

April 3, 1962

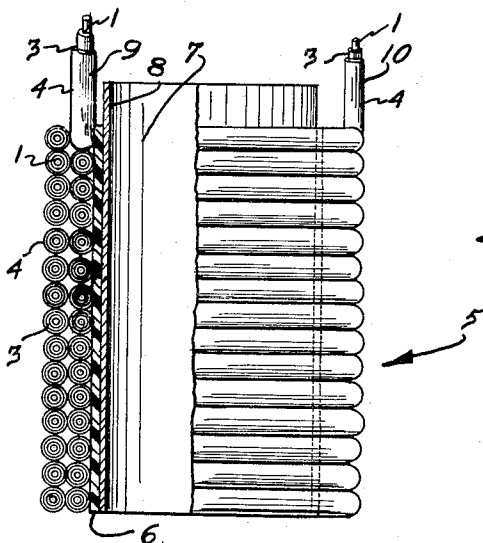
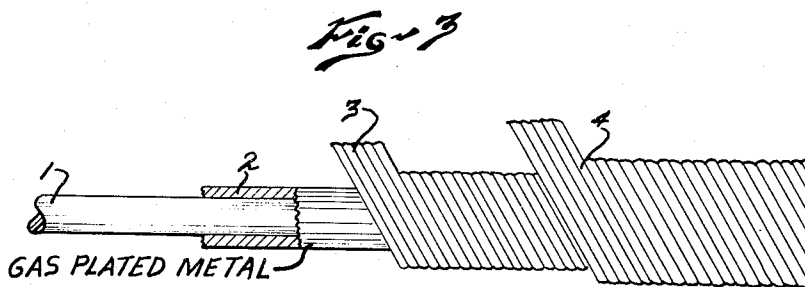
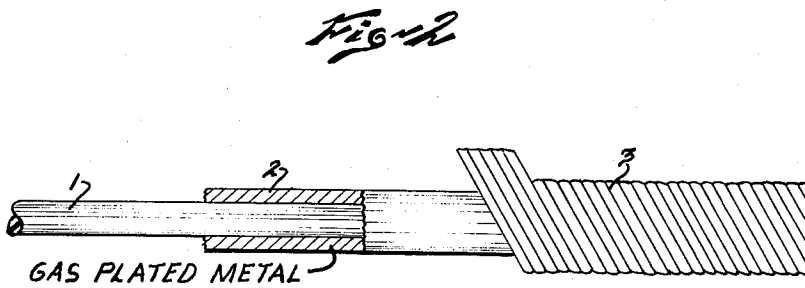
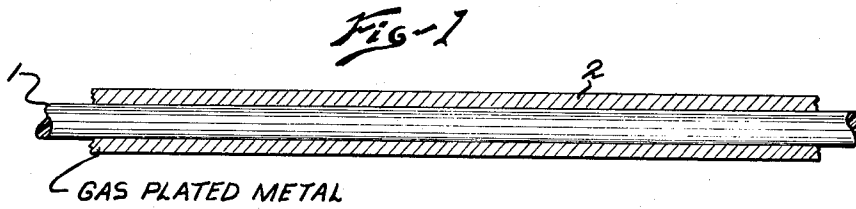
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3,028,446

ENCAPSULATED COILS AND METHOD OF MAKING

Filed Aug. 28, 1958

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig-5

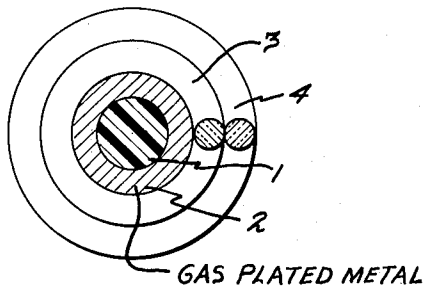


Fig-6

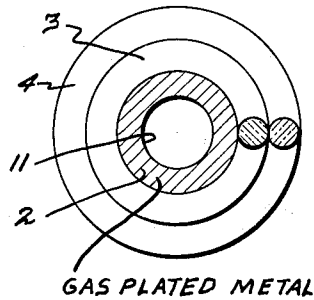


Fig-7

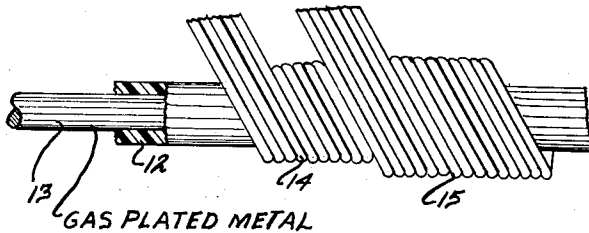


Fig-8

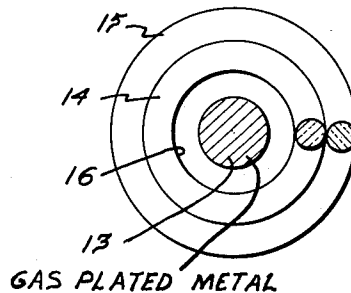
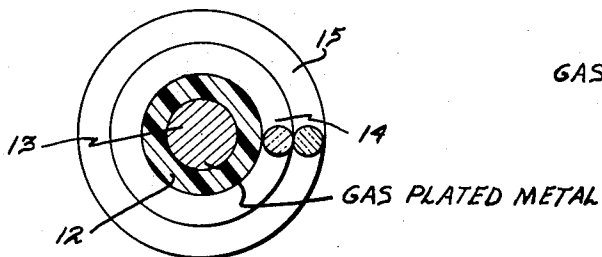


Fig-9



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1

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ENCAPSULATED COILS AND METHOD OF MAKING

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2 Claims. (Cl. 174-110)

This invention relates to improved electrical components and particularly to insulated electrical conductors for such components.

It has been found that desirable electrical components having inorganic insulation and suitable for high temperature applications may be formed without the occurrence of cracks in the insulation. Such cracking—which destroys the insulation quality of a coil—has limited the application of inorganics such as glass fibers. The cracking has been attempted to be eliminated by matching the coefficients of expansion of the electrical conductor and the inorganic insulating material as closely as possible. In accordance with the copending application of Hermann C. N. Heckel and Robert T. Jefferson, Jr., Serial No. 757,789 filed August 28, 1958, now Patent No. 3,015,686, it has been found that if provision is made for expansion of the conductor and that if the conductor is slippable relative to the insulation, then matching of materials may be avoided while achieving a crack-free insulation.

This invention contemplates the provision of an insulated conductor having particular utility in applications where components, such as coils, of high quality are necessary. Specifically the invention provides a conductor which is itself substantially unstressed, and wherein the metal of the conductor is pure and accordingly corrosion resistant. The conductor, although not limited thereto, has considerable utility in relatively short lengths, as for military application wherein coils of only a few turns are employed.

The invention further contemplates novel methods of providing the conductors and electrical components, such as coils, and wherein the method is facilitated by the corrosion resistant characteristic of the metal of the conductor.

Specifically, in the practice of the invention, metal deposited from the gaseous state, particularly from heat decomposable metal bearing compounds, is employed in the conductor. This metal may be copper, aluminum or nickel. Where good electrical conductivity and temperature resistance is required copper serves the purpose well. Aluminum has utility in the less severe temperature applications. Nickel has utility in applications where temperature resistance is of importance and electrical conductivity is secondary. Thus the invention permits of the selection of metals to fulfill the specific requirements of a given application, an important feature in connection with military devices.

The metallic conductor is attained by depositing the metal from the gaseous state on a resinous material, which material is itself heat decomposable at temperatures above that at which the metal is deposited. Polytetrafluoroethylene and similar resins serve the purpose. In the course of component formation this resin is removed from the metal in a firing procedure. The metal deposit exhibits the advantage, that it is resistant to corrosion. This is important in the firing process wherein at elevated

2

temperature the metal is exposed to gaseous products of the resin decomposition.

The metal bearing compounds useful include copper acetylacetonate, which is decomposable, under vacuum, at 300° F.; aluminum tri-isobutyl—decomposable under vacuum at 300° F. also; and nickel carbonyl which is readily decomposable at 300° F. Specific procedures for metallizing insulating materials in continuous lengths by the heat decomposition of gaseous metal bearing compounds are described, for example, in Nack Patent 2,812,272.

The metal in the practice of the invention may be externally or internally of the resin. Suitably the conductor, comprising the metal and resin body, is formed into an electric component prior to resin removal. For the formation of a component, such as a coil, the conductor is first wound with a layer of inorganic high softening point fibers and then wrapped with a layer of lower softening point inorganic fibers. In the course of component manufacture such low softening fibers are sintered to the high softening point fibers; this is effected after the resin removal from the component, which removal produces the expansion cavity necessary for free relative movement between the fibrous insulation and the electrically conductive metal.

The invention will be more fully understood by reference to the following detailed description and accompanying drawings wherein:

FIGURE 1 is a fragmentary elevational view, partially in section, illustrating an electrical conductor useful in the practice of the invention prior to the application of the insulation to the conductor;

FIGURE 2 is a view similar to that of FIGURE 1 but illustrating the application of the high softening point fibrous material to the conductor;

FIGURE 3 is a view similar to that of FIGURE 2 but illustrating the application of the lower softening point fibers to the conductor;

FIGURE 4 illustrates, in elevational and fragmentary view, partially in section, a coil formed with the finished insulated conductor;

FIGURE 5 is a sectional view of a conductor of the coil of FIGURE 4 prior to firing the conductor;

FIGURE 6 is a view similar to that of FIGURE 5 but taken after the firing of the coil;

FIGURE 7 is a fragmentary elevational view of another modification of a conductor useful in the practice of the invention and particularly illustrating the application of the inorganic fibrous insulating material; and

FIGURES 8 and 9 illustrate, respectively, in cross section a view of the conductor after firing and before firing.

Referring to the drawings more in detail the numeral 1 designates a solid rod of resinous material, such as polytetrafluoroethylene. This material is heat decomposable at temperatures of about 550° F. to 600° F.

Surrounding the resinous body 1 is an electrically conductive tube, such as copper, aluminum or nickel, 2. This tube is formed by the heat decomposition of a metal bearing gas, such as acetylacetonate, aluminum tri-isobutyl, or nickel carbonyl. The particular metal may be selected advantageously for the specific purpose involved. Copper is, of course, the best electrical conductor of the specific metals mentioned and suitable for most purposes. The thickness of the copper may be of any desired value and may be formed to be comparable to a No. 26 wire, for example, in conductivity.

Fibers in continuous filament form designated at 3

3

in FIGURE 2 are wound on the electrically conductive metal 2. This winding 3 is of high softening point material, such as silica fibers. Such fibers are available commercially under the trade name of Refrasil and are constituted of about 96 percent silica, the remainder being inorganic oxides, but substantially free of alkali oxide.

Illustrated by the numeral 4 in FIGURE 3 is an outer layer of lower softening point fibers, such as fibers of commercial E glass. A preferable form for the purpose of this invention is E glass treated with methacrylate chromic chloride, having a sintering point of about 1517° F. A suitable composition of the glass fibers is:

Constituent:	Percent
SiO ₂ -----	53.5
Al ₂ O ₃ -----	14.5
B ₂ O ₃ -----	10.0
CaO -----	17.5
MgO -----	4.5

The outer wrapping 4 is suitably present on the conductor to the extent of about 0.4 gram per foot of length of conductor. The inner layer comprising the high silica content fibers is preferably present to the extent of 0.3 gram per foot of length of the conductor.

The insulating conductor of FIGURE 3 is formed into a coil 5, as illustrated in FIGURE 4, by winding the conductor on a core 6 of ceramic material. This core 6 may itself be supported by an inner supporting core 7 having an extension 8 whereby the inner core is removable. The inner core may suitably be a body of aluminum silicate. Leads of the coil are indicated at 9, 10.

Initially the coil of FIGURE 4 is fired at a temperature of about 550° F. to 600° F. to occasion removal of the resin body 1 from within the coil. The resin body is volatilized by continued firing of the coil at the temperature indicated and the resin is removed through the coil ends.

While this practice requires a considerable length of heating time, which is dependent upon the coil length, the gas deposited metal is advantageous in this procedure since it is less affected by the heating than the more impure metals. Where the coil is relatively short the heating period may itself be shorter in order to effect resin removal.

The resin removal must be sufficient to provide a cavity internally of the metal body 2. As may be seen by reference to FIGURES 5 and 6 the resin 1 occupies a considerable volume of the conductor. The expansion cavity designated at 11 in FIGURE 6 is attained by this resin removal. Such expansion cavity provides for conductor movement independently of the inorganic insulation, which insulation itself is merely wrapped about the conductor. Since there is no uniting of the conductor with the surrounding insulation, the conductor may clearly move freely.

To complete coil formation after resin removal the coil temperature is raised to about 825° C. (1517° F.) for about one hour. This heating causes a sintering of the glass at the outer layer, resulting in a continuous film of the glass over the silica fibers 3, thus rendering the structure impervious to the entry of air.

After firing at the temperature of 825° C. the coil is cooled slowly to about 550° C. (1022° F.); as the temperature falls the glass of the outer layer, in the initial stages, hardens, and there is materially less shrinkage of the glass than of the metal of the conductor. Therefore a tendency exists for strains to be set up and in order to relieve these strains it has been found effective to anneal the coil at about 550° C. for two hours and to thereafter cool the coil to room temperature.

An advantage of the utilization of the pure gas deposited metals is that there is less tendency for the metal to oxidize during the sintering operation and before the interstices of the fibers are closed.

In connection with the coil itself it is to be noted that

4

as the temperature falls the conductor of FIGURE 6 shrinks longitudinally and the coil diameter therefore decreases. Such action places a considerable strain on the insulation of the conductors of the inside layer of the coil. However, due to the formation of the exposed cavity this strain is materially relieved and the fibrous layer 3 combines with the expansion cavity 11 to effect a cushioning action, thereby inhibiting glass cracking.

In a further embodiment of the invention, as illustrated in FIGURES 7, 8 and 9, the resin body 12 is tubular in form and the gas plated metal conductor 13 is deposited internally of the resin body.

The numerals 14, 15 in FIGURE 7 designate, respectively, high softening point and low softening point fibers as previously described. When the structure of FIGURE 7 is formed into a coil and fired as described in connection with FIGURE 4 the resultant product will have a cross section such as that illustrated in FIGURE 8, that is, an expansion cavity will exist between the conductor 13 and the electrical insulation designated by the numerals 14, 15. The expansion cavity 16 of FIGURE 8 is formed by the removal of the resin body 12 as may be clearly seen from FIGURE 9.

The coil formed as described is particularly useful for high temperature applications, since all of the materials in the finished coil will withstand temperatures of 700° C. (1292° F.) and above. However, as may be clearly noted from the foregoing, coils operable at high temperatures, that is, in the range of 400–500° C. (752–932° F.) could be formed by the method of invention and utilized in conjunction with the gas plated metals while employing resins of lower softening points, such as the methyl methacrylates, the polyurethanes, and nylon, for example.

Further, while it is usually preferable to form the electrical component and then to effect removal of the resin, such removal could be achieved in the conductor itself prior to component formation.

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions and accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

What is claimed is:

1. An article of manufacture comprising superposed turns of an electrical conductor forming a coil and having inorganic fibrous electrical insulation extending over the conductor insulating the adjacent turns of the coil, said insulation defining with the conductor an annular expansion cavity, said conductor comprising an elongated conductive mass of a deposit of corrosion resistant metal deposited by the heat decomposition of a metal bearing gaseous compound, and said fibrous insulation comprising an inner layer of high softening point insulation material and an outer layer of lower softening point and sinterable material.

2. An article of manufacture comprising superposed turns of an electrical conductor forming a coil and having inorganic fibrous electrical insulation extending over the conductor insulating the adjacent turns of the coil, said insulation defining with the conductor an annular expansion cavity, said conductor comprising a deposit of corrosion resistant metal deposited by the heat decomposition of a metal bearing gaseous compound, said corrosion resistant metal being selected from the group consisting of aluminum, nickel and copper, and said fibrous insulation comprising an inner layer of high softening point insulation material and an outer layer of lower softening point and sinterable material.

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