

July 9, 1946.

P. L. HARTMAN

2,403,444

ELECTRON DISCHARGE DEVICE

Filed May 31, 1941

2 Sheets-Sheet 1

FIG. 1

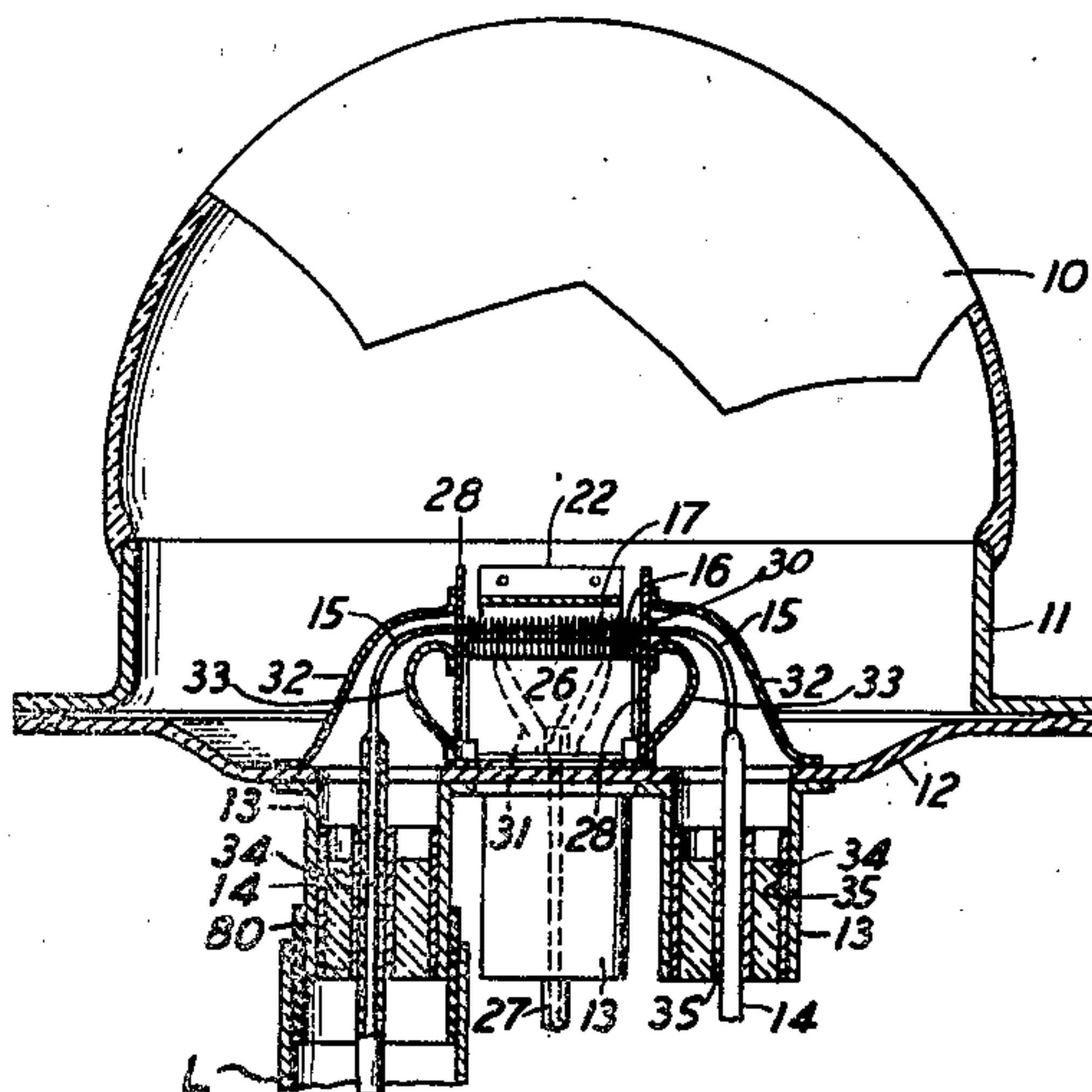


FIG. 2

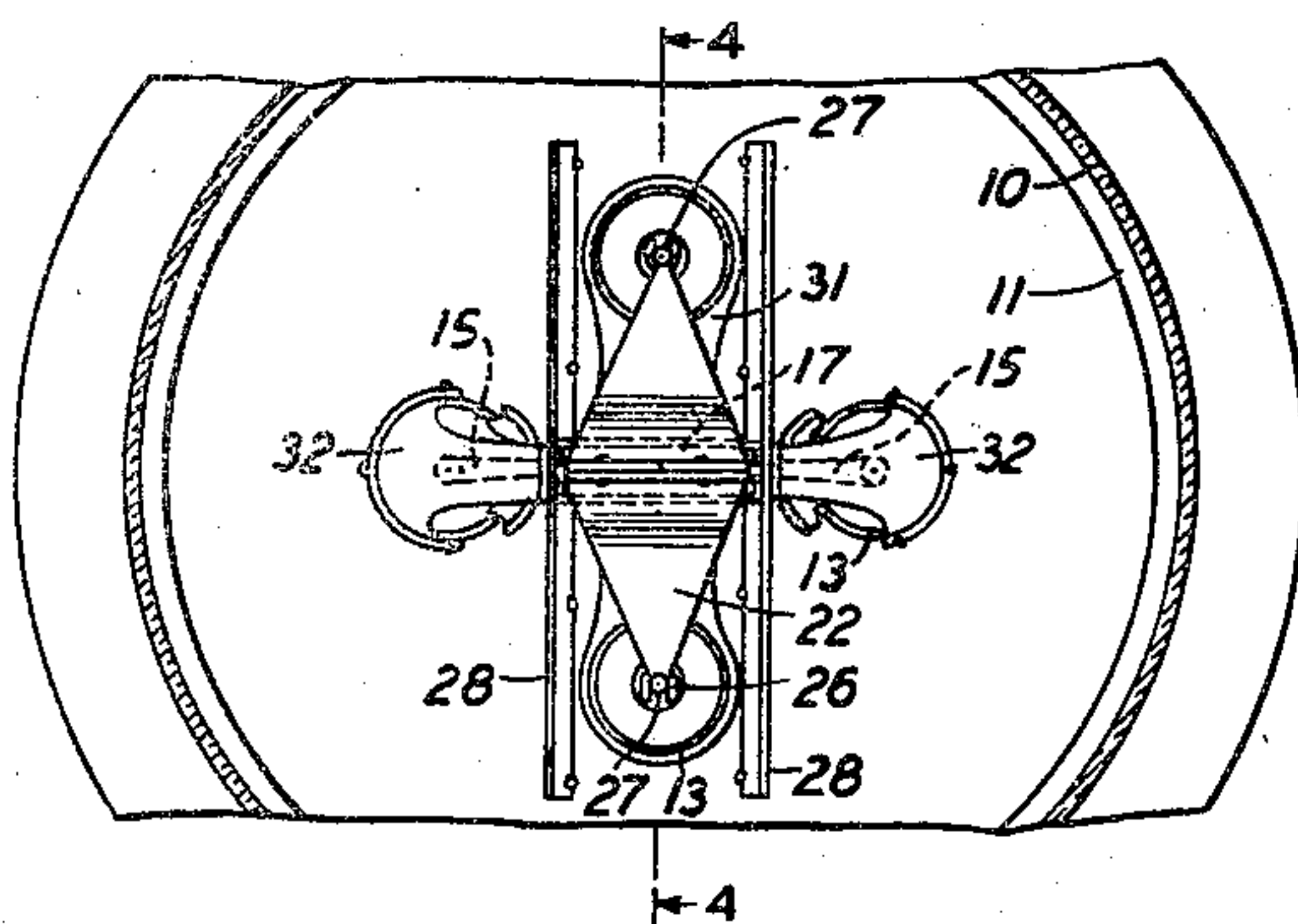
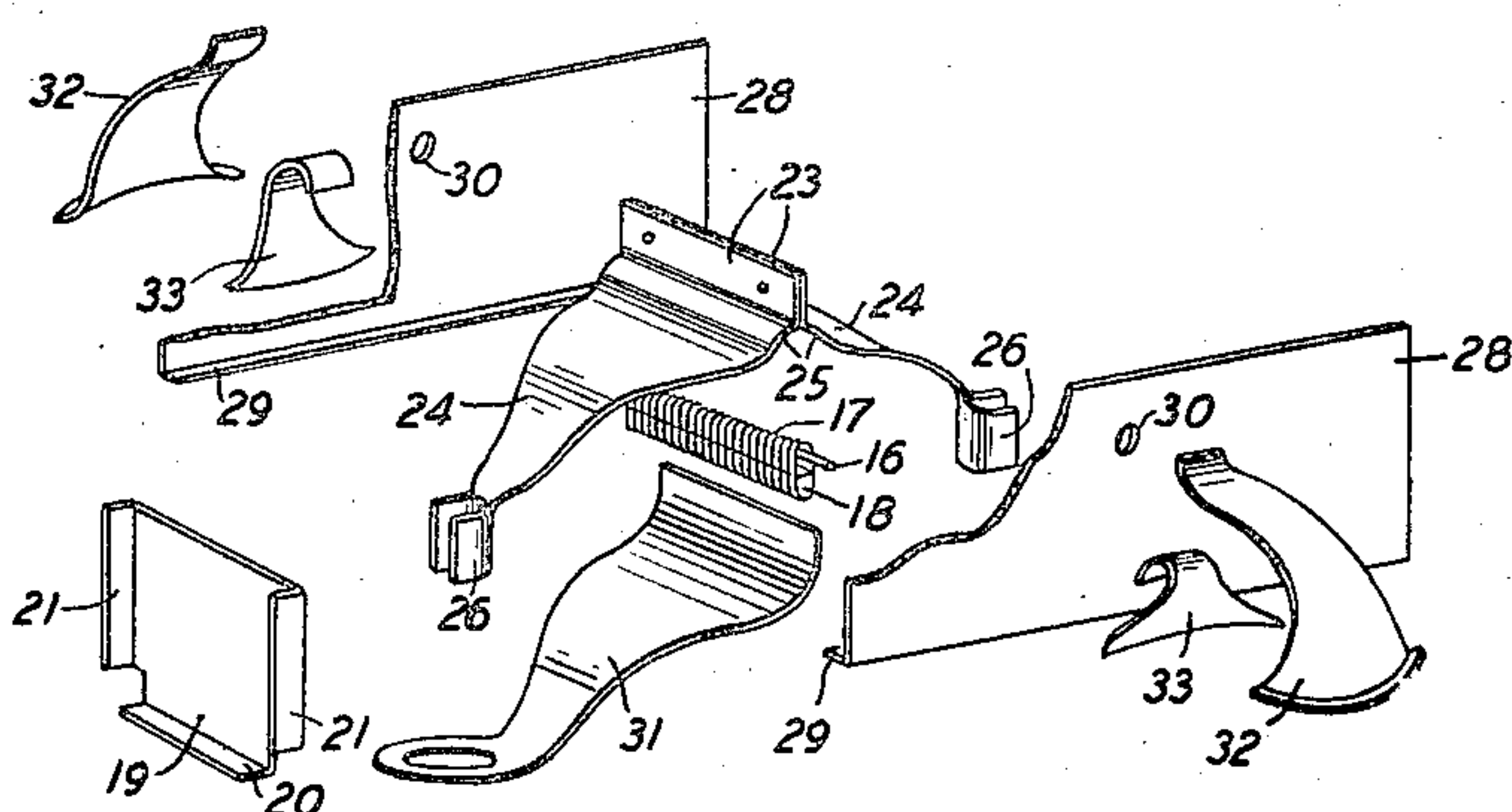


FIG. 3



INVENTOR
P. L. HARTMAN
BY
Walter C. Kiesel
ATTORNEY

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P. L. HARTMAN

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FIG. 4

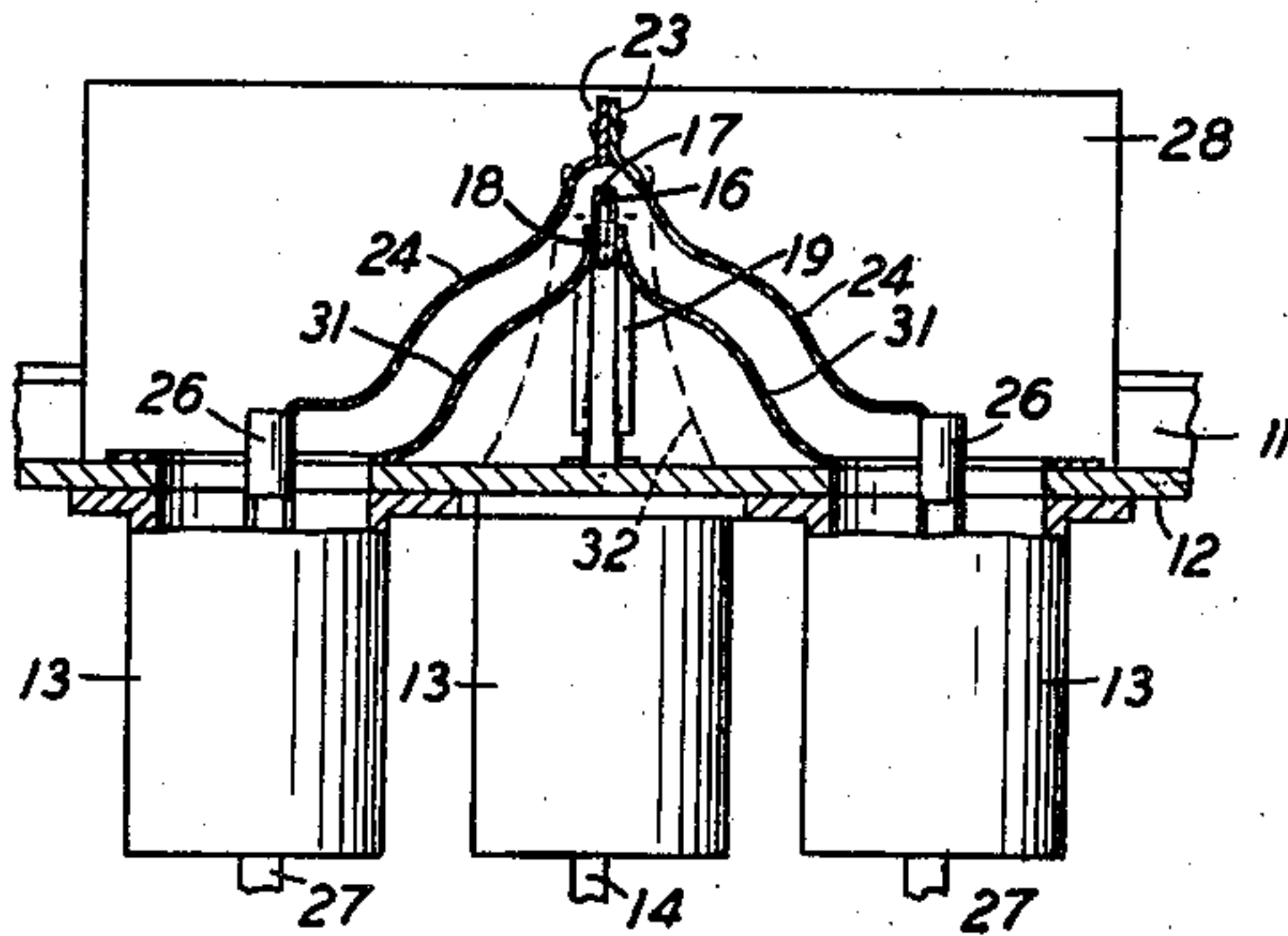


FIG. 5

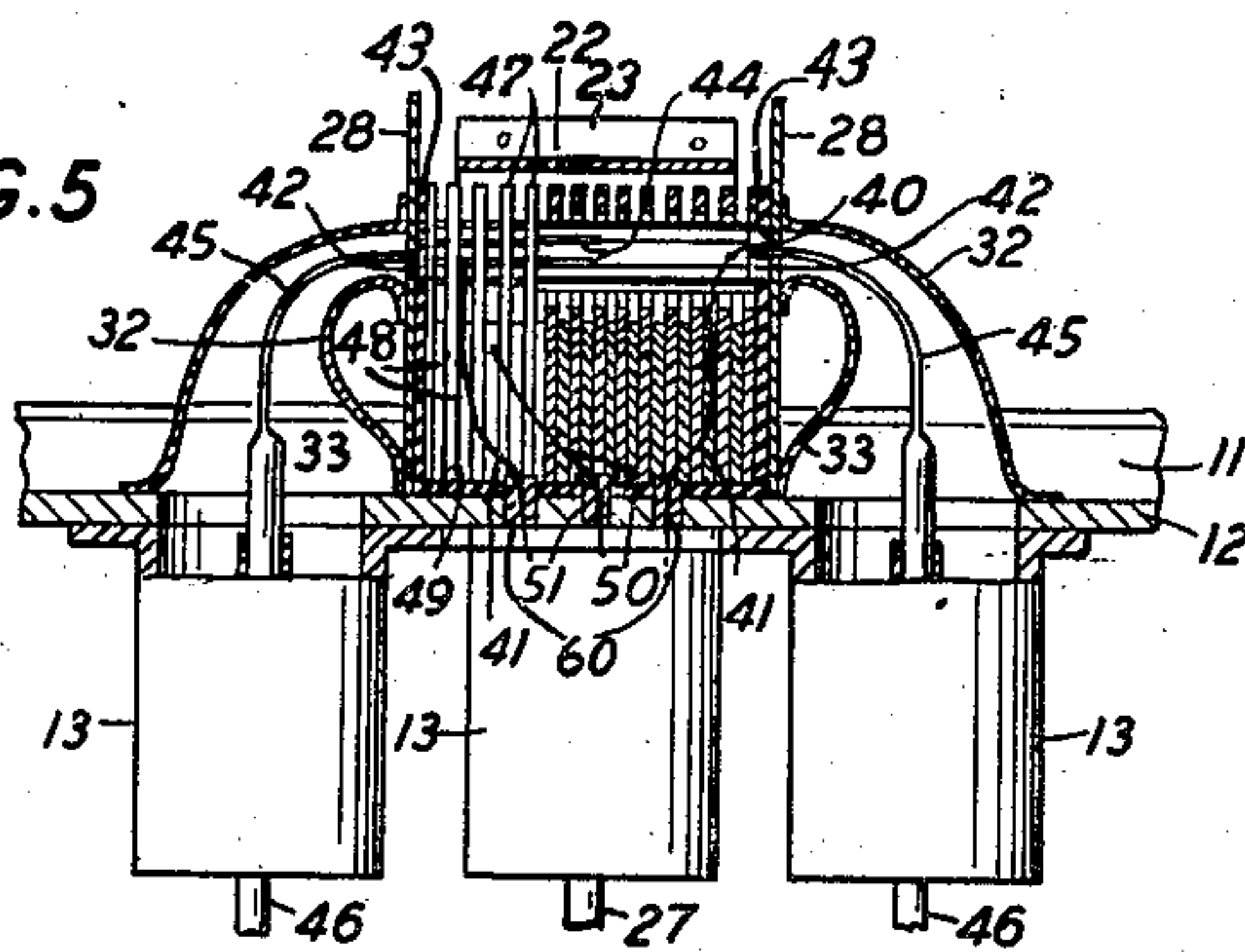


FIG. 8

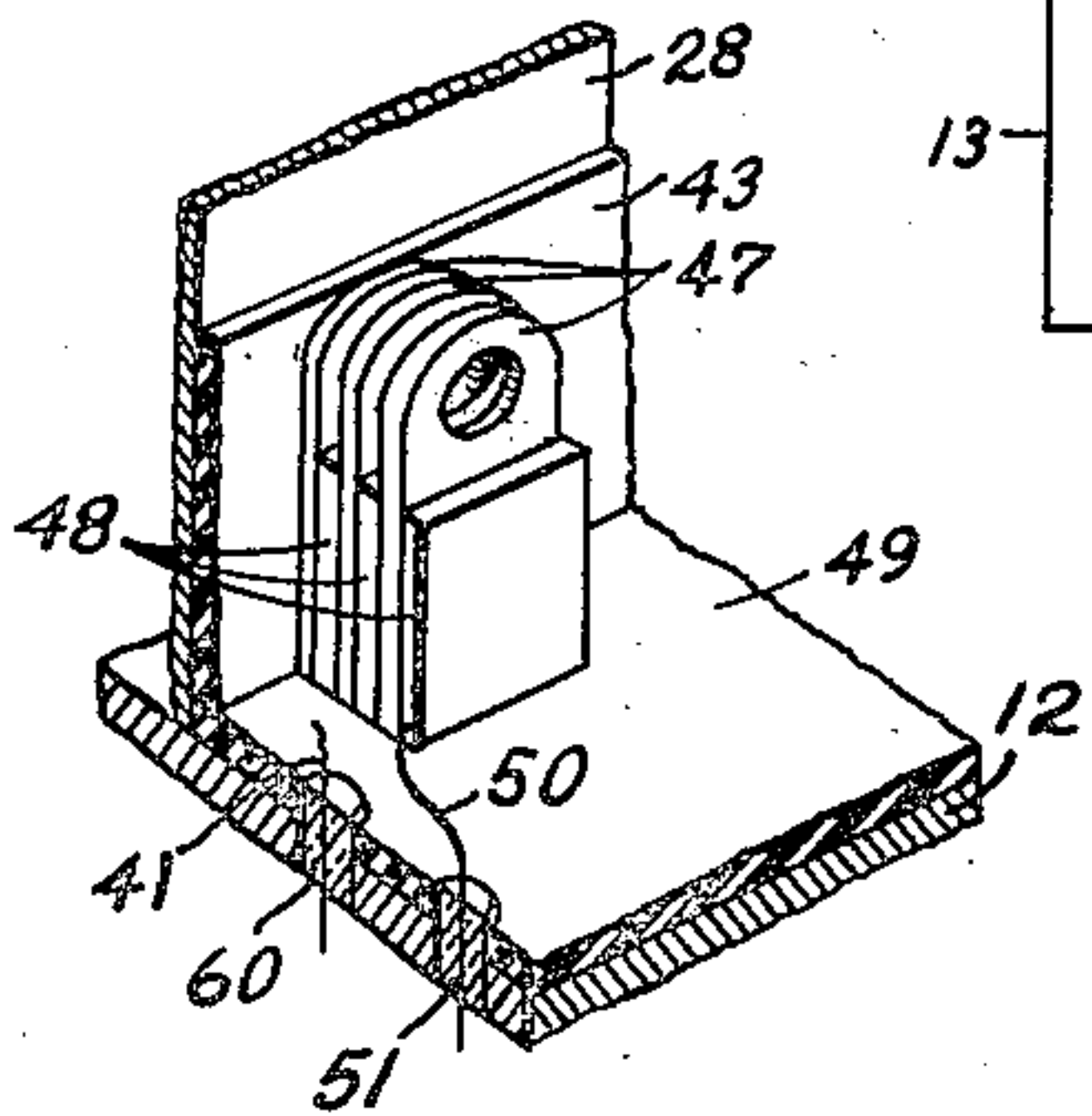


FIG. 6

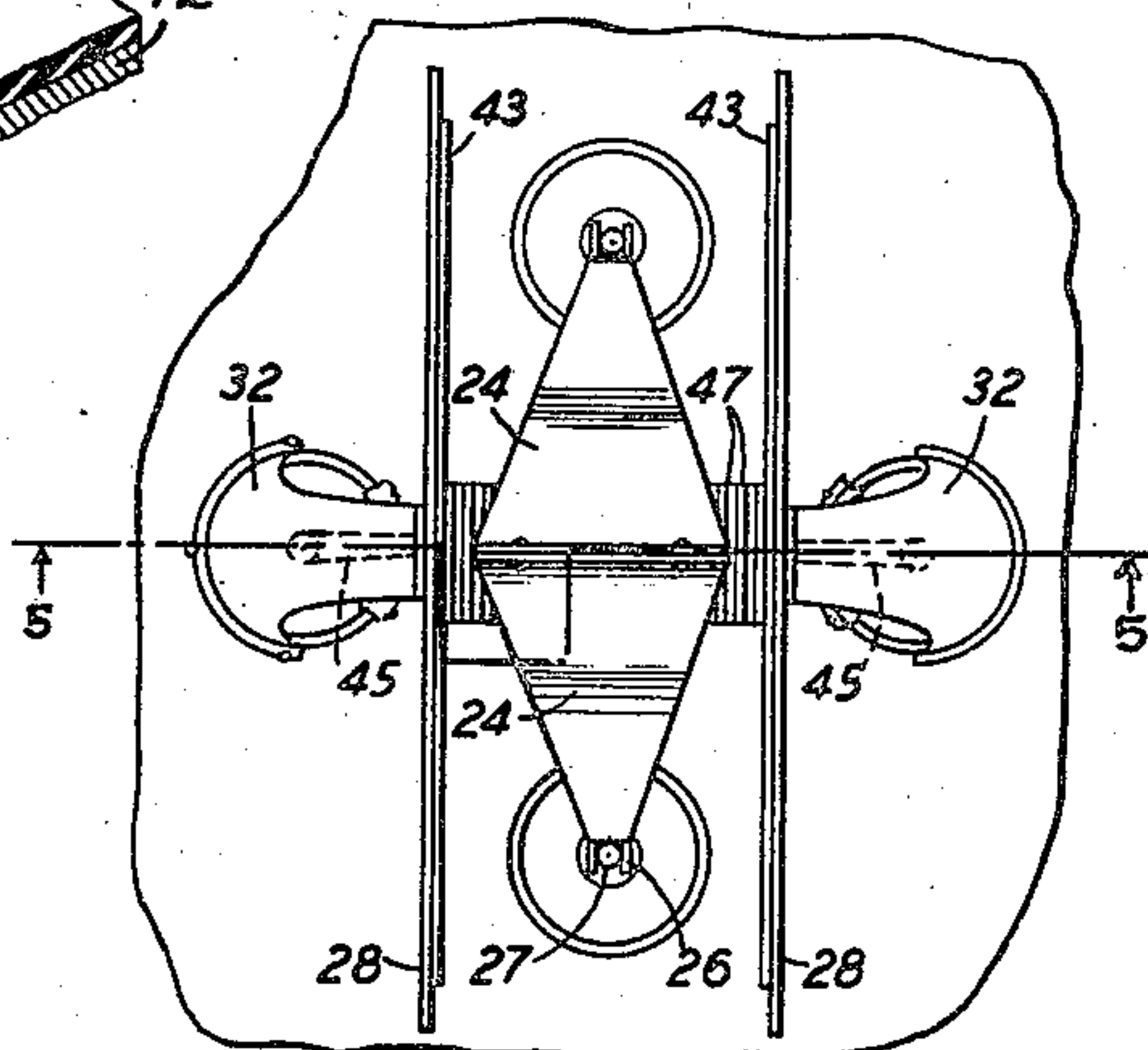
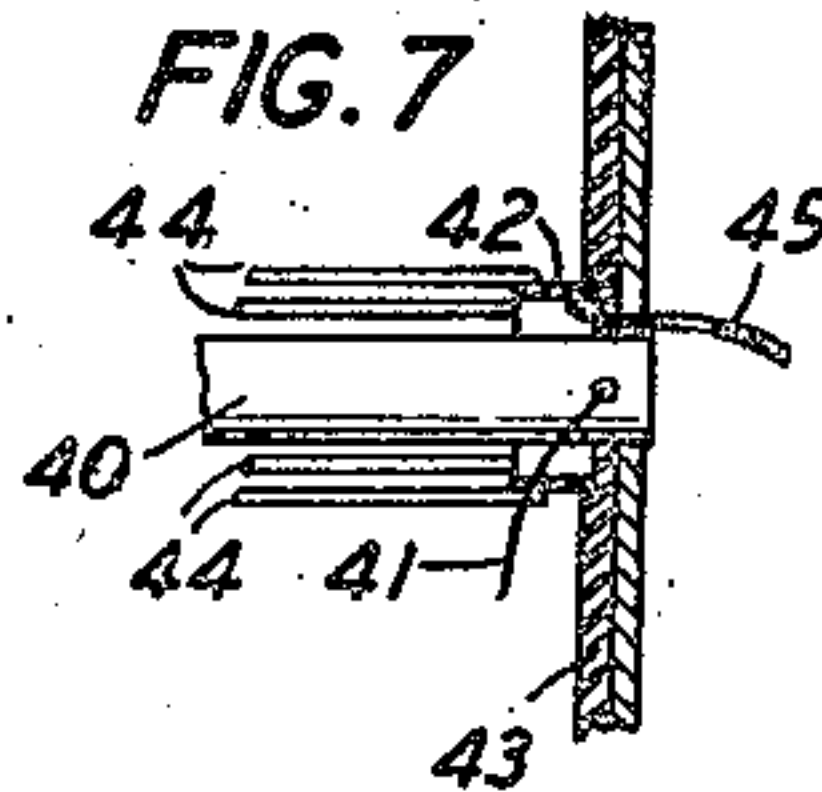


FIG. 7



INVENTOR
P. L. HARTMAN
BY
Walter C. Kiesel
ATTORNEY

UNITED STATES PATENT OFFICE

2,403,444

ELECTRON DISCHARGE DEVICE

Paul L. Hartman, New York, N. Y., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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11 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices and more particularly to such devices especially suitable for use as amplifiers at ultra-high frequencies, such as frequencies in the centimeter wave-length range.

In ultra-high frequency electron discharge apparatus including an electronic device, the electrodes of the device and the leading-in conductors therefor constitute a large part of the circuit and the interelectrode impedances play a major part in determining the upper frequency limit of the range in which the apparatus may be operated. Also in such apparatus, a very high impedance across the input elements of the electronic device usually is desired and to this end a distributed constant external circuit, such as a coaxial line, short-circuited at the end thereof remote from the electronic device, is associated with the electrodes, such as the cathode and control electrode or grid, of the device.

The end impedance of a short-circuited coaxial line of a length somewhat less than a quarter wave-length is primarily inductive. The impedance of an open line, such as simulated by a pair of electrodes is primarily capacitive. If the short-circuited and open-ended lines are connected together, a very high impedance is obtained across the line provided that the total length of the two lines is equal to a quarter of a wave-length of the desired transmitted frequency.

In known electron discharge devices, the lumped capacity between the electrodes and the leading-in conductors therefor is very appreciable. Hence, where a short-circuited coaxial line is associated with two of the electrodes, there is placed across the coaxial line a lumped capacity so that the length of the resultant circuit may be quite short and less than the quarter wave-length requisite for the very high impedance desired. Even if the external coaxial line is short-circuited in immediate proximity to the electron discharge device, the circuit within the device defined by the electrodes and the leading-in conductors therefor has such characteristic impedance that the minimum operating wave-length is relatively long.

Also in electron discharge devices operable at ultra-high frequencies, interaction between the input and output elements of the device presents an important problem in that it affects materially the operating characteristics of the device.

Furthermore, in such devices the dielectric losses occurring in the seals between the electrode leading-in conductors and the enclosing vessel

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are appreciable and hence reduce the operating efficiency of the device.

One object of this invention is to extend the frequency range of operation of ultra-short wave electron discharge devices.

Another object of this invention is to facilitate the attainment of a very high impedance across the input elements of electron discharge devices operable at extremely high frequencies.

Still another object of this invention is to effectively segregate the input and output elements of electron discharge devices whereby interaction therebetween is minimized.

A further object of this invention is to reduce dielectric losses in ultra-high frequency electronic discharge devices and thereby to increase the operating efficiency of such devices.

In one illustrative embodiment of this invention, a grounded grid centimeter wave-length amplifier comprises elongated parallel cathode, control grid and anode electrodes having uniformly spaced juxtaposed surfaces and mounted within an enclosing vessel having a metallic wall or base portion electrically integral with the control grid and to which the leading-in conductors for the cathode and anode are hermetically sealed, the wall or base portion having thereon eyelets through which the leading-in conductors extend and with which they define coaxial conductor elements for associating the electrodes with external coaxial conductor lines.

In accordance with one feature of this invention, the leading-in systems for the electrodes are constructed and arranged so that the circuits within the enclosing vessel are substantially matched with the external coaxial conductor circuits. More particularly the leading-in systems are of such construction that the characteristic impedance thereof is substantially the same as the characteristic impedance of the coaxial conductor lines with which they are associated. The characteristic impedance may be expressed as

$$\sqrt{\frac{L}{C}}$$

where L and C are the inductance and capacity respectively, per unit length of the system or line.

The characteristic impedance of the external coaxial lines is given by the relation

$$Z_c = 138 \log_{10} \frac{b}{a} \quad (1)$$

where Z_c is the characteristic impedance and a and b are the diameters of the inner and outer conductors respectively. The characteristic im-

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pedance of a line consisting of two strip-like conductors, uniformly spaced and with major surfaces thereof in juxtaposition is given, neglecting edge effects, by the relation

$$Z_c = 377 \frac{b}{a} \quad (2)$$

where b is the spacing between the conductors and a the width of the narrower conductor. Such strip-like conductors may be parallel and plane, curved or of other forms. The characteristic impedance of a line composed of a strip-like conductor mounted midway between two wider strip-like conductors of greater width is given, neglecting edge effects, by the relation

$$Z_c = 188 \frac{b}{a} \quad (3)$$

where a is the width of the intermediate conductor and b is the spacing therebetween and each of the two outer conductors. The conductors may be plane and parallel, curved or of other forms.

In one specific construction embodying the aforementioned feature of this invention, the leading-in system for the anode and control electrode comprises two uniformly spaced strip members, one connected to the control electrode and the other to the anode, associated with the coaxial conductor and eyelet structure, the geometry of the strip members being such that the characteristic impedance of the line defined thereby substantially matches the characteristic impedance of the external coaxial line to be associated therewith. The cathode-control grid leading-in system includes a pair of strip-like conductors electrically integral with the control grid and a strip-like conductor mounted midway between these two conductors, the geometry of the several conductors being such, in accordance with the principles noted above, that the characteristic impedance thereof substantially matches that of the external coaxial line portion of the cathode-control grid circuit.

In accordance with another feature of this invention, shield plates are provided opposite the ends of the electrodes and electrically integral with the control electrode or grid for screening the leading-in system for the cathode from the anode.

In accordance with a further feature of this invention, certain of the leading-in conductors are insulated from the base plate through quartz sleeves hermetically sealed to the eyelets through which the leading-in conductors extend.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings, in which:

Fig. 1 is an elevational view mainly in section of an ultra-high frequency electron discharge device illustrative of one embodiment of this invention;

Fig. 2 is a partial plan view of the device shown in Fig. 1, a portion of the enclosing vessel being broken away;

Fig. 3 is an exploded view of the electrode structure included in the device shown in Figs. 1 and 2;

Fig. 4 is a view of the electrode structure, mainly in section along plane 4—4 of Fig. 2;

Fig. 5 is an elevational view mainly in section along line 5—5 of Fig. 6 of the electrode and base structure in an electron discharge device

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of the screen grid type illustrative of another embodiment of this invention;

Fig. 6 is a plan view of the structure illustrated in Fig. 5; and

Figs. 7 and 8 are fragmentary views showing details of construction of the structure illustrated in Figs. 5 and 6.

Referring now to the drawings, the electron discharge device illustrated in Figs. 1, 2 and 3 is particularly suited for use as a grounded grid amplifier and comprises an evacuated enclosing vessel including a substantially hemispherical vitreous portion 10 which is hermetically sealed at its edge to a flanged metallic ring 11, the flange of which is hermetically joined, as by welding, to a metallic base plate 12. The base plate 12 has joined thereto four metallic eyelets 13 through which leading-in conductors for the electrodes of the device extend and to which the conductors are sealed hermetically in the manner described in detail hereinafter.

Two of the leading-in conductors 14 include curved, flexible, tapered strip portions 15 to which there is secured a rectilinear, filamentary cathode 16 extending substantially parallel to the base plate 12, the cathode 16 being maintained under tension, to preserve the linear form thereof, by the flexible strip portions 15, the spring action occurring immediately adjacent the junction of the portions 14 and 15. Encompassing the cathode 16 and uniformly spaced therefrom is a helical control grid 17 which is mounted on a rigid metallic support 18 extending therefrom and is supported in parallel relation to the cathode 16 by a pair of plates 19 secured to the support 18, as by welding, and having flanges 20 welded to the base plate 12, and having also flanges 21, the purpose of which will be set forth hereinafter.

Mounted in cooperative relation with the cathode 16 and control grid 17 is an anode, designated generally by the reference numeral 22, composed of two similar halves having joined flanges 23, laterally extending generally triangular portions 24, and intermediate arcuate portions 25 which together define a substantially semicircular electron receiving portion uniformly spaced from and parallel to the cathode and control grid. The laterally extending portions 24 are provided at their outer ends with sockets 26 in which leading-in conductors 27 are secured.

Extending across the ends of the grid 17 are a pair of parallel metallic shield plates 28 having flanges 29 secured, as by welding, to the base plate 12, the plates 28 being secured also to the flanges 21 on the grid supporting plates 19. The shield plates 28 are provided with suitable apertures 30 through which the filamentary cathode 16 extends and, as shown in Fig. 1, extend upwardly from the base plate 12 to at least the height of the anode flanges 23 above the base plate and extend laterally beyond the extremities of the anode.

Extending from opposite sides of the grid structure 17, 18 and affixed thereto and to the base plate 12 are a pair of tapering metallic strips 31 which, as shown clearly in Fig. 4, conform to and are spaced from the laterally extending portions 24 of the anode.

Each of the cathode leading-in conductors 14, 15 extends substantially midway between a pair of curved strip metallic conductors 32 and 33, the outer, 32, of which are secured to the base and shield plates 12 and 28 respectively, and the oth-

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ers, 33, of which have their ends secured to the corresponding shield plate 28.

During operation of the device, tunable coaxial lines L, only one of which is shown, may be associated with each of the eyelets 13 and the leading-in conductor 14 or 27 extending there-
through, the outer conductor of each line being connected to the corresponding eyelet and the inner conductor of the line being connected to the leading-in conductor. The outer conductor of each line is spaced from the corresponding eyelet 13 by a thin insulating sleeve 80, for example of mica, so that the outer conductors are associated with the respective electrodes through blocking condensers.

It will be noted that the electrodes are mounted in close proximity to the base plate 12 so that the internal circuits, of which the electrodes and their leading-in conductors form a part, have a relatively short physical length. Also the shield plates 28 and the strip conductors 32 and 33, which are at the same, control grid, potential, provide a high degree of shielding between the anode and the cathode and its leading-in conductors.

The portion of the control grid to anode circuit within the enclosing vessel of the device comprises in the main two spaced conductors of very gradually varying width, the anode constituting one conductor and the grid 17 and metallic members constituting the other. Hence, it will be appreciated that the characteristic impedance of the internal grid-anode circuit may be made substantially the same as that of the coaxial line associated with the grid and anode through the leading-in conductors 27 and the eyelets 13 associated therewith, whereby the portions of the anode-grid circuit within and outside of the enclosing vessel are matched.

Similarly, the internal part of the cathode-control grid circuit, which includes the leading-in conductors 15 mounted between two grounded conductors 32 and 33 and a hybrid line section, i. e., between the cathode 16 and the grid 17, and is at right angles to the anode-control grid leading-in system, may be substantially matched with the part of the cathode-grid circuit external to the device.

Although in both the cathode-control electrode and anode-control electrode leading-in systems the width of the conductors and the spacing therebetween vary, it will be appreciated that for the lines defined thereby the ratio b/a may be maintained substantially constant so that the characteristic impedance of these systems may be made substantially constant throughout the length of the lines and substantially matched with that of the external coaxial lines to be associated therewith.

The cathode and anode leading-in conductors 14 and 27 respectively are joined to the corresponding eyelets 13 by insulating bodies 34 of quartz which are sealed to the leading-in conductors and the eyelets by quantities of silver 35. In the fabrication of the seals, coatings of copper are produced upon the inner and outer cylindrical surfaces of a quartz sleeve, as by depositing copper on these surfaces by vaporization. The leading-in conductor, which may be of copper or other metal, such as Invar, copper-plated, is inserted into the quartz sleeve and a silver sleeve is inserted between the quartz sleeve and the conductor. The assembly is then heated, as by passing a suitable current through the conductor, to melt the silver and fuse it to the cop-

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per coating on the inner surface of the quartz sleeve and to the copper conductor or the copper plating on the conductor. Similarly, the eyelets may be of copper and the quartz sleeve joined thereto through a silver sleeve which when heated, as by high frequency induction in a vacuum or heating in a hydrogen furnace, melts and fuses to the copper eyelet and to the copper coating on the outer surface of the quartz sleeve.

The leading-in conductor to eyelet seal may be made also by mounting the conductor, eyelet, plated quartz sleeve and silver sleeves in a suitable jig and heating the assembly in a hydrogen furnace and both seals, that is, quartz to eyelet and quartz to leading-in conductor, made simultaneously.

In another form, the eyelet may be silver-coated on its inner surface and the quartz sleeve silver-coated on its outer surface and the two silver coatings sealed to one another by a silver solder having a melting point somewhat lower than that of silver itself.

A conductor to eyelet seal of the construction described provides low resistance current paths and exhibits low dielectric losses and, hence, is particularly suitable for use in ultra-high frequency devices.

The electron discharge device illustrated in Figs. 5, 6 and 7 is of the screen grid type and suitable for grounded cathode operation. It comprises an indirectly heated equipotential cathode including a cylindrical metallic sleeve 40 fitted in apertures in the shield plates 28 and coated on its outer surface with a thermionic material, the sleeve enclosing a heater filament, not shown, to which heating current may be supplied through conductors 41 extending through apertures in the sleeve 40, as shown in Fig. 7, and through the base plate 12, the conductors 41 being sealed to the base plate by insulating beads 60. The cathode is encompassed by a cage type control grid coaxial therewith, the grid comprising a pair of metallic collars 42 fitted in apertures in thin insulating plates 43, for example of mica, secured to the shield plates 28, and a plurality of equally spaced parallel wires 44 secured at their ends to the collars 42. The control grid is provided at opposite ends with tapering, strip leading-in conductors 45 which extend midway between the shields 32 and 33 and are connected to conductors 46 joined to two of the eyelets 13 in the manner described hereinabove.

The control grid is encompassed in turn by a screen grid which comprises a plurality of metallic laminations 47 apertured adjacent one end to provide circular openings coaxial with the control grid and maintained in parallel relation by metallic spacers 48. The screen grid abuts the insulating members 43 and is seated upon a thin insulating member 49, such as a mica plate, upon the base plate 12, so that the screen grid is at radio frequency cathode or ground potential. Direct current connection to the screen grid may be established through a leading-in conductor 50 extending through the base plate 12 and hermetically sealed thereto by an insulating bead 51.

The anode 22 is similar to the anode in the device illustrated in Figs. 1 to 4 and has its semi-cylindrical surface defined by the portions 25 coaxial with the other electrodes.

The internal control grid-cathode circuit, it will be noted, includes two portions comprising a strip conductor, one of the conductors 45, mounted midway between a pair of conductors 32

and 33 at cathode potential so that an impedance match between the external coaxial and internal portions of the control grid cathode circuit may be obtained.

It will be appreciated that although the devices shown and described are single-ended mechanically, they are double-ended electrically. That is, in both devices, the anode and cathode may be connected at opposite ends to two coaxial external circuits and the control grid and cathode likewise may be connected at opposite ends to two external coaxial systems.

Although specific embodiments of the invention have been shown and described, it will be appreciated that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron discharge device comprising an enclosing vessel, a plurality of cooperative electrodes within said vessel, and a leading-in system for two of said electrodes including an outer coaxial line section and an inner section composed of spaced metallic strip members and having a characteristic impedance substantially the same as that of said coaxial line section.

2. An electron discharge device comprising an enclosing vessel housing a cathode, a control electrode and an anode, and a leading-in system for said cathode and said control electrode including a coaxial line section, a pair of spaced conductive strip members connected to the outer conductor of said coaxial line section and to one of said cathode and control electrode and a conductive strip extending midway between said spaced strips and connected to the inner conductor of said line and to the other of said cathode and control electrode.

3. An electron discharge device comprising an enclosing vessel housing a cathode, a control electrode and an anode, and a leading-in system for said control electrode and said anode including an outer coaxial line section and an inner section composed of metallic strips having major surfaces in juxtaposition, said strips being adjacent and substantially coextensive.

4. An electron discharge device comprising an enclosing vessel housing a cathode, a control electrode and an anode, a leading-in system for said anode and control electrode including an outer coaxial line section and a second section comprising spaced conductive strip members defining a line having a characteristic impedance substantially the same as that of said coaxial line section, and a leading-in system for said cathode and said control electrode including an outer coaxial line section and a second section formed of spaced conductive strips defining a line having substantially the same characteristic impedance as said second coaxial line section.

5. An electron discharge device comprising an elongated cathode electrode, a grid electrode substantially coaxial with said cathode electrode, an anode, an enclosing vessel having a metallic portion extending parallel to said grid and cathode electrodes, a pair of spaced metallic strips adjacent each end of said cathode and grid electrodes electrically connected to said metallic portion and to one of said electrodes, and a pair of metallic strips connected to opposite ends of the other of said electrodes and insulatingly sealed through

said metallic portion, each of said second pair of metallic strips extending between one pair of said first metallic strips.

6. An electron discharge device comprising an enclosing vessel having a metallic base wall, a cathode and a grid substantially coextensive therewith, within said vessel and extending substantially parallel to said wall, an anode, a pair of leading-in conductors connected to opposite ends of said cathode and insulatingly sealed to said base wall, means connecting said grid electrically to said base wall, and two pairs of metallic strip members electrically connected to and extending from said wall, each of said leading-in conductors being positioned between one pair of said strip members and said strip members extending into proximity to the ends of said grid.

7. An electron discharge device comprising an enclosing vessel having a metallic base wall, a cathode and a grid substantially co-extensive therewith within said vessel and extending substantially parallel to said wall, an anode substantially coextensive with said grid, a pair of leading-in conductors connected to opposite ends of said cathode and insulatingly sealed to said base wall, means connecting said grid electrically to said base wall, two pairs of metallic strip members electrically connected to and extending from said wall, a pair of shields adjacent opposite ends of said anode and electrically connected to said strip members, each of said leading-in conductors being positioned between one pair of said strip members and said strip members extending into proximity to the ends of said grid.

8. An electron discharge device comprising an enclosing vessel having a metallic wall portion, a cathode and a grid extending substantially parallel to said wall portion, an anode opposite said grid, means electrically connecting said grid to said wall portion, a pair of metallic shields opposite the ends of said anode and extending from said wall portion, and leading-in conductors for said cathode extending through said shields and said wall portion and hermetically sealed to said wall portion.

9. An electron discharge device comprising an enclosing vessel having a metallic wall, an anode overlying said metallic wall, a pair of shield plates opposite the ends of said anode, mounted on and electrically connected to said wall, cathode and control electrodes adjacent said anode and mounted between said plates, means electrically connecting one of said electrodes to said wall, and leading-in conductors for the other of said electrodes extending through said shield plates and said wall.

10. An electron discharge device in accordance with claim 9 comprising two pairs of metallic members electrically connected to said wall and each pair extending from said wall to one of said shield plates on opposite sides of a corresponding one of said conductors.

11. An electron discharge device comprising an enclosing vessel having a metallic wall, a cathode within said vessel and electrically connected to said wall, a control electrode and an anode adjacent said cathode, an insulating member on the inner surface of said wall, and a screen grid comprising a plurality of spaced laminae seated on said insulating member and having a portion between said anode and control electrode.

PAUL L. HARTMAN.