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STRIP ELECTRICAL COILS
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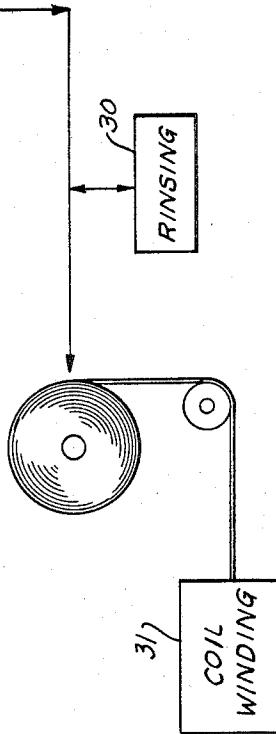
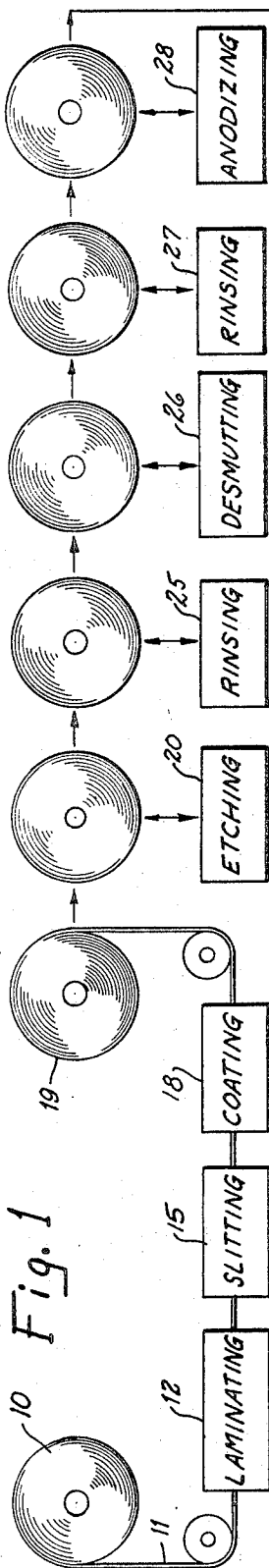


Fig. 3

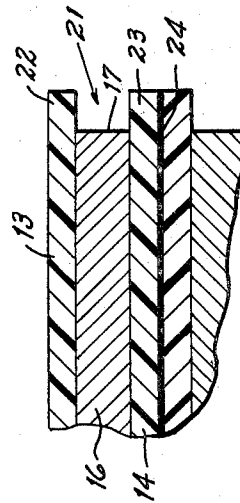
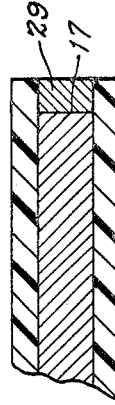


Fig. 4



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STRIP ELECTRICAL COILS

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Continuation-in-part of application Ser. No. 80,546, Jan. 4, 1961. This application Oct. 12, 1965, Ser. No. 495,297

The portion of the term of the patent subsequent to Dec. 13, 1983, has been disclaimed
5 Claims. (Cl. 336—206)

This is a continuation-in-part of my application Ser. No. 80,546, filed Jan. 4, 1961 and entitled "Aluminum Strip Roll for Forming Electrical Coils," now Patent No. 3,223,896, which application is a continuation-in-part of my application Ser. No. 10,851, filed Feb. 25, 1960, now abandoned, and entitled, "Aluminum Strip Electrical Coils."

This invention relates to the manufacture of strip electrical coils, and more particularly it relates to a method of making strip electrical coils and to rolls of metal strip formed for rewinding into electrical coils.

Electrical coils are often made up of a plurality of turns of flat metal strip such as aluminum with a continuous coating of dielectric material disposed between the turns of the coil to electrically insulate them from one another. Leaves of thin paper or a film of insulating enamel, varnish or lacquer are generally used as the dielectric coating between the turns of the strip. Alternatively, a deposit of aluminum oxide frequently serves the purpose.

It has been found that the most practical method of making the strips which form these coils is to cut them from a wider aluminum strip which has been previously coated or laminated with a dielectric material. One of the major advantages in coating the dielectric material over a single wide strip and then cutting from it the individual narrow strips is that one expansive coating can be formed with much more uniform thickness and quality than can many narrow coatings. Also, a succession of individual coatings cannot be applied nearly as economically as can one single coating.

It is evident, however, that when a relatively wide dielectric coated strip is cut longitudinally into narrower strips, the cutting operation exposes the aluminum base metal at the edge portions of the narrower strips and leaves them rough with slivers and burrs. These bared edge portions must be covered over, or otherwise they may cause short circuits between the turns of the coil. Various proposals have been offered to suitably insulate the exposed edges of otherwise insulated strips of coil width but none have proven to be both effective and economically practical. For example, it has been suggested that as the narrower strips emerge from the cutting station their edge portions may be folded inwardly so that the periphery of the folded strip is defined by fold lines covered with the previously applied dielectric material. A forming operation of this type is rather complicated and expensive, and it has been proposed instead that a layer of varnish or lacquer be spread over the edge portions of the strip after it leaves the cutting station. This, however, does not effectively insulate the strip edges because frequently the roughened edges project through the applied varnish and short circuiting may still occur. Furthermore, such a second application of varnish overlaps the originally applied dielectric coating and causes variations in the thickness of the insulation between the turns of the coil.

It is the major purpose of this invention to provide a method of forming insulated aluminum strip for electrical coils which avoids all these various shortcomings

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found in the conventional methods. Broadly stated, the new method is in combination with the method of making an electrically insulated strip conduction wherein a dielectric film is applied to at least one of the sides of a relatively wide strip of metal and the wide strip is cut into a plurality of relatively narrow strips, which are each bare of the film at their edge portions. The improvement comprises the steps of winding at least one of the narrow strips into a coil in which the bare edges of the narrow strip are exposed at the end faces of the roll. A sealant is applied to at least the edge portions of the strip on at least one side thereof but leaving bare the side edges of the strip and thereby the sealant seals the turns of the roll. The roll is immersed in an etching bath to etch back to the side edges to a width less than the width of the film to define integral marginal edges of said films with the sealant maintaining the roll free from blocking by preventing penetration of the etching solution between the turns of the roll. The strip is then unwound from the roll and wound into an electrical coil. The dielectric film is advantageously a dielectric organic material such as varnish or lacquer, or it may be an inorganic material such as an anodic film or a thin organic sheet laminated to the face of the strip.

It sometimes happens, however, that when the invention is practiced to this extent a certain amount of binding occurs between the turns of the wound strip which makes it difficult to unwind the roll in use. This is not always the result, but it does happen frequently enough to warrant protective measures in the invention. Apparently one of the major causes of this inter-turn sticking or binding problem (which is known as "blocking") is that the organic dielectric film is often a thermoplastic resinous material which plasticizes between the turns. Such plasticizing sometimes occurs when the rolls are immersed in high-temperature cleaning baths or when exposed to the electrolyte, and it causes the organic coating to become tacky and adhere to the turns.

Accordingly, it is to be noted that the invention also provides applying a sealant to at least the edge portions of the strip on at least one side thereof and leaving bare the edges of the strip, whereby the compound is disposed between and seals the turns of the roll. With the turns of the roll sealed by this compound, the hot cleaning solutions, etching solutions, or the electrolyte cannot penetrate between the turns to plasticize the organic coating and blocking is prevented. Also, no residual deposits of etching solutions or electrolyte can remain between the turns to corrode or otherwise attack the metal. The sealing compound need not extend entirely across the strip between the turns since it usually suffices only to seal the edge portions, but if it is likely that the entire roll will be heated to the plasticizing temperature of the organic coating then it is preferable to cover the strip edge-to-edge with a sealing compound or a thin plastic sheet which will resist attack of the solutions or electrolyte and has a high plasticizing temperature.

The invention also provides a roll of strip conductor formed for rewinding into electrical coils which is comprised of an extended length of conductive metal strip wound into a multi-layer roll, which strip has a dielectric film adherent to at least one of its broad faces and is disposed between successive layers of the roll. The side edges of the strip are free from the film and are etched back to a width less than the width of said film to define integral marginal portions of said insulating films which extend beyond the side edges of said strip. A sealant is disposed between and seals the turns of the roll on at least the marginal edge portions of the strip on at least one side thereof, with the side edges of the strip being free from said compound, the roll is wound with the suc-

cessive layers formed by adjacent turns of the strip being free from blocking and separable from each other so that rewinding into electrical coils is permitted.

In accordance with the method of the invention only one coating operation or one lamination of dielectric film is required to properly insulate one or both broad flat faces as desired, of a considerable number of the relatively narrow strips. Hence, particularly uniform thickness and continuity is imparted to the insulation between the turns of the individual rolls or coils. Also, when anodizing the edges of aluminum strip, all of the bared base metal on the edge portions of the narrower strips is effectively insulated by the deposition of oxide thereon. Such an oxidic dielectric coating is practically always continuous because the oxide forms on any of the exposed base metal, even on the edge portions of the strip between the turns of the roll or coil where some of the varnish has flaked off during the cutting operation. Since the edges are etched back any burns and slivers on the edges of the strip are removed by chemical attack when the roll is submerged in the electrolyte.

In one preferred embodiment of the new method, a relatively wide aluminum strip of say .003 inch thickness is run over one or more applicator rolls carrying a liquid organic dielectric coating composition, for example a polyvinyl acetal or a silicone insulating enamel, whereby a layer of such composition of uniform thickness is transferred to the surface of the advancing aluminum strip. Any conventional coating apparatus and method may be used, and the strip may be coated on only one side or on both sides, as desired. Upon emerging from this coating apparatus, the coating composition is dried to a hardened condition. Alternatively, the wide strip may be covered by an inorganic dielectric coating, such as an anodic film, in which case the later-applied anodic edge-coating is still separate from insulation on the broad surface of the strip. The coated wide strip is then directed through continuous cutting apparatus where it is divided longitudinally into a plurality of narrow strips, each the width of a roll.

Any type of cutter used in this step bares the aluminum base metal and leaves a certain amount of slivers, burrs or other irregularities on the edges of the narrow strip. Also, the cutters often flake off small amounts of dried varnish from portions of the flat sides of the narrow strips adjoining their newly cut edges.

The narrow strips exiting from the cutting apparatus are then directed into winding apparatus where they are formed into rolls of a multiplicity of turns about suitable cores. The cores preferably are made either of aluminum, or of an electrically non-conducting material which is resistant to attack in the subsequent anodizing operation. Aluminum cores, although conducting, soon become insulated by becoming coated with a non-conducting anodic film in the anodizing operation and so are equivalent to non-conducting cores for purposes of this invention.

Both flat ends of the cylindrical rolls so wound are defined, of course, by the exposed edges of the aluminum strip which are in ragged condition as a result of the cutting operation. Small flakes of varnish may be missing between edge portions of the successive turns so that in addition to their roughness the strip edges defining the sides of the roll also have small gaps between them. The roll is then transferred to an etching bath where the side edges are etched back to remove a portion of the strip conduction along the side edges and leave a void between the insulating films and define new side edges of smaller width than the width of the insulating films. Marginal edge portions of the insulating films extend laterally outward beyond the side edges of the strip conductor on both sides, and the side edges are still free from insulation. The etching bath can contain any of the conventional etching reagents such as 15 percent NaOH at 150° F. The period of etching is dependent upon the desired depth of etch. The rolls are then taken in batches to anodizing equip-

ment where they are subjected to conventional cleaning operations and then are lowered into an electrolytic bath which may advantageously be chromic, sulphuric, oxalic or other acid, or it may be a caustic alkaline bath. Low-voltage direct current (or sometimes alternating current) is passed through the bath with each of the rolls therein serving as the anode. A lead, stainless steel, or other conducting electrode is employed as the cathode. A film of aluminum oxide is thereby formed on any surface exposed to the electrolyte. Thus all exposed edges of the narrow strips defining the flat sides of the rolls are covered with an even and continuous insulating anodic film.

When the roll core is aluminum, it too becomes anodized and thus electrically insulated. Insulated or non-conducting cores are desirable to minimize the tendency for the anodizing current to by-pass interior turns of the roll in cases where the core is supported in the anodizing equipment on a supporting element which is anodically charged.

When the anodizing is completed, the batch of rolls is lifted from the bath, rinsed and dried. The resulting rolls each comprises a multiplicity of turns of aluminum strip which is electrically insulated on one or both flat faces by the coating composition, and at both side edges by the oxidic anodized film. Such strip is eminently suited for being rewound from the roll into electrical coils, to which suitable leads may be attached. Alternatively, in some cases leads may be attached to the strip when it is first wound into rolls directly after slitting, and such rolls after having their side edges anodized in the manner described may be employed without further preparation as electrical coils.

In general, the use of a sealant as described previously is warranted if the organic dielectric coating disposed between the edges of the strip is likely to plasticize after the roll is wound. For example, rolls of aluminum strip formed in accordance with the invention are normally subjected to a cleaning process wherein the strips are immersed in a mild caustic (for example, a 3-5 percent sodium hydroxide) solution before they are wound and the finished rolls are later submerged in a hot water rinse (near 212° F.) after anodizing. There are suitable organic dielectric coatings which will plasticize at temperatures below that of the hot water rinse and become tacky. Vinyl dielectrics, for instance, soften at about 175° F. When this happens, the turns of the wound roll stick together and it is difficult to unwind the strip in use.

Another major reason for carrying out the sealing process contemplated by the invention is that the electrolyte used in the anodizing step should be prevented from penetrating the turns of the wound rolls. One of the more common electrolytes is an aqueous 15 percent sulfuric acid solution which is readily drawn between unsealed turns of a roll by capillary action where it remains and later corrodes the metal or attacks the organic coating. Phosphoric and sulfonic acid electrolytes are also likely to penetrate a roll and chemically attack the metal or organic coating.

The sealant can be applied in at least three ways. It may be wiped over the flat sides of the strips before they are wound and thereby cover the strips edge-to-edge, or it may be drawn between the turns of a wound roll by impressing both end faces of a roll against a pad saturated with the compound, in which case edge-to-edge sealing between the turns is a possible but not necessary result or it may be applied in film form, such as a film of polyethylene which may be interleaved between turns of the roll when wound. In the first method the sealing compound may be chosen solely for its sealing properties, whereas in the second manner of application the compound should also be sufficiently low in viscosity to penetrate readily by capillary action between the turns. The third method demands attention of the type of plastic

selected and its plasticizing temperature in relation to the chemical baths selected and their operating temperatures. A clear pure mineral oil (such as a white refined hydrocarbon oil) has been found satisfactory for wiping the strips before they are wound and kerosene has proven to be advantageous for impregnation between the turns of a wound coil. These two examples of sealing compounds are by no means conclusive, however, since virtually any compound resistant to the electrolytes now used may be suitable. Generally, the best sealing compounds will be found among hydrophobic liquids.

In many cases, the penetration of the compound between the turns of a wound coil is the better method of application because less of the compound is used. When the compound is wiped over the sides of a strip before winding, much of it squeezes out from between the turns as the roll is formed. This can be somewhat messy for production purposes.

With either method of applying the compound to the rolls, it is necessary that the bared edges at the end faces of the rolls be left exposed thereafter so that they can be effectively etched and anodized in accordance with the invention. This can best be done by batch cleaning the sealed wound rolls in a bath such as a caustic solution. The sealing compound should be chosen then from among those which are capable of being dissolved in a caustic cleaning solution. Such cleaning steps satisfactorily bare the edges of the strip on the end faces of the roll but do not wash the sealing compound out from between the turns of the roll.

Films of sealing compound so deposited between the turns of a wound roll of electrically insulated strip serve to prevent penetration between the turns by the electrolyte or other liquids to which the roll is exposed. Thus, corrosion or other attack by those liquids is prevented. To fulfill this purpose it is generally necessary only to dispose the sealing compound along the two edge portions of the wound strip. In addition, the sealing compound serves as a release agent which prevents the organic dielectric coating on the strip from adhering to the turns of a roll together when such coating is heated above its plasticizing temperature. For purposes of achieving this end, the sealing compound should be disposed as far in toward the center of the strip as the over-heating is likely to progress. If necessary, the strip should be covered entirely from one edge to the other.

A second preferred embodiment of the invention is described hereinbelow with reference to the drawing wherein:

FIG. 1 is a schematic of one method for forming the coil;

FIG. 2 is an enlarged fragmentary section showing the side edges of a strip conduction after slitting from a relatively wide strip;

FIG. 3 is an enlarged fragmentary section taken along the side edge of a strip in a roll, after etching; and

FIG. 4 is an enlarged fragmentary section taken along the side edge of a strip in a roll after anodizing.

Here a roll 10 of aluminum strip 11 of a thickness of 0.005 inch was used. Although specific reference is being made to aluminum it is intended that copper strip can be used and the method followed is the same with the exception that the edge anodizing step is not performed. The strip 11 being removed from the roll 10 is too wide for windings and is first coated with any of the dielectric coating compositions described with respect to the first embodiment or as in this specific example it is laminated at the laminating station 12 on one or both of its broad faces without this dielectric film. In one example the strip 11 was laminated without 1½ inch thickness film of polyethylene terephthalate (e.g. Mylar, tradename of E. I. du Pont de Nemours and Co., Inc., Wilmington, Delaware) and in a second example a strip of aluminum of the same thickness was laminated on both its faces with ½ inch thickness of polyethylene terephthalate.

The wide strip 11 with dielectric films 13 and 14 on both broad faces is then directed through a slitting station 15 where conventional cutting apparatus is located for slitting the advancing strip longitudinally into a plurality of narrow strips 16. Upon slitting, the side edges 17 of the strip are bare of any insulation and the dielectric films are coextensive with the side edges of the strip as shown in FIG. 2.

The narrow strips 16 exiting from the cutting apparatus can then be coated at a coating station 18 with mineral oil as described above, or can be interleaved without this plastic sheet, such as polyethylene. The roll can also be interleaved without hydrocarbon oil by winding into a roll and then immersing the roll into a bath and drawing the oil between turns by capillary action as described in the first embodiment. After leaving the coating station the strip is wound into a roll 19 with the sealant disposed between turns of the roll.

The roll 19 is then transferred to the etching station 20 where it is immersed in an etching bath and the side edges 17 are etched back to remove a portion of the strip conduction and leave a void 21 between dielectric films on both broad faces and a strip conduction of reduced width from the width of the dielectric films. Marginal edge portions 22 and 23 of the circulating film extend laterally out beyond the side edges 17 of the strip conduction. The etchant is preferably the 15 percent NaOH solution described above, and in roll form it was found that 20 minutes were required with a bath temperature of 150° F. to etch back 6 mils of strip conductor.

During etching the sealant 24 (shown in FIG. 3) serves as a barrier to the etchant penetrating between the turns of the roll where it might react with the dielectric film and bond the turns together.

After etching, the roll is rinsed in running water in the rinsing station 25 and then is passed to a desmutting station 26 for desmutting the edges and core by immersion in a 10 percent HNO₃ solution which is maintained at room temperature.

After desmutting the roll is transferred to a second rinsing station 27 where it is immersed in hot running water.

Following this rinsing operation, the roll is transferred to an anodizing station 28 and the bare edges are anodized as described with respect to the first embodiment to form an oxidic dielectric layer 29 on the side edges 17 of the strip conductor. The roll is then transferred to a third rinsing station 30 where the roll is rinsed in running water and the roll is now prepared for unwinding and rewinding into a coil at the coil winding station 31. Because of the presence of the sealant throughout the operations this unwinding and winding into coil form is effected into blocking between turns.

It is intended that the anodizing operation can be eliminated in many applications. The anodizing operation whereby additional dielectric protection is provided to the otherwise bare edges of the metal, is a safety factor. It becomes more desirable as the thickness of the dielectric film decreases and with thick films it may not be necessary at all.

In the following claims, which define the scope of the invention, the term "aluminum" is intended to cover both commercially pure aluminum and any aluminum-base alloys which are suitable for use in electrical coils. Also, in those claims reciting the use of the sealing compound, it is to be understood that the step of applying the compound can be carried out either before or after the winding of the roll, unless otherwise indicated. It is further intended that by strip conduction metal is meant aluminum or copper of the grades commonly used for strip conduction. Of course when copper is used the anodizing operation is eliminated.

I claim:

1. A roll of strip conductor formed for rewinding into electrical coils comprising an extended length of conduc-

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tive metal strip wound into a multi-layer roll, said strip having a dielectric film adherent to at least one face thereof which is disposed between successive layers of the roll, side edges on said strip which are free from said film and are etched back to a width less than the width of said film to define integral marginal portions of said insulating films which extend beyond the side edges of said strip, and a sealant disposed between and sealing the turns of the roll on at least the marginal edge portions of the strip on at least one side thereof with the side edges of the strip being free from said sealant, said roll being wound with the successive layers formed by adjacent turns of the strip being free from blocking and separable from each other so that rewinding into electrical coils is permitted.

2. A roll of strip conductor according to claim 1 wherein said sealant is disposed between and seals the turns of the roll on at least the marginal edge portions of the strip on both sides thereof.

3. A roll of strip conductor according to claim 1

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wherein said strip is aluminum and a distinct dielectric oxide layer covers and insulates the side edges of the strip.

4. A roll of strip conductor according to claim 1 wherein a sealing compound of hydrocarbon oil is used as sealant.

5. A roll of strip conductor according to claim 1 wherein said sealant is a dielectric film laminated to the strip conductor.

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