July 26, 1949. C. J. GANCI 2,477,121

RESISTIVE DEVICE

Filed March 11, 1947

Fig. 1.

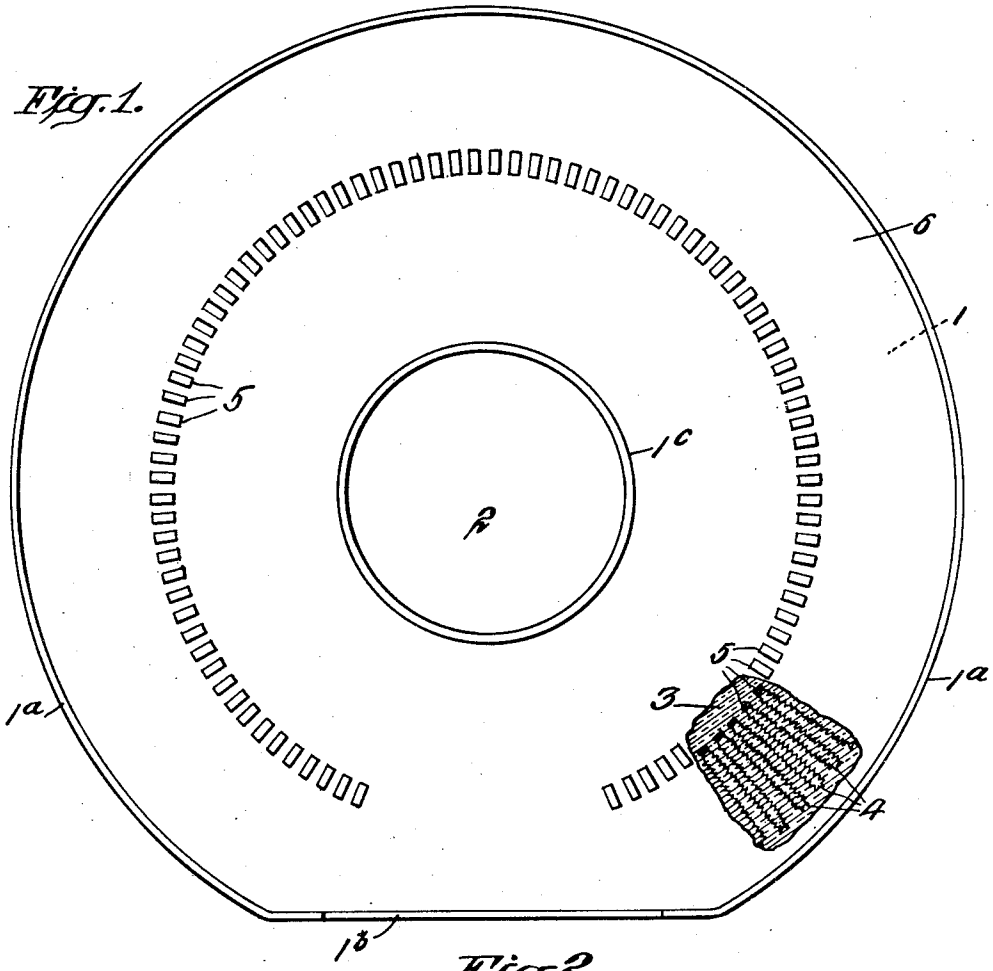
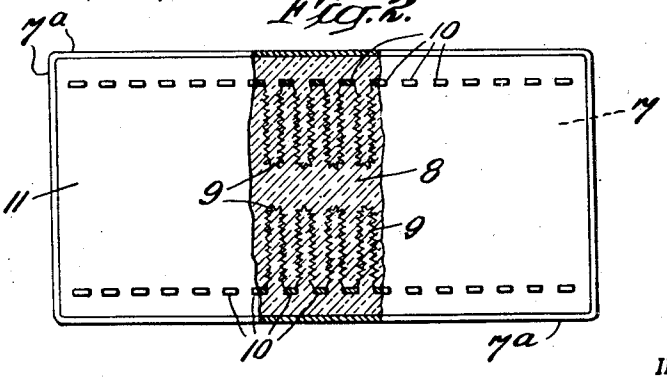


Fig. 2.



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RESISTIVE DEVICE

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This invention relates to resistive devices of plate form wherein a metal plate forms the support for the insulated resistive conductors, the resistors being embedded in insulating material. The resistive conductors may be provided with contacts for engagement by a movable conducting arm as in rheostats, or may be provided with projecting leads for connection to one or more circuits in any desired manner. Likewise, the plate may be circular, rectangular or of any other form.

The plate is provided with an upturned edge and is first covered with an insulating ground coat on which the resistors are placed, after which another insulating coating is applied for embedding and protecting the resistors. The present invention relates to devices having a vitreous enamel embedding and covering material with an appropriate filler and to the method of making resistive devices of such character.

Heretofore the method of making this type of resistive devices has been tedious and time consuming, involving much successive handling and various treatments. In general the process has been as follows: first, a ground coat of vitreous enamel and filler is applied to the metal plate in a wet or plastic condition and then dried; next the plate with its dried ground coat is fired to maturity in a muffle kiln at about 1500° F. for approximately ten minutes; then it is removed from the kiln and allowed to cool in air to room temperature; the inside rim is then brushed to remove the oxide scale; next the resistive conductors, with or without contacts according to the intended use, are placed in their proper spaced positions on the matured ground coat; next a wet enamel and filler mixture is poured over the conductors and the device is then vibrated to insure an even flow of the material over the resistors and to cause segregation of water to the top; next the excess water is drained off and the surface is then mopped with a sponge; then another coating of dry enamel and filler mixture is sifted on the wet enamel material sufficiently to cover all of the resistive wire; then the device is dried out in preparation for firing; next the device is placed in a kiln and fired at a temperature of about 1450° F. for a period of from 10 to 15 minutes depending on the size and shape of the plate; the plate with its molten enamel is then removed from the kiln at the firing temperature and is then sifted while hot with another covering of powdered enamel material; after this additional coating, the plate is again placed in the kiln for the final maturing of the enamel at the temperature of 1450° F.; the plate is then removed from the kiln and given another sifting of a thin coat of mixed

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powdered enamel material and coarse sand on the molten enamel for obtaining a rough or irregular surface of increased area for better heat dissipation; and finally, after the plate has cooled, the back and edges of the plate are subjected to sand blasting for removing the scale which has formed on the metal plate during the firing operations. The device is then tested electrically by applying 2500 volts between the resistive wire and the metal plate for checking the dielectric strength of the insulating enamel. The resistance of the insulation is also measured at room temperature and at about 600° F. for determining its acceptability and freedom from defects.

Enamels or glass compositions exhibit a decline in resistivity upon increase in their temperatures in use and this decrease in resistivity is quite marked at elevated temperatures with the enamels that have been used. New requirements and designs have imposed greater and more stringent specifications on the manufacture of control components and the insulation and watt carrying capacity require increasingly higher values.

One object of the present invention is to provide resistive devices which will meet and exceed the increasing requirements of higher insulation resistance and greater heat dissipation. Another object is to greatly lessen the reduction in insulation resistance at the higher operating temperatures. A further object is to produce an improved enamel composition for aiding in the attainment of the foregoing objects. Another object of importance is the method of making the resistive devices for reducing the time required, the number of operations and the manual labor. Another object is to relate the character of the compositions used in the ground coat and in the cover coat and their mode of application in such manner that only one firing of the devices is required. This firing matures the ground coat and the cover coat simultaneously and may be matured at a temperature lower than that previously required. The lower temperature and single firing has the further advantage that only a small amount of scale is formed on the metal plate and this avoids the necessity of sand blasting. The oxide formed on the plate is readily removed by a light wire brushing of the metal surface. Another object is to provide an enamel ground coat and cover coat having a coefficient of expansion approximating that of the metal support over the range of temperatures to which the device is subjected. These and other objects and advantages will be understood from the following description disclosing preferred embodiments and methods of the invention.

Fig. 1 is a plan view of a circular rheostat plate, partly broken away to show the ground coat and resistors applied thereon; and Fig. 2 is a plan view of a rectangular resistive device with projecting taps, and partly broken away to show the ground coat and resistors with taps applied.

The figures show general examples of the type of devices to which the present invention is applicable. Fig. 1 shows a form of rheostat plate having a flat metal supporting plate 1 of circular outline except at one portion of the periphery where it is straight. The outer edge 1*a* of the plate extends outwardly at right-angles to the main portion to form a retaining rim. The straight portion 1*b* of the rim is partially cut away inwardly from the outer edge and provides means for mounting the terminals thereon. The remaining portion 1*b* of the rim extends outward sufficiently to form a retaining rim. The base plate has a circular central opening 2 and an outwardly extending edge 1*c* to form an inner retaining rim. The inner ground coat 3 of insulating material is first applied to the surface of the plate, its composition and method of maturing being later explained. The resistive wire, or resistors 4, connected to contacts 5 are next applied in proper position on the ground coat, the contacts 5 extending outwardly from the ground coat in a circular row. An insulating cover coat 6 is then applied over the ground coat and resistors and around the base of the contacts. The composition of the cover coating and method of application and of maturing will be explained hereinafter. The rheostat plate is formed into a completed rheostat by the mounting thereon of the movable contact arm, and the connections and terminals. However, as they form no part of the present invention their description is omitted.

Fig. 2 shows a resistive device having a rectangular metal base plate 7 with an outwardly extending edge or retaining rim 7*a*. The insulating ground coat 8 is first applied thereto, the resistors 9 with their outwardly extending taps 10 are next properly positioned thereon and then the insulating cover coat 11 is applied over the resistors and inner portions of the taps. The compositions of the insulating material and method of manufacture are similar to that in the making of the rheostat plate and the following description applies to both forms and to devices of similar character. The taps 10 facilitate the connection of lead wires thereto as may be desired for its particular use.

Glasses formed of silica, SiO_2 or boric oxide, B_2O_3, or of both, have excellent dielectric and insulation properties but owing to their comparatively high melting point and viscosity are not suitable as such for the manufacture of resistive devices. The alkali group oxides, sodium oxide, Na_2O, potassium oxide, K_2O and lithium oxide, Li_2O, and the alkaline earth group oxides, such as barium oxide, BaO, zinc oxide, ZnO, and calcium oxide, CaO, when added separately or in a group reduce the melting point and viscosity of the glass.

In the present invention vitreous adhesive enamel frit is prepared in which a desirable blend of selected alkali group oxides, alkaline earth group oxides and the glass is obtained for securing maximum insulation resistance, high dielectric strength and good working qualities. In the present case an iron or sheet steel supporting plate is assumed to be used and therefore the composition used for the ground and cover coatings was selected to have approximately the same coefficient of expansion as that of the iron or steel plate. As to insulation resistance and dielectric properties, it was found that the use of three alkali group oxides with at least three alkaline earth group oxides in the enamel frit produced much improved results over using less than that number. The preferred enamel developed for this improvement, designated as Enamel A, after being matured or fritted, is as follows:

Enamel A

Na_2O	14.
K_2O	5.
Li_2O	2.
BaO	9.
CaO	.5
ZnO	6.5
CoO	.6
Al_2O_3	13.0
B_2O_3	20.4
SiO_2	29.0
	100.00

The preceding percentages of the composition may be varied a few per cent and still secure desirable results; and other alkaline earth group oxides may be used in place of those given, or in addition, although excellent results are obtained with those selected. This enamel is ground to produce a fine and a coarse frit. This enamel is dark in color which aids in heat emissivity.

The preferred ground coat is composed in relative weights as follows, the Enamel A being that already described.

Ground coat

	Pounds
Enamel A (fine—100% through 200 mesh)	50
Enamel A (coarse—between 20–60 mesh)	50
Black alundum, Al_2O_3 (between 20–60 mesh)	50
Fused magnesia, MgO (between 20–60 mesh)	50

A borax solution saturated at room temperature is used as the suspension medium for the ground coat composition.

The alundum and magnesia are used as they were found to have good heat conductivity as compared with other ceramic materials and also possess the characteristic of minimum decrease in resistivity with increase in temperature. White alundum could be used but the black alundum is preferred for obtaining high heat emissivity. The alundum, which is fused alumina, and the fused magnesia could be replaced by 100 lbs. of either of these materials with satisfactory results, and likewise the relative proportions of all of the ingredients could be varied. In this variation the coefficient of expansion of the ground coat should be adapted to approximately equal that of the supporting plate. The preceding preferred ground coat has a coefficient of expansion approximately equal to that of an iron or steel plate within the range of temperatures to which they are subjected.

After the iron plate is cleaned, as by sand blasting or pickling, the ground coat mixture in the borax suspension medium is applied to the plate which is vibrated to insure an even distribution and full coverage to a proper depth. It is then dried preferably in an infra-red dryer, requiring about 15 minutes.

The resistive conductors, with or without the metal contacts, are then set on the dried ground

coat in proper position, preferably by means of jigs for proper placing and space relationship.

The next step in the process is to sift a dry cover coat material on the resistive conductors and ground coated plate sufficiently to fully cover and embed the resistors. A preferred composition of this cover coat by relative weights is as follows:

Cover coat

	Pounds
Enamel A (between 20–60 mesh)	112.5
Black alundum (between 20–60 mesh)	100

The black alundum is preferred for the reasons above given. It may be replaced by fused magnesia or by a combination of these two materials in proper combination with the selected amount of enamel for the appropriate coefficient of expansion. The preferred cover coat given has about the same coefficient of expansion as that of an iron or steel plate.

The device is then placed in a muffle kiln and fired at about 1300° F. for about an hour, the time depending upon the character of the device. The comparatively low firing temperature permitted by the character of the ground and cover coats previously described has the additional advantage of merely forming a thin uniform oxide on the iron plate with no scale formation. Thus sand blasting of the plate is unnecessary, a light wire brushing being sufficient to remove the oxide. This completes the process in preparation for final finish and assembly of auxiliary parts and connections.

The complete cycle of operations in making these resistive devices of the plate type may be accomplished in a period of about two hours and only one firing is required. A very considerable saving in time and labor is thus accomplished and the number of operations and handling is reduced to a minimum. Also the insulation resistance of the coatings is superior to that previously attained and the decrease in this resistance with increase of temperature is much reduced. The dark color of the embedding coatings, their high heat conductivity and the rough top surface of the insulation result in high heat dissipation. The ground coat with its vitreous enamel and filler material adheres firmly to the plate; and similarly the cover coat with its vitreous enamel and filler material adheres firmly to the ground coat. The cover coat and the ground coat both adhere firmly to the resistors, effectively embedding them.

An important feature in this improved process in obtaining the best results relates to the size of the particles of the enamel and of the added grog or filler. In the ground coat the proportion of the fine enamel particles should not be so great, or the particles so extremely fine, as to produce initial cracking and pulling during the maturing operation. Also there should be a certain proportion of coarse enamel in the ground coat and coarse filler material. The proportion of fine enamel material to the total coarse material of the ground coat mixture may vary from 20 to 40 per cent by weight. The best firing results are obtained when the particle size of the coarse material is such that it will pass through a 20 mesh screen and not pass through a 60 mesh screen. This last statement likewise applies to the material of the cover coat. However, the size of the particles in the ground and cover coats may be varied somewhat and also the relative proportions of the ingredients and still obtain satisfactory results.

Where an especially high insulation resistance of the ground and cover coats is required, a further step in the process may be taken to satisfy special requirements. This consists in subjecting the device to further heat treatment by placing it in a furnace and raising the temperature of the furnace from room temperature to between 750° F. and 1000° F. depending upon the melting point of the enamel base and must be somewhat less than the melting point. The device is subjected to the temperature of from 750° to 1000° F. for about 2 hours or more, after which it is allowed to cool gradually in the furnace; and at about 250° F. it may be removed from the furnace. This heat treatment may be varied as to time and temperatures depending on the nature and size of the device and the composition of the coatings. The electrical resistivity of the embedding insulation may be increased by this special heat treatment from 50 per cent to as much as 300 per cent.

Although preferred embodiments of this improvement have been described, it will be understood that modifications of the compositions of the ground and cover coatings and of the method of making may be made without departing from the scope of the invention.

I claim:

1. The method of making a resistive device of the plate type comprising covering the plate with a ground coat containing relatively fine and coarse particles of vitreous enamel material, placing the resistors on said ground coat, applying a cover coat containing relatively coarse particles of vitreous enamel material over the resistors, and firing the device to mature the ground coat and cover coat simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

2. The method of making a resistive device of the plate type comprising covering the plate with a ground coat containing particles of vitreous enamel material and particles of a filler, said filler being of coarse particles relatively to a portion of the particles of said enamel material, placing the resistors on said ground coat, applying a cover coat containing particles of vitreous enamel material and particles of a filler over the resistors, the last named filler being of similar relatively coarse particles, and firing the device to mature the ground coat and cover coat simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

3. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

4. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler of fused alumina and fused magnesia, said enamel material being of partly fine and partly relatively coarse particles and the

filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

5. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler of fused alumina, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

6. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler of fused magnesia, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

7. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler of fused alumina, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

8. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler of fused magnesia, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

9. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler of fused alumina and fused magnesia, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

10. The method of making a resistive device of the plate type comprising covering the plate with a ground coat mixture of vitreous enamel material and a filler, said enamel material being of partly fine and partly relatively coarse particles and the filler being of relatively coarse particles, said enamel material containing at least three of the alkali group oxides and at least three of the alkaline earth group oxides, placing the resistors on said ground coat, applying a cover coat over the resistors in the form of a mixture of vitreous enamel material and a filler, said enamel and filler of the cover coat being of relatively coarse particles, and firing the device to mature the ground and cover coats simultaneously to cause the ground coat to adhere to the plate and the cover coat to adhere to the ground coat.

11. The method of increasing the electrical insulation of a resistice device having resistors embedded in a fused vitreous enamel by additional heat treatment of the device which comprises placing the device in a furnace, raising the temperature of the furnace gradually to a temperature somewhat near but below the melting point of the enamel, continuing the heating, and then gradually reducing the temperature of the furnace to a few hundred degrees F.

12. A resistive device comprising a supporting plate, a ground coat thereon of vitreous enamel material and a filler of fused alumina and magnesia, resistors on said ground coat, and a cover coat of vitreous enamel material and a filler of fused alumina over said resistors and ground coat.

13. A resistive device comprising a supporting plate, a ground coat thereon of vitreous enamel material and a filler of fused alumina and magnesia, resistors on said ground coat, and a cover coat of vitreous enamel material and a filler of black fused alumina on said resistors and ground coat.

14. A resistive device comprising a supporting plate, a ground coat thereon of vitreous enamel material and a filler, resistors on said ground coat, and a cover coat of vitreous enamel material and a filler over said resistors and ground coat, said enamel material of the ground and cover coats containing at least three of the alkali group oxides and at least three of the alkaline earth group oxides.

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