July 21, 1942. R. C. HERGENROTHER 2,290,748

VACUUM TUBE AND METHOD OF MANUFACTURE THEREOF

Filed March 5, 1941

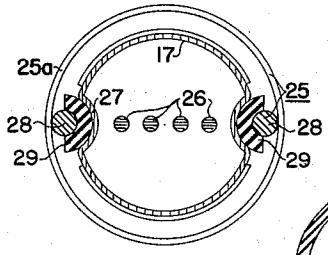
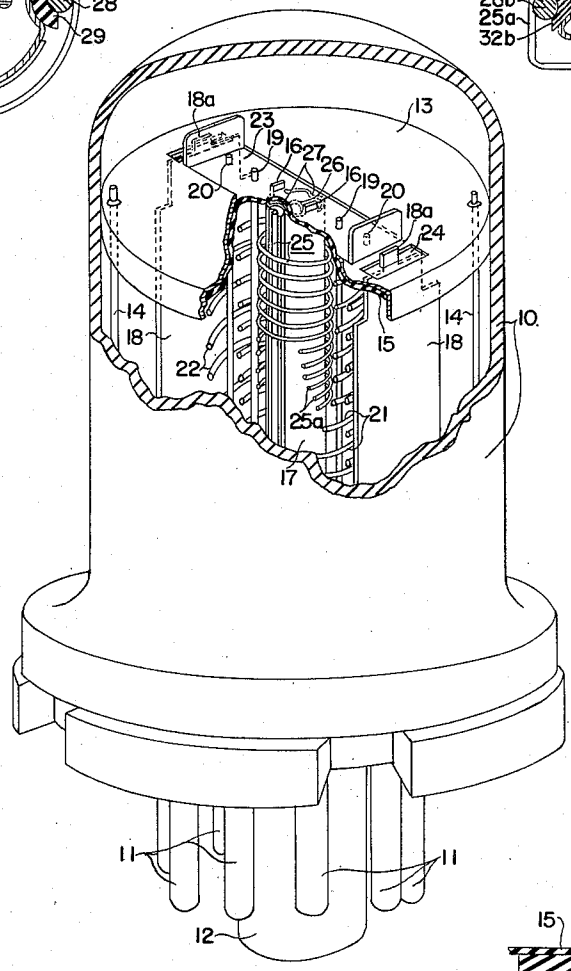


FIG. 2.

FIG. 1.



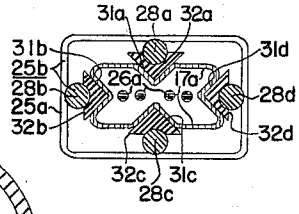
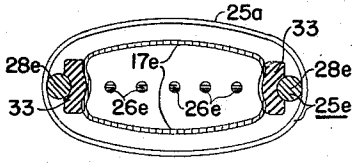


FIG. 3.

FIG. 4.



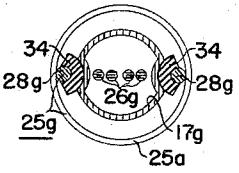
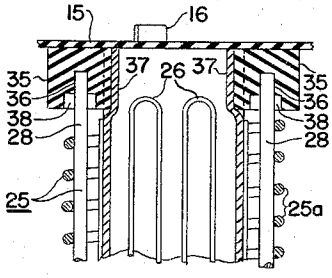


FIG. 5.

FIG. 6.



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VACUUM TUBE AND METHOD OF MANUFACTURE THEREOF

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14 Claims. (Cl. 250—27.5)

The present invention relates to vacuum tubes and, particularly, to the method of and means for supporting certain of the electrodes thereof. In greater particularity, the invention relates to the method of and means for supporting the control-grid electrode in vacuum tubes designed to have high values of transconductance.

In order to obtain high values of transconductance (g_m) in a vacuum tube of conventional type, the control grid must be made of small diameter wire having a close pitch and must closely surround the cathode. For example, a vacuum tube of the 1852 type has a grid-cathode spacing of 0.006 inch. The close tolerances required in such a small grid-cathode spacing applies a limit on the maximum practicable values of transconductance obtainable in vacuum tubes of this type which can be economically manufactured in large quantities. Small variations of the order of a few ten-thousandths of an inch in the grid-cathode spacing result in large percentage changes of transconductance. It is quite difficult in practice to attain reproducible and accurate grid-cathode spacing with such close tolerances in conventional vacuum tubes having the grid and cathode independently supported only at their ends, as by the usual mica insulators. The close tolerances in the size and spacing of the apertures in such mica insulators through which the grid support wires and cathode extend lead in the conventional tube to a relatively expensive construction. The conventional grid structure is not supported at its center and distortions which can occur by bowing of the structure tend to an appreciably large percentage of tube rejects for nonuniformity of operating characteristics.

Furthermore, close grid-cathode spacing of high transconductance vacuum tubes requires delicate handling of the control grid and cathode elements during the assembly of the tube to avoid accidental removal of the fragile electron-emissive coating of the cathode. This coating is sprayed on the cathode at the time when the latter is formed and is fairly easily brushed or scraped off the cathode should the cathode surface accidentally contact the control grid during assembly of the tube. Since the conventional vacuum tube includes a number of grids in addition to the control grid, it is generally deemed necessary during the assembly of such tubes to insert the cathode into position within the control grid as the last step in the assembly of the tube elements. This method of assembly has the disadvantage that the cathode can only be grasped at one end by the person performing the assembly and must be inserted, while so held, through the relatively long and only slightly larger control grid, great care being required to avoid contact of the former with the latter.

It is an object of the present invention, therefore, to provide a new and improved vacuum-tube construction which is particularly suited for vacuum tubes having high values of transconductance.

It is a further object of the invention to provide a vacuum-tube construction which greatly facilitates the attainment of uniform values of high transconductance in successively constructed tubes of the same type.

It is an additional object of the invention to provide a new and improved unitary grid-cathode assembly having an easily reproducible and uniformly high accuracy of grid-cathode spacing with consequent uniformity of tube operating characteristics and one which greatly simplifies and facilitates the assembly of the tube elements.

In accordance with the invention, a vacuum tube comprises an envelope, a cylindrical cathode supported from the envelope, and an anode supported in spaced opposing relation to the cathode. The tube also includes a unitary preformed cylindrical electron-permeable conductive grid member and means for supporting the grid solely from the cathode, independently of the tube envelope, and between the cathode and the anode comprising insulating means positioned between and engaging the grid and the cathode.

In a preferred form of the invention, a vacuum tube of the type described comprises a cylindrical cathode, the surface of which has a plurality of spaced longitudinal grooves formed therein, and the electron-permeable conductive grid structure includes a plurality of longitudinal rigid supporting members corresponding in number and in spacing to the cathode grooves. There are also provided means for supporting the grid structure solely from the cathode and between the cathode and the anode comprising a plurality of insulating members individually positioned between and engaging the rigid supporting members of the grid and the cathode grooves.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring now to the drawing, Fig. 1 is a perspective view, with the envelope partly broken

away, of a vacuum tube embodying the invention; Fig. 2 is an enlarged cross-sectional view of the unitary grid-cathode structure of the Fig. 1 arrangement; and Figs. 3–6, inclusive, are enlarged cross-sectional views of unitary grid-cathode structures of modified configuration and embodying modified forms of the invention.

Referring now more particularly to Fig. 1, there is represented a vacuum tube embodying the present invention in a preferred form. In general, the vacuum tube comprises a metallic envelope 10, partly broken away in the figure, including a conventional base comprising terminal prongs 11 and a centering pedestal 12. Enclosed within the tube envelope 10 is an upper cup-shaped metallic supporting member 13 and a similar lower supporting member (not shown) which are maintained in assembled relation by means of longitudinal support bars 14, 14 fixedly secured thereto, as by welding. Positioned within the supporting member 13 is a mica disc 15 having apertures through which extend the mounting lugs 16, 16 of a cylindrical cathode 17, the mounting lugs 18a, 18a of anode plates 18, 18, which are thus supported in spaced opposing relation to the cathode 17, and the longitudinal rigid support wires 19, 19 and 20, 20 of a screen grid 21 and a suppressor grid 22, respectively. The supporting cup member 13 is provided with enlarged apertures 23 and 24 to prevent electrical contact of the supporting member with the supporting lugs and support wires of the cathode, anode and grid elements. It will be understood that the lower support plate (not shown) is similarly formed and has positioned therein a similar mica disc (not shown) which supports the lower ends of the tube elements in similar manner. Supported from the cathode 17, in a manner presently to be described, and closely spaced thereto is a unitary preformed cylindrical electron-permeable conductive control grid 25, this grid and the cathode comprising a unitary grid-cathode structure. A filamentary heater 26 is positioned within the cathode 17. The several tube elements are connected by individual conductors (not shown) to the contact prongs 11 of the tube base.

It will be understood that the vacuum-tube construction thus far described, except for the unitary grid-cathode structure, presently to be described in detail, involves a conventional tube construction.

Referring now more particularly to the portion of the tube construction embodying the present invention, the cathode 17 is directly supported from the tube envelope 10 by means of the upper supporting member 13 and mica disc 15 and the lower supporting member and mica disc (not shown) as previously explained, and is provided with a pair of longitudinal grooves 27, 27 at diametrically opposite points on its periphery. These grooves, which are more clearly shown in the detailed cross-sectional view of the unitary grid-cathode structure of Fig. 2, are preferably formed by running the cathode 17 through a die either during or after the formation of the cathode but before the cathode has been sprayed with a suitable electron-emissive coating. It may be desirable thereafter to run the sprayed cathode through a trimming die to scrape the coating material out of the grooves.

The control grid 25 comprises a helix 25a of small diameter wire having a close pitch mounted on a pair of longitudinal rigid conductive supporting members or wires 28, 28 attached or integrally secured to the helix at diametrically opposite points. In order to support the grid 25 solely from the cathode 17, independently of the tube envelope 10, and between the cathode and the anodes 18, 18, there are provided insulating means positioned between and engaging the grid 25 and the cathode 17. These insulating means comprise grooved semi-cylindrical insulating members 29, 29 which are individually positioned between and engage the grid support wires 28 and cathode grooves 27. The insulating members 29, 29 are preferably formed of a ceramic material, for example, a $BeO—Al_2O_3$ mixture of the type used for cathode-heater insulation, this material having been found to have an actual resistance in cathode-heater construction in excess of 8000 megohms at a temperature of 1100 degrees K. The ends of the grid support wires 28, 28 and the ends of the insulating members 29, 29 engage the lower surface of the upper mica disc 15 and the upper surface of the lower mica disc (not shown) when the tube is assembled, thereby to prevent longitudinal movement of the grid 25.

The unitary grid-cathode structure thus provided may be assembled in a number of ways, as by sliding the grid 25 and insulating members 29, 29 together into position on the cathode 17, in which case the rounded outer surface of the insulating members 29, 29 engage the cathode grooves 27, 27 and serve as guiding surfaces during the telescoping step, thus to maintain the grid structure 25 out of contact with the cathode 17 during this operation; or the grid 25 may be positioned over the cathode 17 and the insulating members 29, 29 may then be slipped into position. The grid 25 and cathode 17 are maintained in assembled relation prior to their assembly with other tube elements into the vacuum tube either by suitably cementing the insulating members 29, 29 to the grid and cathode elements or by simply relying on the tension of the grid helix 25a to hold the assembly in frictional engagement. Since the control grid and cathode are assembled into a unitary structure prior to their assembly in the vacuum tube, it will be evident that this construction has the advantage that both the control grid and cathode elements can be grasped at each end, preferably in an assembly jig, whereby these elements can be adequately supported and carefully guided during the entire time that they are being assembled into a unit. Consequently, the control grid and cathode can be assembled together with facility and with negligible chance of injury to the cathode electron-emissive surface. Moreover, the cathode surface is protected by the control grid in the final assembly of the complete tube. Additionally with this construction, the control grid and cathode are securely locked together to produce a rigid unitary structure with accurately reproducible grid-cathode spacing. The accuracy of reproducibility of the spacing is limited only by the tolerances within which the parts can be made and this may well be less than 0.0005 inch.

It is well known that an oxide-coated cathode very slowly gives off barium atoms which may build up a conductive film on its supporting insulating members. However, this film is built up only on surfaces which are directly exposed to the cathode-emissive surface. It will be noted particularly from the enlarged cross-sectional view of Fig. 2 that the insulating members 29, 29 have concave surface portions in engagement with the longitudinal supporting members 28, 28

of the grid structure **25** and additionally have flat or plane surface portions contiguous to the outer edges of the concave surface portions, the plane surface portions being out of the direct line of sight of all portions of the surface of the cathode **17**. Consequently, since the plane surfaces of the insulating members **29, 29** of the construction described are not exposed to the cathode-emissive surface, they are not subject to the formation of this conductive film and, therefore, serve to ensure a high resistance path between the control grid **25** and the cathode **17** over a long period of operation.

It will be evident that, where friction alone is utilized to maintain the insulating members **29, 29** in proper position between the grid **25** and cathode **17**, the maximum frictional force is developed when each of the insulating members **29, 29** has one surface shaped to conform to the cathode grooves **27, 27** and the other surface shaped or grooved to conform to the surfaces of the rigid supporting wires **28, 28** of the grid **25**.

The term "cylindrical" as used in this specification and in the appended claims is intended to have its generic meaning and to refer not only to a member having a circular cross-section, but also to such members having other cross-sectional configurations, for example, elliptical or rectangular.

Fig. 3 represents a cross-sectional view of a unitary grid-cathode structure comprising a control grid and cathode having similar rectangular cross-sections, elements of this figure corresponding to elements of Figs. 1 and 2 being designated by corresponding reference characters with added subscripts. In the modification of the invention represented by Fig. 3, the cathode is provided with a plurality of longitudinal V-shaped grooves **31***a*—**31***d*, one on each of its four sides. The grid **25***b* comprises a plurality of longitudinal rigid supporting members or wires **28***a*—**28***d*, corresponding in number and in spacing to the cathode grooves, on which are wound the grid wires **25***a*. A plurality of wedge-shaped insulating members **32***a*—**32***d* are individually positioned between and engage the rigid supporting members **28***a*—**28***d* and the cathode grooves **31***a*—**31***d*. This modified form of unitary grid-cathode structure and the method of its assembly are otherwise the same as that of Figs. 1 and 2.

The modification of the invention represented by the cross-sectional view of Fig. 4 is essentially similar to that of Fig. 2, similar elements being designated by similar reference numerals with added subscripts, except that the grid **25***e* and cathode **17***e* have an elliptical cylindrical cross-section. Additionally, whereas the insulating members **29, 29** of Fig. 2 are shown as separately-formed elements of the grid-cathode assembly, the modification of Fig. 4 includes insulating means integral with or fixedly secured to the cathode **17***e*. This means comprises ceramic insulating members **33, 33** formed on the cathode **17***e* as by extrusion or spraying, trimming to a desired configuration, and subsequent baking in well-known manner.

In the modification of the invention represented by the cross-sectional view of Fig. 5, which is essentially similar to the modification of Fig. 2, similar elements being designated by similar reference characters with added subscripts, the insulating means between the grid **25***g* and cathode **17***g* comprises a plurality of insulating pedestals **34, 34** integral with the grid **25***g*. These pedestals are preferably formed by extruding or spraying the insulating material on the longitudinal rigid supporting members **28***g*, **28***g* of the grid either before or after the wire helix **25***a* is wound over the members **28***g*, **28***g*, the insulating material being subsequently shaped to the desired configuration and baked in well-known manner. The insulating pedestals **34, 34** of this modification thus comprise insulating means fixedly secured to the grid member **25***g* and engaging the cathode **17***g* to support the grid solely from the cathode.

To avoid excessive grid emission when it is negative relative to the cathode and other tube electrodes, it is desirable that the control grid helix **25***a* and supporting members **28, 28** have low heat conductivity and high coefficient of heat emissivity. Additionally, the grid emission may be reduced by so proportioning the ceramic insulating members as to ensure minimum heat transfer to the grid.

The modification of the invention represented by the cross-sectional detail view of Fig. 6 is designed to provide minimum transfer of heat energy from the cathode **17** to the grid **25**. In this modification, the insulating means between the control grid and cathode elements is comprised of a plurality of cylindrical ceramic buttons **35, 35** each having an axial bore **36** adapted to receive one end of the longitudinal rigid support wire **28** of the control grid **25**. The cathode **17** has longitudinal grooves **37, 37** which, in this case, extend only the length of the ceramic buttons **35**. When the grid **25** is assembled with the cathode **17** to provide a unitary grid-cathode structure, the grid and cathode elements are effectively locked together by the ceramic buttons **35**. The grid **25** is held against longitudinal movement with respect to the cathode **17** in the final assembly of the tube elements by the abutment of the ceramic buttons **35, 35** against the upper mica disc **15** and the lower mica disc (not shown). Each of the ceramic buttons **35** has an axial counter bore **38** at the end facing the grid **25** for the purpose of providing a surface which is not exposed to barium atoms given off by the electron-emissive coating of the cathode **17**, thus to maintain high electrical insulation between the grid and cathode elements. The relatively short length of the ceramic buttons **35** ensures minimum transfer of heat from the cathode **17** to the grid **25**, thereby to ensure minimum grid emission.

From the foregoing description of the invention, it will be evident that a vacuum tube embodying the invention is adapted to have extremely uniform control grid-cathode spacing between successively fabricated tubes of the same type, whereby such tubes have a high degree of uniformity of their operating characteristics. Additionally, the support of the control grid solely from the cathode greatly facilitates the assembly of the vacuum-tube elements and ensures maximum protection of the rather delicate cathode-emissive surface at each step of the assembly process.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid member, and means for supporting said grid member solely from said cathode and between said cathode, independently of said envelope, and said anode comprising insulating means positioned between and engaging said grid and said cathode.

2. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid conductive supporting members, and means for supporting said grid structure solely from said cathode, independently of said envelope, and between said cathode and said anode comprising insulating means positioned between and engaging said rigid supporting members and said cathode.

3. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid structure comprising a plurality of longitudinal conductive members integrally secured to and supporting a wire helix of spaced turns, and means for supporting said grid structure solely from said cathode and between said cathode, independently of said anode and said anode comprising insulating means positioned between and engaging said conductive members and said cathode.

4. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid supporting members, and means for supporting said grid structure solely from said cathode and between said cathode and said anode comprising a plurality of insulating members individually positioned between and engaging said rigid supporting members and said cathode.

5. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, the surface of said cathode having a plurality of spaced longitudinal grooves formed therein, an anode supported in spaced opposing relation to said cathode, a cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid supporting members corresponding in number and in spacing to said cathode grooves, and means for supporting said grid structure solely from said cathode and between said cathode and said anode comprising insulating means positioned between and engaging said rigid supporting members and said cathode grooves.

6. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, the surface of said cathode having a plurality of spaced longitudinal grooves formed therein, an anode supported in spaced opposing relation to said cathode, a cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid supporting members corresponding in number and in spacing to said cathode grooves, and means for supporting said grid structure solely from said cathode and between said cathode and said anode comprising a plurality of insulating members individually positioned between and engaging said supporting members and said cathode, each of said insulating members having one surface shaped to conform to said cathode grooves and having another surface shaped to conform to the inner surface of said rigid supporting members.

7. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, the surface of said cathode having a plurality of spaced longitudinal grooves formed axially therein, an anode supported in spaced opposing relation to said cathode, a cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid supporting members corresponding in number and in spacing to said cathode grooves, and means for supporting said grid structure solely from said cathode and between said cathode and said anode comprising a plurality of semi-cylindrical insulating members individually positioned between and engaging said rigid supporting members and said cathode grooves.

8. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid member, and means for supporting said grid member solely from said cathode and between said cathode, independently of said envelope, and said anode comprising insulating means fixedly secured to said grid member and engaging said cathode.

9. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced opposing relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid structure including a plurality of longitudinal rigid supporting members, and means for supporting said grid structure solely from said cathode, independently of said envelope and between said cathode and said anode comprising insulating means fixedly secured to said cathode and engaging said rigid supporting members.

10. The method of constructing a unitary grid-cathode assembly for a vacuum tube comprising, the steps of forming a cylindrical cathode, forming a cylindrical electron-permeable conductive grid, positioning insulating means on said cathode, and telescoping said grid over said cathode and said insulating means into position with said insulating means engaging said grid and said cathode fixedly to support said grid solely from, and in spaced relation to, said cathode.

11. The method of constructing a unitary grid-cathode assembly for a vacuum tube which comprises the steps of forming a cylindrical cathode, forming a cylindrical electron-permeable conductive grid, telescoping said grid and said cathode, and inserting a plurality of insulating members between said grid and said cathode at a plurality of points spaced around the periphery of said cathode fixedly to support said grid from, and in spaced relation to, said cathode.

12. The method of constructing a unitary grid-cathode assembly for a vacuum tube which comprises the steps of forming a cylindrical cathode, forming a plurality of grooves in the surface of said cathode and spaced equidistant around its periphery, forming a cylindrical electron-permeable conductive grid with a plurality of longitudinal rigid supporting wires corresponding in number and peripheral spacing to said cathode

grooves, telescoping said grid and said cathode, and inserting insulating members in each of said cathode grooves and in engaging relationship with corresponding ones of said supporting wires fixedly to support said grid from, and in spaced relation to, said cathode.

13. A vacuum tube comprising, an envelope, a cylindrical cathode supported from said envelope, an anode supported in spaced relation to said cathode, a unitary preformed cylindrical electron-permeable conductive grid member, and means for supporting said grid member solely from said cathode, independently of said envelope, and between said cathode and said anode comprising insulating means positioned between and engaging said grid and said cathode, said insulating means including surface portions in engagement with said grid member and surface portions contiguous to the outer edges of said first-named surface portions, said contiguous surface portions being out of the direct line of sight of all portions of the surface of said cathode.

14. The method of constructing a unitary grid-cathode assembly for a vacuum tube comprising, the steps of forming a cylindrical cathode, forming a cylindrical electron-permeable conductive grid, forming insulating members having supporting and guiding surfaces on the periphery thereof, positioning said insulating members on one of said cathode and grid members, and telescoping with the aid of said guiding surfaces said grid over said cathode with said insulating members positioned therebetween and engaging said grid and said cathode fixedly to support said grid solely from, and in spaced relation to, said cathode, said guiding surfaces of said insulating members serving to maintain said grid out of contact with said cathode during the telescoping step.

RUDOLF C. HERGENROTHER.

CERTIFICATE OF CORRECTION.

Patent No. 2,290,748. July 21, 1942.

RUDOLF C. HERGENROTHER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 14-15, for "Enlosed" read --Enclosed--; page 4, first column, line 9, claim 1, strike out ",independently of said envelope," and insert the same after "cathode" and before "and" in line 8, same claim; lines 32 to 34, claim 3, for "cathode and between said cathode, independently of said anode and" read --cathode, independently of said envelope, and between said cathode and--; and second column, line 31, claim 8, strike out ", independently of said envelope," and insert the same after "cathode" and before "and" in line 30, same claim; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of September, A. D. 1942.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)