July 4, 1967 W. W. STEIL 3,329,922

WELDED TERMINAL RESISTOR

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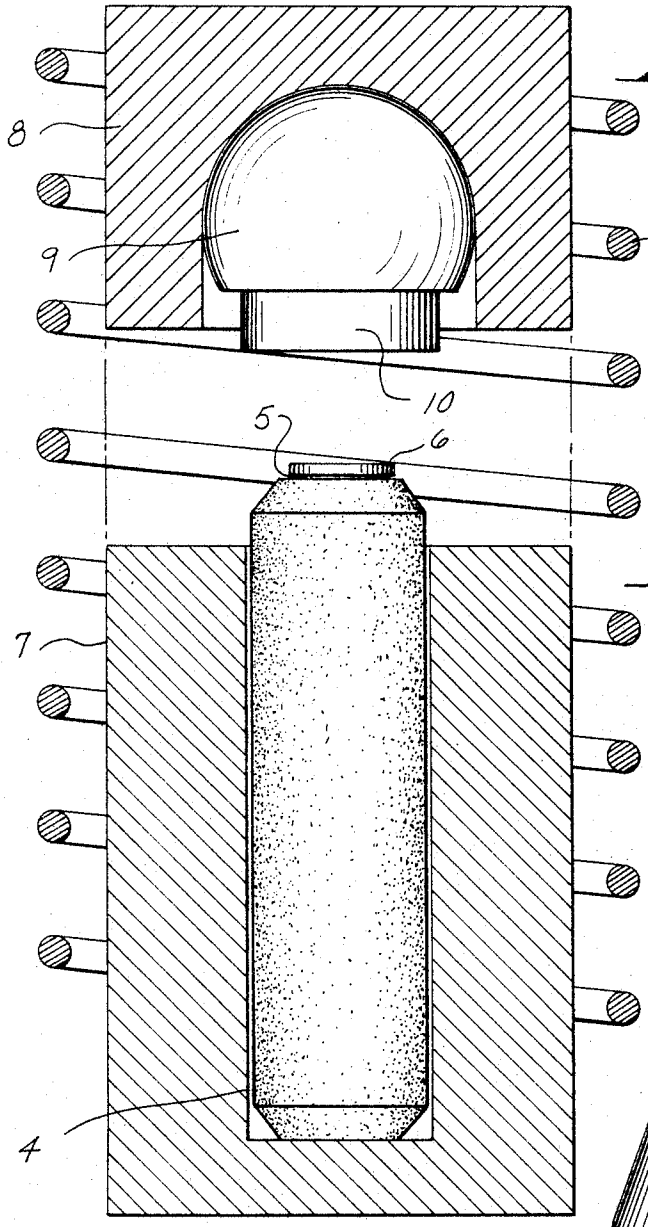


Fig. 1

Fig. 2

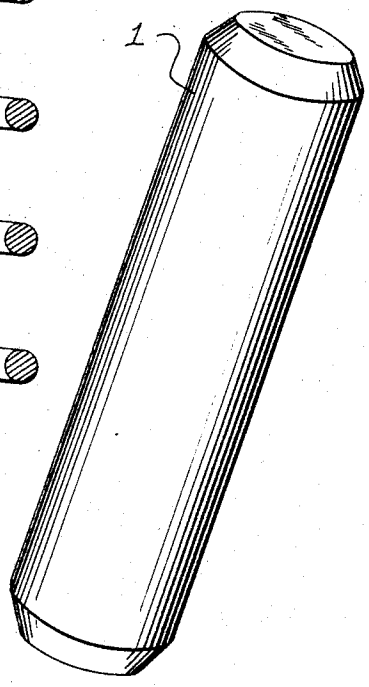
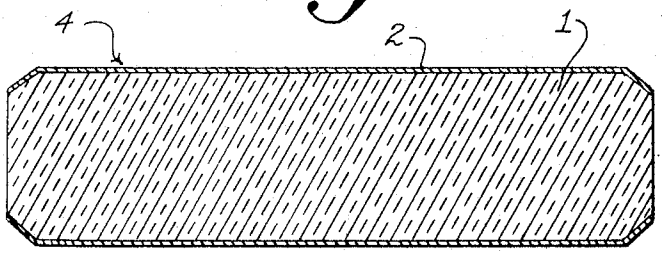


Fig. 3



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Fig. 4

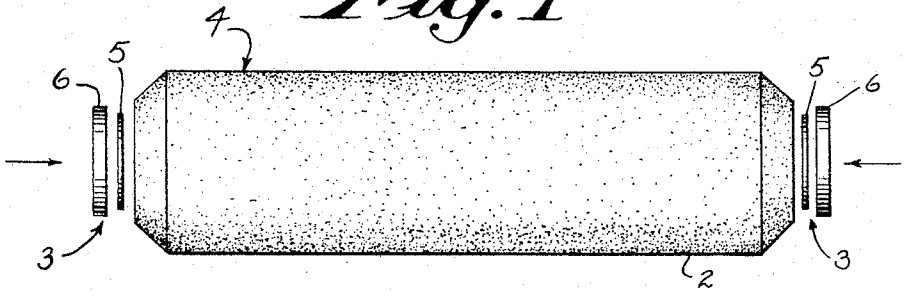


Fig. 5

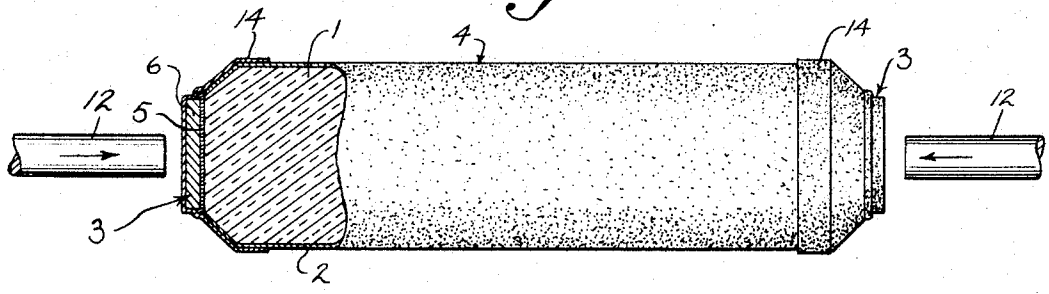


Fig. 6

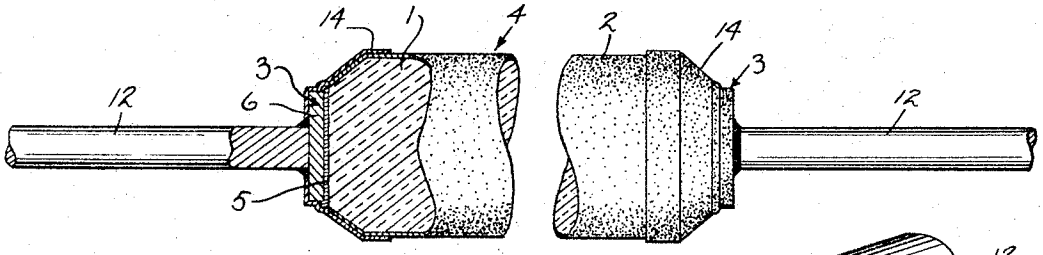
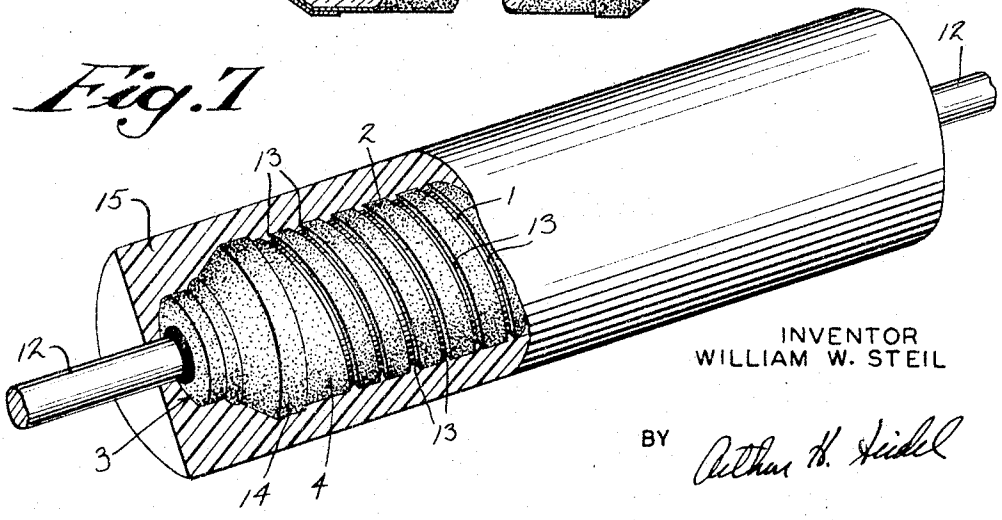


Fig. 7



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WELDED TERMINAL RESISTOR

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1 Claim. (Cl. 338—329)

The present invention relates to a resistor and a method for mounting lead wires on said resistor; the resistor is comprised of a ceramic dielectric body having a deposited resistive conducting film, a metallic tab anchored to the ceramic body by a thermal compression bond, and a lead wire attached to the tab and electrically connected to the resistive film; and the method for mounting the lead wire includes the steps of pressing said metallic tab against said ceramic body at elevated temperatures and pressures until a thermal compression bond is formed, attaching the lead wire to said tab, and electrically connecting the lead wire to the resistive film.

The needs of rapidly developing technologies in recent years have brought into extensive use electrical resistors of the film type construction. These resistors are made by depositing a conducting film of carbon or some appropriate metal onto the surface of a cylindrical rod or tube of refractory insulating material by such methods as vapor deposition, evaporation, sputtering and the like. The desired resistance rating is achieved by cutting or otherwise forming the conducting film into a spiral, or other tortuous path, using such tools as electron beams or diamond cutting wheels and the like. Lead wires are then attached to the resistor which is finally encased in a jacket of resin. A significant disadvantage that can arise in such resistors is a difficulty in obtaining a suitably small, but mechanically strong and electrically satisfactory, connection of the lead wire to the resistor. Commonly, metallic caps are fitted over the ends of the resistors by a cement or frit, and lead wires are welded or soldered to the caps. A silver loaded epoxy resin cement is then utilized to obtain the necessary electrical connection between the metallic cap and the deposited conducting material. However, the electrical bond has proved to be noisy due to corrosion of the silver particles and other causes.

The present invention overcomes that disadvantage by providing a resistor wherein the lead wire is bonded to the ceramic core body with a mechanically strong connection and a separate, suitable electrical connection can then be employed between the lead wire and the resistive film. In addition, the present invention provides a commercially feasible method of joining the lead wire to the ceramic core, involving a thermo-compression bond of a metallic tab to the ceramic core and a conventional weld or other attachment securing the lead wire to the metallic tab. While thermo-compression bonds between metals and ceramics are not broadly new, the present invention provides a novel process whereby the bond can be effected very rapidly at readily obtainable temperature and pressures in an ambient atmosphere, whereas the prior art methods have required a longer period of time and a special, non-oxygen or inert atmosphere in which to carry out similar processes.

Accordingly, it is an object of the present invention to provide a ceramic core resistor with an improved mechanical connection between the lead wires and the resistor body.

It is another object of the present invention to provide a ceramic core resistor wherein an electrically quiet connection is made between the lead wires and the resistor element.

It is another object of the present invention to provide a ceramic core resistor with a connection between the lead wire and the resistor which is as mechanically strong as a lead wire itself.

It is another object of the present invention to provide a ceramic core resistor wherein the lead wire is anchored to the ceramic core by a weld and is connected electrically to the resistor element by a thin conducting overlay.

It is another object of the present invention to provide a method for mounting lead wires to a ceramic core of a resistor.

It is another object of the present invention to provide a commercially feasible method for bonding metallic tabs directly to the ceramic core of a resistor.

It is another object of the present invention to provide a commercially feasible method of achieving a thermo-compression bond of a metallic tab to a ceramic core in ambient air.

The foregoing and other objects will appear from the description to follow. In the description, reference is made to the accompanying drawings which form a part hereof and in which there is shown by way of illustration a specific embodiment in which this invention may be practiced. This embodiment will be described in sufficient detail to enable those skilled in the art to practice this invention, but it is to be understood that other embodiments of the invention may be used and that structural changes may be made in the embodiment described without departing from the scope of the invention. Consequently, the following detailed description is not to be taken in a limiting sense; instead, the scope of the present invention is best defined by the appended claims.

In the drawings:

FIG. 1 is a side view partly in section of apparatus used to carry out a method of the present invention,

FIG. 2 is a view in perspective of a ceramic core of a resistor of the present invention,

FIG. 3 is a view in section of a ceramic core of the resistor of the present invention with a conductive film deposited thereon,

FIG. 4 is a side view of a ceramic core coated with a deposition of conductive material with tabs and discs aligned at the ends preparatory to carrying out the process of the present invention,

FIG. 5 is a side view partially in section of the coated core showing the tabs and discs bonded to the ends of the core body, a thin conducting film over the ends, and lead wires positioned for connection to the discs,

FIG. 6 shows the components of FIG. 5 with the lead wires welded to the discs, and

FIG. 7 shows a completed resistor in perspective partly in section illustrating the electrical connection of a lead wire to the resistor element.

Referring now to the drawings, there is shown in FIG. 2 a ceramic core **1** that forms the structural body of the resistor of the invention. The ceramic core may be a common alkaline earth oxide ceramic as well as glass and other commonly used ceramic components, however, alumina, which is approximately 96% aluminum oxide, is decidedly preferable. Not only does alumina most readily form a thermo-compression bond, but it has extraordinary compression strength permitting the use of high pressures.

The alumina core material **1** is coated with a deposited electrically conducting film **2**. Any of the metal films used in precision resistors are applicable, and a chromium-

cobalt mixture has been found highly satisfactory, both in its electrical and physical characteristics. Such film can be applied by vapor deposition or sputtering techniques, and various other processes are also available for depositing the conductive film 2 on the ceramic core 1. Usually, the material for the film is applied from a point source, or a set location, and the ceramic core 1 is rotated to have the film 2 confined to the cylindrical surfaces with the end surfaces of the ceramic core 1 free of deposition, as shown in FIG. 3. The coated core is designated in the drawings by the numeral 4. It is important that the surface of the ceramic core 1 be clean before deposition, but no special atmospheres or treatments are required to achieve the necessary degree of cleanliness.

After the conducting film 2 has been deposited on the ceramic core 1, the next step is to bond a metallic tab 3 to the ends of the ceramic core 1. The tabs 3 are shown in FIG. 4 as each being comprised of a separate aluminum foil 5 placed opposite an end of the coated ceramic core 4, and an outer disc 6 of a metal such as the iron-cobalt-nickel alloy sold under the name of "Kovar." Alumnium is the only metal presently known that will satisfactorily perform the function of strongly adhering to the core 1 and for good results the aluminum can be in the form of a thin foil about .004 inch thick. "Kovar" has been found to be a very satisfactory and convenient metal to use for the discs 6, but other alloys and metals known to the art may also be used. The characteristics required of the discs 6 are that they be of a hard metal to which lead wires may be welded easily, and have coefficients of expansion and contraction compatible with the material of the core 1, so that temperature variations will not set up deleterious stresses in the bond. The glass sealing metal alloys having the desired thermal expansion characteristics can, in general, be used for the purpose. Finally, it is worthy of note that although FIG. 4 shows discrete aluminum foil 5 and discs 6, in practice the alloy "Kovar" may be purchased with a film of aluminum already formed on one surface to thereby have unitary tabs 3 before applying them to the coated core 4.

The step of bonding the tabs 3 in place is best illustrated in FIG. 1, where the coated core 4 is seated in a lower die 7 with a tab 3 comprising aluminum foil 5 and metal alloy disc 6 placed on top of the upper end of the coated core 4. In this position the elements are ready for the bonding process. Immediately above the lower die 7 is an upper die 8 which mounts a steel ball 9 with a carbide pressure tip 10 facing the lower die 7. About the upper and lower dies 7 and 8 is a heating coil 11 which is connected by conventional means (not shown) to a heating energy source (not shown). The upper die 8 is supported in a stationary mounting (not shown), and the lower die 7 is mounted in conventional means (not shown) so that it will rise upward toward engagement with the upper die 8.

To achieve the bond of the present invention in a preferred manner, the dies should be heated to about 800° Fahrenheit or higher. The lower die 7 should then be raised upward to contact and heat the tab 3, and then to exert a pressure, of which 110,000 pounds per square inch is typical, upon the tab 3. Such a pressure need be exerted for no more than one second, and a period of one-half to one second has been found to be sufficient. At the end of that time, the pressure may be released, and the coated core 4 removed from the lower die 7 and cooled. The tab 3 is now bonded to the ceramic core 1, and it should be noted that this entire process is carried out in ambient air. No special atmosphere is required.

Since temperature, pressure and time are all interdependent variables, there is no single value for any one of them which alone will achieve a bond. The upward limit of the pressure is established by the compression strength of the ceramic core 1 used, and a lower limit for obtaining a very quick bond is about 100,000 pounds per square inch. It is essential to a proper bond that the aluminum foil 5 not melt and vacate portions or all of the interface between the core 1 and disc 6, but that it be forced to flow under the pressure exerted. The aluminum will be squeezed to a nearly immeasurable thinness, and it will flow out from under the discs 6, as shown in FIGS. 5 and 6. Hence, the temperature at the point of the bond should not exceed the melting point of aluminum, and a die temperature of 1400° has been used with success. Within the range of those variables, it may be said that the higher the temperature and pressure the shorter the length of time required to achieve the bond, and, vice versa, the lower the temperature or pressure or both the longer the time required to achieve a satisfactory bond. A satisfctaory bond may be defined as a bond which is equal in strength to the ceramic core 1. For example, in a ¼ watt resistor having a tab 3 .070 inch in diameter the bond achieved according to the preferred process will withstand about 75 pounds of force, or about 19,500 pounds per square inch. In this example, the ceramic core was .290 inch long, .100 inch in diameter, the "Kovar" disc 6 was .030 inch thick, the aluminum foil 5 was .004 inch thick, the pressure tip 10 was held against the tab 3 for about 3.5 seconds to heat the materials, and a pressure of 110,000 pounds per square inch was applied for less than a second.

The exact nature of the bond thus achieved between the aluminum tab 3 and the ceramic core 1 is not known. The fact that no intermediate adhesives are used, that the aluminum is not permitted to melt, and the extraordinary strength of the bond thus achieved supports an inference that some form of chemical bond is formed between the ceramic and the aluminum. Also, although it is not known why, only aluminum will form this bond under the conditions of the present process, and it is believed that this is due in some way to the peculiarity of the thin oxide layer formed upon the metallic aluminum. It is believed that this oxide layer is of such quality that it is readily penetrated exposing the aluminum molecules for interaction with the ceramic core 1.

After the tabs 3, made up of the aluminum foil 5 and the metallic alloy discs 6, have been bonded to the ends of the ceramic core 1, a thin conductive coating 14 is applied to each end of the unit, as shown in FIG. 5, to obtain a good electrical connection between the resistive film 2 and the tabs 3. This coating 14 can be a silver paste, or a metal film applied by electroless plating or other satisfactory plating process, with copper, nickel and gold being examples of applicable metals. This electrical connection will be quiet, and it does not contribute to mechanical strength, nor is it subject to physical flexure. Next, lead wires 12 are attached to the tabs 3. It is preferable to weld the lead wires 12 to the tabs 3 by conventional means, such as percussion welding, and when this has been completed, the product is in the form illustrated in FIG. 6. Copper leads, or of other metals commonly used as lead wires, can be attached in this manner, and the union can be stronger than the wire itself. For example, in actual test an attached copper lead wire was placed under a pull, and ruptured at a point remote from the connection with the tab 3. Next, the conducting film 2 is formed, by means of diamond wheels, electron beam devices, or similar tools, into a helical path, by cutting a spiral groove 13 in the film 2 as shown in FIG. 7. In this manner the desired value of electrical resistance is achieved, and the resistor is carefully calibrated as the groove 13 is cut. Finally, to complete the resistor, the coated core 4 with the lead wires 12 mounted thereon is encased in a conventional manner, as by potting in a non-conducting resinous material 15, leaving the ends of the lead wires 12 protruding for connection into an electrical circuit.

As is evident now from the foregoing description of the present invention, the mechanical stresses applied to the lead wires 12 are transmitted directly through the lead wire tabs 3 to the ceramic core 1, and do not interfere

in any way with the electrical connections between the lead wires **12** and the resistive conducting film **2**. The electrical connection between the lead wires **12** and the resistive conducting film **2** is entirely independent of the mechanical mounting of the lead wires, and hence the material with the best electrical characteristics may be used to achieve that connection, without regard to the mechanical characteristics of the connection thus made. By this means, resistors made according to the present invention overcome a primary disadvantage of prior art resistors.

I claim:

In a ceramic core electrical resistor the combination comprising:

a non-conducting core comprised of alumina with opposite ends for attachment of lead wires;

a resistive conducting film deposited on said core between said core ends;

a lead wire tab attached to each end of said core that is formed of a hard, weldable metal disc having a coefficient of expansion compatible with that of said core, and a thin layer of aluminum interposed between the metal disc and the core end that unites the tab to the core with an unfused, thermal, compression bond between the aluminum and alumina;

a lead wire welded to each hard metal disc that is of a diameter smaller than the surface area of said disc to which the lead wire is attached; and

an electrically conducting path connecting each lead wire with said resistive conducting film.

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