July 2, 1940.

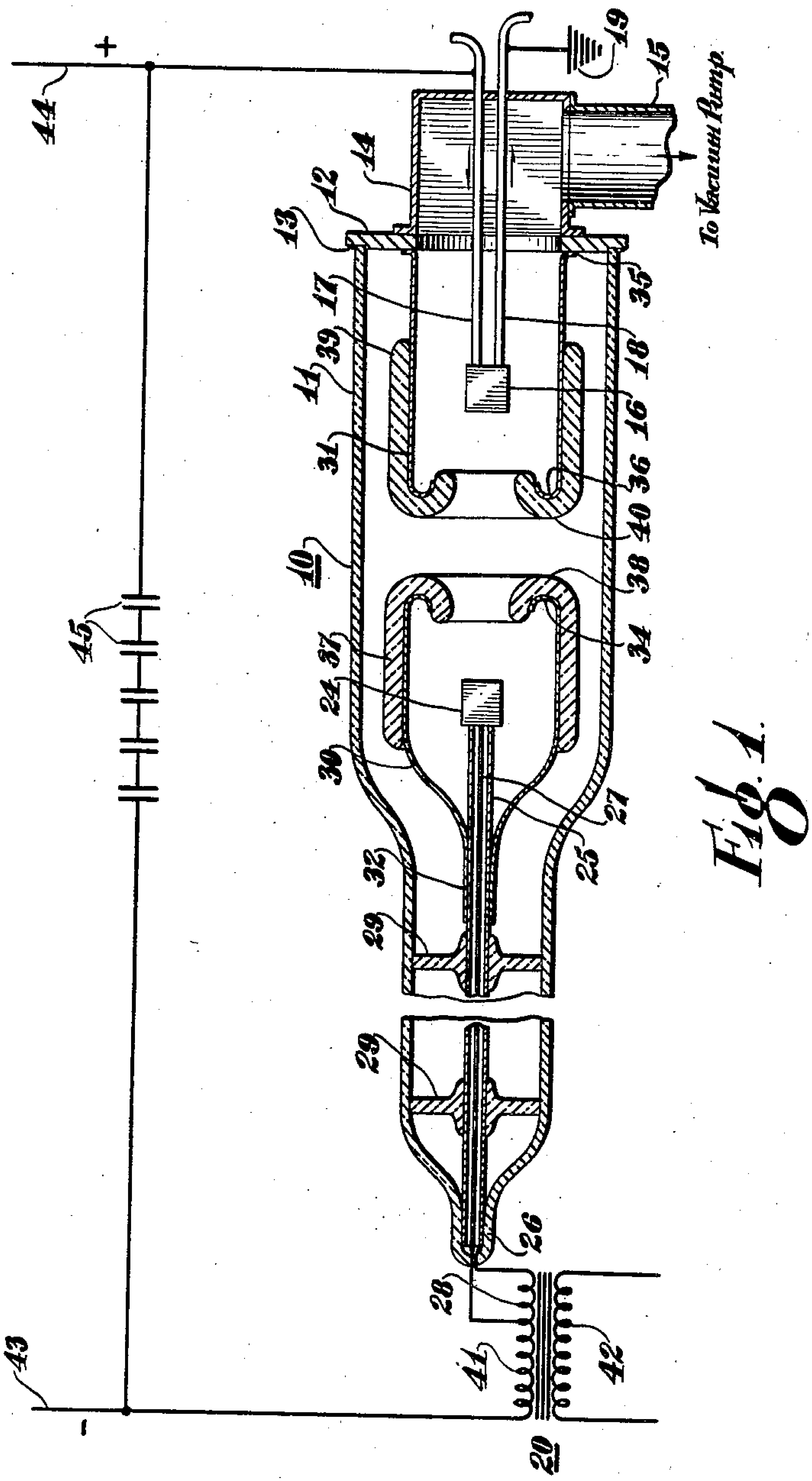
W. H. BENNETT

2,206,558

HIGH VOLTAGE VACUUM TUBE

Filed July 9, 1937

4 Sheets-Sheet 1




INVENTOR.
Willard H. Bennett.

BY Stoodling and Krost
ATTORNEY.

HIGH VOLTAGE VACUUM TUBE

Filed July 9, 1937



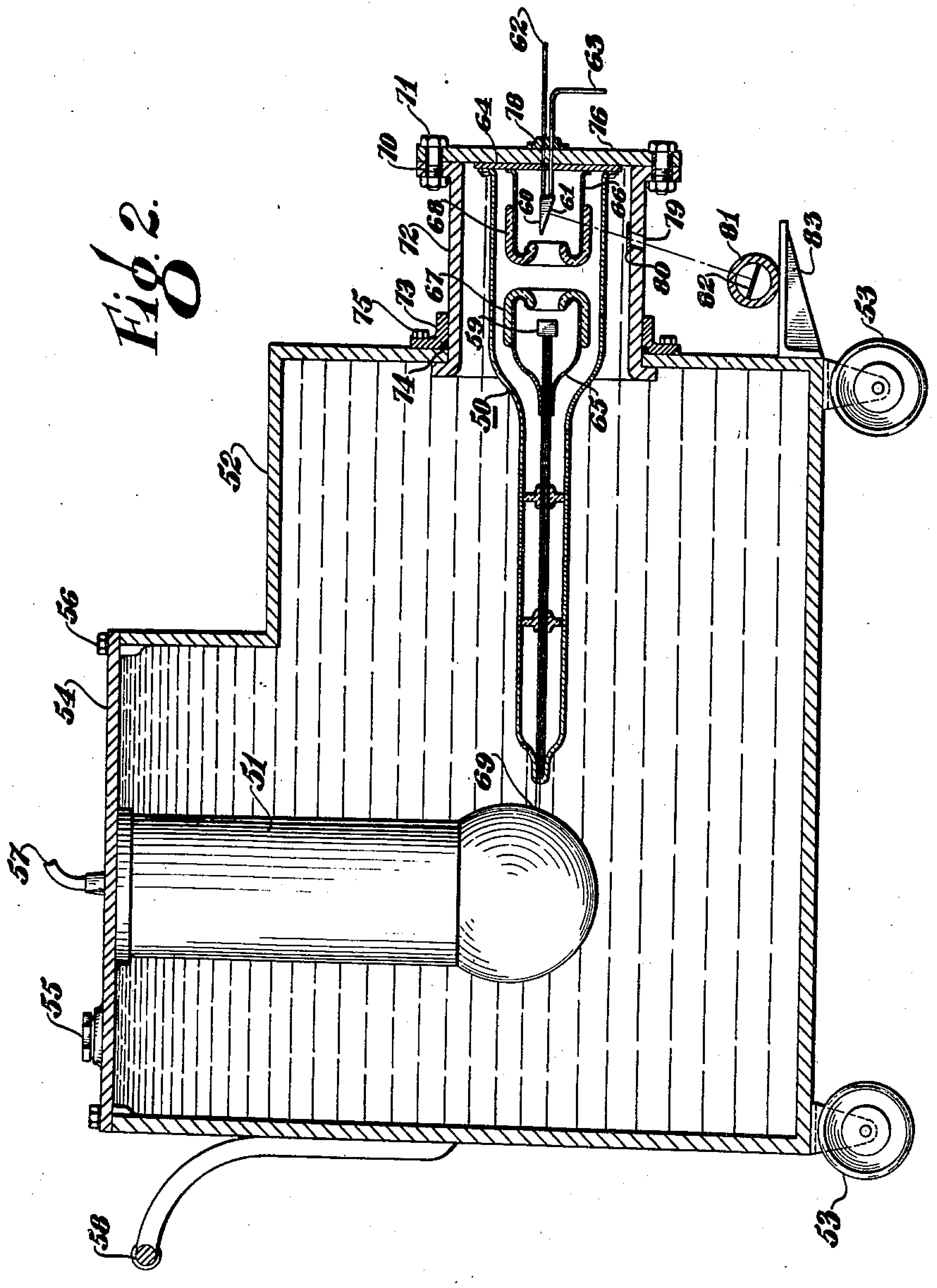


Fig. 2.

INVENTOR.
Willard H. Bennett.

BY Stoodling and Krost

ATTORNEY.

July 2, 1940. W. H. BENNETT 2,206,558

HIGH VOLTAGE VACUUM TUBE

Filed July 9, 1937 4 Sheets-Sheet 3

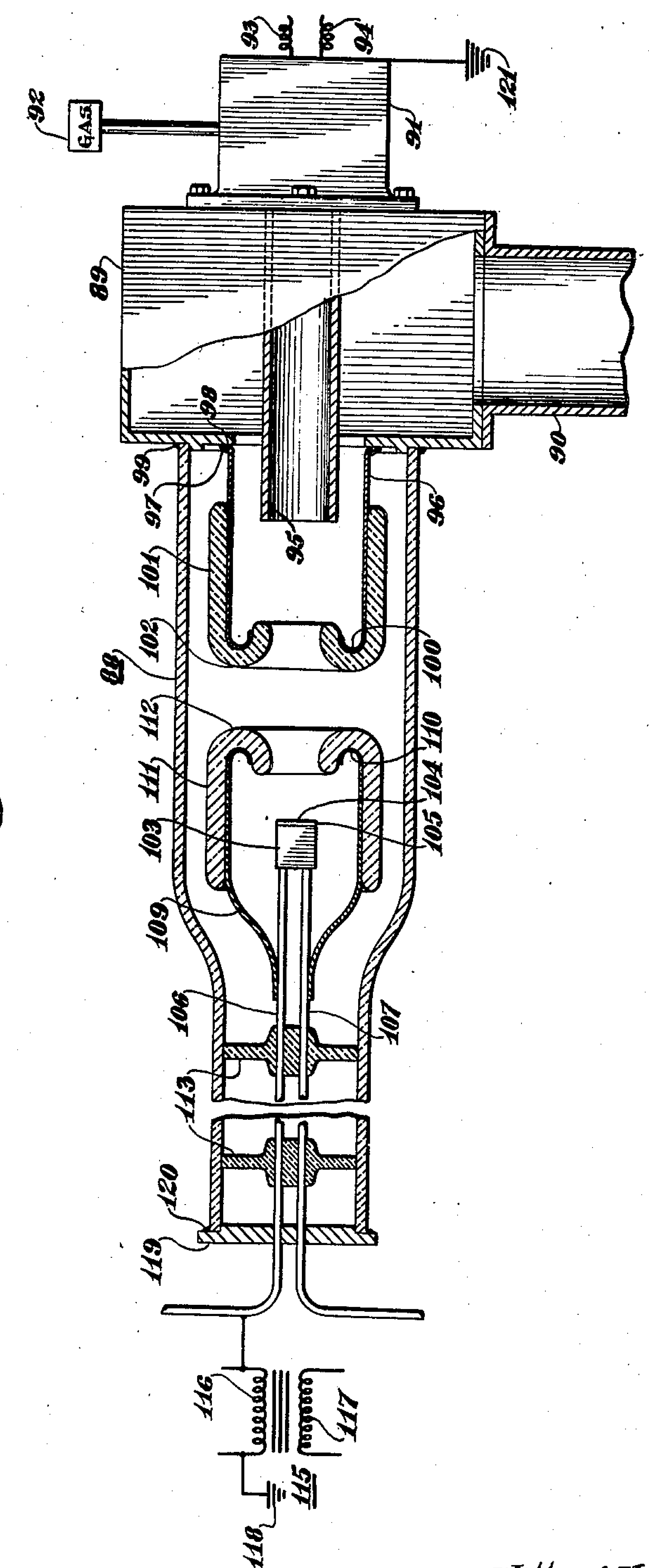



Fig. 3.

INVENTOR.
Willard H. Bennett.

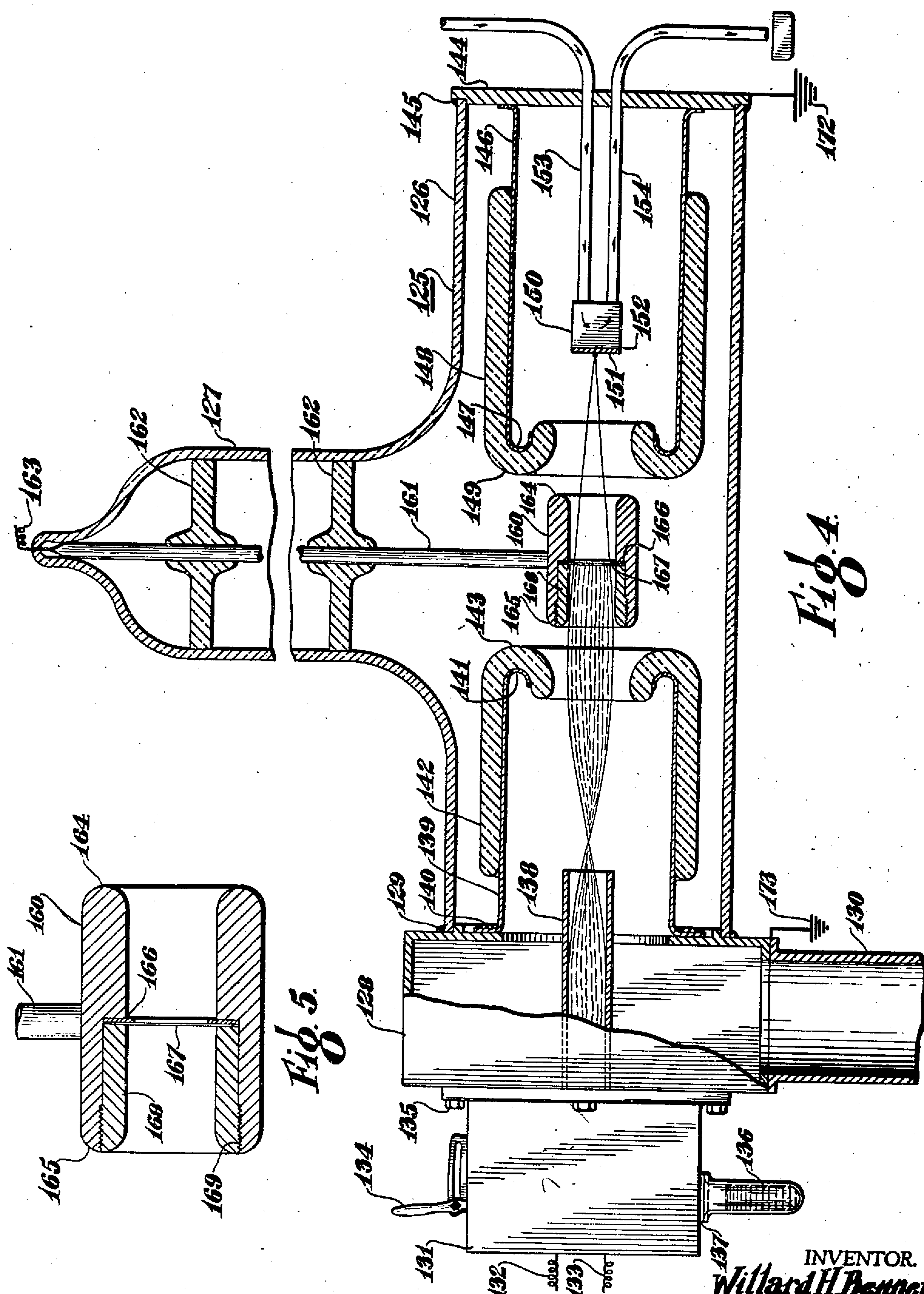
BY

Woodling and Krost
ATTORNEY.

July 2, 1940. W. H. BENNETT 2,206,558

HIGH VOLTAGE VACUUM TUBE

Filed July 9, 1937 4 Sheets-Sheet 4




INVENTOR.
Willard H. Bennett.
BY
Woodling and Krost
ATTORNEY.

Patented July 2, 1940

2,206,558

# UNITED STATES PATENT OFFICE

2,206,558

## HIGH VOLTAGE VACUUM TUBE

Willard H. Bennett, Columbus, Ohio

Application July 9, 1937, Serial No. 152,787

18 Claims. (Cl. 250—154)

My invention relates to high voltage vacuum tubes and particularly to vacuum tubes operating within the upper voltage range of several hundred thousand volts to a million volts or more.

An object of my invention is the provision of high voltage vacuum tubes arranged to be subjected to large electrical differences of potential of sufficient value to cause formation of cold emission streams, and an insulating material to prevent the formation of said cold emission streams.

Another object of my invention is the provision of a high voltage vacuum rectifier tube adapted to operate at extremely high voltages in the order of several hundred thousand volts to a million volts or more without rupture.

Another object of my invention is the provision of a high voltage X-ray tube which may be operated at extremely high voltages in the order of several hundred thousand volts to a million volts or more without rupture.

Another object of my invention is the provision of a portable X-ray device having a high voltage transformer and a high voltage tube mounted within a portable container, so that the X-ray device may be moved about to accommodate the uses to which it is to be put.

Another object of my invention is the provision of a high voltage tube for producing radio active elements, which may be operated at several hundred thousand volts or higher without rupture.

Another object of my invention is the provision of a high voltage vacuum tube which causes the ions to strike the material which they are bombarding with energy corresponding to substantially twice the voltage on the tube.

Another object of my invention is to provide for stripping the electrons off the nuclei of the ions during their travel and cause the ions to strike the material being bombarded with energy corresponding to substantially twice the voltage on the tube.

Another object of my invention is the provision of a very thin metal foil charged at a very high electrical potential and supported transversely of the direction of the motion of the ions to strip the electrons off the nuclei of the ions and cause the ions to strike the material being bombarded with energy corresponding to substantially two or more times the voltage on the tube.

Another object of my invention is to provide for making the operating portion or head of my vacuum tube relatively small, so that it may be readily adaptable to many uses which would be denied to a relatively large operating portion or head.

Other objects and a fuller understanding of my invention may be had by referring to the following description and claims, taken in combination with the accompanying drawings in which:

Figure 1 illustrates a cross-sectional view of a high voltage rectifier tube embodying the features of my invention;

Figure 2 shows a cross-sectional view of an X-ray device which may be moved about to accommodate the uses to which it is put;

Figure 3 is a cross-sectional view of a high voltage tube arranged to produce radio active elements;

Figure 4 is a cross-sectional view of a high voltage tube arranged to produce radio active elements, and is designed to cause the ions to strike the material which they are bombarding with energy corresponding to substantially twice the voltage on the tube; and

Figure 5 is an enlarged cross-sectional view of the intermediate electrode shown in the vacuum tube in Figure 4.

My invention applies to high voltage tubes of all kinds and is not limited to the particular high voltage tubes shown and described herein.

In Figure 1 of the drawings, my invention is shown as being embodied in a rectifying tube indicated by the reference character **10** and comprises generally a vacuum glass container **11** having a hot cathode **24** and cooled anode **16**.

The right-hand end of the glass container **11** is closed by means of a sealed head member **12** which abuts against the end of the glass **11** and is sealed thereto by means of a sealing material **13**. Attached to the sealed head member **12** is a vacuum header **14** having a vacuum pipe **15** extending therefrom connected to a vacuum pump for exhausting the air from inside of the vacuum tube.

The anode **16** may be cooled by passing a cooling fluid through the pipes **17** and **18**, which pipes also constitute a support for the anode **16**. The anode may be grounded at **19** or at any other suitable connection. The cathode **24** may be supported by an electrically conducting tube **25**, which is in turn supported in longitudinal space relationship to the glass **11** by means of insulating brackets **29**. The left-hand end of the tube **25** is arranged to fit snugly in a restricted end **26** of the glass. Inside of the tube **25** and electrically insulated therefrom is a conductor **27**. The electrical heating of the cathode **24** is obtained by connecting the conducting tube **25** and the conductor 27 to the filament winding 28 of the transformer 20. The winding 41 of the transformer 20 is the high voltage winding and the left-hand side is connected to the negative load conductor 43. The anode 16 is connected to the positive load conductor 44. The tube must be long enough from the high voltage lead-in conductor on the left-hand end of the tube to the ground at the base on the right-hand end of the tube to prevent spark-over on the outside. Accordingly, the reduced diameter of the tube may be a few feet long or more in atmosphere. This distance may be considerably reduced by immersing the tube in oil or other good dielectric material. A plurality of series connected condensers 45 may be connected across the load conductors to give a smooth wave form to the load.

Surrounding the cathode 24 is a shield 30 to reduce the field intensity upon the cathode and prevent disintegration thereof. The shield comprises a hollow cylindrical body having the left-hand end 32 reduced to a relatively small diameter to fit snugly on the outside of the tube 25 and to be supported thereby. The forward or right-hand end of the shield is open and is internally bent back upon itself for a relatively short distance to form a round end as indicated by the reference character 34. The external surface of the cathode shield 30 is protected by a body of insulating material 37 having a round end 38 and snugly fitting against the external surface of and around the end 34 of the cathode shield.

Surrounding the anode 16 and in substantial longitudinal alignment with the shield 30 is an anode shield 31 comprising a hollow cylindrical body having its rear end flanged outwardly and suitably connected as at 35 to the sealed head member 12 in a suitable manner. The shield 31 reduces the field intensity upon the anode 16 and prevents disintegration thereof. The left-hand or forward end of the shield 31 is internally bent back upon itself for a relatively short distance to form a round end 36. Closely fitting the external surface and the round end 36 of the shield 31 is a body of insulating material 39 having a round end 40. The insulating bodies 37 and 39 are substantially identical and each has its adjacent ends open to allow the electrons to flow from the cathode 24 to the anode 16. The insulating bodies 37 and 39 and the supporting brackets 29 comprise a porous non-vitreous structure. The insulating bodies 37 and 39 prevent the formation of cold emission streams from the external surface of the shields 30 and 31 when the tube is in operation. The nature of the insulating materials 37 and 39 and the brackets 29 and the process for making same is described in my pending patent application, entitled Insulating material, filed July 8, 1937, and Serial No. 152,617. The insulating materials 37 and 39 and the brackets 29 may be drilled or worked by a sharp tool. The insulating bodies 37 and 39 may be mounted on a lathe and turned to fit snugly the shields 30 and 31. The methods of working are similar to those of wood turning.

In the operation of my high voltage rectifying tube, when the primary winding 42 is energized, the high potential winding 41 subjects the cathode 24 and the anode 16 to a large electrical difference of potential. The cathode 24 is heated by the filament winding 28, and emits electrons which travel at high velocity to the anode 16 during one-half of the alternating current cycle to impress a rectified current upon the load conductors 43 and 44. The electrons flow from the cathode 24 to the anode 16 during the one-half cycle when the anode 16 is positive with respect to the cathode 24. No electrons flow during the other half of the alternating current cycle. Under this arrangement the load conductor 43 would be negative and the load conductor 44 would be positive.

While the arrangement just described will deliver a high negative steady potential, the tube may be changed to enable the arrangement to deliver high positive potential. These changes may be effected by exchanging the positions of the anode 16 and the cathode 24 and suitably cooling the anode and using a separate filament transformer to heat the cathode.

The insulating materials 37 and 39 may be worked to fit closely over the external surfaces and around the ends of the shields 30 and 31 to prevent the formation of cold emission streams, so that the tube may be operated at extremely high voltages in the order of several thousand volts to a million volts or more without rupturing the tubes.

The focusing of the electrons upon the anode 16 may be determined by varying the space between the cathode 24 and the anode 16. The shields 30 and 31 aid in focusing the electrons as they travel from the cathode 24 to the anode 16.

While I have shown only one rectifying tube, two or more may be connected to provide a full-wave rectification. In installation, the rectifier tube should be shielded in some suitable manner by the use of lead or by having it placed in a separate guarded room. These features are not shown as they are usually taken care of when any tube to be used for this purpose is installed.

In Figure 2, I illustrate the embodiment of my invention in an X-ray device which may be moved about to accommodate the several uses to which it may be put. The X-ray device comprises generally a tube 50 and a high voltage transformer 51 mounted in a portable container 52 carried by wheels 53. The transformer may be of any suitable type and may be suspended vertically from the cover 54. As illustrated, the cover 54 may be bolted or otherwise connected to the top of the container 52 by means of bolts 56.

A fill cap 55 is provided so that the container may be filled with oil or other dielectric material.

The X-ray tube 50 embodies the general construction of the rectifier tube shown in Figure 1 and comprises a glass container having its right-hand end sealed by means of a head member 64, a cathode 59 and an anode 60 having an inclined forward face 61 to direct the rays upon the object 81 being X-rayed. The cathode 59 may be electrically connected at 69 at the lower end of the suspended transformer and charged to a high potential. The connection 69 also constitutes a support for the left-hand end of the tube. The cathode may be heated by a filament winding provided in the transformer 51. The anode 60 may be cooled by means of cooling fluid passing through the cooling tubes 62 and 63. These tubes support the anode 60 and pass through the lead header 76 and the head member 64 which is suitably connected to the lead header 76. Accordingly, the anode 60 is grounded to the container. The buoyant effect of the oil or other dielectric will approximately support the tube and the joint from the glass to the head member 64 will guide the tube. The cathode 59 is surrounded by a shield 65 and an insulating body 67 to prevent the formation of cold emission streams when the tube is operated at high voltages. The anode 60 is similarly surrounded by a shield 66 and an insulating body 68. The construction of the shields and the insulating bodies is the same as that described with reference to Figure 1.

The lead header 76 may be suitably connected by means of clamping bolts 71 having steel inserts 70 to the outward end of a cylindrical hollow lead portion 72 which shields the tube and which constitutes a portion of the container. The inner end of the lead portion 72 is flanged outwardly and engages the internal peripheral edge of the opening in the right hand end of the container 52. In order to prevent leaking of the oil or dielectric material, a good seal may be provided where the lead portion 72 enters the opening in the container 52 by using an annular flange 73 suitably fastened against the end of the container 52 by means of bolts 75, compressing a packing material 74. A suitable flange 78 may be employed to make a good seal where the cooling tubes 62 and 63 extend through the header 76.

The X-rays may be emitted through an opening 79 provided in the lead portion 72 and strike the object being X-rayed. The opening 79 may be at any convenient position at the bottom as shown, at a side, or at the top of the lead portion 72 and may be covered by a plate 80 to keep the oil or other dielectric material from leaking out. A bracket 83 mounted on the forward lower-most portion of the container 52 may be provided as a support for the article being X-rayed. The film for the X-ray is indicated by the reference character 82.

My X-ray device is a self-contained unit. This construction is made possible by reason of the fact that the insulating material, which prevents the formation of cold emission streams, permits the operating head of the tube to be condensed into a very small space. The entire device may be pushed about by the handle 58 and for this reason it possesses great utility for testing devises using high grade steels or other metals during the process of their manufacture. For instance, in the manufacture of gun barrels, my X-ray device has great utility, because in the event that an apparent defect is observed while the barrel is being turned in a lathe, my X-ray machine may be positioned relative to the gun barrel while in the lathe and used to take a picture of the apparent defect without removing the gun barrel from the lathe which consumes a great deal of time and expense. My X-ray machine may be wheeled about a factory and used to take X-rays of heavy pieces of steel which would be difficult to carry into a specially built X-ray room as now employed for this purpose. As my X-ray device is moved about, it is only necessary to connect the supply conductors 57 to a low voltage supply source and it is ready for operation. The opening in the lead portion through which the X-rays are emitted may be positioned in any suitable place about the lead portion to accommodate the several uses to which the X-ray device may be put. My X-ray device may be operated at several hundred thousand volts to a million volts or more and yet be made small enough to move about.

Another application of my invention may be embodied into a high voltage vacuum tube arranged to produce radio active elements. This embodiment is shown in Figures 3 and 4. The embodiment shown in Figure 3 makes use of positive ions introduced into the vacuum tube indicated by the reference character 88. The right-hand end of the tube is connected to a vacuum header 89 which is in turn connected to a vacuum pipe 90 which leads to a vacuum pump for removing the air from the inside of the tube 88. The vacuum header 89 may be abutted against the right hand end of the tube 88 and sealed by means of sealing material 99. Attached to the right-hand end of the vacuum header 89 is a positive ion producing device 91 arranged to deliver positive ions through the exit or left-hand open end of the tube 95. The embodiment of the positive ions producing device 91 may be of any suitable kind and may be connected to a gas supply indicated by the reference character 92 and energized by the supply conductor 93 and 94. The gas supply may be hydrogen, helium, or other gas used as a source of bombarding material. The positive ion producing device 91 may be grounded to a suitable ground as indicated by the reference character 121.

Surrounding the exit end of the positive ions producing tube 95 is a shield 96 which may suitably fasten to the left-hand wall 98 of the vacuum header 89 by means of the bolts 97. The left-hand end of the shield 96 is bent inwardly back upon itself for a short distance to form a round end indicated by the reference character 100. Closely fitting the external surface and the forward round end of the shield 96 is an insulating body 101 having a round forward end 102.

Mounted in longitudinal alignment with the positive ion introducing tube 95 is a target or anode 103 upon which the ions may be focused. The forward face of the target may be provided with a relatively thin strip of metal 104 suitably attached thereto by means of silver solder 105 or other suitable means. The target 103 may be cooled by cooling fluid flowing through the pipes 106 and 107 which also constitutes a support for the target. The cooling tubes 106 and 107 may be supported in longitudinal spaced relation with the reduced portion of the glass container by means of insulating supports 113. The cooling tubes 106 and 107 are air tight where they pass through the end cover 119 which abuts against the left-hand end of the glass container and is sealed thereto by means of the sealing material 120.

The target 103 is provided with a shield 109 supported by the tubes 106 and 107. The forward or right-hand end of the shield 109 is folded back internally upon itself and forms a round end 110. An insulating body 111 having a round forward end 112 may be snugly fit over the shield 109. The construction and purpose of the shields 96 and 109, the insulating bodies 101 and 111, and the insulating brackets 113 are the same as heretofore described with the other embodiments of my invention. The target 104 may be energized to a high potential with respect to the grounded positive ion introducing tube 95, by means of a transformer 115 having a primary winding 117 and a high voltage winding 116 grounded as at 118.

In operation, the positive ions emitted from the positive ion introducing tube 95 are propelled at a high velocity against the metal 104, when the alternating current wave is such that a negative potential exists upon the anode 103 to attract the positive ions. The ions bombard the metal 104 with energy corresponding to substantially the voltage upon the tube, which may be in the order of several hundred thousand volts to a million volts or more. The bombardment is sufficient to disintegrate the metal 104 and produce radio active elements. After the bombardment has been continued for a sufficient length of time, the tube may be dismantled and the metal piece 104 removed, after which the metal is treated to render the radio active elements suitable for use.

In Figures 4 and 5, I illustrate another embodiment of my invention for producing radio active elements in which the ions bombard a material with energy corresponding to substantially twice the voltage impressed upon the tubes. In this form of my invention, the glass vacuum container 125 has a relatively short working head 126 and a relatively long stem 127. The general outline of the glass container 125 is substantially T-shaped. Abutting against the left-hand end of the working head 126 of the glass container is a vacuum header 128 which is sealed to the open end of the glass container by means of a suitable sealing material 129. A vacuum pipe 130, leading from the vacuum head 128, is connected at its lower end to a vacuum pump for removing the air within the glass container 125. In this embodiment of my invention, negative ions are introduced into the tube for bombarding a material to produce radio active elements. The device for producing the negative ions is indicated by the reference character 131 which may be bolted or otherwise suitably connected to the left-hand end of the vacuum header 128 by bolts 135. The negative ions producing device 131 may be of any suitable construction and may be energized by the supply conductors 132 and 133. The focusing of the negative ions, as they move through the negative ion introducing tube 138 may be effected by actuating the control lever 134. The negative ions may, for example, be hydrogen negative ions and may be obtained by using water in the tube 136 which is sealed by means of a sealing material 137 to the bottom of the negative ion producing device.

A shield 139 may be mounted around the exit end of the negative ion producing tube 138. The left-hand end of the shield 139 may be suitably fastened to the abutting wall of the vacuum header 128 by means of screws 140 or by any other means. The right-hand end of the shield 139 is open and may be folded internally upon itself for a short distance to form a round end 141. An insulating body 142 having a round end 143 may be snugly fit over the external surface of the shield 139 and the round end 141.

Positioned in substantially longitudinal alignment with the negative ions producing tube 138 is a target or anode 150 which may be supported by cooling tubes 153 and 154. A piece of metal 151 which is to be bombarded by the ions to produce radio active elements is mounted on the forward face of the target 150 by means of silver solder 152 or any other suitable means. The cooling tubes 153 and 154 make an air tight fit where they pass through the sealing head member 144 which, in turn, abuts against the right-hand end of the glass container and is sealed thereto by means of suitable sealing material 145. The target or anode 150 may be grounded to any suitable connection such as at 172.

A shield 146 is arranged to surround the target 150, and has its right-hand end suitably connected to the inside surface of the sealing head member 144. The left-hand or forward end of the shield 146 is folded internally upon itself for a short distance to make a round end 147. Snugly surrounding the external shield 146 and the round end 147, is a body of insulating material 148 having a round end 149. The construction and purpose of the shields 139 and 146 and the insulating bodies 142 and 148 are substantially the same as that described hereinbefore with reference to the other embodiment of my invention. Positioned intermediate the adjacent ends of the insulating bodies 142 and 149 and in substantial alignment with the travel of the ions, is an electrode 160 arranged to strip the electrons off the nuclei of the ions as they travel from the negative ions producing tube 138 to the material 151 which is being bombarded. An enlarged view of the electrode 160 is shown in Figure 5 and comprises a substantially cylindrical tube member having round ends 164 and 165, supported by means of a conducting rod 161 which is, in turn, supported by means of the insulating brackets 162, in substantally longitudinal spaced relation with the relatively long portion 127 of the glass container. The upper end of the supporting rod 160 is connected to a wire terminal 163 which extends through and makes a sealed connection with, the glass. A very thin metal foil 167 is positioned internally of the hollow electrode and substantially intermediate the ends thereof. The thin metal foil may be of gold and in order to facilitate the handling thereof it may be mounted on an annular member 166 which fits against a shoulder in the inside surface of the cylindrical electrode 160. The metal foil 167 and the annular member 166 may be held in a fixed position by means of a threaded sleeve 168 which threadably engages the threads 169 in the cylindrical electrode.

In the operation of my device a very high positive potential is impressed upon the conductor terminal 163 and the negative ions producing device 131 is grounded as at 173 and the target 150 is grounded as at the ground 172. The distance between the conductor terminal 163 to the grounded end of the tube must be such as to eliminate flash-over on the external surface of the tube. Accordingly, the distance or length of the glass portion 127 may be in the neighborhood of a few feet or more when the tube is used in atmosphere or shorter when immersed in oil or other good dielectric material. When the conductor terminal 163 is impressed with a relatively high positive potential and the negative ion producing device 131 is in operation, a beam of negative ions will emerge from the negative ions introducing tube 138. These negative ions will proceed toward the intermediate electrode 160 and strike the gold foil 167 which is positioned transversely of the line of travel of the ions. When the ions pass through the foil, the electrons are stripped off the nuclei of the ions and leaves positively charged ions. These positively charged ions upon emergence through the foil still retain energy corresponding to the full voltage applied to the tubes minus the absorption of the foil. The positively charged ions upon leaving the gold foil proceed toward the target 150 and bombard the material 151 to make radio active elements. In going to the target 150 the ions are given additional energy corresponding to the voltage of the tube because they are now positive ions. Therefore, the ions arrive at the material 151 with energy corresponding to substantially twice the voltage of the tubes minus the absorption of the foil 167. The focusing of the ions as they leave the negative ions introducing tube 138 may be controlled by the control lever 134 upon the ion producing device 131, and in the embodiment of my invention the focusing may be such that the ions are scattered when they strike the gold foil 167 to prevent damage thereto, but are concentrated at a point where they strike the material 151 to produce effective disintegration.

If negative atomic ions of elements with higher atomic numbers than hydrogen be used, the increase in energy during the acceleration from the intermediate electrodes 160 to the target 150 can be made much larger than for hydrogen, since there are more electrons which can be stripped off each ion when it passes through the gold foil 167. Thus, if mercury be used in the tube 137 instead of water, the ions will possess substantially 80 times the energy corresponding to the voltage on the tube when water is used. When mercury is used in the tube 136, the negative ion producing device 131 must be modified to take care of the focusing of the ions.

In the embodiment of my invention, the operating hand may be very small and yet operate under very high voltages in the order of several hundred thousand volts to a million volts or more. The reduction in size of the operating head is made possible by my insulating material 142 and 148 and insulating brackets 162 which prevent the formation of cold emission streams when the tube is under operation. The operating head of substantially the size of that illustrated in the drawing of Figure 4 may be operated successfully without rupture up to 400,000 volts. Upon removal of the insulating material, the tube would fail at approximately 82,000 volts, all metal parts remaining in the same position. The insulating bodies 142 and 148 will stand 400,000 volts with a thickness of approximately 5 millimeters. The pressure in the vacuum tube was less than one-tenth micron of mercury. After the bombardment by the ions upon the metal 151 is continued for a sufficient length of time, the tube may be dismantled or opened at the connection 145 and the metal 151 removed and treated to render the radio active elements suitable for use.

By reason of the fact that my insulating material prevents the formation of cold emission streams, the operating portion or head of my vacuum tube may be made relatively small, so that they may be readily adaptable to many uses which would be denied to a relatively large operating portion or head. The insulating material will withstand bombardment in vacuum by electrical particles having a higher energy than that required to rupture glass, quartz, or porcelain. The insulating material may be worked by a cutting tool and made to fit snugly over metal surfaces and electrodes in vacuum in order to eliminate open evacuated volumes next to metal surfaces at which high negative electric fields exist. The insulating material has a high porosity and permits rapid evacuation and elimination of gas which may accompany the initial application of high voltage due to local electrical disturbances such as sparks or the bombardment by high velocity electrical particles. After assembling the tubes, they are evacuated. During the period of evacuation, the tubes may be baked at approximately 500 degrees centigrade. In this manner the residual gas pressure due to the insulating material, after baking, does not seriously exceed that due to the metal parts of the same size.

The insulating material may be used for the insulating support for wires and electrodes in any kind of vacuum tube, and is especially convenient because it can be machined or worked after firing, so that warps and contractions due to firing are eliminated.

Although I have described my invention with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. A high voltage vacuum tube comprising, in combination, a vacuum container, spaced negative electrodes operatively mounted in the vacuum container, one of said electrodes having means extending in the tube for introducing negative ions in the tube, another of said electrodes having means mounted in the tube and arranged to be bombarded by the ions, a hollow cylindrical metal shield electrically connected with and surrounding the exit of the negative ion introducing means which extends into the tube, a second hollow cylindrical metal shield electrically connected with and surrounding the bombarded means, said shields having spaced adjacent rounded ends and mounted in substantial alignment with each other, an insulating material closely fitting the external surfaces of each of said metal shields to prevent the formation of cold emission streams, so that the tube may be operated at extremely high voltages, a positively charged electrode mounted in the tube intermediate the said spaced adjacent ends of the shields and in alignment with the path of the ions traveling from the ion introducing means to the bombarded means, and means mounted on the positive electrode for stripping the electrons off the nuclei of the ions, and leaving positively charged ions which are given additional energy corresponding to the voltage on the tube, with the result that the ions strike the bombarded means with energy corresponding to twice the voltage of the tube minus the absorption of the stripping means.

2. A high voltage vacuum rectifying tube comprising, in combination, a vacuum container, a hot cathode and an anode operatively mounted in the vacuum container, a hollow cylindrical metal shield surrounding the cathode and electrically connected thereto, a hollow cylindrical metal shield surrounding the anode and electrically connected thereto, said shields being in substantial alignment with each other and having their spaced adjacent ends rounded, and an insulating material closely fitting the external surfaces and the rounded ends of each of said shields to prevent the formation of cold emission streams, so that the tube may be operated at extremely high voltages, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the shields.

3. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said electrodes having a surface portion from which cold emission streams would normally tend to flow under large electrical differences of potential between said electrodes, and insulating material positioned externally of the said surface portion to prevent the flowing of said cold emission

streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said surface portion.

4. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said electrodes having a surface portion from which cold emission streams would normally tend to flow under large electrical differences of potential between said electrodes, and insulating material positioned externally of the said surface portion to prevent the flowing of said cold emission streams, said insulating material having a porous non-vitreous structure which will withstand 100,000 volts or more per five millimeters of thickness at a pressure of one-tenth of a micron or less.

5. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, each of said spaced electrodes having a metal body with open adjacent ends through which said useful current passes, and insulating material positioned externally of each said metal bodies to prevent the flowing of cold emission streams therefrom, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal bodies.

6. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, each of said spaced electrodes comprising a metal body with open adjacent ends, said adjacent ends having a curved surface at the shortest distance between said metal bodies, and an insulating material closely fitting the external surface of each of said metal bodies to prevent the formation of said cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal bodies.

7. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, each of said spaced electrodes having a hollow cylindrical metal body with open adjacent ends mounted in substantial alignment with each other, said adjacent ends having a curved surface at the shortest distance between said metal parts, and an insulating material closely fitting the external surfaces of each of said metal bodies to prevent the formation of said cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit said metal bodies.

8. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said spaced electrodes having means extending in the tube for introducing ions in the tube, another of said spaced electrodes having means mounted in the tube and arranged to be bombarded by the ions, a hollow cylindrical metal shield electrically connected with and surrounding the exit of the ion introducing means which extends into the container, a second hollow cylindrical metal shield electrically connected with and surrounding the bombarded means, said shields having spaced adjacent ends and mounted in substantial alignment with each other, and an insulating material closely fitting the external surfaces of each of said metal shields to prevent the formation of cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal shields.

9. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vauum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said spaced electrodes having means extending in the tube for introducing negative ions in the tube, another of said spaced electrodes having means mounted in the tube and arranged to be bombarded by the ions, a hollow cylindrical metal shield electrically connected with and surrounding the exit of the negative ion introducing means which extends into the tube, a second hollow cylindrical metal shield electrically connected with and surrounding the bombarded means, said shields having spaced adjacent ends and mounted in substantial alignment with each other, and an insulating material positioned externally of each of said metal shields to prevent the formation of cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal shields.

10. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said spaced electrodes having means extending in the tube for introducing positive ions in the tube, another of said spaced electrodes having means mounted in the tube and arranged to be bombarded by the ions, a hollow cylindrical metal shield electrically connected with and surrounding the exit of the positive ion introducing means

which extends into the tube, a second hollow cylindrical metal shield electrically connected with and surrounding the bombarded means, said shields having spaced adjacent ends and mounted in substantial alignment with each other, and an insulating material positioned externally of each of said metal shields to prevent the formation of cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal shields.

11. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, one of said electrodes emitting negative atomic ions of an element with a higher atomic number than hydrogen, the said negative ion emitting electrode having a surface portion from which cold emission streams would normally tend to flow under large electrical differences of potential between said electrodes, and insulating material positioned externally of the said surface portion to prevent the flowing of said cold emission streams, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said surface portion.

12. A high voltage vacuum tube comprising, in combination, a vacuum container, spaced negative electrodes operatively mounted in the vacuum container, a positively charged electrode operatively mounted between the negative electrodes, one of said negative electrodes emitting negative ions, said positively charged electrode having a thin metal foil supported transversely of the direction of the motion of the ions to strip the electrons off the nuclei of the ions and cause the ions to strike said other negative electrode with energy corresponding to substantially twice the voltage on the tube.

13. A high voltage vacuum tube comprising, in combination, a vacuum container, spaced negative electrodes operatively mounted in the vacuum container, a positively charged electrode operatively mounted between the negative electrodes, one of said negative electrodes emitting negative ions, said positively charged electrode having a thin gold foil supported transversely of the direction of the motion of the ions to strip the electrons off the nuclei of the ions and cause the ions to strike said other negative electrode with energy corresponding to substantially twice the voltage on the tube.

14. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, two spaced electrodes and an intermediate electrode operatively mounted in the container in substantially straight alignment, said spaced electrodes being grounded and said intermediate electrode being subjected to a high positive electrical potential, each of said spaced electrodes having a surface portion from which cold emission streams would normally tend to flow under large electrical differences of potential between the intermediate electrode and the two spaced electrodes, and insulating material positioned externally of the said surface portions to prevent the flowing of said cold emission streams.

15. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, two spaced electrodes and an intermediate electrode operatively mounted in the container in substantially straight alignment, said spaced electrodes being grounded and said intermediate electrode being subjected to a high positive electrical potential, each of said spaced electrodes having a surface portion from which cold emission streams would normally tend to flow under large electrical differences of potential between the intermediate electrode and the two spaced electrodes, and insulating material positioned externally of the said surface portions to prevent the flowing of said cold emission streams, one of said spaced electrodes emitting negative ions, said intermediate electrode having a thin metal foil supported transversely of the direction of the motion of the ions to strip the electrons off the nuclei of the ions and cause the ions to strike said other spaced electrode with energy corresponding to substantially twice the voltage on the tube.

16. A high voltage vacuum tube arranged to prevent the formation of cold emission streams which would otherwise occur therein when subjected to a high electrical potential comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and arranged to be subjected to large electrical differences of potential to cause useful electric current to flow therebetween, each of said electrodes having a metal shield extending in advance and surrounding the active part of the electrodes between which the useful current passes, the advanced end of the said shields having an opening through which the useful current passes, a sheath of insulating material surrounding each of said metal shields to prevent the formation of destructive cold emission currents, said insulating material having a porous non-vitreous structure which may be worked with a cutting tool to closely fit the said metal shields.

17. A high voltage vacuum tube comprising in combination, a vacuum container, spaced negative electrodes operatively mounted in the vacuum container, a positively charged electrode operatively mounted between the negative electrodes, one of said negative electrodes emitting negative ions, said positively charged electrode having ion permeable means supported transversely of the direction of the motion of the ions to strip the electrons off the nuclei of the ions and leave positively charged ions which travel with increased energy to said other negative electrode.

18. A high voltage vacuum tube comprising, in combination, a vacuum container, spaced electrodes operatively mounted in the vacuum container and adapted to be charged of one polarity, an intermediate electrode operatively mounted between the spaced electrodes and adapted to be charged of the opposite polarity, one of the said spaced electrodes emitting ions of one polarity, said intermediate electrode having ion permeable means supported transversely of the direction of the motion of the ions to change the polarity of the ions which travel with increased energy to said other spaced electrode.

WILLARD H. BENNETT.