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E. R. STOEKLE ET AL

2,188,667

RESISTOR AND METHOD OF MAKING THE SAME

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FIG. 1.

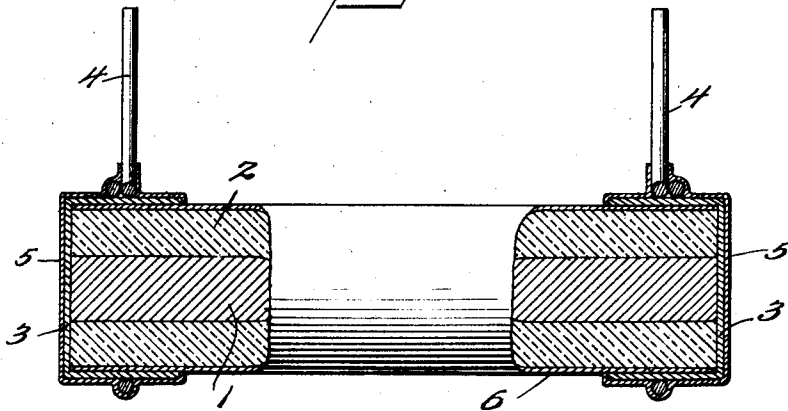


FIG. 2.

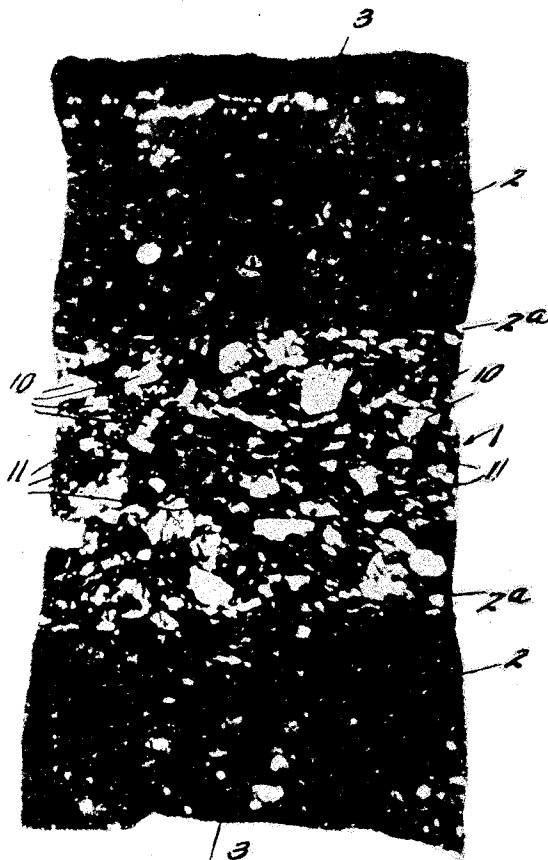
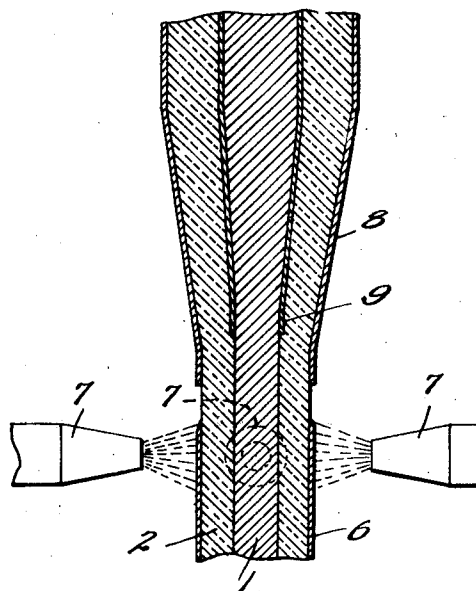


FIG. 3.



Inventors

Erwin R. Stoekle

George M. Ehlers,

By *Robert H. Hudnall, Jr.*
William W. Michener Attorney

UNITED STATES PATENT OFFICE

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RESISTOR AND METHOD OF MAKING
THE SAME

Erwin R. Stockle and George M. Ehlers, Milwaukee, Wis., assignors, by mesne assignments, to Globe-Union Inc., Milwaukee, Wis., a corporation of Delaware

Application January 8, 1935, Serial No. 890

6 Claims. (Cl. 201-76)

This invention relates to improvements in electrical resistors of the so-called ceramic composition type, in which an electrically conducting material is incorporated with an insulating ceramic material to make resistors of any desired resistance value.

Our present invention is particularly applicable to fixed resistors of the character disclosed in the co-pending applications of one of the applicants hereof, George M. Ehlers, Serial No. 700,872, filed December 4, 1933, now Patent No. 2,084,840, granted June 22, 1937; and Serial No. 746,840, filed October 1, 1934, the latter being a division of the former and covering the extruding method of and apparatus for making such resistors.

We have found that the usual method of incorporating conducting material in the composition comprising the resistance in the form of finely ground particles, does not give as satisfactory characteristics with respect to its so-called voltage co-efficient or change of resistance with voltage, as does the resistor of our present invention. We have also found that the minute changes of resistance when the resistor carries currents which evidence themselves as noises in the speaker of a radio receiver in which the resistance is used, have been substantially decreased in our improved form of resistor. The noise so originating is referred to in the art as the noise characteristic of the resistor.

The composition resistors heretofore used vary in their so-called voltage co-efficient and noise characteristic a great deal, depending on how finely divided and how stably held is the electrically conducting material incorporated in the composition of the resistance. In the resistors of the Ehlers applications, aforesaid, the conducting material is very firmly and stably held in a vitrified ceramic core enclosed in and surrounded by a ceramic jacket. In addition to firmly fixing the conducting material in the ceramic core, our experiments have shown that further improvements can be made in the noise characteristic of these composition resistors by the method of incorporating the conducting material into the composition which is the subject of our present invention.

Resistors manufactured prior to our present invention are composed of conducting particles separated by insulating particles, the high value of the resistance resulting to a large extent from the contact resistance between adjacent contacting particles. Since such contacting conducting particles, especially when of carbon, have the

characteristics of a microphonic contact, conditions are favorable for creating variations in the contact resistance of such microphonic contacts which we believe is a principal source of the unfavorable noise characteristics of most composition resistors as heretofore placed on the market.

This thought is further confirmed by the fact that in the resistors heretofore available, the noise characteristics become progressively worse as the resistances increase. This is to be expected, since most of the resistance in existing resistors of high value comprises contact resistance between adjacent particles. The resistors of our present invention and their method of manufacture are new and substantial departures from the previous composition resistors and their methods of manufacture, having reference here to resistors in which the contacting particles are embedded in an insulating matrix. Our new resistor provides a continuous, but tortuous conducting path for the electric current through the resistor instead of permitting the current to pass from conducting particle to conducting particle as in the previous forms. In the Ehlers applications aforesaid, it is pointed out that his resistance core includes a relatively coarse grained refractory material and a fine grained plastic material to cement the coarse grained particles together. The cementing together of these coarse grained particles is accomplished when the vitrifying temperature causes the fine grained ceramic to flux. After firing, the core of the Ehlers resistors comprises a porous mass, the pores appearing between the coarse grains of the refractory ceramic and being filled with finely powdered carbon or graphite, held there under compression by the shrinking of the ceramic during firing and the cooling after firing. This firm holding of the carbon particles in the Ehlers core makes this resistor a relatively stable and quiet one. We have, however, found by experiments that improvements in quietness and other characteristics of this type of resistor may be accomplished by introducing the carbon conducting material in a different form, which we believe substantially eliminates contact resistance between particles of the carbon.

It is obvious that in order to get a continuous path for the electrical current between the terminals of the Ehlers resistors, adjacent pores in the porous core of the resistor must communicate with one another. Now if in this porous core structure and in the communicating passages between the pores, there could be deposited a continuous electrical conducting medium

or the walls of the pores and passages coated with a continuous conducting medium, we would have the desired continuous resistance path free from all contact resistance such as might give rise to microphonic noises.

We have found an excellent method of accomplishing this result by introducing into the core, carbon as a conducting material in the form of a hydrocarbon, such as pitch, resin, or similar material carbonizable at high temperatures. This carbonizable material is ground with the finer ceramic of the core to practically colloidal fineness, and it is then intimately mixed with the coarser refractory material composing the core. The core and the jacket materials, in accordance with the method disclosed in the Ehlers applications, are simultaneously extruded from a forming die into the form of rods with the core material enclosed by the jacket material. Up to this point in the process the hydrocarbon which later yields carbon is not an electrical conductor.

The dried rods, in accordance with our invention, are first subjected to a temperature of 300 to 700 degrees Fahrenheit, depending upon the desired resistance value of the finished resistor. Careful regulation of this first temperature governs the resistance of the finished resistor over a wide range of resistance and furnishes an excellent control over the resistance of the finished product. This first temperature treatment governs the distribution of the hydrocarbon in the core, since the pitch used melts and reaches various degrees of fluidity in this temperature range, and also certain of the more volatile constituents thereby pass off in vapor. The carbon is thus dispersed throughout the communicating interstices of the core in a nascent state and it is maintained in such dispersion by the fusion of the plastic ceramic. The carbon is in a nascent state in the sense that it is converted while in the mixture from a hydrocarbon such as resin, pitch, or the equivalent thereof, into carbon and its dispersion is a combined result of the initial grinding and mixing of the ceramic and hydrocarbon, the presence of the coarser grained refractory, and the subsequent melting and conversion of the hydrocarbon. The resistance rod is then brought to the fusion temperature of its glazed coating and to the vitrifying temperature of its ceramic jacket, which seals the core from ambient gases. At this temperature, which is about 2300 degrees Fahrenheit, the hydrocarbon remaining in the core is completely carbonized depositing its carbon in the cavities or interstices of the core and their connecting passages. Thus a continuous, electrically conducting path of hard carbon is formed throughout the length of the core, resulting from the cracking and carbonization of the hydrocarbons present. The deposited carbon does not depend on contact resistance between adjacent particles and a conducting path free of objectionable microphonic noises is obtained.

One form of resistor made in accordance with our invention is shown in the accompanying drawing, in which:

Figure 1 is a perspective view partly in section, of a finished resistor;

Fig. 2 is a fragmentary longitudinal sectional view taken through one end of the resistor to show its internal structure on a greatly magnified or enlarged scale, the showing following that as depicted in a micro-photograph of a similar

section of a finished resistor made in accordance with our invention; and

Fig. 3 shows the extruding method and die for making the resistor.

As shown in the drawing, the resistor is in rod-like form, comprising a core 1 and a surrounding ceramic jacket 2. The core and the jacket are co-extensive in length and terminals 3, 3 of electrically conducting material are applied to the ends of the jacket and in electrical contact with the ends of the core. These terminals may be in the form of metal caps, sprayed on the ends of the resistor, and lead wires 4, 4 for connecting the resistor in an electrical circuit may be soldered to the caps, as in the Ehlers applications. The solder coatings on the caps for securing the lead wires thereto are indicated at 5, 5.

In extruding the resistor from a forming die, as shown in Fig. 3, the core material is surrounded by the jacket material. The rod as it leaves the die is coated on its outer side with a coating of enamel frit, marked 6 in Fig. 3. The nozzles for applying this coating are marked 7, 7. The concentric nozzles of the die are marked 8, 9. The core and the jacket materials are simultaneously extruded from the nozzles, the core material from the inner nozzle and the jacket material from the outer nozzle. The extruded rods are cut to the desired lengths and thereupon dried and fired as heretofore described.

Fig. 2 shows the core structure on a very much enlarged scale. The figure follows the showing in a micro-photograph of a longitudinal section through one end of a finished resistor constructed in accordance with our invention. The metal terminal sprayed on the end of the resistor is shown at 3. The ceramic jacket surrounding and protecting the core is shown at 2, and the approximate boundary line between the core and the jacket is shown at 2a. The ceramic material of the jacket is vitrified into an integral mass in the firing of the resistor and this mass is integrally connected with the fusible ceramic particles in the core mixture to connect the jacket and the core together. The irregularly shaped coarse particles 10 of the core are the insulating refractory distributed through the core. The larger particles are fused together by the fine ceramic fluxing material with which the carbon is mixed. The carbon, indicated at 11 in Fig. 2, is deposited in the spaces or interstices and their connecting passages between and about the coarse particles 10 and provides a continuous, but tortuous path for the electric current through the core. This current enters the core from the metal terminal 3. The current follows a tortuous path around the coarse particles 10 of insulating material. The various passages between the insulating particles shown in Fig. 2 are magnified about 135 times. They are only a few thousandths of an inch wide in the actual specimen. These minute passages form a continuous tortuous path for the current. The higher the proportion of coarse refractory incorporated in the core, the smaller will become the passages between adjacent particles, and therefore the higher will become the resistance of the core. The carbon 11 is deposited in these passages in the process of making the resistor as heretofore described. The period of time for each heating to which the extruded rods are subjected is such as to give the results herein described.

Another consideration of particular importance

with respect to our invention is the ability to adjust such of the finished resistors as happened to fall above the required resistance range. This is accomplished by heating the completely fired resistor in vacuo to a sufficient temperature to expel all the air from the pores in the core. As previously described the finished resistors after vitrification have an impervious ceramic jacket. However, the ends of the core of the resistor are not covered by the jacket but are covered by the metal caps which are sprayed on the ends of the resistor. The portions of these metal caps which overlie the ends of the core are sufficiently porous to allow the vacuum and temperature just referred to to operate throughout the core. The resistors so treated are then immersed in a liquid hydrocarbon or other carbonizable compound, which is drawn into the pores of the core through the portions of the sprayed metal end plates which overlie the ends of the core and which may be then carbonized by heating the resistor to the required temperature which will lower its value.

It is to be understood that other electrical conducting materials may be used, such as silicon or metals which may be introduced during the mixing of the core material in the form of compounds which are thermo-chemically converted into their component metals during the firing of the resistor.

When desired, the electrical characteristics of our resistor such as temperature co-efficient of resistance, may be modified by including in the ceramic mixture for the conducting path, two elements such as carbon and a metal, each derivable from the thermo-decomposition of a suitable compound or from a thermo-chemical interaction of two compounds such as a metallic compound and a carbon yielding compound.

It is to be understood, that the details herein described with respect to the method and the resistor may be variously changed and modified without departing from the spirit and scope of our invention except as pointed out in the annexed claims.

We claim as our invention:

1. The method of making an electrical resistor which comprises mixing with a fine grained plastic ceramic a portion of a compound convertible by heat into an electrical conductor, adding to said mixture a coarse grained refractory ceramic, mixing the whole into a uniform plastic mass, extruding said mass into rods, drying said rods and firing them at the maturing temperature of said ceramic mixture.

2. The method of making an electrical resistor which comprises mixing with a fine grained plastic ceramic a carbonizable compound, adding to said mixture a relatively coarse grained refractory, intimately mixing the same to form a plas-

tic ceramic mixture, extruding said mixture into rods, drying said rods, and firing them at the maturing temperature of said ceramic mixture during which firing said carbonizable compound is decomposed to form a multiplicity of minute conducting paths of carbon between the grains of said coarse grained refractory.

3. The method of manufacturing an electrical resistor characterized by forming a core of ceramic material in which is included a compound thermally convertible into an electrical conductor, surrounding said core with a protective insulating ceramic jacket simultaneously formed with said core, and firing the formed and dried resistor into a strong integral unit whereby the conductor yielding compound is retained in said core to form conducting paths therethrough and both compound and conductor are protected from the deleterious effects of ambient gases during the firing process.

4. The hereindescribed method of making an electrical resistor comprising grinding to approximately colloidal fineness a fine grained plastic ceramic and an initially non-conductive hydrocarbon, intimately mixing therewith a coarser grained refractory material, heating the resulting mixture to disperse the hydrocarbon and convert it into carbon and fix the value of the resistance and then rapidly raising the temperature of the material to the vitrifying point of the ceramic.

5. The hereindescribed method of making an electrical resistor comprising grinding to approximately colloidal fineness a fine grained plastic ceramic and an initially non-conductive hydrocarbon, intimately mixing therewith a coarser grained refractory, extruding the resulting mixture and an insulating ceramic into rods with the mixture the core and the ceramic the jacket of the rods, drying the rods, heating the rods up to a temperature to melt and distribute the hydrocarbon, convert it into carbon and fix the value of the resistance thereof, and then subjecting the rods to a vitrifying temperature.

6. The method of controlling the desired resistance value of ceramic resistors including a thermally convertible conductor yielding compound, which consists in first heating the resistor for a controlled period of time at a temperature below the vitrifying temperature of the ceramic, in order to distribute and volatilize off the desired amount of conductor yielding compound, then rapidly raising the temperature to the vitrifying point of the ceramic whereby the remaining contained conductor yielding compound is sealed within said resistor and is thermally converted into electrically conducting material within the body of the resistor.

ERWIN R. STOEKLE.
GEORGE M. EHLERS.