Dec. 3, 1963 A. ZACK 3,112,556

METHOD OF MANUFACTURING ELECTRICAL COILS

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Fig. 1

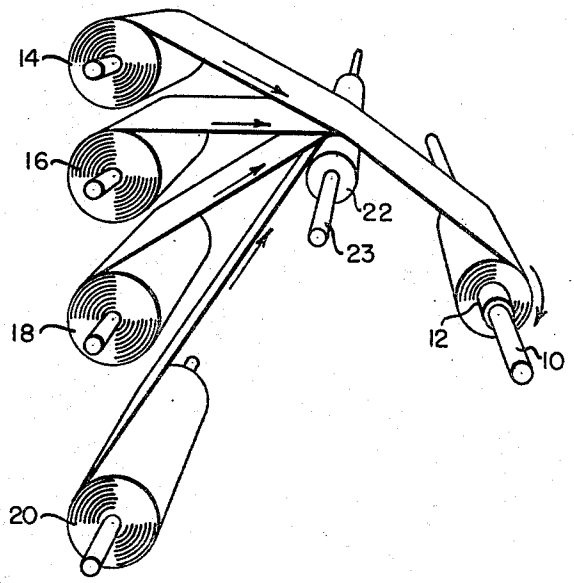
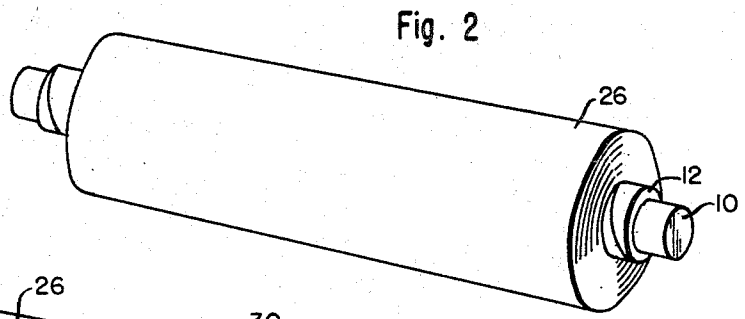


Fig. 2



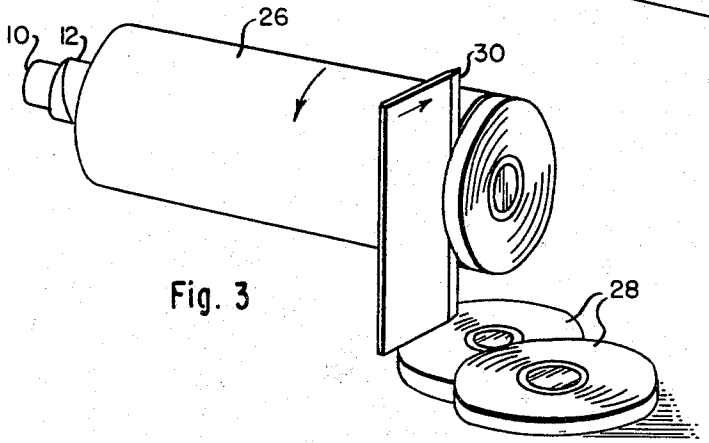


Fig. 3

INVENTOR.
ALBERT ZACK

BY Lawrence Burns,

ATTORNEY

METHOD OF MANUFACTURING ELECTRICAL COILS

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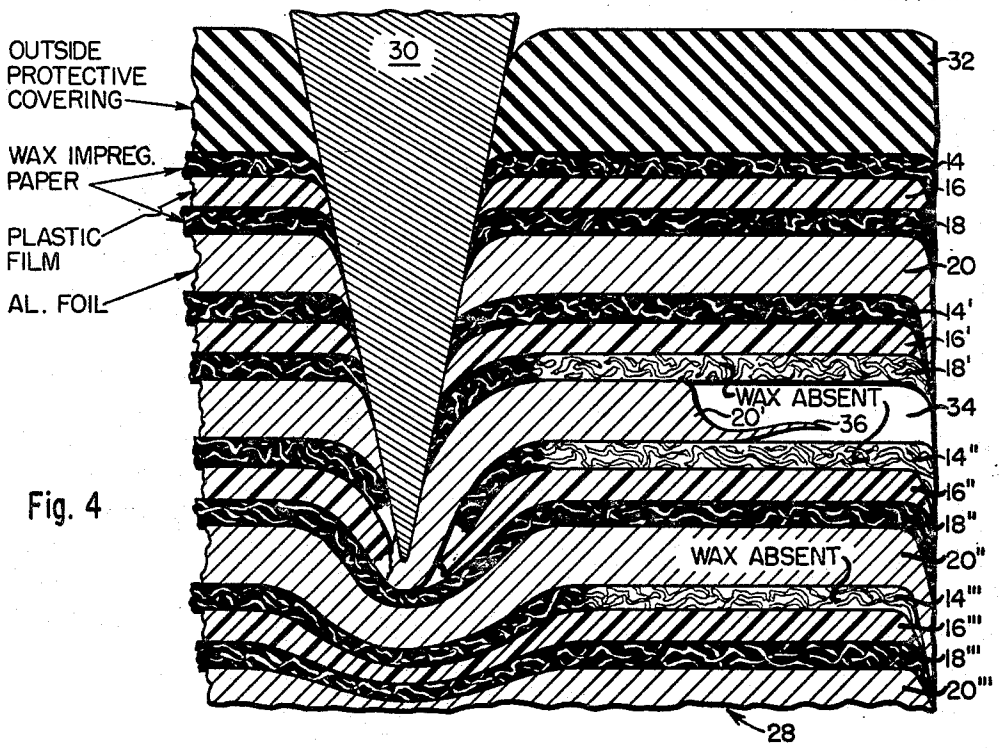


Fig. 4

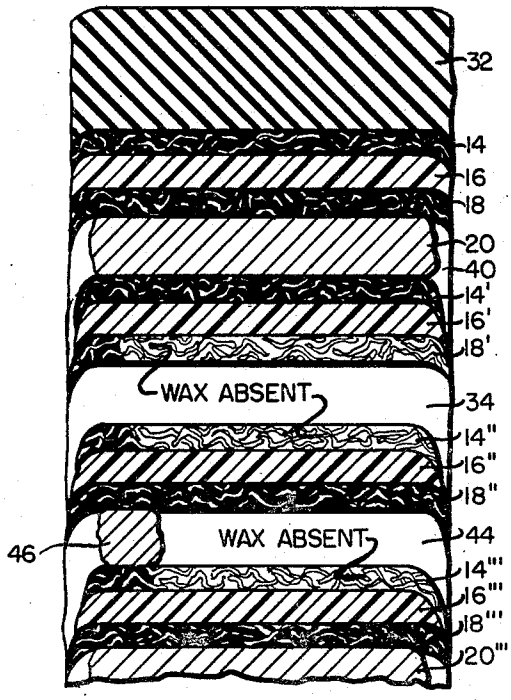


Fig. 5

INVENTOR.
ALBERT ZACK
BY Laurence Brown,
ATTORNEY

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METHOD OF MANUFACTURING ELECTRICAL COILS

Albert Zack, Danvers, Mass., assignor, by mesne assignments, to Sylvania Electric Products Inc., Wilmington, Del., a corporation of Delaware

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1 Claim. (Cl. 29—155.57)

My invention relates to electrical coils and their manufacture. The present application is a continuation-in-part of my previously filed application Ser. No. 401,333 filed December 30, 1953.

In recent years the vast increase in demand for electronic equipment has emphasized the need for the development of cheaper and better methods of production not only for the complete devices, but also for the elements generally required as parts. So-called "printed circuit" techniques have thus far proved enormously effective for the mass production of certain electrical elements such as conductors, condensers and resistors, and combinations thereof, but printed circuit techniques are not, so far as I know, applicable in the manufacture of inductors. That fact is particularly troublesome because the manufacture of inductors has historically been difficult, expensive and one which requires an abnormally large and skillful labor force.

While various machines and methods have been suggested as a means of increasing the rate of production of coils, I am not aware that any of the expedients thus far suggested have proved commercially satisfactory. The basis of my invention is the discovery that a technique suggested in broad form and generally regarded as impracticable was subject to an unrecognized problem which I have solved successfully. Coils manufactured in accordance with my invention are now being made on a commercial scale with satisfactory results both as to method and product.

It has been suggested, as for example in the patent to Rich No. 2,334,584 that it would be possible to produce coils by first winding upon a mandrel a sheet of metal and interleaving the turns with an insulating material such as paper; then the completed roll could be cut transversely to its axis to form individual coils of desired thickness. Although my invention involves the use of a similar technique, it is characterized by the addition thereto of a step which has been effective to transform the process into one of considerable commercial importance.

I discovered that while the winding operation presented no particular difficulties, the cutting of the wound material into individual coils could not be successfully carried out unless each metal turn in the roll was firmly and securely bonded to the adjacent insulating turns throughout its entire extent; furthermore the presence of any voids or pockets within the winding rendered it such a difficult matter to cut the roll into individual coils as to make the technique commercially valueless. The presence of such voids or pockets also leads to the further difficulty that upon the application of acid to etch the exposed surfaces of the individual coils in order to remove swaged edges or metal filaments which would otherwise short across two or more turns, the acid would enter a pocket and eat completely through a turn, thus producing a break in the electrical winding.

The primary object of my invention is to facilitate the manufacture of electrical coils.

Another object of the invention is to reduce the cost of manufacture of electrical coils.

Still another object of the invention is to produce a small compact electrical coil exhibiting superior electrical properties.

An important feature of the invention resides in subjecting a roll of sheet metal interleaved with turns of bibulous insulation material to immersion in a bath of wax or similar impregnating material and drawing a vacuum over the bath, the immersion being maintained until the insulating material is completely saturated with the impregnant and there are no remaining voids within the winding. Upon removal from the bath the saturated roll is allowed to cool so that the wax or other material hardens in situ to bring about a complete and effective bond between the metal and the adjacent insulating material. The cutting operation may then be carried out without difficulty.

Another feature of my invention resides in providing as the insulating material between the adjacent metal windings a laminated sheet comprising two thin plies of bibulous paper encompassing between them a tough, flexible ply of homogeneous plastic material, the result being that the paper plies serve effectively as wicks to draw the impregnant into the interior of the roll, while the middle ply of homogeneous plastic material serves as a stiffener lending toughness and rigidity to the windings not only to facilitate the cutting but also to increase the mechanical strength of the finished coil.

These and other objects and features of the invention will best be understood and appreciated from the following detailed description of a preferred embodiment thereof selected for purposes of illustration and shown in the accompanying drawings, in which:

FIG. 1 is a diagrammatic view illustrating the operation of winding the plies of metal, paper and plastic upon a mandrel,

FIG. 2 is a view in perspective showing the completed roll,

FIG. 3 is a view in perspective illustrating the operation of cutting individual coils from the winding,

FIG. 4 is a view in cross section, on a very greatly enlarged scale, illustrating somewhat diagrammatically the action of the cutting knife cutting off an individual coil in which voids are present due to insufficient impregnation, and

FIG. 5 is a view similar to FIG. 4 illustrating, also diagrammatically, the detrimental result of the presence of voids or pockets in the winding.

As shown schematically in FIG. 1 the initial step in the manufacture of coils in accordance with our invention is to provide a cylindrical metal mandrel **10** carrying a tube **12** of cardboard or other suitable material, it being understood that the mandrel **10** will be suitably engaged with mechanism for rotating it (not shown). Leading to the core **12** are four plies of material. As shown in FIG. 1 the uppermost ply **14** is led from a roll of bibulous paper. Although the dimensions of the materials employed are not believed to be critical, I have found it satisfactory to employ paper .0002" thick. The next ply **16** leads from a roll of a tough pliant homogeneous material such as an epoxy resin. This ply may conveniently be .00025" thick, and I have found a satisfactory epoxy resin film currently sold under the trade mark "Mylar." It is also contemplated that a polyethylene film may be employed for the purpose.

The third ply **18** is again bibulous paper .0002" thick. The paper plies **14** and **18** which sandwich the plastic film **16** are superposed on a ply 20 of aluminum, copper, or other suitable conducting material. While I contemplate the use of my invention upon sheet metal of varying thicknesses, I have successfully employed aluminum and copper foils approximately .0005" thick. The several plies lead over an idler roll **22** mounted on a suitable shaft 23 and then to the core **12**. In FIG. 1 the winding step is shown as it appears after a substantial number of

turns have been wound. The precise number of turns will of course depend upon the electrical characteristics desired in the finished article, as will also the thickness of the metallic sheet. The finished roll is, shown in FIG. 2, a protective covering of cardboard or similar material having been cemented to the periphery of the winding (see FIG. 4 at 32).

The next step in manufacturing the coils comprises baking the winding to drive out excess gas. For example, I have found it convenient to bake the winding for four hours at an approximate temperature of 250° F. Then the baked winding is immersed in molten wax. The exact composition of the wax is not of critical importance so long as it melts at reasonable temperature, is hard at room temperature, and also forms an adhesive bond between the metal and the paper. It is to be understood that the invention is not limited to a wax but may be practiced with any impregnant having similar physical and dielectric properties. The term "waxy thermoplastic material is therefore employed in an illustrative sense.

The wax is preferably one whose melting point is above the temperature to which the coil is brought by the friction of slicing. Waxes melting at 240° F. have been found satisfactory, and they can be heated to 275° F. during impregnation. Various resins and plastics can be used instead of wax, for example polyethylene, polystyrene, and polyvinyl plastics. In addition to its insulating effect the impregnation holds the wound cylinder **6** together and keeps it from unravelling.

The wax or other impregnant is disposed in the heated container provided with an air-tight cover and associated with an exhaust pump by means of which the pressure within the container may be reduced below atmospheric. Of course, a substantial reduction in the pressure within the container causes a corresponding increase in the volume of air or gas entrapped within the roll, the result being that substantially all gas is driven from the roll and any voids are completely filled with the impregnant material. I have found that it is desirable to continue the immersion of the roll in the wax for about forty-eight hours in order to secure substantially complete saturation.

After the completion of the impregnation, the roll is removed from the wax and permitted to cool and dry so that the wax hardens and bonds the several plies of the windings into an adhesively laminated solid structure. The mandrel **10** carrying the roll is then mounted in a lathe or similar machine by means of which the roll may be rotated rapidly on its long axis and operated on, as suggested in FIG. 3 by a sharp cutting blade **30** advanced slowly and steadily into the roll along a path perpendicular to the axis of the mandrel. The distance between successive cuts of course determines the thickness of the individual coils **28** being cut from the roll and the thickness in turn will be determined by the electrical characteristics desired in the finished coil.

I have found in practice that the action of the blade necessarily causes considerable distortion of each individual coil **28** from a flat condition, the resultant coils being dished to a considerable extent. It is of course both necessary and desirable to flatten the dished coils, and it has been my experience that a coil which contains voids or paper which has not been completely saturated with the impregnant cannot withstand the mechanical stresses engendered in the flattening operation, whereas a completely filled and saturated coil can easily be flattened without detrimental effect.

In any coil manufactured in accordance with the general technique here disclosed it will be found that the blade has not cut cleanly through the successive metal turns but that the advancing blade bends over or swages very thin edge flanges of metal, the result being that such coils will be ordinarily shorted when they have been cut. It is therefore necessary to remove the swaged metal extensions. While that may be accomplished by a grinding operation, I prefer to etch the surfaces of the coils because the result is a coil in which the insulating turns extend outwardly with respect to the etched metal surfaces, thus providing overhangs of insulation minimizing the possibility of shorting contact between adjacent turns of the metal. On the other hand, grinding produces a flat surface and the metal turns are not so well protected. Here the importance of completely filling any voids in the roll and of completely saturating the bibulous paper plies with wax becomes extremely significant. If there is a void which is exposed as the result of the cutting operation, acid will enter the void and eat away the adjacent metal, not upon its outer edge as is desired but with the compass of the coil itself, the result being in many cases to cut completely through the metal and thus produce a coil with an open winding. The same adverse result takes place in paper areas where saturation by the impregnant is not complete, the acid being drawn into the bibulous paper to attack the adjacent metal surface.

Finally, the presence of a void in the interior of the windings will often result in bringing it about that the advancing knife blade will not cut through the metal foil but rather pull it out sideways from between adjacent layers of insulating material, thus ruining the product.

FIGS. 4 and 5 are sections through portions of coils of the type herein disclosed and were drawn to illustrate the adverse effects produced by incomplete saturation of the paper and by voids resulting from slight irregularities in the winding operation and incomplete impregnation. It is to be noted that these drawings are not represented to be actual images but are to be taken as illustrative and suggestive of the difficulties herein discussed.

In FIG. 4 a blade **30** is shown entering the roll to cut off an individual coil **28**. As previously set forth, the roll comprises an outer casing of cardboard **32** enclosing superposed spiral layers of paper **14**, plastic film **16**, paper **18** and metal foil **20**. It has been assumed for purposes of illustration that the impregnation was incompletely carried out with the result that there was an absence of wax in the paper layers **18'** and **14''** the result being that the edge of the advancing blade **30** is pulling the metal layer **20'** out from between the two adjacent paper layers, leaving a hole **34**. This action is shown as it has progressed to a point where the metal layer **20'** is pulled about half way out, it being understood that further inward movement of the blade **30** might well result in a complete bodily displacement of the layer **20'**.

It has also been assumed that a portion of the paper layer **14'''** has not been saturated with wax. The swaged edges of the metal layers **20** and **20'** are suggested at the right hand end of FIG. 4.

FIG. 5 represents a section through the same coil shown in FIG. 4 but after the completion of the cutting and etching operations. Here it will be seen that the hole **34** resulting from the lateral displacement of the metal layer **20'** now extends completely through the coil. It will also be seen that acid has infiltrated the layer **14'''** and attacked the metal layer **20''**, leaving only a filamentary vestige **46**. Incidentally, the desired effect of proper etching is illustrated by reference to the metal layer **20** from which the swaged edges or flanges have been eaten away by the acid, and the exposed edge of the layer now is recessed between the adjacent paper layers **18** and **14'**. FIG. 5 therefore shows at **20** the desired result, one form of defect at **34** due to insufficient bond of the metal to the adjacent paper layers, and at **44** and **46** the result of uncontrolled etching attacking the interior portions of the layer **20''**.

We have also discovered another important advantage resulting from the use of the plastic film. The passage of the knife through the coil tends to distort and bend the wax impregnated paper and the metal foil. These

elements have no appreciable resilience, the result being that a coil composed of foil and paper will be given a permanent "set" as the result of the cutting operation. On the other hand, the plastic film is sufficiently resilient to bring about a restoration of the edges of the layers in the foil after the cutting operation, particularly after the swaged edges of the foil have been renewed during the etching operation. While I regard it as preferable, for the reasons stated above, to employ the sandwich type of insulation herein shown, in order to secure the beneficial effect of the tough plastic film, I wish to point out that a single insulating layer of bibulous paper may also be employed to produce better results than have heretofore been accomplished.

Commercial experience with the type of coil herein disclosed and with the method of manufacture of my invention has shown that electrical coils of superior quality and of various sizes and characteristics can be, and are being, produced at a cost roughly 50% lower than is normally encountered, a reduction in cost which is expected to be significantly improved by the development of machinery for automatically carrying out the various steps herein disclosed.

Having described and illustrated a preferred embodiment of my invention, what I deem as new and desire to secure by Letters Patent of the United States is:

A method of making electrical elements, comprising winding upon a mandrel a plurality of turns of thin flexible metal foil interleaved with turns of insulating material to form a coil, each insulating turn comprising a film of homogeneous plastic material backed on both surfaces by plies of bibulous paper, baking the coil, immersing the coil in a wax bath, maintaining the immersion until the paper turns and voids in the coil have become completly saturated with wax, permitting the wax to harden, then cutting the wax-saturated coil transversely of its axis to form a plurality of smaller coils, and etching both surfaces of each of said smaller coils with acid.

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