April 11, 1939. J. H. VAN DER TUUK ET AL 2,154,368

DISCHARGE TUBE AND METHOD OF MAKING SAME

Filed April 20, 1937 2 Sheets-Sheet 1

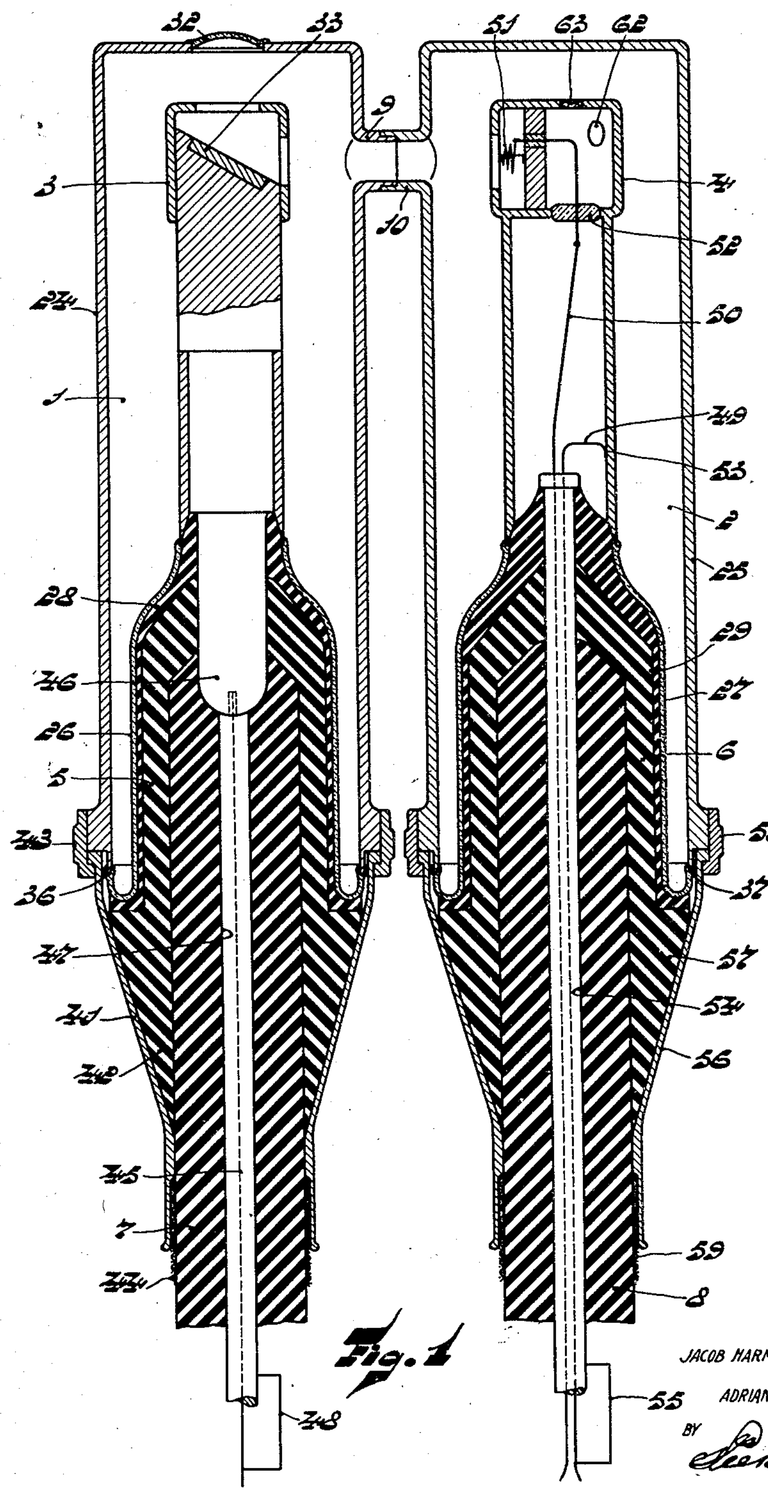

Fig. 1

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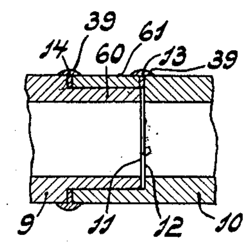

Fig. 2

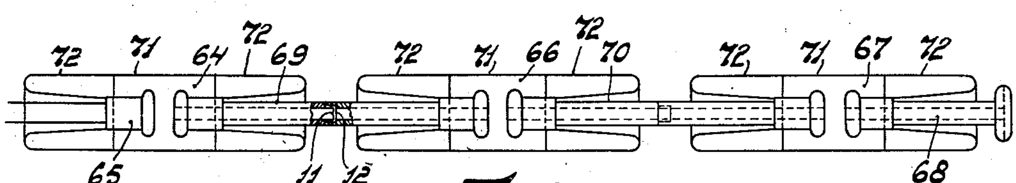

Fig. 3

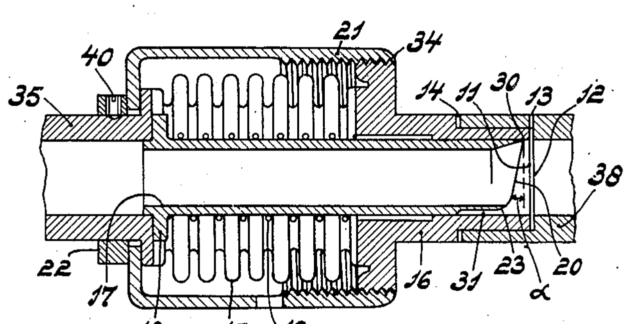

Fig. 4

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UNITED STATES PATENT OFFICE

2,154,368

DISCHARGE TUBE AND METHOD OF MAKING SAME

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Application April 20, 1937, Serial No. 138,022
In Germany April 23, 1936

7 Claims. (Cl. 250—27.5)

Our invention relates to high-voltage discharge tubes comprising a plurality of interconnected compartments, and to a method for making such tubes.

In manufacturing such tubes considerable difficulties arise in forming the rather complicated envelope, and also in evacuating same. In making high-voltage discharge tubes with stepwise electron acceleration, it has been proposed to overcome these difficulties by individually evacuating a plurality of vessels and arranging same in cascade whereby the electrons pass from one vessel through a thin window, through a small intermediate air gap, and then through a second window into the adjacent vessel. Such an arrangement, however, has the disadvantages that the thin windows through which the electrons pass during operation absorb considerable energy and are easily damaged.

The main object of our invention is to provide a method of making such tubes which eliminates the above difficulties.

Another object of our invention is to provide a tube having an interconnected vacuum space, but which comprises a plurality of vessels which have been individually evacuated and completed as sub-assemblies.

Further objects of our invention will appear as the specification progresses.

In accordance with the invention, we form a plurality of individually-evacuated vessels each having a fragile envelope portion, then join the vessels to form a hermetically-tight envelope whose evacuated space is separated into several parts by these portions, and finally perforate the portions to connect the evacuated spaces of the vessels.

With such a method the vessels may be completed as units, and individually exhausted in a simple manner, while at the same time the operation of the completed tube is not deleteriously affected by the presence of partitioning members in the discharge path.

We prefer to perforate the partitioning members by electron impact, and for this purpose the electron speed is not increased to an excessive degree in order that the maximum amount of energy may be absorbed by the members.

In another embodiment of our invention we perforate these members by mechanical means.

To absorb any gases which may be introduced into the evacuated space of the tube due to the perforating of the partitioning members, we prefer to provide a getter in one or more of the vessels, which getter is preferably so disposed as to be protected from the impact of moving particles and to be free from any electric field.

In order that the invention may be clearly understood and readily carried into effect, we shall describe same in more detail in connection with the accompanying drawings, in which:

Figure 1 is a sectional view of an X-ray tube according to the invention;

Fig. 2 is an enlarged view of the connecting portion of the tubes shown in Figs. 1 and 3,

Fig. 3 is a sectional view of a discharge tube for generating cathode rays and embodying the invention,

Fig. 4 is a sectional view of a connecting device according to another embodiment of the invention.

The X-ray tube shown in Figure 1 comprises two vessels or compartments 1 and 2 of somewhat similar construction. Vessel 1 has an envelope comprising a vitreous re-entrant portion 26 hermetically sealed at 36 to a cup-shaped metal portion 24 provided on its closed end with a window 32 for the exit of the X-rays, and forming a tubular protuberance 9, later to be described. Supported by re-entrant portion 26 and hermetically sealed thereto is an anode structure 3 having an inclined target 33 of tungsten. Current is supplied to the anode by a high-tension cable 7 extending into the hollow of re-entrant portion 26. Surrounding the end portion of cable 7 and extending into the space formed between this portion and the re-entrant portion 26 is a bushing 5 of molded insulating material or of rubber. To prevent the occurrence of air spaces between bushing 5 and the surface of re-entrant portion 26, a layer of insulating material 28, for instance a coagulated insulating material applied in a plastic constitution, is provided.

A metal shaft 41 encloses a conical portion 42 of the bushing 5 and is secured to the metal portion 24 by means of a screw cap 43. It connects the metal portion 24 electrically with a flexible metal coating 44 spun round the cable, which may be grounded during the operation of the tube. The current conductor 45, secured to the projecting portion 46 of the anode is led through a hollow flexible conductive tubing 47 to which it is electrically connected, as shown schematically at 48.

Vessel 2, which as stated is similar in construction to vessel 1, has an envelope comprising a vitreous reentrant portion 27 hermetically sealed at 37 to a cupshaped metal portion 25 provided with a tubular protuberance 10. Carried by re-entrant portion 27 and hermetically sealed thereto is a cathode structure 4 comprising an incandescible cathode 51. The high voltage is applied to cathode 51 by a high-tension supply cable 8 extending into the hollow of re-entrant portion 27. An insulating bushing 6 and layer of insulating material 29, similar to that described in connection with vessel 1, are also provided.

For the supply of heating current to filament 51 cable 8 comprises two current conductors 49 and 50. Conductor 50 is hermetically sealed in a little glass disc 52 and kept insulated from the metal structure 4. Conductor 49 is secured to structure 4 at 53. The filament 51 is connected between conductor 50 and structure 4. Conductors 49 and 50 are insulated from each other for the low tension necessary for energizing the cathode and together enclosed in a flexible conductive tubing 54, to which conductor 49 is electrically connected as shown schematically at 55. A metal shaft 56 encloses a conical portion 57 of the insulating bushing 6 and is secured to the metal portion 25 by means of a screw cap 58. It connects the metal portion 25 electrically with a flexible metal coating 59 spun round the cable, which as coating 44 may be grounded during the operation of the tube.

If such a tube were manufactured by first joining protuberances 9 and 10 together to form a U-shaped metal vessel and then making the seals at 36 and 37, considerable difficulties would be encountered. More particularly, because of the shape of the tube it would be extremely difficult to make the first of these seals, for instance seal 37. Furthermore, it would then be difficult, if not impossible, to make the seal 36 without the sealing flame damaging the seal 37.

Still further difficulties would be encountered in the evacuating process. Thereby it is necessary that the tube is baked in a furnace. The shape of the tube deviates considerably from that of the conventional type of tube, which is more or less cylindrical. Baking and pumping the complete tube would therefore require a special furnace.

In accordance with the invention, these difficulties are avoided by making the seals 36 and 37 before the two vessels are placed in the position shown. Then the two vessels are evacuated separately and the cables 7, 8 and bushings 5, 6 may also be assembled before the two vessels are joined together.

The open ends of protuberances 9 and 10 are hermetically closed by means of thin metal members 11 and 12 respectively (see Fig. 2), which members may be of constantan and have a thickness of about 50 microns. The vessels are then individually evacuated to the proper degree. In other words, the vessels are constructed as sub-assemblies and individually evacuated.

After the vessels 1 and 2 have been completed in the above manner they are arranged parallel as shown in Fig. 1 with the members 11 and 12 in the position shown in Fig. 2. For this purpose protuberance 9 has a reduced end portion 60 snugly fitting into a counterbore 61 of protuberance 10. To allow for the escape of air when portion 60 is inserted into counterbore 61, the end of portion 60 is diametrically grooved, and a vent hole 13 is provided in protuberance 10.

When the vessels 1 and 2 have been placed in the position shown in Fig. 1, the walls of the protuberances 9 and 10 are hermetically sealed together by filling annular groove 14 and hole 13 with a suitable solder as indicated by 39. At this stage the two vessels 1 and 2 are mechanically interconnected while at the same time a common hermetically-sealed envelope is formed; however the evacuated spaces of vessels 1 and 2 are separated by members 11 and 12.

We then interconnect the evacuated spaces of vessels 1 and 2 by perforating members 11 and 12 by electron bombardment. For this purpose we apply a high voltage between cathode 51 and anode 3, and heat cathode 51 to such a high degree that an energetic flow of electrons impinges upon members 11 and 12 and heats same, whereby they are partly or entirely melted. The voltage required to melt members 11 and 12 depends of course upon their material and thickness, and for members of the type described above, a voltage of between 100 and 200 kilovolts is sufficient.

As the vacuum within vessels 1—2 may be impaired by the gases produced when melting members 11 and 12 or by the small amount of air which may be entrapped between these members, we prefer to provide a suitable getter, such as barium, within one or both of the vessels. Preferably such a getter is disposed at a point at which there is a minimum amount of moving particles and at which there is no electric field. This is illustrated in Fig. 1 in which a suitable getter 62 is provided within a chamber of cathode structure 4, which chamber is connected to the discharge space through an aperture 63 in the wall of this chamber. In this case the getter material will deposit as a coating on the wall of the chamber. The use of a getter in this manner has been described in the copending U. S. patent application Ser. No. 67,331 to van der Tuuk.

Although we have described the invention in connection with an X-ray tube, it is equally applicable to other high-voltage discharge tubes. For example, Fig. 3 illustrates a high voltage discharge tube for the radiation of cathode rays comprising a vessel 64 containing an incandescible cathode enclosed in a metal structure 65, an intermediate vessel 66, and a third vessel 67 containing an anode 68. Vessels 64—66 and vessels 66—67 are joined together by means of intermediate electrodes 69 and 70 respectively, each comprising two parts closed by thin metal members 11 and 12 and connected together in the manner described in connection with Figs. 1 and 2. In this construction also, the several vessels are constructed as sub-assemblies and individually exhausted, because exhausting the vessels when joined together would require a furnace of undue large dimensions.

The wall of the vessels 64, 66 and 67 comprises a metal waist section 71 and two glass portions 72, having reentrant portions as described in Patent No. 2,093,002, granted Sept. 14, 1937 to Bouwers and van der Tuuk.

The members 11 and 12 of Figs. 1 to 3 may be perforated by mechanical means such as illustrated in Figure 4. The perforating-connecting device shown in the latter figure comprises two tubular members 35 and 38, which may be considered as forming parts of two vessels, i. e. similar to the protuberances 9 and 10 of Fig. 1. Hermetically secured with one end to the flanged end of member 35 is a bellows 15, for instance of copper plate, whose other end is hermetically secured to a tubular flanged member 16. The ends of members 16 and 38 are closed by metal discs 11 and 12, whereas these members are joined together and the groove 14 and vent hole 13 closed in the manner described in connection with the protuberances 9 and 10 of Figs. 1 and 2.

A cap 21 surrounds bellows 15 and has one end inwardly flanged so as to bear upon the flanged end of member **35**. A collar **22** secured to member **35** by means of a set screw prevents axial displacement of cap **21** relative to member **35** while allowing rotation of the cap. The other end of cap **21** is provided with internal threads cooperating with threads on member **16** whereby rotation of cap **21** changes the relative positions of members **16** and **35**. It will be noted that collar **22** prevents bellows **15** from being compressed by atmospheric pressure.

Slidable within the bore of member **16** and having a flanged end pressed against member **35** by a compression spring **19**, is a tubular perforating mandrel **17**. Mandrel **17** is provided on its right-hand end with a cutting or perforating edge **20** tapering inwardly from a point **30** at an angle α of about 12 degrees. The lower part of edge **20** is rounded at **23**, whereas the bottom of mandrel **17** is provided with a groove **31** for a purpose later to be described.

With the device of Fig. 4 in the position shown, and with evacuated vessels (not shown) connected to members **35** and **38**, the groove **14** and hole **13** are sealed in the manner described in connection with Figs. 1 and 2. Cap **21** is then rotated whereby member **35** and mandrel **17** are moved to the right. Point **30** of cutting edge **20** first pierces members **11** and **12**, and upon further movement of mandrel **17** these members are cut along a circular path. However, due to the rounded edge **23**, a complete circular cut is not effected, but strips are cut from discs **11** and **12** and bent downwardly. Upon further movement of mandrel **17**, these strips are pressed against the inner surface of member **38** and confined within groove **31** so they will not interfere with the operation of the tube.

While we have described our invention in connection with specific examples and applications, we do not wish to be limited thereto, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What we claim is:

1. A method of making an electric discharge tube comprising the steps, forming a plurality of evacuated vessels each having a fragile wall portion, arranging said vessels adjacent each other with the wall portions of adjacent vessels in contact with each other, hermetically connecting the envelopes of adjacent vessels to form a common hermetically-tight envelope, and perforating the wall portions to connect the evacuated spaces of the vessels.

2. An electric discharge tube comprising a plurality of individually-evacuated vessels each having at least one thin metal envelope portion, said vessels being hermetically sealed together to form a single sealed envelope with said metal portions dividing the evacuated spaces of adjacent vessels, and means to mechanically perforate said metal portions comprising a compressible member forming a part of the envelope of the tube, a perforating member movable upon compression of said compressible member, and means to compress said member.

3. An electric discharge tube comprising a plurality of individually-evacuated vessels having thin metal envelope portions, said vessels having their envelopes hermetically sealed together to form a single envelope with said metal portions dividing the evacuated space of adjacent vessels, and means to mechanically perforate said metal portions comprising a compressible member forming a part of the envelope of the tube, a tubular perforating member movable upon compression of said compressible member, and means to compress said member, said perforating member being provided with a groove and having an inclined cutting edge rounded near said groove, said groove serving to receive the strips cut from said metal portions.

4. A method of making an electric discharge tube from a plurality of evacuated vessels each having a tubular metal wall portion whose end is closed by a metal foil, comprising the steps, arranging the vessels adjacent each other with the foils of adjacent vessels in contact with each other, hermetically connecting the metal wall portions together to form a single hermetically-sealed envelope enclosing an evacuated space separated by said foils, and perforating the foils to connect the evacuated spaces of the vessels.

5. A method of making an electric discharge tube from a plurality of evacuated vessels each having a tubular metal wall portion whose end is closed by a metal foil, comprising the steps, arranging the vessels adjacent each other with the foils of adjacent wall portions in contact with each other, hermetically connecting the metal wall portions together to form a single hemetically sealed envelope enclosing an evacuated space separated by said foils, and perforating the foils by electron bombardment to connect the evacuated spaces of the vessels.

6. A method of making an electric discharge tube from a plurality of evacuated vessels each having a tubular metal wall portion whose end is closed by a metal foil, comprising the steps, arranging the vessels adjacent each other with the foils of adjacent wall portions in contact with each other, hermetically connecting the metal wall portions together to form a single hermetically-sealed envelope enclosing an evacuated space separated by said foils, and mechanically perforating the foils to connect the evacuated spaces of the vessels.

7. A method of making an electric discharge tube from a plurality of evacuated vessels each having a tubular wall portion whose end is closed by a fragile metal member, comprising the steps, arranging the vessels adjacent each other with the members of adjacent vessels in contact with each other, hermetically connecting the metal wall portions together to form a single hermetically-sealed envelope enclosing an evacuated space separated by said members, perforating the members to connect the evacuated spaces of the vessels, and volatilizing a getter within the evacuated space to absorb any gases introduced into the space by the perforation of said members.

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