Aug. 3, 1965 H. A. CRAMER ETAL 3,199,058

PRECISION RESISTOR

Filed March 9, 1962

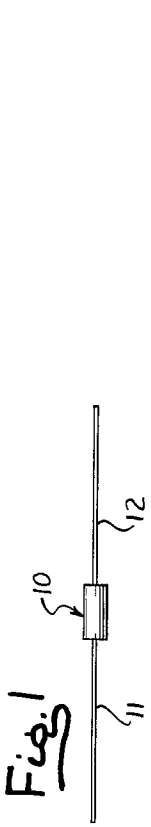


Fig. 1

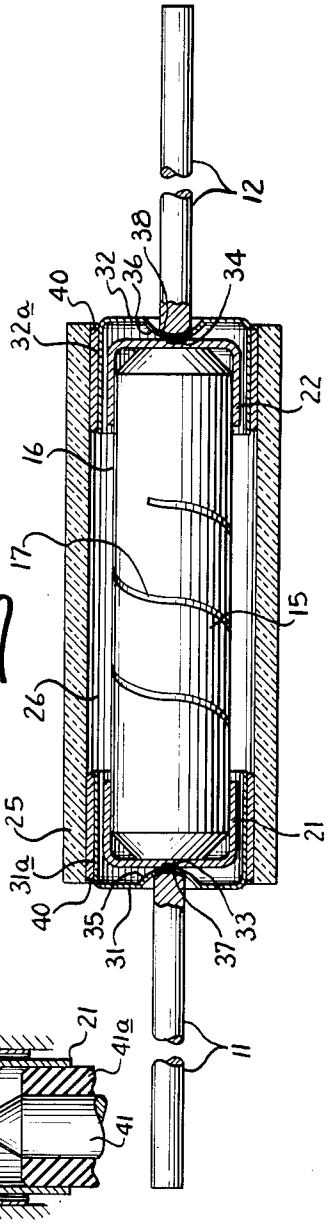


Fig. 2

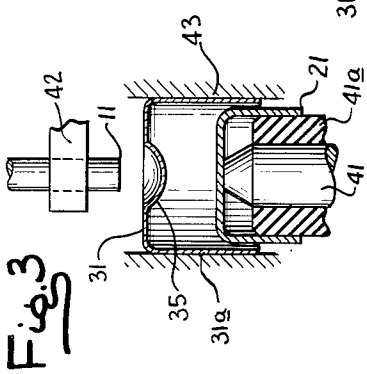


Fig. 3

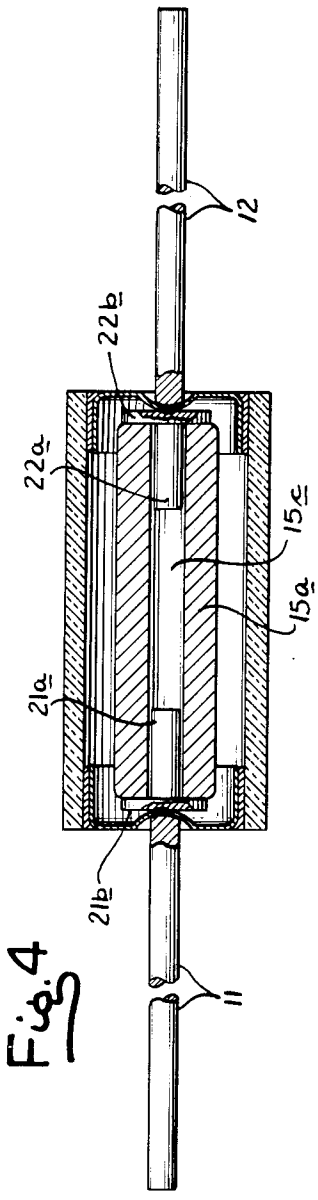


Fig. 4

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PRECISION RESISTOR

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The present invention relates to the encapsulation of electrical components and more particularly to precision resistors of the hermetically-sealed type.

It is an object of the present invention to provide an encapsulated resistor in which the resistance element is hermetically sealed in a rigid nonconducting cylinder but which is capable of withstanding wide and abrupt changes in temperature without failure or without the setting up of internal strains producing a condition of incipient failure. It is a general object of the invention to provide an encapsulated precision resistor having reliability of the highest order, approaching absolute, and which is suitable for use wherever continued operation in the face of sudden environmental changes is essential as, for example, in guided missiles, satellites, or the like. It is an object, therefore, to produce an encapsulated resistor which is capable of enduring extreme physical or thermal shock and which is capable of withstanding electrical overload.

It is one of the specific objects of the invention to produce an encapsulated resistor which is immune to relative dimensional changes occurring in the resistance element and in the cylinder which encloses it.

Other features and advantages of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIGURE 1 shows a resistor of the wire pigtail type to which the present invention has been applied.

FIG. 2 is an enlarged axial section of the resistor shown in FIG. 1.

FIG. 3 shows the setup employed in making the terminal assembly employed in the device of FIG. 2.

FIG. 4 is an enlarged axial section of a resistor embodying a modified construction.

While the invention has been described in connection with certain preferred embodiments, it will be understood that we do not intend to limit the invention to the embodiments disclosed but on the contrary we intend to cover the various alternative and equivalent constructions included within the spirit and scope of the appended claims.

Turning now to the drawings a resistor constructed in accordance with the present invention has a body **10** with axially extending lead wires **11**, **12**, the form factor being similar to resistors of conventional film or composition type. The details of construction are revealed in the enlarged axial section, FIG. 2. Here it will be noted that the resistor includes a circuit element, here shown as a resistor element **15**, which is cylindrical in shape having a resistive film **16** which may be severed by a shallow helical groove **17**. For the purpose of making contact with the film **16**, resistor terminals in the form of metal end caps **21**, **22** are provided which are snugly fitted to the ends of the resistor elements.

For the purpose of encapsulating and sealing the resistor element **15**, an impervious cylinder **25** is used formed of rigid non-conducting material, the cylinder having a diameter which is sufficiently larger than the resistor element to define an annular inner space **26**.

In accordance with the present invention thin-walled flexible diaphragm members are provided for sealing the ends of the cylinder **25** and which are secured to the resistor terminals at a localized area along the axis so that such members are free to yield, with diaphragm action, in response to relative expansion between the resistor element and the cylinder which surrounds it. In the present embodiment the diaphragm elements are indicated at **31**, **32** respectively, with the elements being welded or otherwise secured to the resistor terminals **21**, **22** at the center as indicated at **33**, **34** respectively. To insure freedom of movement of the diaphragm elements in response to endwise forces in both directions, the diaphragm elements are spaced from the terminals which they engage. In the present instance such spacing is accomplished by inwardly dimpling or embossing the diaphragm elements as at **35**, **36**. Thus it is not possible for the resistor terminals to bottom, face to face, against the diaphragm elements. If desired, and without departing from the invention, the embossment could be provided on the resistor terminals **21**, **22**. In either event, the embossment not only insures freedom of movement but also serves to localize the weld or connection between the adjacent members so that it occupies a limited area centered on the resistor axis. The lead wires **11**, **12** are preferably butt-welded in axial position against the outside surface of the diaphragm members **31**, **32** as indicated at **37**, **38** respectively, but they may be attached by other suitable means.

For the puprose of providing a good seal and strong mechanical connection between the diaphragm members **31**, **32** and the ends of the cylinder **25**, the diaphragm members are preferably provided with walls or flanges **31***a*, **32***a* respectively having a diameter which is just slightly smaller than the inner diameter of the cylinder. The walls are sealed to the cylinder by a suitable sealant **40**. The seal between the diaphragm members and the tubing may be brought about using any one of a number of well known "glass or ceramic to metal" sealing techniques. For example, the inner end surfaces of the cylinder may be metalized and the sealant **40** may consist of a suitable solder. Or, if desired, the sealant may be in the form of frit capable of wetting both the cylinder and the surface of the metal. Finally, when the cylinder is of fusible material sealing may be accomplished by direct fusion; in this case it is desirable to employ a metal for the diaphragm elements **31**, **32**, which has substantially the same coefficient of expansion as the material of which the cylinder **25** is made.

In the preferred embodiment of the invention illustrated in FIG. 2, the resistor terminal element **21** and the associated diaphragm element **31** are preferably in the form of nested cups or wafers having parallel walls and with a small clearance space being maintained between them so that there is minimum interference with relative axial movement.

The terminal assembly at each end of the resistor, for example, the terminal assembly which consists of the terminal **21**, diaphragm **31**, and lead wire **11**, may be welded together using a simple and effective welding setup as shown in FIG. 3. This figure shows the parts in exploded relation prior to making the weld. Arranged within the terminal element **21** is a centering jig **41***a* and a coaxial first electrode **41**. A second electrode **42**, which is shown diagrammatically and which may be of any desired configuration, clamps the lead wire **11**. Guide means **43** may be used for centering the diaphragm element **31** to insure that concentricity is maintained. In operation the electrode **42** and the lead wire **11** which it engages are brought down into bottomed contact against the diaphragm member **31**, thus conditioning the electrical circuit and permitting formation of the welds previously indicated at **33–37**.

After the individual electrode assemblies are welded together, they are secured to the opposite ends of a resistor blank or substrate having a conductive film deposited on the surface. The resistance of the blank may be brought to a precise value by grooving in a so-called "spiraling" lathe or by other suitable means. After the

resistance of the blank has been adjusted and the electrode assemblies secured thereto, the protective cylinder is slipped over the assembly and sealed, as heretofore stated, to the diaphragm elements **31**, **32**.

While the invention has been described in connection with cup-shaped inner terminals **21**, **22** at the ends of the resistor element, it will be apparent to one skilled in the art that other terminal configurations may be employed without departing from the invention. For example, in FIG. 4 there is shown an alternate construction in which the resistor electrodes indicated at *21b*, *22b* are disc shaped having a central projecting portion *21a*, *22a* projecting into an opening **15***c* which extends longitudinally through the resistor element **15***a*. The elements may be joined together using techniques similar to those disclosed in FIG. 3. Both structures posess substantially the same features and advantages.

It is found that resistors constructed in accordance with the present teachings are capable of resisting thermal shocks which would fracture or destroy encapsulated resistors of more conventional design. For example, the units disclosed herein have been subjected to sudden changes in temperature between −65° and +150° C., a difference of 215° C., without damage. Conventional encapsulated resistors were found to suffer a 70% failure rate when subjected to this treatment. The high degree of reliability of the present design is considered to result from the fact that any applied temperature change tends to act first upon the cylinder **25** effectively changing its length, with the differential expansion between the cylinder and the resistor element being accommodated by the movement which takes place in the end walls of the diaphragm elements. If desired, the end walls of the diaphragm elements may be concentrically waved or convoluted to provide additional flexibility. However, this has not been found to be necessary in practice.

It has been found that resistors of the present design are also capable of resisting severe shock and vibration without failure. Some of the severity of the shock is, of course, taken up by the lead wires **11**, **12** but it is believed that substantial added resistance to shock is provided by "floating" mount provided by the diaphragms.

From an electrical standpoint it is found that the present resistors are capable of handling over-current conditions in excess of those which can be withstood by ordinary precision resistors. The good thermal coupling between the resistor terminals and diaphragm elements assists in conducting the heat outwardly where it can be effectively radiated and conducted into the environment. Moreover, any differential expansion between the resistor element and the cylinder which encloses it brought about by the conducted current is immediately taken up by diaphragm action.

Since the reliability of the present units approaches absolute, such units are ideally suited for use in computers, guided missiles or satellites, wherever the highest order of reliability is essential.

Notwithstanding the above features and advantages it is noteworthy that resistors of the present design may be manufactured at low cost. It will be appreciated by one skilled in the art, and having in mind the discussion of FIG. 3 above, that welding, assembly, and sealing may all be easily automated enabling the present resistors to sell for little more than resistors of conventional type.

While the enclosing cylinder **25** may be made of glass, it will be apparent that the invention is not limited thereto and that the member may be made of ceramic material or any other rigid non-porous material which permits an effective seal with respect to the diaphragm members.

We claim as our invention:

1. An encapsulated resistor or the like comprising, in combination, a circuit element, cooperating inner and outer terminal caps at each end of the element, a rigid cylinder surrounding said element, said inner terminal caps being connected to the element and providing electrical connection therewith and said outer terminal caps being dimensioned to engage the ends of the cylinder for sealing thereto, the outer terminal caps being in the form of thin flexible metal diaphragms having an inwardly projecting central protuberance secured to the cooperating inner caps over a limited area at the axis to take up differential expansion of the circuit element and the cylinder which surrounds it incident to abrupt temperature changes, and axial lead wires secured to the outer caps.

2. An encapsulated resistor comprising, in combination, a cylindrical resistance element, inner and outer nested terminal caps at each end of the element, a rigid cylinder surrounding said element, said inner terminal caps being dimensioned to engage the element and to provide electrical connection therewith and said outer terminal caps being dimensioned to fit snugly with respect to the ends of the cylinder for sealing thereto, the outer terminal caps being made of thin flexible metal and having an embossed central portion secured to the inner terminal caps over a limited area at the axis so that relative movement between the adjacent caps may occur incident to differential expansion between the element and the cylinder incident to abrupt temperature changes, lead wires engaging the centers of the outer caps, the lead wire, inner cap and outer cap at each end being coaxially fused together.

3. An encapsulated resistor or the like comprising, in combination, a cylindrical circuit element, inner and outer nested terminal caps at each end of the element, a rigid cylinder surrounding said element, said inner terminal caps being dimensioned to engage the element and to provide electrical connection therewith and said outer terminal caps being dimensioned to fit snugly within the ends of the cylinder for sealing thereto, the outer terminal caps being made of thin flexible metal and having a concave central portion secured to the inner terminal caps over a limited area at the axis so that relative movement between the adjacent caps may occur incident to differential expansion between the element and the cylinder incident to abrupt temperature changes, and means for making external electrical connections to the center of the outer terminal caps.

4. An encapsulated resistor or the like comprising, in combination, an elongated circuit element having conductive end terminals axially positioned thereon, a rigid protective cylinder surrounding said element, a cup-shaped diaphragm member at each end of the circuit element, each of said diaphragm members having a generally radially disposed imperforate metallic central portion and a peripherally disposed axially directed portion, said axially directed portion of each diaphragm member being secured to respective opposite ends of said cylinder and sealingly engaged therewith so as to define a totally enclosed chamber surrounding said element, said imperforate central portion of each of said diaphragm members being in the form of a diaphragm sufficiently thin as to deform axially in both directions when force is applied to the center thereof, each diaphragm member being secured to the adjacent terminal over a limited area at the center and allowing for differential expansion between the circuit element and the cylinder, and external electrical contact means secured to said diaphragm members with freedom for movement therewith as said diaphragm members flex due to differential expansion between said circuit element and said cylinder.

5. An encapsulated resistor or the like comprising, in combination, a cylindrical resistor element having conductive end terminals axially positioned thereon, a hollow cylinder telescoped thereover, a diaphragm member at each end of the resistor, each of said diaphragm members having a generally radially disposed imperforate metallic central portion and a peripherally disposed axially directed portion, said axially directed portion of each diaphragm member being secured to respective opposite

ends of said cylinder and sealingly engaged therewith so as to define a totally enclosed chamber surrounding said element, said imperforate central portion of each of said diaphragm members being in the form of a diaphragm sufficiently thin as to deform axially in both directions when force is applied to the center thereof, each diaphragm member being secured to the adjacent resistor terminal over a limited area at the center and allowing for differential expansion between the resistor element and the cylinder, and external electrical contact means secured to said diaphragm members with freedom for movement therewith as said diaphragm members flex due to differential expansion between said circuit element and said cylinder.

6. An encapsulated resistor or the like comprising, in combination, a cylindrical circuit element, cooperating inner and outer terminal caps at each end of the element, a rigid cylinder surrounding said element, said inner terminal caps being dimensioned to engage the element and to provide electrical connection therewith and said outer terminal caps being dimensioned to engage the ends of the cylinder for sealing thereto, at least one of the caps at each end having an axial projection providing a limited welding area for the cooperating cap and the outer terminal caps being in the form of diaphragms of thin flexible metal so that relative movement may occur between the cooperating caps incident to differential expansion between the circuit element and the cylinder upon abrupt change in temperature, and axial lead wires welded to the caps.

7. An encapsulated resistor or the like comprising, in combination, a cylindrical circuit element, cooperating inner and outer terminal caps at each end of the element, a rigid cylinder surrounding said element, said inner terminal caps engaging the element to provide electrical connection therewith and said outer terminal caps being dimensioned to telescope within the cylinder for sealing to the ends thereof, the outer terminal caps being made of thin flexible metal and secured to the inner terminal caps at the axis and at least one of the cooperating caps at each

end being dimpled to provide a limited welding area with the caps spaced apart a small distance axially so that relative movement may occur between them incident to differential expansion between the circuit element and the cylinder upon abrupt changes in temperature, and axial lead wires welded to the caps.

8. An encapsulated resistor or the like comprising, in combination, a cylindrical circuit element, inner and outer nested terminal caps mounted on one end of said element, a rigid protective cylinder of impervious material surrounding said element and spaced therefrom, said inner terminal cap being dimensioned to engage said element so as to provide electrical connection therewith, said outer terminal cap being dimensioned to fit snugly within one end of the cylinder for sealing engagement therewith, means for sealing the other end of said cylinder and for providing electrical engagement with the other end of said circuit element, said outer cap being made of thin flexible metal and having an embossed central portion secured to said inner cap over a limited area in the region of the axis thereof so that relative movement between the adjacent caps may occur incident to differential expansion between said element and said cylinder resulting from abrupt temperature changes.

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