

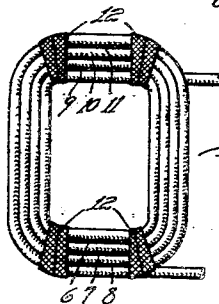
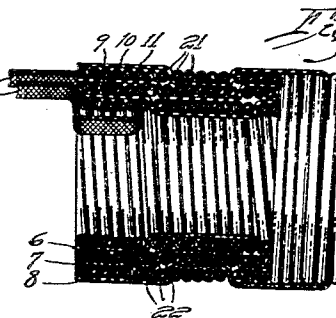
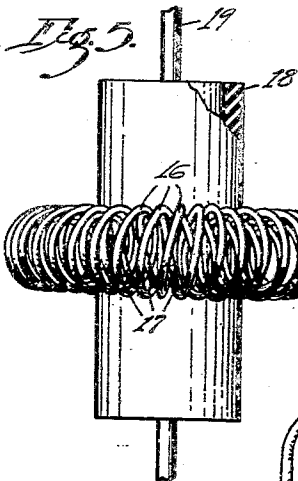
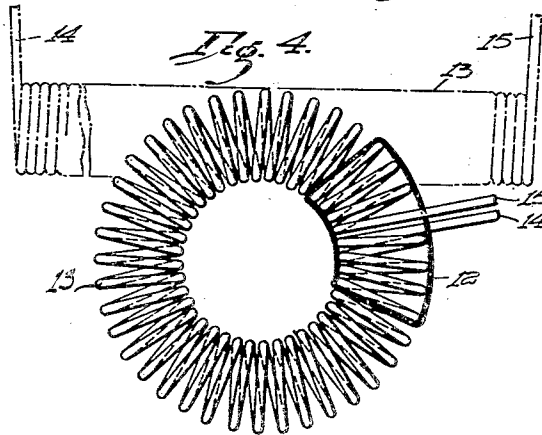
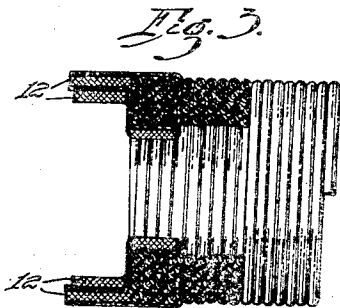
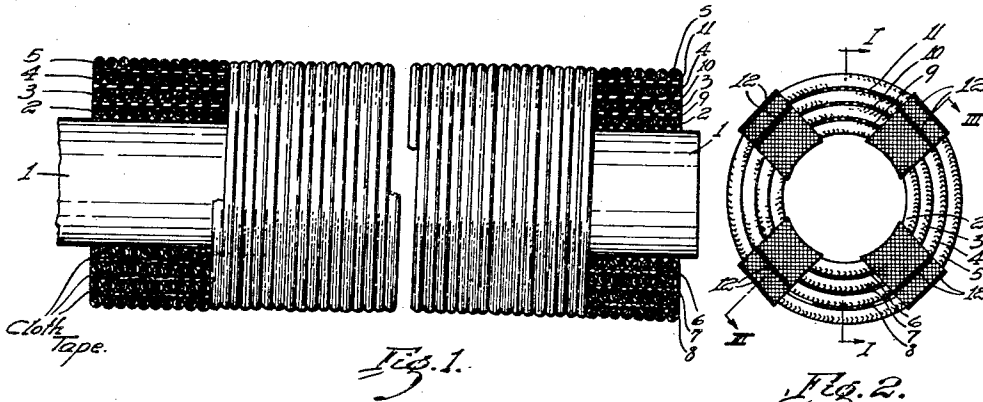
Nov. 19, 1946.

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2,411,403

LINEAR COUPLER

Filed May 7, 1942



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2,411,403

LINEAR COUPLER

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Application May 7, 1942, Serial No. 442,128

5 Claims. (Cl. 175-21)

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My invention relates to linear couplers or mutual inductance coupling devices, and particularly to the provision of toroidal windings for such devices.

In certain protective devices or systems for protecting a multi-terminal bus or other electrical apparatus against internal faults therein, it has been found useful to employ parallel connected voltage producing couplers or mutual inductances which are substantially linearly responsive to the currents in the respective terminals of the bus or other protected apparatus. It is required that these transformers or couplers be both substantially linearly responsive to the terminal current and also substantially astatic, that is, non-responsive to external fields. In order to meet the first requirement, it is necessary to use a non-saturating core and in order to meet the second requirement it is necessary to use a toroidal secondary winding in which the several turns are equally spaced.

These toroidal transformers produce results differing from ordinary iron core current transformers in developing an internal voltage that is substantially linearly responsive to the line current rather than in developing a secondary current that reflects the phase and magnitude of the primary current regardless of the secondary impedance. These toroidal transformers overcome a limitation of the iron core type of current transformer which fails properly to reproduce the primary current when it is much greater than normal (during line faults) because of saturation of the iron core of that type of current transformer.

In order to provide a toroidal transformer winding having the desired characteristic of being astatic or non-responsive to external fields, it is necessary that the turns of the winding be equally spaced about the axis of the toroid. This is not easy to accomplish in forming such windings. It has been the practice to form such windings by hand using an annular form upon which the conductor forming the winding is wound. This operation requires a repeated passing of the winding conductors through the opening in the toroid and bringing it about for as many times as the winding is to be provided with winding turns. Many such windings require many hundred turns which makes the operation of winding by hand a very tedious and difficult one, since it is necessary to evenly distribute the various turns about the axis of the toroid.

It is an object of the invention to provide a transformer or inductive coupler having a toroi-

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dal winding that is substantially astatic and in which the winding turns are evenly distributed over the toroid.

It is a further object of the invention to provide a method of forming a toroidal winding which will result in a substantially uniform distribution of the winding turns about the axis of the toroid to provide a substantially astatic winding.

It is a further object of the invention to provide a method for forming a winding of the above indicated character which is inexpensive and easily practiced and can be relied upon to give uniform results.

Other objects and advantages of the invention will be apparent from the following description of preferred embodiments thereof, reference being had to the accompanying drawing, in which:

Figure 1 is a side elevational view partly broken away and partly in section of a winding after the winding turns have been formed into a cylindrical winding structure and before being bent into the finished toroidal shape. The sectional portion of the figure is taken on lines I—I of Fig. 2.

Fig. 2 is an end view of the winding shown in Fig. 1, with the mandrel removed.

Fig. 3 shows a portion of the end of the winding in Fig. 1 taken along the section line III—III in Fig. 2.

Fig. 4 is a view illustrating the method of bending the cylindrical winding into the form of a torus.

Fig. 5 illustrates the use of the toroidal winding. Fig. 6 illustrates a modified form of the winding, and

Fig. 7 illustrates the end view of a winding similar to Fig. 2 but wound on a substantially rectangular form.

In accordance with the invention, the conductor forming the winding is first wound, as shown in Fig. 1, into a cylindrical or other suitably shaped form, the winding turns being placed about a mandrel or form 1, the several layers 2, 3, 4, 5, etc., being wound the one about the other until the desired number of winding turns have been provided. When the winding turns are being placed upon the mandrel 1, positioning members 6, 7 and 8, which may be formed of cloth tape are placed between the several layers of turns as best shown in Figs. 1 and 2, on one side of the winding, and positioning members 9, 10 and 11, which may be formed of rubber tape, are placed between layers on the opposite side of the turns. The positioning members on the lower side, as

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illustrated, are usually much less elastic than members 9, 10 and 11 and tend to bind the turns of the layers against excessive relative movement while the spacing members on the opposite side are more elastic, and, as they stretch to form the toroid, frictionally engage the individual turns of the adjacent layers and tend to effect a like movement between the turns of each layer. The several positioning tape members 6, 7 and 8, may, if desired, be formed of the same elastic material as the members 9, 10 and 11.

Also when the winding is being formed on the mandrel 1 suitable means, such as cloth tape 12, best shown in Figs. 2 and 3, are placed about a few end turns of the winding for attaching the opposite ends of the cylindrical winding together after it has been completed and formed into a toroid. If the number of layers used in forming the cylindrical winding is an even number, the opposite ends of the conductor will be at opposite ends of the winding, and if an odd number of layers are used, it is necessary to thread the terminal conductor from one end of the winding through the cylindrical winding so that the two terminals of the winding will be at the opposite ends of the cylinder.

Fig. 4 illustrates the method of bending the winding to form the toroidal structure. For purposes of simplifying the drawing, a single layer toroidal winding is shown, but it will be appreciated that the winding as actually formed will be a multiple layer winding such as shown in Figs. 1, 2 and 3. The cylindrical winding 13 having terminals 14 and 15 shown in dot and dash lines and corresponding to the windings shown in Figs. 1 and 2 is bent by hand or otherwise to bring the two opposite ends together, and these opposite ends are attached by tying the tape 12 or fastening members provided for that purpose. In bending the cylindrical winding of Fig. 1 into a toroidal shape, the non-elastic spacer members 6, 7 and 8 will be on the inside of the opening so formed and the elastic members 9, 10 and 11 will be on the outside. When the elastic members 9, 10 and 11 stretch as required to form the toroidal shaped winding, the adjacent parts of the winding turns in each layer separate equally about the axis of the toroid because of their frictional engagement with the expansible members. The adjacent turns on the inner side of the toroid will, of course, be compressed together and will be held by the spacer members 6, 7 and 8, so that, as the cylindrical winding is bent into the form of a toroid the various parts of adjacent turns of the winding separate equally about the axis of the toroid. The completed winding is shown in perspective in Fig. 5, the drawing attempting to show only a two-layer winding instead of a winding having the larger number of layers that would be employed. The several turns are wound on layer upon layer progressing from one end to the other in one layer and in the opposite direction in the next layer, thus giving the turns in succeeding layers pitches in the opposite directions. It will be noted that the individual turns 16 in the outer layer have a slight pitch in one direction while the turns 17 of the next lower layer have a slight pitch in the opposite direction, so that the alternate change in pitch between layers tends to support the turns of the structure, and this supporting characteristic is increased in efficiency by placing a tubular member 18 within the opening of the torus snugly fitting the opening so as to create a slight outward pressure against the turns of the toroidal winding. The

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winding and tube are also dipped in a varnish or binding compound which cements the various turns in their existing positions and reinforces the structure. As commonly used, the primary winding of the transformer is, as shown in Fig. 5, a conductor 19 extending through the central opening of the tube 18.

Fig. 6 shows a winding in which the spacer members 9, 10 and 11 and also the members 6, 7 and 8 change their position between the windings so as to weave back and forth between layers as shown at 21 and 22, respectively. Such weaving of the spacing tape back and forth between the layers of turns as initially wound tends to increase the frictional contact between the spacing members or tapes and the winding turns. It has been found, however, that usually the frictional engagement resulting from placing the binding tape members between layers in the manner shown in Figs. 1 and 2 is adequate to maintain the equal spacing of the corresponding parts of the winding turns when the cylindrical winding is bent into the form of a torus.

Fig. 7 is an end view, similar to Fig. 2, showing a winding wound on a substantially rectangular mandrel instead of on a cylindrical mandrel. It will be appreciated that any suitable cross section of mandrel and coil shape may be employed, the wound coil, in each case being thereafter bent into a toroidal shape.

It will be appreciated that a winding built in accordance with the invention results in a rugged construction in which the spacing of the individual conductors throughout the entire winding is equalized by a very simple method, so that similar windings similarly formed will, upon test, show a remarkable accuracy with extremely small differences in different windings, thus avoiding the errors that inevitably result in the manufacture of different individual specimens of windings where the winding is formed by threading the conductor continuously through a toroidal form in accordance with prior methods of manufacture.

It will be apparent to one skilled in the art that modifications in the structural details from the subject matter disclosed may be made within the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. The process of forming a toroidal winding assembly which consists in winding several layers of insulated conductor on a form, and in placing relatively non-stretchable tapes between layers on one side of the winding turns and in placing relatively stretchable tapes of elastic material between layers of turns on the opposite side of the winding turns, in removing the form and in bending the assembly of winding turns so formed into a toroid in a manner to position the relatively non-stretchable tapes on the inner side of the toroid and the relatively stretchable tapes of elastic material on the outer side of the toroid, so that, as the toroid is formed, the tapes of elastic material are elongated to equally space the winding turns of the toroid.

2. The process of forming a toroidal winding assembly which consists in winding several layers of insulated conductor on a form, and in placing relatively non-stretchable tapes between layers on one side of the winding turns and in placing stretchable tapes of elastic material between layers of turns on the opposite side of the winding turns, in removing the form and in bending the

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assembly of winding turns so formed into a toroid in a manner to position the substantially non-stretchable tapes on the inner side of the toroid and the stretchable tapes of elastic material on the outer side of the toroid, so that, as the assembly of winding turns is bent to form the toroid, the tapes of elastic material are elongated to equally space the winding turns of the toroid, and in thereafter fastening the ends of the initially formed winding together, in placing a circular tube through the opening in the toroid having a sufficiently tight fit to shape the toroid, and in thereafter dipping the structure in a binding material to cement the winding turns against relative movement.

3. The process of forming a toroidal winding assembly which consists in winding several layers of insulated conductor on a form and in placing a substantially non-stretchable tape between layers on one side of the winding turns and in placing a stretchable tape of elastic material between layers of turns on the opposite side of the winding turns, in removing the form, in bending the assembly of winding turns to form a toroid having the substantially non-stretchable tape on the inner side of the winding and the stretchable tape of elastic material on the outer side of the toroid to effect an even elongation of the elastic material to effect an equal separation of the like parts of the winding turns while forming the toroid, and in thereafter attaching the opposite end turns of the initially formed winding.

4. The process of forming a toroidal winding assembly which consists in winding several layers of insulated conductor on a form and in placing

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a substantially non-stretchable tape between layers on one side of the winding turns and in placing a stretchable tape of elastic material between layers of turns on the opposite side of the winding turns, in removing the form, in bending the assembly of winding turns to form a toroid having the substantially non-stretchable tape on the inner side of the winding and the stretchable tape of elastic material on the outer side of the toroid to effect an even elongation of the elastic material to effect an equal separation of the like parts of the winding turns while forming the toroid, and in thereafter attaching the opposite end turns of the initially formed winding, in placing a circular tube through the opening in the toroid having a sufficiently tight fit to shape the toroid, and in thereafter dipping the structure in a binding material to cement the winding turns against relative movement.

5. A multi-layer toroidal winding having a plurality of layers of winding turns telescoped one layer within another in close proximity with closely adhering spacer members between the layers on the inner and outer parts of the convolutions of the winding, the spacer members between the layers on the outer parts of the convolutions of the winding being of elastic material subject to an even elongation per unit length when stretched for effecting an even spacing between the outer parts of the turns of the winding, and the spacer members between layers on the inner part of the convolutions of the winding being of non-elastic material.

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