Dec. 8, 1964 O. N. BLOOM 3,159,907

METHOD OF MAKING SMALL TO SUB-MINIATURE SIZES OF ELECTRIC COILS

Filed Jan. 9, 1962

FIG. 2.

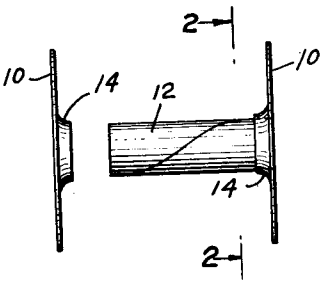


FIG. 1.

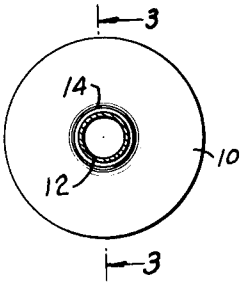
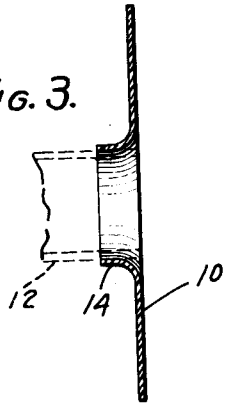


FIG. 3.



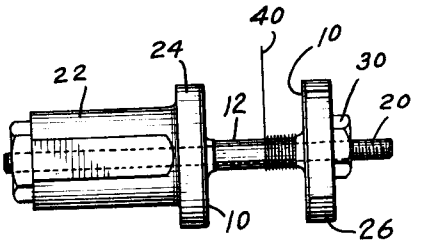


FIG. 4.

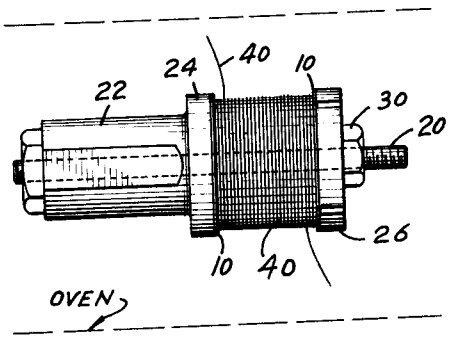
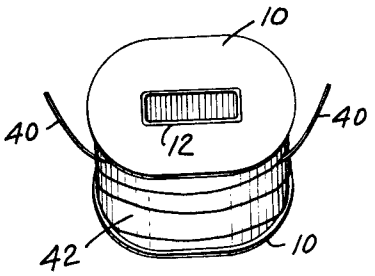


FIG. 5.

FIG. 7.



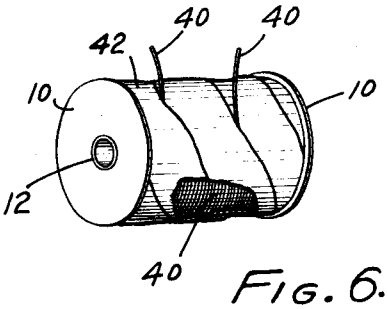


FIG. 6.

INVENTOR.
OTTO N. BLOOM
BY
ATTORNEY

United States Patent Office

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METHOD OF MAKING SMALL TO SUB-MINIATURE SIZES OF ELECTRIC COILS

Otto N. Bloom, San Gabriel, Calif.
(5825 Earle St., Rosemead, Calif.)

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3 Claims. (Cl. 29—155.57)

This invention relates to the manufacture of electric coils such as are used in contactors, relays and solenoids, and more particularly it relates to the manufacture of small, miniature and sub-miniature coils for the uses mentioned having substantially more ampere turns than standard coils, without increase in over-all coil size.

This application is a continuation-in-part of my prior application Serial No. 651,226, filed April 8, 1957, and now abandoned.

Prior to this invention the idea had largely prevailed in the coil art that while the bobbin could be quite thin, it should never be made so thin as to sacrifice the strength and rigidity required for supporting the winding. A typical expression of this attitude of rigid bobbins is the United States patent to Wyss, No. 1,953,035. The United States patent to Forrest et al., No. 2,856,639 (1958) discloses a bobbin of "epoxy resin of *thin* wall section, say 0.030 inch thick;" and the Du Pont Company managed to produce a thin molded nylon bobbin of 0.012 inch thickness (Fortune, July 1945). A few patentees, of whom Warnken No. 2,459,605 is typical, recognize the aim in the past has been to employ as thin a bobbin as possible "without sacrificing strength and rigidity," and while this patentee, and a few others, discard bobbins altogether, they rely upon heavier insulation for the wire strand and cementing or fusing the convolutions of the coil together, or similar modes involving a cementitious material to furnish solidity and rigidity. Omission of the bobbin, inter alia, exposes the coil to abrasion, as well as complicating the manufacturing procedure, while the use of cement for bonding of the convolutions adds weight to the coil and usurps space which otherwise could receive additional winding.

With the foregoing in mind, an important object of this invention is to provide a method of making coils of the kind mentioned above wherein more ampere turns of standard size wire can be provided than in prior coils of the same dimensions.

One of the most important objects of this invention is to provide a method of making a coil of the kind mentioned which will be free of all out-gassing substances.

A further object of this invention is to provide a method of manufacturing coils wherein the convolutions of the coil are caused to adhere to one another, without fusion of the insulating sheath of the wire or use of binding materials.

A still further object of this invention is to provide a method of making coils wherein the coil is heat treated to normalize same by relieving all internal stresses in the wire and its coating of insulation.

Yet another object of this invention is to provide a method of manufacturing coils wherein the resultant coil is sturdy and self-supporting without resorting to cements, adhesives or other binding material.

Other and further important objects of this invention will be apparent from the disclosure in the accompanying drawings and the specification to follow.

In general, I accomplish the foregoing objects by winding an insulated dry strand of wire, such as copper or aluminum, onto a specially designed bobbin of dielectric material, which is so extremely thin that of itself it is insufficient to support the coil or even lend any material support thereto. The coil so wound is then subjected to a heat treatment, preferably under vacuum, to relieve

all stresses from the turns or convolutions of the winding and coincidentally to remove all substances therefrom that may liberate objectionable gases or contaminants during use of the coil and which might foul contact points when one or a set of such coils are used in a sealed compartment. Upon cooling to room temperature, the turns of the coil are found to adhere to one another, without fusion or use of a binding material, sufficiently to present a rigid, self-supporting coil.

The invention will now be set forth in detail in the following specification, to be read in conjunction with the accompanying drawing, in which:

FIGURE 1 depicts in elevation a special bobbin of a power coil manufactured according to the present invention;

FIGURE 2 is a view taken along line 2—2 of FIGURE 1, looking in the direction of the arrows;

FIGURE 3 is an enlarged section taken along line 3—3 of FIGURE 2, looking in the direction of the arrows;

FIGURE 4 is an elevation of a form of bobbin holder employed in the winding and heat treatment of a coil;

FIGURE 5 shows a coil wound on its bobbin and the bobbin mounted on the holder of FIGURE 4, for placement in an oven for heat treatment;

FIGURE 6 is a perspective view of the complete coil according to the present invention, a portion of the outer covering or wrapping being broken away; and

FIGURE 7 is a perspective view of a modified coil produced according to the method of the present invention.

According to the present invention, I first provide the bobbin or spool illustrated in FIGURES 1–3. This bobbin is comprised of a tubular cylinder **12**, having an annular flange **10** mounted on each end thereof. It is impractical, if not impossible, to mold bobbins of the thinness contemplated herein, and it is very difficult and extensive to machine or grind bobbins down to the thickness here contemplated. Therefore I have devised the bobbin shown, and form same by first extruding the tubular cylinder **12** and cut same in lengths corresponding to the coil length desired. The flanges are stamped out of sheet material, and an opening is punched in the centers thereof. The edge portion about said opening is then flanged into a continuous cylindrical sleeve **14** for snugly fitting onto the cylinder **12**, whereby a nice interfitting of the flanges on the cylinder is readily and quickly acomplished. As will be explained hereinafter, sleeve **14** is to become fixed to cylinder **12** during the winding of the coil thereon. In forming the sleeves on the flanges **14**, as well as in sliding same onto the cylinder, great care should be taken not to nick or crack the sleeve portion, as such flaw will lead to failure by "hipotting" when voltage is applied to the coil.

Both cylinder **12** and flanges **10** are composed of dielectric material which can be made extremely thin without having holes or electrically weakened portions therein. By the expressions designating the bobbin as "extremely thin" and "of a strength insufficient in itself to support its winding," a thickness on the order of 0.001 to 0.006 of an inch is contemplated. In miniature coils, say 3/16 inch outside diameter and 5/16 inch long, the bobbin thickness should be on the order of 0.001 to 0.002 inch. However, for certain sub-miniature coils the thickness of the bobbin may be reduced to a mere film considerably less than 0.001 inch thickness, for the finished coils of this type often are no more than 0.020 inch in outside diameter and 0.050 in length. Since the bobbin affords no—or at most, negligible—support for its coil, in every case the minimum thickness of the material of the bobbin and of the insulation on wire **40** is limited only by the dielectric rating of the material.

The bobbin may be formed of any material offering the necessary dielectric rating, and which can be made into an extremely thin bobbin. Where temperature in the environment the coil is to be used is not to exceed on the order of 400° F., I have found the well-known plastic polyetetrafluoroethylene, available under the trademark "Teflon," and other products of the fluorocarbon family, will serve quite satisfactorily. For lower temperatures, nylon or Mylar, or their equivalents, may be employed.

For most small coils, wire 40 is generally of AWG24–56 gauge, but it will be understood that the size of the wire should be varied to correspond with the duties of the particular coil. The wire 40 has been provisionally sheathed with insulation by passing same through a bath of one of the materials enumerated above or of insulating enamel. The diameter of such wire used in small coils, including insulation, is roughly .0021–.000525 of an inch.

It may be mentioned at this point, that by reason of the extreme thinness of the bobbin herein disclosed, additional coil space is provided, and it is possible to wind more turns or wire thereon than is possible with a conventional "thin" bobbin of the same over-all dimensions. In fact, in a bobbin according to the present invention, of ¾ inch diameter and ½ inch length, wound with size AWG40 wire, from 500 to 600 additional turns of wire may be added over that of prior "thin" bobbins. This addition in ampere turns is reflected in increased pull-in strength of the coil, and when the coil is used in a relay, many of the usual critical adjustments pertaining to air gap at contact points, the armature spring, and the like formerly necessary in the manufacture of relays are obviated. This additional pull-in strength as added to the reliability of my coils under severe shocks and vibration, such as is encountered in aircraft on missile systems. Conversely, in accordance with my invention, on a bobbin of the same over-all size of prior bobbins, I am able to apply the conventional number of turns of a size larger wire, thus increasing the ampere-turns without adding to the resistance of the coil.

As best shown in FIGURE 4, in winding my bobbin, cylinder 12 with its flanges thereon, is mounted upon a metal shaft or mandrel 20, the latter comprising part of a unit 22 adapted to be installed on a winding mechanism. Unit 22 includes a rigid disk portion 24 formed as part thereof, and an opposed similar disk 26, the latter being adjustable along shaft 20. Shaft 20 is threaded on its end portions and nuts 30 on opposite ends thereof may be adjusted to position disks 24, 26 in fixed position contiguous flanges 10 of the bobbin. Disks 24 and 26 thus buttress and confine the flanges during the winding operation, and prevent bulging of the ends of the coil at this stage.

When the bobbin elements 10, 12 have been assembled on the mandrel 20 and the disks properly positioned with respect to the flanges of the bobbin, the sheathed wire 40 can be precision wound onto the bobbin in snug contact. According to my method, the winding should be applied in what is known in the winding art as "random fashion," in contrast to layer and honeycomb types of winding. In random fashion winding there is a limited cross-over of the turns or convolutions during traverse of the winding mechanism, establishing an interlock of the turns lengthwise the axis of the coil. This interlock comprises one of the important factors in producing a wholly self-sustaining coil without resorting to fusion of the adjacent turns or use of space consuming binder materials.

In starting the winding operation, as shown in FIGURE 4, the first run should begin at the edge of one of the sleeves 14 and continue back and forth between such edges until the winding has built up substantially even with the outer surface of the sleeves, whereupon the winding is extended over the sleeves on each traverse. As the winding begins to overlap the sleeves 14, the tension of the turns of wire causes the wire to grip the sleeves 14, and the sleeves are thus compressed against the cylinder 12, becoming bound thereto. A final wrapping 42 may then be applied to the coil and the ends of wire 40 brought out for conventional terminal connections.

After winding and applying the final wrapping 42 to the coil, the unit 22, with the wound bobbin thereon, is placed in an oven, where it is subjected to a controlled temperature, preferably under vacuum, for a predetermined time. The duration of the heat treatment may vary somewhat, depending upon the gauge of the wire and the number of turns, as well as the kind of wire and the material with which it is sheathed, and the temperature applied. For coils up to ¾ inch diameter and which contain on the order of 6,000 turns of AWG40 wire on a Teflon bobbin and the wire also sheathed with the same material, I have found a temperature of substantially 375° F. should be maintained for a period of at least one hour, while optimum results are obtained at an hour and a half. For larger coils the same heat and vacuum is applied, but the duration is prolonged in proportion to the size of the coil. Two hours of heating is sufficient for the larger coils.

The primary purpose of the heat treatment is to normalize or relieve the wire and its sheathing of the stresses induced in the winding operation, whereby the coil will tend to preserve its shape upon removal from the mandrel. The heat treatment, however, performs two further important functions: (1) It establishes a marked adherence of adjacent convolutions of the coil, which coupled with the random winding and the aforementioned normalizing of the coil, produces a rigid, self-sustaining coil. (2) The heat treatment drives out substances picked up in the processing and handling of the wire, such as oils and other contaminants which otherwise would liberate gases apt to cause failure of the control mechanism of sealed units in which such coils are commonly used. These items will now be elaborated upon:

(1) My experience reveals that adherence of the convolutions of the coil may be effected at a temperature of 350° F., while the sheathing will stand a temperature of 375° F. without cold flow. "Cold flow" is known to designate the deformation or squeezing of insulation from between adjacent turns sufficient to permit contact of the wires and short circuiting at such areas of deformation. Since the optimum normalizing temperature is found to be at 375° F., I employ this temperature for both normalizing and obtaining adherence of the convolutions.

Concerning the adherence of convolutions effected by the aforementioned heat treatment, it is pointed out that during the heating both the mandrel and the coil expand, during which expansion the turns of wire are thought to press against one another and cause slight indentations or deformation of the contiguous sheathing. The 375° F. temperature is found to be precisely sufficient to bring the turns of the coil into solid contact without reaching the stage of cold flow.

Regardless of whether the insulation on the wire be resin or enamel, the turns of the coil once brought into solid contact as herein described establish a marked adherence of the contiguous turns to one another. That is to say, thereafter it appears that a molecular force is exerted across the contacting surfaces of the many turns, normally retaining them, after cooling of the coil, in intimate relationship without bulging of the ends of the coil. The foregoing explanation of this phenomenon is fortified by the fact that after the winding of the coil on the mandrel and before the heat treatment, a wrench is needed to loosen nut 30; but after the heat treatment and the coil is allowed to cool, nut 30 can be removed with the fingers. No fusion of the turns together is involved, and no binder material is necessary nor used.

(2) In drawing of wire, some of the cutting oil and other substances adhere to the strand and other contaminants are picked up by a coil in the course of its handling in manufacture. These substances, when the coil is ex-

posed to a material increase in temperature, tend to volatilize and escape as a gas—herein termed "gassing." This gas may condense or otherwise accumulate on the contact points of a relay and cause failure of the system controlled thereby. Where several such devices are arranged in a sealed chamber the gas exuded from one coil may cause failure of the others, and when the coils are employed in a control for an airplane, for example, the result may be disastrous. It is therefore of utmost importance to drive out such gas liberating substances as may be incorporated in coils. I have found that this, too, is effectively accomplished in the aforementioned heat treatment, especially when carried out under vacuum at five microns or less at 375° F.

While the coils are under vacuum, an inert gas may be introduced into the vacuum oven for penetration into the coil upon relieving the vacuum. This inert gas should be bone dry, thereby avoiding any possibility of moisture entering the coil.

Following the heat treatment, the coil, while still on the mandrel, is allowed to cool slowly to room temperature, either while in the oven or removed therefrom. This normally takes about a half-hour. Too rapid heating or cooling of the coils may induce what is known as "thermal shock," and damage or even ruin the coil. The heating and cooling cycles complete what, for lack of a better term, I term herein as "normalizing" of the coil. By this term I designate the change within the wire resulting from the heating and cooling of the coil while still on the mandrel, whereby stresses in the coil, though to be by reason of rearrangement of the molecules, are completely relieved. The cooling results in a contraction and setting of the wire and its sheath into a final form. On removal from the mandrel 20 the coil will not expand or bulge at the ends. The coil dimensions remain precisely that of the inside length of the mandrel. With the elimination of bulging of the coil end by the present invention, when the ends of a coil are clamped during assembly in a relay frame, there is no compressive shear movement of the wire, with resultant broken wire and shorted turns.

As indicated above, in a coil produced according to the present invention, it is unnecessary that the bobbin be of sufficient strength to support or sustain the finished coil, for wire 40, when wound and heat treated as herein described results in a self-supporting or self-sustaining coil. By the expression "self-supporting or self-sustaining" is meant that the coil will retain its shape and condition without assistance from a bobbin for all reasonable applications thereof. The bobbin, therefore, merely serves as a dielectric for and protector of the coil against abrasion. The flanges of the bobbin likewise do not buttress the coil, but serve only for the purpose just noted.

The fact that in my coil, the stresses within the wire have been completely relieved by said heat treatment, together with the adherence of the turns of the coil to one another, virtually eliminates wire breakage and cold flow, with resultant shorted turns and open circuits under all conditions of heat and vibration likely to be encountered in use.

The coil of FIGURE 7 differs from that of FIGURE 6 only in that it is oblong in cross-section.

While in the foregoing description certain details of my method have been set forth, it is to be understood that variations thereof may be made by those skilled in the art without departing from the scope of the invention as defined in the following claims.

I claim as my invention:

1. The method of producing small and miniature self-sustaining relay coils, comprising providing a bobbin of dielectric material, having a thickness of not more than 0.006 inch, fitting said bobbin on a support having spaced buttress elements for the ends of said bobbin, random winding wire provisionally insulated with polytetrafluoroethylene onto said bobbin to form a coil, thereafter subjecting said coil while on said support to a dry heat treatment at a temperature on the order of 375° F. for not less than one hour to relieve substantially all internal stresses in said coil, thereafter allowing said support and coil to cool to room temperature, and finally removing the coil from said support.

2. A method of making compact small to sub-miniature sizes of self-supporting relay coils comprising providing a bobbin of dielectric material having a thickness not in excess of 0.006 inch, fitting said bobbin on a support having spaced parallel-buttress elements for the ends of said bobbin, random winding fine wire provisionally insulated with polytrafluoroethylene onto said bobbin while on said support to form a coil, then subjecting said coil without fustion thereof or use of bonding material at a temperature on the order of 375° F. for a period of at least one hour to cause adherence of the turns of said coil without fusion thereof or use of banding material and to relieve internal stresses in the wire resulting from the winding operation, subsequently permitting said support and coil to cool to room temperature, and finally removing the coil.

3. A method of making small, miniature and sub-miniature self-supporting relay coils comprising providing a bobbin of dielectric material having a thickness not in excess of 0.006 inch, said bobbin including a tubular cylinder and separate end flanges each flange including a sleeve fitted onto said cylinder, mounting said bobbin on a mandrel having buttress elements for the flanges of said bobbin, random winding fine wire provisionally insulated with polytetrafluoroethylene onto said bobbin while on said mandrel, with the winding running onto said sleeves for gripping same against said cylinder in forming the coil, then subjecting said coil while retained on said mandrel to a dry heat treatment in an oven at a temperature on the order of 375° F. for a period of not less than one hour to remove any out-gassing substances from the coil, as well as to relieve the coil of all internal stresses, thereafter and while still on the mandrel cooling said coil to room temperature, the heating and cooling effecting adherence of the turns of said coil to one another without fusion thereof or use of bonding materials.

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JOHN F. CAMPBELL, *Primary Examiner.*