

May 15, 1956

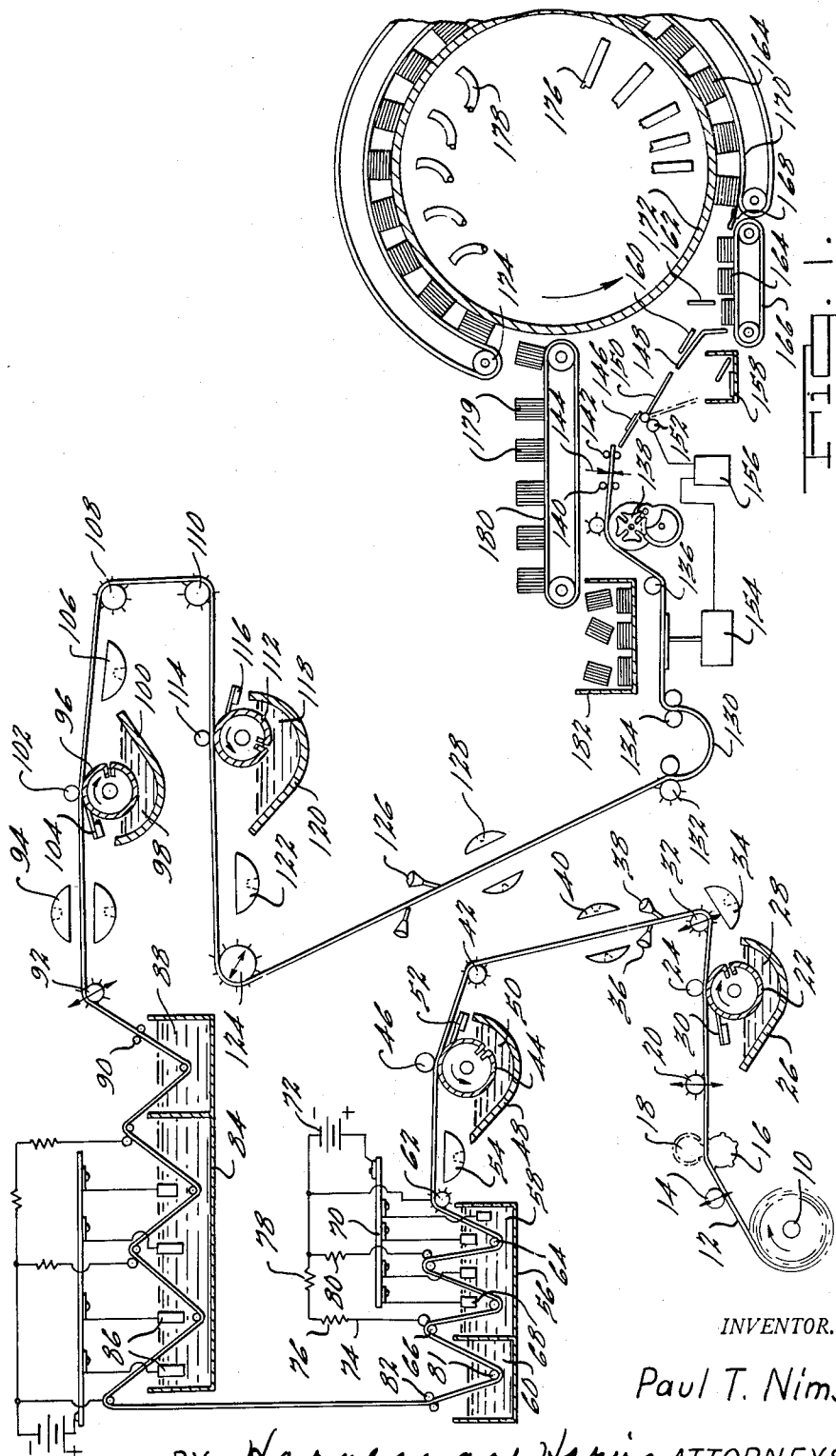
P. T. NIMS

2,745,170

PROCESS FOR MANUFACTURING ELECTRICAL COILS

Filed June 30, 1950

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

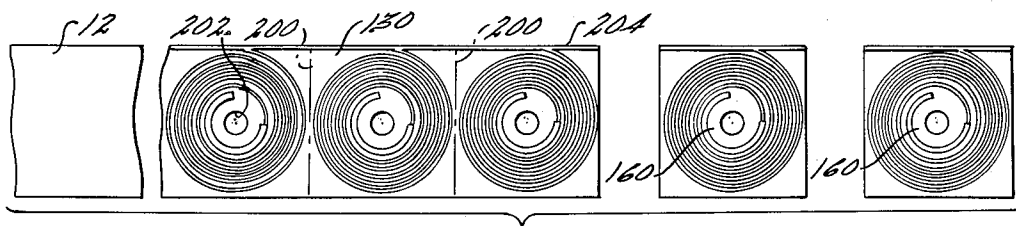


Fig. 2.

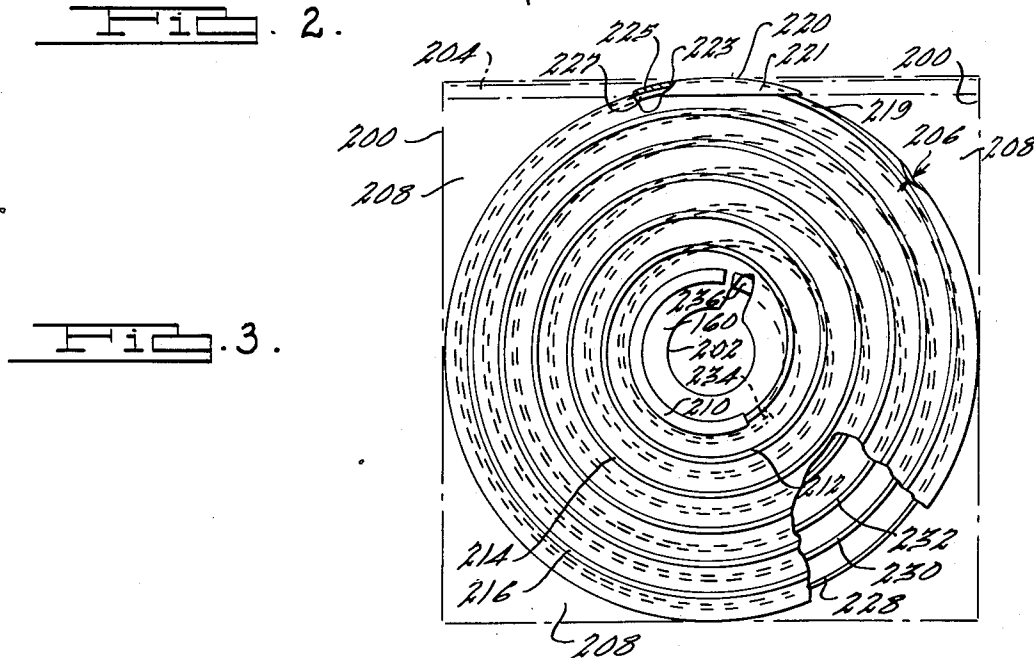


Fig. 3.

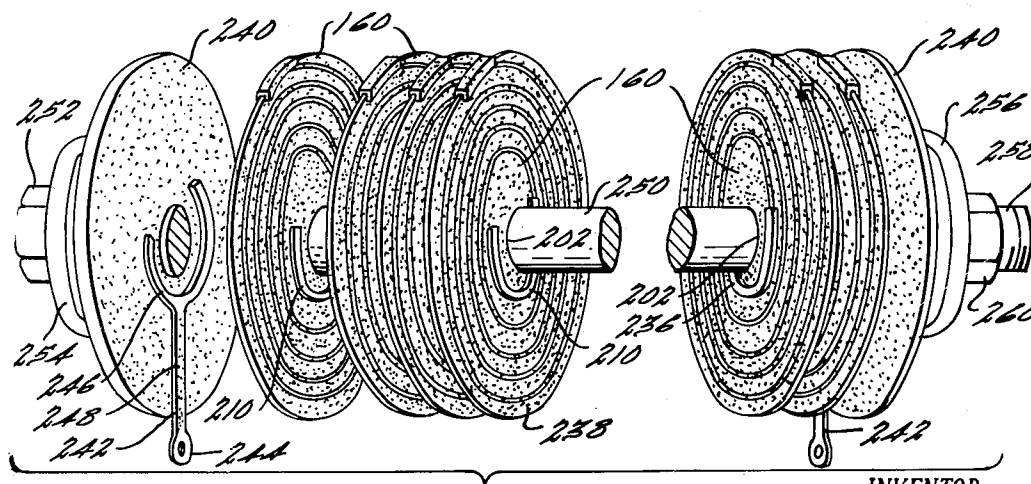


Fig. 4.

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PROCESS FOR MANUFACTURING ELECTRICAL COILS

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Application June 30, 1950, Serial No. 171,441

5 Claims. (Cl. 29—155.5)

The present invention relates to an apparatus and a process for manufacturing articles requiring a recurrent design configuration, one such article, for instance, being an electrical coil as is disclosed in my copending application Serial No. 154,312, filed April 6, 1950.

It is the traditional practice in coil making to wind a continuous flexible conductor an appropriate number of consecutive turns about itself or about a spool, mandrel, or the like, producing a coil having the requisite number of coil turns desired. Then the conductor is severed and a new and separate coil is begun. Severing the conductor is but one of several disadvantages attendant with continuously-wound coils, since for each time the conductor is severed and for each time a sheet of insulation is applied for use between consecutive layers of turns of the continuous conductor, and for each time a wound coil is removed and a new coil started, the winding process and portions of the winding machinery may necessarily need to be stopped and some manual or semi-automatic step performed prior to resumption of operations. According to a feature of the present invention, provision is made to manufacture a coil by a continuous process requiring no interruptions from the time a strip or web of blank stock is first unreeled to the time that integrated stacked coils emerge.

According to another feature of the invention, apparatus is provided by which a series of separate design configurations may be applied to the surface of an advancing non-conductive strip, to any reasonable thickness desired even though the individual configurations be sharply delineated and intricate.

According to still another feature, provision is made to integrate pluralized components into a unitary stack as held together by the cohesive action of the insulating coatings effective between adjacent components.

According to yet another feature, provision is made to electroplate a series of spaced individual design configurations on a non-conductive strip or web without the apparent necessity of effecting an individual cathode connection to each configuration separately and without the apparent need of immersing the actual cathode connection in the electrolyte solution at all.

Other features, objects, and advantages will either be specifically pointed out or become apparent when for a better understanding of the invention reference is made to the accompanying drawings wherein:

Figure 1 is a sectional elevation view of apparatus employed in the invention;

Figure 2 is a plan view of typical work handled and produced by the apparatus of the invention;

Figure 3 represents an enlarged view of the typical work of Figure 2, with certain portions thereof broken away; and

Figure 4 is an exploded view of an ultimate article yielded upon final assembly.

As briefly stated in the order of the steps leading to its accomplishment, the instant objective is to print spiral delineations of conductive ink at intervals on a non-con-

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ductive strip, apply a conductive stripe passing intersectingly adjacent but not through the spot areas on the strip devoted or to be devoted to the delineations, energizing the electrically interconnected delineations as a continuous group and electroforming metallic deposits along the delineations, covering the delineations with an insulative material to leave exposed one end portion on each delineation, severing the strip into wafers and stacking the wafers and compressing the stack to bring the exposed portions into contact, and fusing the coverings of the insulative material to bind the wafers into permanent enforced contact.

In Figure 1, a feed reel 10 of wafer stock 12 is provided pursuant to the above. Wafer stock 12 is in the convenient blank form of a continuous strip or web of thin non-conductive material. Cellulose acetate, which has been found satisfactory, celluloid, and certain forms of plastics and resins are examples of such a material. Between reel 10 and a punching press 16, 18 may be located on idler 14. The male roller 16 of the punching press cooperates with the female roller 18 to provide spaced apertures along central portions of strip 12. A drive sprocket mechanism, formed of sprockets such as drive sprocket 20, is used to advance and translate the strip 12 by engagement in the apertures formed therein by the punch press 16 and is connected by suitable gearing for coordinated rotation with the various other elements in the apparatus, among which is included printing roller 22. Printing roller 22, having an opposed roller 24, is adapted to have a writing fluid or ink such as fluid 28 applied to the surface thereof for transfer as a delineated film to strip 12. Ink 28, suitably held in a container 26, is of a conductive type. Metallic silver powder in suspension has been found suitable for this purpose and other suitable conductive inks may be employed such as copper powder in an appropriate vehicle, or particles of carbon as suspended, for instance, in a rubber cement. For the results desired, the recommended practice is to load the vehicle with the particles in excessive quantities such that physical contact from particle to particle will result. Roller 22 has a scraper 30 for removing excessive quantities of ink from the roller surface having a series of spaced delineated designs which are transferred by means of ink 28 onto one face of the strip 12 at intervals therealong. Adjacent another drive sprocket 32 is located a drying device 34, which may be a lamp useful to dry the ink applied by roller 22. Striping devices 36 and 38 which may be funnels, rollers, or brushes, effect contact with an edge portion of strip 12 and apply more conductive ink in a manner such as to provide a conductive path leading from one surface of the strip across the edge thereof and to the other surface of the strip. Drying devices 40 serve to dry the stripe applied by striping devices 36 and 38. Over drive sprocket 42, the strip is passed to a printing roller 44 having an opposite idler 46 and a scraper 52 therefor. A container 48 holds a supply of ink 50 similar to ink 28 which is applied to the surface of roller 44 for transfer to the surface of strip 12 opposite to the surface acted upon by roller 22. Roller 44 is formed with a series of delineated designs which are duplicated in film on the surface of strip 12 through the medium of conductive ink 50. A drying lamp 54 cooperates with roller 44.

The wafer stock with designs on both sides and a stripe along an edge thereof is trained over a drive sprocket 62 for passage through a plating bath 56. The electrolyte 58 may consist of an appropriate solution for copper plating and a suitable rinsing medium 60 is provided in a separate portion of the bath 56. By means of rollers such as at 64 immersed in the plating bath and squeezing rollers 66 located without the bath the wafer stock is circulated by a continuous process such as to be electroplated along the designs formed in conductive ink on its relatively non-

conductive surface. The anodes 68 in the plating bath may be of copper and so disposed as to be accessible to both sides and to the edge of the strip. Anodes 68 have a common connection to a buss 70 appropriately connected to an electroplating power source 72. By means of such conductors as conductor 74, a cathode connection is effected through squeezing rollers 66 to the individual designs on the strip through an arrangement whereby the squeezing rollers 66 are in continuous contact with the stripe along the edge of the strip. Conductors such as 74 may be connected to power source 72 as by means of resistors 80. Inasmuch as the delineated designs will be progressively acquiring a layer of plated metal on their surface, the resistance will tend to vary progressively along the strip and accordingly the resistors 76, 78, and 80 may be found useful in order to balance or trim the loads through various arms of the circuit. Cooperating with squeezing rollers 66 is an immersed roller 81 in rinse 60 and a squeezing roller 82.

In the next station to plating bath 56 may be located a plating bath 84 suitable for applying a silver plate over the copper plate. The anodes 86 in bath 84 are of silver and the cathode connection to the delineated designs through the stripe is effected through rollers in the manner described in connection with bath 56. The rinsing medium 88 of the silver plating bath 84 has squeezing rollers 90 past which the strip is trained over a drive sprocket 92. Between drive sprocket 92 and a printing roller 96 there is located a drying lamp 94. Printing roller 96 is provided with printing delineations varying somewhat from the delineations of rollers 22 and 44 in a manner which will later be set forth more in detail.

Adapted to be applied to the surface of printing roller 96 is a liquid 98 having non-conductive qualities. The liquid 98 preferably is a heat-fusible varnish although within the broader aspects of the invention, certain thermoplastics and resins may satisfactorily be employed. Roller 96 has an idler 102 and is provided with a scraper at 104 for removing excessive quantities of the insulative coating liquid 98. A drying lamp 106 serves to dry the insulative coating applied to one side of the strip by roller 96. For applying an insulative coating to the opposite side of the strip a similar roller 112 is provided to which the strip is translated by drive sprockets 108 and 110. Roller 112 has an idler roller 114 and a scraper 116 for wiping off excessive quantities of the applied liquid 118. Liquid 118 has a container 120 therefor and is desirably similar in characteristic to the liquid 98. Previous to being trained over a drive sprocket 124, the strip is subjected to a drying operation such as by a heating lamp 122 and thereafter is engaged by suitable striping devices indicated by funnels 126. Devices 126 apply an insulative material similar to liquids 98 and 118 to the edge of the strip and adjacent portions thereto previously covered by the striping devices 36 and 38 and drying devices 128 serve to dry it. The spiral-bearing stock 130 is gathered into a slack loop through the cooperation of a drive sprocket 132 and rollers 134. The slack loop serves to take up the intermittent motion of an intermittent mechanism 138 which cooperates with an idler 136. Intermittent motion mechanism 138, which may employ a conventional Geneva movement, passes the spiralled stock through guide rollers 140 and 142 for operation thereupon by shears 144 to sever the spiralled stock into individual wafers. The individual wafer such as 146 is passed down a ramp which includes a trap 150 operated by a suitable motor 152. Motor 152 is operated by a testing device 154 in conjunction with a remembering mechanism 156. Testing device 154 comprises essentially the primary of a transformer from which the power loss at any instant can be readily determined. The secondary for the transformer consists of the spirals on the spiralled strip and the mode of testing will later be set forth more in detail.

All wafers, of which wafer 146 may be defective, are

tested at the station of testing device 154 and by appropriate actuation of remembering mechanism 156 the trap 150 is opened to permit defective wafers to fall into a reject container 158. Satisfactory wafers, such as wafer 160, are passed along the guideway 148 and by means of stacking guides 162 are arranged in appropriate stacks as at 164. A conveyer belt supports the stacks 164 and is adapted to move in intermittent motion. A step 168 is provided between conveyer belt 166 and another conveyer belt 170 disposed around the circumference of a drum 172. Drum 172 and conveyer 170 contribute to define a path for the stacks 164 of wafers wherein the stacks are first compressed due to the close proximity of drum 174 to conveyer belt 170 and then passed through heated and unheated portions of the path for appropriate treatment. Heating jets such as 176 which may be gas-fired, are adapted to play against roller 172 and bring the stacks 164 to a temperature at which the coatings of insulative material are caused to heat, soften, and fuse together. Cooling jets such as jet 178 may be used in the unheated portion of the path wherein the insulative coatings may be caused to fuse together and permanently bond themselves one to the other. At the end of conveyer 170 is a pulley 174 from which the individual stacks 164 are delivered and placed on a conveyer 180. Adjacent the end of conveyer 180 is a container 182 for the completed stacks.

With particular respect to Figure 2, the typical work of the apparatus of Figure 1 is shown during stages of its transition from the blank or wafer stock 12 to the completed wafers 160. It will be noted that between designs are located intervals along which, such as at 200, a severing or dividing line may pass. Every spot area on the spiralled stock alternating with the intervals noted, is distinct from the other spot areas as regards each individual spiral although the spot areas will be seen to be mutually connected by the edge stripe 204. Inwardly of each spiral will be noted a central opening 202.

In Figure 3 an enlarged view of one of the wafers 160 is shown. Centrally of the wafer is the central aperture 202; along an edge thereof is the stripe 204. The wafer preferably has the characteristic of thinness as is indicated at 206. Originally of square shape, the individual wafers may, by having the corners 208 removed, be converted substantially into discs. Adjacent the central opening 202 of wafer 160 may be noted a semi-circular conductive portion 210 having an end thereof connected to a turn 212 forming a part of a general conductive spiral path. The insulative coating or varnish is not specifically indicated in Figure 3, but, however, in no case is applied over the semi-circular portion 210 of conductive material. The semi-circular portion 210 serves as a contact point in the stack of wafers whereas the balance of the spiral configuration is in fact insulated by the insulative coating. Subsequent turns from turn 212 conform to a series beginning with turn 212 and ending with a spiral turn 216 having an end portion 219 effecting contact with a portion 221 of an aggregation 220 of conductive material remaining from the original stripe 204. The portion of aggregation 220 going across the edge of wafer 160 is indicated at 223 and effects a connection with another portion of the stripe at 225. Regardless of how drastically the corners 208 are trimmed off, at least one part of the stripe 204 between the intermediate lines 202 is permitted to remain. Portion 225 is connected with a portion 227 of a spiral turn 228 which marks the beginning of a series of spiral turns 230, 232 on the opposite surface of the wafer stock ending with a spiral turn having a portion 234. Spiral portion 234 connects with a semi-circular central contact portion 236 of conductive material. It is to be noted that although the spiral paths on the respective spaces of wafer 160 are of the opposite spiral sense in diaphanous view, they happen to be of the same hand as viewed by the observer from their respective sides of wafer 160.

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In Figure 4, a completed stack of wafers 160 is shown in assembled view, exploded, complete with insulative varnish. It is to be noted that the semi-circular contact portions 210 of the wafers 160 are adapted contactingly to register with the corresponding portions 236 of the next adjacent wafer 160. Except for these contacting portions the balance of the electrically conductive path on the non-conducting wafer stock is covered with insulative varnish as at 238. Provided at the ends of the stack are discs 240 mounted to which are terminal connectors 242. Connector 242 has a semi-circular central portion uninsulated, which is adapted to contact either of the contacting portions 236 and 210 of the end spirals. The main body portion of the terminal 242, indicated at 248, is coated with a layer of insulative material and the connecting lugs 244 remain exposed for effecting terminal connections. A central core means 250 for the electrical coil formed which may be of highly resistive iron, is receivable in the respective apertures 202. The core means 250 may be in the form of a bolt having a head 252 engaging a washer 254 at one end of the coil. The other end of core means 250 may comprise a threadable portion 258 and a nut 260 which retain another end washer 256. An overall operation in connection with Figures 1 through 4 will now be set forth.

From feed reel 10, the blank or non-conductive strip 12 is passed to a punch press where central apertures 202 are punched at intervals. The sprocket teeth of drive sprockets such as sprocket 20 register with these apertures to coordinate the strip 12 with the printing plates which act on the surface of the strip. Roller 22 applies a conductive ink in spirals about the central openings 202 such as will conform to the nearer or farther design shown enlarged in Figure 3. The tortuous conductive ink path will, therefore, consist of a semi-circular portion 210, later to be used as a contact portion, and a series of spiral turns 212, 214, and so forth leading to the outer spiral turn 216. The conductive ink is thereupon dried by the drying lamp 34 and then along one edge of the blank is applied a stripe of conductive ink by the striping devices 36, 38. Subsequent to the next drying step at 40 the blank is passed over the printing roller 44 at which time the opposite surface has applied to it the spiral designs indicated by the remaining design of Figure 3. The central portion of the spiral design terminates in a semi-circular broadened path 236 which acts as a contact portion. After being dried on the side to which the printing ink is applied by roller 44, the blank containing the spirals of conductive ink on both sides are passed through a copper plating bath at which time copper metal is electroformed over the conductive ink. The rinsing medium 60 removes traces of the electrolyte from strip 12 whereupon the strip is passed into a silver plating bath 84. The use of the silver plating bath is optional depending on how necessary is felt a coating of silver over the copper plate in order to provide the proper effectiveness at the contact semi-circular portions 210 and 236. It is highly desirable in both plating baths that the electrolyte be at the same temperature as the rinse medium, that is to say, that electrolyte 58 and rinse 60 be at substantially the same temperature and the electrolyte in the silver bath 84 be at the same temperature as the rinsing medium 88. This balance of temperatures serves to prevent any thermal shock from occurring during the electroplating process such as would tend to make the electroplated paths expand or contract and work free of the actual wafer stock. Within the broader aspects of the invention, silver may altogether be used, however, as plating material to the exclusion of copper in bonding the ink particles into a coalesced mass properly defining a delineated path. From the rinse 88 of silver bath 84 the strip is advanced to the varnish applying roller 96. This roller operates on one side of the strip and serves to cover each spiral completely over with insulative varnish with the exception of the semi-circular con-

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tacting portion 210 or 236 depending on which side of the strip the roller 96 acts. The opposite side is similarly treated with insulative varnish through roller 112 and on being dried at 122 is passed to the striping device 126 which serves to cover over stripe 204, as seen in Figure 2, with varnish.

The spiralled stock 130 theoretically is composed of spot areas on both sides of a strip which register with one another and spirals printed over these spot areas and electroplated thereupon. The circuit provided by each spiral is desirably an open circuit and is closed at no point except possibly where successive turns might be shorted out, as for instance, turns 212 and 214 could be mutually shorted in Figure 3. So long as the circuit is open on both sides of the wafer stock the primary winding of testing device 154 will register a negligible power loss as the open circuits are passed across it. However, when a spiral having a shorted turn is passed across the primary, a power loss will become noticeable such as to indicate a defective spiral. This power loss is registered with the remembering mechanism 156 and after appropriate delay during which the defective spiral has had a chance to make its way to the station of trap door 150, the motor 152 is actuated by mechanism 156 permitting the defective wafer to fall into the reject container 158.

Satisfactory wafers 160 are arranged in stacks by means of guides 162 and intermittently moved by conveyer 166 to a step 168 at which point they are squeezed together and compressed between the converging roller drum 172 and conveyer belt 170. Roller drum 172 and conveyer belt 170 are synchronized such that their angular speeds are the same. The compressed stacks 164 are then passed around the periphery of drum 172 through a heated path affected by burner jets 176 and through an unheated air-cooled path acted on by air jets 178. By means of the heat the varnish may be made pressure-sensitive by being brought to a fusible temperature and then through appropriate cooling may be allowed to fuse together such as to bind the individual wafers of the stack into a unitary stack. The varnish then will serve to hold the contacting portions 210 and 236, Figure 4, together and provide a conductive path as from one wafer to the next. The unitary stacks, indicated at 179, are passed along a conveyer 180 to an appropriate hopper as at 182.

Preferably the corners 208 of the resulting square wafers are removed according to the indications of Figure 3 and through the registering central apertures 202 of the wafers may be passed the core means 250 of Figure 4. The end terminals 242 and the wafers 240 on which they are mounted may then be applied and the coil will ultimately result when the ends of core means 250 are drawn together. For a fuller and more complete description of the actual specific completed coil, reference may be had to the aforesaid copending application of Paul T. Nims, Serial No. 154,312 filed April 6, 1950.

It is to be observed that from the outset of the operation at which the blank material is unreeled from reel 10, to the point at which the integrated wafers are delivered into a hopper 182, the process is entirely automatic and there is no need for intervention of manual steps or for the stoppage of machinery. One explanation lies in the fact of there being no reason for severing a continuous conductor, no reason to interpose layers of insulation as between layers of turns of a continuous conductor, and no reason to remove a spool from a mandrel and replace the spool in order to start a new coil.

Variations within the spirit and scope of the above described invention are equally comprehended by the foregoing description.

What is claimed is:

1. In a method for fabricating electrical circuit components comprising a plurality of laminations, the steps of printing a series of adjacent patterns on opposed sides of a continuous strip of a non-conductive sheet, said patterns being constituted by an electrically conductive

material, depositing a continuous edge stripe of said conductive material along one edge portion of said non-conductive sheet on both sides thereof, said stripe blending with an extremity of each of said patterns, electrodepositing metal on said pattern and said stripe, covering portions of said patterns with an insulating material, severing said continuous strip between adjacent patterns to provide a plurality of individual sheets, and stacking said individual sheets in juxtaposed adjacent relationship to form a laminated structure, the uncovered portions of said patterns mutually contacting each other thereby forming an internal electrical path within said laminated structure.

2. In a method for fabricating electrical circuit components comprising a plurality of stacked laminations, the steps of printing a series of adjacent patterns on opposed sides of a continuous strip of a non-conductive sheet, said patterns being formed from an electrically conductive liquid material, depositing a continuous stripe of said conductive material along one edge portion of said non-conductive sheet on both sides thereof, said stripe blending with an extremity of each of said patterns, drying said pattern and said stripe, electrodepositing metal on said pattern and said stripe, covering portions of said patterns with an insulating material, severing said continuous strip between adjacent patterns to provide a plurality of individual sheets, and stacking said individual sheets in juxtaposed adjacent relationship to form a laminated structure, the uncovered portions of each of said patterns mutually contacting each other thereby forming a laminated structure having a continuous internal electrical path.

3. In a method for fabricating electrical coils having a laminated structure, the steps of applying an electrically conductive material to both sides of a continuous strip of pliable material in a series of adjacent patterns, said patterns being spiral in shape, applying said conductive material to an edge portion of said continuous strip on both sides thereof, a portion of the outer extremity of each spiral lying along said one edge portion, electrolytically depositing a metal on said spiral patterns and on said edge portion, coating said spiral pattern with an insulating material at convolutions spaced radially from a radially inward convolution of each of said spirals, severing said continuous strip between adjacent spiral patterns into individual sheets, and assembling said sheets into a stacked laminar structure whereby the radially inward convolution of each spiral pattern contacts the corresponding convolution of the immediately adjacent juxtaposed spiral.

4. In a method for fabricating electrical coils having a laminated structure, the steps of forming a series of spaced apertures in a continuous strip of non-conductive material, applying an electrically conductive material to both sides of said continuous strip in a series of adjacent patterns and to an edge portion of said strip, said pat-

terns being spiral in shape, the outer periphery of each pattern lying adjacent said edge portion of said strip and the inner convolution of each spiral being disposed about one of said apertures, depositing a metallic material upon said spiral pattern and said edge portion, coating the convolutions of said spiral pattern radially outward of said innermost convolution with an insulating material, severing said continuous strip between adjacent spiral patterns into individual sheets, assembling said sheets into a stacked laminar structure whereby the innermost convolution of each spiral pattern contacts the corresponding convolution of the immediately adjacent juxtaposed spiral, said assembling step including inserting a suitable core through said apertures and clamping the assembled stack of sheets together.

5. In a method for fabricating electrical coils having a laminated structure, the steps of forming a series of spaced apertures in a continuous strip of non-conductive material, applying an electrically conductive fluid material to both sides of said continuous strip in a series of adjacent spiral patterns and to an edge portion of said strip, the outer periphery of each pattern lying adjacent said edge portion of said strip and the inner convolution of each spiral being disposed about one of said apertures, drying said conductive material to a solid state, electrodepositing a metallic material upon said spiral pattern and said edge portion, drying a substantial portion of the electrotype after the electrodepositing step, coating the convolutions of said spiral pattern spaced radially outward of said innermost convolution with insulating fluid material, at least partially drying said insulating material, severing said continuous strip between adjacent spiral patterns into individual sheets, assembling said sheets into a stacked laminar structure whereby the innermost convolution of each spiral pattern contacts the corresponding convolution of the immediately adjacent juxtaposed spiral, said assembling step including inserting a suitable core through said apertures and clamping the assembled stack of sheets together.

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