Oct. 17, 1939. G. F. BENKELMAN 2,176,604

RESISTOR UNIT AND METHOD FOR MAKING SAME

Filed May 19, 1937

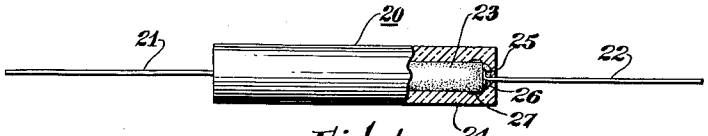


Fig. 1.

Fig. 2.

Fig. 3.

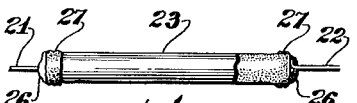


Fig. 4.

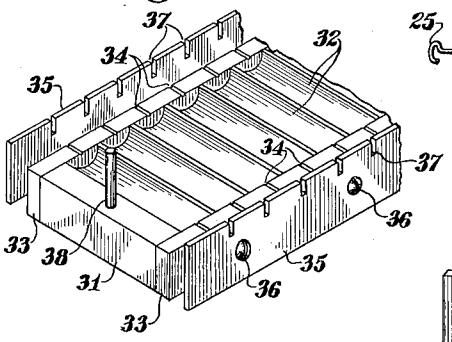


Fig. 6.

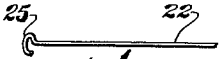


Fig. 5.

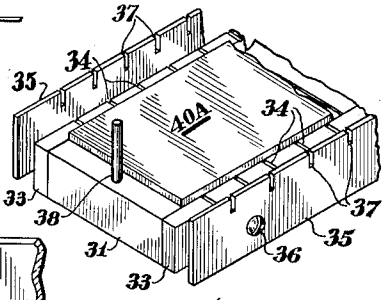


Fig. 8.

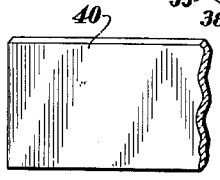
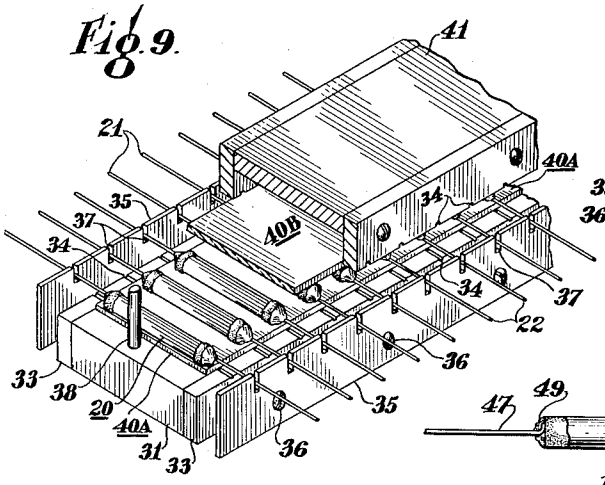
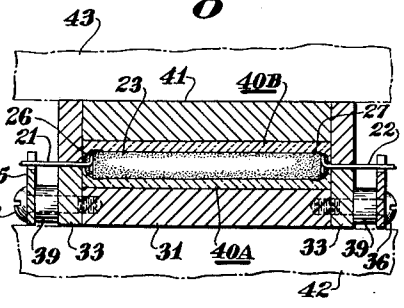


Fig. 7.

Fig. 10.

Fig. 9.





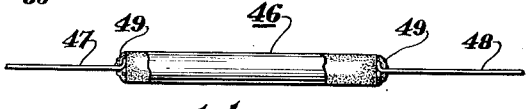


Fig. 11.

INVENTOR.
GLEN F. BENKELMAN.

BY Woodling and Krost.
ATTORNEY.

Patented Oct. 17, 1939 2,176,604

UNITED STATES PATENT OFFICE

2,176,604

RESISTOR UNIT AND METHOD FOR MAKING SAME

Glen F. Benkelman, Cleveland, Ohio

Application May 19, 1937, Serial No. 143,449

7 Claims. (Cl. 201—64)

My invention relates in general to resistor units for electrical circuits, and more particularly to resistor units having terminal conductors mechanically and electrically connected thereto, and the method of making same.

Resistor units of the type herein described may comprise a resistance element of any suitable electrical characteristic having terminal conductors connected to each end thereof. Heretofore in such resistor units, the most difficult part of manufacture has been to electrically and mechanically connect the terminals conductors to the ends of the resistance element, and produce a good strong mechanical connection with a substantially constant fixed minimum resistance. It is found that if the mechanical and electrical connections were not properly made, the contact resistance between the resistance element and the terminal conductors would be relatively high and give poor operating results. Moreover, a faulty connection would cause the contact resistance to fluctuate, and when connected in electrical circuits of sound communicating systems, would give rise to noises or other disturbances in the equipment.

Therefore, an object of my invention is the provision of an improved electrical and mechanical connection between the terminal conductor and the end of a resistance element.

Another object of my invention is the provision of a resistor unit having an excellent connection between the terminal conductor and the resistance element with a substantially constant and fixed minimum resistance.

A still further object of my invention is to so connect the terminal conductors to the lateral end surfaces of the resistance element that substantially 100% of the over-all length of the resistance element serves as an effective resistance material.

Another object of my invention is the provision of a mechanical and electrical connection between the terminal conductor and the resistance element which maintains its resistance substantially constant throughout a relatively long period of use.

Another object of my invention is the provision of cementing terminal conductors to the lateral end surfaces of the resistance element, which gives excellent electrical connections of a substantially constant and fixed minimum resistance, but provides relatively weak mechanical connections, and of completely encasing the electrical resistance element and the said connections by a solid electrical insulating material to prevent short circuits to the resistance element from outside sources and to give good strong mechnical connections to re-inforce the relatively weak cement mechanical connections between the terminal conductors and the resistance element.

Another object of my invention is to connect and support the terminal conductors to the laterally disposed end surfaces of the resistance element, so as to utilize substantially 100% of the over-all length of the resistance element as an effective resistor.

Another object of my invention is to provide for encasing the resistance element and the connections between the terminal conductors and the resistance element with very little material wasted.

Another object of my invention is the improved method of molding an insulating casing completely around the resistance element and the said connections.

Another object of my invention is the provision of a resistor unit which maintains its electrical characteristic substantially constant and which thereby eliminates disturbances and noises in electrical communicating systems.

Other objects and a fuller understanding of my invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawing, in which like parts are designated by like reference characters, and in which:

Figure 1 illustrates a resistor unit made in accordance with the provisions of my invention, a portion of the casing of the resistor unit being cut away at one end to show its internal construction;

Figure 2 illustrates a resistance element of my resistor unit;

Figure 3 shows the ends of my resistance element coated with a material of a higher conductivity than the conductivity of the resistance element;

Figure 4 shows my resistance element having the terminal conductors cemented to the lateral end surfaces thereof by a suitable cementing material of a higher conductivity than the conductivity of the resistance element;

Figure 5 shows a terminal conductor which may be abutted against the lateral end surfaces of the resistance element;

Figure 6 shows a fragmentary and perspective view of the lower half of a mold for molding an electrical insulating casing around the resistance element and the connections between the terminal

conductors and the ends of the resistance element;

Figure 7 shows a fragmentary view of a strip of insulating coating material used in the mold;

Figure 8 is a fragmentary and perspective view of the lower half of the mold with a strip of the insulating coating material arranged on top of the cavities thereof;

Figure 9 shows a fragmentary and an assembly view prior to pressing the lower half and upper half of the molds together, with the resistance elements sandwiched between the strips of insulating material;

Figure 10 is a cross-sectional view taken transversely through the molds, and illustrating the position of one of the molded resistor units; and

Figure 11 illustrates a modified arrangement of my resistance element.

With reference to Figure 1 of the drawing, my resistor unit is indicated generally by the reference character 20 and comprises a resistance element 23, terminal conductors 21 and 22 connected to the opposite lateral end surfaces 28 of the resistance element 23, and an insulating casing 24 which completely surrounds the resistance element 23 and the connections of the terminal conductors.

The resistance element 23 may be of any desired shape and size and may comprise any suitable material having the desirable characteristics. In one form of my invention, the resistance element may comprise a small rod of porcelain or glass having a film of conducting material like graphite, colloidal graphite, or amorphous carbon deposited thereon. In another form, the resistance element 23 may comprise any suitable conducting material mixed with a fine insulating filler like silica and a cementing bond to form a homogeneous structure. The resistance values of the resistance elements may vary in the order of $\frac{1}{10}$ ohm to 1000 megohms, carrying relatively small currents of 1000 milliamperes or less. In all cases of high resistance elements, the most difficult part of manufacture is to make the proper electrical and mechanical contact between the resistance elements and the terminal conductors or the lead-off wires. As previously pointed out, if the mechanical and electrical connections are not properly made, the contact resistance between the resistance elements and the terminal conductors is relatively high and gives poor operating results. Moreover faulty connections cause the contact resistance to fluctuate and when connected in electrical circuit of sound communicating systems gives rise to noises or other disturbances in the equipment. With my invention I have succeeded in making a nearly perfect contact which gives a substantially constant and fixed minimum resistance and remains stable throughout a relatively long period of use.

I will describe my invention by utilizing a resistance element 23 comprising a homogeneous structure molded into rods as illustrated in the drawing. But it is understood that other shapes may be formed and that the resistance element 23 may comprise a film of conducting material like graphite, colloidal graphite, or amorphous carbon deposited on a small rod of porcelain or glass.

The first step in constructing the preferred form of my resistor unit is to mold a resistance rod or element 23 of conducting material, as amorphous carbon, mixed with a fine insulating filler like silica and a cementing bond into a homogeneous structure. The cementing bond may be Bakelite or any other suitable phenol condensation product. In the initial stages this resistance element 23 is in a green state, meaning that the Bakelite or phenol condensation product bond of the resistance element has not set, or in other words has not been polymerized.

After the molded resistance element 23 has been formed in a green state, its ends are coated or dipped into a mixture having a greater conductivity than that of the resistance element 23. This coating or dip is designated by the reference character 27. The coating or dip mixture may comprise a thin liquid alcohol solution of approximately 50% Bakelite, or phenol compensation product, and approximately 50% graphite. The ends may be covered or dipped to any convenient depth but it is desirable that the depth be not greater than $\frac{1}{16}$th of an inch. This coating or dip 27 is of very low resistance and will short out or make useless any part of the high resistance material to which it is applied in the direction of the current flow.

The dipping or coating the ends of the resistance element 23 in the green state allows the graphite particles in the coating or dipped solution to penetrate the pores of the resistance element 23 and thereby makes a nearly perfect low resistance electrical contact having the qualities of measured low sound level when a current is passed through the resistance element 23. After the resistance element 23 is coated or dipped as indicated at 27 in Figure 3, the unit is heated in the neighborhood of 450° F. to polymerization and then tested to determine its resistance value. The coating or dip 27 provides a perfect contact during the testing of the unit to insure accuracy.

The next step of my invention is illustrated in Fig. 4, and is to mechanically and electrically connect the terminal conductors 21 and 22 to the lateral end surfaces 28 of the resistance element 23. The terminal conductors are bent at one end to form a head 25 of an open structure. The plane of the head 25 is disposed laterally of the general longitudinal length of the terminal conductor and is arranged to abut against the lateral end surfaces 28 of the resistance element 23. The heads 25 may be cemented, as indicated by the reference character 26, to the lateral end surfaces 28 of the resistance element 23 by utilizing a paste consisting of substantially 50% graphite, 50% Bakelite resin or phenol condensation product, and enough alcohol to make the cement paste-like. The heads 25 have an open construction and thereby permits the cement to penetrate through and around the same for sticking the terminal conductors to the end surface 28 with as much mechanical strength as possible. The abutting heads 25 are smaller than the lateral end surfaces 28 of the resistance element 23 so that the cement material overlaps the outer edge of the abutting heads and makes good electrical contact with the outer peripheral edge of the end surfaces 28 of the resistance element 23. The hole in the heads 25 allows the cement material to make a good electrical contact with the central portion of the end surfaces 28 of the resistance element 23. The cement, after the heads 25 are abutted against the ends of the resistance element 23, is fixed by heating the entire combination as shown in Figure 4 to a temperature in the neighborhood of 350° F. which polymerizes or sets the Bakelite or phenol condensation product, but does not oxidize the terminal conductors 21 and 22. After the cement

is fixed the terminal conductors 21 and 22 may stand from 3 to 15 pounds pull or more before the connection is fractured or destroyed. For practical installations, the connection is relatively weak and not acceptable, because it will not stand the pull or strain which may sometimes be exerted thereon during the assembly of the resistance element into an electrical circuit.

The next step in the manufacture of my resistance unit is to completely surround the assembly as shown in Figure 4 by the casing 24. This may be done by employing a mold having transversely disposed cavities into which the assembly shown in Figure 4 may be inserted during the molding operation. A lower half of such a mold is shown in Figure 6 and is indicated generally by the reference character 31, and comprises two longitudinal side members 33 between which is arranged transversely disposed cavities 32 to receive the assembly as shown in Figure 4. In using the mold as shown in Figure 6, a strip of insulating material is first placed on top of the cavities 32, as shown in Fig. 8. The insulating strip may be made of a Bakelite molding compound, or a phenol condensation product consisting of Bakelite resin mixed with wood flour, and a plasticizer. The plasticizer may be any alcohol derivative which will act to dissolve the Bakelite wholly or partially to make the mixture plastic to flow under pressure when cold or warm. The insulating strip is indicated by the reference character 40 in Fig. 7, and may be extruded in ribbon like form equal in width to the lateral dimension of the mold or the length of the cavities of the mold. As shown in Figure 8, the strip of extruded compound being characterized as 40A is layed on the lower half of the mold after which the resistance units as shown in Figure 4 are passed therein, see Fig. 9. To facilitate the mounting of the resistance unit in the mold, I provide guide plates 35 suitably mounted at a short distance from the longitudinal sides 33 of the mold by means of the screws 36 and spacers 39, as shown in Figure 10. The guide plates 35 are provided with longitudinally spaced notches 37 into which the terminal conductor or leads 21 and 22 may be first inserted, so that as the resistance elements are pressed into the lower strip of insulating compound 40A they will be concentrically placed with respect to the cavities 32. In this manner the finished mold is completed the casing 24 is substantially concentric with the resistance element 23. The longitudinal sides 33 of the upper and lower halves of the molds are provided with spaced semi-circular notches 34 to receive the terminal conductors 21 and 22 when the upper and lower half of the mold are completely pressed together. Prior to the positioning of the upper half of the mold 41 upon the lower half of the mold 31 there is positioned a top strip of molding compound characterized as 40B on top of the resistance elements 23. This assembly is shown in Figure 9. The top and bottom molds may be guided accurately together by a guide pin 38, and then placed into a heated press or platens having a lower plate 42 and an upper plate 43 as shown by the dot and dash lines in Figure 10. Under the heated platens 42 and 43, the lower and upper molds 31 and 41 are gradually brought together as the Bakelite compound or phenol condensation product softens under heat. By properly determining the thickness of the extruded insulating strips 40A and 40B, very little material will be forced out as excess between the two lower and upper halves of the molds as they come together, and that which is forced out may fall between the longitudinal sides 33 and the guide plates 35. The guide plates 35 are spaced from the longitudinal sides 33 in order that the excess material may not lodge in the guide notches 37. When the molds under pressure reach a temperature in the neighborhood of 350° to 400° F. the insulating material sets or polymerizes around the resistance element 23 and makes a fixed insulating casing 24. This insulating casing 24 prevents short circuits to the resistance element 23 from outside sources when mounted in electrical circuits. The insulating casing 24 also provides a good strong mechanical connection to re-inforce the relatively weak mechanical connection between the abutting heads 25 and the lateral end surfaces 28 of the resistance element 23. The mechanical connection is strong enough that the terminal conductors or leads themselves will break instead of pulling off the ends of the resistance element 23.

If the coating or dip 27 is kept within 1/16th of an inch, the resulting resistor unit is such that substantially all of the resistance element 23 serves as an effective resistance material.

In Fig. 11, I show a resistance unit where the coating or dip 27 has been dispensed with, because the cement or paste 26 performs the same function as the coating or dip 27, and the graphite particles in the cement paste penetrate the pores of the resistance element and thereby make a nearly perfect low resistance electrical contact. In his arrangement the resistance element 46 is polymerized before the terminal conductors 47 and 48 are pasted thereto by the cement 49. The cement or paste 49 is then fixed by heating as previously described. The unit in Fig. 11 may be provided with a casing 24 in the same manner as that previously described. In this Fig. 11, the resistance element 46 cannot be accurately tested until the terminal conductors 47 and 48 are connected thereto and the paste set. Therefore if variation in the resistance values are too wide, the lower valued resistance elements may be ground to decrease their cross-sectional area to bring their value up to high marginal value within acceptable limits. In this arrangement the 100% of the overall length of the resistance element 23 constitutes an effective resistor.

Although I have described my invention with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. A resistor unit of the character described comprising, in combination, a resistance element having end surfaces transversely disposed relative to the general longitudinal length of said element, a terminal conductor externally connected to and supported by each of said end surfaces, each of said terminal conductors having an abutting head formed at one end thereof by bending the conductor to abut externally against said end surface, cement material for mechanically and electrically connecting the abutting head of each of the terminal conductors to the said end surfaces, said cement material providing an excellent electrical connection of a substantially constant and fixed minimum resistance but providing a relatively weak mechanical connection, said abutting heads

being smaller than the end surfaces and having an open construction to permit cement material to penetrate through and around same for sticking the terminal conductors to the end surfaces, and a coating of solid electrical insulating material completely encasing said resistance element and said abutting heads of the terminal conductors with the free ends of the terminal conductors extending therethrough and forming terminals for external connection, said coating providing an insulating covering to prevent short circuits to the resistance element from outside sources and in addition providing a good strong mechanical connection to re-inforce the relatively weak mechanical connections between the abutting heads and the end surfaces.

2. The method of constructing a resistor unit which comprises the steps of molding in a green state a heat setting phenol condensation product having finely distributed electrical conducting particles into a resistance element having end surfaces, heating the molded resistance element to set and harden same, providing for each said end surface a terminal conductor with an abutting end smaller than the said end surface, providing a heat setting cement of a phenol condensation product having finely distributed electrical conducting particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, and heating the resistance element and the applied cement with the abutting ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element.

3. The method of constructing a resistor unit which comprises the steps of molding in a green state a heat setting phenol condensation product having finely distributed carbon particles into a resistance element having end surfaces, heating the molded resistance element to set and harden same, providing for each said end surface a terminal conductor with an abutting end smaller than the said end surface, providing a heat setting cement of a phenol condensation product having finely distributed carbon particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, and heating the resistance element and the applied cement with the abutting ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element.

4. The method of constructing a resistor unit which comprises the steps of making a carbon resistance element having end surfaces, providing for each said end surface a terminal conductor with an abutting end smaller than the said end surface, providing a heat setting cement having finely distributed electrical conducting particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, and heating the resistance element and the applied cement with the abutting ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element.

5. The method of constructing a resistor unit which comprises the steps of making a carbon resistance element having end surfaces, providing for each said end surface a bendable terminal wire conductor with a deformed abutting end smaller than the said end surface, providing a heat setting cement having finely distributed electrical conducting particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, and heating the resistance element and the applied cement with the abutting ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element.

6. The method of constructing a resistor unit which comprises the steps of molding in a green state a heat setting phenol condensation product having finely distributed electrical conducting particles into a resistance element having end surfaces, heating the molded resistance element to set and harden same, providing for each said end surface a terminal conductor with an abutting end smaller than the said end surface, providing a heat setting cement of a phenol condensation product having finely distributed electrical conducting particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, heating the resistance element and the applied cement with the abutting ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element, and molding an electrical insulating material completely around the resistance element and the cement connections with the free end of the terminal conductors extending through the molded insulating material and forming terminals for external connection.

7. The method of constructing a resistor unit which comprises the steps of making a carbon resistance element having end surfaces, providing for each said end surface a terminal conductor with an abutting end smaller than the said end surface, providing a heat setting cement having finely distributed electrical conducting particles and having a greater electrical conductivity than the resistance element, externally applying the cement to each said end surface and embedding the abutting end of each said terminal conductors in the applied cement to electrically connect the terminal conductors to the end surfaces of the resistance element, heating the resistance element and the applied cement with the abutting

ends of the terminal conductors embedded therein to set and harden the cement to make a mechanical connection between the terminal conductors and the end surfaces of the resistance element, and molding an electrical insulating material completely around the resistance element and the cement connections with the free end of the terminal conductors extending through the molded insulating material and forming terminals for external connection.

GLEN F. BENKELMAN.