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H. L. B. GOULD ET AL

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RESISTOR AND METHOD OF MANUFACTURING THE SAME

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FIG. 1

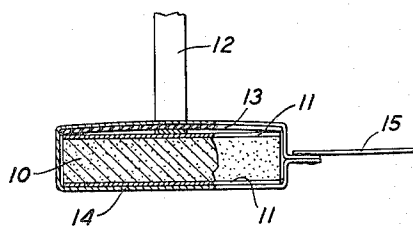


FIG. 2

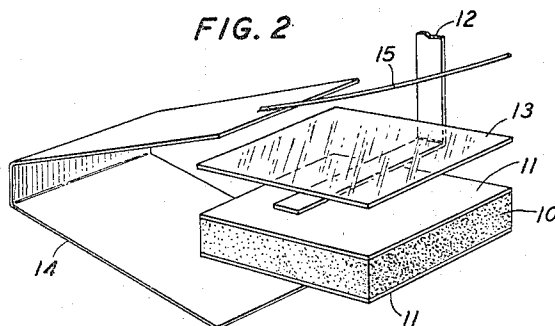
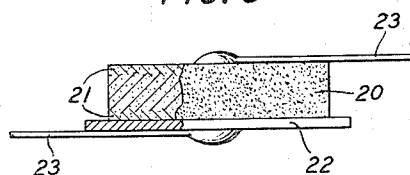


FIG. 3



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RESISTOR AND METHOD OF MANUFACTURING THE SAME

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9 Claims. (Cl. 201—76)

This invention relates to resistors having negative resistance-temperature coefficients and to methods of making such resistors. More particularly, this invention relates to resistors made from materials, the major constituent of which comprises one or more of the oxides of the so-called heavy metals and, more particularly, the oxides of the metals classified as magnetic.

Resistors, the conductance of which is highly dependent upon temperature, have been produced from various semiconductive materials, such as compounds of the metallic elements, notably the oxides. Difficulties have been encountered in the manufacture of resistor elements of this type for several reasons. Some materials when made up into resistor units initially exhibit desired characteristics as to specific resistance and resistance-temperature coefficients, but do not remain stable under operating conditions. Many materials having high electrolytic conduction are not available for use with direct current, because of the consequent change in characteristics caused thereby. Some materials are limited in applicability by the necessity of operation in vacuo or inert gases to avoid permanent change in their characteristics. Since most of the materials generally used have a negative resistance-temperature coefficient, a particular difficulty encountered has been the formation of "hot spots." If, in resistor units of this type, the heat is not substantially uniformly distributed throughout each plane perpendicular to the direction of current flow, the portions of each plane at the highest temperature will take an undue share of the current. The increase in current further raises the temperature in these regions with the resulting decrease in resistance and the "hot spot" condition is aggravated. The temperature at the "hot spot" may become sufficiently high to effect a permanent change in the resistance material or even destroy the unit.

One object, therefore, of this invention is to improve the stability and life of negative resistance-temperature coefficient resistors.

Another object of the invention is to increase the availability of resistors having a negative temperature coefficient of resistance by the use of relatively inexpensive materials.

A further object of the invention is to improve the methods of manufacture of resistance devices that are highly sensitive to temperature changes.

A feature of the invention resides in the employment of the oxides of the heavy metals, particularly the magnetic elements, as resistor materials.

In accordance with another feature of the invention small amounts of other materials, such as glass, are added to the resistor materials to improve the resistance characteristics and stability thereof.

A further feature of the invention resides in a heat treatment that produces very stable resistor units.

Another feature of the invention resides in resistor units that will operate properly in air, inert gases or vacuo under either alternating or direct current.

A further feature of the invention resides in providing oxidic resistor units with a heat distributing contact plate of metallic material.

Other and further objects and features of the invention will be more clearly and fully understood from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is a sectional view of an illustrative resistor unit made in accordance with this invention;

Fig. 2 is an exploded view in perspective of the unit of Fig. 1 to show the relation of the various parts; and

Fig. 3 is a view partly in elevation and partly in section of another form of resistor unit illustrating the invention.

In the manufacture of resistor units in accordance with this invention, oxides of the heavy metal elements, such as iron, nickel and cobalt are employed as the chief ingredient of the negative temperature coefficient element. These oxides are used in a finely divided state. Small amounts of additional material, such as lead borate glass, are added. The materials are thoroughly mixed in any convenient manner. One method comprises mixing the materials dry in a tumbling barrel that contains means such as steel balls and bars to prevent caking. A preferred method of mixing is to use a water suspension of the oxides. The material may be placed in a tumbling barrel as in the case of dry mixing. After a thorough mixing, the resulting conglomerate is removed from the barrel and evaporated in air to dryness. The mixed materials are then pressed to suitable shapes.

Good results have been obtained with a relatively thin disc or plate. Suitable pressures range from approximately 2×10^3 to 2×10^5 pounds per square inch. The discs or plates may be pressed to the size desired, or a larger plate may be pressed and later cut up into suitable sizes. Bars, rods and other shapes may also be used.

The pressed pieces are next heat treated. The time, temperature and atmosphere of heat treatment determines the final resistance of a unit of given composition. The time for a given temperature is a function of the size of the unit and more particularly the thickness. In general, thicker units require more time or a higher temperature. Temperatures of from 500° C. to 1400° C. have been used with good results. The atmosphere may be oxidizing or reducing, depending upon the resistance desired. For example, if iron oxide is heat treated in a slightly reducing atmosphere its resistance will be relatively low. On the other hand, the same oxide heat treated in an oxidizing atmosphere exhibits a high resistance. This is true whether the oxide used is the high ferric oxide Fe_2O_3 or the low ferrous-ferric oxide Fe_3O_4 . In the case of cobalt oxide a reducing atmosphere increases the resistance. Knowing the effect of the heat treating atmosphere on the different materials, the final result may be controlled by the choice of an appropriate atmosphere for a given oxide.

The addition of small amounts of other materials to the oxides or the addition of one oxide to another also affects the final resistance. When less than ten per cent of lead borate glass is added to iron oxides, it raises the resistance of the material where an oxidizing atmosphere is employed and lowers the resistance for a reducing heat treatment. Cobalt oxide added to the iron oxide decreases the resistance in the case of oxidizing heat treatment and increases it where a reducing atmosphere is used.

Stable iron oxide units containing up to about ten per cent of glass may be made as follows: A water suspension of powdered ferric oxide with finely pulverized lead borate glass is mixed for several hours in a tumbling barrel. After mixing, the conglomerate is evaporated to dryness in air and pressed into discs about one and one-quarter inches in diameter and 20 to 40 mils thick with a pressure of approximately 2×10^5 pounds per square inch. These discs are separated from one another and covered with 80-mesh aluminum oxide powder and placed in a nickel boat or receptacle. The aluminum oxide powder is used to provide a uniform support and to absorb the excess glass which may run out at elevated temperatures. The loaded nickel boat is placed in a quartz tube which is continuously evacuated to less than 1 millimeter of mercury. The quartz tube is placed for one hour in an oven at 950° C. and then removed. The pumping is continued until the tube cools. Thus, the resistor material is rapidly heated from room temperature to 950° C. and rapidly cooled to room temperature under slightly reducing conditions.

The two faces of the heat treated discs may be provided with contact electrodes by the evaporation in vacuum of a metallic layer thereon. A preferred electrode material is vaporized gold. Contact electrodes may also be provided in other ways, one of which will be pointed out in connection with the following description of the making of a cobalt oxide resistance element.

Cobalt oxide resistor units may be prepared by methods similar to those employed for the iron oxide unit. The oxide material in powdered form may be pressed, heat treated and metallic electrodes applied as previously described. Electrodes may also be applied during the pressing operation in the following manner: Fine metallic powder, such as permalloy (over 30 per cent nickel remainder iron) or nickel dust is spread in a

thin layer in the bottom of a die. A measured quantity of oxide powder is placed over the metallic powder and then a thin layer of metallic powder is placed over the oxide. The materials are then pressed, consolidating the two powders and firmly bonding them together. The layer of metallic dust is made sufficiently thin so that upon pressing it will form a lattice rather than a continuous metallic sheet. The pressed unit may be then heat treated. The heat treatment may be in air or in a reducing atmosphere, depending upon the final resistance desired. A suitable temperature is about 600° C. Conducting leads may be attached to the pressed metallic electrodes by soldering or other suitable means. Units comprising chiefly cobalt oxide may be used with relatively high current. This is due to the high heat conductivity of cobalt oxide, which inhibits the formation of "hot spots."

The resistor units may be made up from the heat treated resistor elements in several forms, two of which are shown in the drawing. One type of unit is shown in Figs. 1 and 2 and another in Fig. 3. A disc or plate unit pressed to the proper size or cut from a larger plate may be employed.

Referring now to the drawing, Figs. 1 and 2, 10 is the heat treated disc or plate having the metallic electrodes 11 attached thereto. A conductive lead 12 of platinum ribbon or other suitable material is applied to one metallic electrode and covered by a thin sheet of insulating material 13, such as mica. The sheet 13 is of sufficient extent to fully cover the electrode 11. A thin sheet 14 of nickel or other metal having good electrical and heat conductivities is bent into U-shape around the assembly to hold the elements 10, 12 and 13 firmly together. The open end of the U is closed and the ends secured together as by welding. The metal encasing sheet 14 not only holds the parts together but makes contact with the uninsulated electrode 11. A conductive lead 15 may be secured to the encasing sheet by welding or equivalent bonding means. Conductor 15 may be of any suitable conducting material such as a nickel chromium alloy. The formed metallic sheet 14 makes a rigid protective mounting and aids in equalizing temperature differences on the surfaces of the unit.

The unit shown in Fig. 3 comprises an oxide disc 20 with metallic electrodes 21 attached to a metal plate 22. The electrodes shown are of the compressed metallic powder type, although vaporized or other metallic electrodes may be employed. The plate 22 may be of nickel or other metal having sufficiently high thermal and electrical conductivity. The plate 22 is broader than the disc 20 so that it extends beyond the limits of the resistor element. One current conducting lead 23 is attached to the electrode 21 and the other to the plate 22. The leads 23 may be attached by soldering, welding or equivalent means. The plate 22 acts as a support, a cooling fin and one terminal, and at the same time equalizes current and heat flow in the unit.

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

What is claimed is:

1. The method of forming a stable, high, negative resistance-temperature coefficient resistor

unit that comprises pressing intimately mixed, finely divided iron oxide and powdered glass, the glass not exceeding 10 per cent of the mixture, at about 200,000 pounds per square inch to form a thin plate, heat treating said plate in a vacuum, less than 1 millimeter of mercury, with a trace of reducing agent at about 950° C., and applying a thin metallic layer to each face of the plate.

2. The method of forming a stable, high negative resistance-temperature coefficient resistor unit that comprises pressing finely divided cobalt oxide at about 200,000 pounds per square inch to form a thin plate, a thin layer of metallic dust being applied to the surfaces of the oxide that are to become the face portions of the plate before pressing, heat treating the plate at about 600° C., and applying heat distributing, electrical connecting means to the metallic surfaces.

3. The method of forming a stable, high negative resistance-temperature coefficient resistor unit of the type having a short current path of large cross-sectional area, that comprises thoroughly mixing finely divided iron oxide with powdered glass, pressing the mixed materials into a thin disc at a pressure of about 200,000 pounds per square inch, heat treating the disc in vacuum with a trace of reducing agent at above 800° C., applying metal contacts to the faces of the disc, applying a connecting lead to one contact surface, covering said lead and surface with a sheet of insulating material, inserting this assembly between the arms of a U-shaped member of sheet metal, securing the ends of the U together to bind the parts into an integral unit, and attaching a connecting lead to the sheet metal member.

4. The method of forming a stable, high negative resistance-temperature coefficient resistor unit that comprises pressing finely divided cobalt oxide at about 200,000 pounds per square inch to form a thin plate, a thin layer of permalloy dust being applied to the surfaces of the oxides that are to become the face portions of the plate before pressing, heat treating the plate at about 600° C., securing a metal, heat distributing plate to one of said faces, and attaching connecting leads to said plate and to the other of said faces.

5. A stable, high negative resistance-temperature coefficient resistor unit comprising a dense, plate-like body, of pressed, finely divided, heat treated resistance material, the major constituent of which is at least one of the oxides from the group consisting of iron, nickel and cobalt oxides, metallic contact surfaces secured to two faces of said body, a connecting lead in contact with one of said surfaces, a plate of insulating material covering said lead and said one sur-

face, a sheet metal member having a portion covering the insulating plate and another portion contacting the other contact surface, said member securing the parts together in an integral unit, and a connecting means attached to the sheet metal member.

6. A stable, high negative resistance-temperature coefficient resistor unit comprising a dense, plate-like body of pressed, finely divided, heat treated, iron oxide and powdered glass, said glass comprising not more than ten per cent of the body, metallic contact surfaces secured to two faces of said body, a connecting lead in contact with one of said surfaces, a plate of insulating material covering said lead and surfaces, a sheet metal member having one portion covering the insulating plate, and another portion contacting the other contact surface, said member securing the parts together in an integral unit, and a connecting lead attached to said sheet metal member.

7. A stable, high negative resistance-temperature coefficient resistor unit comprising a thin plate-like body of pressed, finely divided, heat treated cobalt oxide having a contact of pressed finely divided metallic material integral with each of two faces of said body, a metal plate of greater area than one contact and secured thereto, and connecting leads secured to said plate and to the other contact surface.

8. The method of making a stable, high negative resistance-temperature coefficient resistor unit of the type having a short current path of large cross-sectional area, that comprises pressing finely divided material, having one of the oxides from the group consisting of iron, nickel and cobalt oxides as its major constituent, into a dense thin plate, heat treating the plate in a controlled atmosphere at a temperature above 500° C., and applying contact means including at least one heat distributing means to opposite faces of the plate.

9. A stable, high negative resistance-temperature coefficient resistor unit comprising a self-supporting plate of consolidated, finely divided heat treated resistance material, the major constituent of which is at least one of the oxides from the group consisting of iron, nickel and cobalt oxides, said plate having a thickness less than approximately one-twelfth of its smallest surface dimension, and contact means including at least one heat distributing member on opposite faces of said plate.

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