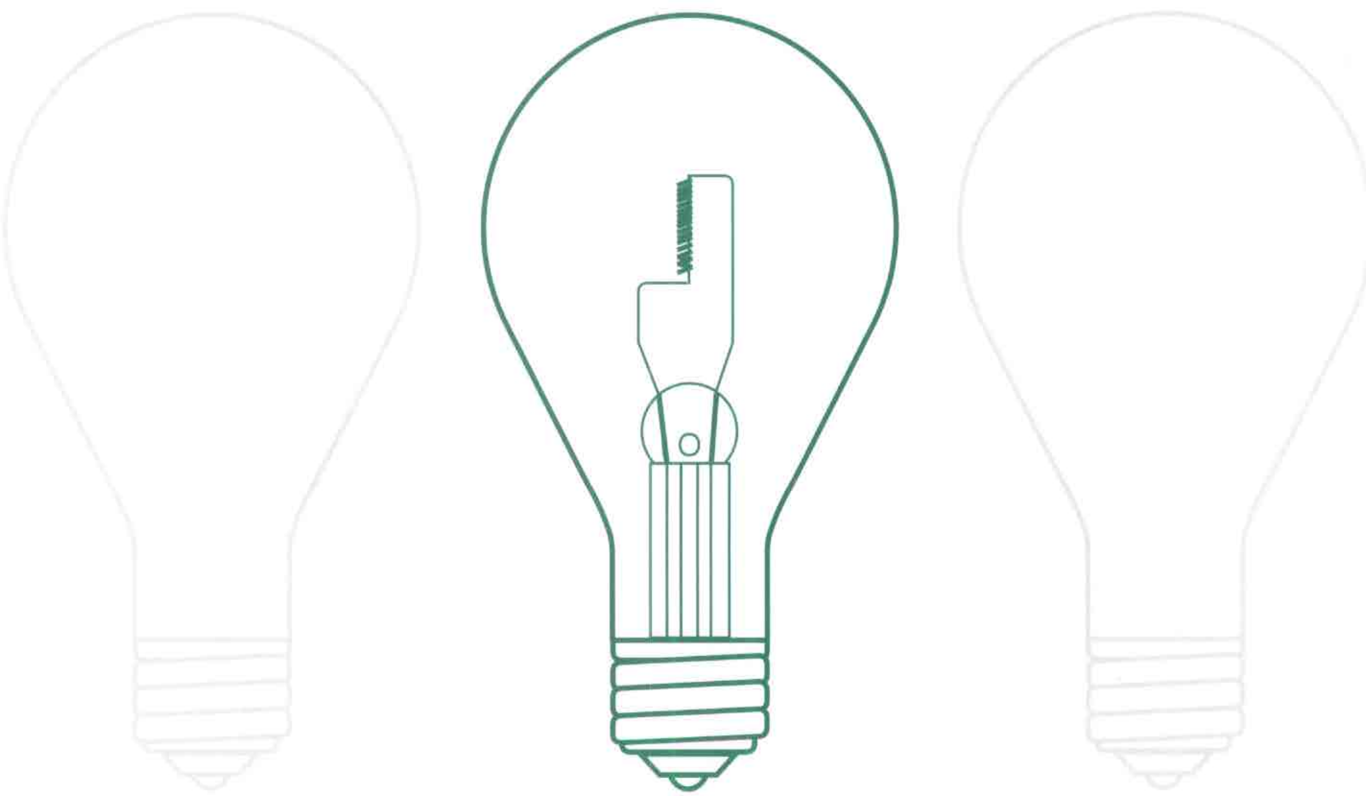
Engineering Bulletin

Incandescent Lamp Manufacture



OSRAM SYLVANIA

IN002

There are about 500 different types of incandescent lamps; various voltages, finishes and bases increase the selection to several thousand. To describe the production process of each type is impractical. This bulletin, therefore, discusses the manufacturing of CC-8 mounts for A-19 lamp types.

Modern incandescent lamp manufacturing is highly automated with tolerances more stringent than most manual processes. The result is a very uniform product.

The Filament

The filament is the part of the lamp that heats to incandescence and provides us with light. To make the filament, high speed coiling machines wrap tungsten wire as a single continuous coil around a molybdenum wire (the mandrel). The finished coil and mandrel then run through a high temperature, hydrogen fired furnace to remove a manufacturing lubricant and, more importantly, to anneal the tungsten. Annealing reduces the strains in the wire, which helps the coils maintain their shape thereafter. To increase the surface area of the tungsten filament, the continuous single coil is itself coiled again around a retractable steel mandrel. Cut to size, the coils then pass through the hydrogen fired furnace again. Next, the coils go to an acid bath to dissolve the molybdenum mandrel (on which the primary coil was wound). Removal of the acid then readies the coils for inspection. The finished filament is now ready to meet the other parts of a "lamp mount" on the "automount" machine.

Mount Assembly Operation

The "mount parts" are two glass tubes (an exhaust tube and a "flare" tube), two "lead-in" wires and the filament. A complete "lamp mount" is at the heart of the incandescent lamp. The "automount" machine is a conveyor system that holds the mount parts in a desired position and carries them through a series of heating and forming operations. Below is the process in detail.

A "flare" tube (figure 1) is positioned automatically and vertically with the flared end up. Two lead-in wires then are fed through the top of the flared end of the glass tubing and aligned in "positioning guides" below. Next, a piece of exhaust tubing - a hollow glass tube about 3/16" in diameter - is placed into the flare tube. At the straight end of the flare tube, fires are played on the assembly until the glass becomes soft (about 1800°F). Clamps are then moved in to form a flat solid section called the "press" (figure 2). Just before the press solidifies, however, a puff of air is blown through the exhaust tube to create a hole in the press.

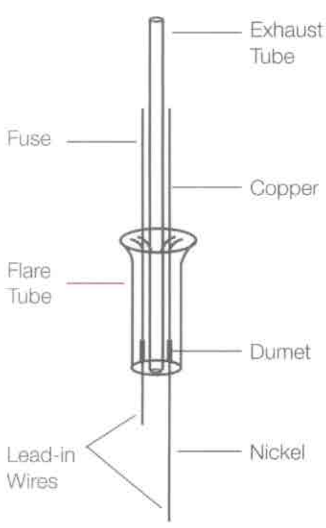


Figure 1- Mount parts assembled

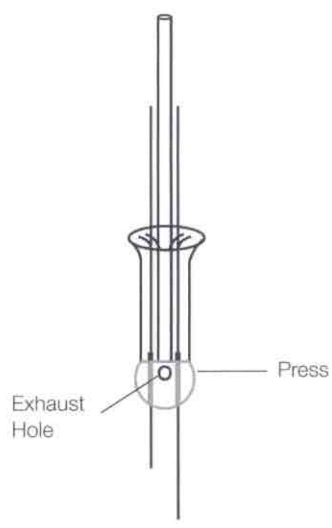


Figure 2 - Lead-in wires sealed in glass press

This hole is blown to provide a means for removing air from within the assembled bulb (later). Next, the lower ends of the two lead wires are shaped and separated to a distance of a millimeter or two less than the length of the coil – about 1" (figure 3). Finally, a coil is lifted into place and mechanically clamped to the two lead wires (figure 4). The entirely automatic lamp mount assembly operation is now completed, and the lamp mount is carried on the conveyor to the "sealing-in" machine.

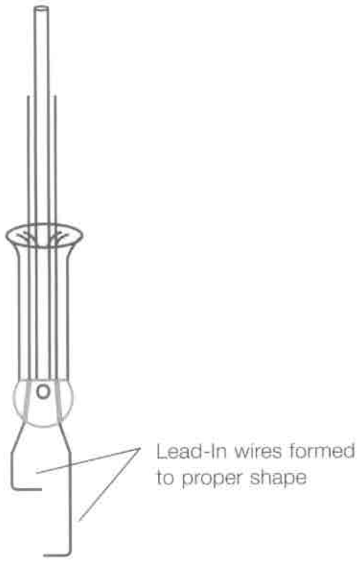


Figure 3

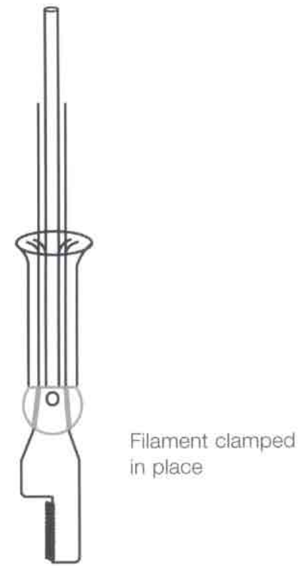


Figure 4

Sealing-in Process

The next series of operations position the lamp mount in an air tight bulb. The entire sealing and exhausting process is a continuous operation performed on a machine with two rotating turrets.

Initially, the lamp mount is positioned in the first turret and held fairly rigidly. A bulb is placed over the mount (figure 5), and the bulb neck and the flared end of the mount are heated and pressed together as they rotate on the turret. As the two are fused into one, the extra glass at the base of the bulb, the cullet, is dropped down around a pin (figure 6). Later, this pin is withdrawn and the cullet is blown into an excess glass container and recycled. As cullet is being disposed, the hot end of the bulb is shaped in a mold to ensure a better fit with a metal base that will be attached later. The aesthetics of the bulb contour above the base are improved in the process.

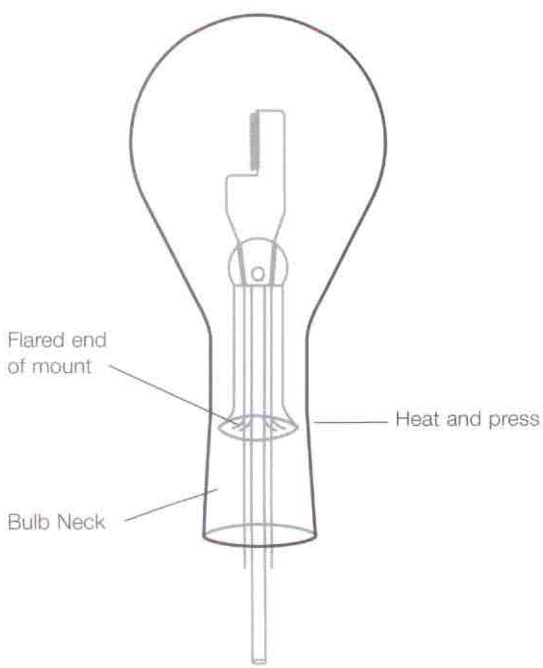


Figure 5 - Mount inserted into bulb

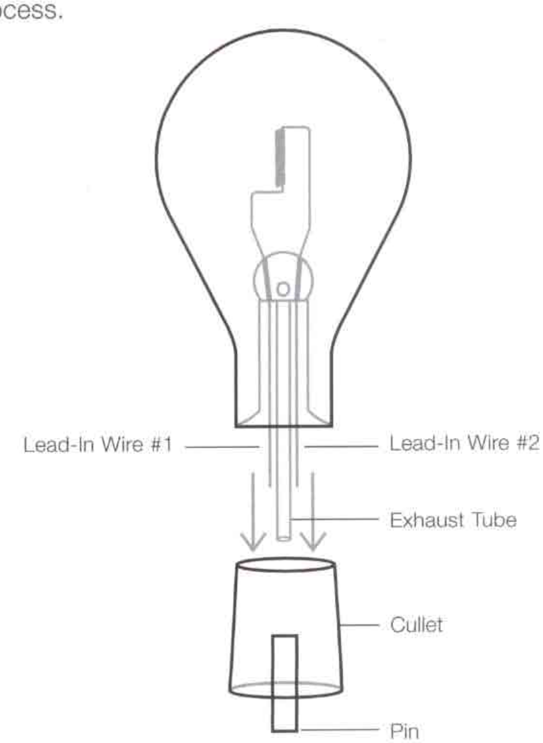


Figure 6

Automatically, this new bulb assembly is transferred to the next turret. Here, the exhaust tube is positioned onto a vertical compression rubber fitting which, through a series of valves, is connected to the "exhaust-flush" and "fill-gas" manifolds of the turret. The exhaust manifold is connected to a fine vacuum source. For gas filled lamps, the air is removed (exhausted), the bulb is flushed with nitrogen and then re-exhausted. After this exhaust/flush/re-exhaust cycle is repeated several times, the bulb is filled with an argon-nitrogen mixture to a pressure slightly below atmosphere before being "sealed-off." For vacuum lamps, the vertical compression rubber fitting is connected only to the exhaust manifold. As the turret is indexed, the bulb assembly is vacuum exhausted several times before "sealing off." In the "sealing-off" process, the exhaust tube is heated to a molten state, separated and then closed just below the point where the flare tube and the bulb have been fused together (figure 7). With the exhaust tube closed and the proper gas pressure or vacuum maintained, the bulb assembly has become a lamp minus a base. The lamp now is transferred automatically to a finishing turret, where a metal base will be fitted.

Figure 7 - Bulb exhausted of air, filled with gas, sealed off and ready for basing

Basing Operation

The "finishing turret" is a large rotary turret with vertical bulb positioning mechanisms equally spaced around the circumference. Above each positioning mechanism is a holder that later will retain the finished bulb-base assembly in a base-up position.

To begin, metal bases are automatically loaded onto the turret and filled with a thermosetting cement which, in viscous form, is forced around the inner periphery, just below the start of the threaded section. As the bulb assembly is automatically loaded onto the turret, one lead-in wire is fed through the center of the base and the other is bent along the bottom of the bulb, up and over the top of the base. The turret is indexed uniformly and several sequential operations are performed on the lamp-base assembly: both lead-in wires are cut, the side lead-in wire is welded to the base (where the bulb and base meet), and the other lead-in wire is soldered to the base eyelet. As the turret is rotated, fires of varying temperatures are played on the base to cure the cement. In the finishing operation, the last few positions of the rotating turret are used to "flash" the lamps. Flashing (instantaneously lighting) a vacuum lamp is done mainly to ignite a reducing chemical material (getter) to eliminate any traces of air (oxygen) not removed during the exhaust/ flush cycles. Tungsten filaments are reacted upon and destroyed by oxygen left in the lamp. Getters are also used in gas filled lamps, but these lamps are flashed at less than rated voltage to slowly condition the filament for the impact received when full voltage is applied.

The lamp is now complete and ready to be used (figure 8).

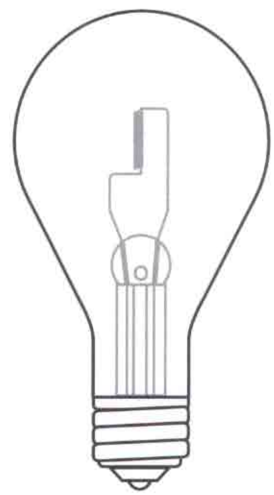


Figure 8 - Completed Lamp

Filaments

Generally, manufacturers make lamp filaments from drawn tungsten. With a melting point of 3380°C (6120°F), tungsten has two important advantages: 1) strength and ductility, which permit a great variety of filament designs and ratings; and, 2) a relatively low rate of evaporation, which permits high operating temperatures (5000°F). Tungsten filaments can be straight sections, coils or double coils. While the ultimate application influences filament type and shape, the primary goal of most filament designs is to concentrate the tungsten to minimize heat loss. The relationship among filament temperature, heat loss and efficacy (lumens per watt) is of the greatest importance.

Almost any heated material radiates electromagnetic energy as conduction and convection losses are minimized. Nevertheless, this radiation is wholly in the infrared unless the temperature brings the material above the critical point where released energy is in the visible region of the spectrum.* As more visible light is emitted for a given energy input, efficacy increases. Thus, efficient filament designs concentrate the tungsten bundle, which increases filament temperature and hence the effectiveness of the lamp as a light source.

The discussion above illustrates how broad the range of radiated electromagnetic energy from an incandescent lamp truly is. This broad spectrum extends far beyond the relatively narrow range in which the eye perceives visible radiation (380nm to 780nm). Even within this narrow range the eye is very sensitive, reaching peak sensitivity at 555nm (green) and dropping downward rapidly to the limits. For these reasons, the practical efficiency of tungsten is on the order of only 6%.

* *In electromagnetic terms, the visible region is usually considered to be from 380 to 780 nanometers (human eyes differ slightly), the infrared region from 780 to 15,000 nanometers.*

Lead-in Wires

"Lead-in" wires conduct electrical current from the base of the lamp through the glass bulb to the filament. For most lamps copper, nickel or nickel plated copper wires are used. Constructed properly, these materials are ideal for lamp construction because: 1) they are "non-gassy" – they outgas no pollutants into the lamp's atmosphere and 2) they have adequate structural strength for sizes commensurate with the electrical currents to be carried. Although less costly, these three lead-in wire materials sometimes yield to the use of molybdenum for lamp types where mounts and filaments are close together (e.g. projection lamps). Typical lead-in wires are three part units made on high speed welding equipment.

- *Lead-in wire #1:* The first section, which is adjacent to the exhaust tube and later outside the sealed bulb (figure 6), is copper about 2" long. The second section is Dumet (dual metal), a nickel-iron alloy core with a copper sleeve that has a coefficient of expansion equivalent to that of glass. The third part, which clamps the filament, is nickel, nickel plated copper or sometimes copper about 2" long.
- *Lead-in wire #2:* The first section is a fuse that activates if the filament fails and arcing begins across the broken section. Without the fuse, the lamp otherwise may draw a high current and damage the socket or activate a circuit breaker. The Dumet section and the third part are the same as on the first lead.

Copper wires conduct current outside of the sealed bulb. Inside the bulb however, a tendency to occlude the gas limits copper's applications to low wattage lamps.

Molybdenum

Not suitable for filament wire, molybdenum is far superior to most metals for an ability to maintain good strength characteristics in fine diameters at high temperatures. Although cost considerations limit its use, molybdenum is an excellent choice for secondary filament supports as well as conducting leads and main supports.

Bulbs

An incandescent filament must operate in a vacuum or inert gas environment within a sealed envelope to prevent rapid oxidation and subsequent disintegration. All incandescent lamps are glass – in most cases lime glass. Lead glass has been used in the past, but lime glass has similar advantages, is lighter in weight and costs less. However, with a practical maximum operating temperature of 850°F, high wattage lime glass lamps require large bulb sizes that are quite susceptible to thermal shock. To keep bulbs reasonably sized and safe, the more temperature tolerant borosilicate glass is a better choice for higher wattage and outdoor lamps.

To avoid concentrated brilliancy, most bulbs are coated on the inside with a silica powder to obtain a highly translucent or diffuse transparent effect. Additionally, colored glass, lacquer and ceramic coatings are used for diffusion and decoration. In this way, virtually any texture, color and output can be achieved.

Gas

After going through a flush/exhaust cycle several times, all incandescent lamps (except vacuum lamps) are filled with a "fill gas." Argon, nitrogen and krypton are used, but argon, with a trace of nitrogen, is utilized in 98% of all gas filled lamps. Because of argon's low heat conductivity and relatively high molecular weight, smaller heat losses and a slower rate of tungsten evaporation are realized. As a result, higher temperature filaments can be utilized, which increase lamp efficacy. The trace of nitrogen is added to mitigate the probability of the fill gas short circuiting between filament coils or lead-in wires. Nitrogen is still used in small high wattage lamps, where the distances between current carrying parts are kept minute.

Krypton, which is heavier than but has characteristics similar to argon, is an excellent fill gas. Using krypton produces an increase up to 10% in efficacy (lumens per watt) without a decrease in lamp life. Unfortunately, Krypton is considerably more expensive than argon and nitrogen. Some OSRAM SYLVANIA Traffic Signal Lamps utilize krypton since the advantages of krypton more than offset the increased cost.

Bases

The criteria for the selection of a material for a lamp base are: 1) whether the material has the proper electrical characteristics 2) whether these characteristics last over the service period and 3) whether the material is easy to form and draw. Bases for all incandescent lamps are either aluminum or brass.

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