Aug. 2, 1949. J. J. VIENNEAU 2,478,030

METHOD OF MAKING ELECTROMAGNETIC INDUCTION APPARATUS

Original Filed May 24, 1945 2 Sheets-Sheet 1

Fig. 1.

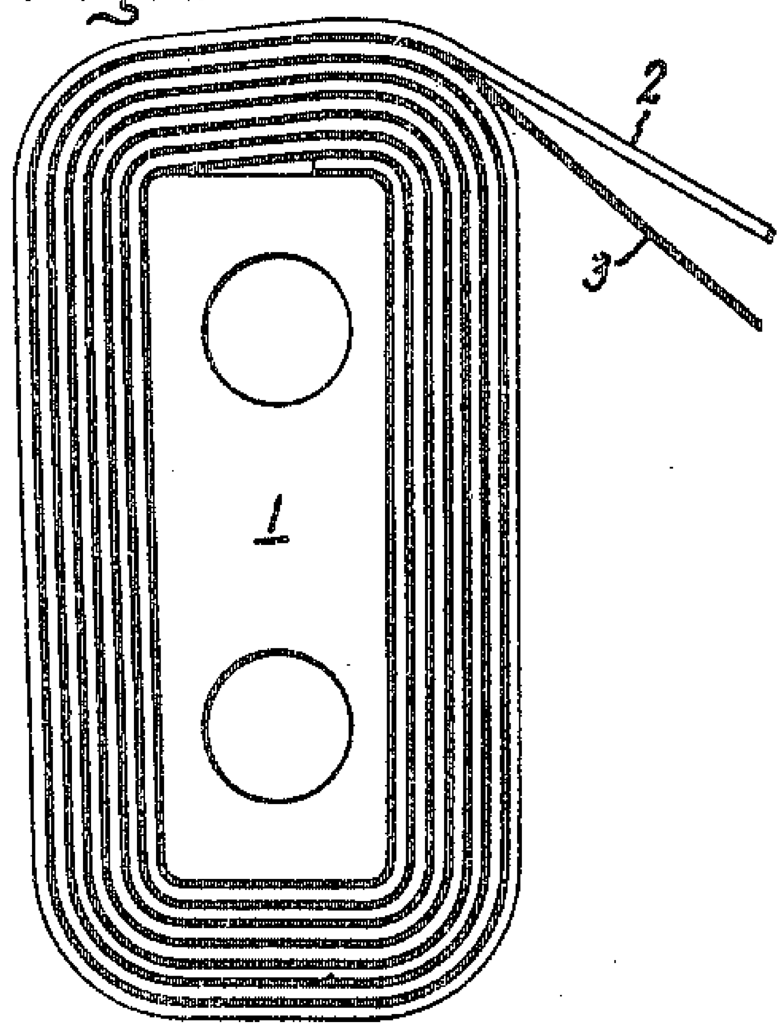


Fig. 2.

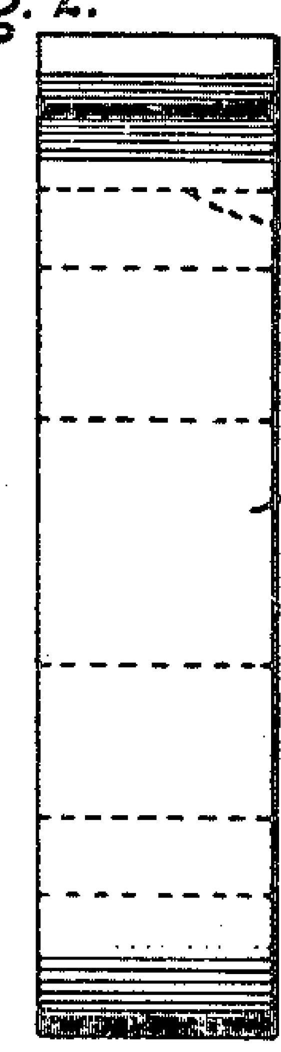


Fig. 3.

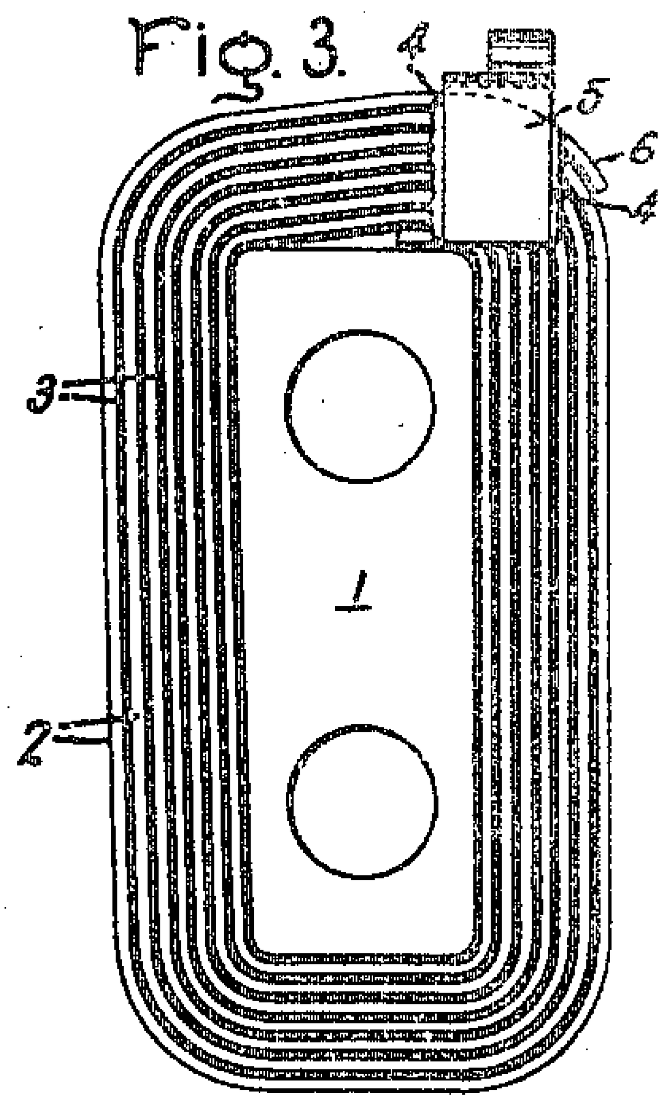
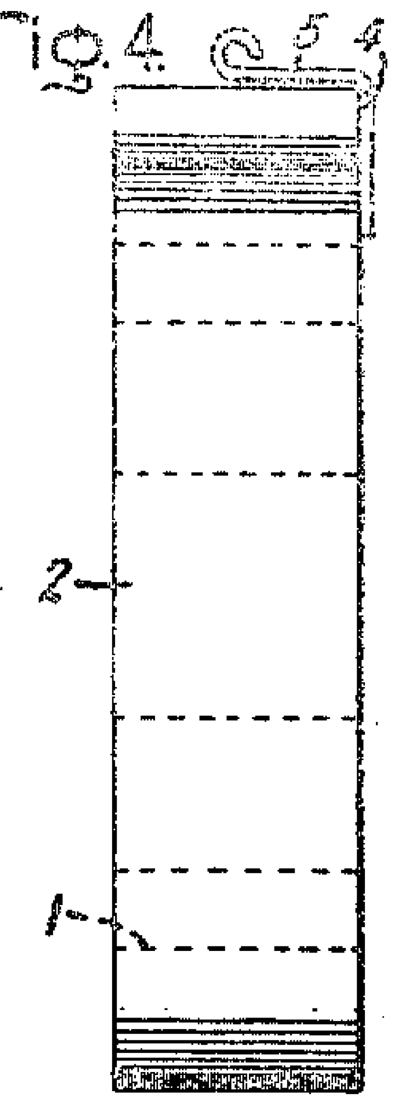


Fig. 4.



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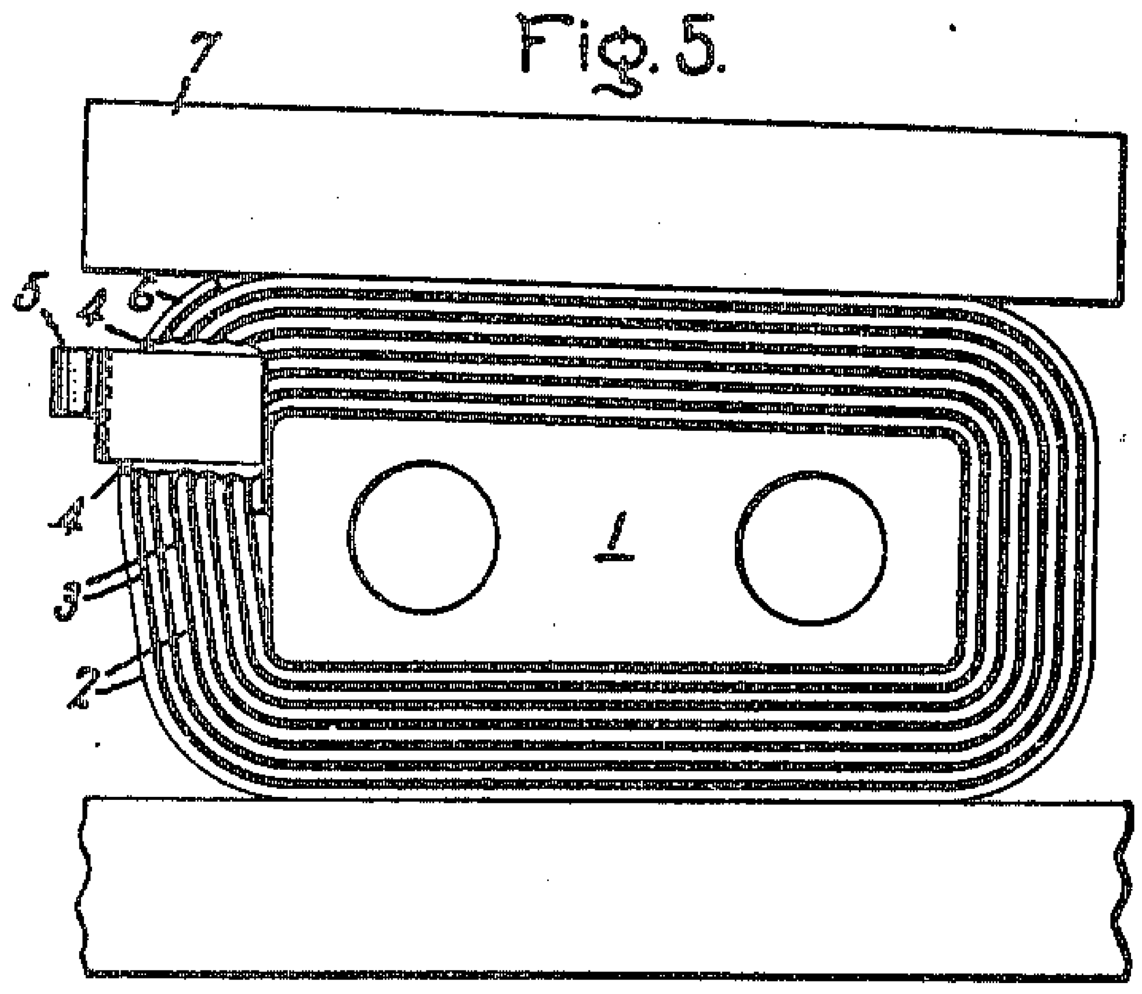


Fig. 6.

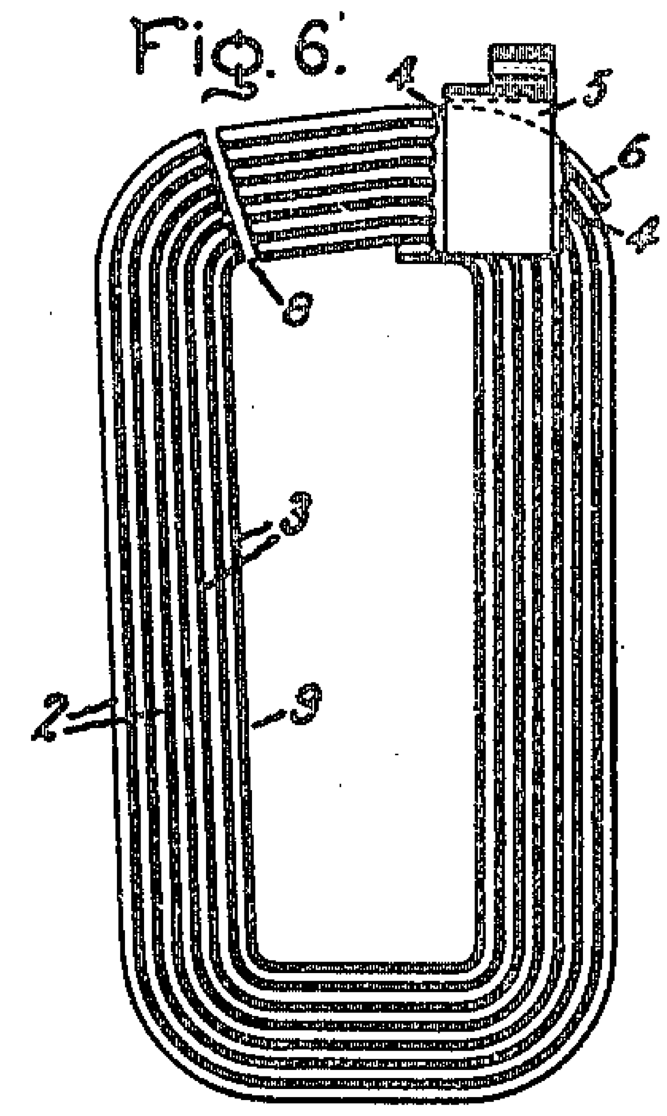


Fig. 7.

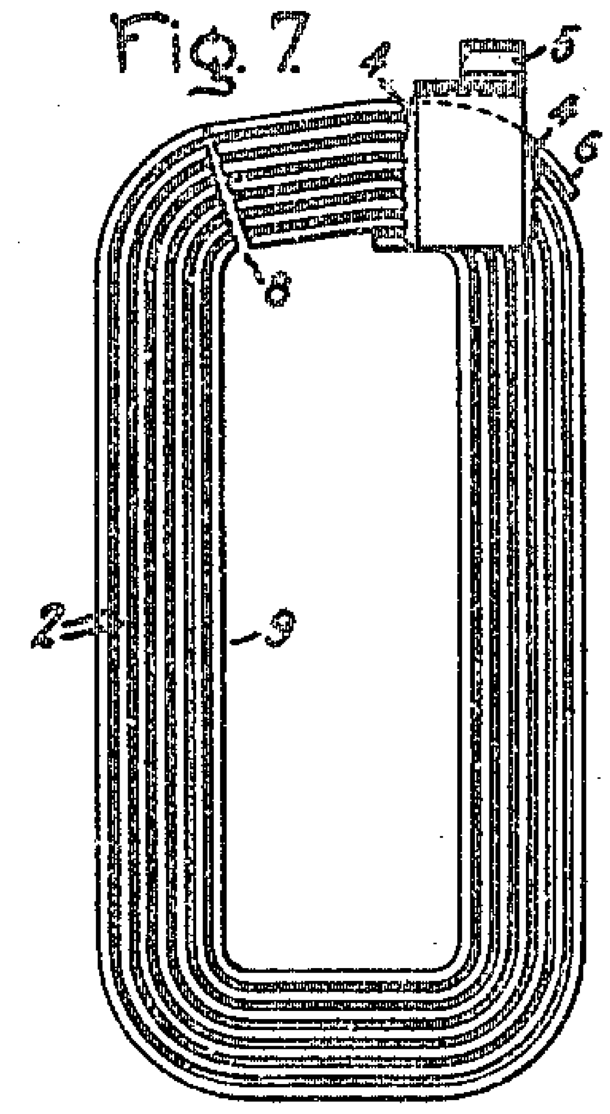


Fig. 9.

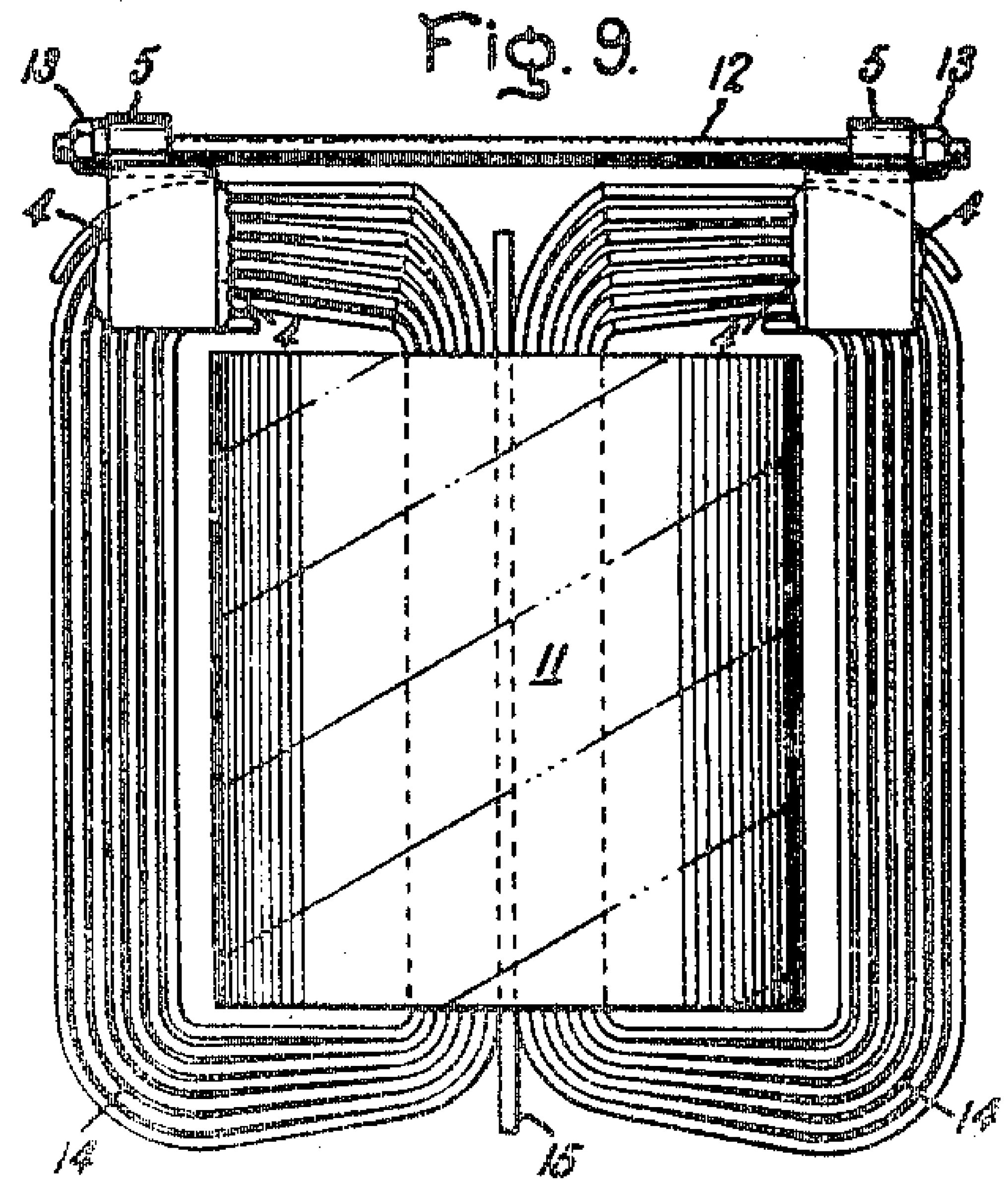
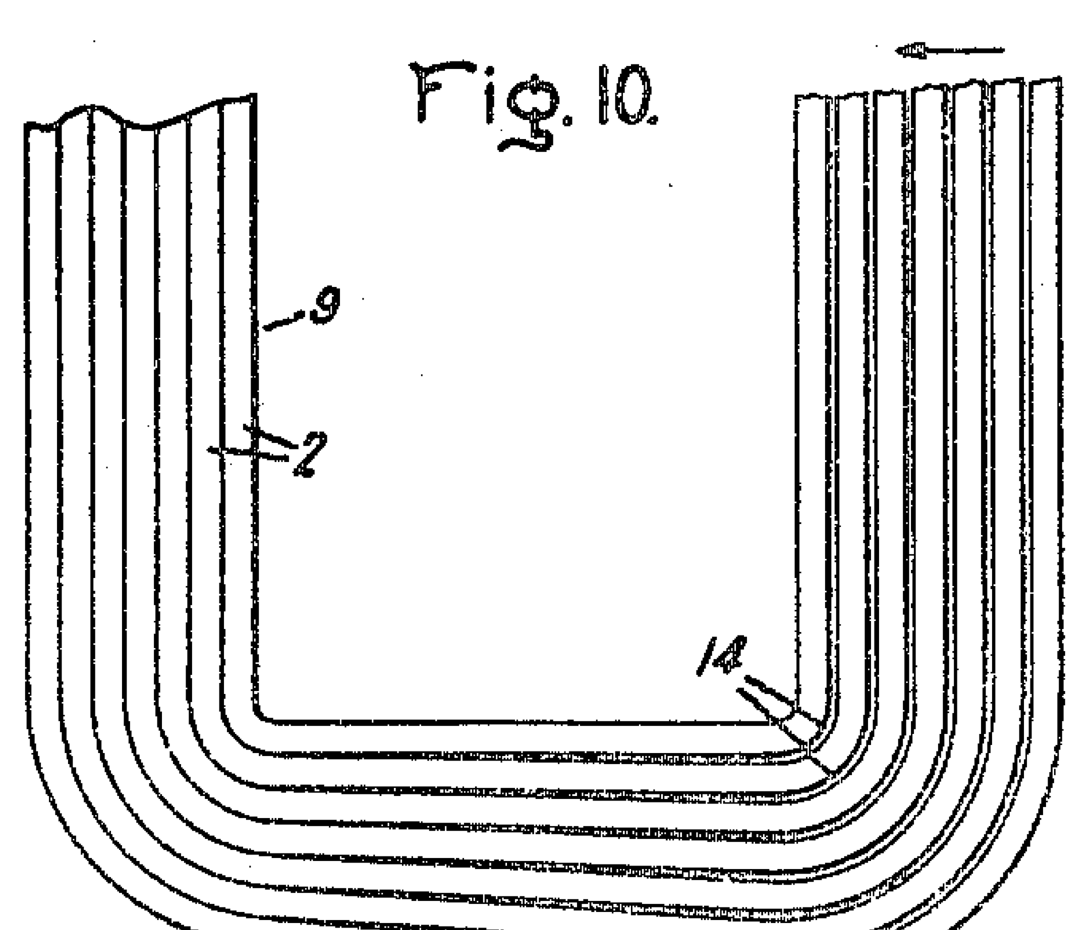


Fig. 10.



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INDUCTION APPARATUS

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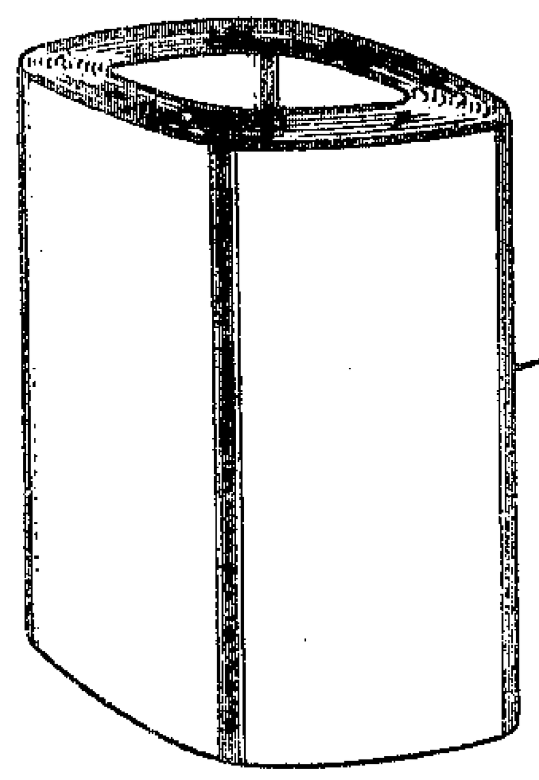
Fig. 8.



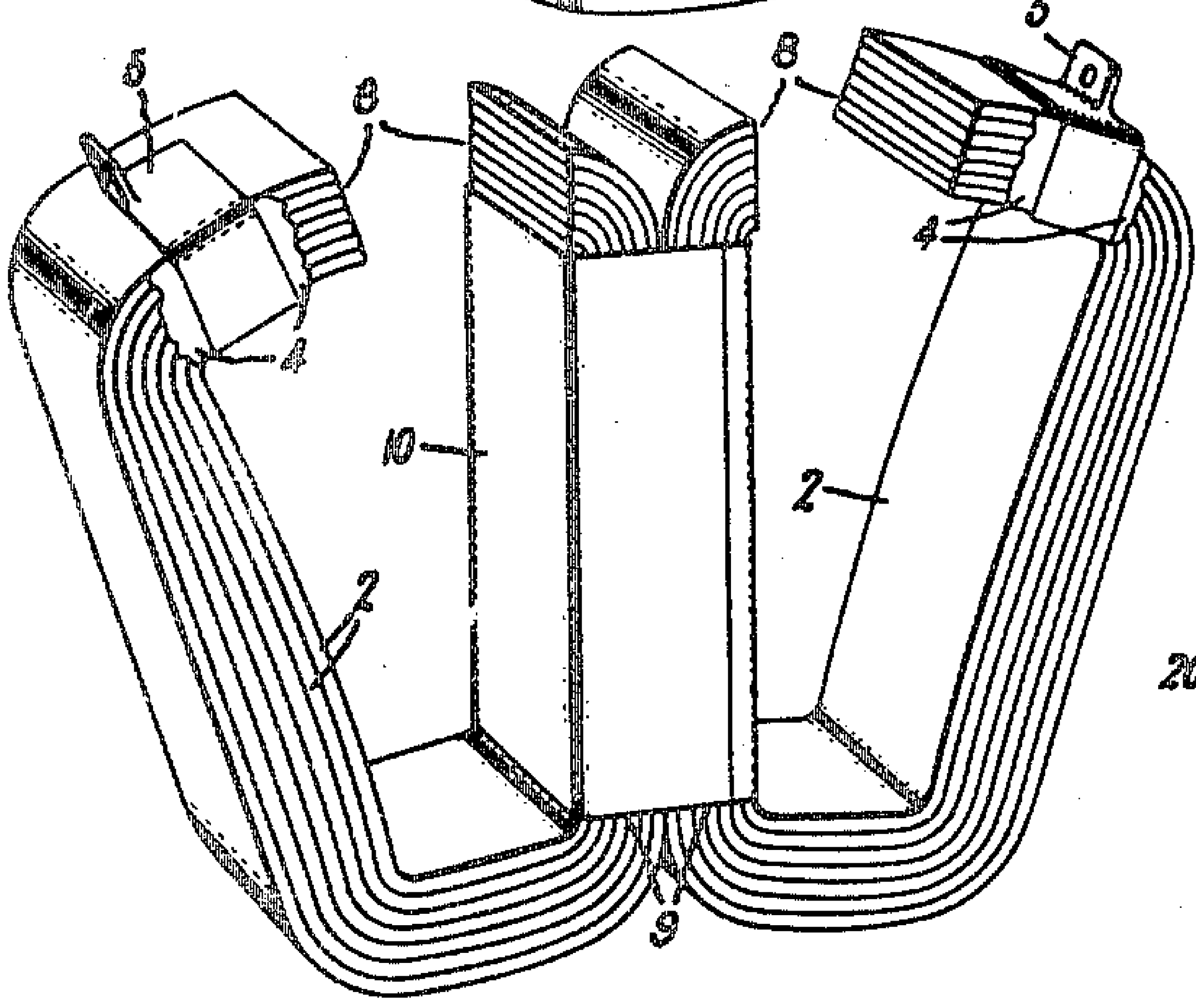


Fig. 12.

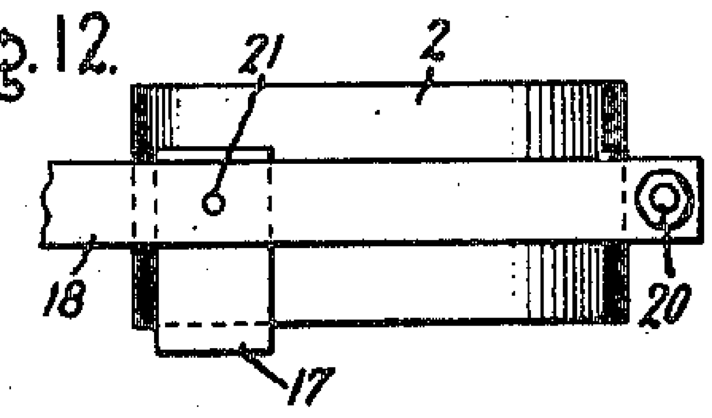


Fig. 11.

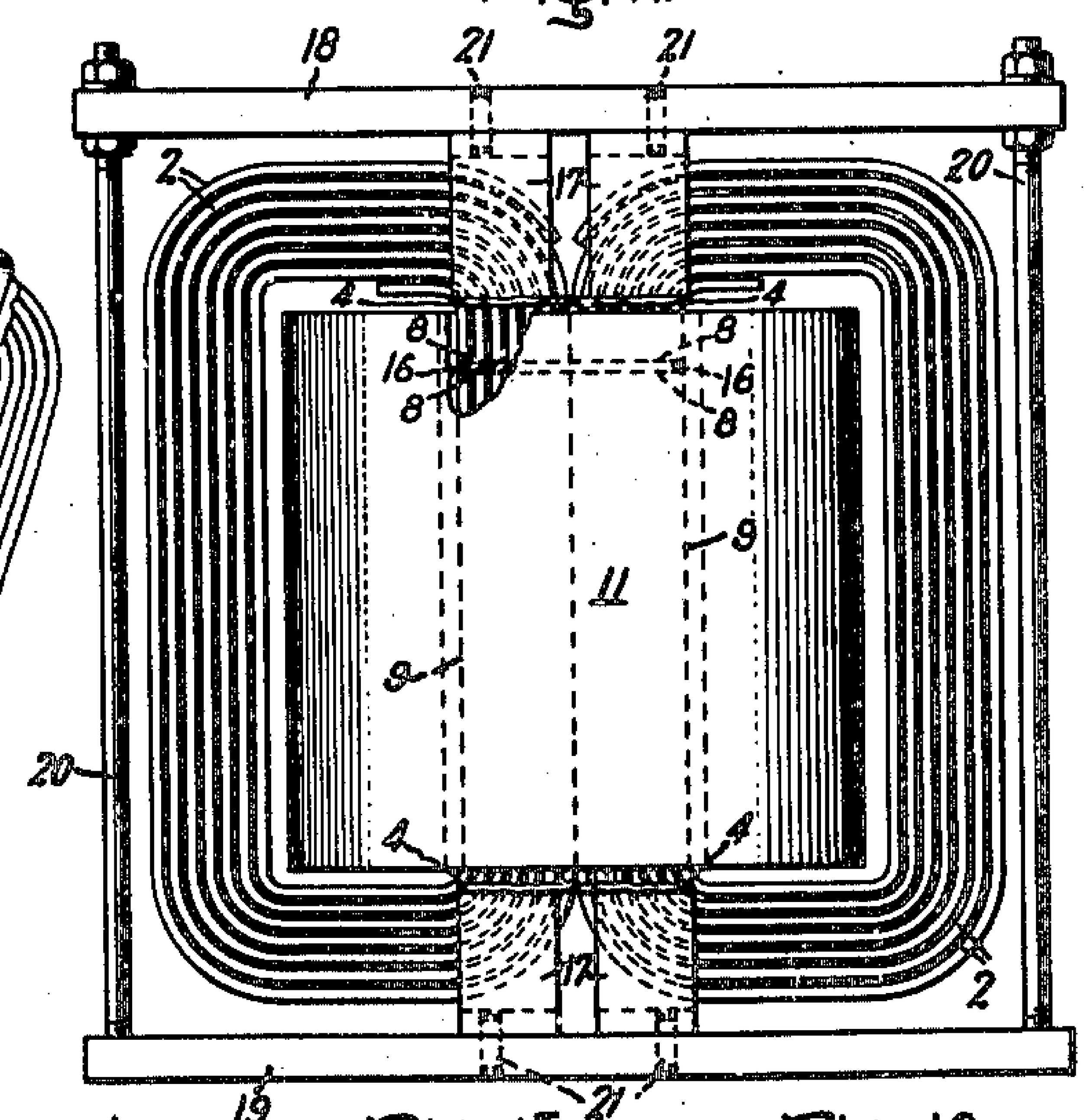


Fig. 13.

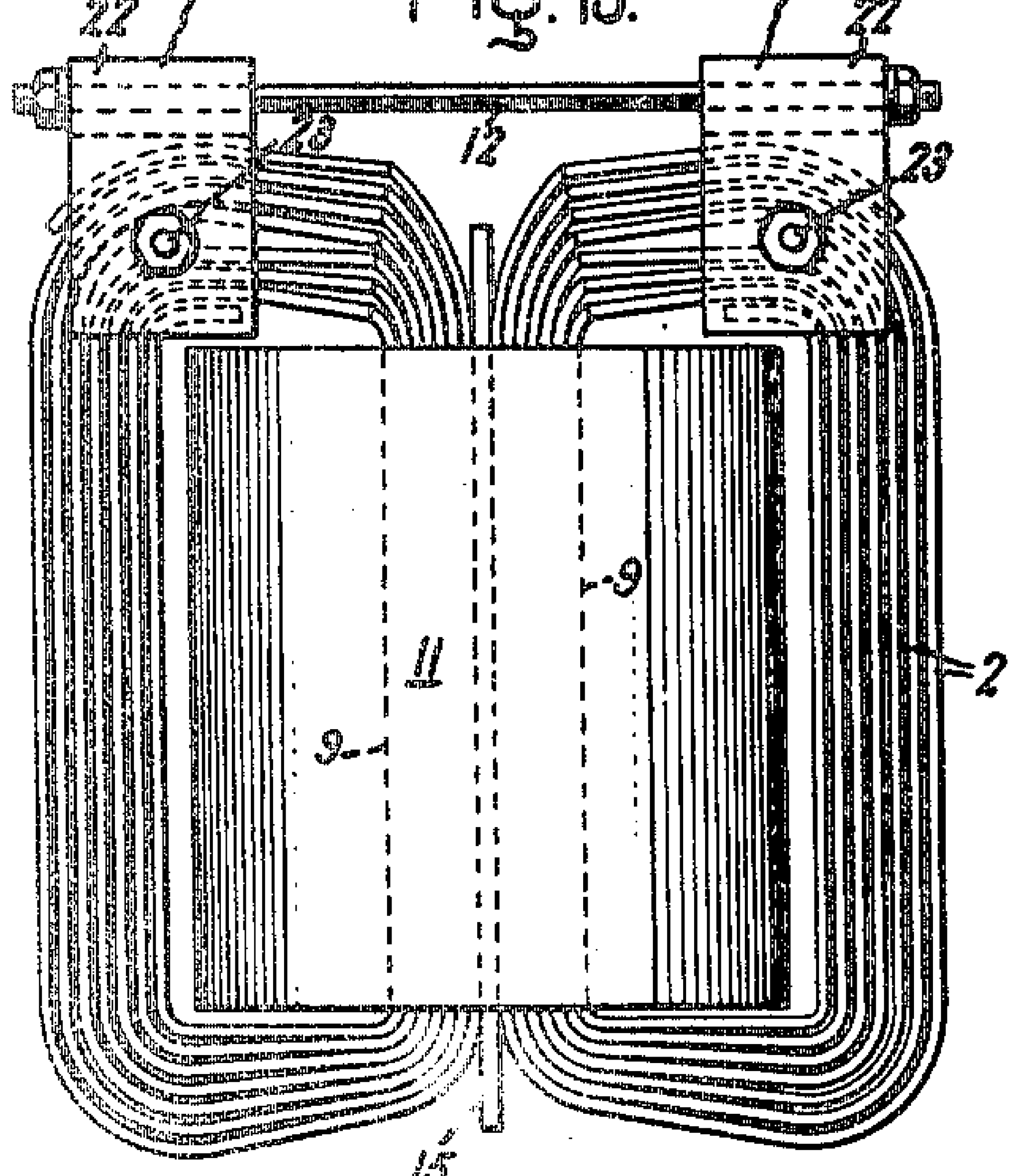


Fig. 14.

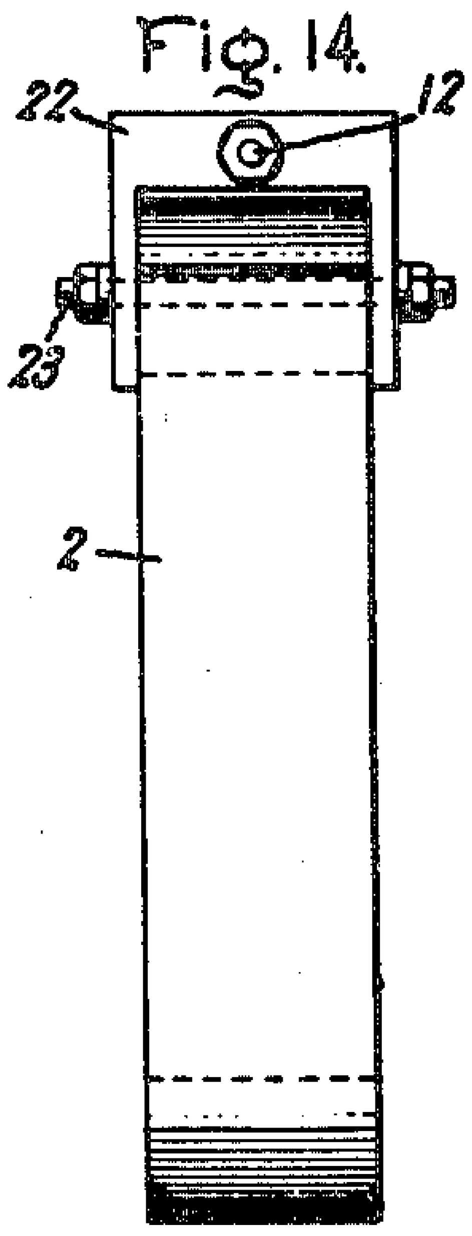


Fig. 15.

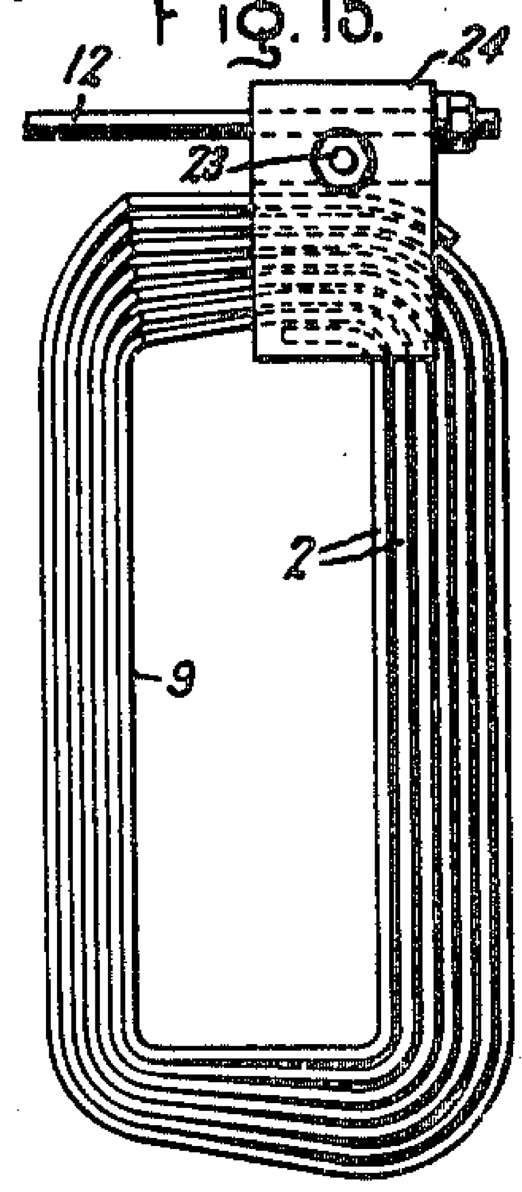


Fig. 16.

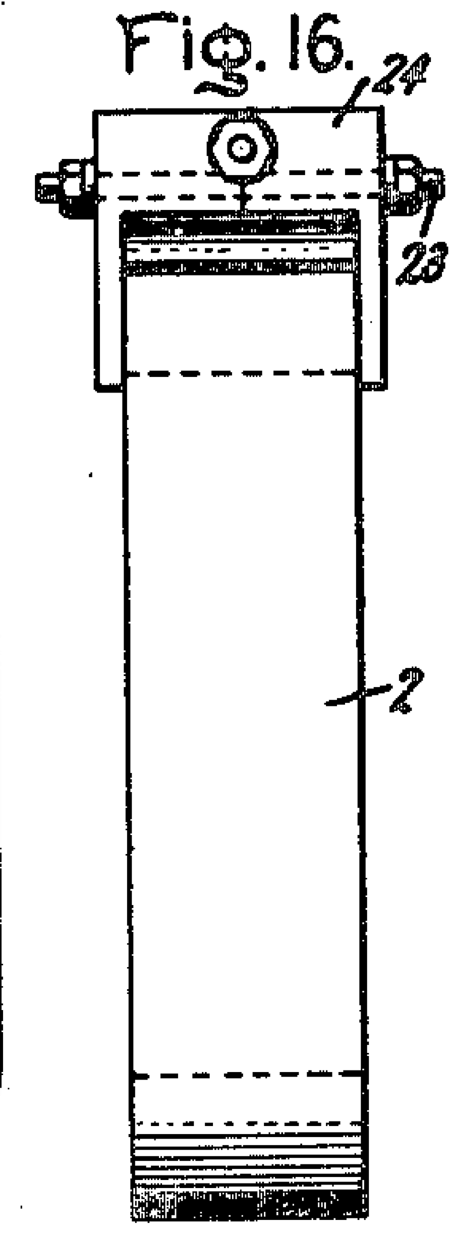
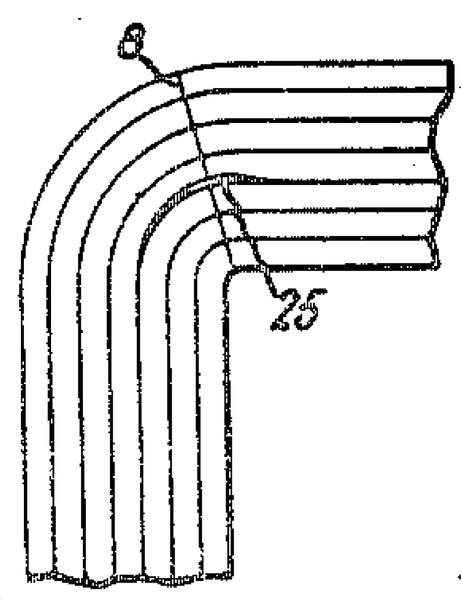


Fig. 17.



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UNITED STATES PATENT OFFICE

2,478,030

METHOD OF MAKING ELECTROMAGNETIC INDUCTION APPARATUS

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Original application May 24, 1945, Serial No. 595,518. Divided and this application June 17, 1946, Serial No. 677,390

4 Claims. (Cl. 29—155.61)

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This invention relates to a method of making electromagnetic apparatus and more particularly to a method of making magnetic cores for such apparatus.

This is a division of my application Serial No. 595,518, filed May 24, 1945, and assigned to the present assignee.

Since the comparatively recent discovery of magnetic materials having substantially lower losses than heretofore, when the flux is in a particular direction therein, the problem has been how best to utilize such materials in magnetic cores. By best utilization is meant the optimum relation between economy in manufacture and reduction in losses, and it is to be understood that these two considerations usually conflict.

One well-known way of using the directional properties of the newer core steels is to form it in the shape of a flat strip or ribbon with the grain or most favorable magnetic direction coinciding with its lengthwise dimension and winding or bending it flatwise into a multi-layer closed magnetic loop. The flux then always goes with the grain and low losses result. However, there is then the problem of getting the coil or conductive winding to link the closed core. Numerous ways of overcoming this difficulty have been suggested and one is to cut completely through the core so that the parts can be separated for receiving a preformed coil. This in turn results in joints or gaps in the magnetic circuit which increase the magnetizing current and sometimes increase the eddy current losses. Special treatment of the cut ends has also been used to reduce such losses.

In practicing this invention the closed magnetic loop is cut at only one place, so as to have the minimum number of gaps or joints, and the ends are bent apart to permit the insertion of the coil and are then brought together again. This in itself is not new and it was suggested in 1889, long before the discovery of low loss directional steels, in British Patent 7,856 to Johnson and Phillips. However, the British construction is not practical and is especially unsuitable when low loss directional steel is used. In the first place, it is practically impossible to bring the edges of the cut together again once the core has been bent open enough to allow the insertion of the coil. This is because the adjacent layers of strip bind on each other. The result is that a V gap is formed with the closed point of the V at the inner periphery of the core. In order to close the arms of the V excessive forces must be used, thus putting the inner layers under heavy compression and the outer layers under heavy tension. In the second place, such stresses in directional steel would greatly increase its hysteresis losses as it is well known that this material is very sensitive to stresses and strains. In the third place, the adjacent layers at the cut edges would be under heavy radial pressure, thus greatly increasing the tendency for burrs produced by the cutting to short circuit the layers and increase the eddy current losses.

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This invention is characterized by providing a predetermined space between the turns or layers of such a core. As a result the gap can be adjusted or reclosed without difficulty. Furthermore, this space causes the gap initially to assume a V shape with the closed part of the V at the outer periphery of the core and specially located clamping means is provided so that as the arms of the V are closed the outer layers of the core are progressively separated in a radial direction, thus effectively preventing burrs at the butt joints from short circuiting the laminations.

An object of the invention is to provide a novel method of making a magnetic core for electromagnetic induction apparatus.

Another object of the invention is to provide a novel method of interlinking a conductive winding and a magnetic core.

The invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings Fig. 1 is a side elevation view illustrating how the core may be wound on a mandrel, Fig. 2 is an edge elevation of the core shown in Fig. 1, Fig. 3 is a side elevation view illustrating a way of fastening the turns or layers of the core together and also illustrating a desirable location of the fastening means, Fig. 4 is an edge elevation of the core shown in Fig. 3 and illustrates further the position of a clamping bracket which is preferably attached to the core by the same means which fastens its turns or layers together, Fig. 5 illustrates the step of annealing the core, Fig. 6 illustrates the location of a cut in the core, Fig. 7 illustrates the change in the shape of the cut or joint after the spacing strip or filler material between the turns of magnetic strip has been removed so as to provide predetermined spaces between these turns, Fig. 8 shows how two of the cut loop cores are mounted relatively to each other and their cut ends spread apart so as to receive a coil winding on their common center winding leg, Fig. 9 shows the two core parts drawn together by a clamping screw and illustrates the separating action at the butt joints which results during closing of the V gaps, Fig. 10 is an enlarged view of a portion of one of the core parts showing how the spaces between layers allow the yoke part of the core to be moved so as to close the gap without straining the core material, Fig. 11 shows a reactor construction with the core joint in the form of a gap in the winding leg, Fig. 12 is a plan view of a detail of Fig. 11, Figs. 13 and 14 show a modified form of clamping bracket, Figs. 15 and 16 show another form of clamping bracket, and Fig. 17 shows the use of a key for strengthening the butt joint in the core.

Referring now to the drawings and more particularly to Fig. 1, there is shown therein a mandrel 1 which is mounted for rotation about an axis (perpendicular to the drawing) in any suitable manner, such as in a lathe (not shown). The mandrel may be of any suitable shape and, as shown, it is substantially rectangular but, as will be explained later, it is preferable to have it slightly trapezoidal. Wound on this mandrel are a magnetic strip or ribbon 2 and a thinner spacing strip 3 which may be made of paper. The strips are wound one on top of the other so that the spacing strip is between the layers of the magnetic strip. The magnetic strip is preferably of the type which has a most favorable magnetic direction, that is to say, its hysteresis losses and reluctance are lowest for flux in a given direction and this direction is along the length of the strip.

The thickness of both the magnetic strip and the spacing strip relative to the over-all core thickness or number of turns or layers of the strip has been exaggerated for the purpose of showing more clearly the principal features of the invention and it should be understood that in practice both strips will be very much thinner and will make correspondingly more turns or layers.

The strips may be of any suitable width so that, for example, the core may have the relative dimensions shown in Fig. 2, which is an edge view of the core.

After as many layers of magnetic strip have been wound on the mandrel as are necessary to give the desired flux density in the iron, the turns are securely fastened together in any suitable manner. For example, they may be welded together in a line along their edges as shown in Fig. 3 where the weld is indicated at 4. This same weld may also serve to attach a clamping bracket 5 to the core and, as shown in Fig. 4, this bracket is bent over so that it terminates above the center of the core. After the turns have been securely fastened together the strips may be cut off as at 6 in Fig. 3.

It is important that the weld 4 be on one side of the core only so as not to provide a short circuit path for eddy currents, as such a path would substantially increase the eddy current losses in the core.

After the turns of the core have been securely fastened together, the core is preferably annealed so as to free the magnetic material from all strains and thus reduce its losses to a minimum. As the core when it is assembled with its coil is normally clamped together, it is preferable that the core be under an equivalent pressure or compression when it is being annealed so that its normal operating state will be as close as possible to its state when it comes out of the annealing furnace. Therefore, it is preferable to place the core on its side with a weight 7 on top of it when it is in the annealing furnace.

After the core has been annealed the mandrel 1 is removed and the core is completely cut through as indicated at 8. This cut may be made by any suitable means, a preferred device being an abrasive wheel. The cut 8 is in a part of the yoke portion of the core which is in line with the winding leg portions of the core. Thus, in Fig. 6, 9 indicates the winding leg of the core and the cut 8 is made past the end of this leg in that part of the yoke portion of the core which is in line with the winding leg 9. Note that the weld 4 and bracket 5 are on the yoke portion of the core relatively near the cut 8.

If the mandrel 1 were exactly rectangular the core material removed by the cut 8 would result in a slightly trapezoidal core when the cut 8 is closed to form a butt joint. This would give a poor space factor with a rectangular coil. Therefore, in order to compensate for the width of the cut 8, the mandrel is preferably made slightly trapezoidal, the widest part being at the core end which is to be cut.

The spacing means or spacing strip between the adjacent layers of the magnetic strip is now removed from the core. When the spacer is a paper strip it will be turned to ash when the core is annealed and therefore it can be blown out from between the metal layers by compressed air and this will be facilitated by slightly flexing the core so as to separate slightly the adjacent layers of metal. After the spacing strip has been removed there will be a predetermined free space between each layer of the core with the result that the cut 8, instead of having parallel sides as in Fig. 6, will now be V-shaped as in Fig. 7 with the point or closed part of the V at the outer periphery of the core This is because as the layers are considered from the innermost to the outermost they in effect get progressively longer due to the removal of the spacing strip so that the outer layer will butt together first at the cut 8 and then each succeeding inner layer being relatively shorter will have a relatively greater space between its cut ends.

Another way to remove the spacer strip is to loosen carefully the core turns by partially unwinding the core into an eight-sided figure and then pull or shake the spacer strip out. The core is then rewound to the shape it had while it was being annealed.

The cut 8 can also be made before the core is annealed but its turns should first be fastened together as by the weld 4 so as to prevent it from coming apart after it had been cut.

The core indicated in Fig. 7 can now be spread apart at the cut 8 so as to slip a coil or winding on the winding leg 9. While a single core loop as shown in Fig. 7 can be used, it is usually preferable to use two or more so as to provide a so-called distributed core. Fig. 8 shows a two-part distributed core with the winding legs 9 wrapped together with insulating material 10 and with the parts spread apart at the cuts so as to provide space for slipping the coil 11 in place. While only a two-part core has been illustrated, it will be obvious to those skilled in the art that the distributed core can have any desired additional number of parts.

After the coil 11 has been slid into place the yoke portions of the core are bent back into place so as to close the gaps 8 and a clamping bolt 12 is inserted in clamping brackets 5 and nuts 13 on the ends thereof are drawn up.

The wrapping 10, as shown most clearly in Fig. 8, binds the winding legs relatively tightly together so as to provide a favorable space factor in the coil window and this results in separating the layers of the core at the corners indicated at 14 in Fig. 9. Alternatively, the core may be inserted into the coil one leg at a time and then forced tightly against the sides of the coil with a spacer 15. Fig. 10 is an enlarged view of the right-hand core part in Fig. 9 showing how the layers have little space between them in the winding leg 9 and have relatively large spaces between them at the corner 14. This makes it possible for the yoke portion of the core to be bent very easily in the direction of the arrow in Fig. 10 so as to close the gap 8 without excessively straining the magnetic material.

As the nuts 13 on the clamping screw are drawn up the cut ends of the outer turn or layer of the core first come into abutting relation. Continued tightening of the nuts causes the outer layer of both sides of the cut to spring outward slightly so that the cut ends of the next layer come into abutting relation. Continued tightening of the nuts therefore progressively causes the layers to come into abutting relation and then to spring outwardly slightly so that the next succeeding layer in the inwardly extending direction will come into abutting relation. This continues until the cut ends of all of the layers are in abutting relation. By reason of the separation between layers at the cut it will be seen that it is difficult for adjacent layers to be short circuited by minute burrs which are usually raised at the cut edges during the cutting operation. Consequently, the butt joint does not need to have its surfaces smooth worked or treated in any special way and no noticeable increase in eddy current losses is produced by my improved butt joint. Also, as the cut ends of each layer are in abutting relation the reluctance of the joint is quite low and hence the exciting ampere-turns of the core are relatively low compared with other butt-jointed cores.

In order to strengthen the joint and also to make additionally sure that its laminations are insulated from each other the abutting faces of the joint are preferably coated with an insulating varnish, such as a thermo setting synthetic resin, before they are clamped together. The above-described spreading action of the joint laminations then allows the varnish to run between the laminations with the result that they are well insulated and are firmly held in place after the varnish becomes hard.

It is not essential to my invention that the joint be in the yoke portion of the core and it can also be in the winding leg portion of the core. Furthermore, the joint need not be closed and it can be kept open magnetically any desired amount so as to provide an air gap. An example of such construction is shown in Fig. 11 and it is particularly well adapted for use with reactors. In this figure the gaps 8 are shown in the winding legs 9, near one end thereof, and they are spaced by suitable non-magnetic insulating spacers 16 which are inserted between the cut ends of the winding legs.

The core parts are shown welded in two places and these welds also serve to fasten brackets 17 in place. These brackets bear against upper and lower clamp members 18 and 19 respectively which are pulled together by clamping poles 20. In order to prevent the brackets 18 and 19 from slipping relative to the members 17 pins 21 passing through registering holes in the members 17, 18 and 19 are provided.

The core parts are sufficiently flexible so that when the cuts or gaps 8 are near the ends of the winding legs the core parts can be brought together readily after the coil 11 has been put in place in the manner shown in Fig. 8. As the clamping bolts 20 are tightened the ends of the laminations will be progressively pressed against the insulating spacers 16 so as to separate them slightly in a manner similar to the way the laminations are spread apart, as shown in Fig. 9.

It is not essential to fasten the core turns together by welding nor is it essential that the clamping brackets be attached to the core by welding and these brackets can be made of insulating material which is cemented to the core. Such construction is shown in Figs. 13 and 14, in which one-piece brackets 22 of insulating material are U-shaped and fit tightly over the yoke portions of the core and are cemented to the core by any suitable adhesive cement, such as a polyvinyl butyral-phenol aldehyde resin solution. In addition, these brackets can be held in place by bolts 23 which pass through the core. The space for permitting these bolts to pass through the core is provided by placing a spacer in the core at the necessary point when the core is being wound. After the core is annealed this spacer is removed the same time that the spacing strip between the magnetic strip is removed.

In the modified construction shown in Figs. 15 and 16 a two-part clamping bracket 24 is provided and the bolt 23 instead of passing through the core passes through the bracket 24 outside of the core. The bracket 24 is preferably also cemented to the core as in Figs. 13 and 14.

In order to strengthen the core joint one or more keys 25 may be placed between the cut laminations so as to straddle the joint, as shown in Fig. 17. The space for the key is provided by inserting a metal spacer in the core when it is wound. The two halves of this spacer are removed after the core has been cut at 8 so as to provide space for the key.

While there has been shown and described a particular embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. The method of making a magnetic core for electromagnetic induction apparatus which comprises, winding on a mandrel a steel strip with a spacing strip between turns of the steel strip so as to form a wound core having a winding leg, a yoke leg and two end yokes, attaching a clamping bracket to said core by welding across all the turns of said wound strip on one side of the core near the junction of the yoke leg and one end yoke, annealing said core, removing the mandrel, cutting completely through said core near the junction of said winding leg and welded end yoke, removing said spacing strip to form a V-shaped joint with the closed end of the V at the outer periphery of the core, and urging said clamping bracket toward said winding leg whereby the layers of steel strip adjacent the V joint are radially separated in order that the cut ends of the strip form butt joints at each layer.

2. The method of making a magnetic core for

electromagnetic induction apparatus which comprises, winding a steel strip and an organic spacing strip in interleaved relation on a mandrel so as to provide a wound core having a winding leg and a yoke portion, securely fastening the turns of said steel strip together in the yoke portion substantially nearer one end of the winding leg than its other end, annealing the core, removing the mandrel, completely cutting through the core substantially within the lateral confines of the winding leg and near said one end thereof, removing said spacing strip whereby after said core is spread apart at said cut to allow insertion of said winding leg through a coil window the core can be closed again without excessively straining the layers of steel strip, and forcing the cut ends of the core together so as to provide a butt joint at which adjacent layers of steel strip are radially separated so as to prevent short circuits between adjacent layers by burrs raised during the cutting.

3. The method of making a magnetic core for an electromagnetic induction apparatus which comprises, winding a steel strip and a spacing strip in interleaved relation on a mandrel so as to provide a wound core having a winding leg and a yoke portion, securely fastening the turns of said steel strip together in the yoke portion substantially nearer one end of the winding leg than its other end, annealing the core, removing the mandrel, completely cutting through the core in a plane whose area of intersection with the core is substantially within the lateral confines of the winding leg, removing said spacing strip whereby after said core is spread apart at said cut to allow insertion of said winding leg through a coil window the core can be closed again without excessively straining the layers of steel strip, and forcing the cut ends of the core toward each

other so that adjacent layers of steel strip are radially separated in order to prevent short circuits between adjacent layers by burrs raised during the cutting.

4. The method of making a magnetic core for electromagnetic induction apparatus which comprises, winding a steel strip and a spacing strip in interleaved relation on a mandrel so as to provide a wound core having a winding leg and a yoke portion, securely fastening the turns of said steel strip together in the yoke portion near one end of the winding leg, annealing the core, removing the mandrel, completely cutting through the core within the portion of the winding leg normally occupied by a conductive winding and near said one end of the winding leg, removing said spacing strip whereby after said core is spread apart at said cut to allow the insertion of said winding leg through a conductive coil window the core can be closed again without excessively straining the layers of steel strip, placing a nonmagnetic spacer between the cut ends of the core and forcing the cut ends of the core against opposite sides of said nonmagnetic spacer so that adjacent layers of steel strip are radially spaced in order to prevent short circuits between adjacent layers by burrs raised during the cutting.

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