RADIOACTIVE RESISTOR

Filed June 27, 1945 2 SHEETS—SHEET 1

FIG. 1.

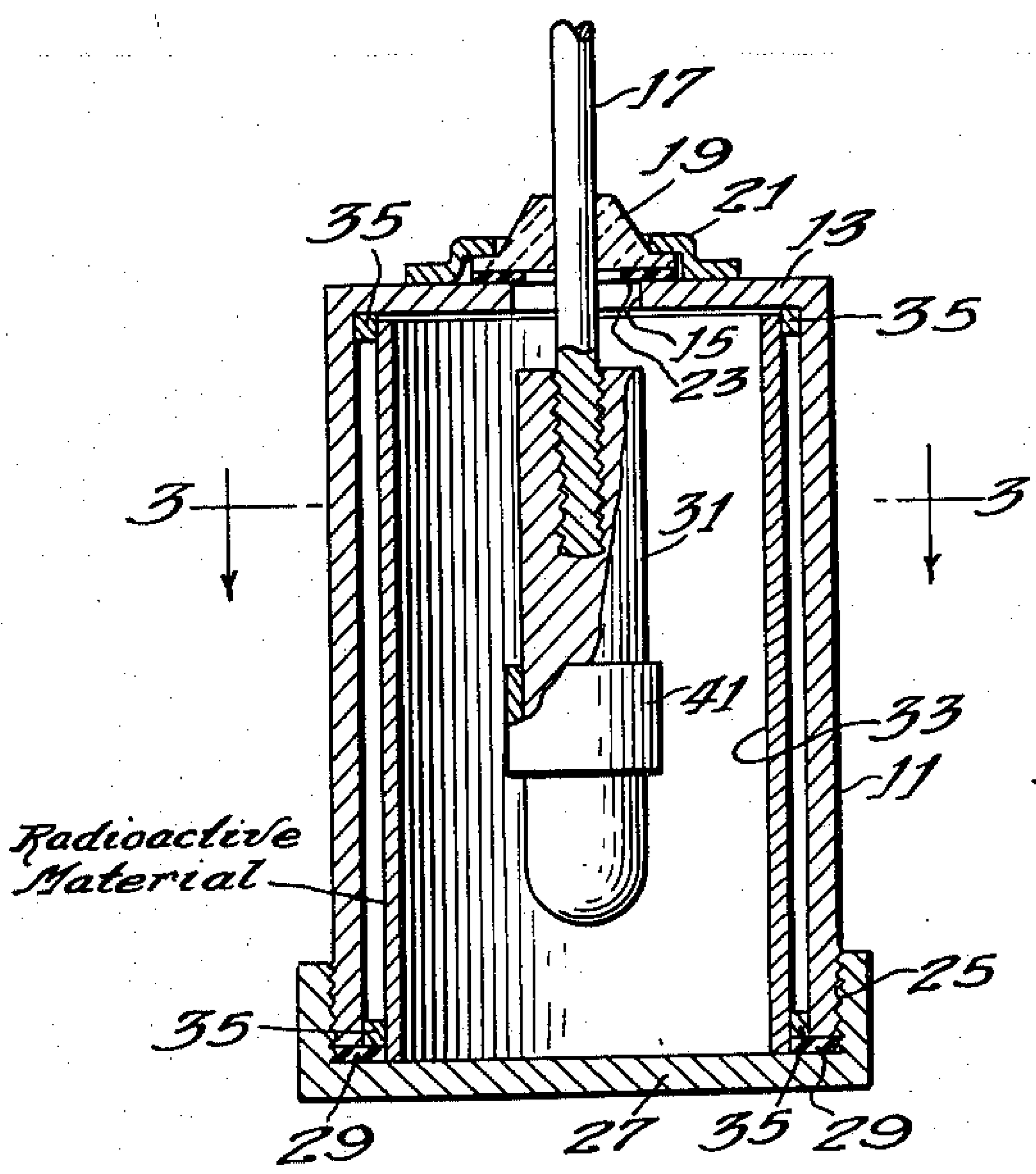


FIG. 2.

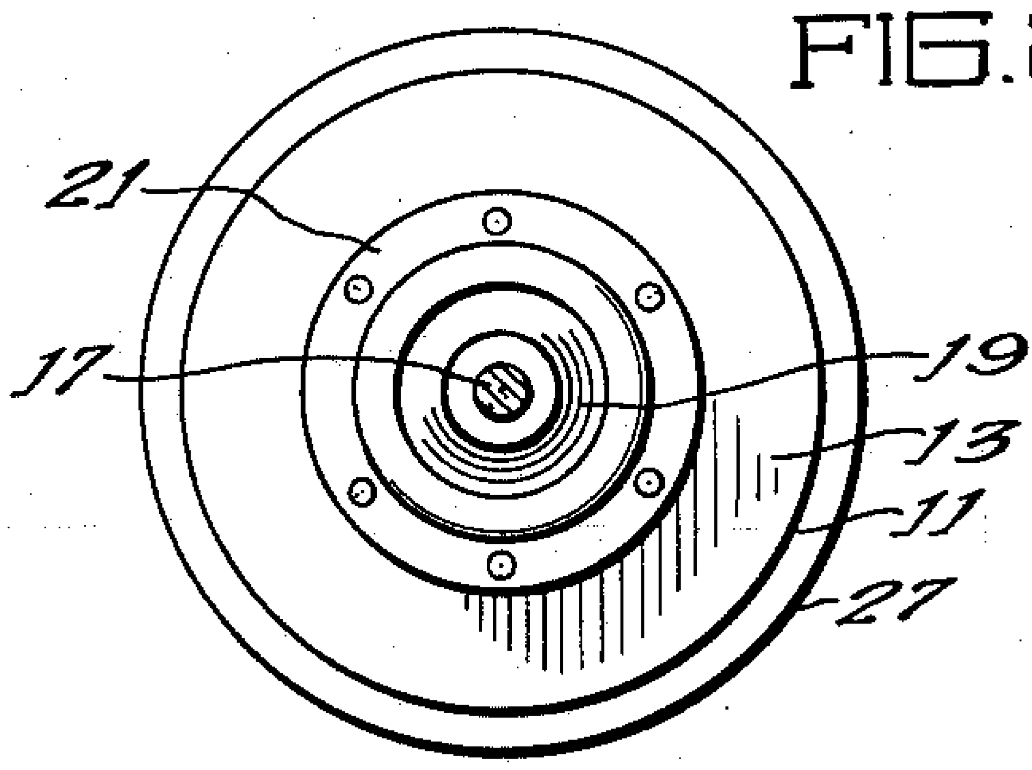


FIG. 3.

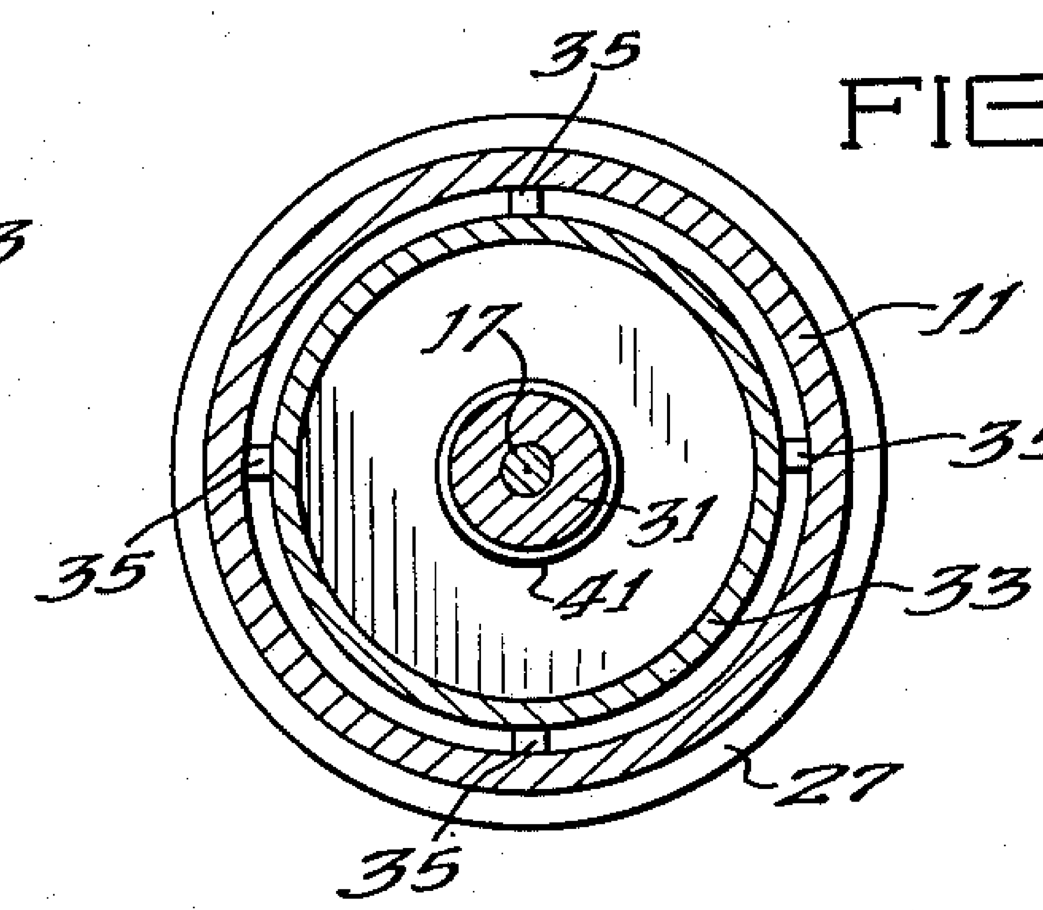


FIG. 8.

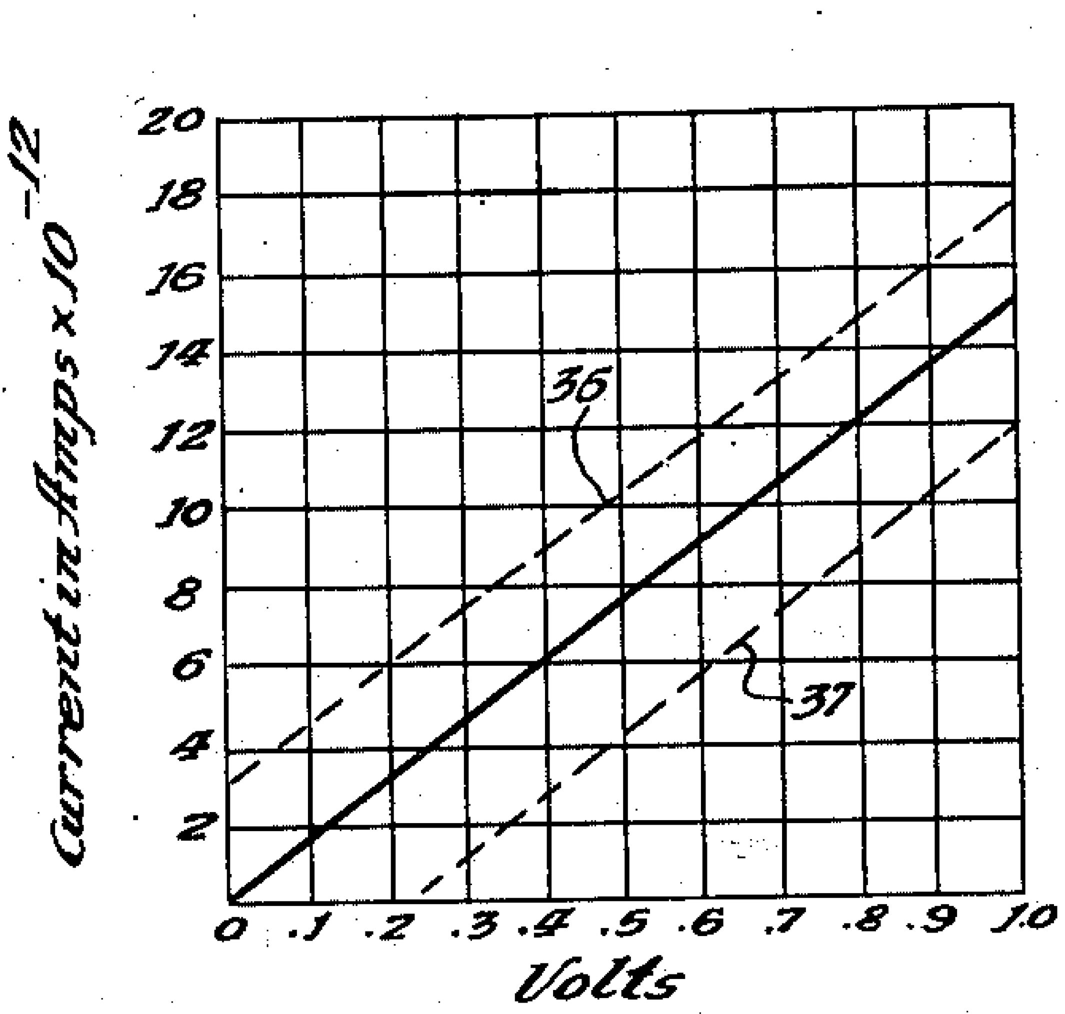
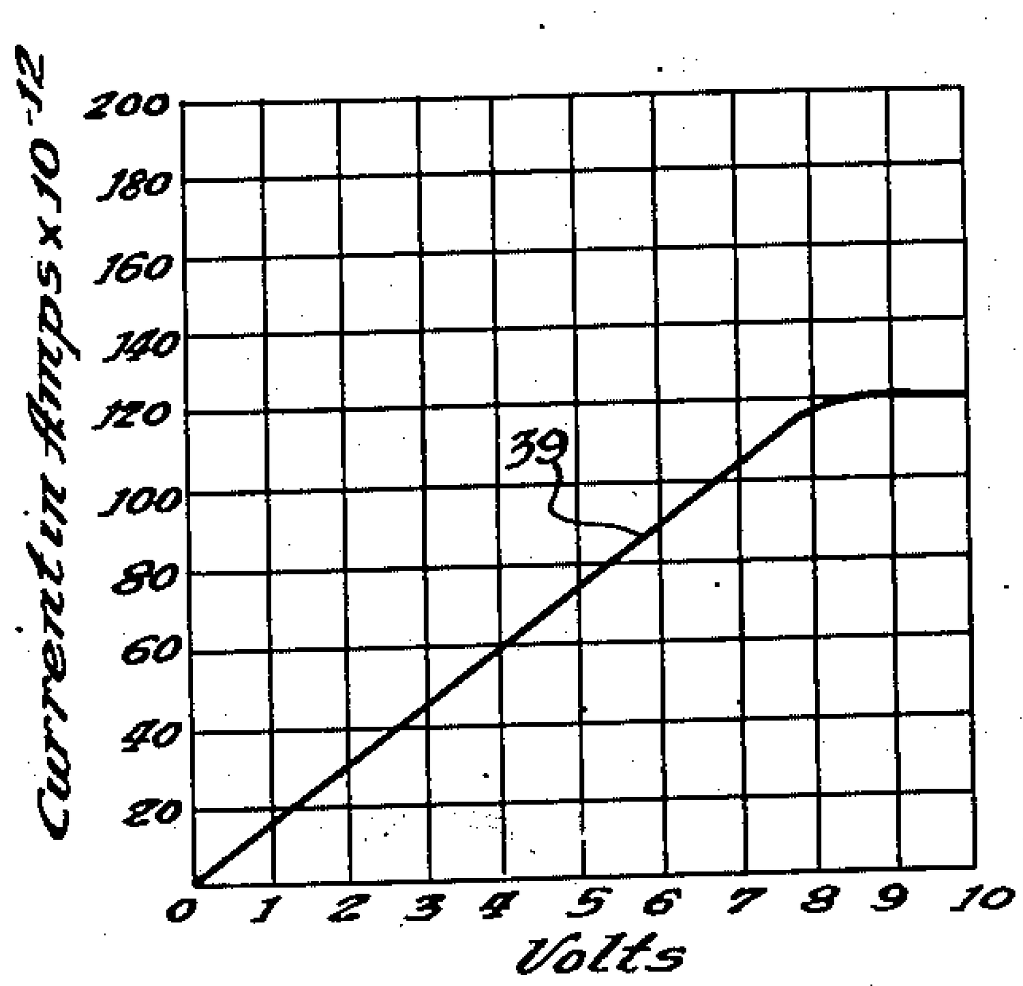


FIG. 9.



Witnesses:
Hubert E. Metcalf
Paul J. Glaister

Inventors:
James M. Benade
Edmund E. Goodale
William P. Jesse
By: Robert A. Lavender
Attorney.

Feb. 24, 1953 J. M. BENADE ET AL 2,629,837

RADIOACTIVE RESISTOR

Filed June 27, 1945 2 SHEETS—SHEET 2

FIG. 4.

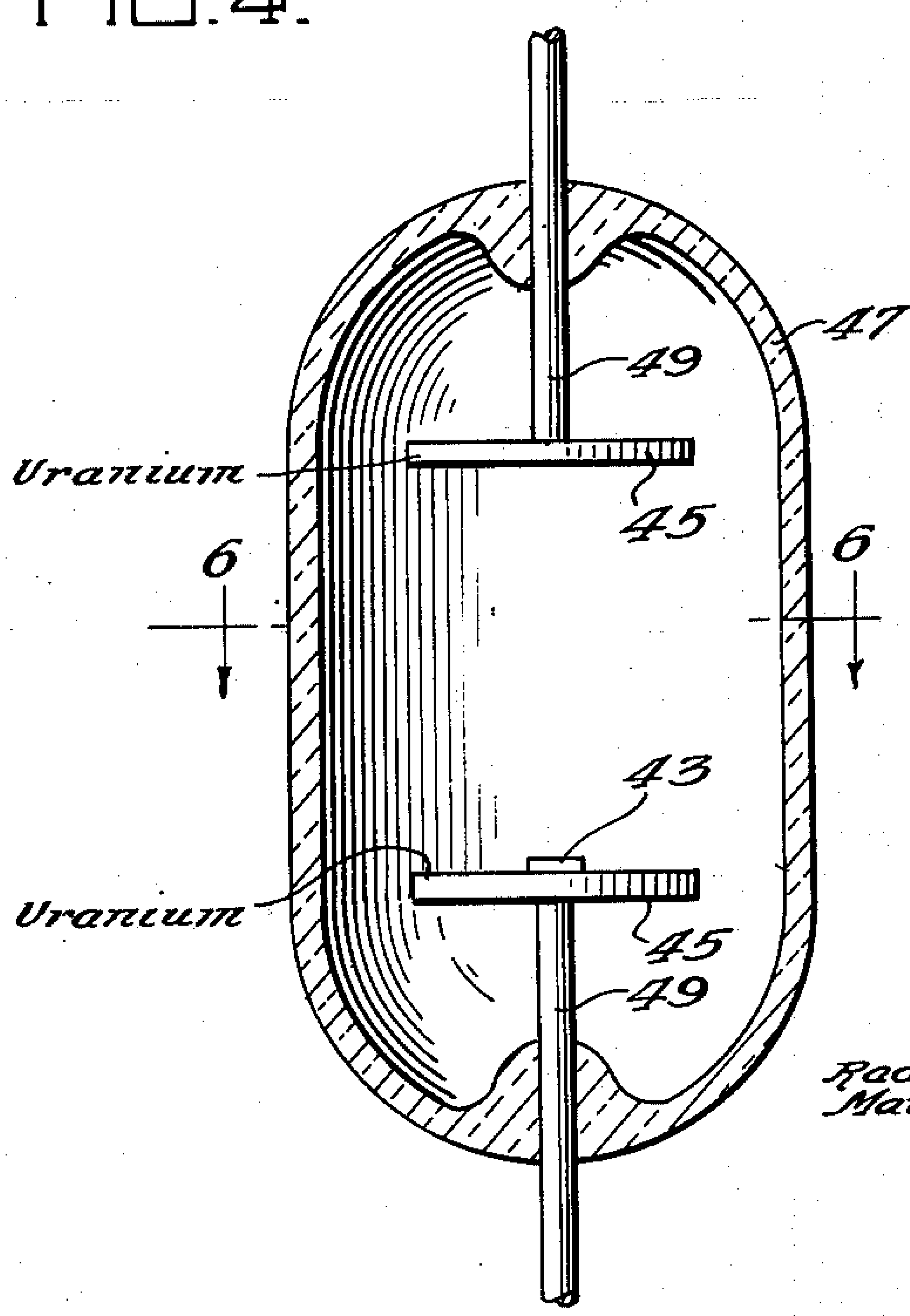


FIG. 5.

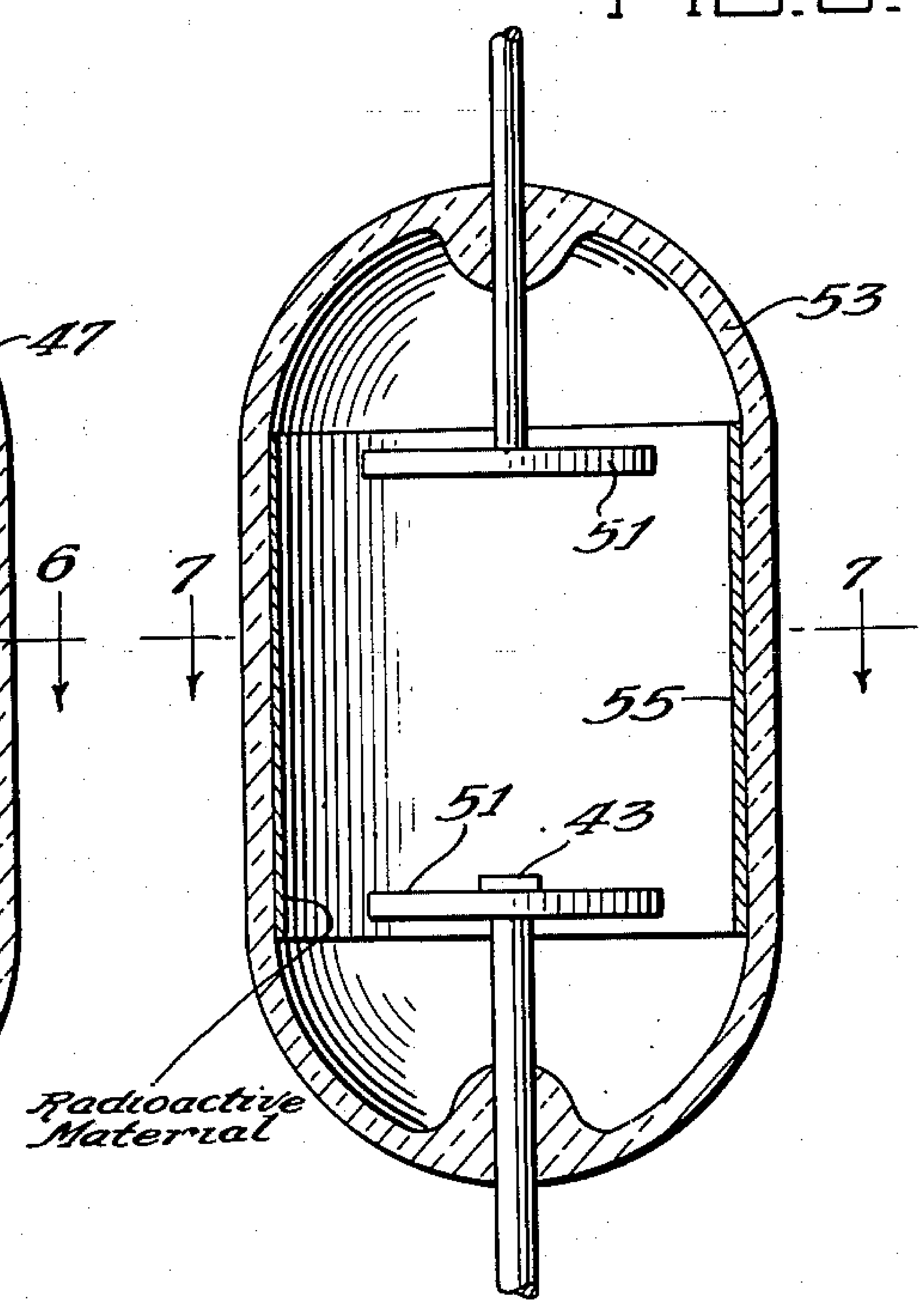


FIG. 6.

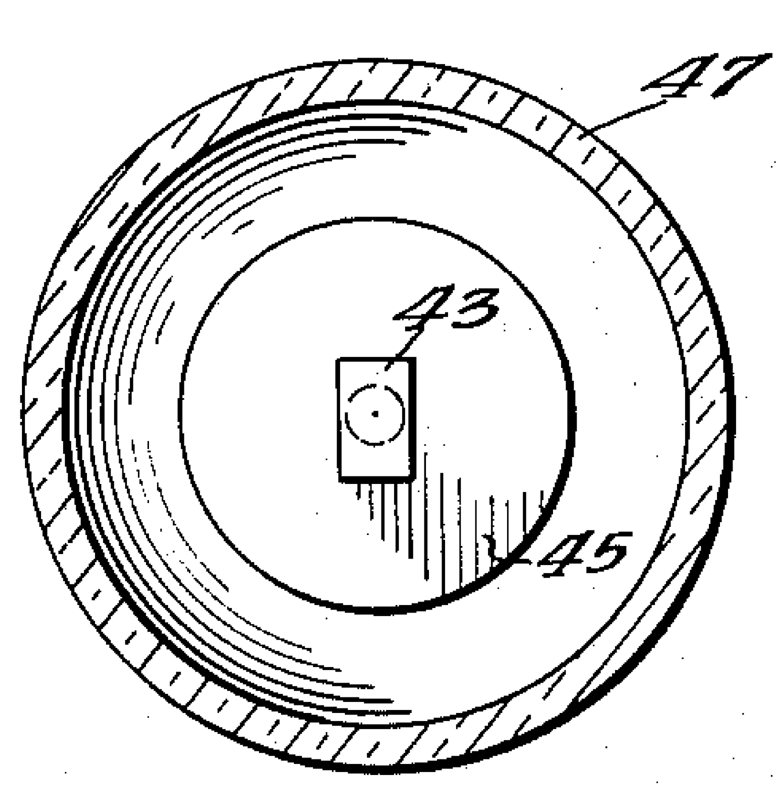
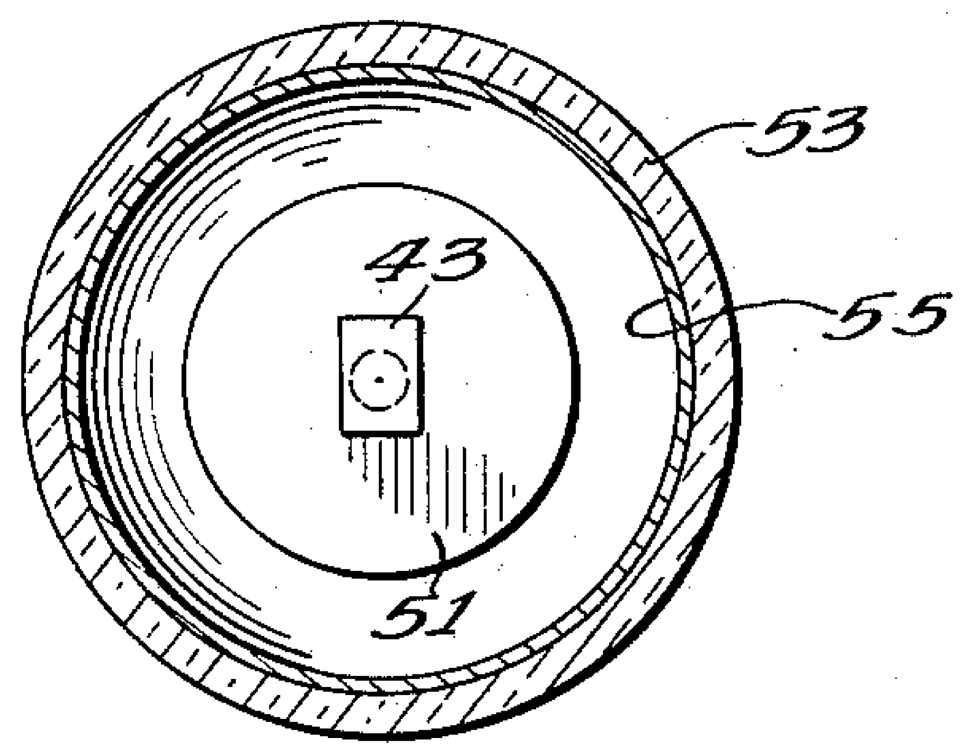


FIG. 7.



Witnesses:
Herbert E. Metcalf
Paul J. Glaister

Inventors:
James M. Benade
Edmund E. Goodale
William P. Jesse
By: Robert A. Lavender
Attorney.

Patented Feb. 24, 1953 2,629,837

UNITED STATES PATENT OFFICE

2,629,837

RADIOACTIVE RESISTOR

James M. Benade, Chicago, Ill., Edmund E. Goodale, Hiram, Ohio, and William P. Jesse, Chicago, Ill., assignors to the United States of America as represented by the United States Atomic Energy Commission

Application June 27, 1945, Serial No. 601,805

7 Claims. (Cl. 313—54)

1

The present invention relates to radioactive apparatus, and particularly to radioactive devices suitable for use as electrical resistances of large ohmic value.

It is well-known, that if a potential gradient be maintained between a pair of spaced-apart electrodes which are submerged in a uniformly ionized gas, a current will flow across the electrodes, and that this current will be almost exactly proportional to the potential gradient maintained between the electrodes. The straight line voltage-current characteristic of such devices pertains until a maximum current value is reached, this value being determined by the physical dimensions of the device and by the degree of ionization provided in the gaseous medium separating the electrodes. When this maximum value is reached, the device is said to be saturated, and it exhibits the characteristic that current flow therethrough continues at a level value which is not increased by any further increase in voltage short of that which will effect complete insulation breakdown across the electrodes.

Since radioactive materials, and especially those of long half lives, constitute a most convenient means for obtaining constant ionization, devices of the above described type are readily constructed by supporting a pair of insulated electrodes in a vessel containing an ionizable gas and a quantity of suitable radioactive material. Since radioactivity—and hence the ionization of the gas contained in such a vessel—is substantially independent of temperature, and since the resistance characteristics of the device are determined by its physical dimensions, which are fixed and substantially independent of temperature, and by the ionization resulting from the radioactivity, which is likewise substantially fixed and independent of temperature, it becomes apparent that such a device may be used as an electrical resistor which is substantially fixed in value regardless of its temperature. That is, the device has a zero temperature coefficient of resistance. This is a most important characteristic, because the obtaining of an electrical resistance with a zero temperature coefficient is extremely difficult to accomplish by any other known means.

There are, however, certain difficulties and limitations inherent in radioactive resistors. Of particular importance, it has been observed that these devices exhibit a self-generated or self-induced voltage effect, that is, even with no external potential applied to the device, current will flow in a conductor connected across the electrodes. Self-generated or self-induced voltages of the order of from about ½ to 1½ volts are commonly observed, and since the entire voltage drop across the resistor is usually of the order of 6 to 8 volts or less, it is evident that a self-generated or self-induced internal voltage of the magnitude stated is a most serious matter. The present invention is concerned with the overcoming of this difficulty, and has for its principal object the provision of an improved novel radioactive type resistor which shall not exhibit any self-induced or self-generated voltage when no external source of potential is applied to the electrodes thereof.

2

The features of certain embodiments of the invention described hereinafter are illustrated in the accompanying drawings. In the drawings:

Fig. 1 is a longitudinal sectional view partly in elevation illustrating a preferred embodiment of the invention;

Fig. 2 is a plan view of the device shown in Fig. 1;

Fig. 3 is a sectional view taken on the line **3—3** of Fig. 1;

Figs. 4 and 5 are longitudinal sectional views, similar to Fig. 1, illustrating two other embodiments of the invention;

Figs. 6 and 7 are sectional views taken on the lines **6—6** and **7—7** of Figs. 4 and 5, respectively; and

Figs. 8 and 9 are graphic representations of the current-voltage characteristics of devices of the general type illustrated in the other figures of the drawings.

The particular embodiment of the invention illustrated in Fig. 1 includes a cylindrical outer casing or closure **11** of metal having an integral end plate **13** having a centrally disposed, circular opening **15** provided therein for admitting an electrode support rod **17**. The electrode support rod **17** is held in position centrally of, and coaxially with, the outer closure **11** by a suitable flanged insulator **19**, preferably of glass, which, in turn, is supported upon the upper end plate **13** by an annular clamp ring **21** riveted or otherwise attached to the end plate **13**. The insulator **19** is suitably sealed gas tight to the rod **17**. A gasket **23** placed between the under surface of insulator **19** and the adjacent upper surface of the end plate **13** provides a gas tight seal at the upper end of the closure **11**. The other end of the closure **11** is provided with a screw thread portion **25** which is engaged by a suitable cap member **27**, as illustrated. A gasket **29** assures the maintaining of a gas tight seal at this end of the closure 11 when the cap member 27 is screwed into place.

A cylindrical electrode 31 having a rounded end is screwed onto the inner end portion of the electrode support rod 17 and is thereby supported centrally of the main closure 11. The central electrode 31 may be made of various conducting materials, such as carbon, uranium, platinum, etc. A thin, tubular member 33, of radioactive material, which is conveniently made by bending into cylindrical shape a sheet of uranium metal having a thickness of the order of .005 to .010 inch, is disposed inside the main closure 11 adjacent the inner wall thereof. This tubular member 33, being of radioactive material, constitutes the means utilized for providing constant ionization within the closure during the operation of the device, and it is also utilized as the other electrode. The member 33 is held in position in the closure 11 by means of suitably spaced members 35 which may be of metal or of insulating material and which are located at both ends of the closure 11, and it is electrically connected to the outer closure which thus serves as one of the terminals of the device.

The main outer closure 11 is preferably made of metal, brass being particularly suitable; this permits the closure to be used as one of the terminals. The closure 11 may, however, be made of an insulating material in which instance some other means must be provided for completing the electrical circuit to the outer electrode. If the radioactive means is not of conducting material, as in the device illustrated in Fig. 5, a separate electrode of conducting material must be provided. In any case, the outer closure should be gas tight, and it should be filled with a readily ionizable gas, such as air or argon at atmospheric pressure, in order that the space between the two electrodes may be uniformly ionized. The natural radioactivity of the uranium electrode 33 will produce sufficient ionization to satisfactorily ionize air or argon in a device such as has been described.

The electrical resistance of an air or argon filled cell of this general type is a rather complicated function depending upon the size of the electrodes, the steepness of the potential gradient, the gas pressure maintained within the cell, and the physical dimensions of the various parts of the device. In general, however, the resistance of a cell constructed as illustrated in Figs. 1–3 and containing argon, at atmospheric pressure under standard temperature conditions (760 mm. of mercury pressure at 20° C.), will be of an order of magnitude which is substantially indicated by the equation

$$R=\frac{2.5\times10^{12}}{A}\text{ ohms}$$

where A is the effective surface area of the electrodes in square centimeters, and where the spacing of the electrodes is greater than the range of the principal ionizing particles emitted from the ionizing material, these being alpha particles in the case of uranium. For example, a cell wherein the outer electrode has an internal diameter of about 5 cm., a length of about 7.5 cm., and wherein the central collecting electrode is about 4 mm. in diameter and about 5 cm. long, and which contains argon at 760 mm. pressure (at 20° C.) will have a resistance of the order of 10^{12} ohms.

If a cell of the general type illustrated in Fig. 1 is constructed with a uranium outer electrode 33 and a central electrode 31 of carbon or platinum, the central electrode 31 will be found to acquire a small positive potential due to emanations from the radioactive material, and if the two electrodes are connected by an external conductor, a current will be observed to flow in such conductor even when no external voltage is applied to the electrodes. Suitable instruments will show that the device exhibits a self-generated or self-induced voltage, similar in character to contact voltage effect, of the order of about .3 volt. The application of external voltage to such a cell will, however, yield a straight line current-voltage curve as illustrated by the dotted line numbered 36 in Fig. 8. If the cell is constructed with the central electrode 31 of aluminum, a negative, self-generated or self-induced voltage will appear at the central electrode, and a current voltage-curve, such as is illustrated by the lower dotted line 37 in Fig. 8, will be observed. In such instances the observed negative voltage may be as large as 1.25 volts. The saturation voltage of a cell of the type and dimensions stated is of the order of 6 to 8 volts, and when voltages above the saturation value are applied to the electrode, the current through the device flattens off and becomes stable at a constant value and remains so until breakdown voltage is reached. This flattening off of the current flow through the cell at saturation is illustrated by the current-voltage curve 39 in Fig. 9. Since saturation of the cell may occur at a voltage which is only a small multiple of the self-generated or self-induced voltage, that voltage is very undesirable, especially when the resistor is to be used, as is often the case, in the grid circuit of an electronic amplifier.

As previously stated, the present invention is particularly concerned with the provision of means for overcoming the inherent characteristic of these devices to exhibit a self-generated or self-induced voltage effect. Specifically, it has been discovered that this effect can be overcome by the use of one or more composite electrodes which are constructed by combining a material which yields a positive voltage effect when employed as one of the electrodes of a radioactive resistor with a material which yields a negative voltage effect when employed in that manner. For example, if the central or collecting electrode comprises a composite member of carbon and aluminum, or platinum and aluminum, in the proper relative proportions, the resistance cell will exhibit zero potential across the electrode when no external voltage is connected thereto. The composite electrode can be constructed conveniently by placing a short aluminum tube over a cylindrical carbon or platinum electrode, as illustrated at 41 in Fig. 1, or it may simply comprise a small sheet or block 43 of aluminum or other material which is fastened to a flat electrode by any suitable means, as illustrated in Figs. 4 to 7.

It appears preferable to employ the combination of dissimilar materials as the collecting electrode although elimination of the self-generated of self-induced voltage can be obtained by the addition of the necessary area of dissimilar material to either electrode. The exact relative areas to be used must be determined by experiment, but once the values are established for a given type of construction, the required area can be accurately predicted. Since the negative voltage effect is usually greater than the positive effect, it is usually most convenient to fabricate the collecting electrode of material yielding a positive effect and correct by adding small pieces of material or materials exhibiting a negative effect. Other arrangements are, however, obviously possible and are within the contemplation of the invention. The material used to eliminate the self-generated or self-induced voltage should be conductively attached to the associated electrode and should preferably overlie a portion of the active surface thereof, as illustrated.

Other embodiments of the invention are illustrated in Figs. 4 and 5. The device of Fig. 4 includes a pair of circular electrodes **45** made of flat, sheet uranium and supported in spaced-apart, opposed alignment within a glass envelope **47** by means of suitable conducting supports **49** sealed into the envelope **47**. The sealed envelope **47** contains argon or other ionizable gases, preferably at atmospheric pressure. Since the electrodes **45** are made of uranium, a naturally radioactive material, no other ionizing means is required. Either electrode may be used as the collecting electrode (the lower electrode is so used in the structure illustrated), and the voltage balancing material, which may conveniently comprise a small square **43** of sheet aluminum, is welded or otherwise applied to the face of the collecting electrode in conducting relationship therewith, as illustrated.

The device illustrated in Fig. 5 is of similar construction except that neither of the opposed electrodes **51** provided therein is of radioactive material, any conducting material being utilized. As a result, it is necessary in this cell to provide other means for obtaining constant, uniform ionization of the gas occupying the space between the electrodes **51**. Conveniently, the inner surface of the glass envelope **53** is coated, as illustrated at **55**, with a radioactive material, such as a thin sheet of uranium, a precipitate of a radioactive salt, or other radioactive material. To assure that the constants of the device will not change during its useful life, the radioactive material should be one having a long half life, preferably of the order of years. The half life of uranium, for example, is of the order of thousands of years and this material is thus particularly suited for use in such devices.

By proper selection of electrode materials and the voltage compensating material, it is a comparatively simple matter to produce a radioactive resistor which does not produce any substantial self-generated or self-induced voltage and which has straight line current-voltage characteristics up to the saturation value. Further, since the resistance of the resistor depends only on the physical dimensions of the device and on the radioactivity of the ionization producing material, and since both of those quantities are substantially unchanged by any reasonable change in ambient temperature, the device has a zero temperature coefficient of resistance. Such a device is especially adapted for use in connection with the electronic amplifying and control systems where a stable resistance is of great importance.

In the foregoing there has been disclosed the features of certain improved radioactive resistance devices. Particularly, means has been disclosed for eliminating the inherent characteristic of these devices to exhibit self-generated or self-induced voltages. The invention greatly extends the field of utility of radioactive resistors and solves a problem which has confronted the art for a very long period of time. The features of the invention which are believed to be new are expressly pointed out in the appended claims.

What is claimed is:

1. A radioactive resistance unit comprising, in combination, a sealed envelope which contains an ionizable gas, a pair of electrodes supported in spaced apart insulated relationship within said envelope, radioactive means for effecting substantially constant continuous ionization of the gas contained within said envelope, and a covering of electrically conducting material disposed in contactual relationship with a portion of the surface of at least one of said electrodes and confronting the other of said electrodes, said covering being of a different material than the electrodes which yields a self-induced voltage of opposite polarity to that induced in the contacted electrode, thereby effectively canceling at least a portion of the self-induced voltages from the resistance unit.

2. A radioactive resistance unit comprising, in combination, a sealed envelope which contains an ionizable gas, a pair of electrodes supported in spaced apart insulated relationship within said envelope, one of said electrodes comprising a hollow cylindrical member of conducting material and the other of said electrodes comprising a cylindrical rod of conducting material disposed centrally of and coaxial with said hollow cylindrical member, at least one of said electrodes being of radioactive material which effects substantially constant continuous ionization of the gas contained within said envelope, an electrically conducting member disposed in contactual relationship over a part of the surface of the other electrode, said member being constructed of materials which yield a self-induced voltage of opposite polarity to that induced in the electrode adjacent to electrically conducting member, thereby at least partially canceling the self-induced voltages from the resistance unit.

3. A radioactive resistance unit comprising, in combination, a sealed envelope which contains an ionizable gas, a pair of electrodes of different materials supported in spaced apart insulated relationship within said envelope, at least one of said electrodes being of a radioactive electrically conducting material which effects substantially constant continuous ionization of the gas contained within said envelope, a member of electrically conducting material disposed in contactual relationship on a portion of the surface of the non-radioactive electrode, said member being constructed of a material which yields a self-induced voltage of opposite polarity and equal magnitude to that induced in the non-radioactive electrode, thereby canceling the self-induced voltages in the resistance unit.

4. A radioactive resistance unit comprising the elements of claim 3 wherein the radioactive electrode of the resistance unit is constructed of uranium.

5. A radioactive resistance unit comprising a sealed envelope which contains an ionizable gas, a pair of electrodes supported in spaced-apart, insulated relationship within said envelope, one of said electrodes comprising a hollow cylindrical member of uranium and the other of said electrodes comprising a cylindrical rod of conducting material disposed centrally of and coaxially with said hollow cylindrical member, the natural radioactivity of the uranium electrode effecting substantially constant continuous ionization of the gas contained within said envelope, and means comprising a member of a conducting material which yields a self-generated or self-induced voltage of opposite polarity to that

induced in the central electrode conductively attached to that electrode so as to substantially eliminate self-induced or self-generated voltage effects in said unit.

6. A radioactive resistance unit comprising a sealed envelope which contains an ionizable gas, a pair of electrodes supported in spaced-apart insulated relationship within said envelope, one of said electrodes comprising a hollow cylindrical member of uranium and the other of said electrodes comprising a cylindrical rod of a conducting material which yields a positive self-induced or self-generated voltage when submerged in an ionized gas, said rod electrode being disposed centrally of and coaxially with said uranium electrode, the natural radioactivity of said uranium electrode effecting substantially constant continuous ionization of the gas contained within said envelope, and a member of sheet material covering a portion of and being conductively attached to said rod electrode, the material of said last mentioned member yielding a negative self-induced or self-generated voltage effect when submerged in an ionized gas and being of such size and proportions relative to said central electrode that self-induced or self-generated voltage effects are substantially eliminated in said unit.

7. A radioactive resistance unit comprising, in combination, a sealed envelope which contains an ionizable gas, a pair of electrodes disposed

within the envelope in spaced apart insulated relationship, one of said electrodes being constructed of a radioactive material and the other of said electrodes being constructed of a material yielding a positive potential with respect to said radioactive material, and a member of electrically conducting material disposed in contactual relationship with the non-radioactive electrode, said member being constructed of material which yields a self-induced voltage of opposite polarity and equal potential to that induced in the non-radioactive electrode, thereby effectively canceling out the self-induced voltages from the resistance unit.

JAMES M. BENADE.
EDMUND E. GOODALE.
WILLIAM P. JESSE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,523,013	Greenslade	Jan. 13, 1925
1,530,555	Greenslade	Mar. 24, 1925
1,531,301	Metzger	Mar. 31, 1925
1,658,568	Moore	Feb. 7, 1928
2,195,913	Bachman	Apr. 2, 1940
2,212,643	Koros et al.	Aug. 27, 1940