

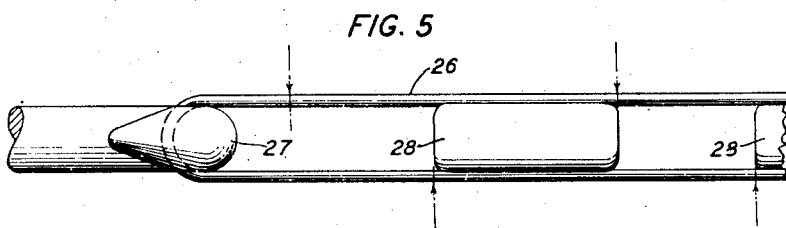
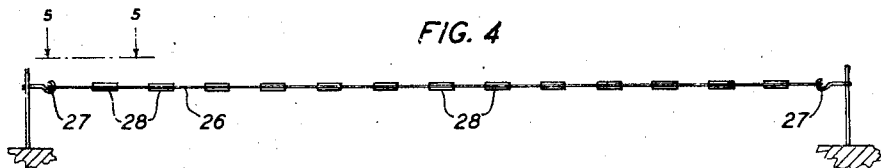
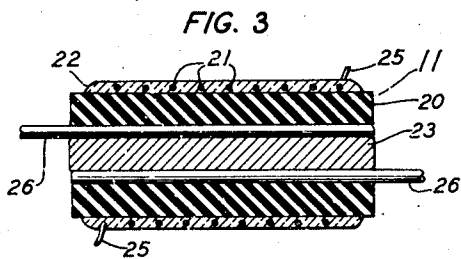
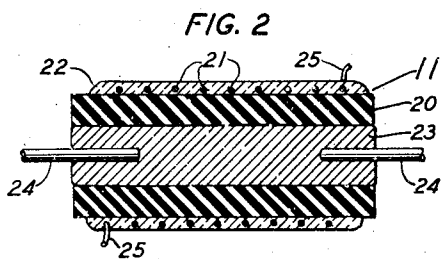
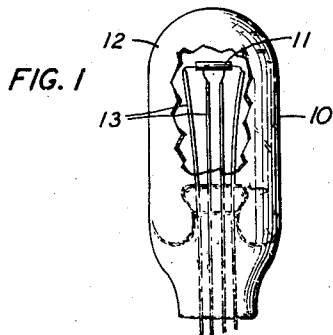
Aug. 26, 1941.

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2,253,577

RESISTANCE DEVICE

Filed April 7, 1939



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2,253,577

RESISTANCE DEVICE

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Application April 7, 1939, Serial No. 266,506

4 Claims. (Cl. 201—64)

This invention relates to electrical resistance devices and more particularly to indirectly heated thermal resistors having a high negative resistance-temperature coefficient element.

Indirectly heated resistors having high resistance-temperature coefficients may comprise a semi-conductive element, the resistance of which is highly sensitive to temperature, and an electrical heater for controlling the temperature of the semi-conductive element. The heater is separated from the semiconductive element by a barrier of insulation. This barrier may comprise a relatively non-conductive gas, such as air, or an insulating liquid or solid. A convenient form of solid barrier is a tube of insulation material enclosing one of the semiconductive and conductive elements and having the other applied to its exterior surface. One of the difficulties involved in such devices is the obtaining of a barrier having suitable mechanical, electrical and thermal properties. A further difficulty heretofore encountered has been the obtaining of a barrier that would retain satisfactory mechanical, electrical and thermal properties over an extended period of operation. Another problem has been to maintain the initial relative positions of heater and semiconductor.

One object of this invention, therefore, is to improve the structure of thermal resistors.

Another object of the invention is to increase the useful life of thermally sensitive resistance devices.

A further object of the invention is to improve the mechanical, electrical and thermal characteristics of indirectly heated resistors.

In accordance with one feature of this invention, the barrier means for insulating the heater from the thermally sensitive resistance comprises a ceramic tube, for example, of aluminum oxide material known commercially as "Alundum."

In accordance with another feature of this invention, the thermal resistor means comprises silver sulphide made by sulphurizing chemically pure silver in place within the insulating barrier.

A further feature resides in employing a body of silver of such size that when sulphurized it expands to tightly grip the inner wall of the "Alundum" tube thereby making good thermal contact with the tube and insuring against shifting of the silver sulphide in the tube.

Another feature of the invention involves the use, as cementing material for holding the heater coil in mechanically firm and good thermal contact with the insulating tubing, a mixture of

zirconium silicate and zirconyl chloride and water.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an elevational view of an illustrative embodiment of the invention showing a resistor unit mounted in a protecting envelope, a portion of the envelope being broken away to show the unit more clearly;

Fig. 2 is a sectional view of one form of resistor unit constructed in accordance with this invention;

Fig. 3 is a sectional view of another form of resistor unit;

Fig. 4 is a view in elevation of apparatus useful in one method of attaching conducting leads to bodies of silver used in the production of the silver sulphide elements; and

Fig. 5 is an enlarged view of that part of Fig. 4 indicated by line 5—5.

Resistor devices made in accordance with this invention are often very small in size. The drawing, therefore, is made on an enlarged scale in order that the invention may be more clearly illustrated.

Referring now to Fig. 1 of the drawing, 10 denotes a resistor device comprising a unit 11 mounted on conducting supports 13 in an envelope 12, which may be of glass. Any convenient means suitable to the use involved may be employed for mounting the device. A base of the type employed for vacuum tubes and the like provides one adequate form of mounting. The unit 11 may take several forms, two of which are illustrated in Figs. 2 and 3.

The unit disclosed in Fig. 2 may be constructed as follows: A length of ceramic tubing 20, for example of "Alundum," is held by suitable means such as a wire support passing through its bore. A coil 21 of previously wound heater wire is slipped over the tube and a thin paste of cementing material applied thereto. A preferred cement comprises a mixture of zirconium silicate (ZrSiO_4), zirconyl chloride (ZrOCl_2) and sufficient water to make a suitable paste. Sufficient cement is applied to form a layer 22 coating the tube 20 and covering the coil 21. The cement layer 22 is allowed to dry several hours. The heater wire may comprise a nickel-chromium alloy oxidized on its surface to provide insulation between turns. A preferred method of applying the heater coils to the tubing is to start with a

piece of "Alundum" tubing several times longer than the section 20 needed for one unit. A plurality of heater coils may then be cemented along this tube and after drying, the units are cut apart and trimmed to the desired length.

A slug or billet of silver, such as a length of chemically pure silver wire of somewhat less diameter than the tube bore, is inserted in the tube so that the silver projects slightly. This assembly is heat treated in sulphur vapor at about 160° C. for approximately one hour followed by about ten minutes at 220° C. On cooling, the resulting silver sulphide element 23 is trimmed flush with the ends of the tubing 20. The sulphurizing process is of sufficient extent to completely change the silver to silver sulphide. During the change from silver to silver sulphide, the material expands so that the element 23 entirely fills the tube 20 and makes firm mechanical contact therewith.

Conducting leads 24 may be applied to the silver sulphide in the following manner: With the assembly firmly held, the end of a conductor 24 is brought to a red heat in a small flame, such as a pin-point gas flame, and pressed against one end of the silver sulphide. As soon as penetration occurs the flame is quickly removed. Due to the small heat capacity of the material, solidification of the liquefied silver sulphide occurs very rapidly and a contact is established. The unit should be resulphurized to reconvert any of the silver sulphide that may have decomposed in the neighborhood of the contacts. The conductors 24 may be of a refractory conducting material such as platinum.

The assembled unit may next be mounted on a support comprising four electrically conductive wires 13. These wires should be of a material that gives a satisfactory seal with the glass of the envelope 12. A suitable material is platinum wire or a wire comprising an alloy of copper, nickel and iron. A coating of borax on the wire assists in making a good seal by eliminating air bubbles in the glass. The conductors 24 from the silver sulphide are connected to one pair of the support wires 13 and conducting leads 25 from the heater coil are connected to the other pair of support wires. Both sets of conductors preferably are attached to the supports with silver solder. The length of the wires and their cross-section should be chosen to give the minimum thermal conduction consistent with adequate electrical properties.

The assembly formed in accordance with the foregoing is placed in an envelope such as a lead glass tube 12 and the press formed. This resultant structure, or preferably a plurality thereof, is connected to a vacuum pump through a tubulature (not shown) and enclosed by an oven. The temperature within the oven is raised to about 350° C. An interval of several minutes should be allowed before starting the pump so that any sulphur driven off from the silver sulphide may be recombined with the silver. After the pump is started it is desirable to reduce the pressure within the envelope 12 to 10⁻³ millimeters of mercury in the first fifteen minutes. The baking at 350° should continue for from one to two hours to properly bake the heater cement and obtain pure silver sulphide. Subsequently, a suitable current is passed through the heater winding for about one-half hour. The completed units are sealed from the pump at a pressure less than 10⁻⁵ millimeters of mercury.

The unit shown in Fig. 3 is similar to the one

shown in Fig. 2 but differs therefrom in the manner of attaching the conducting leads to the silver sulphide. The assembly of insulating tube 20 and heater coil 21 by the cementing material 22 may be as previously described.

The lengths of silver wire or slugs of silver from which the silver sulphide is to be formed may be attached to the conductors in the following manner: Referring to Figs. 4 and 5, two wires 26 of platinum or the like are stretched between supports 27. These supports may be a pair of hooks made from piano wire of sufficient diameter to properly space the wires 26. Slugs of silver 28 of suitable dimensions are placed at intervals between the wires 26 and heat, such as from a pin-point flame, is applied until the wires 26 are firmly attached to the sides of the slugs 28. The string of slugs is removed from the support 27 and the wires 26 cut at the points indicated by the arrows in Fig. 5. The resulting assemblies are of the same general form as the silver sulphide element 23 with its lead conductors 24 in Fig. 3. Silver slugs with oppositely projecting conducting lead conductors are placed in coll-tube assemblies and sulphurized in a manner similar to that employed for the unit shown in Fig. 2. The sulphurized silver expands to fill the tube 20 and tightly grip the conductors 26. Mounting, baking and evacuating are done as previously explained.

In view of the small size of the devices and their constituent parts, extreme care must be exercised throughout the manufacture of the units. Some typical dimensions of the units will serve to illustrate this. For example, a unit for regulation in telephone circuits made in accordance with Fig. 2 may have the following dimensions: Tube 20, 0.085 inch long, 0.019 inch outside diameter and 0.0085 inch bore; lead conductors 24, 0.002 inch diameter; and heater wire 21, 0.00125 inch diameter.

Although specific embodiments have been shown 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 this invention as defined in the appended claims.

What is claimed is:

1. The method of manufacturing a silver sulphide resistor unit that comprises inserting a silver wire into a tube of insulating material, the wire diameter being somewhat less than the tube bore, placing a heater element around said tube, applying a cement to completely cover the element, hold it in place on, and in good thermal contact with the tube, and heating the assembly in sulphur vapor until the silver is completely changed to silver sulphide and expanded into intimate thermal contact with said tube.

2. The method of making a negative resistance-temperature coefficient resistor unit that comprises the following steps: attaching conductors of relatively non-oxidizable metal to the sides of a piece of pure silver wire, inserting the silver wire and conductors into an insulating tube of substantially the same length as the silver wire and having a bore slightly greater in diameter than the combined thickness of said wire and conductors, applying a heater element to the outside of said tube and securing it in intimate thermal contact therewith, and heating the assembly thus formed in sulphur vapor until the silver is completely changed to silver sulphide and expanded to tightly engage the tube walls and the conductors.

3. The method of making a resistor unit that comprises inserting an insulating tube into a coil of heater wire, applying cementing material to the coil and tube to cover the former and secure it to the latter, attaching connecting leads of fine wire to opposite sides of a length of silver wire, inserting the silver wire with the leads into the tube and applying heat to the assembly in the presence of sulphur vapor until the silver is all converted to silver sulphide and expanded to 10 tightly grip the inner wall of the tube and the connecting leads.

4. A resistor unit comprising an insulating support having a cavity therein, an element of silver sulphide within said cavity, said element being in close thermal and mechanical contact with said support due to radial forces exerted between said support and element and a heater means mounted on and in intimate thermal contact with said support and separated from the silver sulphide thereby.

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