March 20, 1945. W. W. WATROUS, JR 2,372,037

THERMIONIC DEVICE AND MEANS AND METHOD OF FABRICATION

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Fig. 1.

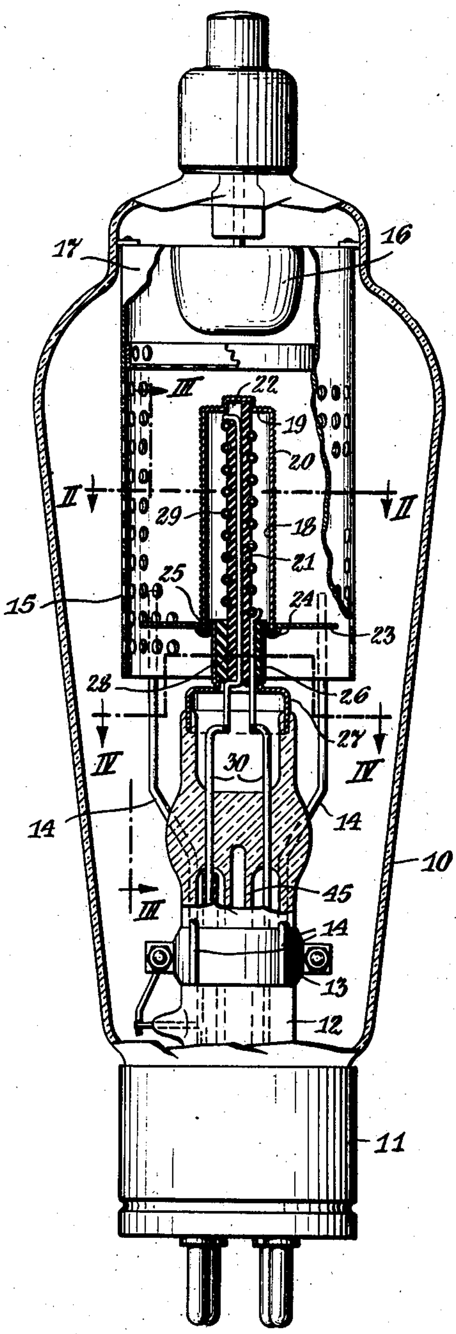

Fig. 2.

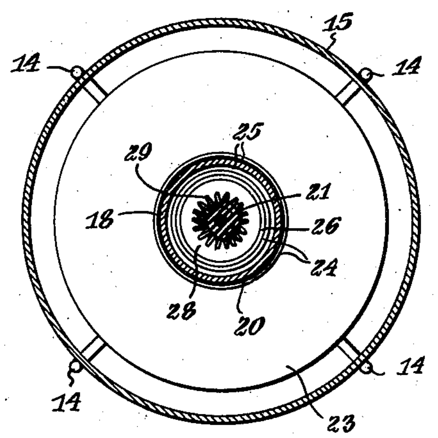

Fig. 3

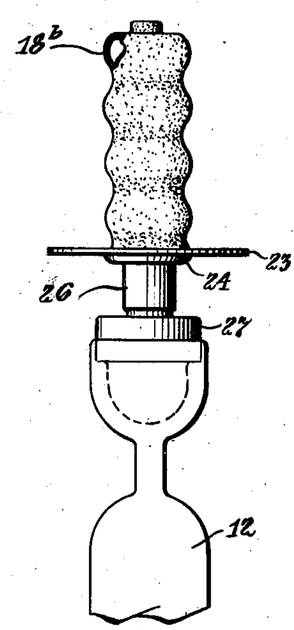

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Fig. 4.

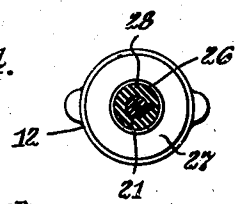


Fig. 5.

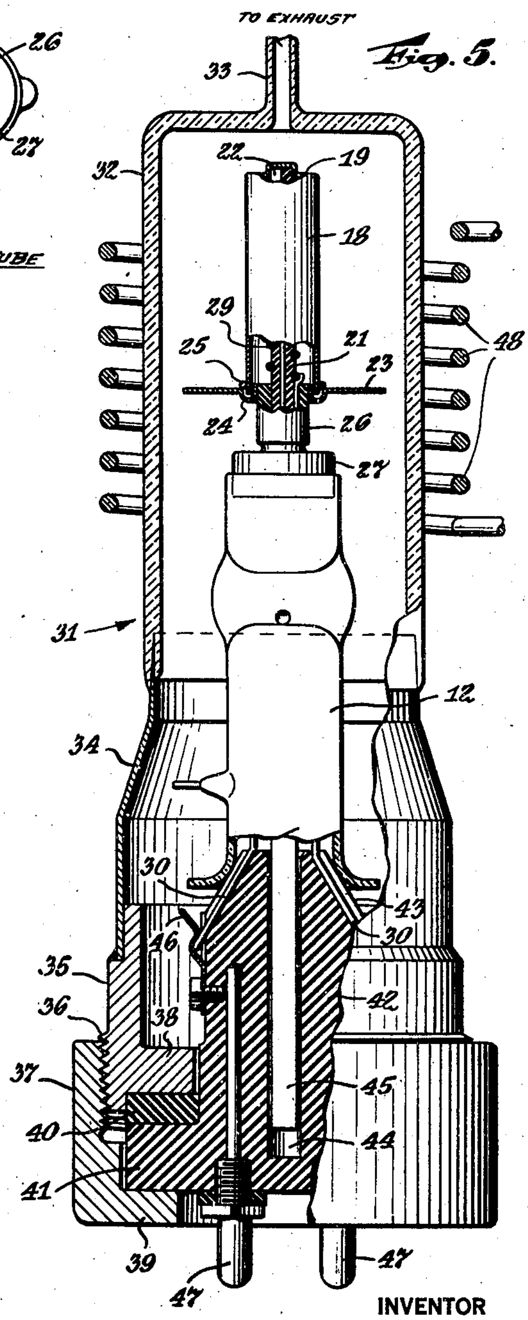
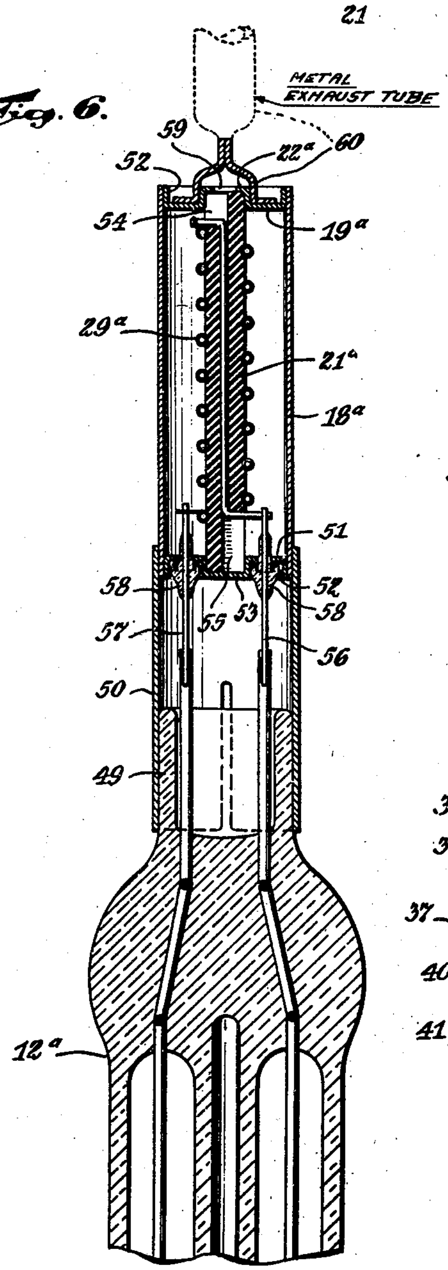


Fig. 6.



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THERMIONIC DEVICE AND MEANS AND METHOD OF FABRICATION

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Application October 17, 1942, Serial No. 462,342

5 Claims. (Cl. 250—27.5)

This invention relates to thermionic devices and means and method of fabrication thereof, and is directed more particularly to the cathode structure and its manufacture and assembly, and has relation more especially to cathodes capable of employing high potentials.

The use of high potential, that is, any potential above approximately ten volts, for energizing the cathode of a gas or vapor filled electronic tube has been extremely limited due to the difficulties involved in the construction and use of such a device. As a matter of fact, despite the desirability of high cathode potentials for cathode supply, probably 95% of the gas or vapor filled tubes used today operate with cathode potentials under seven volts.

The major difficulty in the use of higher cathode potentials is the fact that as soon as any portion of the cathode, which has attained an emitting temperature, assumes a potential in excess of approximately twelve volts (instantaneous) in respect to any other portion of the cathode, the gas or vapor content of the tube becomes ionized and a discharge occurs. Depending on circumstances, this discharge current may be of sufficient value to actually melt the cathode structure. In any event, the ionization present may very likely cause arc-back in a rectifier, and is almost certain to cause a control tube, such as a thyratron, to lose control.

It has been a common practice in the art to build up, by spraying, dipping, or otherwise, a thick coating of insulation on the filament of an indirectly heated cathode. Such a structure has numerous drawbacks, amongst which may be mentioned the fact that the insulation of that character readily cracks due to expansion and thermal shock. Such cracks may expose the heater or filament so that discharge can occur or in severe cases so that an actual short-circuit occurs. Furthermore, insulation becomes less insulative and more conductive as temperatures are increased, and this tendency to become conductive has rendered insulation of the character described undesirable but heretofore necessary in the character of tubes of present concern. Impurities in the insulative material will greatly exaggerate the condition just mentioned of conductivity, and the expense and difficulty of purification of the material to be used as the insulation also is an adverse condition to use of indirectly heated cathodes by insulated filaments.

An object of the invention accordingly is to provide an indirectly heated cathode which will avoid the drawbacks of a heavily coated heater filament.

An equally important object of the invention is to provide a cathode which will be capable of operation at high voltages without detrimental effects arising affecting tube life or operation.

Another object of the invention is to provide a cathode which will avoid arcing with a cathode potential in excess of present-day usual voltage for heater purposes of indirectly heated cathodes.

A further object of the invention is to provide a cathode of the character indicated which is of practical manufacture and assembly.

A still further object of the invention is to provide a cathode of the character indicated utilizing a heater within the same which is prevented from arcing to the cathode in use with high potentials.

Another object of the invention is to enable a cathode heater to be situated in vacuum in a gas or vapor filled tube.

Yet another object of the invention is to provide an improved method of fabrication of a tube fulfilling the above objects in whole or in part.

Again, an object of the invention is to provide apparatus for evacuating the cathode-heater region and seal the same against ingress of the gas or vapor of the discharge tube.

Additional objects of the invention will appear as the description progresses, both by direct recitation thereof and by implication from the context.

Referring to the accompanying drawings in which like numerals of reference indicate similar parts throughout the several views;

Figure 1 is a vertical sectional view of a thermionic device wherein my improved cathode is shown in longitudinal section;

Figure 2 is a cross-sectional view on the line II—II of Fig. 1;

Figure 3 is a vertical elevational view of a cathode and associated parts viewed as indicated by arrows III—III of Fig. 1, and showing a modified configuration of cathode;

Figure 4 is a cross-sectional view on the line IV—IV of Fig. 1;

Figure 5 is a sectional elevation of apparatus for evacuation of the cathode-heater region, and showing a cathode and associated parts situated therein for evacuation; and

Figure 6 is a modified construction of cathode having tubulation connection shown therewith for purposes of evacuation.

In the specific embodiment of the invention illustrated in said drawings, the reference numeral 10 designates a glass or other envelope having a base 11 thereon and a stem 12 therein as customary in the art. In the particular showing in the drawings, the stem is illustrated as having a collar clamp 13 thereon from which extend upwardly supporting rods 14 in turn mounting a grid 15 of foraminous material in the region above the stem and within the envelope. An anode 16 is depicted at the upper part of the envelope within a cylindrical extension 17 of the grid.

A cathode in accordance with the present invention is situated coaxially within the grid and has support from the stem. Said cathode is preferably a hollow metallic shell providing a cylindrical wall 18 the upper end of which is closed by an end wall 19 shown as integrally formed with the said cylindrical wall with the outer surface of both said walls coated with suitable electron emissive coating 20 or otherwise rendered electron emissive. Within the shell, coaxial therewith, is an insulator 21 of generally cylindrical shape and longer than the shell. The end wall 19 of the shell has an appropriate pocket 22 pressed therefrom to receive and position the end of said insulator 21.

At the lower end of shell 18 of the cathode is a transverse disc-shaped metallic plate 23 which has a central orifice somewhat larger than the diameter of the aforementioned insulator 21 but of less diameter than the said shell. At the part of said plate underlying the end of said shell, said plate is impressed with an annular trough 24 of ample capacity for receiving the said end of the shell and a continuous filling of solder 25 by which a vacuum-tight seal is obtained between the shell and plate. Use of plate 23 promotes inductive heating for melting the solder during fabrication and constitutes a shield between the stem and lead-in wires and the main part of the interior of the envelope where ionization takes place in use of the device. Projecting from below and into the orifice of said plate and sealed to said plate by welding or otherwise, is a sleeve 26 constituting a mounting means for the cathode. The lower part of said mounting means or sleeve 26 shoulders outward and then downward to provide an integral enlargement 27 the lower rim whereof is sealed in the glass of stem 12. Preferably said sleeve is an integral piece of material of cylindrical shape having a coefficient of expansion which is substantially that of the glass of the press. Material sold in the trade under the trade-name of "Kovar" may well be used for the purpose. Within the said sleeve 26 and engirdling a lower end portion of said insulator 21 which depends into the sleeve substantially the full length thereof, is an intervening collar of insulative material 28 which according positions the insulator coaxially with respect to the sleeve, plate and shell.

A heater filament 29 such as a coiled spiral shown, is wound around the insulator 21 for the length thereof from the upper end of collar 28 substantially to the upper end of the insulator but sufficiently below the upper end so as to be out of contact from the end wall of the shell. The insulator is shown as having a central bore therethrough thereby enabling an upper end connection for the heater filament to be extended downwardly therethrough and to protrude into the region confined by the enlargement of the sleeve and its seal with the stem. The other end of the filament coil has a connection which extends downwardly into this same region by passing between the insulator and said collar 28. The filament may be coated with a thin layer of insulation if desired as a precaution against short circuiting between parts thereof which might, in use, contact one another due to expansion, sagging or other causes. A thin insulation apparently expands and contracts more readily without cracking than heavy coating of insulation, and thin insulation is ample in the present case. Furthermore cracking of the filament insulation in the present construction does not promote discharge as in the prior art. The downwardly extended ends of the filament connections are secured to appropriate lead-in wires 30, 30 which are sealed through the stem in usual manner. The regions within the shell 18 of the cathode and between the sleeve and the stem are intercommunicating due to the looseness of the collar and insulator and of the filament wire connection within each, or otherwise as found desirable as by communicating holes or grooves, so that evacuation of the one region obtains evacuation of both. It will be observed that said regions are wholly confined so that a vacuum may be maintained therein. Such a vacuum is provided, and in consequence thereof it is now to be observed that the heater filament is operating in a vacuum irrespective of what pressure of gas or vapor may exist on the exterior of the cathode within the envelope.

The particular device shown is one wherein the envelope is evacuated to remove the air therefrom and thereafter has a gas of desired character and quantity admitted into the envelope before sealing. The completed device consequently comprises a tube containing a gaseous atmosphere and having therein an evacuated enclosure for a heater which is thus operating in vacuum while the surrounding part of the tube is operating with gas present. The heater voltage therefore will have no opportunity to cause gas breakdown even though that voltage is considerably higher than ordinarily used in present-day practice. The structure accordingly enables me to accomplish the desired result of operating the filament heater at considerably more than seven volts, so that I am enabled to connect the filament direct to commercial lines and operate the device with 110, 220 or other voltages if so desired.

The method of fabrication by which I obtain a sealed enclosure for the cathode heater filament is illustrated in one embodiment in the showing particularly of Figures 1 and 5. Apparatus used in conjunction with the method will be simultaneously described. Before assembly of the stem and cathode in the envelope, evacuation of the heater region is effected. For that purpose, the stem is mounted temporarily in a housing 31 which in the present showing comprises a glass dome 32 having an exhaust connection 33 at its top. The bottom edge of the dome is sealed to a copper or other sleeve 34 the lower margin of which is in turn soldered or otherwise secured vacuum tight to a rigid collar 35 having an internal diameter sufficient to admit insertion of the stem and cathode therethrough into the interior of the dome. The outside of the collar is threaded at 36 to receive a threaded coupling ring 37. The collar 35 and coupling ring 36 have inwardly directed flanges 38, 39 respectively adapted to tightly clamp therebetween a rubber or other washer 40 superposed upon an annular rim 41 of an inwardly directed insulative nipple 42 formed with a tapered inner end 43 constituting a temporary seat for the lower end of the stem 12. Said nipple also has a deep pocket 44 for reception of the tubulation 45 forming part of the stem structure and has spring clips 46 on its sides to receive and grip the filament lead-in wires 30. Suitable electrical connectors 47 are provided from the clips to the bottom of the nipple enabling heating current to be applied to the filament while mounted in the apparatus being described. It is now appropriate to observe that the apparatus thus assembled is a complete enclosure for the stem and cathode and may be subjected to evacuation which thereby effects evacuation of the interior region of the cathode shell, prior to the soldering of said shell to plate 23.

Upon introduction of the stem and cathode into the evacuating apparatus of Fig. 5, shell 18 is not yet sealed to plate 23, but is loose with respect thereto thereby enabling evacuation within the dome to be effective to evacuate air from within the shell. A ring of solder is situated around the base of the shell ready for melting, and when out-gasing and evacuation has been accomplished, augmented by running the filament at a high temperature, a high frequency coil 48 placed around the dome obtains an inductive heating of the plate 23 sufficient to melt the ring of solder which thereupon flows into the trough 24 where it is allowed to harden and which then seals the shell vacuum tight in place. There being no other openings into the interior region of the cathode, it is thereafter an evacuated region and may be removed from the evacuating apparatus and the tube completed as shown in Fig. 1.

A structure of cathode capable of evacuation through tubulation is illustrated in Figure 6. Furthermore in this modified construction, evacuation is not extended to include the region between the cathode and stem, but is confined to the region within the cathode only. Describing this modification more in detail, stem 12*a* is provided with an upper cylindrical neck 49 around which is mounted the lower end of a metallic cylindrical sleeve 50 having appropriate fit thereon for the purpose. The upper part of said sleeve projects above the neck portion of the stem and overlaps the lower end of a cylindrical cathode shell 18*a* to which it is welded or otherwise secured. The cathode shell in this instance is shown as tubular and of course electron emissive on its outer surface, and is closed at both ends by headers or end walls of which the upper one is identified as upper end wall 19*a* and the lower one is identified as bottom end wall 51. Each is shown as fitting within the cathode shell and as having an outwardly directed flange 52 which fits the shell and is welded or otherwise sealed thereto. The upper end wall has a pocket 22*a* pressed upwardly therefrom and the bottom end wall has a similar pocket 53 pressed downwardly therefrom, both pockets being coaxial with the shell and adapted to receive the ends of a cylindrical insulator 21*a* supporting and positioning the same. A filament 29*a* is shown as wound spirally around the insulator, the upper end of the spiral being connected through a lateral slot 54 next the upper end of the insulator to make electrical connection downwardly through a central bore of the insulator and outwardly through another lateral slot 55 to a lead-in wire 56. The lower end of the spiral part of the filament makes connection to another lead-in wire 57. Said lead-in wires pass through the bottom wall, suitably insulated and sealed with respect thereto as by glass beads 58, 58.

The upper end wall 19*a* provides an opening 59 therein for evacuation purposes, said opening preferably being provided at the upper part of pocket 22*a*. A tubulation 60 is secured to the upper end wall at the outside of said pocket and provides means for evacuation of the interior region of the cathode shell by virtue of the passage made by the presence of slot 54 in the insulator of the aforementioned opening 59 in the upper end wall. Tubulation 60 is preferably metal and after evacuation has been accomplished, said tubulation is pinched and sealed together closely above the said upper wall and tubulation severed at or above the pinched and sealed portion. The interior region is accordingly readily evacuated and maintained in the evacuated condition so that the assembly can be completed by addition of the grid, as in Fig. 1, to the stem and the stem sealed within the envelope.

While in the foregoing description cathode shell 18 and 18*a* has been defined as cylindrical, it is to be understood that other shapes and configurations of hollow cathode may be employed of which an additional example is given in Fig. 3. In that figure the cathode shell 18*b* is shown as having a corrugated wall which constitutes one illustration not only of a different configuration of cathode, but also of a cathode of limited length having increased emissive surface. Except for this difference in Fig. 3, this view may be considered an elevation of the cathode and stem assembly otherwise shown in Fig. 1, its lower end being sealed in trough 24 of plate 23 as in that figure.

While in the foregoing description of the several constructions shown reference has been made to the evacuation and maintenance of the interior region of the cathode evacuated, it is within the scope of the invention to refill said region with a suitable gas at a relatively high pressure as compared to the pressure in the body of the envelope. The pressure difference should of course be well above a pressure at which breakdown or "end-to-end" discharge would occur, and as example thereof, the pressure difference should be in the range, say from 25 to 760 mm. where the cathode contains gas under pressure. Where the cathode is evacuated the pressure difference thereof from the body of the envelope may be in the range, say from 50 to 5000 microns. Examples of gases that are contemplated are xenon, krypton, neon, argon, helium, nitrogen, hydrogen and the like, which will not combine with materials present in or forming the cathode. Presence of gas within the cathode region when of this suitable character, aids in heat transfer from the heater to the cathode shell and will thus enable the heater to operate at a lower temperature. The invention accordingly is exemplified in either construction, namely, a radical difference of pressure is maintained between the interior of the cathode and the interior of the body of the envelope. The tube will therefore operate in the part of the voltage-pressure curve well above the low dip of the curve and in the parts of the curve tapering toward infinity.

Since the various details of construction, as well as the precise relation and functioning of parts, are subject to variation and change without departing from the inventive concept or scope of the invention, it is intended that all matter contained in the specification or illustrated in the drawings, shall be interpreted as exemplary and not in a limiting sense. It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein shown and described and all statements of the scope of the invention herein set forth as a matter of language which might be said to fall therebetween.

I claim:

1. A cathode comprising a hollow shell having an exterior emitting surface, a heater within said shell, means closing the upper end of said shell to external pressure, means closing the bottom end of the shell to external pressure, and means rigidly carried by the respective closing means at both the upper and bottom ends of said shell, centering said heater coaxially therein, said shell maintaining pressure within the same different than pressure outside said cathode.

2. A cathode comprising a hollow shell, an upper end wall for said shell, said end wall having a centrally disposed pocket therein, an insulator longitudinally situated in said shell and projecting at its upper end into said pocket, and means at the lower end of said insulator positioning said insulator coaxially of the cathode and sealing the cathode to maintain a vacuum therein.

3. A cathode and stem assembly comprising a glass stem having a sleeve sealed thereto, a plate transverse to and sealed to said sleeve, said plate having an annular trough therein, a closed cathode shell having one end thereof sealed in said trough, and a heater within said shell, said stem, sleeve and shell providing a confined region and said region being evacuated thereby preventing ionization and discharge between the heater and cathode.

4. A cathode comprising a hollow shell, an end wall at each end of said shell sealed thereto, each end wall having a pocket, an insulator longitudinally situated in said shell and carried at its ends in said pockets, and a tubulation sealed to one of said pockets, said pocket to which said tubulation is sealed having an opening from the interior of the shell into said tubulation for evacuation purposes, said hollow shell being evacuated and said tubulation pinched and sealed closed for maintaining the vacuum in said shell, and a heater on said insulator within said shell and operating in the vacuum in said shell.

5. A method of fabrication of a hollow cathode for mounting said cathode on a stem and evacuating the cathode, comprising positioning a cathode in a trough carried by the stem, providing solder in position to flow around said cathode in said trough, placing a dome over the cathode and stem temporarily sealing the dome and evacuating the same, and melting said solder and causing it to seal the cathode in said trough for maintaining the acuum within said cathode and the cathode assembled on the stem.

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