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D. W. LIGHT

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RESIN BONDED ELECTRIC RESISTOR

Filed April 27, 1939

Fig. 1.



Fig. 2.

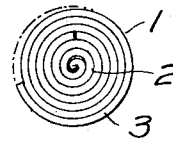


Fig. 3.

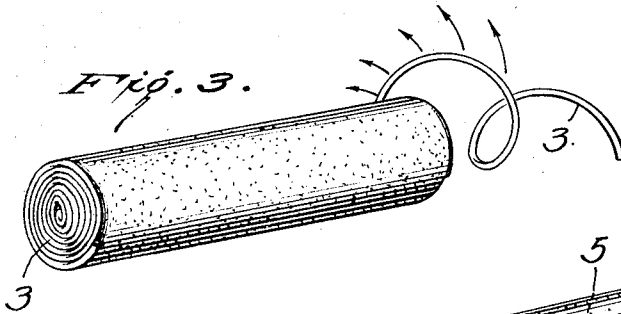


Fig. 4.

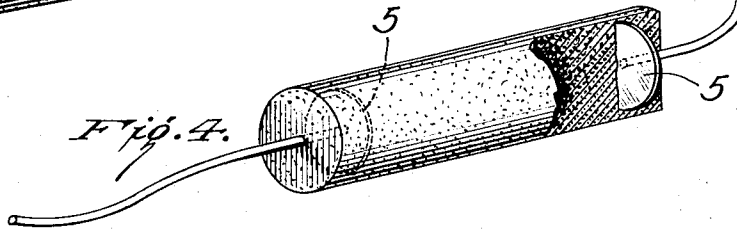
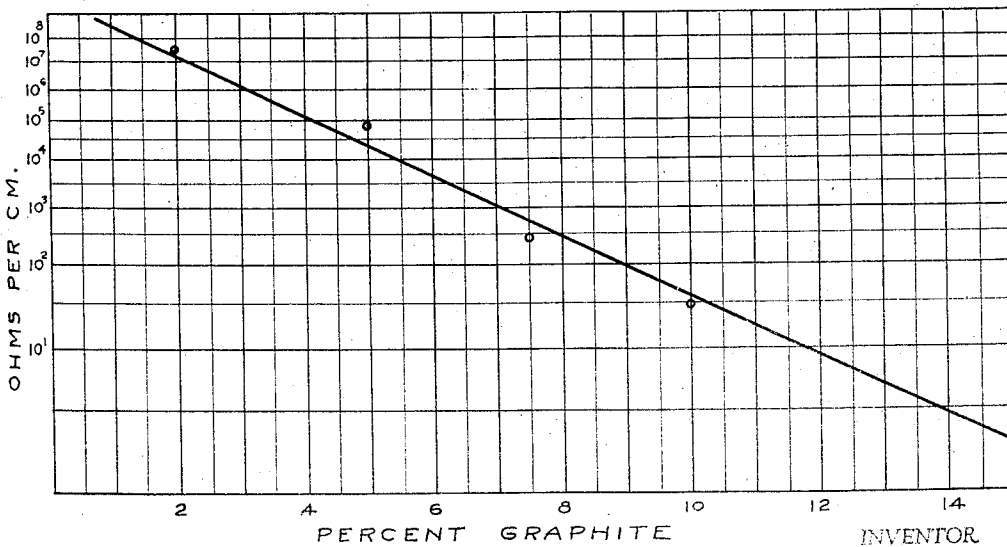


Fig. 5.



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UNITED STATES PATENT OFFICE

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RESIN BONDED ELECTRIC RESISTOR

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5 Claims. (Cl. 201—76)

This invention relates to bonded electric resistors, and more particularly to resistors bonded with a thermosetting binder comprising an improved class of synthetic resins.

Heretofore electric resistors, and particularly resistors of the discharge or rectifying type, have been bonded with ceramic material such as clay. The preparation of a clay bonded resistor has, however, required firing of the articles at relatively high temperatures, which frequently results in an undesirably high proportion of defective pieces.

I have now discovered that resistors having most of the properties of clay bonded articles of this class can be prepared by the use of binders containing aminotriazine-aldehyde resins. Resins of this class possess unusually good heat resistance; so good, in fact, that electric resistors containing them can frequently be used to replace the more expensive clay bonded resistors that have heretofore been used in discharge and rectifying resistors such as lightening arresters and the like. I have found that the resistors of my invention can be prepared by the ordinary molding and curing procedure now employed in preparing molded pieces from thermosetting resins, which permits important savings in their cost of manufacture.

The invention will be described in detail with particular reference to resistors of the discharge or rectifying type, since many of its most important advantages are obtained with this class of resistors. It should be understood, however, that the invention in its broader aspects is not limited to this class of articles, but that some of its advantages may be obtained with other classes of resistors.

The invention will be described in detail with reference to the accompanying drawing in which:

Fig. 1 is a diagrammatic illustration of one method which may be employed in pressure molding copper lead wires into a cylindrical resistor;

Fig. 2 is an end view showing the method of coiling the wire to fit the end of the mold;

Fig. 3 is a perspective of the resistor illustrated diagrammatically in Fig. 1, after molding, showing the uncoiling of one lead wire;

Fig. 4 is a perspective view, with parts broken away, and parts shown in dotted lines, of a second modification of the invention, and

Fig. 5 is a graph showing the effect of changes in carbon content on the resistance at constant voltage.

As indicated above, the essential feature of my invention resides in the discovery of a new class

of thermosetting bonding material which will permit the manufacture of resistors by the molding methods now used for other articles of manufacture. The aminotriazine-aldehyde condensation products may be used for this purpose as the sole bonding material, or in some cases they may be mixed or blended with other resinous materials such as phenol-formaldehyde type resins. Bonded resistors containing aminotriazine-aldehyde resins are extremely heat resistant; the bond does not weaken at the high temperatures generated by heavy loads, but on the contrary the stability of the resistor is actually increased by heating at high temperatures for long periods of time, and this is another important advantage of the invention.

The broad principles of my invention are not limited to any single aminotriazine-aldehyde condensation product, and any resinophoric material of this class may be used if desired. However, the condensation products of melamine and its derivatives such as 2,4,6 triethyl and triphenyl triamino 1,3,5 triazines, 2,4,6 trihydrazino 1,3,5 triazine and the corresponding condensed triazines, such as melam and melem appear at the present time to be of greatest immediate commercial importance, by reason of the availability of melamine and its derivatives from dicyandiamide or cyanuric chloride as raw materials, and for this reason resin bonded resistors containing these classes of materials constitute preferred embodiments of the invention. On the other hand, triazines containing one or two reactive amino groups such as ammeline, ammelide, formoguanamine, 2 amino 1,3,5 triazine and their substitution products as well as nuclear substituted aminotriazines such as 2 chloro 4,6 diamino 1,3,5 triazine, 2 phenyl 4 amino 6 hydroxy 1,3,5 triazine, 6 methyl 2,4 diamino 1,3,5 triazine and the like can be condensed with lower or higher aliphatic, aromatic or heterocyclic aldehydes to produce heat-resistant binders for resistors and such condensation products are therefore included in the invention in its broader aspects.

Any of the foregoing aminotriazines, including melamine, substituted melamines and melamine derivatives, can be condensed with any suitable aldehyde of the aliphatic, aromatic or heterocyclic series such as formaldehyde, acetaldehyde, propionaldehyde, butyraldehyde, hexaldehyde, heptaldehyde, crotonaldehyde, allylaldehyde, benzaldehyde, cinnamylaldehyde, furfural and the like to produce resins suitable for use in the

manufacture of resin bonded resistors in accordance with the principles of the invention.

The condensation between the aminotriazine and the aldehyde may take place under acid, neutral or alkaline conditions, and in the presence or absence of a solvent for the incompletely polymerized reaction products which are first formed. These condensation products may be prepared by any suitable process and in any desired combining ratio of aldehyde to aminotriazine from 1:1 up to and including 6:1. A representative method of preparation will be described in the example which is to follow.

While resistors of excellent characteristics can be prepared by using the aminotriazine-aldehyde resins as the only bonding constituent it is frequently of advantage to employ these binders in admixture with other resins or adhesive materials. This is particularly true in the case of molded resistors designed to carry only small amounts of current, as in radio receiving sets. Thus, for example, I have found that mixtures of aminotriazine-aldehyde condensation products such as melamine-formaldehyde resins with phenol-formaldehyde resins can be prepared which have almost as good heat resistance as the melamine-formaldehyde resins themselves, and which are considerably cheaper and easier to manufacture. These mixed resins are prepared by reacting a mixture of the aminotriazine and phenol with formaldehyde, followed by dehydration and curing of the resinous bonding agent in admixture with the resistor material in the presence of a suitable curing agent such as phthalic acid. It is a remarkable feature of the invention that by employing an acid curing agent such mixed aminotriazine-phenol-formaldehyde resins can be cured in a much shorter time than can the corresponding phenol-formaldehyde resins prepared from similar classes of material.

The above described binding agents are preferably incorporated with the conducting material of high resistance which forms the body of the resistor, with or without the incorporation of smaller amounts of a conducting material of relatively low resistance. Thus, for example, in the preparation of resistors of the rectifying or discharge type having an exponential R_I relationship, a finely divided conducting material of high resistance such as "Carborundum," galena, crystalline ferrosilicon, silicon or similar materials may be mixed with the binder containing a conducting material of relatively low resistance such as graphite, lamp black or copper dust. Preferably the conducting material of high resistance constitutes from 85-98% of the mixture and the conducting material of relatively low resistance constitutes the balance of the conducting material present, the exact proportions of the two materials depending upon the conductance range desired in the resistor and the amount of current it is intended to carry.

An intimate mixture of the two types of conducting materials may also be first prepared and intimately mixed with a thermosetting binder containing an aminotriazine-aldehyde condensation product such as a melamine-formaldehyde condensation product in amounts sufficient to produce a permanent and homogeneous bond. In either case the mixture is then molded under heat and pressure until a cured piece of the desired heat resistance is obtained.

In preparing heat and pressure molded resistors of this nature it is frequently desirable to mold copper lead wires into the article during its

manufacture, and Figures 1-4 of the drawing illustrate embodiments of the invention which accomplish this purpose. As shown in Figures 1 and 2, copper lead wires 1 are shaped in the form of small inner spirals 2 and outer spirals 3 which may be substantially the same outside diameter as the finished cylindrical resistor. A short length of wire 4 may form an intermediate shank or connector between the spirals 2 and 3. The spirals 2 are then embedded within the shaped material of the resistor, as shown in Figure 1, for example by placing the outer spiral 3 on the bottom of the mold, filling in the powdered molding material around it and placing a similar spiral upon the top. The plunger of the mold then rests upon the top spiral 3 and pressure is transmitted through it. In this case the finished article after molding will have the form shown at the left of Figure 3, and the spirals 3 can be easily uncoiled, leaving the inner ends of the conductor firmly held within the resistor by means of the inner spirals 2. Flat and preferably perforated disks 5 may be employed instead of inner spirals 2, as illustrated in Figure 4 but otherwise the molding procedure is substantially the same.

Resistors can easily be molded in other forms by employing the features of the invention. Thus, for example, resistors of the type having an exponential R relationship are frequently prepared in the form of essentially flat disks having a coating of copper or other conductive material sprayed on each side. Such disks may be prepared easily and rapidly by employing thermosetting aminotriazine-aldehyde resins as binders. Cylindrical resistors, for example of the fixed carbon type, may also be molded or extruded using aminotriazine-aldehyde condensation products as binders and may be sprayed with conductive metal at their ends, after which a copper or other metal cap may be applied by electroplating if desired. It will thus be seen that the principles of the invention may be applied to a wide range of resistors, such as those prepared for use as heating elements, current limiting devices, fixed carbon resistors for radio television, etc., graded resistors for electrical circuits and the like, as well as rectifying resistors such as lightning arrestors, self-protecting molded terminal boards, self-protecting entrance bushings for high voltage apparatus and commutation brushes for electrical machines.

The invention will be illustrated in greater detail by the following specific example. It should be understood, however, that although this example describes certain of the more specific features of the invention it is given primarily for illustrative purposes, and that the invention in its broader aspects is not limited thereto.

Example

126 parts by weight of melamine were suspended in 162 parts by weight of 37% formaldehyde to which sufficient sodium hydroxide had been added to raise the pH to 7.2-9.0. The mixture was heated to reflux temperatures and refluxed for 10 minutes. The resulting syrup was cooled and introduced into a commercial spray drier of the following construction:

The drier consisted of a cylindrical chamber 16 feet in diameter and 18 feet high provided with a non-shearing feed disk 12 inches in diameter rotated at 10,000 R. P. M. Hot air was introduced at a temperature of 470° F. and taken off at 205° F. A 2 inch vacuum was maintained in

the chamber and 10½ inches pressure across the hot air fan.

The syrup was fed to the spray drier at the rate of 10 pounds per minute, and the spray-dried product was removed continuously in the form of a dry white powder.

Resistors containing silicon carbide ("Carborundum") of 100-200 mesh with an average of 160 mesh particle size were prepared using this resin as binder. These resistors were molded at 150° C. in the cylindrical form shown in Figure 3, using a 1:4 ratio of resin to non-resin. Varying amounts of flake graphite were ground with the resin until a uniform blend was obtained after which the "Carborundum" was added and thoroughly mixed.

In order to mold the leads into the ends of the resistors it was necessary to coil the lead wires as shown. The larger coil was made to fit the cylindrical mold used and was placed so that it formed the end of the resistor while the smaller coil projected inside about 25 mm. The larger coil could then be unwound after molding, furnishing a 4 inch copper lead.

The results obtained with these resistors are shown in the following table. Tests were made on the freshly molded resistor and after aging for several days to determine changes in resistance due to atmospheric conditions. Values were also taken after rapping the resistor several times with a hammer to evaluate the effect of shock. Finally the pieces were baked for a total of 47 hours at the temperatures shown, to establish the fact that continued heating at high temperatures will stabilize the resistor for lower temperatures.

Ohms/cm. at 90 volts

Resistor No.	Percent graphite	Effective length, cm.	Original	Percent	After aging	Percent	After rapping	Percent	After 16 hrs. at 150° C.	Percent	After 21 hrs. at 200° C.	Percent	After 10 hrs. at 150° C.	Percent
1	2	2.1	5X10 ⁷											
2	5	1.9	80,000	88.7	38,500	98.2	90,200	100	59,300	65.8	24,200	26.8	23,700	26.3
3	7.5	1.7	385	96.8	377	100	377	100	304*	80.6	253	67.1	248	65.8
4	10	1.9	45	97.8	46	100	46	100	39	84.8	33.5	72.8	33.3	72.4
5	15	1.9			2.85	99.6	2.86	100	2.28	79.6	2.05	71.6	2.04	71.3

* Resistance drops with continued passage of current.

In order to aid comparison the values after rapping were arbitrarily chosen as 100% and the other values rated accordingly. It will be seen that the bake at 200° C. stabilized the resistors against excessive losses at 150° C., which indicates that they can be manufactured more cheaply by shortening the molding time to 8-10 minutes and completing the cure in an oven heated above the maximum expected operating temperatures. The addition of acid curing agents such as phthalic acid in amounts of 0.75-1.5%, based on the weight of the resin may also be used to shorten the curing time.

The effect of changes in carbon content on the resistance at constant voltage is shown in Figure 5, in which the percent graphite is plotted

against the log of the resistance. It will be noted that a straight line function is obtained, which indicates that this type of resistor is well suited for use in discharge and rectifying devices.

What I claim is:

1. A heat and pressure molded electric resistor of substantial thickness in cross section comprising an intimate mixture of a conducting material and a thermosetting binder containing a sufficiently large proportion of an aminotriazine-aldehyde condensation product to insure a quick cure and to impart a high degree of stability and heat resistance thereto.

2. A heat and pressure molded electric resistor of substantial thickness in cross section comprising an intimate mixture of a conducting material and a thermosetting binder containing a mixture of a phenol-formaldehyde resin and an aminotriazine-aldehyde resin, the aminotriazine-aldehyde resin being present in substantial amounts sufficient to insure a quick cure and to impart a high degree of stability and heat resistance to said binder.

3. A heat and pressure molded electric resistor of substantial thickness in cross section comprising an intimate mixture of a conducting material and a thermosetting binder containing a sufficiently large proportion of a melamine-formaldehyde condensation product to insure a quick cure and to impart a high degree of stability and heat resistance thereto.

4. A heat and pressure molded electric resistor of substantial thickness in cross section comprising an intimate mixture of a conducting material and a thermosetting binding comprising an aminotriazine-aldehyde condensation product,

the aminotriazine-aldehyde resin being present in substantial amounts sufficient to insure a quick cure and to impart a high degree of stability and heat resistance to said binder.

5. A heat and pressure molded electric resistor of substantial thickness in cross section comprising an intimate mixture of a conducting material of high resistance and a conducting material of relatively low resistance and a thermosetting binder comprising an aminotriazine-aldehyde condensation product, the aminotriazine-aldehyde resin being present in substantial amounts sufficient to insure a quick cure and to impart a high degree of stability and heat resistance to said binder.

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