March 22, 1960 J. M. HINKLE 2,930,018

GLASS-SEALED RESISTOR

Filed June 15, 1954

Fig. 1

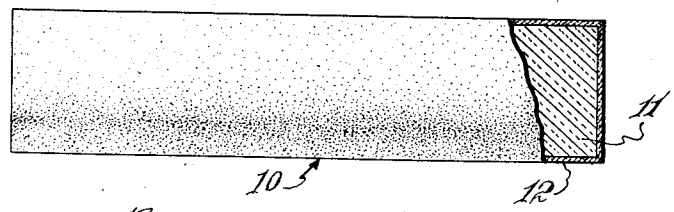



Fig. 2

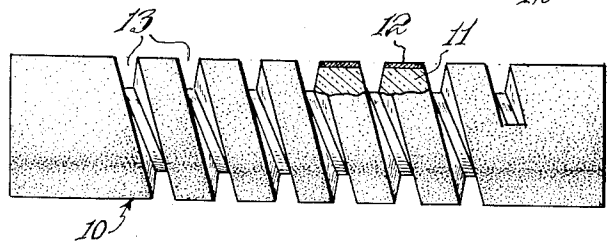



Fig. 3

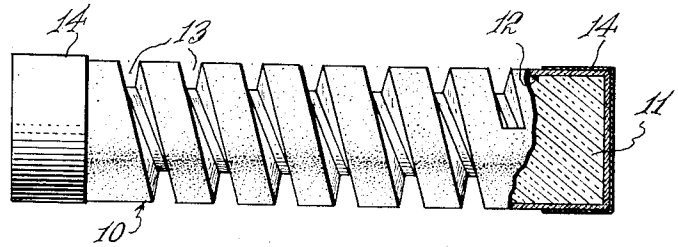



Fig. 4

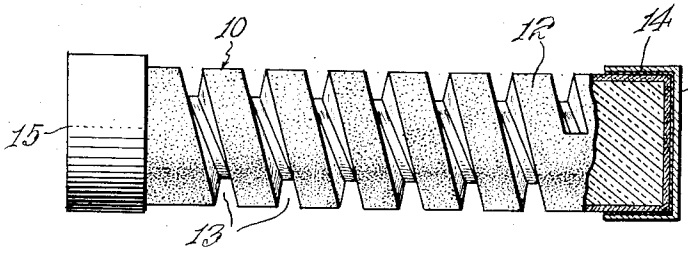
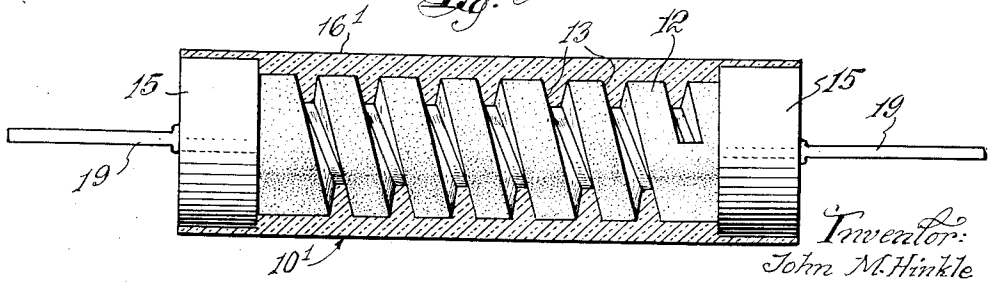



Fig. 5




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# GLASS-SEALED RESISTOR

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3 Claims. (Cl. 338—237)

This invention relates to electrical resistors of the well known "film" type, in the construction of which the resistive conductor is constituted by a thin film of suitable material which has been deposited on the exterior surfaces of a rod-like base or core of electrical insulation resistance material, such as porcelain-type ceramic. Other materials possess the required electrical properties, such as platinum-gold alloy, but carbon is so commonly used for the deposited resistive conductor film that a carbon film resistors has been chosen as the illustrative example to be described in detail in disclosure of the present invention, which has particular reference to the means employed to hermetically seal the delicate resistive conductor film against exposure to physical and chemical damage.

Prior to the present invention, it has been common practice to seal the resistor in a glass envelope that completely encloses it and is spaced radially from the resistive conductor film. If the film were exposed to air, decomposition would occur, so the space between the film and envelope customarily is filled with a pure inert gas, such as helium.

The prior art sealing structure just mentioned possesses numerous disadvantages. The over-all size is objectionably large for uses in which miniaturization is almost mandatory. The gas atmosphere surrounding the resistive conductor film affords relatively poor heat dissipation, resulting in a comparatively long thermal time constant, and produces changes in the state of sorption of the film surface and damage from gas ionization, which latter also has the effect of limiting the high voltage capabilities of the resistor. Still other disadvantages of the earlier glass sealing structure are lack of ruggedness, the difficulties of installing leading-in wires, and the necessity for making the sealed resistors one at a time. Consequently, due to the amount of hand labor required, production costs have been very high.

It, therefore, is my primary object to provide a glass seal for a resistor in the deposited carbon film category in an improved manner which renders the product free from the above-enumerated objectionable features of the earlier gas-containing glass envelope.

To be more explicit, in one embodiment of the invention, my improved sealing medium is produced by shrinking an enclosing glass tube in heat-softened condition into such close contact with the core-supported resistive conductor film that all air or other gases will be excluded from between the glass and carbon layers. In another embodiment, the glass tube is shrunk into contact with the end portions only. Both the tube shrinking and the gas exclusion are facilitated by connecting the tube with a vacuum line while heat is being applied.

I am aware that others have applied a contact coating of varnish to the carbon film of a resistor to produce a gas-excluding sealing medium, but use of any such organic material is objectionable because of the deleterious effect on the carbon film of gases evolved by decomposition of the organic material under the influence of the high temperatures to which a resistor often is subjected in operational use.



It is also true that in the course of my earlier experimentation along this line, I provided a resistor with a sealing coat of glass that was in close contact with the carbon film, but the result was not nearly so satisfactory as the shrunk-on glass tube of the present invention. In that earlier attempt, glass powder was applied to the exterior surfaces of a resistor and then fused into a glaze coating. The sealing coat thus produced was observed to be bubbled and probably was subject to pinhole difficulties. It was then that I conceived the idea of inserting the resistor in a glass tube and shrinking the latter into tight gas-excluding contact with the peripheral surfaces of the resistor.

Another object of the invention is to provide a glass sealing coat for the resistor that leaves the ends of the latter exposed for direct connection of lead wires without having the problem of leading them in through the sealing medium in a hermetically sealed manner. This provision introduced the problem of insuring against opening of the joint between the edges of the sealing coat and the resistor under the influence of thermal expansion and contraction in operational use. It is therefore a further object of the invention to prevent failure of the seal under any such conditions, which has been accomplished by use of novel contact caps at the opposite ends of the resistor which cooperate with the glass sealing coat to provide a highly effective end seal.

Other objects, advantages and features of the invention will become apparent as the following specific description is read in connection with the accompanying drawings, in which:

Fig. 1 is a side elevation, partly in section and on a greatly enlarged scale, of a typical carbon resistor, showing the same in its primary elemental form prior to the usual film scoring operation to increase the effective length of the resistive conductor; and Fig. 2 is a similar view showing the resistor in its secondary elemental form upon completion of the film scoring operation but in unsealed condition.

Fig. 3 is a view similar to Figs. 1 and 2, showing a thin coating of solid electrically conductive metal covering the end portions of the carbon film in preparation for application of contact caps; Fig. 4 is a similar view showing the contact caps in place; and Fig. 5 is a similar view of the completed resistor, showing the glass sealing wall in shrunk-on coextensive peripheral contact with the carbon film and contact caps and also showing the lead wires in welded connection with the end walls of the contact caps.

Referring now in detail to the drawings, in which like reference characters designate corresponding parts in the several views, Figs. 1 and 2, respectively represent a typical carbon resistor **10** in its successive elemental forms. The process of manufacturing such a resistor starts with a blank to serve as a base body or core upon which a coating or film of carbon may be supported to function as the resistive conductor thereof.

Fig. 1 shows the base body or core **11** after deposition of its carbon coating or film **12**, which covers all exterior surfaces, both peripheral and at the ends. Carbon film **12** is almost microscopically thin and may be applied by a process that has been used for many years in this and other countries.

This process consists in exposing the core blank to an atmosphere of a dilute hydrocarbon vapor, such as methane or benzene, at a suitably elevated temperature. I prefer to use high purity nitrogen to dilute methane and coat at about 1100° C. Several blanks may be coated as a batch in a gas-tight bottle which is rotated to expose the blanks uniformly as the coating gas is passed through the bottle. However, they may be coated singly in a suitable

oven. The desired carbon film generally is from $10^{-3}$ cm. to $10^{-7}$ cm. in thickness.

The structure and composition of the core of each resistor are important. Preferably, the core **11** is in the form of a cylindrical rod of good mechanical strength and made from a material which possesses the electrical property of high insulation resistivity and which is sufficiently refractory to withstand high temperatures. The selected material also should be of such composition that the finished blanks will be non-porous and have a very high degree of surface perfection in order to permit the deposition thereon of a uniform layer of carbon which will insure the stability of the resistor. The surface, therefore, must be free from pinholes, cracks, blebs, iron spots, and heterogeneities of any sort, as well as being free from scratches, die marks, and the like. Moreover, the surface should be smooth, but of microscopic roughness which mechanically keys deposited carbon to the surface and thus provides excellent adherence.

A ceramic material of the porcelain type disclosed in U.S. Patent No. 2,386,633, dated October 9, 1945, meets all of the above-enumerated requirements for the carbon resistors now in general use, and, at least one of the several exemplary combinations of chemical ingredients described in that patent possesses thermal expansion properties well suited to the matching of expansion coefficients which is involved in the choice of materials for use in composition of the core, contact caps and sealing medium of my improved resistor, as will be explained more fully later herein.

While the resistor in its primary elemental form represented in Fig. 1 is quite capable of operational use, the effective length of the resistive conductor constituted by carbon film **12** will be relatively short and the ohmic value of the resistance interposed thereby in an electric circuit will be proportionately low. Therefore, it is customary to increase the effective length of the resistive conductor by cutting a helical groove **13** through carbon film **12** into core **11** to transform the interior peripheral portion of the film into a helical strip in the manner shown in Fig. 2. The axial extent of groove **13** should be such as to leave undisturbed areas of film **12** adjacent to the ends of resistor **10** for application of terminal contact means, which latter, in accordance with prior practice, sometimes have been in the form of encircling bands of conducting metal (not shown).

Up to this point in the disclosure, all physical and chemical details of the two embodiments of the elemental resistor illustrated in Figs. 1 and 2 are old and well known in the art. However, the details of structure and chemical composition disclosed in the subsequent figures of drawing are either novel in themselves or are inventively combined with novel details.

As previously stated, the present invention contemplates direct connection of lead wires to the respective ends of the improved glass-sealed resistor through the media of metallic contact caps at said ends. The use of contact caps is to increase the electrical contact area between the carbon surface and the lead wires to insure low contact resistance and consequent electrical stability. The contact caps also hermetically seal the terminal portions of resistive conductor **12**.

Preparatory to installation of the contact caps, the end faces and adjacent ungrooved peripheral portions of the carbon film **12** are given a microscopically thin coating of a metal possessing high electrical conductivity. Although silver or some other metal which satisfies this requirement may be used within the scope of the invention, it is preferred to use copper. Organic paint pigmented with metal flakes might be used to form the metallic coating, but the presence of any organic substance inside the finally applied glass sealing coat or wall is objectionable due to the release of deleterious gases upon inevitable decomposition of the organic vehicle in which the metal flakes are suspended by the heat to which the resistor will be subjected during formation of the glass seal and in subsequent operational use. Instead, it is preferred to apply a deposited coating of pure solid copper by successively exposing the respective end portions of the resistor in its Fig. 2 form to evaporation of copper in an evacuated bell jar or equivalent chamber. Fig. 3 shows the preparatory copper coatings **14—14** at the opposite ends of carbon film **12**.

Fig. 4 shows the resistor after cylindrical contact caps **15—15** have been force-fitted onto the copper coated areas **14—14**. Each contact cap includes integral side and end walls which must be imperforate so that no air or other gas can possibly penetrate to the carbon film **12** through the end wall thereof. Gas penetration in peripheral areas is prevented by the glass sealing medium to be described in detail presently.

In accordance with the present invention, contact caps **15** are composed of a metal possessing high electrical conductivity which also has substantially the same coefficient of linear expansion as the material of which core **11** is composed and the particular glass to be used in formation of the sealing medium. For use with a core composed of porcelain type ceramic, such as is disclosed in U.S. Patent No. 2,386,633, I prefer to use a metallic alloy containing approximately 29 percent nickel, 17 percent cobalt, .3 percent manganese, and 53.7 percent iron in construction of contact caps **15**. To match the thermal expansion coefficients of the selected core and contact cap compositions, the sealing medium may be composed of a hard boro-silicate glass.

Although the matching of thermal expansion coefficients just described should insure a gas-tight joint between the glass sealing wall and the peripheral surfaces of plain-surfaced contact caps, I have devised a precautionary measure which absolutely precludes any gas penetration in this area and which consists in oxidizing the peripheral surfaces of contact caps **15** for cooperation with the fused glass during installation of the sealing coat or wall. To avoid objectionable oxidation of the inner surfaces of the contact caps, where perfect electrical conduction is desired, the problem was solved by copper-plating one side only of the sheet metal blank from which the contact caps were stamped. Then, by stamping out the caps in such a manner that the copper plated surfaces were on the interior, it became practicable to oxidize the outer peripheral surfaces without affecting the plain inner surfaces by use of a wet hydrogen atmosphere.

Fig. 5 illustrates the completed glass-sealed resistor **10'** of my invention in its preferred form wherein the shrunk-on glass wall adheres closely to the carbon film **12** and the exposed areas of core **11** within grooves **13** as well as to the peripheral surfaces of contact caps **15**. In an alternative embodiment of the invention, glass sealing tube **16** is shrunk into close contact with the oxidized caps **15** only while maintaining radial separation between the said tube and core **11** with its carbon film **12** (not shown).

While I do not wish to be limited to the use of any particular combination of specific chemical compositions for the three principal mechanical constituents of my improved glass-sealed resistor, there are two other core-cap-glass systems with matching thermal expansion coefficients which may be suggested as possible alternatives. One is a hard glass system, like the one previously disclosed herein, and the other is a soft glass system.

The alternative hard glass system comprises a core of dense alumina ceramic, contact caps of molybdenum, and boro-silicate glass; whereas the soft glass system comprises a core of steatite, contact caps of an alloy containing 42 percent nickel, 52 percent iron and 6 percent chromium, and potash-soda-lead glass.

Incidentally, all elements of the three core-cap-glass systems disclosed herein are commercially available.

It will be understood that it is intended to cover all changes and modifications of the examples of the invention herein chosen for the purpose of illustration which do not constitute departures from the spirit and scope of the invention.

Having thus described the invention, I claim:

1. A hermetically sealed resistor comprising: an elongated cylindrical core composed of a refractory material of high electrical insulation resistivity; a thin film-like resistive conductor extending substantially coextensively lengthwise on the peripheral surface of said core; impervious cylindrical contact caps of electrically conductive metal fitted on the respective ends of the core in snug air-excluding telescopically enclosing electrical contact with the terminal portions of the resistive conductor throughout substantially the entire length of each contact cap, each of said contact caps including a flangeless cylindrical tubular side wall and an integral closing wall at one end only, said closing end wall being outwardly presented to provide an impervious end seal for the core and resistive conductor; and a tubular shrunk-on sealing wall of vitreous electrically non-conductive material snugly and air-excludingly enclosing the core, the resistive conductor and the side wall only of the contact caps substantially throughout the entire length of said caps.

2. A hermetically sealed resistor as defined in claim 1, wherein the core is composed of dense alumina ceramic; the contact caps are composed of molybdenum; and the sealing wall is composed of hard boro-silicate glass, whereby the core, contact caps and sealing wall possess substantially the same coefficients of linear expansion to prevent separation under the influence of thermal changes.



3. A hermetically sealed resistor as defined in claim 1, wherein the core is composed of steatite; the contact caps are composed of an alloy containing approximately 42 percent nickel, 52 percent iron and 6 percent chromium; and the sealing wall is composed of soft potash-soda-lead glass, whereby the core, contact caps and sealing wall possess substantially the same coefficients of linear expansion to prevent separation under the influence of thermal changes.


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