# United States Patent

[11] 3,587,169



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[73] Assignee **Westinghouse Electric Corporation,**
**Pittsburgh, Pa.**


## [54] METHODS OF TRANSPOSING SHEET MATERIALS

**14 Claims, 43 Drawing Figs.**


[52] **U.S. Cl.** ..... **29/624,**
29/605, 156/49, 174/34, 310/213, 336/187
[51] **Int. Cl.** ..... **H01f 7/06**
[50] **Field of Search** ..... 29/605,
624, 628; 156/49; 174/34, 114; 336/187; 310/213



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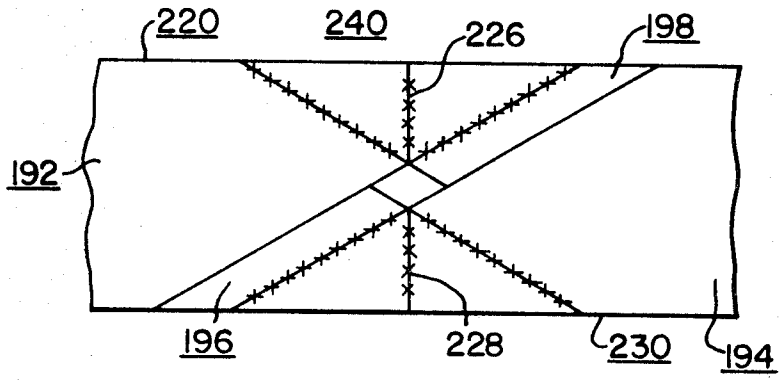
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*Primary Examiner*—John F. Campbell
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**ABSTRACT:** Methods of radially transposing radially adjacent electrically conductive sheet materials in an electrical winding, which include forming notches in opposite edges of the through the notch in the other. The notches are formed by cutting each of first and second sheet materials to be transposed into first and second separate portions, and folding the cut ends of the portions in a predetermined manner. The first and second portions of the first and second sheet materials are electrically joined, with the folding providing a notch in one edge of the resulting composite conductor, and the second and first portions of the first and second sheet materials are electrically joined, with the folding providing a notch in the opposite edge of this composite conductor. The composite conductors are inherently radially transposed by the method of forming them, and the transposed conductors maintain radial alignment by each proceeding through the notch in the other.

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SHEET 1 OF 5

FIG. 1.

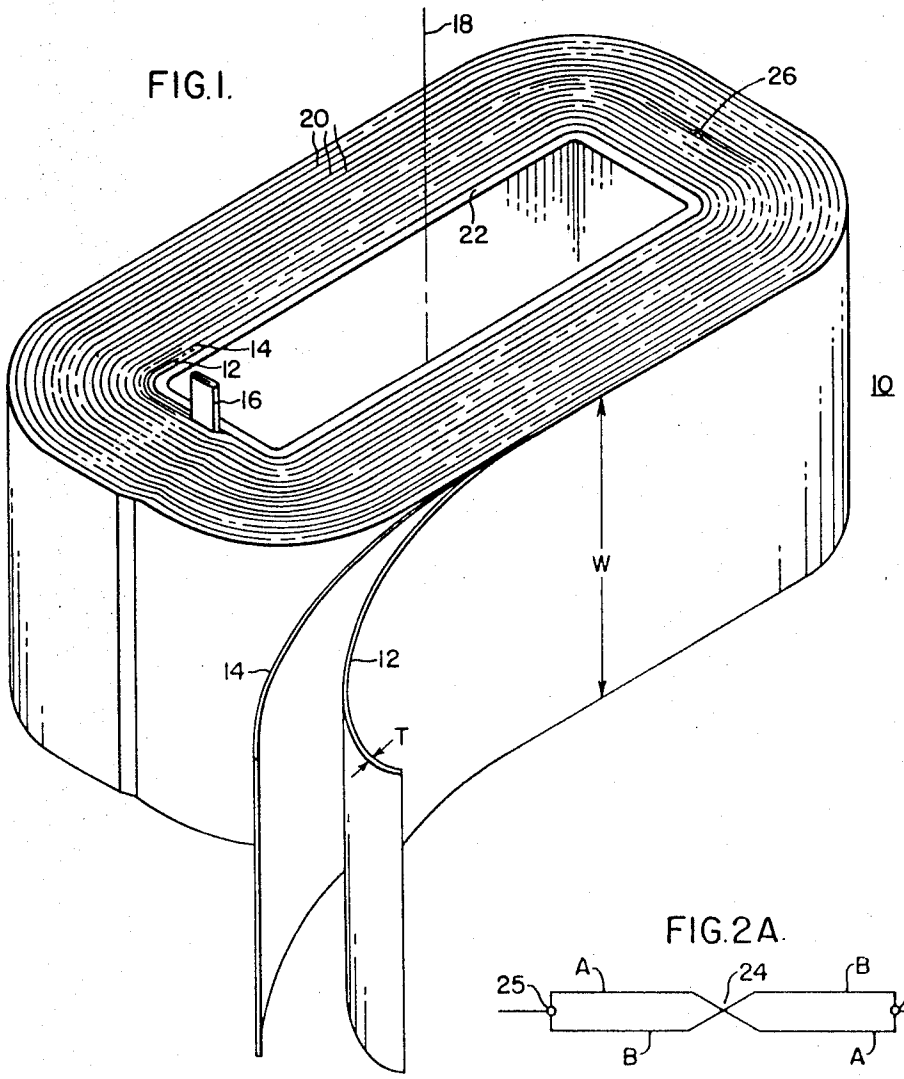



FIG. 2A.




FIG. 2B.

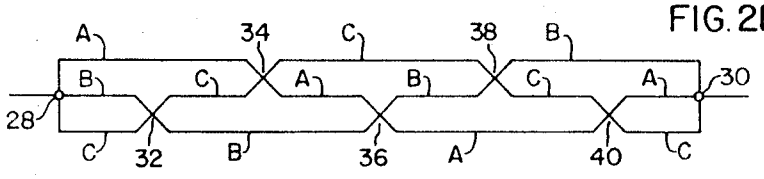
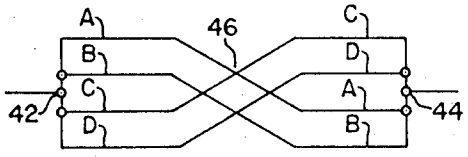



FIG. 2C.



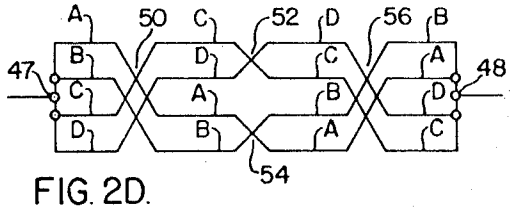




FIG. 2D.

WITNESSES

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Gary E. Uitto

BY Donald R. Lackey

ATTORNEY

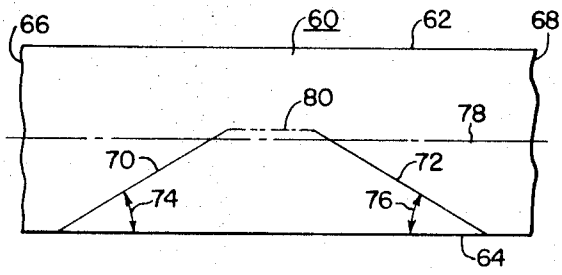



FIG.3A.

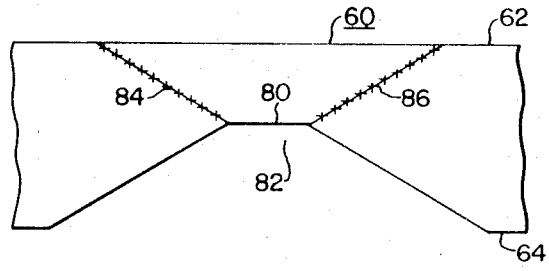



FIG.3B.

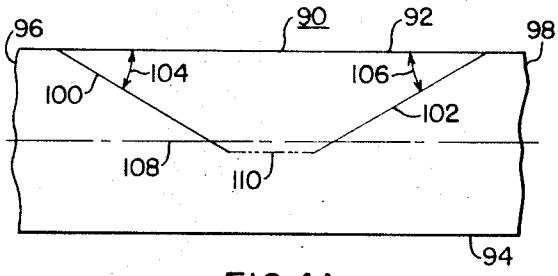



FIG.4A.

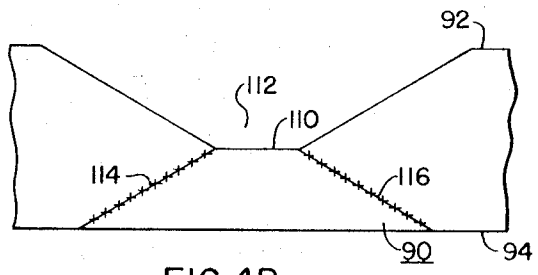



FIG.4B.

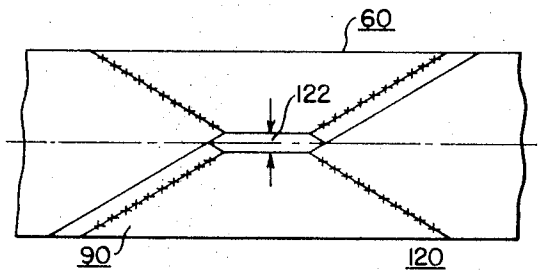



FIG.5.

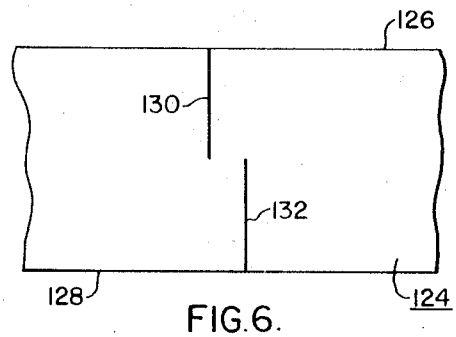



FIG.6.

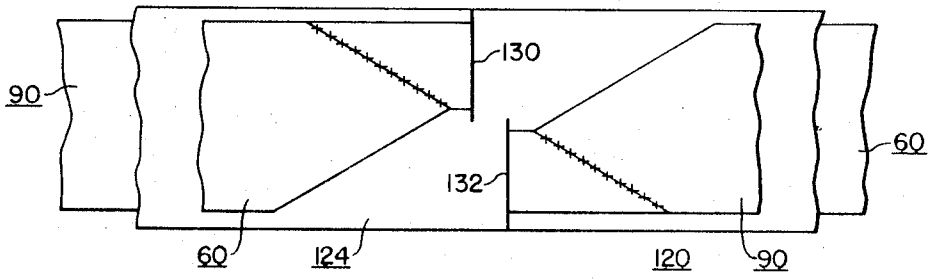



FIG.7.

FIG.8.

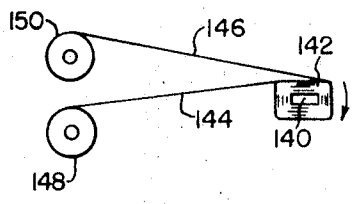



FIG.9.

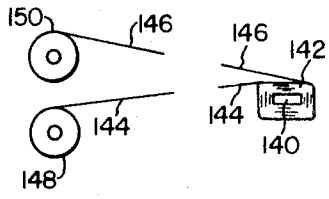



FIG.10.

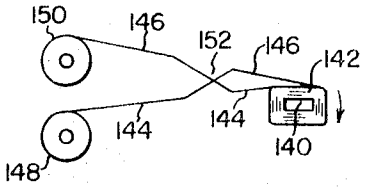



FIG.11A.

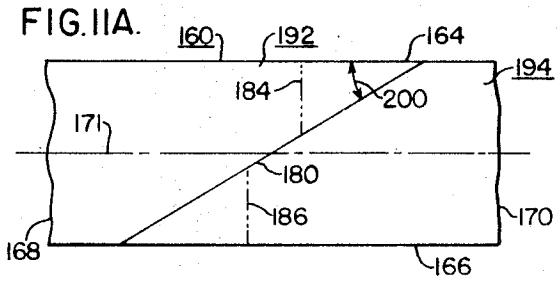



FIG.11B.

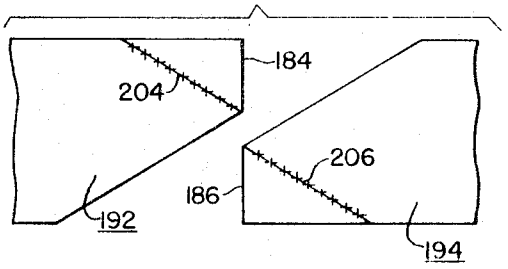



FIG.11C.

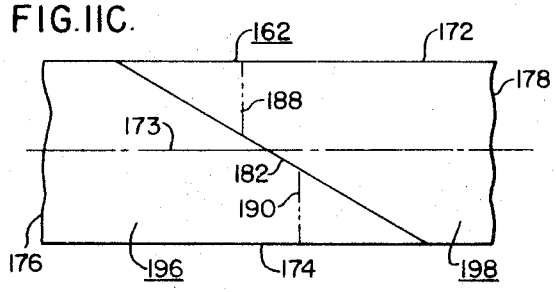
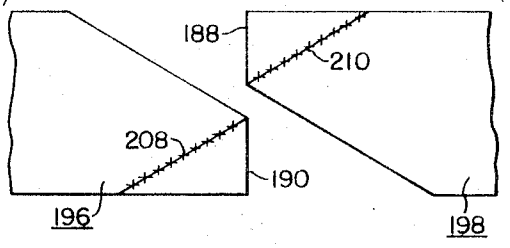



FIG.11D.



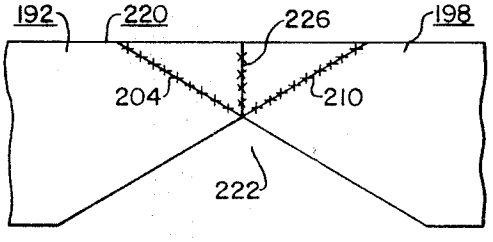




FIG.11E.

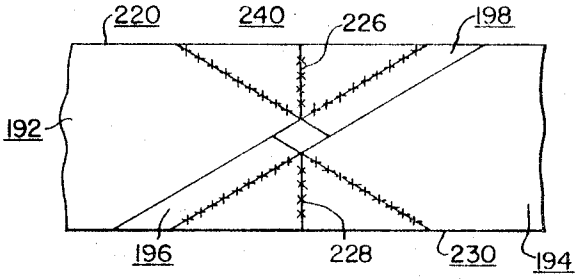



FIG.12.

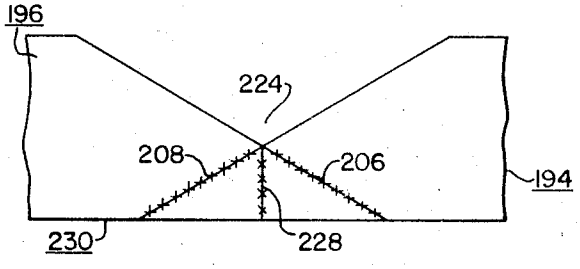



FIG.11F.

FIG.13A.

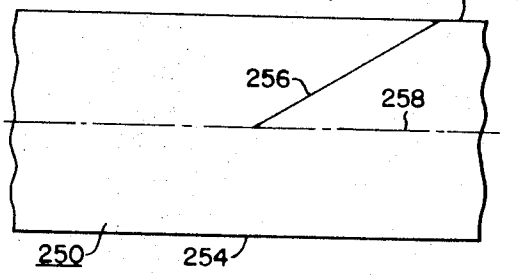
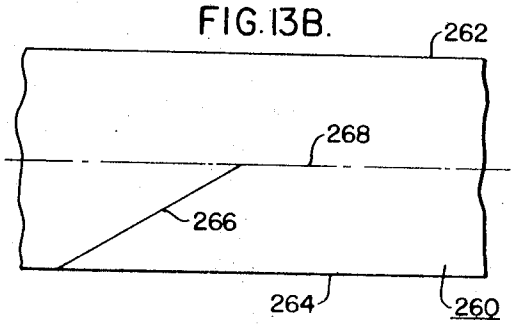



FIG.13B.



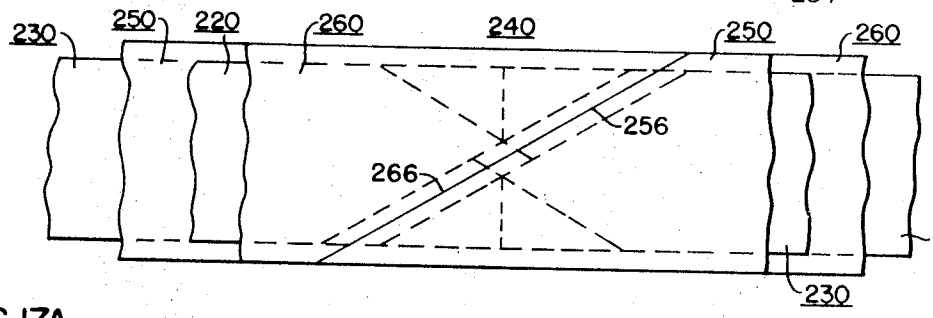




FIG.14.

FIG.17A.

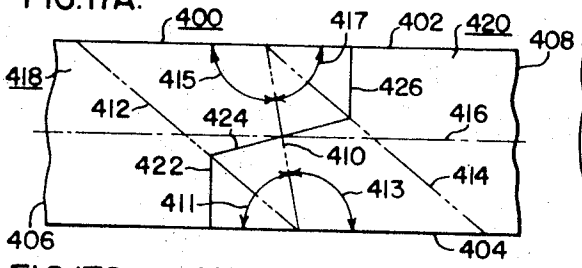



FIG.17B.

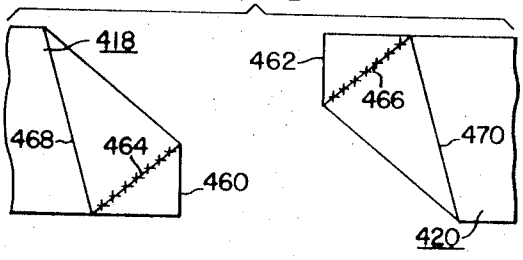
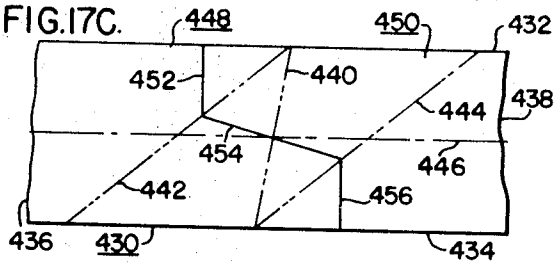



FIG.17C.



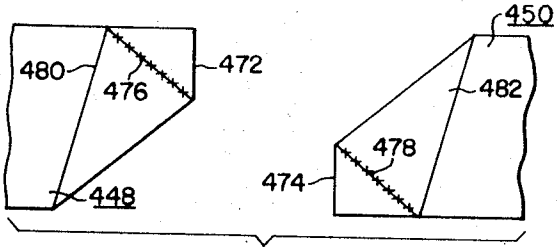




FIG.17D.

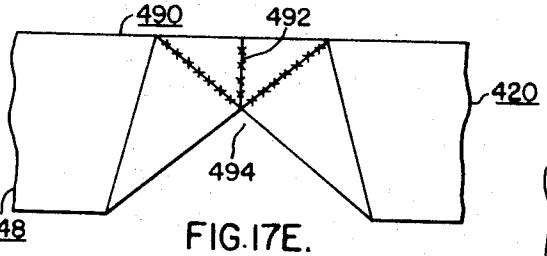



FIG.17E.

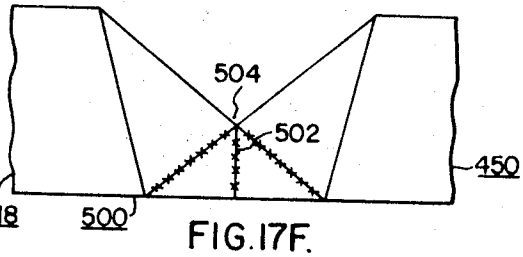



FIG.17F.

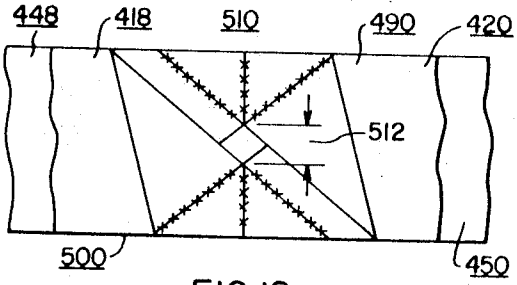



FIG.18.

FIG. 15A.

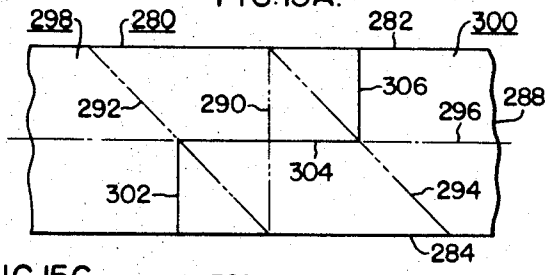



FIG. 15B.

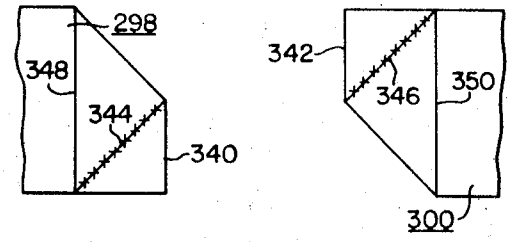
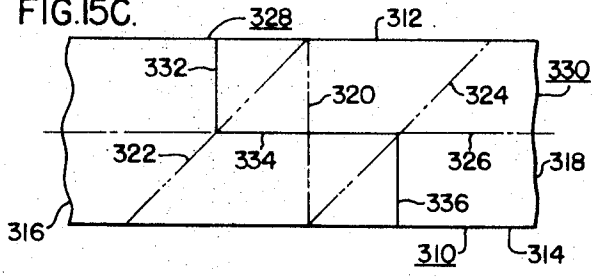



FIG. 15C.



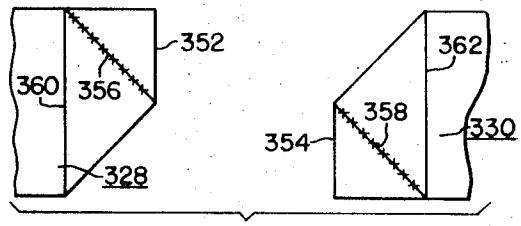
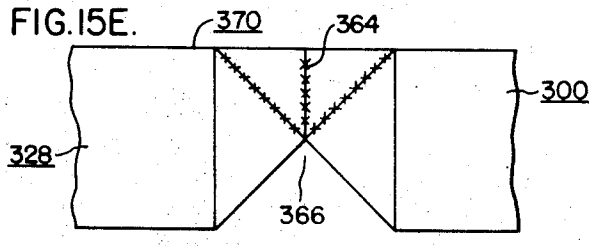




FIG. 15D.

FIG. 15E.



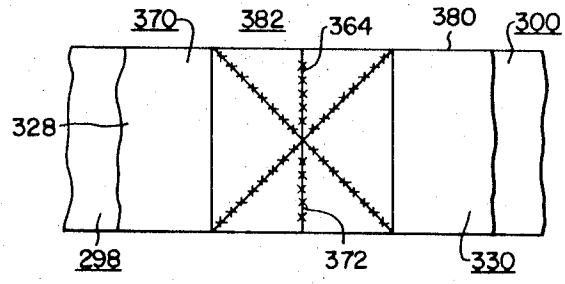




FIG. 16.

FIG. 15F.

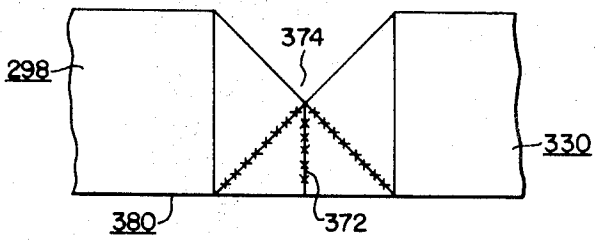



FIG. 15I.

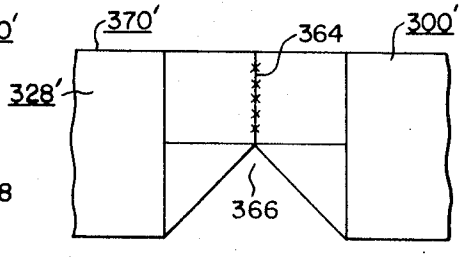
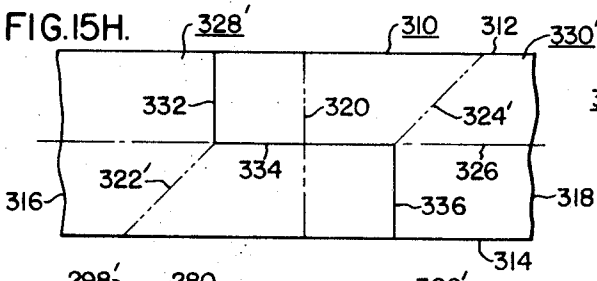



FIG. 15H.



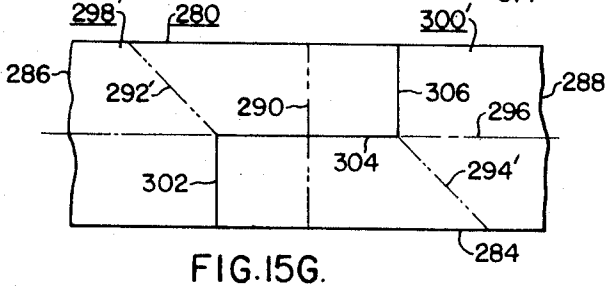




FIG. 15G.

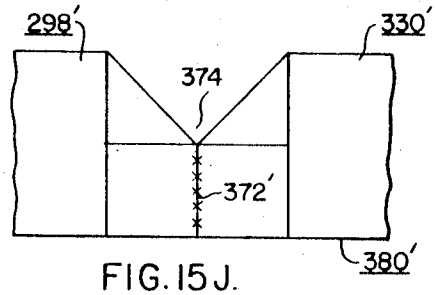



FIG. 15J.

# METHODS OF TRANSPOSING SHEET MATERIALS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to methods of transposing electrically conductive sheet materials in windings for electrical inductive apparatus, such as transformers and reactors, and more particularly to methods of transposing sheet conductors in such windings.

2. Description of the Prior Art

Constructing windings for electrical transformers of metallic foil, sheet or strip material, has certain advantages over windings constructed of wire-type conductor. For example, windings constructed of wire or strap conductor require electrical insulation between radial layers of conductors, as well as turn-to-turn insulation, which increases the size of the winding. Further, with wire or strap wound windings, it is difficult to accurately determine the electrical center of the winding, i.e., the axial location which divides the ampere turns equally, especially when the winding is tapped. When the primary and secondary windings of the transformer are assembled in concentric adjacent relation, any axial displacement of their electrical centers creates a force during short circuit stresses which forces the windings axially apart.

Electrical windings constructed of sheet material, such as copper or aluminum strip or foil, wherein the winding includes a plurality of superposed conductor turns, requires only turn-to-turn insulation, as the conductor turns extend across the axial dimension of the coil; or where axially aligned, electrically connected part-coils are used, the conductor of each part-coil would extend across the axial dimension of its associated part-coil. Since the turn-to-turn voltages are relatively low, the turn-to-turn insulation may be a thin strip of insulating material, such as kraft paper, which is wound between the conductor turns at the time the winding is constructed, or it may be a thin coating of an insulating enamel applied to one or both of the major surfaces of the sheet material. Thus, the space factor of an electrical winding formed of electrically conductive sheet materials is excellent, resulting in a smaller winding, which reduces the size of the magnetic core and the casing, and thus reduces the size, weight and cost of the transformer, Also, since the electrical center of a winding constructed of sheet material is the same as its mechanical center, there will be less force tending to separate concentric windings axially during short circuit stresses The sheet winding is also inherently stronger than a winding formed of wire or strap conductor, as the individual conductors of a wire-type winding may be deformed by short circuit stresses, eventually causing turn-to-turn and layer-to-layer short circuits, while the sheet conductor turns resist deformation, and are not as subject to movement and vibration which may abrade and wear the insulation disposed between two conductors.

When the current rating of an electrical winding is increased, more conductor cross-sectional area is required to carry the increased current, if the winding temperature is to be maintained below the maximum temperature allowable for the class of insulation used. However, since eddy current losses are proportional to the square of the dimension of the conductor at right angles to the leakage flux, it is common to subdivide the required conductor area into two or more parallel connected conductive elements, which are electrically insulated from one another, except at their common connections at the start and finish of the winding, and at any tap connections to the winding. The stranding of the conductor is easy to accomplish with wire, strap, or sheet-type conductive material. With wire or strap conductors, the required plurality of strands are electrically insulated from one another, and then may be taped together to form a single structure which facilitates winding. With sheet, the required number of sheet conductors are wound simultaneously, in superposed relation, with electrical insulating means disposed between the conductors.



Subdividing the conductive cross-sectional area required into a plurality of parallel connected elements, however, introduces loses due to circulating currents in the parallel connected elements. Losses due to circulating currents may be reduced by transposing the relative radial positions of the conductive elements, in an effort to subject each element to the same net leakage flux and, therefore, equalize the induced voltages in the various elements and provide a net induced voltage around each loop of substantially zero. When using wire or strap conductor, the transposing of the individual strands is relatively easy, with a number of transposing arrangements being known in the art for transposing any number of parallel connected strands.

Transposing the relative radial positions of a plurality of sheet conductors, which are wound about a winding form or mandrel, each from a separate roll or supply of sheet material, and with the conductor turns all being in superposed or nested relation, presents a much more difficult problem. The transposing arrangement, and methods of accomplishing the transposition, should perform the necessary radial interchange of sheet conductors without being unduly complicated, without substantially reducing the effective cross-sectional area of the conductor, and without substantially increasing the size of the winding.

## SUMMARY OF THE INVENTION

Briefly, the present invention discloses new and improved methods for radially transposing electrically conductive sheet materials. One of the disclosed methods of radially transposing first and second electrically conductive cutting both the first and second sheet materials into first and second portions, folding the cut ends of the first and second portions of each of the sheet materials in a predetermined manner, electrically joining the cut and folded ends of the first and second portions of the first and second sheet materials, respectively, to form a first composite conductor in which the folds define a notch in a predetermined edge thereof, and joining the cut and folded ends of the second and first portions of the first and second sheet materials, respectively, to form a second composite conductor in which the folds define a notch in a predetermined edge thereof. This method of joining transposes the relative radial positions of the first and second composite sheet conductors, with each composite sheet conductor passing through the notch in the other in order to allow the transposition to be made while keeping the conductors in radial alignment.

## BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is a perspective view of an electrical winding formed of first and second electrically conductive sheet materials, which may utilize the teachings of the invention to transpose the radial positions of the sheet materials;

FIGS. 2A through 2D are schematic diagrams of typical transposing arrangements which may utilize the methods of the invention;

FIGS. 3A and 3B illustrate the steps in a method, according to the teachings of the invention, for providing a notch in the edge of an electrically conductive sheet material;

FIGS. 4A and 4B illustrate the method shown in FIGS. 3A and 3B, for providing a notch in the opposite edge of an electrically conductive sheet material;

FIG. 5 illustrates the transposition of the sheet conductors shown in FIGS. 3B and 4B;

FIG. 6 illustrates a sheet of electrical insulating material, which may be used to electrically insulate the two transposed sheet conductors shown in FIG. 5;

FIG. 7 illustrates the sheet materials which formed transposition of FIG. 5, electrically insulated from one another with the sheet of insulating material shown in FIG. 6;

FIGS. 8, 9 and 10 diagrammatically illustrate the steps of another method of transposing electrically conductive sheet materials, according to the teachings of the invention;

FIGS. 11A through 11F illustrate the steps of a method for preparing notches in sheet conductors for use with the transposition shown in FIGS. 8, 9 and 10;

FIG. 12 illustrates a transposition performed with the prepared sheet conductors shown in FIGS. 11E and 11F;

FIGS. 13A and 13B illustrate sheets of electrical insulating material which may be used to insulate the transposition shown in FIG. 12;

FIG. 14 illustrates the transposition of FIG. 12, insulated with the sheet materials shown in FIGS. 13A and 13B;

FIGS.15A through 15J illustrate the steps of another method of preparing notches in electrically conductive sheet material, for use with the transposition shown in FIGS. 8, 9 and 10;

FIG. 16 illustrates a transposition performed with the prepared sheet material shown in FIGS. 15E and 15F;

FIGS. 17A through 17F illustrate the steps of another method of preparing notches in sheet material for use with the transposition shown in FIGS. 8, 9 and 10; and

FIG. 18 illustrates a transposition performed with the prepared sheet materials shown in FIGS. 17E and 17F.

## DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is shown an electrical winding 10 of the type which may utilize the teachings of the invention. While winding 10 is shown as being rectangular, it may be round, or any other desired shape. Electrical winding 10, which may be a primary or a secondary winding for an electrical transformer, or a coil for a reactor or autotransformer, is constructed of at least two sheets 12 and 14 of electrically conductive sheet material, such as copper or aluminum. Sheets 12 and 14 may be strip or foil of any desired thickness T and width W, as required by the specific application. Typical thickness dimensions are in the range of 0.008 inch to 0.063 inch, and typical width dimensions are in the range of 10 inches to 56 inches, for electrical power transformers, but it will be understood that the invention will apply to the transposition of sheet conductors having any desired dimensions. For example, distribution-type transformers may utilize sheet conductors having smaller thicknesses and with dimensions.

As the thickness dimension T of the sheet material increases, it becomes more difficult to wind the sheet material about a mandrel with a good space factor. Further, as the thickness dimension T increases, the losses due to eddy currents increase, Therefore, for both mechanical and electrical reasons, when the current requirements dictate a thickness dimension which exceeds, in general, 0.063 inch for power transformers, the required conductor cross-sectional area may be subdivided into a plurality of sheet conductors which are wound simultaneously and connected in parallel at the ends of the winding.

As shown in FIG. 1, sheet conductors 12 and 14 are connected to a power terminal 16, such as by welding, and the two sheet conductors are wound about a common axis 18, forming a plurality of superposed or nested conductor turns 20. The sheets of electrically conductive material may be wound directly upon an expandable mandrel, or they may be wound about a winding tube 22, which is disposed on a mandrel.

In order to prevent the two sheet materials from contacting one another, except at the ends of the winding, and at any tap connection points, and from contacting the conductors of adjacent turns the two sheet materials must be electrically insulated. The electrical insulation between conductor turns, and between the multiple conductors of each turn, may be an insulating coating disposed on one or both of the major opposed surfaces of the sheet materials, such as an enamel coating formed of an epoxy, or other good electrical insulating material; or, the electrical insulating may be one or more sheets or strips of insulating material, such as kraft paper, which are disposed between the electrically conductive sheet materials, and adjacent the outer surface of at least one of the sheets, and wound simultaneously therewith.

After winding 10 is complete, the two sheet materials 12 and 14 will have their ends connected to another power lead, similar to the lead 16.

While dividing the conductive cross-sectional area required into a plurality of parallel connected conductive elements reduces the eddy current losses of the electrical winding, the reduction in losses may be offset by an increase in losses due to circulating currents in the parallel connected elements. Losses due to circulating currents in the parallel connected elements. Losses due to circulating currents may be reduced by transposing the relative radial positions of the parallel connected elements, in an attempt to subject all of the parallel connected elements to the same net leakage flux. With two parallel connected elements, such as shown in FIG. 1, a standard transposition wherein the radial sequence of the conductors is reversed, will produce a perfect transposition, if performed at the midpoint of the total conductor length, since each conductor occupies the relative radial position of the other for substantially the same conductor length. The standard transposition is shown schematically in FIG. 2A, wherein two conductors A and B are connected in parallel between terminals 25 and 27, and transposed at transposition point 24 to reverse their radial positions.

The sheet conductors 12 and 14, as shown in FIG. 1, start at terminal 16 with sheet conductor 12 being the inner conductor, and their relative radial positions are transposed or reversed at transposition 26, such that sheet conductor 14 becomes the inner conductor. As will be hereinafter described, the standard transposition 26 may be performed according to the teachings of this invention.

FIG. 2B is a schematic diagram illustrating how three sheet conductors A, B and C, connected in parallel, between terminals 28 and 30, may be transposed, using all standard transpositions, to provide a perfect transposition wherein each sheet conductor successively occupies the positions of the other sheet conductors, for substantially the same distance. The standard transposition alternates between the two outer conductors and the two inner conductors, until completing five transpositions. Thus, the two inner conductors B and C are transposed at point 32, the two outer conductors A and C are transposed at point 34, the two inner conductors A and B are transposed at point 36, the two outer conductors B and C are transposed at point 38, and the two inner conductors C and A are transposed at point 40.

In addition to making the standard transposition with two conductors, any number of conductors may be divided into two groups and the two groups transposed with a standard transposition. This type of transposition is shown schematically in FIGS. 2C, with conductors A, B, C and D being connected between terminals 42 and 44 and transposed at transposition 46. Transposition 46, however, since it does not reverse the positions of the conductors, is technically not a standard transposition, and is often called a complete transposition. Also, it is not a perfect transposition, as the conductors do not occupy the positions of all of the other conductors.

Four conductors may be perfectly transposed using a combination of standard and complete transpositions. This arrangement is shown schematically in FIG. 2D, with conductors A, B, C and D being connected in parallel between terminals 47 and 48. The first transposition point includes a complete transposition 50, the next point includes two standard transpositions 52 and 54, and the next transposition point includes a complete transposition 56. This arrangement causes each conductor to occupy each of the radial positions for the same distance. This result can also be achieved by using two standard transpositions at the first transposition point, a complete transposition at the next transposition point, and two standard transpositions at the last transposition point.

The different transposing arrangements shown in FIGS. 2A, 2B, 2C and 2D are examples of interleaving arrangements which may be used with electrically conductive sheet materials, according to the teachings of the invention. Other arrangements, however, may also be used.

Copending application Ser. No. 742,722, filed July 5, 1968, which is assigned to the same assignee as the present application discloses transposing arrangements for sheet-type electrically conductive materials wherein a notch is disposed in opposite edges of the superposed conductors to be transposed, with each conductor proceeding to its transposed position through the notch in the other conductor. Also disclosed in this copending application are methods of forming a notch in electrically conductive sheet material, which relate to forming the notch while minifying the amount of scrap, minifying current crowding in the vicinity of the notch, and preventing the current density in the narrowed portion of the sheet from increasing substantially above that in the unnarrowed portion. The present application relates to new and improved methods of forming a notch in electrically conductive sheet materials, and also to new and improved methods of transposing sheet materials which do not require the relative positions of the rolls of supply material be changed after each transposition point.

FIGS. 3A, 3B, 4A, 4B, 5, 6 and 7 illustrate the steps of a new method of forming notches in electrically conductive sheet material, which is essentially scrapless, and which maintains substantially the same current density in the portion of the sheet material adjacent the notch, as that in the unnarrowed portion. FIGS. 3A and 3B illustrate the steps of a method of forming a notch or opening, on one edge of an electrically conductive sheet material, with FIG. 3A illustrating a sheet **60** of electrically conductive material, such as copper or aluminum, having first and second edges **62** and **64**, respectively, and first and second ends **66** and **68**, respectively. End **66** may be form a partially wound electrical coil or winding, such as from winding **10** shown in FIG. 1, which is wound to the point where transposition **26** is to be performed. End **68** is attached to a roll of supply material, disposed on a suitable payoff reel (not shown).

The first step is to cut the sheet **60** with first and second cuts **70** and **72**, respectively, starting from the edge in which the notch is to be provided, In this instance, the sheet **60** is cut from the second edge **64**. The cuts **70** and **72** are cut at predetermined angles **74** and **76** with respect to the edge, with the cuts converging towards one another, until reaching predetermined points with respect to the width of the sheet **60**. They should proceed at least to the centerline **78** of the sheet width and preferably a short distance beyond, in order to simplify the electrical insulating of the transposition. The two cuts are spaced from one another such that they meet the predetermined point relative to the width of the strip a predetermined distance apart. The predetermined angles **74** and **76** shown in FIG. 3A are 30°, as this has been found to provide excellent results. The exact angle, however, is not critical. If the angles **74** and **76** are too great, the transition zone between the unnarrowed width and the narrowed width of the sheet will be too short, causing undue current crowding, which in turn increases the temperature of the conductor in this area. If the angles **74** and **76** are too small, the notch and therefore the resulting transposition will become large with respect to the diameter of the conductor turns at the transposition point, which should be avoided. The angle of 30° has been found to be suitable, since the current density in the narrowed portion will be substantially the same as in the unnarrowed portion of the sheet, when following the teachings of the disclosed method.

The next step, shown in FIG. 3B, is to fold the section between cuts **70** and **72** along fold line **80**, back against the portion of the sheet which is disposed between the ends of the cuts **70** and **72** and the edge **62**, with the folding of this section automatically forming a notch or opening **82** in edge **64**. If the cuts have extended past centerline **78**, the outer edge of the folded section will extend past edge **62** by a predetermined small amount, and this small excess may be trimmed to coincide with edge **62**, if desired. The amount trimmed, however, is negligible compared with its affect on the current density, and it is the only scrap in this method.

The next step, also shown in FIG. 3B, is to electrically join the cut edges of the folded section to the immediately adjacent portion of the sheet conductive material, as shown at **84** and **86**. The electrical joining may be accomplished by welding, soldering, brazing, or any other suitable method. The portion of the sheet material between the apex of the notch **82** and edge **62** is thus a double section, doubling the cross-sectional area of the conductive material in this area, which maintains the current density through the narrowed section of the sheet at substantially the same magnitude as it is in the remaining portions of the sheet. If the folded sections were not electrically joined to the main portion of the sheet, the result would be the same as if the folded sections were removed from the sheets, which would then double the current density adjacent the notch and substantially increase the temperature of the strip in this area.

FIGS. 4A and 4B illustrate the method steps of FIGS. 3A and 3B, for providing a notch in the other edge of sheet conductive material. Specifically, FIG. 4A illustrates a sheet **90** of electrically conductive material having first and second edges **92** and **94**, respectively, and first and second ends **96** and **98**. End **96** may be from a partially wound electrical coil, and end **98** may be connected to a roll of supply material. Sheet material **90** is also provided with first and second cuts **100** and **102** which are disposed at angles **104** and **106** with edge **92**. The angles **104** and **106** should be the same as angles **74** and **76** shown in FIG. 3A, and the cuts **100** and **102** should proceed to the same point relative to the strip width that the cuts **70** and **72** proceeded to in FIG. 3A, Thus, the cuts **100** and **102** should proceed just beyond the centerline **108** of the strip or sheet conductor **90**, with the section of conductor between the two cuts being folded along fold line **110**, as shown in FIG. 4B. The cut edges of the folded section are then electrically joined to the immediately adjacent sheet material, as shown at **114** and **116**. The folding of the sheet material between the cuts automatically forms an opening or notch **112** in the edge **92** of the sheet material.

FIG. 5 illustrates a transposition **120** formed with the prepared sheet conductors **60** and **90** shown in FIGS. 3B and 4B, with sheet **60** proceeding to its new position through the notch **112** in sheet material **90**, and sheet material **90** proceeding to its new position through the notch **82** in the sheet conductive material **60**.

Since sheet conductors **60** and **90** have the edges of their folded sections electrically joined to the immediately adjacent surface of the sheet conductor, the plurality of parallel connected sheet conductors may be best insulated with a separate sheet of electrical insulating material, instead of an insulating coating applied to the sheet materials, which would have to be removed, at least in the area of the joint, for most types of joining methods. Thus, the electrical winding would have a sheet of insulating material disposed between each adjacent pair of sheet conductors, which would be wound simultaneously with the winding of the sheet conductors. The sheet insulating material which separates the two sheet conductors to be transposed, may be prepared as shown in FIG. 6, at the point which is to be adjacent the transposition of the sheet conductors. FIG. 6 illustrates a sheet **124** of insulating material having first and second edges **126** and **128**, and having cuts **130** and **132** which start at edges **126** and **128**, respectively. Cuts **130** and **132** may be made along lines which are perpendicular to the edges **126** and **128**, or they may be cut at an angle thereto, such as at the same angle which the notch makes with the edge of the sheet conductive material. Cut **130** should proceed towards edge **128** at least for the dimension necessary to receive the portion of sheet material **60** between edge **62** and fold line **80** on sheet material **60**, and cut **132** should proceed towards edge **126**, at least for the dimension

necessary to receive the portion of sheet material **90** between edge **94** and fold line **110**.

FIG. **7** illustrates the transposition **120** shown in FIG. **5**, with sheet insulating material **124** shown in FIG. **6** disposed between sheet conductors **60** and **90**, on both sides of the transposition point. Sheet conductive material **60** proceeds through the opening provided by cut **130** in the sheet of insulating material **124**, and sheet conductive material **90** proceeds through the opening provided by cut **132**.

The method of forming the transposition **120** shown in FIG. **5** provides a transposition having negligible scrap, without requiring that any of the conductors be turned over as they proceed through the transposition point, with completely severing a conductor, and without substantially increasing the current density through the narrow portion of the conductor adjacent the notch. However, transposition **120** does require that the positions of the two reels of conductive material which supply sheet conductors **60** and **90**, have their relative positions reversed after the transposition point. This could be accomplished by exchanging the positions of the supply rolls on the payoff reels, or by moving the payoff reels and their associated supply rolls. While this change in the relative positions of the supply rolls may be readily accomplished if the payoff reels are designed for this specific function, it would also be desirable to be able to perform essentially scrapless transpositions of sheet conductors, without changing the relative positions of the supply rolls, or payoff reels, after each transposition point.

FIGS. **8**, **9** and **10** diagrammatically illustrate a transposing arrangement for sheet conductors which does not require that the positions of the conductor supply rolls be interchanged after each transposition point. FIG. **8** illustrates a mandrel **140** having two electrically conductive sheet materials **144** and **146** being simultaneously would thereon, from supply rolls **148** and **150**, respectively. When the point in the winding build is reached where a radial transposition of the sheet conductors is required, each of the sheet conductors **144** and **146** is severed, as shown in FIG. **9**, and their cut ends prepared, such as by folding, such that the cut end of conductor **146** from the supply roll **150** may be electrically and mechanically joined to the cut end of conductor **144** from winding **142**, and automatically form a notch in the desired edge of the resulting composite conductor; and, the cut end of conductor **144** from supply roll **148** may be electrically and mechanically joined to the cut end of conductor **146** from winding **142**, and automatically form a notch in the opposite edge of the resulting composite conductor. The forming of the composite conductors transposes the sheet conductors without requiring that the relative positions of the supply rolls be changed, with transposition point **152** illustrating that the inner conductor on the winding **142** is now connected to supply roll **150**, becoming the outer conductor after the transposition point **152**, and illustrating that the outer conductor **146** on winding **142** is now connected to supply roll **148**, becoming the inner conductor after the transposition point **152**. Thus, the radial transposition of the two sheet conductors has been accomplished, without requiring that the positions of the conductor supply reels be interchanged. Each composite sheet conductor proceeds through the notch in the other, in order to complete the transposition while maintaining radial alignment of the conductors.

FIGS. **11A** through **11F** illustrate the steps of a first method for providing notches in sheet conductors, for completing the transposition shown in FIGS. **8**, **9** and **10**, with the method shown in FIGS. **11A** through **11F** being completely scrapless, and performing the transposition without any substantial increase in the current density adjacent the notches in the sheet materials.

FIG. **11A** illustrates a sheet **160** of electrically conductive material which is superposed with sheet **162** of electrically conductive sheet material shown in FIG. **11C**, which sheet materials are to have their relative radial positions transposed. Sheet material **160** shown at **11A** has first and second edges **164** and **166**, and first and second ends **168** and **170**. End **168** is from a partially finished electrical winding, and end **170** is from a supply roll of sheet material.

Electrically conductive sheet material **162**, shown in FIG. **11C**, has first and second edges **172** and **174** and first and second ends **176** and **178**. End **176** is from the unfinished winding, and end **178** is connected to a roll of supply material.

Each of the sheet materials **160** and **162** are cut into first and second portions, with sheet material **160** being cut along line **180** into first and second portions **192** and **194**, and with sheet material **162** being cut along line **182** into first and second portions **196** and **198**. Line **180** on sheet material **160** is disposed at a predetermined angle **200** with respect to edge **164**, such as 30°. The angle selected determines the angle of the converging portions of the hereinafter formed notch, and is thus selected according to the same considerations hereinbefore set forth relative to the selection of the angles for the cuts in FIGS. **3A** and **4A**. Line **182** on sheet conductor **162** is a mirror image of line **180**, with the slope of lines **180** and **182** being of like magnitude, but of opposite sign.

After the step of cutting each of the sheet materials **160** and **162** into first and second portions along their respective cut lines **180** and **182**, each of the resulting portions have cut ends which have a triangular point thereon. Each of the triangular points are folded back along bend or fold lines which are perpendicular to the side or edge of the sheet which intersects the triangular point, with the fold line intersecting the diagonally cut edge. The exact point at which the fold line intersects the cut edge is determined by the desired depth of the notch. Since the notch must extend to at least the midpoint of the strip width, and preferably slightly beyond in order to facilitate insulating the transposition, the fold lines should have a dimension slightly less than one-half of the width dimension of the sheet. Thus, in sheet material **160**, as shown in FIG. **11A**, the triangular point of portion **192** has a fold line **184** disposed perpendicular to edge **164**, which intersects the diagonal cut line **180** short of the centerline **171**, and portion **194** of electrically conductive sheet material **160** has a bend line **186** which is disposed perpendicular to edge **166**, and which intersects the diagonal cut line **180** short of centerline **171**.

In like manner, portions **196** and **198** of sheet material **162** have bend lines **190** and **188**, respectively, similarity disposed on their respective triangular points, with respect to the sheet centerline **173**.

FIGS. **11B** and **11D** illustrate portions **192** and **194** of sheet **160**, and portions **196** and **198** of sheet **162**, respectively, with their triangular points folded back along their respective bend lines. The next step, also illustrated in FIGS. **11B** and **11D**, is to electrically join the diagonally cut edge of each of the folded sections to the surface of the immediately adjacent portion of the sheet material, in order to increase the cross-sectional area of the sheet conductor adjacent the narrow portion of the sheet. Thus, as shown in FIG. **11B**, the diagonally cut edge **204** of the folded section on portion **192** is electrically joined to the surface of portion **192**, such as by welding, and the diagonally cut edge **206** of the folded section on portion **194** is electrically joined to the surface of portion **194**.

In like manner, the diagonally cut edges **208** and **210** of the folded sections on portions **196** and **198**, respectively, are joined to the immediately adjacent portion of its respective sheet material.

The next steps, shown in FIGS. **11E** and **11F**, are to join the folded ends of the first and second portions **192** and **198** of sheet conductors **160** and **162**, respectively, and to join the folded ends of the second and first portions **194** and **196** of sheet materials **160** and **162**, respectively. Thus, as shown in FIG. **11E**, portion **192** is joined to portion **198** along line **226**, such as by welding, soldering, brazing or any other suitable joining means, which provides a first composite sheet conductor **220** having a notch **222** disposed on one edge thereof. As illustrated in FIG. **11F**, portion **196** is joined to portion **194**, along line **228**, which provides a second composite sheet con-

ductor **230** having a notch **224** disposed on the side opposite the side of sheet **220** in which notch **222** is disposed.

The composite sheet conductors **220** and **230** automatically transpose the relative radial positions of the two sheet conductors which form the winding, which is inherent in the way the composite conductors are formed. FIG. **12** illustrates the resulting transposition **240**, in which composite sheet conductor **220** is directed through the notch **224** in composite sheet conductor **230**, and composite sheet conductor **230** is directed through the notch **222** in composite sheet conductor **220**, in order to keep the transposed sheets radially aligned. Assuming portion **192** was the outer conductor on the electrical winding being formed, and portion **196** was the inner conductor, the outermost supply reel would have been connected to portion **192**, and the innermost supply reel would have been connected to portion **196**. Now, after transposition **240**, the outermost supply reel is connected to the inner conductor at joint **228**, and the innermost supply reel is connected to the outer conductor at joint **226**. Thus, the winding, up to the transposition **240**, includes inner and outer sheet conductors, which are transposed to become the outer and inner sheet conductors, respectively, after the transposition. Further, this radial transposition of sheet conductors has been achieved without scrap, and without requiring the rolls of supply material to be moved relative to one another. The narrowed portion of each composite sheet conductor has two thicknesses of sheet material, thus enabling the current in the conductors to flow through the transposition point without a substantial increase in the current density.

The transposition **240** shown in FIG. **12** may be electrically insulated with a sheet of insulating material similar to the sheet insulator **124** shown in FIG. **6**, which would be assembled with the transposition as shown in FIG. **7**. Instead of twice cutting the sheet insulator which separates the two transposed conductors, it would be suitable to modify two of the sheets of insulating material which are adjacent the transposed sheet materials, which requires that each be cut only once, but requires the relative positions of supply rolls of insulation to be changed. Thus, as shown in FIGS. **13A** and **13B**, sheet insulating materials **250** and **260** may be provided, respectively, with sheet insulating material **250** having first and second edges **252** and **254**, and a centerline **258**, and with sheet insulating material **260** having first and second edges **262** and **264**, and a centerline **258**. Each of the sheet insulating materials **250** and **260** have a single cut, which may be made at any desired angle with either side, as long as the cut reaches to at least the midpoint of the sheet. As shown in FIG. **13A**, sheet insulating material **250** may have a cut **256** which extends diagonally from edge **252** to substantially the sheet centerline **258**, and as shown in FIG. **13B**, sheet insulating material **260** may have a cut **266** which extends diagonally from edge **264** to substantially the sheet centerline **268**. The angles and slopes of cuts **256** and **266** are shown to be similar to the angles and slopes of the adjacent edges of the notches in the sheet conductors. Thus, each sheet of insulating material is superposed over one of the sheet conductors as they approach the transposition point. Each sheet of insulating material may then be cut along one of the edges of the notch of its adjacent sheet conductor, and the sheet conductor and its immediately superposed sheet insulating material may progress through the transposition point together, by changing the relative positions of the supply rolls of insulating material. FIG. **14** illustrates the transposition **240** shown in FIG. **12**, insulated with the sheet insulating materials **250** and **260**, shown in FIGS. **13A** and **13B**.

Another method of insulating the two transposed conductors from one another would be to simply cut the sheet of insulating material, which separates the two conductors completely in two, at the midpoint of the transposition, and then start the sheet of insulating material between the two conductors as they proceed away from the transposition.

FIGS. **15A** through **15F** illustrate another method of providing notches for transposing sheet conductors according to the teachings of the invention shown in FIGS. **8**, **9** and **10**. The hereinbefore mentioned copending application teaches how to mark a sheet conductor with three bend lines, and to fold the conductor along the bend lines to provide a notch on one edge of the sheet, without scrap, without cutting the sheet, and without substantially increasing the current density adjacent the notch. The plurality of folds adjacent the notch increase the effective cross-sectional area of the conductive material, allowing the current to flow through the narrowed area at substantially the same current density as in the unnarrowed area. This method of the copending application produces excellent results electrically, but the method of achieving the transposition of the conductors requires that each sheet conductor be turned over as it proceeds through the transposition point, and the relative positions of the supply rolls must be changed after each transposition point. By following the teachings of this invention, the same three bend lines may be utilized to build up the cross-sectional area of the conductive material adjacent the notch, and the sheet material may be transposed without turning the sheet material over, and without changing the relative positions of the supply rolls.

More specifically, FIG. **15A** illustrates a sheet **280** of electrically conductive sheet material having first and second edges **282** and **284**, respectively, and first and second ends **286** and **288**, respectively. End **286** may be from a partially completed electrical coil winding, and end **288** may be connected to a roll of supply material. In this embodiment of the invention, the notch is to proceed to the centerline of the sheet material. Therefore, following the teachings of the hereinbefore mentioned copending application, the three bend lines are marked on the sheet, with the first bend line **290** being perpendicular to the edges of the sheet, and the second and third bend lines **292** and **294** extending outwardly from opposite ends of the first bend line **290**, intersecting the opposite edge at 45° angle. When the notch is to proceed to the centerline of the strip width, the second and third bend lines intersect the edges of the sheet material a dimension, from where the first bend line intersects that edge of the sheet material, which is equal to the length of the first bend lines. Since the first bend line, in this instance, is equal to the width of the sheet material, the angles of the second and third bend lines **292** and **294** are 45° with respect to the edges of the sheet.

The next step, as shown in FIG. **15A**, is to lay out the pattern in which the sheet material **280** is to be cut, in order to form first and second portions **298** and **300**. The first step in laying out the cut pattern is to draw a line **304** between bend lines **292** and **294**, which line proceeds along the centerline **296** of the sheet conductor. Then, the intersection of cut line **304** with bend line **292** is used to start a line **302** which is perpendicular to edge **284**. The intersection of cut line **304** with bend line **294** is used as the starting point in which to draw line **306** perpendicular to edge **282**. The lines **302**, **304** and **306** form the pattern in which sheet material **280** is to be cut into the two portions.

FIG. **15C** illustrates a sheet **310** of electrically conductive material, which is superposed with sheet material **280** shown in FIG. **15A**, and is to be radially transposed therewith. Sheet material **310** includes first and second edges **312** and **314**, respectively, and first and second ends **316** and **318**. End **316** may be connected to the partially would electrical winding, and end **318** may be connected to a second roll of supply material. Three bend lines **320**, **322** and **324** are marked on the sheet material **310**, with the bend lines being placed such that they are a mirror image of the bend lines **290**, **292** and **294** shown in FIG. **15A**. In other words, bend line **320** is placed similar to bend line **290**, perpendicular to edges **312** and **314**, but the second and third bend lines **322** and **324** start from opposite ends of the first bend line compared with the first and second bend lines **292** and **294** shown in FIG. **15A**. The pattern on which material **310** is cut, is also a mirror image of the pattern on which sheet conductor **298** shown in FIG. **15A** is cut. The first step is similar to the first step of

forming the cut pattern on conductor **280**, with a line **334** being drawn along the centerline **326** of the sheet between bend line **322** and **324**. The intersection of the cut lines **334** with the bend line **322** is sued as a point in which to draw a line **332** perpendicular to edge **312**, and the intersection of cut line **334** with bend line **324** is used as the starting point for drawing the line **336** perpendicular to the edge **324** of the sheet material **310**. The pattern on which sheet material **310** is to be cut, then follows the lines **332**, **334**, and **336**.

After cutting sheet material **280** along lines **302**, **304** and **306**, which form two separate portions **298** and **300**, portion **298** has its cut end folded along the portions of the three bend lines thereon, and portion **300** has its cut end folded along the portions of the three bend lines which are disposed on it. The folds may be in any desired order, and they may be made towards the winding machine operator, away, or some may be made towards the operator and some away, as desired. FIG. **15B** illustrates portions **298** and **300** after they have their cut ends folded, which provides four thicknesses of the sheet material at the edges **340** and **342** on portions **298** and **300**, respectively. The edges **344** and **346** of the diagonally folded sections of portions **298** and **300**, respectively, may be electrically joined to the immediately adjacent surface of sheet conductor, as illustrated, in order to utilize these folded sections as effective current carrying conductors. The edges of the folds defined by lines **348** and **350** and portions **298** and **300**, need not be electrically joined to the immediately adjacent surface, as the current will flow through these portions of the sheet material without requiring an electrical connection at this point. However, edges **348** and **350** may be electrically joined to the immediately adjacent sheet material, if desired. If only three thicknesses of material are desired at edges **340** and **342**, the diagonal folds which form edges **344** and **346** may be eliminated which, in addition to reducing the buildup at the edges **340** and **342**, eliminates any brazing of the edges of the folds to the adjacent surface of the sheet. In this instance, the portion of bend line **292** from the intersection of cut lines **302** and **304**, to its intersection with edge **284** would not be folded; and, the portion of bend line **294** from the intersection of cut lines **304** and **306**, to its intersection with edge **282**, would not be folded. In other words, the portion of bend line **412** which is on portion **420** would not be folded, and the portion of bend line **414** which is on portion **418**, would not be folded. This embodiment is illustrated in FIG. **15G**.

In like manner, cutting sheet material **310** shown in FIG. **15C** along the cut lines **332**, **334** and **336**, provides first and second sections **328** and **330**. FIG. **15D** illustrates portions **328** and **330** with their cut ends folded along the portions of the three bend lines which appear thereon, providing four thicknesses of sheet material along the lines **352** and **354**. The edges **356** and **358** of the diagonal folds of portions **328** and **330**, respectively, and the edges of the folded sections defined by lines **360** and **362**, may or may not be electrically joined to the immediately adjacent sheet material, as desired. The folds which form edges **356** and **358** may be eliminated, as hereinbefore described relative to portions **298** and **300**, which embodiment is shown in FIG. **15H**.

The next step is to electrically join portion **328** of sheet material **310** with portion **300** of sheet material **280**, by placing their edges **352** and **342** together, respectively, and welding, or otherwise suitably joining the portions along these adjacent surfaces. The electrical and mechanical connection of these two portions automatically provides a notch **366** in one edge thereof, and it provides a first composite conductor **370**, as shown in FIG. **15E**. If the alternative embodiment is followed therein the diagonal folds are eliminated, the first composite conductor would be as shown in FIGS. **15I**, and is given the reference numeral **370'**.

The next step is to electrically and mechanically join portion **298** of sheet conductor **280** with portion **330** of sheet conductor **310**, by placing their edges **340** and **354** together, and welding, or otherwise suitably joining the two portions along these edges. This step provides a composite conductor **380**, as shown in FIG. **15F**, having a notch **374** formed in the edge which is opposite to the edge in which notch **366** is disposed in composite conductor **370**. FIG. **15J** illustrates the composite conductor formed when the two diagonal folds are eliminated, with the composite conductor of this embodiment being referenced **380'**.

The composite conductors **370** and **380** shown in FIGS. **15E** and **15F** automatically have their relative radial positions transposed as soon as they are formed, and as shown in FIG. **16**, they form a transposition **382** in which composite conductor **370** is directed through the notch **374** in composite conductor **380**, and composite conductor **380** is directed through the notch **366** in the composite conductor **370**, in order to keep the transposed conductors radially aligned. Like the transposition **240** shown in FIG. **12**, transposition **382**, shown in FIG. **16** transposes the relative positions of two sheet conductors, without requiring that the rolls of supply material have their positions interchanged. The composite conductors **370'** and **380'** shown in FIGS. **15I** and **15J** would be directed through the notch in the other, similar to that shown in FIG. **16** for composite conductors **370** and **380**.

In most instances, it is not desirable for the notch in the sheet material to proceed only to the centerline of the sheet width, as it is more difficult to adequately electrically insulate the transposition when both of the notches meet at the centers of the sheets. FIGS. **17A** through **17F** illustrate how two sheets of electrically conductive material may be prepared, similar to the method shown in FIGS. **15A** through **15F**, except that the notches will proceed for a short dimension past the width of the strip, in order to separate the notches from one another in the transposition. FIG. **17A** illustrates a sheet **400** of electrically conductive material having first and second edges **402** and **404**, respectively, and first and second ends **406** and **408**. End **406** may be from a partially would electrical coil and end **408** may be connected to a roll of supply material. Three bend lines **410**, **412** and **414** are marked on the sheet, with the first bend line **410** being disposed to form first and second angles **411** and **413** with edge **404**, with the first angle **411** being less than 90° and the second angle **413** being greater than 90°; and, first and second angles **415** and **417** with edge **402**, with the first angle **415** being greater than 90° and the second angle **417** being less than 90°. The bend lines are then disposed within the angles which are less than 90°, with the first bend lines **412** being disposed within angle **411**, and with the second bend line **414** being disposed within the angle **417**. Bend line **412** is disposed at that angle which will intersect edge **402** a dimension from the intersection of the first bend line **410** with edge **402** which is equal to the length of the first bend line **401**. Bend line **414** is parallel with bend line **412**, intersecting edge **404** a dimension from the intersection of the first bend line **410** with edge **404**, which is equal to the length of the first bend line **410**.

The pattern on which sheet material **400** to be cut is generated by drawing a first cut line **424** through the midpoint of the sheet, represented by centerline **416**, such that the dimension of the line **424** between the second and third bend lines **412** and **414** is equal to twice the distance desired between the apex of the notch in the sheet material and the edge of the sheet material nearest the apex. The intersections of the first cut line **424** with the second and third bend lines are then used as starting points from which to draw lines perpendicular to the adjacent edges of the sheet material. Thus, a line **422** is drawn from the intersection of cut line **424** with bend line **412**, which is perpendicular to the edge **404**, and a line **426** is drawn from the intersection of cut line **424** with bend line **414**, to the edge **402**, with the line **426** being perpendicular to the edge **402**. Sheet material **400** is cut along the lines **422**, **424** and **426**, to form first and second separate portions **418** and **420**.

The sheet material to be radially transposed with sheet material **400** is sheet material **430** shown in FIG. **17C**, which has first and second edges **432** and **434**, and first and second ends **436** and **438**. The first end **436** is from the partially

finished electrical winding, and the second end **438** is connected to a second roll of supply material. Sheet material **430** has three bend lines **440, 442** and **444** marked thereon, which are the mirror image of the bend lines **410, 412** and **414** shown in FIG. **17A**. Sheet material **430**, which has a centerline **446**, has a cut pattern disposed thereon which is a mirror image of the cut pattern on sheet material **400** shown in FIG. **17A**. Sheet material **430** has a cut pattern which includes lines **452, 454** and **456**, with line **452** being perpendicular to edge **432** and line **456** being perpendicular to edge **434**. The intersections of lines **452** and **456** with bend lines **442** and **444** are joined by line **454**, which intersects the midpoint of the first bend line **440** at the centerline **446** of the sheet material. The lengths of lines **452, 454** and **456** are equal to the lengths of lines **422, 424** and **426**, respectively, for sheet **400**, and the respective angles formed by the cut and bend lines for sheets **400** and **430** are equal. Sheet material **430** is cut into first and second portions **448** and **450**, along a pattern defined by the lines **452, 454** and **456**.

FIG. **17B** illustrates the first and second portions **418** and **420** of the sheet material **400** shown in FIG. **17A**, with its cut ends being folded along the portions of the bend lines disposed on their respective portions. Portion **418** has an edge **460** having four thicknesses of sheet material, and edges **464** and **468** of folded sections which may or may not be joined to its immediately adjacent sheet material, as desired. In like manner, portion **420** includes an edge **462** which has four thicknesses of conductive material, and edges **466** and **470** of folded portions which may or may not be electrically connected to the sheet material, as desired. The folds which form edges **464** and **466** may be eliminated, if desired, which will provide three thicknesses of material at edges **460** and **462**, and which eliminates the brazing of any folded edges to the adjacent surface of the sheet, as hereinbefore described relative to FIGS. **15A–15J**.

FIG. **17D** illustrates the first and second portions **448** and **450** of the sheet material **430** shown in FIG. **17C**, with its cut ends folded along the three bend lines. Portion **448** includes an edge **472** having four thicknesses of sheet material, and edges **476** and **480** of folded sheet material which may or may not be joined to the sheet conductor, as desired. Portion **450** includes an edge **474** having four thicknesses of conductive material, and edges **478** and **482** of folded sections which may or may not be joined to its immediately adjacent sheet material, as desired. The folds which form edges **476** and **478** may be eliminated, as hereinbefore described relative to portions **418** and **420**.

The next step, as shown in FIG. **17E**, is to join portion **448** to portion **420**, by disposing edges **472** and **462** of portions **448** and **420** adjacent one another, and then electrically join them by welding, or any other suitable method. Joining portions **448** and **420** provides a composite sheet conductor **490** having a notch **494** in one edge thereof which proceeds beyond the centerline of the composite conductor.

The next step, shown in FIG. **17F**, is to join portions **418** and **450** together, by disposing their edges **460** and **474** adjacent one another, and joining these edges by welding, or any other suitable means. As shown in FIG. **17F**, joining portions **418** and **450** forms a composite conductor **500** having a notch **504** disposed in one edge thereof, with the apex of this notch extending beyond the centerline of the composite sheet material.

The composite conductors **490** and **500** shown in FIGS. **17E** and **17F** are radially transposed as soon as they are formed, forming a transposition **510** as shown in FIG. **18**, in which the composite sheet conductor **490** proceeds through the notch **504** in composite sheet conductor **500**, and the composite sheet conductor **500** proceeds through the notch **494** in the composite sheet conductor **490**, in order to keep the transposed conductors radially aligned. Since the apex of the notch **494** and the apex of the notch **504** proceed past the centerlines of their respective sheet materials, a clearance, given the reference numeral **512**, will be provided between the notches, which facilitates the insulating of the transposition. Transposition **510** may be insulated by using any of the hereinbefore mentioned arrangements, or any other suitable means.

In order to describe the steps of the various disclosed methods of transposing sheet conductors, it has been necessary to enumerate the steps in a certain order. It will be apparent that the order of performing certain of the steps may be changed, and these changes are within the scope of the invention.

In summary, there has been disclosed new an improved methods of forming transpositions of sheet conductive materials, and new and improved methods of forming notches in the edges of the sheet conductive materials, preparatory to the making of a transposition. The invention teaches a new transposing arrangement which is scrapless, which doesn't substantially increase the current density adjacent the notches in the sheet material, and which doesn't require that the relative positions of the supply rolls be changed after the transpositions.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

**1**. A method of transposing superposed electrically conductive sheet materials, comprising the steps of:

providing first and second superposed sheet materials each having first and second edges, with their first edges being adjacent to one another, and their second edges adjacent to one another,

cutting the first sheet material into first and second portions each having a cut end and a second end,

cutting the second sheet material into first and second portions each having a cut end and a second end, with the first and second portions of the first sheet material being substantially adjacent to the first and second portions of the second sheet material, respectively,

folding the cut end of the first portion of said first sheet material to provide an end having a predetermined configuration,

folding the cut end of the second portion of said second sheet material to provide an end having a predetermined configuration,

joining the cut ends of the first and second portions of said first and second sheet materials, respectively, to form a first composite sheet conductor having first and second edges, corresponding to the first and second edges, respectively, of the first and second sheet materials, with the predetermined configurations of their cut and folded ends defining a notch in the second edge thereof which extends at least to the midpoint of the width of the first composite sheet conductor,

folding the cut end of the second portion of said first sheet material to provide an end having a predetermined configuration,

folding the cut end of the first portion of said second sheet material to provide an end having a predetermined configuration,

joining the cut ends of the second and first portions of said first and second sheet materials, respectively, to for a second composite sheet conductor having first and second edges, corresponding to the first and second edges, respectively, of the first and second sheet conductors, with the predetermined configurations of their cut and folded ends defining a notch in the first edge thereof which extends at least to the midpoint of said second composite sheet conductor,

directing the first composite sheet conductor through the notch in said second composite sheet conductor, and directing the second composite sheet conductor through the notch in said first composite sheet conductor,

whereby the first and second composite conductors have different positions relative to one another, on opposite sides of the notches.

2. The method of claim 1 wherein the steps of cutting the first and second sheet materials provide cut edges which are diagonal to their first and second edges, with the slops of the diagonal cuts on the first and second sheet materials being equal in magnitude but of opposite sign, to form triangular points on their cut ends.

3. The method of claim 2 wherein the steps of folding the cut ends of the first and second portions of the first and second sheet materials fold each of their triangular points along a fold line which extends perpendicularly from the edge which joins the diagonally cut edge at the apex of the triangular point, to the diagonally cut edge.

4. The method of claim 3 wherein the dimensions of the fold lines which fold the triangular points of the first and second portions of the first and second sheet materials is less than half the width of its associated sheet material.

5. The method of claim 3 including the step of electrically joining the diagonally cut edges of the folded portions to the adjacent portions of the sheet materials, on each of the first and second portions of the first and second sheet materials.

6. The method of claim 1 including the step of providing a sheet of electrical insulating material having first and second edges, cutting the sheet of electrical insulating material to provide first and second cuts which extend inwardly from the first and second edges thereof, respectively, for a predetermined dimension, disposing the sheet of electrical insulating material between the first and second sheet of electrically conductive material, with the first sheet material proceeding through the second cut in the sheet of insulating material, and the second sheet material proceeding through the first cut, at the point of transposing the first and second electrically conductive sheet materials.

7. The method of claim 1 including the step of providing first and second sheet of electrical insulating material each having first and second edges, cutting each of the first and second sheets of electrical insulating material inwardly from one edge thereof, and interleaving the first and second sheets of electrical insulating material with the transposed first and second sheets of electrical conductive material, with the first electrically conductive sheet material and the first sheet of insulating material proceeding through the cut in the second sheet of insulating material, and with the second electrically conductive sheet material and the second sheet of insulating material proceeding through the cut in the first sheet of insulating material.

8. The method of claim 1 including the steps of marking the first sheet material, before the cutting thereof, with first, second and third bend lines, with the first bend line extending between the first and second edges of the sheet and having a predetermined dimension, and with the second and third bend lines starting at the intersection of the first bend line with the second and first edges, respectively, and extending outwardly from the first bend line on predetermined opposite sides thereof, intersecting the opposite edge said predetermined dimension from the intersection of the first bend line with that edge, and marking the second sheet material, before the cutting thereof, with first, second and third bend lines which are disposed in the mirror image of the first, second and third bend lines, respectively, of said first sheet material, and wherein the steps of folding the cut ends of the first and second portions of the first and second sheet materials follow at least portions of the first, second and third bend lines.

9. The method of claim 8 wherein the steps of folding the cut ends of the first and second portions of the first and second sheet materials provide three thicknesses of sheet material where the portions are joined to form the composite sheet conductors.

10. The method of claim 8 wherein the step of folding the cut ends of the first and second portions of the first and second sheet materials provide for thicknesses of sheet material where the portions are joined to form the composite sheet conductors.

11. The method of claim 8 wherein the cutting of said first sheet material is along a line which is generated by drawing a first line through the midpoint of the first bend line, which intersects the second and third bend lines, with the slope of the first bend line being that necessary to provide a length equal to twice the desired dimension from the apex of the notch in the sheet material to the edge nearest the apex of the notch, and by drawing second and third lines perpendicular to the first and second edges, respectively, to the intersections of the first line with the third and second bend lines, and wherein the cutting of said second sheet material is along a line which is the mirror image of the cut line on the first sheet material.

12. The method of claim 8 wherein said first bend lines are perpendicular to the edges of said first and second sheet materials.

13. The method of claim 8 wherein said first bend lines deviate from a line perpendicular to the edges of the first and second sheet materials by a predetermined angle, and with the second and third bend lines being disposed to intersect those angles between the first bend lines and the first and second edges of the sheet materials which are less than 90°.

14. The method of claim 8 including the step of electrically joining the edges of at least certain of the folded sheet materials, to the portion of the sheet material it is folded against.