

Aug. 26, 1958

W. ROTH

2,848,794

METHOD OF MAKING ELECTRICAL COILS FOR HIGH TEMPERATURE USE

Filed Dec. 30, 1953

FIG. 1

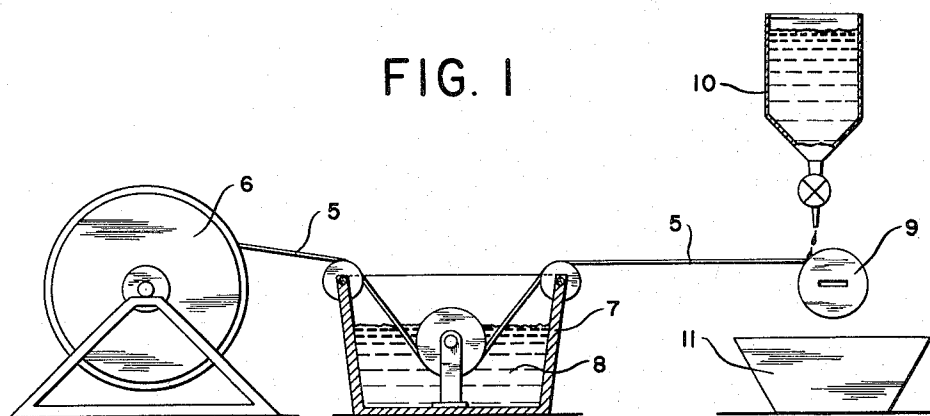


FIG. 2

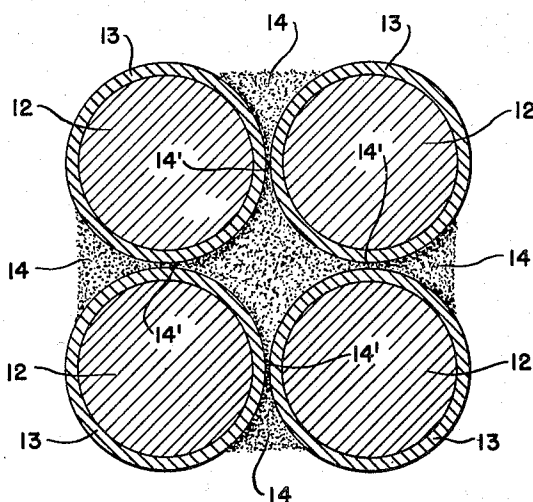
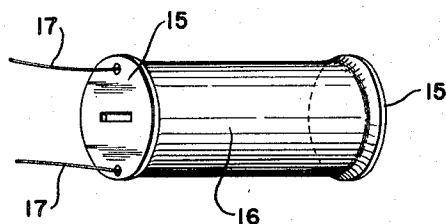


FIG. 3



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METHOD OF MAKING ELECTRICAL COILS FOR HIGH TEMPERATURE USE

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Application December 30, 1953, Serial No. 401,313

3 Claims. (Cl. 29—155.57)

This invention relates to the manufacture of electrical coils for high temperature use. The invention provides a method for making such coils which involves winding into coil form a pre-insulated wire and coating the turns of the coil with a slurry of a refractory cement, and, after the cement has set, heating the coil to above the decomposition temperature of the pre-insulation.

Numerous attempts have been made heretofore to produce coils suitable for operation at temperatures higher than conventional organic insulating materials can withstand. Some such attempts have been based on using an inorganic ceramic material in place of a conventional organic material to form the insulating coating on a wire which is subsequently wound into coil form. Only very limited success has been attained by procedures of this character because of the inherent brittleness of ceramic coating materials and the consequent lack of flexibility on the part of the coated wire. Other procedures have involved winding the coil of bare wire on a ceramic form, or embedding a bare wire coil, after it has been wound with turns spaced widely apart, in a ceramic matrix. While coils usable at high temperatures can successfully be produced by these procedures, such coils are difficult to make and are extremely bulky.

The present invention provides a simple method which has been found to be eminently suitable for making coils capable of operating successfully at temperatures of 250° C. and higher. The new method does not require specially prepared wire, but rather uses conventional insulated wire, advantageously enameled wire, and a conventional refractory cement. In carrying out the method of the invention, a slurry of the refractory cement is prepared in the usual manner. Such a slurry may advantageously be a siliceous cement slurry comprising an alkali metal silicate solution in which powdered siliceous material is dispersed. A coating of the slurry is applied to a wire which has been previously enameled with a conventional organic enamel, or otherwise insulated, and wound into coil form. The cement is then allowed to set and the coil heated to a temperature above the decomposition temperature of the pre-insulation.

In a preferred mode, enameled wire is coated with the slurry and, while still wet with the slurry coating, is wound into coil form. Then the cement is allowed to set, and thereafter the coil is heated to a temperature above the decomposition temperature of the enamel.

The coil thus prepared comprises a multiplicity of turns of metallic wire embedded in a rigid monolithic refractory mass, the wire being surrounded throughout its length within the coil by thermal decomposition products of the organic enamel coating or other insulation with which it was originally provided, and each turn of the coil is held in spaced relation with adjacent turns by the refractory mass.

An advantageous embodiment of the invention is described below with reference to the accompanying drawings, in which—

Fig. 1 is a schematic representation of apparatus suit-

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able for carrying out the preferred method of the invention;

Fig. 2 is a cross section on a greatly enlarged scale through four adjacent turns of a coil made in accordance with the invention, prior to the final heating step; and

Fig. 3 is a perspective of a typical completed coil according to the invention.

Referring to Fig. 1, pre-insulated conductive wire 5 to be wound into an electrical coil is taken from a supply spool 6. Advantageously a conventional enameled wire is employed. Such wire commonly is coated with a baked enamel of an oleo resin composition (i. e. a composition of a natural or synthetic resin dissolved in a drying oil). However, other enameled wires may be used equally well, such, for example, as wires coated with "Formvar" (a vinyl acetal enamel modified by the addition of a phenol formaldehyde resin), and with other conventional organic wire enameling compositions.

The insulated wire is passed through a vessel 7 containing a slurry 8 of refractory cement, whereby the wire is coated with such slurry. The refractory cement slurry may advantageously be a siliceous cement slurry which generally comprises a solution of sodium silicate or other alkali metal silicate (e. g., potassium silicate or lithium silicate) in which a finely divided or powdered solid siliceous material is suspended. The solid material may comprise powdered asbestos, clay, Portland cement, diatomaceous earth, powdered silica, or mixtures of these substances. Various modifying agents, such as lead or zinc oxide, barium sulfate, whiting, or manganese dioxide, may be incorporated with the siliceous material in the cement. The cement may also include magnesium oxide or magnesium chloride, or both, in either major or minor proportions. The composition of the cement is not critical so far as the present invention is concerned. Any conventional siliceous (or equivalent refractory) cement which is not electrically conducting may be used successfully. It is important only that the cement be capable of setting to a hard mass at room temperature or at some moderately elevated temperature below the thermal decomposition temperature of the wire enamel or other insulation (e. g., below 75° C. for enamel), and that after it has set it be capable of withstanding prolonged heating at the elevated temperature at which the coil is to be operated (e. g., 250° C. or higher). Air drying or chemical setting cements may be employed as best suits the particular application.

The wire, while wet with the coating of refractory cement, is wound into an electrical coil on any desired coil form 9. The initial slurry 8 is preferably of fairly thick consistency so that a sufficient quantity will adhere to the wire to thoroughly coat the turns of the coil and fill the interstices. Advantageously, but not necessarily, some of the cement slurry may be allowed to drip on to the coil from a vessel 10, as the coil is being wound, to further insure that the coil is thoroughly permeated with the cement. Excess cement may be drained by gravity from the coil into a receptacle 11.

After the coil has been wound, the refractory cement is allowed to set. Depending on the particular cement composition selected, setting occurs generally in a period from a few minutes to a few hours. Setting may take place at room temperature, or it may be accelerated by heating the coil to a moderate temperature preferably below 75° C. Such heating may be employed, if desired, before the cement has set, simply to accelerate the setting, or it may be employed after the cement has set to insure complete evaporation of moisture from the coil.

After the cement has set, the coil is heated to an elevated temperature above the thermal decomposition temperature of the enamel on the wire, and preferably for a

period of time sufficient to effect substantially complete decomposition of the wire enamel. Such heating may be accomplished in any desired fashion. For example, the coil may be fired in a heated furnace, at a temperature of 250° C. to 375° C. or higher. When thus heated, the temperature of heating should be at least equal to, and preferably is somewhat above, the maximum temperature to which the coil will be subjected in service. Alternatively, the coil may be heated by passing an electric current through it, of such magnitude as to bring the coil temperature to the desired maximum value. Or again, heating may be accomplished simply by putting the coil in high temperature service, and letting it become heated in the course of its normal operation.

The length of time required for the high temperature heat treatment will of course depend on the temperature employed and on the composition of the wire insulation and the cement. Periods of several hours have been employed with success. Generally speaking, periods of heat treatment longer than the minimum time required to effect decomposition of the insulation will do no harm and afford a desirable factor of safety.

A cross section through four adjacent turns of a coil prepared as above described, but prior to the final heating, is shown on a greatly enlarged scale in Fig. 2. Each turn of copper or other metallic wire 12 is surrounded by its film of insulation 13. Adjacent turns may be substantially contiguous and/or overlapping to occupy minimum space. The refractory cement composition 14 fills the interstices between the turns of wire. With a fairly thick slurry and moderate tension on the wire during winding, a thin coating of the refractory cement may remain between adjacent turns as indicated at 14'.

It will be noted that the metallic conductors are held out of contact with each other by the insulation 13. It is essential that an insulated wire be used, in order to insure that adjacent turns of the coil will not be short-circuited when it is freshly wound and while the refractory cement is still in liquid slurry form. When the wire is heated to its final elevated temperature above the thermal decomposition temperature of the enamel, it is probable that some shrinkage of the insulation film takes place. However, the wires appear to be maintained in their spaced relation, out of contact with one another, by the refractory cement, which now is in its hardened condition. Indeed, such shrinkage or decomposition of the insulation may be advantageous in allowing some room for thermal expansion of the wire when the coil is subjected to high temperatures.

The thermal decomposition product of the enamel film, which remains about the wire after the final heating step has been completed, is doubtless carbonaceous. It is not necessary, however, to take any special steps to insure its complete oxidation, or otherwise to eliminate it from the surface of the wire, for it has been found to have no deleterious effect on the coil. Coils made in the manner described above, after heating, do not show any indication of shorted turns or other defects, either electrical or mechanical.

As above mentioned, enameled wire is advantageously employed for the insulated wire. Such wire has the advantage that it is free of any textile or fibrous covering which might give rise to short-circuits between turns after subsequent processing, due to decomposed conductive filaments, etc., and has been found very satisfactory in use. Plastic-insulated wire, such as wire covered with teflon, nylon, vinyl materials, etc., is likewise free of fibrous matter and may be employed if desired.

With suitable precautions fibrous types of insulation may be employed, such as wire covered with cotton, silk, or rayon insulation, etc. In such event it is considered desirable to employ a sufficiently thick slurry and to adjust the winding tension so as to insure that there is at least a thin layer of cement, such as shown at 14', be-

tween the points of tangency of adjacent turns upon setting of the cement. Thus an insulating barrier is interposed between any conductive filaments arising out of the high temperature treatment, and avoids the danger of short-circuits.

While insulated copper wire has been employed with success, in some high temperature applications the copper may become embrittled and lead to eventual failure due to repeated expansion and contraction. In such cases other metals may be employed such as aluminum, silver, etc., if desired.

In the above-described preferred mode of carrying out the method of the invention, the insulated wire is coated with a refractory cement slurry just prior to (and sometimes also during) winding the coil. This insures that each turn of the wire when in coil form is coated with the refractory cement in a slurry condition prior to setting of the cement. While this procedure has been found satisfactory in practice, other methods of applying the refractory cement are possible so long as the turns of the insulated wire when in coil form are coated with the cement in a slurry condition before it has set.

The method of the invention has proved to be eminently satisfactory for making small coils of very fine wire, such, for example, as the transducer coil of the magnetostrictive probe described and claimed in the copending application of Stanley R. Rich and myself, Serial No. 227,694, filed May 22, 1951. Such a coil is shown in perspective in Fig. 3. It comprises steatite or other refractory end forms 15, between which is the coil body of wire embedded in a rigid monolithic mass 16 of refractory material. The coil leads 17 are shown brought out through one of the end forms 15. Such a coil is approximately five-sixteenths inch in diameter by three quarters inch in length, and is random-wound with a large number of turns of No. 40 A. W. G. copper wire. However, coils for other purposes, of larger size and wound with larger wire, can equally well be made in accordance with the invention. Examples are coils for relays, actuators, motors, etc. where the withstanding of high temperatures is important.

I claim:

1. The method of making an electrical coil suitable for high temperature operation which comprises applying a coating of a refractory cement slurry to a wire enameled with an organic enamel, winding the resulting slurry-coated wire into coil form before the cement has set, allowing the cement to set, and thereafter heating the coil to a temperature above the decomposition temperature of the enamel to remove the enamel and prevent short circuiting.

2. The method of making an electrical coil as set forth in claim 1 in which the cement slurry is applied to the wire by passing the wire through a body of the slurry, and in which additional cement slurry is dipped onto the coil as it is being wound.

3. The method of making an electrical coil as set forth in claim 1 in which the coil is heated to about 75° C. to accelerate the setting and drying of the cement, and the coil after the cement has set and dried is heated to at least about 250° C. for a sufficient period of time to effect substantially complete decomposition of the organic enamel.

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