Jan. 26, 1932. C. O. TERWILLIGER 1,842,433

RESISTANCE DEVICE AND INSULATOR

Filed Dec. 28, 1928

Fig. 1.

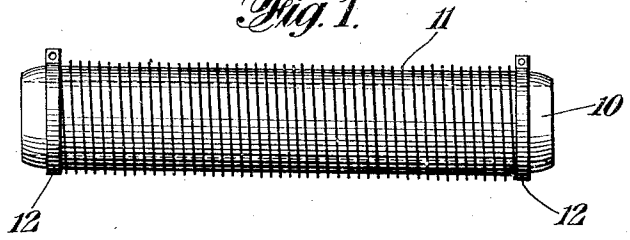


Fig. 2.

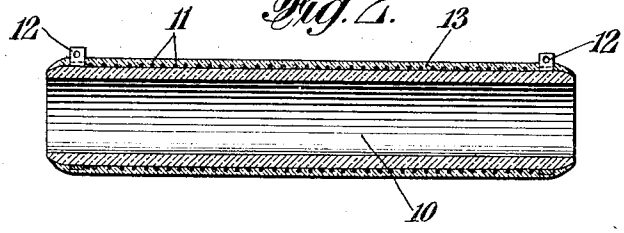


Fig. 3.

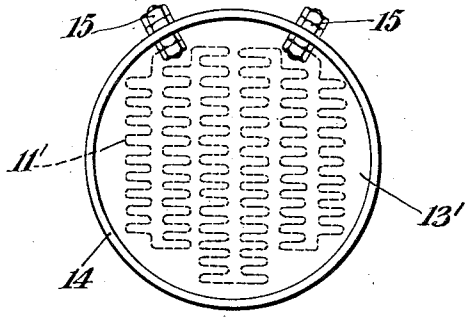
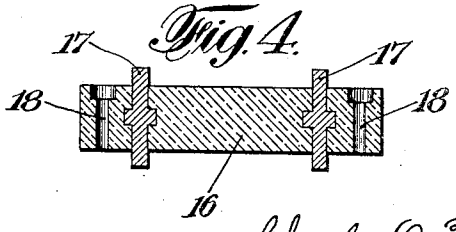


Fig. 4.



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UNITED STATES PATENT OFFICE

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RESISTANCE DEVICE AND INSULATOR

Application filed December 28, 1928. Serial No. 328,938.

This invention relates to improved resistance devices or resistance units and improved insulators or insulating material. It is particularly applicable to those forms of resistance devices in which the resistive conductor is wound or applied to a support of insulating material and covered with an insulating coating, such as vitreous enamel. The invention is also applicable where the apparatus or device including the insulating material is subjected during manufacture, or during use, to comparatively high temperatures. For example, the improved insulating material is adapted to be moulded around metal portions of the device and then fired to form the insulator and support for the metal parts.

It has been customary in the manufacture of resistance units, in the form of tubular units, to use porcelain as the refractory tubular insulating support. On this tube the resistive conductor of the proper size and length is wound and attached to suitable terminals, which latter may be affixed to the tube prior to the winding of the resistive conductor, or after the winding of the conductor. The next operation is to apply an adhesive vitreous enamel coating to the tube over the conductor and terminals. This is accomplished by dipping the unit in the enamel material, or spraying the enamel material over the unit and conductor, after which the unit is heated or fired in a furnace to the necessary temperature to melt or mature the enamel to form a glazed surface over the unit, thus forming an insulating protective coating impenetrable to moisture. In order to mature the enamel, temperatures of from 1,000 to 1,200 degrees F, or more are required.

The usual units of this type are composed of materials having relative expansion and coefficients of expansion as follows:

Porcelain	2.5–4.6	or	.0000025 to .0000046
Resistive conductor	14.	or	.0000140
Terminals	16.	or	.0000160
Enamel	9.–11.	or	.0000090 to .000011

The first column of numerals in the above table indicates approximately the relative expansion of the different parts over the range of the usual enameling temperatures; and the second column of numerals gives approximately the coefficient of expansion per degree centigrade rise. The resistive conductor is assumed to be of nickel chromium, or of similar high resistance conducting material, commonly used.

It is evident that in firing the unit for maturing of the enamel, the resistive conductor and terminals tend to become loose on the refractory tube by reason of their much greater expansion. This sometimes results in a shifting of portions of the conductor relative to other portions; and when the turns are wound quite close together, they sometimes shift to such an extent that they touch each other at different points and form short-circuits. This causes a lack of uniformity in the resistance of the units when finished. When the variations are of sufficient importance, they cannot be used for the purpose intended, requiring their rejection. Another difficulty arises on account of the unequal expansion of the parts due to the enamel flowing into the space between the resistive conductor and the refractory tube when the enamel has become softened during the maturing operation. The greater expansion of the conductor with reference to the porcelain body causes the turns of the conductor to sag and allow the softened enamel to pass between the turns of the conductor and the tube. Then when the units are cooled, after the maturing operation, the resistive conductor is placed under considerable strain, and in the case of fine conductors, they may actually break in one or more places and cause an open circuit in the resulting unit.

Another trouble difficult to overcome arises in the adhesive vitreous enamel coating itself due to the different expansions of the parts composing such resistance units. This difficulty is the development, unless extreme care be taken in the manufacture, of innumerable cracks called "crazing". This "crazing" sometimes permits moisture to reach the coated conductor and in time deteriorates the same and sometimes is sufficiently present to cause the unit to have an unsightly appearance, instead of a smooth glazed surface.

These and other difficulties have required

very great care in the manufacture of tubular resistance units, and also units of other forms, such as plate or disk forms, causing increase in time and cost of manufacture and constant inspection of the work as it progresses, as well as careful testing of the final product.

Recently the demand for high resistance units occupying comparatively small space has made it necessary to use an extremely small size of resistive conductor and to also wind the conductor on the tube to a very close pitch. Thus the difficulties due to the different expansion of the parts become particularly serious in the manufacture of such small high resistance units.

The main object of this invention is to produce an insulating body which will not only have high insulating qualities comparable to that of porcelain, but will have a coefficient of expansion within the range of temperatures to which the body is to be subjected, that will substantially correspond or more nearly correspond to the expansion of the metal portions and other parts with which the insulating body is united, and thereby avoid the difficulties above referred to.

Another object is to produce an improved insulating refractory body, which requires less time of firing than that of the usual porcelains.

Another object is to produce an insulating body which will have insulating properties equal to, or superior to, that of porcelain and have equal or greater strength and toughness than that of porcelain. Another object is to produce an insulating material not only having substantially the same expansion as the resistive conductor, or other metal parts, but one which will also withstand the sudden expansion and contraction without cracking or breaking during the manufacture thereof and during the firing to form the enamel coating. Other objects and advantages of this invention will be understood from the following description and accompanying drawings.

Fig. 1 is a side view of an illustrative resistance unit to which the invention is applicable and showing the unit before the enamel coating is applied; Fig. 2 is a longitudinal cross-section thereof with the enamel applied; Fig. 3 is a plan view of another form of illustrative resistance device to which the invention is applicable; and Fig. 4 is a cross-section showing the improved insulating material moulded about metal parts.

Referring to Figs. 1 and 2, the improved insulating body 10 is shown in the form of a tube and has wound around the same the resistive conductor 11. The latter has connected at its ends two terminal bands 12. The enamel coating 13 is applied to cover the resistive conductor and terminal bands, the enamel material first being applied by dipping the unit therein, by sifting the same thereon, or by spraying, or otherwise; and the unit is then placed in a furnace and heated to a sufficiently high temperature to form the vitreous adhesive insulating enamel coating.

Fig. 3 shows another form of resistance unit or device wherein the improved insulating body is in the form of a disk with an upturned circular edge 14. The resistive conductor 11′ is applied thereto by positioning the same on the face thereof, usually in zigzag form and has its ends connected to terminals 15 mounted in the upturned rim of the insulating body. An enamel coating 13′ is applied to cover and adhesively hold the resistive conductor in position upon the insulating body. Various other forms of resistance devices or resistance units may embody my invention and the illustrations are of known types to which the present invention is applied.

Fig. 4 illustrates an example of the use of this improved material where it is moulded about parts before firing, and where the parts may be metals of a character capable of withstanding the heat of the maturing temperatures. The improved insulating material 16 is shown moulded about metal terminal posts 17, and in the material, holes 18 are formed before firing adapted for securing the terminal block to a support.

It is evident that if the parts forming a resistance unit, or other devices, have substantially the same coefficient of expansion over the range of temperatures to which they are subjected when combined, during manufacture, the difficulties already explained are overcome. In accordance with the present invention, the insulating body is one which, in addition to having high insulating properties, toughness and strength, also has substantially the same coefficient of expansion as that of the part or parts with which it is combined. The improved material will also withstand the sudden expansion and contraction during the enameling without breakage. It also has a much greater maturing range than conventional porcelains, permitting the temperature during the firing of the insulating body to extend over a wider range without danger of making the finished body either over- or under-matured.

If the expansion of the insulating body be made substantially the same as that of the resistive conductor, it is evidently desirable that the enamel be made of material having the same coefficient of expansion. This may be readily accomplished by selecting the materials forming the enamel of such ingredients and in such proportions as to give the desired degree of expansion, as is understood by those skilled in the art. For example, if a nickel chromium conductor be used having an expansion of say 14 during the ma-

turing of the enamel, then a suitable enamel having substantially the same relative expansion may be formed from the following materials: felspar 60 lbs., borax 42 lbs., carbonate of soda 15 lbs., saltpeter 2 lbs. and cobalt oxide ¼ lb.

With reference to the refractory insulating body which will have the required insulating properties, strength and toughness, the withstanding of manufacturing temperatures and operations, and also have substantially the same coefficient of expansion as the resistive conductor, or other parts with which it is to be combined, it has heretofore been impossible to produce an insulating body of the required character, particularly one well adapted for combination with the resistive conductor and adhesive enamel coating.

I have found that an insulating body fulfilling the above requirements and overcoming the above explained difficulties may be made of a number of different materials. The natural mineral or rutile I have found to be particularly advantageous as a principal ingredient of the improved insulating material. This mineral ore, even when not combined with other ingredients when it has been properly ground, moulded and fired, fulfills the above requirements, being superior to porcelain in all of the desired qualities. But rutile when used alone, and ilmenite after treatment with acid to remove most of the iron, although having high insulating properties and being strong and tough and adapted to withstand the effects of manufacture and although having a coefficient of expansion over the enameling range of about 9.67 compared with 2.5 to 4.6 for porcelain, does not have a coefficient of expansion as high as that of the usual resistive conductor. Thus such material when used alone, although superior to porcelain in all respects, for the purposes of this invention, and although advantageous in overcoming the difficulties previously described, would be even more advantageous if its coefficient of expansion were that of the usual resistive conductor.

The mineral ore rutile has titanium dioxide as its main, or principal, ingredient and has approximately 95 to 99% titanium dioxide (TiO_2), the balance being mainly Fe_2O_3. For the purposes of the present invention, instead of using the mineral ore rutile, other materials may be used having titanium dioxide as its principal ingredient, and equivalent to rutile. For example, ilmenite, or any other titaniferous ore may be used after treating the same to remove most of the iron and other impurities.

When titanium dioxide is heated to sintering and then cooled, it produces a mass of needle-like formation; and it is this property which makes the same valuable as a binder for the present improvement in forming insulating refractory bodies.

I have found that various ceramic materials can be added to rutile, or titanium dioxide material and thereby increase the coefficient of expansion of the resulting material to be the same as that of the resistive conductor and other parts, or even higher, if desired, for other special purposes; and at the same time maintain its toughness and strength, ability to withstand temperature changes and other manufacturing effects and likewise have high insulating properties.

I have found that flint, or apatite, and other similar materials when separately combined with rutile, or material sufficiently high in titanium dioxide, may be used to fulfill all of the above-described requirements including a coefficient of expansion substantially equal to that of the resistive conductor or other metal parts. Also flint and apatite, or other similar materials, may be, in some cases, combined and used with the rutile or titanium dioxide material. If apatite or flint, for example, be used by themselves, however, the results are unsatisfactory. For example, apatite when finely ground and formed into a suitable refractory unit and subjected to a temperature of 2400° F., will not produce a sufficiently strong body and is extremely brittle. If flint be utilized in the same way, it will not produce a sufficiently strong body, being quite crumbly. A flint body has a very high coefficient of expansion equal to about 20.4 over the enameling range between 26 and 626° centigrade, but will not withstand the enameling operation. An apatite body has a coefficient of expansion of about 13.3 between the enameling range of temperatures, but does not withstand thermal shock. I have found, however, that if titanium dioxide be added to either flint or apatite so as to form as little as 10% of the combined material, the resultant material is greatly strengthened. I have also found that various amounts of titanium dioxide may be combined with either flint or apatite, or a combination thereof, or with other similar materials, to produce an insulating body having the desired properties and giving, according to the proportions used, a coefficient of expansion of the resultant insulating refractory material substantially the same as that of the resistive conductor and other parts with which it may be desired to use the improved insulating material. In fact, I have found that titanium dioxide material may have combined therewith in proper proportions other materials having high coefficients of expansion and secure a coefficient of expansion very much higher than that required for use in combination with a resistive conductor. For example, a mixture of 25% rutile, 25% flint and 50% apatite by weight gave a comparative expansion over the range

of enameling temperatures as high as 21.34 compared with an expansion of 9.67 when rutile is used by itself. Furthermore, this mixture and others of similar character all give a strong and tough material and well adapted to withstand the temperature changes during formation of the refractory material, and also during the maturing of the enamel.

I sometimes add clay to make the material more moldable, compensating for its low expansion by adding other high expansion material.

Considering more particularly the production of a tubular resistance unit, and assuming that a nickel chromium resistive conductor be used having a relative expansion of 14 and with proper terminals having a relative expansion of 16 and that an enamel material be used as above-mentioned having an expansion of 14 to conform with that of the resistive conductor then, the refractory tube should likewise have an expansion of 14 for best results. That is, the enamel, resistive conductor and tube should have substantially the same expansion over the enameling range. A refractory tube for this particular purpose may be formed of a mixture by weight of rutile two parts and flint one part approximately, or it may be formed by a combination of rutile, flint and apatite. If it be assumed that the expansion of the resistive conductor be 12 approximately, such as is the case with iron wire, then the refractory tube should have an expansion of substantially the same amount. In such a case, the mixture may be formed by weight of one part rutile and two parts apatite approximately.

In forming this improved insulating material, the rutile, flint or apatite is finely ground to pass through a screen of 200 mesh, or even finer. Where necessary, the mineral ore is chemically treated by acid to remove undesired oxides according to known methods, such as in the case of ilmenite, and then finely ground. The finely ground material is then moulded or extruded, according to the usual practise followed with porcelain material, to the desired form under pressure. It is then fired to mature it, as in the case of forming porcelain. Where the material is to be matured while united with the parts it is to support or insulate, it is moulded about the parts, such as the metal contacts, terminals, or conducting portions and then matured. If the material be formed by extrusion, and metal parts are to be united with the insulating material before being fired, this is brought about by machining the formed material and inserting or attaching the metal parts.

To mature or fire the improved material, it is subjected to a temperature of 2000° F. to 2800° F., depending on its particular composition. The maturing or firing does not cause a fusing of the material, but a sintering takes place resulting in a strong refractory body of high insulating properties free from blisters or cracks. During the maturing, the material is merely brought to incipient vitrification, that is, partially vitrified and a homogeneous body is obtained more conveniently than in the making of porcelain and superior thereto in characteristics already described.

The usual process for maturing porcelain takes from 24 to 36 hours, but with my improved material, one to three hours at the maturing temperature is usually sufficient.

I have further found that it is desirable, in some cases, to fire my improved insulating material when maturing it, in a reducing atmosphere, thereby securing a tougher and stronger refractory body. This may be due to the fact that otherwise the slight amount of iron in the rutile, or similar titanium dioxide material, is oxidized or caused to form iron oxides of higher valency; but this does not occur in a reducing atmosphere. When the iron is oxidized to higher valencies, it may be that this does not permit the titanium dioxide to have the same binding power as when this oxidization is not permitted to take place, or it may be due to the titanium dioxide being reduced to a lower valency.

It will be understood that my improved insulating refractory material may be formed of various materials and in various proportions to suit the particular requirements of the particular parts with which it is combined, as hereinbefore explained, without departing from the scope of this invention. It will also be understood that this invention is capable of many uses and adapted for use in various forms of devices and apparatus without departing from the scope thereof.

I claim:

1. A resistance device comprising an insulating refractory support and resistor, and an insulating fused coating covering said support and resistor, said support containing a titanium dioxide ore as a principal ingredient.

2. A resistance device comprising an insulating refractory support and resistor, and an insulating fused coating covering said support and resistor, said support containing rutile as a principal ingredient.

3. A resistance device comprising an insulating refractory support and resistor and an insulating fused coating covering said support and resistor, said support containing titanium dioxide as a principal ingredient and another material as a principal ingredient having a higher coefficient of expansion than titanium dioxide.

4. A resistance device comprising an insulating refractory support and resistor, and an insulating fused coating covering said support and resistor, said support containing

titanium dioxide as a principal ingredient and apatite as a principal ingredient.

5. A resistance device comprising an insulating refractory support and resistor, and an insulating fused coating covering said support and resistor, said support containing titanium dioxide as a principal ingredient and flint as a principal ingredient.

6. A resistance device comprising an insulating refractory support and resistor, and an insulating fused coating covering said support and resistor, said support containing titanium dioxide as a principal ingredient and apatite as a principal ingredient and flint as a principal ingredient.

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