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ALUMINUM STRIP ROLL FOR FORMING ELECTRICAL COILS

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This application is a continuation-in-part of my application, Serial No. 10,851, filed February 25, 1960, now abandoned, and entitled "Aluminum Strip Electrical Coils."

This invention relates to the manufacture of electrically insulated aluminum strip. More particularly, it is directed to a method wherein a strip of aluminum covered on one or both sides with a dielectric material is cut into narrow strips which are wound into rolls and oxidized so that the edge portions thereof are insulated with an oxidic dielectric film. In addition, the invention provides a novel method for sealing the turns of the wound rolls to prevent penetration by the electrolyte into the rolls during formation of the oxidic dielectric film. The invention relates also to strip produced by the method of the invention, and to electrical coils made from such strip.

Electrical coils are often made up of a plurality of turns of flat aluminum strip 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 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 found in the conventional methods. Broadly stated, the method comprises the steps of first applying a continuous dielectric coating to at least one side of a relatively wide strip of aluminum. Such dielectric coating is advantageously a dielectric organic material such as varnish or lacquer, or it may be an inorganic such as an anodic film. This wide coated strip is then cut into a plurality of relatively narrow strips which are each bare of the coating at their edge portions. Then, at least one of the narrower strips is wound into a roll in which the bared edges of the strip are exposed at the side faces of the roll. Finally, the side faces of the roll are treated to form a continuous oxidic dielectric film deposited on the bared edge portions of the strip. Preferably, this oxidizing step is carried out by anodizing the rolled-up strip in an electrolytic bath. The strip thus formed which is itself part of the invention, comprises an aluminum strip having a continuous dielectric coating composition adherent to at least one face, and further having a dielectric oxidic layer covering and insulating it side edges.

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 coating 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, the invention also provides applying a sealing compound 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 or the electrolyte cannot penetrate between the turns to plasticize the organic coating and blocking is prevented. Also, no residual deposits of 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 temperatures of the organic coating then it is preferable to cover the strip edge-to-edge with the sealing compound.

The invention also provides a novel electrical coil. In general, the coil comprises an extended length of aluminum strip wound into a multi-layer coil. The strip has a continuous film of dielectric coating composition adherent to at least one face thereof disposed between successive layers of the coil. The strip further has a dielectric oxidic layer covering and insulating its edge portions the composition being separated from the dielectric layer.

In accordance with the method of the invention only one coating operation is required to properly insulate one or both flat faces or sides, 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, 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. Moreover, by forming the dielectric oxide in an anodizing operation wherein an acidic electrolyte is employed, a considerable amount of the burrs and slivers on the edges of the strip are removed by chemical attack when the roll or coil is submerged in the electrolyte. The oxidic insulation also does not overlap onto the previously applied dielectric material covering the flat sides of the strip as is the case when additional oragnic material is applied to the strip edge portions.

In a 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 rolls are taken in batches to anodizing equipment 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 and the particularly small slivers and burrs on the strip edges are removed. 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 sealing compound 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 sulfamic acid electrolytes are also likely to penetrate a roll and chemically attack the metal or organic coating.

The sealing compound can be applied in at least two 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. 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. 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 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 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.

In the following claims, which the 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.

I claim:

1. A roll of aluminum strip formed for rewinding into electric coils comprising an extended length of aluminum strip wound into a multi-layer roll, said strip having a continuous film of dielectric coating composition 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 composition, a sealing compound 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 compound, and a distinct dielectric oxidic layer covering and insulating said side edges of the strip, 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 electric coils is permitted.

2. A roll of aluminum strip formed for rewinding into electric coils comprising an extended length of aluminum strip wound into a mutli-layer roll, said strip having a continuous film of dielectric coating composition 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 composition, a sealing compound disposed between and sealing the turns of the roll on at least the marginal edge portions of the strip on both sides thereof with the side edges of the strip being free from said compound, and a distinct dielectric oxidic layer covering and insulating said side edges of the strip, 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 electric coils is permitted.

3. A roll according to claim 1 wherein said sealing compound is a hydrocarbon oil.

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