May 31, 1949. H. G. THOMSON 2,471,592

METHOD OF MAKING INSULATED RESISTORS

Filed Oct. 4, 1945

3 Sheets-Sheet 1

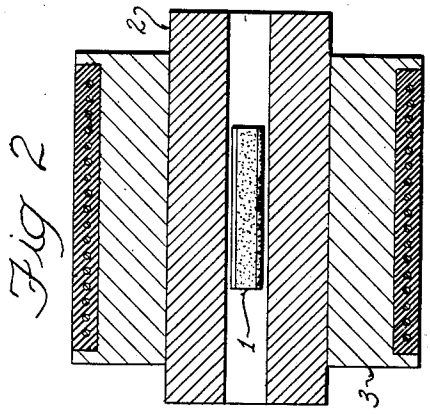


Fig 2

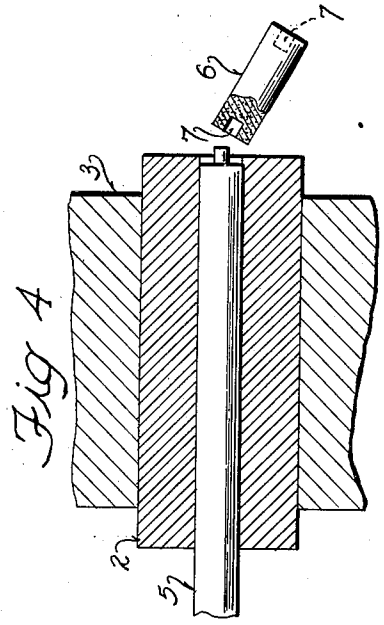


Fig 4



Fig 1

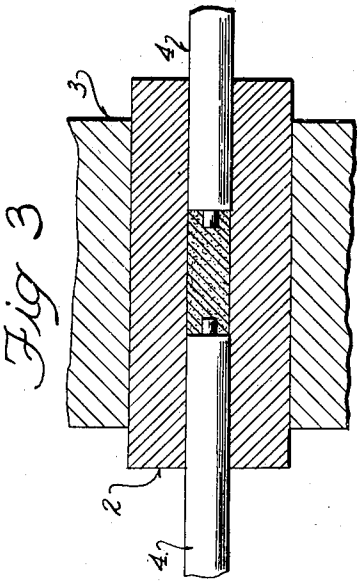


Fig 3

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Fig 8

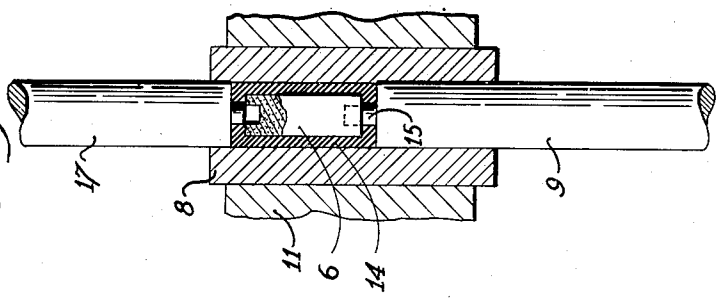


Fig 7

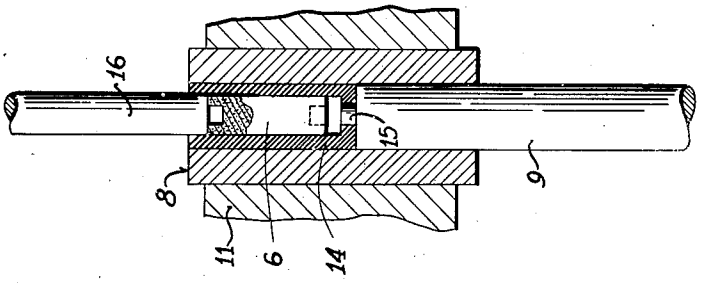


Fig 6

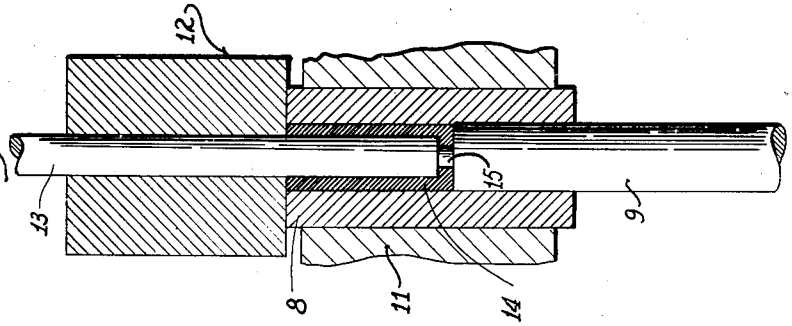
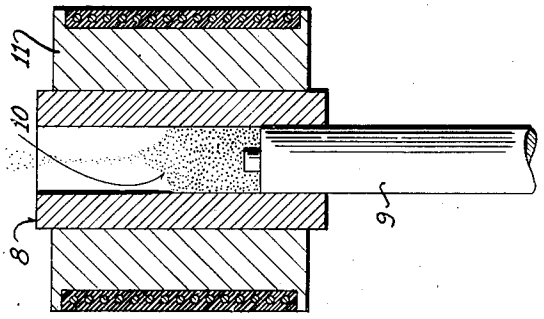


Fig 5



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Fig 11

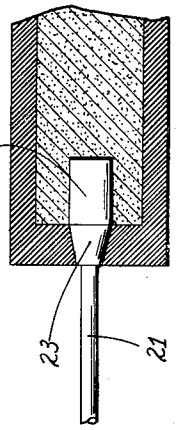


Fig 9

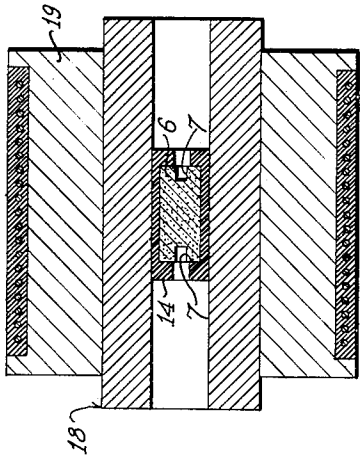
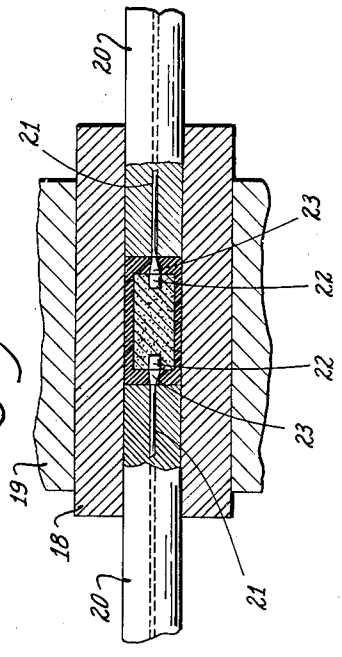


Fig 10



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METHOD OF MAKING INSULATED RESISTORS

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Application October 4, 1945, Serial No. 620,235

5 Claims. (Cl. 18—59)

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This invention relates to an improved method of making electrical resistors of the type employed in electronic control, actuation and communication circuits. The invention from one standpoint resides more specifically in a method in which a pre-bonded core of conductor composition of uniform internal structure is enclosed in a preliminarily formed jacket of insulating material and then terminals are caused to be embedded and the assembly is subjected to treatment to complete the formation of a unitary insulated resistor and in which terminals are employed which are shaped to provide retention surfaces in engagement with insulating jacket material and contact making surfaces engageable with the conductor core the latter surfaces being so shaped as to require a minimum of deformation of the core material during insertion.

Resistors of the type to which this application relates are made up of a conducting core having extremely minute conducting particles such as carbon black particles highly dispersed in a solidified insulating binder. Dependable uniformity in the internal structure of this conducting core is important to economy of manufacture and quality of the resistor. Important properties of the resistor, such as its voltage coefficient, microphonic noise, etc., are also dependent upon a uniform internal structure. In the manufacture of insulated resistors of higher wattage rating and therefore of larger physical dimensions, uniformity of structure in the interior parts of the resistor core has been difficult to attain by methods heretofore in use. Voids, gas pockets, poorly bonded areas, lack of uniformity in structure and density have been encountered in resistors made by previous methods. Through the method of this invention the making of high quality insulated resistors of larger dimension is facilitated.

In accordance with this invention the conductor core composition made up of a binder material with conducting particles dispersed therein is compressed into the desired shape of a resistor core. In so doing the core is operated upon in a manner appropriate to the nature of the binder so as to produce a nearly finished dense uniform molding. Either hot or cold molding procedure may be followed in the case of thermal setting binders in which case the amount of heating is regulated so as to nearly but not quite completely cure the core. In the case of a thermoplastic binder heating or treatment sufficient to produce a high degree of bonding is employed. In this way the core is pre-bonded, brought almost to its final physical dimensions, and curing of the

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core in the case of a thermal setting binder is brought nearly to completion. By so doing the core or conducting part of the resistor is substantially completely formed under conditions which are much more easily controlled to produce uniform interior structure than is the case where both core and insulating jacket are simultaneously formed and treated so as to establish the necessary bond.

The pre-bonded resistor core is preferably formed with terminal receiving sockets into which terminal heads may be ultimately received and surrounded with a minimum of deformation of the pre-bonded core. The pre-bonded core thus formed is then encapsulated within a closely fitting jacket of partially bonded insulating material in a condition much more readily flowable than the pre-bonded core, the jacket having openings therein adjacent the terminal sockets in the core. This assembly is then subjected to pressure and the embedment of terminals in the sockets provided therefor and to treatment to complete the formation of the bond of both jacket and core. In so doing little deformation of the core takes place, since the pre-bonded core has nearly its final shape and is already in a strong nearly completely bonded condition. The final or residual bonding treatment of the core composition, however, results in an intimate and integral bond between it and the insulating jacket material and further causes an intimate embracement of the terminal head by the conducting core by reason of slight but sufficient deformation which takes place in the core material.

In performing the method of this invention it is advantageous to employ metallic terminals having heads shaped so as to closely fit the previously formed sockets in the pre-bonded core but having sloping faces or ledges on the parts thereof which are in engagement with the insulating packet material. These sloping faces or ledges lock the terminal head in place so that it may be withdrawn or broken away from the resistor only with gerat difficulty and only by destruction of the jacket material. The jacket material, being in a much more easily flowable condition at the time of embedment of the terminals, is capable of flowing against and surrounding such sloping faces or ledges of the terminal heads which action the more highly pre-bonded core material would be incapable of performing. As a result, the core is uniform in its internal structure and the finished article is possessed of mechanical and electrical properties of the highest quality.

The method of this invention is herein described in greater detail by reference to one series of steps and one embodiment thereof set forth by way of illustration and not of limitation, the same being described with the aid of the accompanying drawings which form a part hereof.

In the drawings:

Fig. 1 is a perspective view of a loosely compacted fill of powdered conductor core composition at the outset of the molding operation;

Fig. 2 is a side view in section of the core pre-bonding die showing a fill in position therein;

Fig. 3 is a side view in section of the core pre-bonding die showing the pre-bonding plungers acting upon the fill;

Fig. 4 is a side view in section of the core pre-bonding die showing a pre-bonded core being ejected therefrom;

Fig. 5 is a side view in section of a jacket forming die showing jacket forming powder being loaded therein;

Fig. 6 is a side view in section of the jacket forming die showing a tube forming plunger and cap in position after tubular shape has been imparted to the jacket;

Fig. 7 is a side view in section of the jacket forming die showing a pre-bonded core being inserted into a partially formed jacket;

Fig. 8 is a side view in section of the jacket forming die showing the closing of the top of the jacket just prior to ejection of the jacket and core assembly;

Fig. 9 is a side view in section of a final molding die showing a pre-bonded core and jacket assembly in position for the commencement of the final molding step;

Fig. 10 is a side view in section of the final molding die with terminal inserting plungers in position acting upon the core and jacket assembly to perform the final molding operation; and

Fig. 11 is an enlarged detailed view in section of a fragment of the resistor formed by the previous final stage of molding shown in Fig. 10.

As an illustrative instance, in preparing a resistor in accordance with this invention, phenol-aldehyde resin intended to be molded may be mixed with an appropriate proportion of conductor particles such as carbon black and filler material in manner well known in the art and the mixture subjected to milling and heating on rubber milling rolls to disperse the carbon and filler particles in the binder. The material delivered from the milling rolls may then be permitted to harden after which it may be broken up and thoroughly pulverized. This powdered composition may then be divided into quantities of appropriate size and lightly compressed to form a "fill" or slug 1 having substantially the configuration illustrated in Fig. 1.

A cylindrical or tubular die 2 preferably horizontally mounted and provided with heating means 3 is brought to an appropriate molding temperature and a fill 1 is inserted therein as shown in Fig. 2. Thereafter pre-bonding plungers 4 are inserted into the die 2 and very heavy pressure applied to the fill 1 as shown in Fig. 3. During application of molding pressure the temperature of the fill 1 begins to approximate that of the die 2, and this action may be facilitated by pre-heating the plungers 4 before their insertion, to substantially the same temperature as that of the die 2. In this way fill 1 is rapidly brought to a condition of almost complete cure but just prior to the attainment of the completely cured condition plungers 4 are withdrawn and ejecting plunger 5, as appears in Fig. 4, is inserted so as to eject the pre-bonded core which has been formed. As appears in Fig. 4 the pre-bonded core which has been ejected has been given a new designating numeral 6 in recognition of the curing which has occurred in the fill 1 during the treating steps which have been outlined.

The pre-bonded core 6 produced as above described conforms very closely with the shape it is to assume in the final jacketed resistor. In each end of the core there is formed electrode sockets 7 dimensioned so as to receive the end of a nearly cylindrical inner terminal head in close fitting engagement. The pre-bonded core 6 thus made up in advance is adapted to be inserted within a capsule of insulating material.

For the purpose of forming the insulating capsule, an open ended die 8, as shown in Fig. 5, is arranged to be closed by a bottom punch 9. While thus closed, powdered plastic insulating material 10 is added to the die cavity as shown. Die 8 is surrounded by heating means 11 adapted to raise the die 8 to an appropriate temperature from about 325° F. to 375° F.

After a short interval sufficient to raise the temperature of the powdered material 10 to a substantial extent a collar 12 is placed over the upper end of the die 8 and a tube forming plunger 13 forced down through the central opening therein until arrested by engagement with the upper end of the lower punch 9, as more clearly indicated in Fig. 6. By reason of this operation material 10 is caused to flow into the shape of a tube or sleeve 14 closed at its lower end save for a small central opening caused by the upwardly projecting tip 15 on the upper end of the punch 9.

As soon as the sleeve 14 is formed as shown in Fig. 6, a pre-bonded core 6 formed as previously described and closely fitting within the bore in the sleeve 14 is inserted by means of the punch 16 as shown in Fig. 7. Thereafter a top forming punch 17 is caused to act downwardly upon the upper end of sleeve 14 as shown in Fig. 8. The punch 17 acts to inwardly deflect material in the upper end of the sleeve 14 so as to cause the formation of a centrally open closure in the upper end of the sleeve 14. Immediately upon completion of these steps the sleeve and core assembly is ejected. In this way there is formed a capsule of partially condensed insulating material capable of a substantial amount of additional curing and flow enclosing a pre-bonded core requiring only a small amount of further curing. At this stage the parts 6 and 14 are quite independent of one another with no apparent mutual bonding between them, since no appreciable change has been brought about in the pre-bonded core 6 during the steps of enclosing the same within the sleeve 14.

To form the resistor itself the core and sleeve assembly formed as described above is then inserted, as shown in Fig. 9, within an open ended tubular die 18 surrounded by heating means 19 adapted to bring the die 18 to an appropriate final molding temperature of from 450° F. to 500° F. A short interval of time after insertion of the core and sleeve assembly within the die 18 and after the sleeve material has begun to attain a molding temperature, a pair of tubular punches 20—20 carrying headed wire terminals 21—21 within central bores therein, as shown in Fig. 10, are inserted and forced inwardly until the inner cylindrical portions of the terminal heads 22—22 are firmly seated in the sockets 7—7 in the core

body 6. At the the same time the flattened forward faces of the punches 20 upon engagement with sleeve material adjacent the end openings therein causes the sleeve material to flow firmly against the tapering lateral faces 23—23 of the terminal heads which are positioned at the zone where the heads pass outwardly through the sleeve material.

By reason of the temperature maintained in the die 18 and assisted by pre-heating of the punches 20 if desired the material of the sleeve 14 is rapidly advanced or cured, and as the temperature of the same rises, final curing heat becomes imparted to the pre-bonded core 6 also. After application of heat and pressure for a short period the core 6 acquires a sufficient temperature to become finally or completely cured or condensed and this action takes place while the core 6 is in intimate contact with the sleeve material 14 likewise undergoing condensation. As a result the core and sleeve become intimately bonded to such an extent that there is no apparent physical separation or cleavage between the two, even when the finished unit is broken.

As appears more clearly in Fig. 11, the inner ends 22—22 of the heads of the terminals 21—21 are substantially cylindrical. By reason of this shape the portions of the terminals which are embedded in the core 6 may enter the sockets 7 provided therefor without causing any substantial deformation. Furthermore, the amount of deformation of the core 6 required to bring about intimate contact between the terminal heads 22—22 and the core 6 is very minute. Immediately back of the cylindrical portions 22—22 of the heads there is provided as previously explained tapering head portions 23—23 having sloping faces or ledges against which the sleeve material firmly bears thus preventing withdrawal of the terminals 21 from the finished resistor. Herein the sloping faces or ledges of the heads as well as the corresponding meeting faces of the material of the sleeve 14 are sometimes referred to as "retention surfaces" since they are surfaces which act to lock the heads in place. While it is preferred that the end portions 22 be substantially cylindrical so that they may enter the sockets 7 with a close fit and without substantial deformation of the pre-bonded core 6, a small amount of taper in the same direction as that of the retention surfaces 23 such as might be dictated by the requirements of heading machinery used for the formation of the heads of terminals 21 is not objectionable since the core 6 is capable of some deformation sufficient to accommodate a small taper of this nature.

A wide variety of shapes of electrode heads may be employed while at the same time preserving the two important functions detailed above, that is to say, different forms of heads may be used which will enter and be brought in intimate engagement with sockets 7—7 in a pre-bonded core 6 with little or no deformation thereof, and which, nevertheless, will have retaining ledges or retention surfaces engageable during curing by the more flowable sleeve material 14. In this connection square or prismatic heads are regarded as the equivalent of those of circular cross section and inner head portions tapering in the opposite direction from the taper of the retention surfaces the equivalent of those without substantial taper in the direction of the taper of the retention surfaces. Likewise, the taper of the retention surface may be exaggerated to such an extent that it becomes a transverse ledge or shoulder engaged by material of the sleeve 14.

In the case of resistors made from various binders, time schedules for performance of the several process steps will advantageously be varied accordingly. The time schedules also may be appropriately adjusted to accommodate for resistors of various sizes. By way of illustration for a resistor using phenol-aldehyde resin binder for both core and sleeve and having a length of about 11/16 inch and a diameter of about 5/16 inch provided with a core having a length of about 9/16 inch and a diameter of about 7/32 inch and in which terminals are used made from No. 17 wire with heads of an overall length of about 3/16 inch and a maximum diameter of about 3/32 inch the time schedule set forth below is preferred. Those skilled in the art may be guided therefrom in well known fashion in adopting appropriate schedules for other binders and sizes and shapes of resistors. The schedule is as follows:

For formation of the pre-bonded core; die temperature about 450° F.

Process stage:	Time in seconds
Start, fill inserted, (Fig. 2)	0
Application of molding pressure (Fig. 3)	18
Eject (Fig. 4)	22

For formation of insulating sleeve and encapsulation of core; die temperature about 325° F.

Process stage:	Time in seconds
Start, fill introduced (Fig. 5)	0
Tube forming plunger inserted (Fig. 6)	22
Pre-bonded core inserted (Fig. 7)	87
Top formation (Fig. 8)	106
Eject	113

For final molding of resistor; die temperature about 475° F.

Process stage:	Time in seconds
Start, sleeve and core assembly inserted, (Fig. 9)	0
Final molding with insertion of terminals (Fig. 10)	29
Eject	92

The compositions of the jacket and core suitable for use with the above schedule may for example be as follows:

For the jacket.—A phenol-aldehyde composition in the form of a molding resin is placed on heated rubber milling rolls and powdered silica filler mixed therewith during milling. The rolls are preferably maintained at above 225° F. and milling continued until the composition is very stiff and plastic. Resin and filler after mixing are preferably present in the following proportions by weight:

	Per cent
Resin	25
Filler	75

Minor amounts of lubricants such as montan wax, stearic acid, etc., may be included if desired. The material is delivered from the rolls in sheets and after cooling is broken up and pulverized. The powder thus formed is fed in measured amount to the jacket forming die as described.

For the core.—A phenol-aldehyde resin the same as that used for the jacket or similar thereto is applied in like manner to rubber milling rolls maintained above 200° F. and carbon black and filler such as powdered silica added while

milling in the following approximate proportions by weight:

	Per cent
Resin	25
Carbon black	13
Filler	62

Small amounts of lubricants and other ingredients may be included if desired.

When the composition attains a stiff, plastic condition it is rolled into sheets, cooled, broken up and pulverized. The powder thus formed is then compressed in a pill die in appropriate quantity to produce a fill such as is shown in Fig. 1. A composition such as described will be suitable for the formation of resistors of the dimensions given, falling within the resistance ranges most commonly used. For higher or lower resistances the proportion of carbon black may be decreased or increased in a manner well known in the art.

In the embedment of the heads of terminals 21—21, the quantity of jacket material present in relation to the volume of the finished resistor to be produced is preferably so proportioned that the plungers 20 are not arrested in their approach toward one another until the forward ends 22—22 of the terminal heads have been solidly bottomed in the sockets 7 provided therefor in the core 6 and a small but substantial amount of actual upsetting of the heads and flow of the material of the core 6 under the influence of this upsetting pressure has been caused to take place. In this way reliable contact between the heads 22 and the core 6 is ensured.

The residual bonding capability preserved in the core before final molding as previously stated results in the formation of an integral unit without a cleavage surface between the core and the insulating jacket. An important advantage from the standpoint of load rating is obtained from this intimate bonding of core and jacket because the transmission of heat to be released from the interior of the unit is not impeded by a minute cleavage layer which would otherwise be present.

I claim:

1. The method of forming an insulated resistor of the class described which consists in subjecting a pre-determined quantity of plastic binder mixed with conductor particles to sufficient heat and pressure to solidify the same while held within a cavity of predetermined shape adapted to mold the same into the form of a core having electrode sockets therein, forming a tubular capsule having a partially closed end and an open end by subjecting plastic insulating material to heat and pressure while held within a cavity of predetermined shape, then inserting said core within said capsule through the open end thereof, then partially closing said open end of said capsule by application of heat and pressure thereto to form an encapsulated core having openings in said capsule opposite the electrode sockets in said core and then inserting electrode terminal heads through the openings in said capsule into said electrode sockets in said core while subjecting the whole while held within a cavity of predetermined shape to heat and pressure sufficient to cause said core and capsule to flow in the presence of one another into intimate contact with said terminals.

2. The method of forming an insulated resistor of the class described which consists in subjecting a predetermined quantity of partially condensed thermal-setting plastic binder mixed with conductor particles to sufficient heat and pressure to solidify the same while held within a cavity of predetermined shape adapted to mold the same into the form of a nearly condensed core having electrode sockets therein, forming a tubular capsule having a partially closed end and an open end by subjecting thermal-setting plastic insulating material to sufficient heat and pressure to partially cure the same while held within a cavity of predetermined shape, then inserting said core within said capsule through the open end thereof, then partially closing said open end of said capsule by application of heat and pressure thereto to form an encapsulated core having openings in said capsule opposite the electrode sockets in said core and then inserting electrode terminal heads through the openings in said capsule into said electrode sockets in said core while subjecting the whole while held within a cavity of predetermined shape to heat and pressure sufficient to complete the curing of said core and capsule in the presence of one another and to cause the core and capsule to flow against and intimately contact said terminals.

3. The method of forming an insulated resistor of the class described which consists in subjecting a predetermined quantity of plastic binder mixed with conductor particles to sufficient heat and pressure to solidify the same while held within a cavity of predetermined shape adapted to mold the same into the form of a difficulty flowable core having electrode sockets therein of non-diminishing cross section in passing outwardly from within the same, forming a tubular capsule having a partially closed end and an open end by subjecting plastic insulating material to heat and pressure while held within a cavity of predetermined shape, then inserting said core within said capsule through the open end thereof, then partially closing said open end of said capsule by application of heat and pressure thereto to form an encapsulated core having openings in said capsule opposite the electrode sockets in said core, then inserting electrode terminal heads having rearward retention ledge portions and forward portions conforming to said core sockets through the openings in said capsule until said forward portions are seated in said core sockets and said retention ledge portions are within said capsule openings, and then subjecting the whole while held within a cavity of predetermined shape to heat and pressure sufficient to cause said core to flow slightly and said capsule to flow substantially in the presence of one another so as to bond the same to one another and to cause the core and capsule materials to intimately contact said terminal heads.

4. The method of forming an insulated resistor of the class described which consists in subjecting a predetermined quantity of partially condensed thermal-setting phenol-aldehyde plastic binder mixed with conductor particles to sufficient heat and pressure to solidify the same while held within a cavity of predetermined shape adapted to mold the same into the form of a difficulty flowable nearly condensed core having electrode sockets therein of non-diminishing cross section in passing outwardly from within the same, forming a more easily flowable solid tubular capsule having a partially closed end and an open end by subjecting thermal-setting phenol-aldehyde plastic insulating material to sufficient heat and pressure to partially cure the same while held within a cavity of predetermined shape, then inserting said core within said capsule through the open end thereof, then partially closing said open end of said capsule by application of heat and pressure

thereto to form an encapsulated core having openings in said capsule opposite the electrode sockets in said core, then inserting electrode terminal heads having rearward retention ledge portions and forward portions conforming to said core sockets through the openings in said capsule until said forward portions are seated in said core sockets and said retention ledge portions are within said capsule openings, and then subjecting the whole while held within a cavity of predetermined shape to heat and pressure sufficient to cause said core to flow slightly and said capsule to flow substantially in the presence of one another so as to complete the curing of the same and to bond them to one another while flowing into intimate contact said terminal heads.

5. The method of forming an insulated resistor which consists in first forming a nearly completely bonded core of resistor material composed of insulating binder mixed with conducting particles and having electrode sockets therein, then forming a partially bonded capsule of insulating material composed of insulating binder and filler having a partially closed end and an open end, then inserting said core within said capsule through the open end thereof, then causing said

capsule material to flow to partially close said open end to form an encapsulated core having openings in said capsule opposite the electrode sockets in said core, then inserting electrode terminal heads through the openings in said capsule into said electrode sockets in said core while subjecting the whole while held within a cavity of predetermined shape to pressure sufficient to cause said core and capsule to flow in the presence of one another into intimate contact with said terminal heads, and then heating to complete the bonding of said core and capsule.

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