Materials for Vacuum Tube Manufacture

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The requirements of metals and alloys for cathodes, anodes, and grids are presented, and a brief treatment of thermionic emission in the cases of oxide-coated, thoriated-tungsten, and tungsten filaments is given. Metals and alloys for use in glass-metal seals are enumerated. The function of getters is explained in connection with the exhaust process. Types of photoelectric tubes and their uses are discussed. Silicates, sulfides, and tungstates are treated in terms of persistence and color of luminescence when used for fluorescent screens in cathode-ray tubes. Miscellaneous materials and parts are listed, and cleaning of vacuum tube parts is discussed in terms of methods.

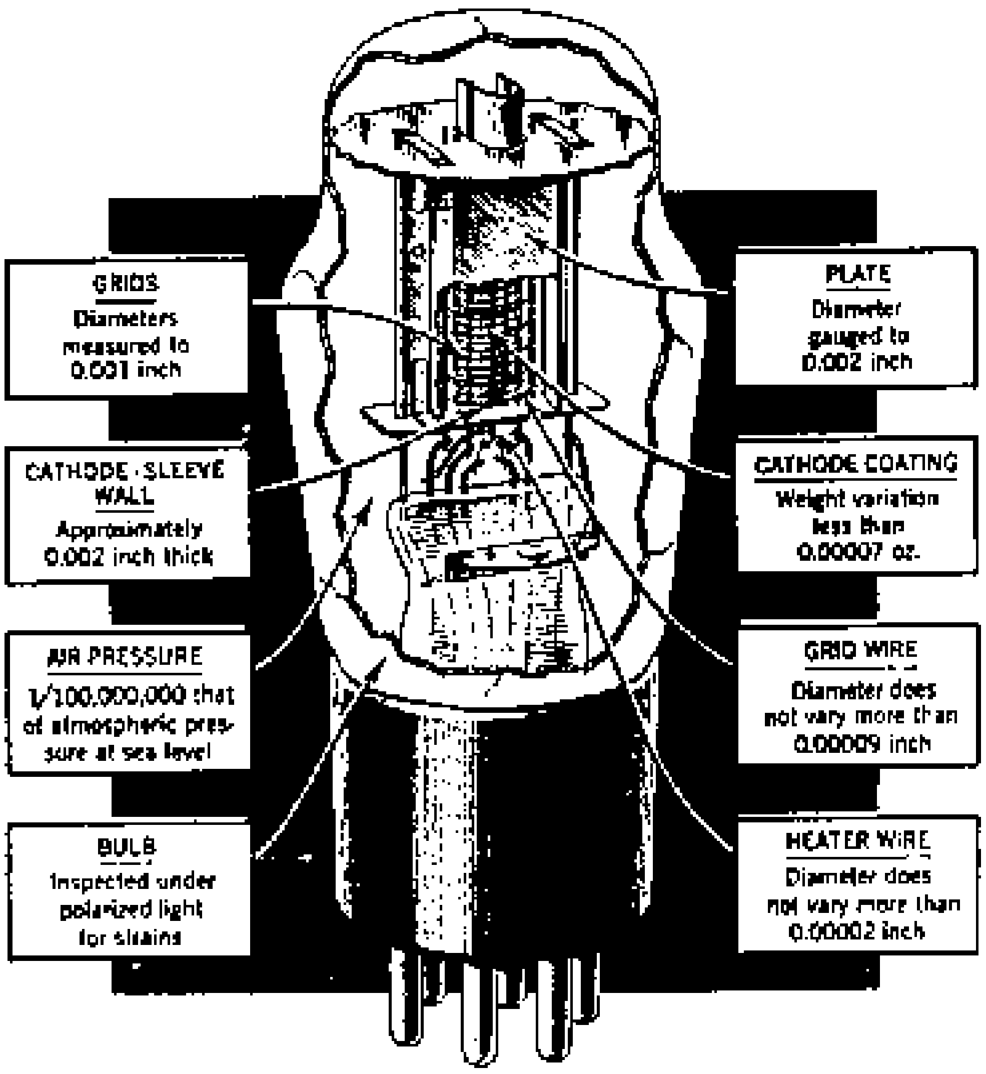
THE term "vacuum tube" is used to identify a large variety of devices which have in common an outer envelope of glass or metal (occasionally quartz), into which one or more electrodes are sealed, and from which the air has been mostly exhausted or has been replaced by some other gas. Mercury rectifiers, gas-filled rectifiers, high-vacuum rectifiers, amplifiers, oscillators, modulators, detectors, photoelectric tubes, cold-cathode tubes, cathode-ray tubes, iconoscopes for television pickup, vacuum thermocouples used for measuring small alternating currents, electron multipliers, ionization gages for measuring the degree of vacuum are among the numerous types that are made. "Electron tubes" is a term considered synonymous with "vacuum tubes"; and the expression "thermonic tubes" is applicable in all cases where the primary electrons are produced thermally.

Filaments and Cathodes

The passage of electric currents between the electrodes of vacuum tubes produces effects which make these tubes useful in various ways; and the cathode is the heart of the tube, since electron emission from this electrode forms the current which determines the characteristics of the tube. The cathode must satisfy three requirements: The required rate of electron emission must be available; the cathode must have a satisfactory life; and the structural strength at high temperatures must be sufficient for the cathode to retain its shape. Since the first two requirements are in opposition, careful choice of materials and design is necessary.

Metals for cathodes must emit electrons easily (low work functions); must have low vapor pressures so that evaporation does not cause early failure; must have high melting points, low thermal conductivities to prevent rapid heat conduction away from the cathode, high tensile strength, and stiffness; and must not fail by creep. Some compensation for failure to meet these requirements completely is possible by changes of cathode shape—e. g., the use of ribbon cathodes.

A heated tungsten filament was one of the early commercial sources of electrons, and tungsten is still the filament material in nearly all large power tubes. The wire must be pure and uniform in properties and dimensions. A local reduction in diameter, for instance, would cause overheating and subsequent burnout at that point. The electron emission efficiency (emission current per watt of heating power) increases as the temperature increases, but the evaporation rate of tungsten sets an upper limit. In order to obtain greater emission efficiency without exceeding the safe operating temperature of the filament, tungsten wire to which has been added 1 to 2 per cent of thoria is often used. The emission efficiency at the operating temperature is increased about tenfold by this method. These filaments may be heated in an atmosphere of hydrocarbons, such as acetylene, benzene, etc., in order to form a surface layer of tungsten carbide. Activation, by heating briefly at 2300–2500° C., results in the production of some thorium by reaction between thorium oxide and tungsten; and subsequent "aging" at 1750–2000° C. permits the



Glass-Type Vacuum Tube

thorium to diffuse to the cathode surface (4), the active surface layer apparently being about one atom thick. Under operating conditions (1500–1700° C.) a small amount of metallic thorium is always diffusing toward the surface. The layer of tungsten carbide, having larger grain size than the tungsten, prevents too rapid diffusion and reduces thorium evaporation from the surface. Thoriated tungsten filaments need not be carbonized and are sometimes used without that treatment.

The use of very high potentials, as in power tubes, results in bombardment of the filament by gaseous ions. These ions remove thorium from the cathode surface at a relatively rapid rate, and for this reason pure tungsten filaments are generally used in high power tubes, despite the higher cathode temperature required and the poorer efficiency obtained.

In many cases it is necessary to obtain good emission at relatively low temperatures, as in the case of receiving-type radio tubes and similar types. Unfortunately, the best emitters have melting points which are too low for use even in such tubes. Cesium is an excellent emitter, as are barium and strontium; but the melting points are too low. However, it has been found that if such metals are applied to the surface of other metals, the evaporation is not so great as when the second metal is not present. Cesium may be deposited upon silver or tungsten, and barium upon nickel, platinum, or their alloys. A mixture of barium and strontium carbonates is usually applied to a wire of nickel or nickel alloyed with silicon, cobalt, iron, or titanium, or to a wire of platinum alloys containing nickel, cobalt, rhodium, or iridium. At the operating temperature (700–900° C.) some metallic barium and strontium are produced (5), and these metals, in a layer probably about one atom thick, act as the emitter. A small amount of the active metals is produced continuously from the oxides by electrolysis resulting from the flow of electron current (1).

With tubes having cathodes heated by alternating current, it is usually necessary to separate the cathode circuit from the heating circuit, which is done by inserting a heater wire into a tubular cathode, usually of nickel, coated with barium and strontium carbonates. An insulator of alumina, beryllia, or magnesia separates the heater from the cathode. In this arrangement the cathode temperature is, as before, 700–900° C., but in order to attain this temperature, the heater must reach 1000–1400° C. Tungsten is one of the most used heater materials.

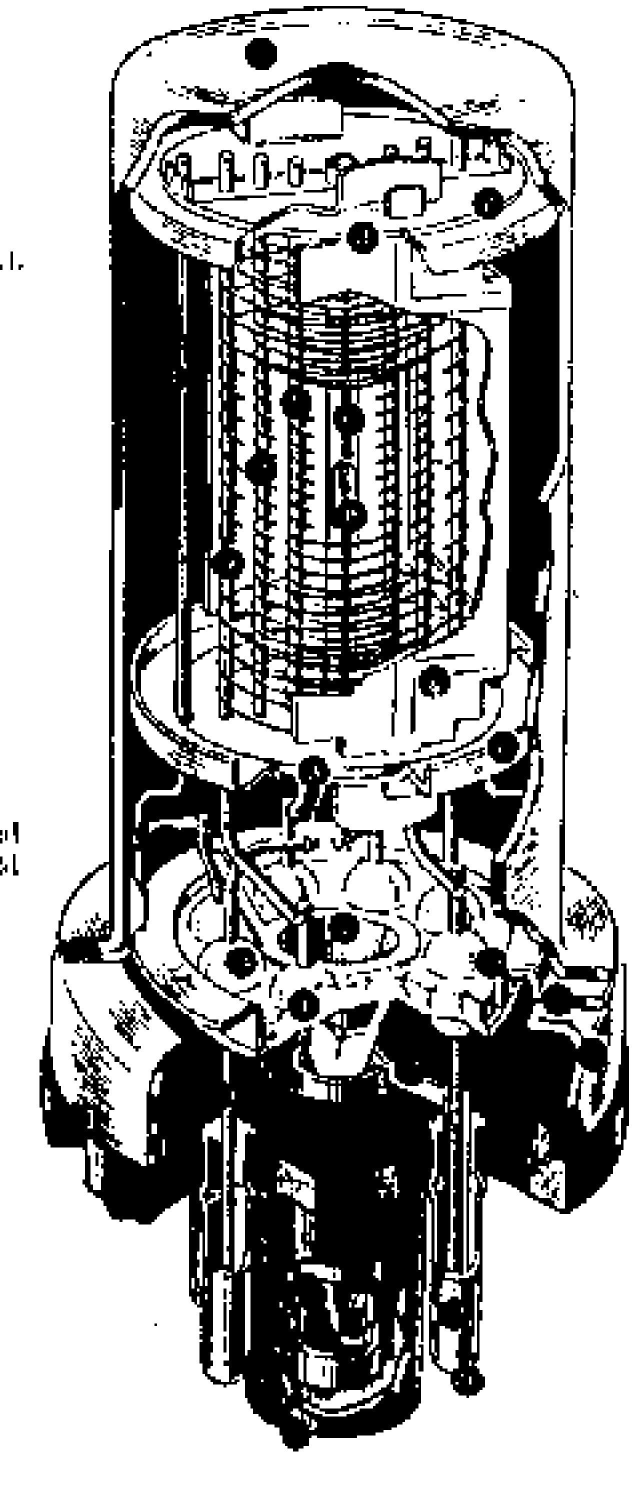
Requirements for the purity of cathode metal, ceramic insulation, heater wire, and the carbonates are specially strict. A cathode is readily "poisoned" by numerous impurities. The resultant poor emission does not become apparent until the tube is practically completed. Oil and grease must be removed from all parts used in a tube, gases must be removed as completely as possible, and the tube parts must not be permitted to stand for any great length of time exposed to the atmosphere. In addition to maintaining the purity requirements, it is essential that the physical and chemical characteristics of the carbonates be controlled with extreme care.

The Anode

The anode (plate) is the second most important electrode in a vacuum tube, since the electrons emitted from the cathode must be collected by the anode in order to furnish output current. To keep the dimensions of the tube as small as possible, the thermal loading of the anode must be as high as possible. This stipulation places definite restrictions on the

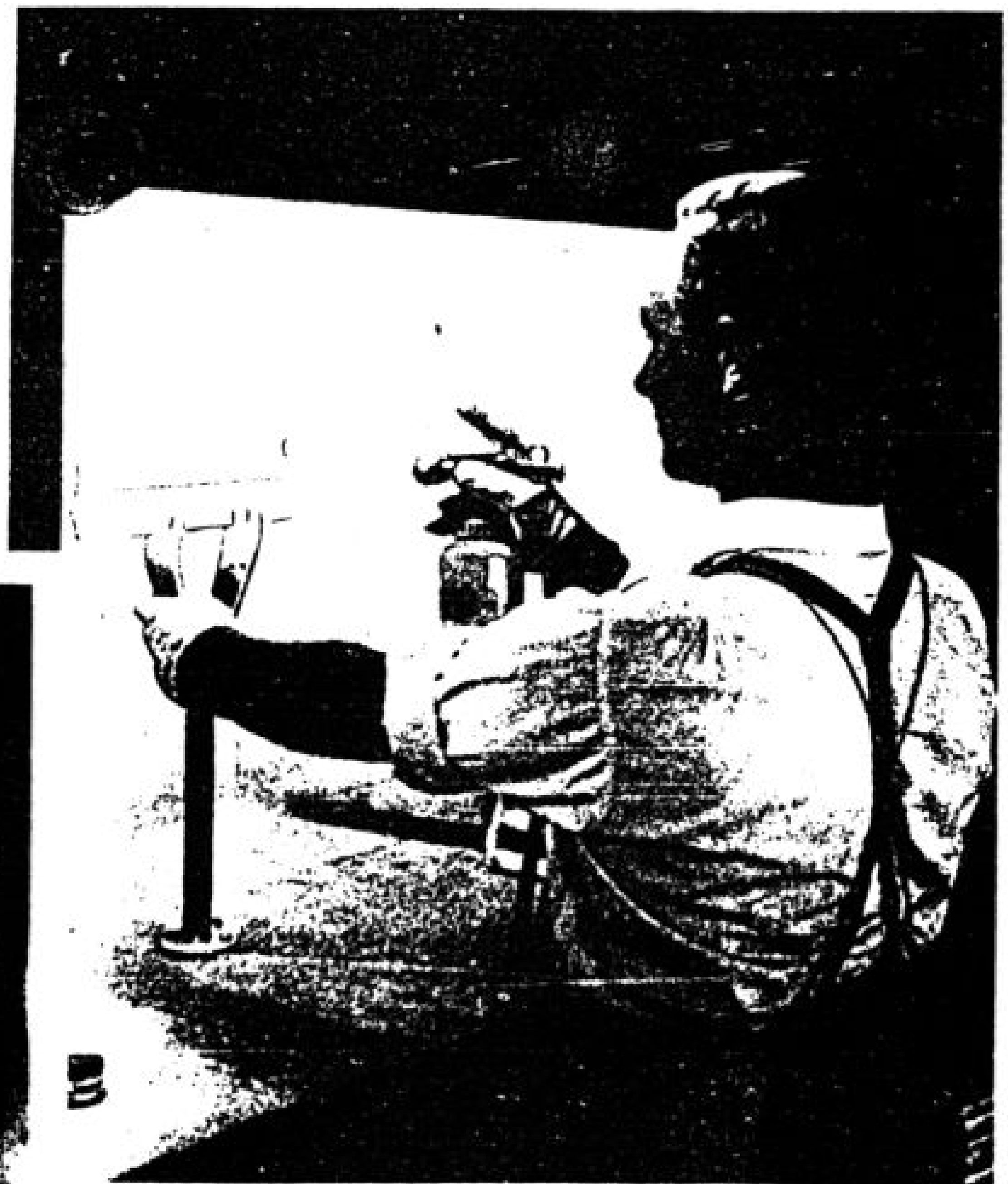
Structure of a Metal Radio Tube

1. Metal envelope
2. Spacer shield
3. Insulating spacer
4. Mount support
5. Control grid
6. Coated cathode
7. Screen
8. Heater
9. Suppressor
10. Plate
11. Batalum getter
12. Conical stem shield
13. Header
14. Glass seal
15. Header insert
16. Glass-button stem seal
17. Cylindrical base shield
18. Header skirt
19. Lead wire
20. Crimped lock
21. Phenolic base
22. Exhaust tube
23. Base pin
24. Exhaust tip
25. Aligning key
26. Solder
27. Aligning plug



(*Right*) Spraying Cathodes

The exterior surface of the cathode sleeve is sprayed with many layers of electron-emitting material. Great care is exercised to maintain uniform thickness of the coating.



(*Below*) Assembling Electrodes of a Metal Receiving Tube

The operator assembles the parts on a jig which aligns and spaces the parts while they are being welded.

(*Below*) Assembling the Electron Gun of a Cathode-Ray Tube

The electrodes are placed on a special jig which maintains correct alignment of parts during the assembly process. Alignment tolerances must be held within a few thousandths of an inch.

materials which can be used. The heat generated by electronic impact can, in small tubes of conventional design, be dissipated only by radiation, since conduction is negligible. In the case of water-cooled tubes or others in which the anode forms part of the external envelope, conduction is utilized for cooling the anode, and radiation is negligible.

With tubes of low power output, the anode is made of nickel, iron strip, or nickel-plated iron. When greater heat dissipation is necessary, the nickel strip is carbonized to give it a coating of amorphous and graphitic carbon. Where plate voltages and operating temperatures are high, the liberation of gas from these anodes would be