The Use of Platinum in High Power Thermionic Valves

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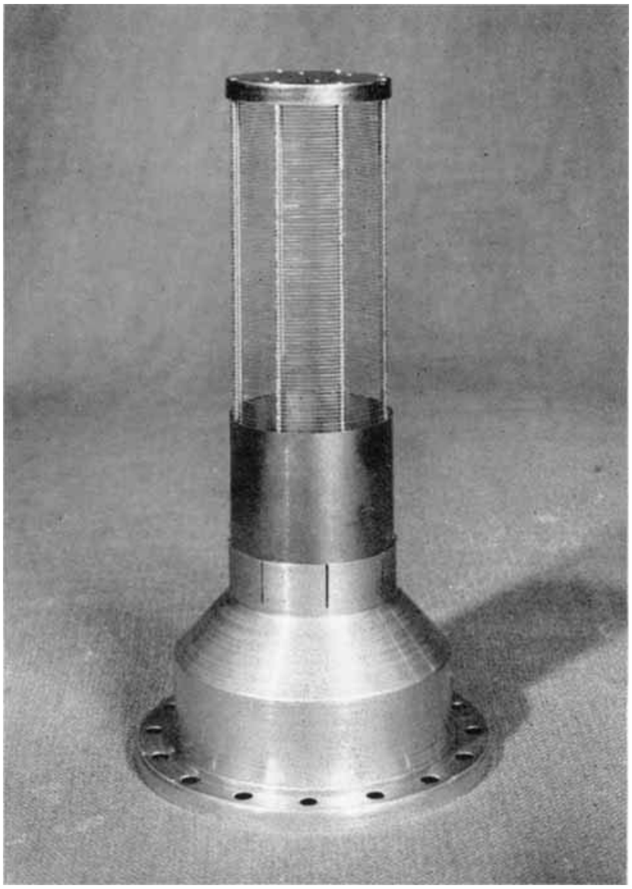
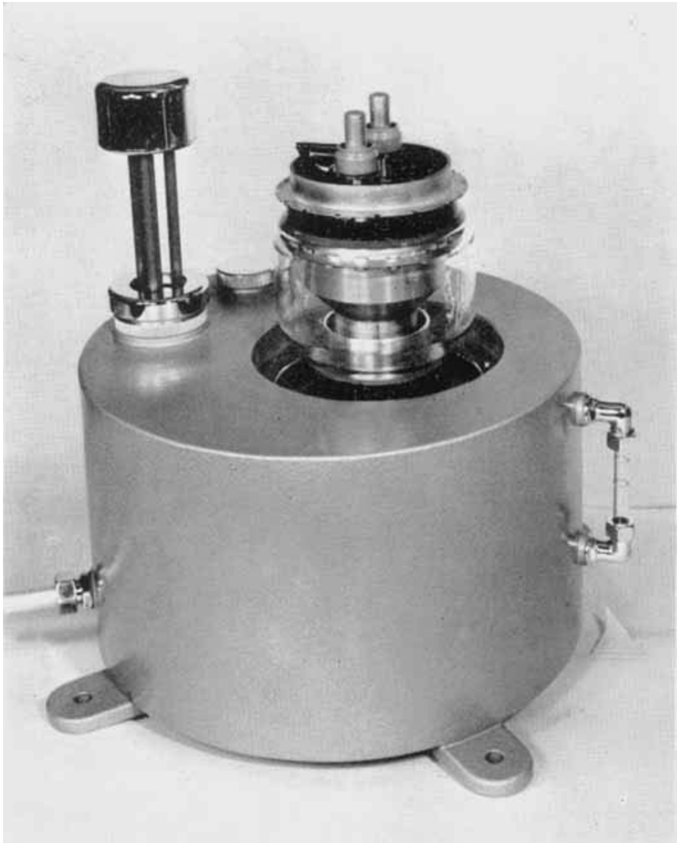
In large thermionic tubes for use in radio transmitters, modulators and such industrial applications as induction heating, platinum is now in regular use in the form of platinum-clad molybdenum wire employed in the construction of the main control grid.

The need for platinum was brought about by the development of valves employing a thoriated tungsten filamentary cathode in the place of the originally used plain tungsten cathode. In the earlier types of valve the control grids were usually made of pure molybdenum wire as being a suitable structural material capable of withstanding the very high running temperatures involved.

The molybdenum grid structure proved perfectly satisfactory until the introduction of the thoriated tungsten filament. This type



To combine the negligibly low grid emission characteristic of platinum with the rigidity and high-temperature strength of molybdenum, control grid assemblies in large thermionic valves for transmission and industrial uses are constructed with platinum-clad molybdenum wire. The illustration shows a typical grid structure of this kind



The grid structure shown on the facing page is fitted in this 35 kW steam-cooled valve. In the illustration the valve is mounted in a jacket, as used in many industrial heating applications

of filament owes its superior emission characteristics to the fact that the thoria present (usually about 1 per cent) slowly breaks down to metallic thorium at the running temperature of the cathode, approximately 1770°C, and this thorium migrates to the surface of the cathode wire where it forms a thin monatomic layer which constitutes the electron emitting surface. Unfortunately the thorium also slowly evaporates from the filament and condenses on the other exposed surfaces of the valve including, of course, the control grids, and in particular g_1, this being the most exposed and closest electrode to the cathode.

In the older types of valve employing a molybdenum grid structure, little or no emission from the grid took place at normal running temperatures, but if thoria is allowed to coat the surface of the molybdenum, the grid can now become an electron emitter at relatively low temperatures and the resultant grid current can lead to failure in operation and in extreme cases to catastrophic destruction of the valve.

The mechanism by which grid emission can lead to valve failure is relatively simple and can best be illustrated by taking as an example a valve employed as a pulse modulator intended to pass extremely short pulses of current at such intervals of time that the mean power dissipated in the valve is not greater than its design and cooling system permit. In such applications the anode potential is invariably high, indeed so high that if the duration of the pulse current were allowed to increase then the total dissipation would be many times the safe figure. Such a valve is normally operated with its control grid (g_1) biased to a potential sufficiently

A high-power television tetrode in which both control grid and screen grid are made of platinum-clad molybdenum wire

negative with respect to its cathode to prohibit electron flow that is beyond cut-off. In practice, due to the necessity for impressing control voltages on the grid, the external grid circuit possesses finite resistive impedance.

Under normal conditions of a non-emitting grid, no grid current will flow under cut-off conditions and only a limited current will appear as the grid becomes more positive and passes the cathode potential. The sense of this grid current is that to be expected where the grid is positive and functioning as an anode in relation to the cathode. If now, however, we consider a grid that has become an electron emitter, grid current can flow under conditions where the grid is biased negatively and is supressing anode current. The grid current in this case tends to force the grid potential positively and anode current will commence to flow in the valve. Unfortunately, this is a steady current and at the high anode potential employed will represent a high anode dissipation. This tends to increase electrode temperatures, the grid itself has probably risen in temperature due to self-emission and the grid emission also tends to rise. It is not, therefore, difficult to see how this ascending spiral can eventually cancel the negative bias on the control grid and the anode current will now "run away".

The solution to these problems obviously lies in the choice of a grid material which even in the presence of thoria has a sufficiently low emission to yield a grid current of negligibly small value. One of the most suitable materials for this purpose is found to be platinum, but in view of its softness, lack of rigidity and low tensile strength it is quite unsuitable as a structural material for grid assemblies, apart from the high cost that would be involved. A logical step towards obtaining a satisfactory compromise is to use a molybdenum wire having a coating of platinum of sufficient thickness to eliminate emission effects while still exhibiting the structural advantages of molybdenum.

Such a wire is produced by drawing a sleeve of pure platinum over a rod of molybdenum and then reducing the size of the composite rod by similar methods, that is, by swaging and drawing, to those used in the manufacture of molybdenum wire. The resulting wire, which normally contains some

25 per cent of platinum by weight, is used in various sizes ranging from some 2 mm diameter for the "back bone" or grid support, down to 0.25 mm diameter or less for the wire used for actual grid winding.

To enable this composite wire to be manufactured, and indeed after manufacture to be satisfactorily used, it is obviously necessary that the bond between platinum and molybdenum should be sound throughout the interface. In the early days of manufacture the molybdenum rod was coated with a thin layer of nickel prior to drawing the platinum in an attempt to improve the bond between the two metals. Unfortunately, while it was successful in assisting the manufacturing process, the nickel was found to diffuse through the platinum during the high temperature pumping schedule of the valve and to condense as a thin film on the exposed surfaces of both valve envelope and electrodes. Non-adherence of this film permitted flash arcing when the valve was operating under high voltage conditions and in extreme cases inter-electrode shorts could take place.

More recently the manufacture of the composite platinum-clad molybdenum wire has been accomplished without the use of the nickel interface, the quality of the bond and of the finished product being maintained by precise control of manufacturing conditions.

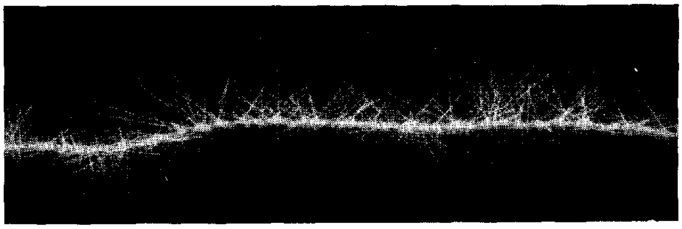
It has been found in practice that the composite wire exhibits the hot strength of the molybdenum core and has the very real advantage of being more readily spot welded than molybdenum largely due to freedom from oxidation.

The disadvantages of employing grid wires of this type are that the wire cannot be run with as high a power dissipation as the bare molybdenum grid will permit, partly due to the lower melting point of platinum (1769°C as against 2620°C for molybdenum) and partly due to the tendency for the two metals to fuse together slightly during life which leads to some grid distortion. For these reasons grids are usually designed to run at a dissipation per unit surface area of 10 watts per sq. cm., at which level the grid wire is generally assumed to operate at a temperature approximating to 1400°C.

Platinum has thus shown itself to be one of the best tools so far in the hands of the transmitting valve engineer for combating one of his main causes of valve loss during manufacture—grid emission.

Exothermic Fuse Wire

Based upon the exothermic reaction that takes place between aluminium or magnesium and platinum or palladium after a critical temperature has been reached, an interesting new product has been developed by the Sigmund Cohn Corporation of Mount Vernon, New York. This comprises a composite wire having a core of aluminium with a sheath of palladium. The wire is strong and ductile, but when heated to about 650°C by the passage of a current it ignites with explosive violence and reaches a temperature of about 2000°C. A similar product is also available in the form of laminated sheet. Applications are expected to develop in the field of detonating devices.



A photograph of 0.003 inch diameter palladium-clad aluminium wire less than 5 milliseconds after ignition