

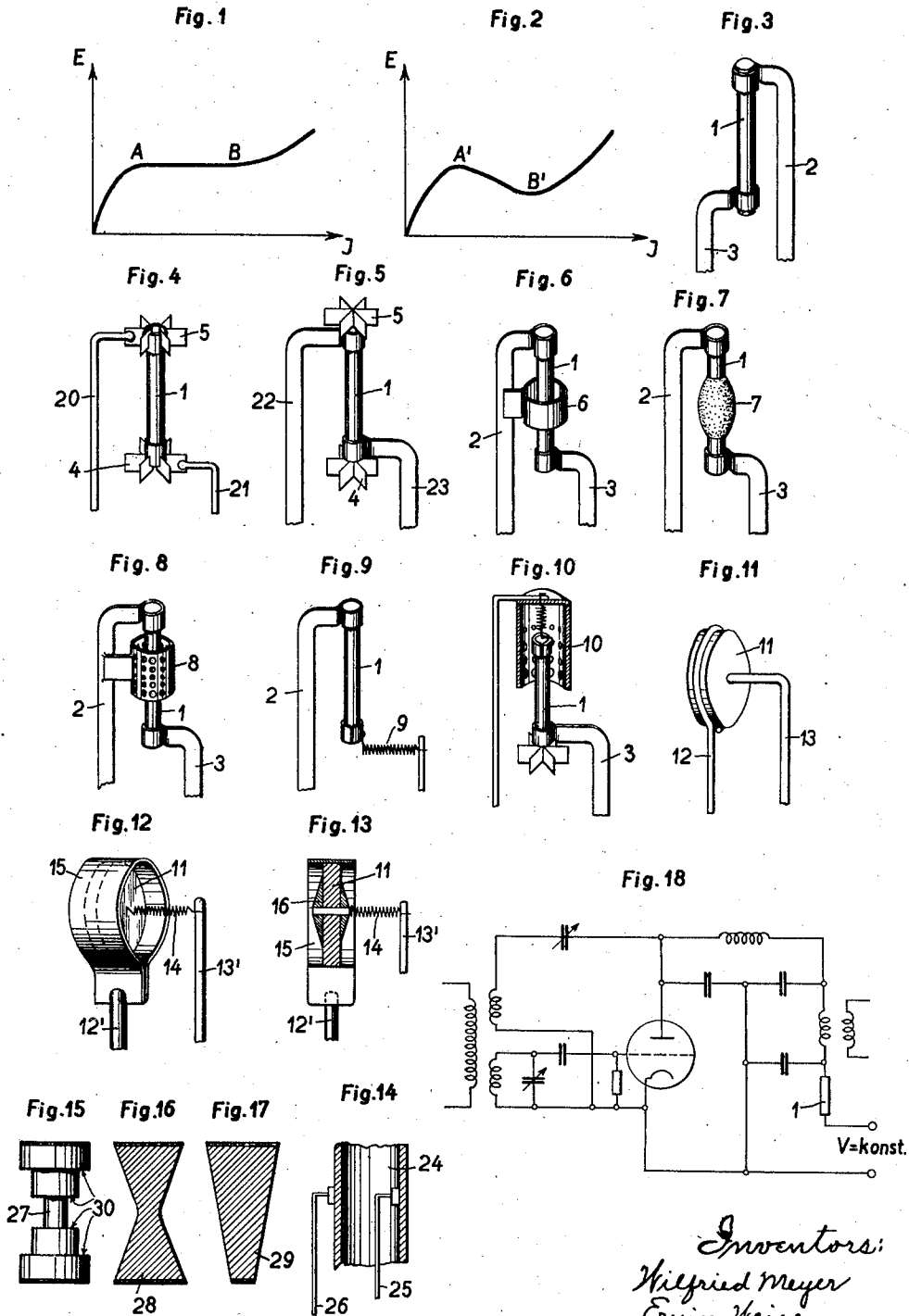
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RESISTANCE BODY MADE FROM SEMICONDUCTIVE SUBSTANCES

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RESISTANCE BODY MADE FROM SEMI-CONDUCTIVE SUBSTANCES

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Our invention relates to improvements in resistance bodies made from semi-conductive substances.

Resistances which have negative temperature coefficients and high resistance values at ordinary temperature are in extended use in the art. In such resistances the fall of the voltage connected with an increase of the current at first rises to a certain point, thereafter it remains constant or substantially constant upon a further increase of the current, and finally it rises again.

The object of the improvements is to produce a resistance of this type in which the fall of the voltage is again reduced after a certain current has been attained, and with this object in view our invention consists in varying the temperature conditions of the resistance in the manner to be described hereinafter.

For the purpose of explaining the invention several examples embodying the same have been shown in the accompanying drawing in which the same reference characters have been used to indicate corresponding parts. In said drawing,

Fig. 1 shows a diagram showing the voltage drop across a known resistance as a function of the current intensity,

Fig. 2 is a similar diagram showing the voltage drop across our improved resistances,

Fig. 3 is an elevation showing our improved resistance body and its mounting,

Figs. 4 to 9 are perspective views showing modifications of the resistance body,

Fig. 10 is a similar perspective view partly in section showing another modification of the resistance body and its mounting,

Figs. 11 and 12 are perspective views showing further modifications of the resistance body and its mounting,

Figs. 13 and 14 are sectional elevations showing other modifications of the resistance body and its mounting,

Fig. 15 is an elevation showing another modification of the resistance body,

Figs. 16 and 17 are sectional elevations showing other modifications of the resistance body, and

Fig. 18 is a diagram showing an audion circuit of an amplifier system having our improved resistance mounted therein.

As appears from Fig. 1, the voltage drop across a resistance having a negative temperature coefficient caused by a gradual increase of the current intensity at first rises up to a point A,

thereafter it remains constant or substantially constant to the point B, and thereafter it rises again.

We have found that in resistance bodies having a resistance value at ordinary temperature of more than 1 ohm in a conductor of a cross-section of 1 cm.² and a length of 1 cm., the temperature conditions of the resistance body may be made so that the voltage drop across the resistance between the points A and B of the said diagram may be changed so that the voltage drop is reduced from the point A to B upon an increase of the current intensity. In Fig. 2 we have shown the diagram showing the voltage drop across our improved resistances as a function of the current. Preferably this reduction of the voltage drop is obtained by producing a fall of temperature longitudinally of the resistance body and in the direction of the current. To produce such a fall of temperature the resistance body may be made with varying cross-section, or it may be cooled or heated along its length in a different way.

Our improved resistances the voltage drop across which follows a falling curve may be manufactured from semi-conductive substances having an electrolytic conductivity of less than .1% of its total conductivity. For example, among the metal oxides the oxides of Cu, Ag, Zn, Hg, Ti, Si, Ti, Zr, Hf, Th, V, Nb, Ta, Bi, Cr, Mo, W, U, Mn, Re, Fe, Co, Ni, and among the sulfides, selenides and tellurides those of the Ag, Zn, Cd, Hg, Ti, Sn, Bi, Cr, U, Mn, are suitable. Among the aforesaid substances the uranium oxides, and particularly the uranium dioxide UO₂, are preferable, because their electrical properties are constant during a long time of use, and because their specific resistances have favourable values. The slope of the negative curve A'—B' (Fig. 2) is, other conditions being the same, the larger, the larger the specific resistance of the semi-conductive body is, and the specific resistance of the same semi-conductive substance depends on a very slight difference of the metalloid content from the stoichiometric composition, and therefore the metalloid content is preferably made such that the specific resistance is as high as possible.

The falling curve A'—B' depends on the resistance of the semi-conductive substance at ordinary temperature, and with very high specific resistances it is not possible without additional heating to operate the resistance on the falling part of the curve A'—B', and therefore it is pre-

ferred to select a median resistance value. Therefore, among the semi-conductive substances, having higher specific resistances, those are particularly suitable the specific resistances of which are from 10^3 to 10^6 ohms in a conductor having a cross-section of 1 cm.² and a length of 1 cm. Within these limits are particularly cobalt oxide and nickel oxide. The resistance values of the said substances largely depend on the oxygen content. Good values are obtained by the following method:

The ground material from which the resistance is made or the body made therefrom either with or without a binding medium is heated in vacuo in a reducing gas or in a flowing gas which does not chemically act on the substance. By such heating the material or the body gives off oxygen, so that its oxygen content is less than the content corresponding to the formulas Co_2O_3 and Ni_2O_3 . Preferably the oxygen content should be reduced so far that it is as near as possible to the oxygen content of the oxides CoO and NiO . The resistance bodies are provided with terminals by fusing metal powder thereon, and the body is confined within a glass receptacle for preventing absorption of oxygen in the operation, or other expedients are used for preventing absorption of oxygen. Where the resistance is confined in a receptacle the said receptacle may be free of air or filled with a reducing or inert gas.

According to the desired use the resistance bodies may take the form of rods, pipes, disks and the like, and the leads must be connected thereto at least at one of the terminals so as to insure cooling by their conductivity. In Figs. 3 to 17 we have shown several examples of constructing the resistance bodies and their mountings.

In the construction shown in Fig. 3 the resistance body 1 takes the form of a rod which is mounted at both ends in very strong supporting members or leads 2 and 3 of high conductivity for heat. Preferably the said supporting members are made from a metal of high heat conductivity and low specific heat, such for example as copper or tungsten. By the said supporting members the resistance body is effectively cooled at its ends, while the loss of heat at the middle is small. Thus in a simple way a strong fall of temperature is produced.

In Fig. 4 we have shown a modification in which the resistance body 1 is provided at both ends with cooling ribs 4 and 5. As is shown the supporting members or leads 20 and 21 consist of wires of circular cross-section which are not shaped with a view of increasing the cooling effect. But we wish it to be understood that we do not limit ourselves to this feature, and that also the leads 20 and 21 may be constructed with a view of increasing the cooling effect, as has been described with reference to Fig. 3. This modification has been illustrated in Fig. 5 in which the said leads have received the reference characters 22 and 23.

In Fig. 6 we have shown a modification in which the fall of temperature is produced by providing means for preventing the loss of heat in the median part of the resistance body 1. The construction of the said resistance body and its mounting is the same as has been described with reference to Fig. 3, and the same letters of reference have been used to indicate corresponding parts. In addition a screen 6 is

provided around the median part of the rod 1. It will be understood that for further increasing the cooling effect at the ends of the resistance body cooling ribs such as have been shown in Figs. 4 and 5 may be provided in the construction shown in Fig. 6. Further, the cooling effect of the said ribs may be increased by imparting thereto a rough surface or blackening the same.

In the modification shown in Fig. 7 the fall of temperature is produced by providing the median part of the rod 1 with a coating 7 of insulating or low radiation property. The said coating 7 may be used in combination with a screen such as 6, with conductive supporting members such as 2, 3, or with cooling ribs such as 4. As is shown in Fig. 7 the insulating coating 7 is reduced in thickness towards its ends so that its effect is reduced towards the ends of the rod 1. In some cases an abrupt variation of the thickness of the coating 7 may be preferable.

Fig. 8 shows a resistance rod which is equipped with a perforated screen 8 adapted to prevent radiation, the perforations of the said screen being increased in area towards the ends, so that a gradual fall of temperature from the median part of the resistance body towards the ends thereof is obtained. In the constructions so far described the temperature falls off from the middle of the rod towards both ends. In many cases it will be preferable to keep the resistance body at elevated temperature at one end and to cool the same only at the opposite end. In Fig. 9 we have shown this modification. The resistance body 1 is supported at one end by a supporting member 2 of high conductivity, and at its opposite end a thin lead 9 is provided which may be wound into a coil. It will be understood that the cooling effect of the supporting member 2 may be further increased in the manner described above. Further, the temperature of the bottom end of the rod may be maintained high by providing an insulating coating.

In Fig. 10 we have shown a modification which is similar in principle to the modification shown in Fig. 9, and in which in addition a screen 10 is provided around the hot end of the resistance body 1 for counteracting radiation. The said screen is perforated and the perforations thereof are enlarged in area from the outer or top end of the device towards the middle of the rod 1, which results in a gradual fall of temperature.

In Fig. 11 we have shown another modification in which the resistance body takes the form of a flat disk 11 through which the current flows in radial direction. Thereby the current intensity is high at the middle of the disk, and the radiation of this part of the surface is small. Further, the outer lead 12 has high conductivity for heat, and therefore a very strong fall of temperature is obtained. The second lead or supporting member has received the reference character 13.

In the modification shown in Fig. 12 the resistance disk 11 is connected at its center with the lead 13' through a thin coiled wire 14, and the lead 12' is connected with a cylinder 15 of high conductivity having the disk 11 mounted therein.

The construction shown in Fig. 13 is similar to the one illustrated in Fig. 12, but in addition a protective coating 16 is provided at the middle

of the disk 11 which reduces the loss of heat by radiation. As is shown in Fig. 13, the coating 16 is reduced in thickness from its middle towards the margin of the disk 11. But we wish it to be understood that we do not limit ourselves to this feature, and that in some cases the coating 16 is enlarged in thickness from the center of the disk towards the margin thereof.

In the modification shown in Fig. 14 the resistance body 24 takes the form of a pipe connected internally and externally with leads 25 and 26. In Figs. 15 to 17 the resistance bodies 27, 28, 29 are constructed so that the density of the current varies longitudinally of the resistance in a way similar to the distribution of the current in the constructions shown in Figs. 1 to 13. Fig. 15 shows a resistance body which is composed of cylindrical disks of different diameters. The said resistance body is particularly suitable for high currents. The current density may be uniformly distributed in the resistance disk by providing metallic coatings on the bounding faces of the bodies as is indicated at 30, the said coatings being applied by fusing. Fig. 16 shows an integral resistance body 28 which is similar in function to the resistance body shown in Fig. 15. But the resistance body is gradually increased in diameter from the middle towards its ends. In Fig. 17 we have shown another modification in which the resistance of the elongated body 29 is gradually increased from one end to the other. We wish it to be understood that the different expedients described for clearness sake with reference to specific examples may be combined in different ways in the same resistance, with the result that the effect is increased or otherwise varied. Further, the details of construction may be varied in different ways. For example, in lieu of the coiled wires shown in Figs. 9 and 10 double coiled wires may be provided. In the modification shown in Fig. 8 a screen 8 may be provided which has no perforations at its middle. The leads connected with the hot ends of the resistance body may be made such that they remove a portion of the heat by conductivity. Further, the function of the resistance body may be varied by confining the same in a container having a filling of a suitable gas. For example, where an increase of the cooling effect is desired, the said container may be filled with hydrogen, and where a reduction of the cooling effect is desired, the container may be filled with argon. With the device shown in Fig. 10 disposed vertically and within a container having a filling of a suitable gas, the current of the hot gas or the hot air improves the fall of temperature. In connection with large resistance bodies cooling by compressed air, water or oil may be provided at one or both ends of the resistance body, and further additional heating means may be provided.

Resistances having negative temperature coefficients are frequently connected in shunt with the current consumers to which the current must be supplied at constant voltage though the voltage of the net may be variable. Of course these resistances may also be connected in series with the current consumer, when the voltage of the net is constant or substantially constant, and the current consumer causes variation of the current. As an example we refer to the use of the resistances in the well known audion circuit of intensifying systems, such as are shown in Fig. 18. In the audion circuit the charge of the

anode is subject to frequent variation, and the voltage applied to the anode is constant or substantially constant. By providing a resistance of the type referred to above the voltage of the anode is reduced, and it remains constant notwithstanding the variation of the charge of the anode. Another advantage of the resistances used in the said circuit consists in that the tuning of the tuning circuit may be mechanically connected with back-coupling. Thus in apparatuses of low cost operation by means of a single handle is obtained. Also in amplifier circuits in which an unvariable biasing potential of the grid is desired, our improved resistance may be used alone or in connection with another ohmic resistance in the anode circuit.

In the audion circuit shown in the figure the resistance having the decreasing branch A'—B' permits compensation of fading and automatic regulation of the intensity of the sound. For example, if with a normal free frequency amplitude the working point is located on the falling portion of the curve A'—B', and if the anode current rises by fading, the working point is shifted towards the point B'. The system is operated with unvariable or substantially unvariable voltage, and therefore the anode potential applied to the tube rises. This results in an increase of back-coupling. Therefore when the high frequency energy falls off a high degree of back-coupling and thereby a higher amplification is obtained.

We claim:

1. A resistance body composed of a semi-conductive metal compound having an electrolytic conductivity of less than 1% of its total conductivity, and having a resistance of more than 1 ohm in a body having a cross section of 1 cm.² and a length of 1 cm. at ordinary temperature, means for controlling the temperature distribution in the body so that the value of the resistance of the body is reduced more than inversely proportional to the current increase and the body has a fall in temperature in the direction of current.

2. A resistance body as claimed in claim 1, in which the semi-conductive compound has a resistance from 10³ to 10⁶ ohms in a conductor having a cross section of 1 cm.² and a length of 1 cm., the compound of which the resistance body is composed being a cobalt oxide the oxygen content of which is smaller than that of the saturated oxide and nearly equal to the unsaturated oxide.

3. A resistance body as claimed in claim 1, in which the semi-conductive compound has a resistance from 10³ to 10⁶ ohms in a conductor having a cross section of 1 cm.² and a length of 1 cm., the compound of which the resistance body is composed being a nickel oxide the oxygen content of which is smaller than that of the saturated oxide and nearly equal to the unsaturated oxide.

4. A resistance body as claimed in claim 1, and having leads one of which is formed as a helix.

5. A resistance body as claimed in claim 1, and having a lead of high heat conductivity and low specific heat connected with the resistance body.

6. A resistance body as claimed in claim 1, and having a terminal provided with cooling ribs.

7. A resistance body as claimed in claim 1,

and having a terminal provided with blackened cooling ribs.

8. A resistance body as claimed in claim 1, and having a screen covering a part of the resistance body.

9. A resistance body as claimed in claim 1, in which the resistance body has the form of a disk

having a terminal connected thereto at its middle and another terminal connected thereto at its circumference, the circumferential terminal having a large portion of its surface connected with the said circumference.

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