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H. J. NOLTE

2,124,428

METAL VACUUM TUBE

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Fig. 1.

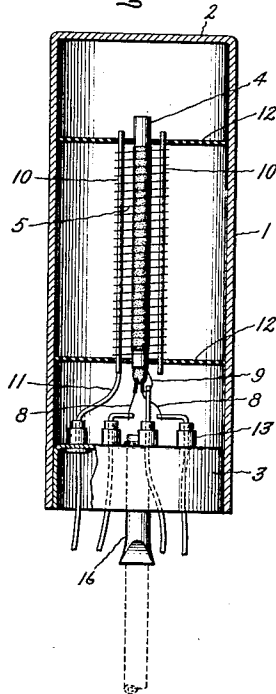


Fig. 2.

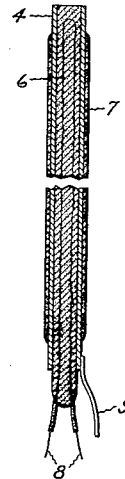


Fig. 4.

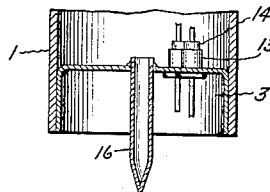


Fig. 3.

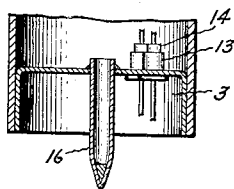
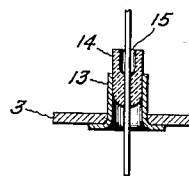


Fig. 5.



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UNITED STATES PATENT OFFICE

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METAL VACUUM TUBE

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2 Claims. (Cl. 250—27.5)

The present invention relates to electron discharge apparatus, and more particularly to thermionic devices employing metal envelopes.

Metal offers many advantages over vitreous substances, such as glass, quartz, etc. for envelope material of electric discharge devices. When the envelope is constituted substantially entirely of metal, the tube is extremely rugged, which promotes long life. The metal envelope not only offers electrostatic and magnetic shielding to the contained electrodes but in addition, may serve as one of the electrodes of the device, thus eliminating one element and its leading-in conductor. In the case of a metal envelope, which constitutes one of the electrodes, electrical connection may be made direct to the exterior surface of the tube. In addition to these advantages, metal envelopes may often be made more cheaply than glass envelopes due to the fact that highly skilled labor, such as glass blowing, etc., is unnecessary and the envelopes may be fabricated on automatic machines. Envelopes of this character may be made of inexpensive metal, such as iron or nickel, and readily shaped to form on a quantity production basis.

Some of these advantages have long been recognized by the art, but the successful development of an all-metal tube, particularly one of small size, has been beset by many difficulties, among which are the leakage at the positions where the leading-in conductors pass through the envelope, and the lack of an effective method for sealing off such a tube from the pump after the required high vacuum has been obtained.

The primary object of my invention is to provide an electron discharge device of simple design and rugged construction and which may be made entirely out of metal, except for the necessary seals about the leading-in conductors. Another object is to provide a tube which employs a metal seal-off communicating with the interior of the tube and one which provides a strictly hermetic seal so that the tube may be permanently disconnected from the pump.

The invention will be better understood when reference is made to the following specification and accompanying drawing in which Fig. 1 is a view partly in section of an electron discharge device improved in accordance with the present invention; Fig. 2 is a sectional view of a typical form of cathode employed in the tube shown in Fig. 1; Fig. 3 is a fragmentary view of the lower end of the envelope and header member showing the metal seal-off in section; Fig. 4 is a view

similar to Fig. 3 but illustrating a different type of metal seal-off, while Fig. 5 is a cross-sectional view of a typical form of leading-in conductor seal.

Referring more particularly to Fig. 1, numeral 1 designates a cylinder consisting of any workable, inexpensive metal such as iron, nickel, etc., closed at the top (as shown) by a transverse member 2 and at the bottom by a metal header 3 which may consist of the same metal as the cylinder. The header conveniently takes the form of a reentrant cylindrical member, fitting snugly within the interior of the cylinder 1, to which it may be secured in any suitable and well-known manner, such as by welding. The member 2 preferably is formed integral with the cylinder 1 so that the entire structure, apart from the header member and electrodes, may be made from sheet metal and formed by a deep drawing process. As stated hereinbefore, the members 1, 2, and 3 consist of an inexpensive metal having a surface which necessitates no treatment other than to remove surface contamination, such as oil, water, etc. The metal preferably should be reasonably smooth, although not polished. The ordinary commercial grade of sheet metal serves this purpose satisfactorily. The reentrant member 3 is provided with a wide flange and extends for a considerable distance into the envelope 1 so as to provide a relatively large contacting surface with the interior of the envelope, sufficient for an adequate weld between the flange and envelope. In forming the weld, one of the welding electrodes may be positioned on the exterior of the envelope 1 and the other electrode on the interior of the flanged header, and the electrodes moved as a unit, in a circular path around the periphery of the envelope, or if desired, the electrodes may be maintained stationary and the envelope and header members moved, in order to produce a "stitch" or "line" weld.

Before the header member is welded or otherwise secured to the envelope 1, one or more electrodes are mounted on top of the header. There are two electrodes shown, the center electrode 4 constituting an indirectly heated cathode and the other electrode 5 taking the form of a grid which surrounds the cathode. It will be apparent that I have exemplified my invention in connection with a three-electrode device consisting of a cathode 4, an electrostatic control member 5 and an anode which is constituted of the envelope 1. This general arrangement of electrodes and their application and proper circuits therefor are well known in the art. Obviously, the invention is not

limited to any particular number of electrodes or kind of electrodes contained within the envelope.

The cathode 4 is shown in detail in Fig. 2 and consists preferably of a "hairpin" filamentary heater member 6 insulatingly mounted within a cylinder, preferably of nickel, which constitutes the cathode proper and is designated by the reference character 4. This cylinder advantageously may be coated with electronically active material such as barium and strontium oxides 7, obtained from the carbonates, as is well known in the art. Leads 8 are taken from both ends of the heater, and a lead 9 taken from the lower end (as shown) of the cathode cylinder 4.

The grid or control member 5 may consist of a wire helix wound on a pair of metal uprights 10. A leading-in conductor 11 may be taken from either one of the uprights.

In order to maintain the proper spacing between the cathode, the control member and the envelope, disks 12 of insulating material, such as mica or alumina, are provided at each end of the electrode structure. These disks are of a shape and size to fit snugly within the envelope and are provided with openings to receive the ends of the electrode structure.

For bringing out the various leading-in conductors through the metal header 3, specially designed seals are employed, an example of which is shown in Fig. 5. The metal header is first provided with openings at the positions where it is desired to pass the leading-in conductors and secured to the header at each of these openings, for example, by welding, there is an eyelet 13 provided at the bottom with an outwardly extending flange for securing to the under side or if desired, to the upper side, of the header member. Fitted snugly within the eyelet 13, there is a cylinder 14 of glass or other vitreous material which may carry any one of the leading-in conductors and is provided with an annular groove 15 which serves to increase the leakage distance or path between the conductor and the eyelet. A hermetic seal is formed between the conductor, the surrounding glass member and eyelet, conveniently by means of a gas flame which is directed at the proper position on the eyelet after the conductor and glass have been assembled within the eyelet.

In order to insure a positive vacuum-tight seal between the glass 14 and the eyelet 13, these members should preferably have substantially the same thermal expansion characteristic at all temperatures between 0° C. and the softening temperature of the glass. Thus, no stress or strain is introduced at the seal during the fabrication of the seal or during any subsequent heat treatment of the tube which contains the seal. While various metals and glasses may be employed for this purpose, the freedom from strain and stress at the seal being dependent upon the respective differences of thermal expansion at the various temperatures reached during the manufacture of the tube, I prefer to employ materials which have been disclosed and claimed in the Burger and Hull application Serial No. 705,250, filed January 4, 1934, and entitled "Glass-to-metal seals," assigned to the same assignee as the present invention. This application has matured into Patent No. 2,071,196. As pointed out in the said patent, a metal which may be employed for this purpose consists of approximately 18% cobalt (Co), 28% nickel (Ni) and 54% iron (Fe), and the glass in this case may have the following approximate composition: 65% silica (SiO₂), 23% boric oxide

(B₂O₃), 7% sodium oxide (Na₂O) and 5% aluminum oxide (Al₂O₃). Under certain conditions, particularly when the manufacturing temperature is relatively low and the thickness of the eyelet is relatively small, it is possible to obtain a satisfactory seal when employing metals such as molybdenum, nickel and copper in connection with certain well-known glasses.

As stated hereinbefore, when the eyelet 13 is welded to the flat portion of the header member 3, either on the under side thereof as shown in Fig. 5, or on the upper side, and further, when the glass member 14 and the metal member 13 are of the proper materials, examples of which are given hereinbefore, the leading-in conductor is carried through the metal header in an insulating manner and at the same time is hermetically sealed. A sufficient number of these seals are provided to accommodate the various leading-in conductors.

The improved seal shown in Fig. 5, including the use of a metal eyelet and glass bead, has been disclosed and broadly claimed in the Elder and Gable application, Serial No. 746,808, filed October 4, 1934 entitled Electric discharge devices and seals therefor, and in a limited aspect has been disclosed and claimed in the Beggs application, Serial No. 744,165, filed September 15, 1934 and entitled Glass-to-metal seals. The Elder and Gable application and the Beggs application referred to are assigned to the same assignee as the present invention.

In addition to these seals, the metal header 3 carries a metal seal-off tube 16, examples of which are shown in Figs. 3 and 4. The seal-off tubulation is preferably constituted of a readily workable metal, such as steel, which may be hermetically secured to the header member in any suitable and well-known manner. As illustrated, the header is provided at the center with an opening of a size snugly to receive the tube 16. The tubulation may extend through the opening for a small distance in order to provide sufficient surface at the upper side (as shown) of the header member to insure a good joint. The tubulation may be welded to the header in order to provide a hermetic joint or if desired, may be brazed or soldered, and for this purpose, a ring of solder is dropped over the upper end of the tube 16 so as to rest on the upper surface of the header member. The header is then heated in a hydrogen furnace to a temperature below the melting temperature of the glass but above the melting temperature of the solder which then flows and forms a firm uniting material between the tubulation and header, sufficiently tight to constitute a hermetic seal. If desired, the eyelets 13 may also be brazed to the header member during the time when the tubulation is being secured and in substantially the same manner, although it has been found preferable to weld the flanges of the eyelets, either to the lower surface or upper surface of the header member as explained hereinbefore.

An excess length of tubulation may be provided, as indicated by the dotted lines in Fig. 1, the additional length being cut off during the seal-off process, as will be described presently.

When the leading-in conductor seals and the metal seal-off tube have been properly secured to the metal header, connections are taken from the various leading-in conductors to their respective electrodes which previously have been fitted within the openings in the disks 12. Thus the metal header and the electrode structure which to-

gether constitute the entire structure contained within the envelope 1, are assembled and mounted in place. The next step in the manufacturing process is to secure the header member and associated elements to the envelope 1. It is apparent that the header member and the disks 12 position and rigidly support the electrode structure within the envelope container. The header member may then be welded to the envelope as explained hereinbefore.

After the electrode assembly has been placed in position and the header member 3 welded or otherwise secured thereto, the tube is placed on an exhaust system and the interior of the envelope evacuated through the metal tubulation 16. During this time, the metal envelope is heated by high frequency or by a gas- or electrically-operated oven to a temperature of approximately 1000° C., the source of heat being so positioned that the seal end of the envelope runs somewhat cooler, for example, approximately 700° C., which is just below the melting point of the glass employed in the leading-in conductor seals. If the tube is heated with the header member and seal structure at the lower end, as illustrated in Fig. 1, and a high frequency coil placed about the mid-section of the envelope, the top member 2 of the envelope will be heated much hotter than the cylindrical portion, and the header member will necessarily run much cooler than the remaining portion of the envelope.

The evacuation should preferably be conducted at a fast rate, something of the order of one minute if possible and if a high frequency coil is immediately lowered over the container, it takes about ten seconds for an envelope of radio-receiving tube size to acquire the necessary temperature and the heating process may be continued for approximately forty seconds, which leaves about ten seconds for the envelope to cool down at the end of the exhaust. It has been found that if the heat treatment does not extend for any considerable length of time, the various insulating materials contained within the envelope are not damaged thereby and yet the deleterious gases occluded in the material of the envelope, also in the electrode and insulating materials, such as water vapor, etc., are effectively removed by the pump. The tube may be gettered in any suitable and well-known manner.

When a sufficiently high degree of vacuum has been obtained, and assuming that no gas is to be introduced, the tube is sealed off the pump by closing the tubulation 16. The preferred manner of doing this is by the use of a weld which is applied to the tubulation through a pair of electrode jaws of suitable shape connected to a source of direct or alternating current. A welding machine suitable for this purpose is well known in the art, as are also satisfactory energizing circuits for the welder. The jaws of the machine are preferably operated by a foot pedal which causes the jaws to press together with considerable force so that when placed on opposite sides of the tubulation 16, the latter is completely collapsed to form a flattened welded portion at any suitable position along the length of the tubulation. If desired, more than one flattened and welded portion may be employed and the length of the seal-off tubulation increased accordingly. The distance between the header member and the position at which the weld is produced should be as short as possible but yet sufficiently long to permit ready access to the welding electrodes. After the weld has been made, the surplus length

of tubulation may be snipped off by cutting pliers whereupon the tube is removed from the evacuating system.

I have found that when a suitable welding apparatus is employed and sufficient pressure applied to the welding electrodes so as completely to flatten the tubulation 16 at the welding position and thereby provide a line weld, the end of the tubulation is hermetically sealed most effectively. In fact, such a seal compares very favorably with seals produced between glasses.

Instead of producing the seal by a weld, a hermetic joint may also be obtained by the use of solder. For this purpose, the tubulation 16 is preferably made of copper and before being secured to the header member 3, is tinned on the inside and outside by immersing the end in liquid solder, leaving an excess of solder sticking to the interior of the tubulation. The tubulation may then be secured to the header member in the manner explained hereinbefore, and after evacuation of the envelope, a pair of parallel jaw pliers and a flame is employed to effect the seal-off. The flame is applied, while the tubulation is held compressed by the pliers, at a position about 2" above the constriction and gradually lowered along the tubulation until it is directed immediately above the constriction. This portion is thoroughly heated to insure complete formation of a solder pool which collects at the constriction. The tubulation must be compressed sufficiently tight to prevent flow of solder through the constriction and this may be accomplished by the use of pliers with rounded inserts in the jaws. The solder seal-off is quite effective from the hermetic standpoint but as stated hereinbefore, the welded seal-off is preferred since, obviously, it may be more quickly done and the choice of metal for the tubulation 16 may be greater.

After the tube has been sealed off, if desired, a base may be applied to the lower or header end of the envelope and the various leading-in conductors taken to the usual contact pins. However, I have found that a base of this character is not necessary because the metal seal-off is so rugged as not to require mechanical protection and to this extent, when the improved tube is mounted in a radio set, a cheaper installation is possible.

It is apparent that the entire tube structure, except for the small glass cylinders 14 and the insulating disks 12 which are employed for supporting the electrode structure within the envelope, is made of metal. The manufacturing processes employed in shaping and securing the various parts together lend themselves to automatic machines so that the improved tubes may be cheaply fabricated. Moreover, the material out of which the envelope of such a tube is constructed, which for the most part is an ordinary grade of iron or nickel, is relatively inexpensive. Finally, a tube of this character is extremely rugged in construction and the only glass or other fragile elements employed is the member 14 which is so protected by the metal eyelet 13 and the reentrant form of header and furthermore, is so constituted of thick material, as to be practically unbreakable and shatterproof. It is apparent that when effective joints and seals are provided in the manner described hereinbefore, the possibility of tube failure by reason of leakage or breakage is substantially eliminated.

In operation, the container or envelope 1 may serve as one of the electrodes, since the remaining electrodes are insulated therefrom, and con-

sequently, the improved construction permits the elimination of at least one electrode and its associated leading-in conductor which are normally found in tubes provided with glass envelopes. The elimination of this electrode adds simplicity to the tube construction as well as assisting in lowering the cost of manufacture. The improved construction is adapted to the design of tubes of all sizes, not only small radio receiver tubes made on a quantity production basis but also large transmitter tubes employed with high voltage.

While I have illustrated and described my invention as applying to a three-electrode high vacuum device in which the envelope constitutes the anode, it is apparent that if desired, the construction may be employed in connection with gas or vapor tubes of the arc or glow discharge type. Furthermore, any number of electrodes, one or more, may be contained within the envelope and the envelope take on the role of any of the electrodes, depending upon the circuits employed. It is also apparent that the metal seal-off tubulation disclosed herein may be employed in connection with tubes having envelopes made en-

tirely of glass except for a metal portion to which the metal seal-off is secured.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electric discharge device comprising an envelope containing a plurality of electrodes, said envelope including a cylinder closed by a flanged metal header member secured at the flange to said cylinder, said header being substantially flat except for the flange, leading-in conductors for said electrodes passing through the header member and insulated therefrom, an all-metal evacuating tubulation secured to the flat portion of said header member and closed by a weld at the end remote from the envelope.

2. An electric discharge device comprising an envelope containing a plurality of electrodes, said envelope including a cylinder closed by a metal header member of substantially flat configuration, leading-in conductors for said electrodes passing through the header member and insulated therefrom, an all-metal evacuating tubulation secured to said header and hermetically closed by the fusion of metal.

HENRY J. NOLTE.