Aug. 16, 1960 J. STALEY ET AL 2,949,593

ELECTRICAL COIL FORMED FROM MULTI-LAYER STRIP CONDUCTOR

Filed May 9, 1957

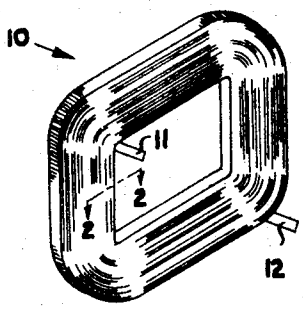


Fig. 1

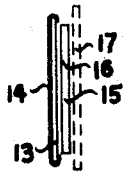


Fig. 2

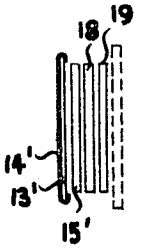


Fig 2A

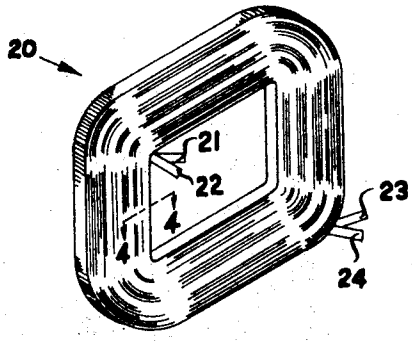


Fig. 3

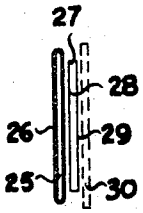


Fig 4

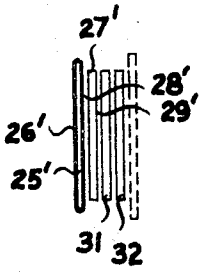


Fig 4A

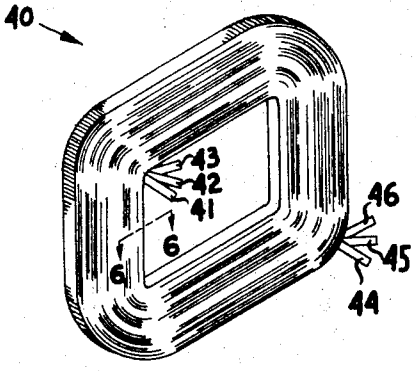


Fig. 5

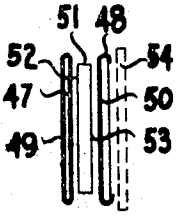


Fig. 6

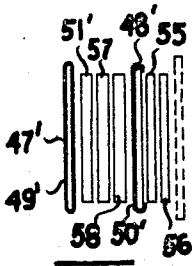


Fig. 6A

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ELECTRICAL COIL FORMED FROM MULTI-LAYER STRIP CONDUCTOR

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3 Claims. (Cl. 336—186)

This invention relates to an improved multi-layer strip conductor suitable for use in electro-magnetic coils as employed in transformer, solenoids, motor and generators fields, as well as in other forms of apparatus wherein electrical conductors in a bent or curved form are used. In particular, the invention relates to an improved coil with a winding including a multi-layer strip conductor having insulated and uninsulated electrically conductive components adapted to be wound to provide an insulated coil and with the several components of the conductor being physically separate from each other. It is well adapted to use in heavy duty coils, as in large size transformers wherein relatively thick conductors insulated by an inorganic coating and capable of operating at high temperatures are employed.

The advantages of an inorganic anodized film on a strip conductor, such as aluminum oxide on aluminum foil, over other types of applied insulation, are well known. In general, such anodic coatings not only give more permanent insulation, but also permit operation of the electrical equipment at higher temperatures and provide adequate insulation with a minimum of insulation thickness.

By means of the methods of edge treatment of such strip conductors, as disclosed in the co-pending application for U.S. Letters Patent, Serial No. 487,457, filed February 9, 1955, of which we are two of the three inventors thereof, such slitted strip conductors may now be provided with an anodically deposited insulation which affords uniform insulating ability and such insulation may be placed not only on both edges but, as desired, upon one or both sides of the conductor. As is known, however, even when the strip conductor is provided with the uniform inorganic insulation, the appreciable cost of that insulation and its inherent tendency to crack when bent upon a small radius are still present and may constitute disadvantages. It is these and similar limitations of the electrical conductor art which our invention is intended to overcome.

An object of our invention is to provide an improved multi-layer strip conductor having insulated and uninsulated electrically conductive components.

Another object is to provide an improved insulated electrical coil having a winding comprising a multi-layer strip conductor with insulated and uninsulated electrically conductive components.

Another object is to provide an improved multi-layer strip conductor characterized by its mechanical flexibility.

A further object is to provide an improved multi-layer strip conductor with a relatively small insulated surface in proportion to its total cross section.

A further object is to provide an improved heavy duty anodically insulated electrical coil adapted to be wound with relatively small mechanical force and to conform readily to a predetermined shape of coil.

Other objects and advantages will become apparent as the description proceeds and when considered in conjunction with the accompanying drawings in which

Figure 1 is a perspective view of one form of coil embodying the invention and having a single electrical circuit therethrough;

Figure 2 is an illustration of the inner turn of the coil winding taken along line 2—2 of Figure 1;

Figure 2A is an illustration of the inner turn of a modified form of winding for heavy duty usage in a coil such as shown in Figure 1;

Figure 3 is a perspective view of a second form of coil embodying the invention and having two electrical circuits therethrough;

Figure 4 is an illustration of the inner turn of the coil winding taken along line 4—4 of Figure 3;

Figure 4A is an illustration of the inner turn of a modified form of winding for heavy duty usage in a coil such as shown in Figure 3;

Figure 5 is a perspective view of a third form of coil embodying the invention and having three electrical circuits therethrough;

Figure 6 is an illustration of the inner turn of the coil winding taken along line 6—6 of Figure 5; and

Figure 6A is an illustration of the inner turn of a modified form of winding for heavy duty usage in a coil such as shown in Figure 5.

In carrying out our invention we subdivide the strip conductor into physically separate insulated and uninsulated electrically conductive components which are so related that when wound into coil form the adjacent turns of that coil are insulated from each other. We have found that the ability of an anodically insulated strip conductor to bend about a coil forming mandrel or the like, without damage to the insulation, is in general inversely proportional to the thickness of that conductor. In contrast, an uninsulated conductor portion of the same material and of comparable or much greater thicknesses may be freely bent about the same mandrel without difficulty. By employing as the insulated component a thin conductor strip having its edges and at least one side covered by an anodic insulation placed thereon following a suitable edge treating operation (as disclosed by the above patent application) and by employing as the uninsulated component any desired number of bare strip conductors of any desired thicknesses, we provide a composite strip conductor which achieves the objectives set forth above. One additional advantage of our invention is that the eddy current losses are lower than by using conventional techniques. It will be noted particularly that each of the strip layers so employed is separate from the other layers and all are simultaneously bent into shape during the coil forming operation. The composite strip conductor is referred to herein as a multi-layer strip conductor.

Referring now to Figs. 1 and 2 showing an elementary form of our invention, a simple coil indicated at 10 may comprise a winding having a number of turns and forming a single electrical circuit. Terminal leads 11 and 12 extend laterally from the winding.

As shown in Fig. 2, the innermost turn of the multi-layer strip conductor includes a thin metal strip 13 which may consist of aluminum foil for example, having a width greatly in excess of its thickness. The strip 13 serves essentially as a mounting means for the coil insulation although it also contributes to the electrical conductivity of the winding. The strip 13 may comprise aluminum foil or sheet having a thickness in the range of 0.00017 to 0.060 inch or higher and on a first side thereof is covered with an anodic coating of aluminum oxide 14 have a thickness of about 0.0001 to 0.001 inch. The rounded lateral edges of strip 13, having previously been subjected to one of the aforementioned edge treating operations, also are covered with the same anodic coating which preferably extends around those edges and terminates on the second side of the strip along parallel

lines disposed inboard of these edges at a distance equal to about 2–3 times the thickness of the strip **13**. As will thus be seen, a substantial saving in the cost of depositing the anodic insulation is gained without adversely affecting the use of the coil, since the entire strip **13** need not be insulated. By reason of the flexibility due to its small thickness, the strip **13** may be bent upon the coil forming mandrel without damage to the inorganic insulation **14**. In order to provide the necessary electrical conductivity for the coil when using the flexible thin strip **13**, another strip **15** which may comprise uninsulated aluminum foil of greater thickness and of less width is disposed in contact with the second side of strip **13** and is bent simultaneously therewith in the forming of coil **10**. The strips **13** and **15** are physically separate although in frictional contact with each other. Since no insulation is present between the juxtaposed surfaces found at the second side of strip **13** and the first side of strip **15**, these strips form a single electrical circuit through the coil and are jointly attached to the leads **11** and **12**, at the respective ends thereof. It can be appreciated that strip **13** may have insulation applied to both sides and still be in electrical contact with uninsulated strip **15** by virtue of the ends of the two strips being physically and electrically united to the same terminations **11** and **12**. On the inner or second side **16** of the innermost turn of the winding, as seen in Fig. 2, a suitable separate insulating layer of material indicated in dotted lines at **17** normally is interposed between that side and the surface of the electrical device upon which the coil may be used. However, in some cases, it is desirable to leave this inner or second side uncovered so that it may come into direct electrical contact with an electrical conducting member onto which it is mounted. It will be understod that Fig. 2 illustrates only a single turn for simplicity and that in the adjacent turn the uninsulated second side **16** will lie in contact with insulated first side **14** of the first turn and that this relation continues throughout the remainder of the coil. We prefer to employ strip **16** with a width less than the width of strip **13** so as to minimize the possibility of arcing between adjacent turns. However, if desired, the strips **13** and **16** may be of equal width or strip **16** may be even of greater width and supplementary insulation may be used over the edges of those strips when the coil is formed. As used herein, the terms "uninsulated component" and "uninsulated layer" are intended to apply to strip **16** and similar components of the strip conductor when its sides are uninsulated regardless of whether its edges may have such supplementary insulation.

In heavy duty usage for this form of coil wherein a substantial cross section of conductor is required, the multi-layer strip conductor may include a large number of uninsulated strips all comprising a single electrical circuit through the coil but capable of being readily wound as a unit. As shown in Fig. 2A, the multi-layer conductor may include not only the thin strip 13^1 insulated at 14^1 and the adjacent uninsulated strip 15^1, but also other uninsulated and physically separate strips **18** and **19**, as well as others, if so desired. As will be apparent, by subdividing the required conductor cross section into a plurality of separate strips, not only is it possible to bend the anodized portion without damage thereto, but also the mechanical force required to bend the uninsulated portion is reduced and the separate strips or layers at the same time permanently conform more readily to the formation dictated by the winding mandrel. Of special significance, the amount of surface of the composite conductor covered by the anodic coating, when compared to the total cross section of the composite conductor, is relatively small and this factor is most noticeable in heavy duty forms of coils wherein an integrally formed strip conductor would necessarily be thick and subjected to insulation damage during the coil formation.

Referring now to Figs. 3 and 4, a form of coil is shown in which two circuits may be established therethrough. Coil **20** is provided with duplicate terminal leads **21**, **22** and **23**, **24** at the ends of the multi-layer strip conductor. This conductor, as shown in Fig. 4, includes as its insulated component a thin strip of metal **25** completely covered with an anodically deposited insulating coating **26**, such as aluminum oxide. At its ends the strip **25** is connected to terminals **22** and **24**, thus forming an insulated electrical circuit through the coil. As its uninsulated component, the conductor includes at least one separate strip **27** whose sides are uninsulated and one side **28** of which is adapted to contact the insulation **26** of strip **25** on one of the sides of that insulated strip and the other side **29** of which is adapted to contact the insulation **26** of strip **25** on the other side of that insulated strip in the wound arrangement of the conductor. As in the form of coil shown in Fig. 1, a separate insulating member **30** may be provided on the innermost section of the inner turn of the coil. At its ends the strip **27** is connected to terminals **21** and **23** thus forming a second electrical circuit through the coil, which separate circuit is insulated by reason of the relation of the uninsulated component of the strip conductor with respect to the insulated component thereof. As in the case of the coil in Fig. 1, the thin, anodically insulated strip **25** may be bent without damage to its insulation, but in this modification, the ratio of the insulated surface of the composite strip conductor to its total cross section is greater and thus a more expensive conductor is required. However, in usages wherein two circuits through the coil are needed, the expense of anodizing the uninsulated layer is avoided.

For heavy duty usages of coils having two circuits therethrough, a modified form, as shown in Fig. 4A, may be used. The strip 25^1 with its insulation 26^1 forms the insulated component of the multi-layer conductor, but strip 27^1 with its bare sides 28^1 and 29^1 forms only a portion of the uninsulated component. Depending upon the metal employed and the total cross sections required, additional uninsulated strips, such as shown at **31** and **32**, are used. It will be understood that in this modified form of coil, strip 25^1 is connected to terminals **22** and **24** to form one circuit and that strips 27^1, **31** and **32** are jointly connected to terminals **21** and **23** to form the second circuit.

In certain cases more than two circuits through the same coil may be required and in Fig. 5 a coil is shown embodying our invention and in which three circuits are used. It will be understod that the number of circuits may be multiplied indefinitely in coils of this type without departing from the invention, but, for brevity, only three variations of coils are described herein.

Referring to Figs. 5 and 6, coil **40** is provided with triplicate terminal leads, **41**, **42**, **43**, and **44**, **45**, **46** at the ends of multi-layer conductor. As seen in Fig. 6, this conductor includes as its insulated component two spaced thin strips of suitably insulated metal **47** and **48**. Strip **47** may be completely covered with an anodically deposited insulating coating **49** in which event strip **48** is covered with the coating only on the confronting side **50**. However, if desired, the strip **48** can be completely covered, in which event, the other strip **47**, is covered only on the side confronting the strip **48**. At its ends the strip **47** may be connected to terminals **41** and **44** to form one circuit and the strip **48** at its ends may be connected to terminals **43** and **46** to form a second circuit.

As its uninsulated component, the conductor includes at least one separate strip **51** whose sides are uninsulated, one side **52** being in contact with the insulation **49** of strip **47** and the other side **53** being in contact with the insulation **50** of strip **48**. As in the case of the coils of Figs. 1 and 3, a separate insulating member **54** may be provided on the innermost section of the inner turn of the coil. At its ends the strip **51** is connected to terminals **42** and **45** thus forming a third circuit through the coil.

For heavy duty usage of coils having three circuits, a modified form, as shown in Fig. 6A, may be used. The

strip 47^1 with its insuating 49^1 forms the first circuit. The second circuit is formed by strip 48^1 and one or more uninsulated strips 55, 56 in contact with the uninsulated side of strip 48^1. Between the spaces confronting insulated sides 49^1 and 50^1 of the insulated component of the conductor, uninsulated strip 51^1 and one or more similar strips 57, 58 are disposed in contact with each other. It will be understood that in this modified form of coil strip 47^1 and strips 55, 56 are jointly connected to terminals 43 and 46 and strips 51^1, 57, 58 are jointly connected to terminals 42 and 45, thus to form three separate circuits through the same coil.

It will be appreciated that in each of the figures depicting the several forms of coil embodying our invention, the respective strips or layers of the conductor are not drawn to scale. In general, the thickness of the insulated component or components of the composite multi-layer strip conductor is appreciably less than the thickness of the uninsulated component or components and in the preferred forms of coils the total cross section of all insulated components is less than the total cross section of all of the uninsulated components. The thin insulated component in all cases is flexible and may be bent into the desired coil shape without damage to the insulation.

We prefer to employ for all strips an aluminum foil or sheet with rounded edges although if desired the rounded edge strips may be used only for the insulated components of the multi-layer strip. Moreover, in its broader aspects, the invention may be carried out with other insulation material or with other electrically conductive materials than aluminum, such as copper, or may be employed with some layers of the conductor formed of aluminum and other layers formed of copper.

Therefore, while we have shown particular embodiments of our invention, it will be understood of course, that we do not wish to be limited thereto, since many modifications may be made; and we therefore contemplate, by the appended claims, to cover any such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electrical coil construction including a multi-layer flexible strip conductor wound in turn layer form, said conductor comprising a first layer consisting of a single aluminum strip having first and second sides and rounded edges, and a second metallic layer having uninsulated first and second sides, said layers being substantially coterminous and being arranged in side-by-side contact with each other, each of said layers being physically separate from each other and readily bendable around a forming mandrel, said first layer having an aluminum oxide insulation covering said first side thereof and establishing an insulating relation with respect to the second side of said second layer in the next succeeding turn of said coil and being uninsulated on at least a portion of the second side thereof for uninsulated contact with the first side of said second layer, and terminals for said coil attached at at least one of said layers at the ends thereof and serving to connect said layers in parallel.

2. An electrical coil as defined in claim 1 and adapted for heavy duty usage and wherein said second layer comprises a plurality of uninsulated strips of material.

3. An electrical coil construction including a multi-layer flexible strip conductor wound in turn layer form, said conductor comprising a first layer consisting of a single aluminum strip having first and second sides and rounded edges, and a second metallic layer having uninsulated first and second sides and with a thickness greater than and width less than that of said first layer, said layers being substantially coterminous and being arranged in side-by-side contact with each other, each of said layers being physically separate from each other and readily bendable around a forming mandrel, said first layer having an aluminum oxide insulation covering said first side and the edges thereof and establishing an insulating relation with respect to the second side of said second layer in the next succeeding turn of said coil and being uninsulated on at least a portion of the second side thereof for uninsulated contact with the first side of said second layer, and terminals for said coil attached to at least one of said layers at the ends thereof and serving to connect said layers in parallel.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,949,593 August 16, 1960

John Staley et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 40, for "Serial No. 487,457" read -- Serial No. 487,057 --.

Signed and sealed this 3rd day of January 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

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