and allied glass works at Harworth, and cap works at Chesterfield, together constitute the largest single lamp-manufacturing organization in the British Commonwealth.

THE GENERAL ELECTRIC CO. LTD.

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