

May 22, 1945.

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2,376,613

ELECTROMAGNETIC DEVICE

Filed Nov. 13, 1941

3 Sheets-Sheet 1

Fig. 1

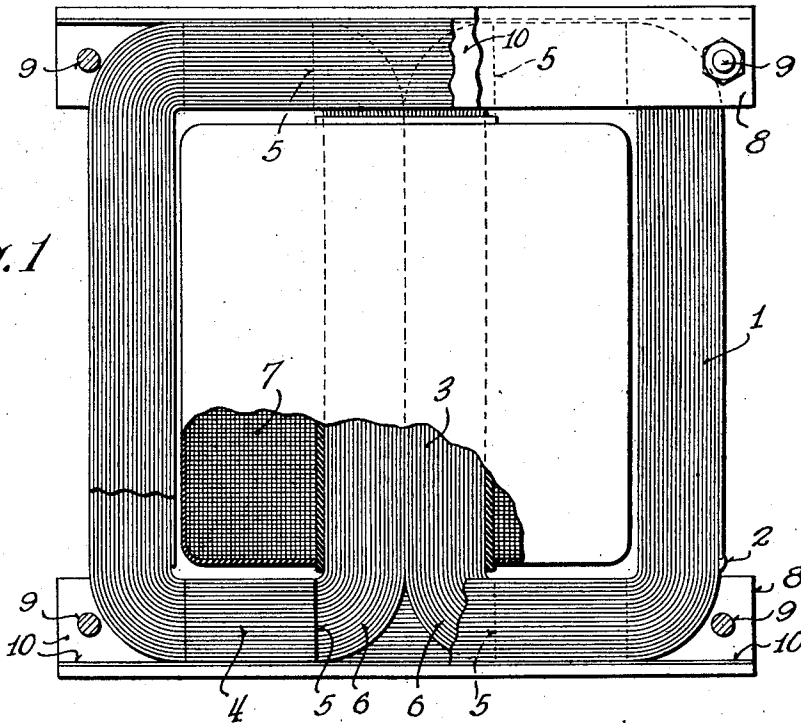
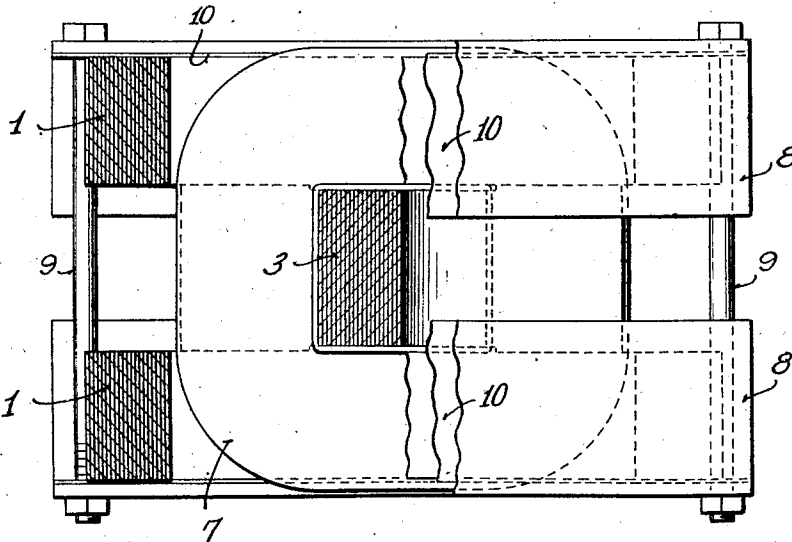


Fig. 2

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3 Sheets-Sheet 2

Fig. 3

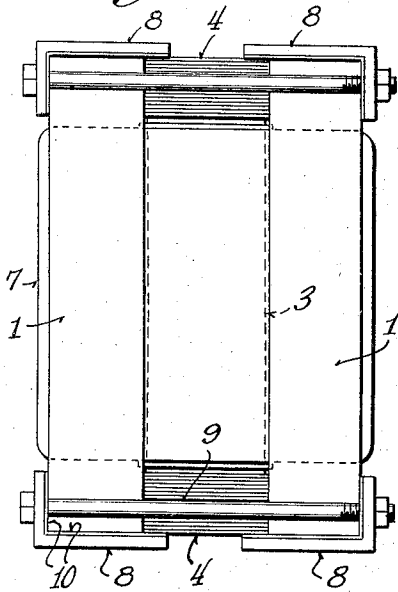


Fig. 4

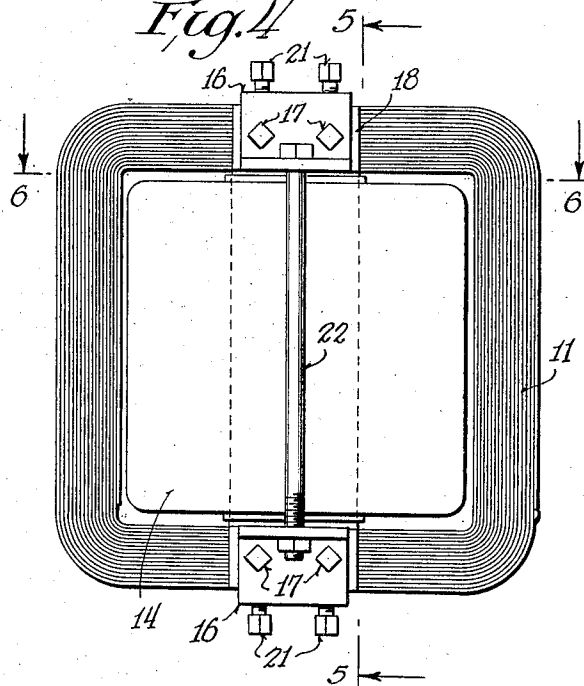


Fig. 5

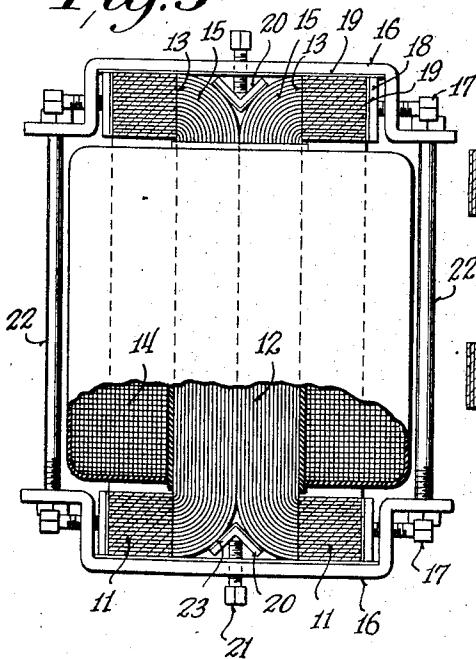
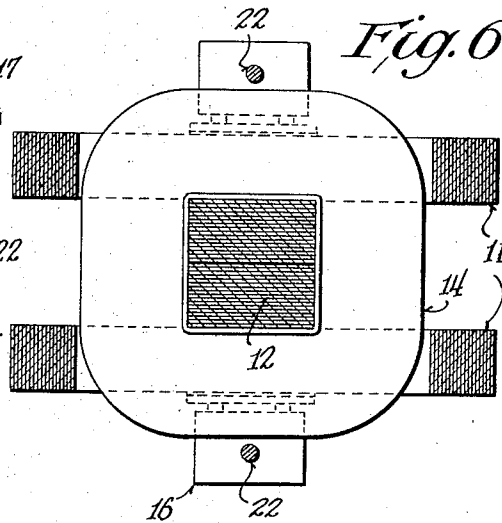


Fig. 6



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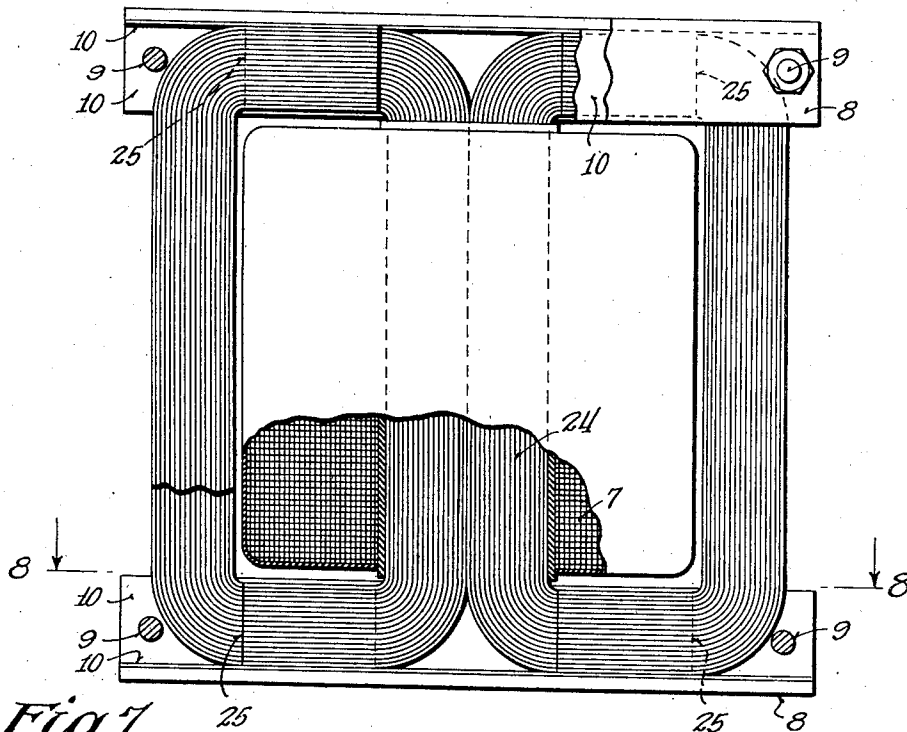
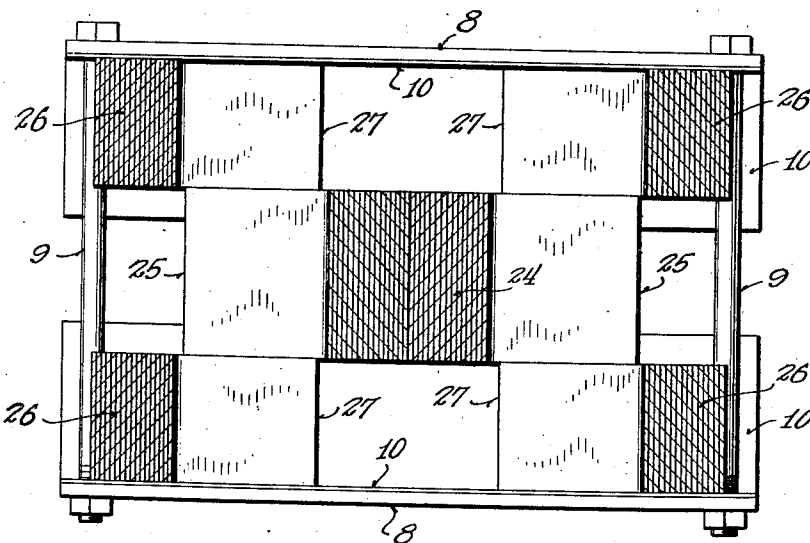
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,376,613

ELECTROMAGNETIC DEVICE

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Application November 13, 1941, Serial No. 418,876

16 Claims. (Cl. 175—356)

This invention relates to electromagnetic devices such as transformers, chokes, and other devices of this general nature.

Transformers have heretofore been made in which wound magnetic cores are employed. However, transformers having wound magnetic cores frequently require a considerable amount of assembly work and often require very great care in order to avoid the danger of imparting mechanical stresses to the magnetic core after the magnetic core has been annealed, as these mechanical stresses adversely affect the magnetic characteristics of the cores thereby resulting in a lowering of the efficiency of the transformer or other electromagnetic device.

This invention is designed to overcome the above noted defects and objects of this invention are to provide a novel form of electromagnetic device which, in its preferred form, has its core structure formed of wound magnetic ribbon, the major portion of the core structure being formed of closed wound cores and the remaining portion of its core structure being formed by winding a closed magnetic core from magnetic ribbon and thereafter cutting the wound closed structure into two sections both of which are used in the completed device, in which no unusual care is required in the assembly of the parts of the device, in which no bending, machining, or other working of the core structure is required after annealing, and in which short-circuiting of the laminations is avoided.

Further objects, for another form of the invention, are to provide an electromagnetic device in which a part of the core structure is composed of magnetic ribbon wound to provide a closed core and a part of stacked magnetic laminations, the constructional advantages of each type of core structure being utilized where it is most desirable.

The invention in its broadest aspect permits the use of stacked magnetic laminations, or a wound core formed of magnetic ribbon some or all portions of which may be cut into parts after winding, or, as stated, a combination of both stacked magnetic laminations and wound magnetic ribbon, in all forms the resulting magnetic core structure being laminated through its entire extent.

Further objects are to provide an electromagnetic device in which there are relatively few joints in the core structure, in which the joints in the core structure are so formed that a substantially edge to edge contact of the adjacent laminations is obtained, thereby materially reducing the reluctance of the magnetic path, and in which these results are obtained in a very simple manner and with a very small amount of work required in the manufacture of the device.

Further objects are to provide a novel construction of electromagnetic device in which the losses are relatively small, and in which a very good space factor is obtained for the conducting winding.

Further objects are to provide a novel form of transformer or other electromagnetic device which is extremely simple to manufacture, and in which the number of operations required in its production is materially reduced.

Embodiments of the invention are shown in the accompanying drawings, in which:

Figure 1 is a view, partly in section and partly broken away, showing a transformer.

Figure 2 is a top view of the structure shown in Figure 1, with parts broken away and parts in section.

Figure 3 is a side elevation of the structure shown in Figure 1, such view being drawn to a smaller scale.

Figure 4 is a view of a further form of transformer.

Figure 5 is a sectional view on the line 5—5 of Figure 4.

Figure 6 is a sectional view on the line 6—6 of Figure 4.

Figure 7 is a view, partly in section and partly broken away, showing a further form of transformer.

Figure 8 is a sectional view on the line 8—8 of Figure 7.

Referring to the drawings, particularly Figures 1, 2 and 3, it will be seen that the transformer is formed of three main portions, namely, two outer closed wound cores 1 formed of magnetic ribbon which may be of approximately rectangular shape as shown with the last convolution tacked down as indicated at 2 by brazing, welding or other similar means, and a central core section indicated generally at 3. The central core section is also a wound core formed of magnetic ribbon which is wound into an approximately rectangular shape and which is thereafter cut in half and the two half sections reversed and put together back to back to form the main body of the central core as indicated at 3 in Figure 1, with the end portions of the central core projecting laterally at each end of the central core, such projecting portions being indicated by the reference character 4. The end portions of the central core are positioned between the outer closed cores 1 in the finished transformer.

In making the transformer, the cores are all wound from magnetic ribbon on suitable mandrels to give the shape desired. Thereafter the central core is cut in half as previously described and the sides of the center core 3 are ground down, up to the lines indicated at 5 in Figure 1, and the sides of end portions 4 are ground down

slightly to provide smooth flat faces. The grinding extends inwardly to a greater distance along the body of the central core 3 than along the portions 4 to thereby provide an air gap between the curved parts 6 of the central core and the adjacent portions of the closed outer cores 1, thus avoiding any short-circuiting across the laminations of the outer cores 1, which would have been caused had the curved sections 6 of the central core contacted these laminations and formed a metal to metal contact. Instead, as stated, these curved sections 6 are ground down a sufficient distance to keep them out of contact with the adjacent portions of the closed cores 1. The grinding need not extend throughout the entire length of the central core 3, though this is a simple way of doing it, for obviously the grinding may extend only along the area immediately adjacent and including the curved portions 6 at the ends of the central core 3 so as to provide the air gap hereinabove mentioned.

A further manner in which the central core may be treated would be to either grind the central core on both sides of the central core including the outwardly extending portions 4, or else grind merely that portion of the central core included between the outer wound cores 1 without grinding the central portion of the central core to a greater extent than the outer portions. When either of these two methods is followed, insulating paint would be placed on the central portion of the central core, particularly at its end portions 6 between the lines 5, 5 to thereby prevent short-circuiting of the laminations of the outer cores 1.

The grinding of the portions 4 is for the purpose of securing smooth, uniform side faces for these portions. It is preferable also to slightly grind the adjacent faces of the closed cores 1 so that there will be a very intimate, close and accurate contact between the portions 4 at the ends of the central core 3 and the adjacent portions of the closed cores 1. Inasmuch as the laminations in the portions 4 are in parallelism with the adjacent laminations of the closed cores 1, it is apparent that an edge to edge contact is secured between the laminations of the central core 3 and the laminations of the closed outer cores 1 and thus the reluctance at this joint is greatly reduced. Also it is to be noted from an examination of Figure 1, that an extended or long contact is secured at these portions of the structure, thus also materially reducing the reluctance of the joints at these points.

After the closed cores 1 have been wound with their ends secured as indicated at 2, and after the central core 3 has been wound and cut in half while it is held in a suitable clamping means not shown, and after the grinding has been done on the central and closed cores as described hereinabove, these cores are held clamped by any suitable means so as to retain their shape and are then annealed. During the annealing any wire edges or burrs that may be left from the grinding or cutting are burned off, but if by chance any remaining burrs or wire edges should be left after annealing, these may be readily removed by means of a wire brush, or, in fact, they may be removed by a wire brush prior to annealing.

After the parts forming the core of the transformer have been annealed, they are not thereafter subject to any kind of machining, bending or other working and consequently they have no stresses imparted thereto, with the result, there-

fore, that their magnetic characteristics are unimpaired.

After the parts have been annealed, the central core 3 is placed in an ordinary winding lathe and the conducting winding 7 is wound thereon, suitable insulation being provided in the customary manner. After the central core 3 has been wound, it is then positioned between the closed outer cores 1, and the parts are then clamped together to form the finished transformer. This clamping may be accomplished in any suitable manner. A very simple means is shown in Figures 1, 2 and 3 in which L-shaped angle irons 8 are provided and are drawn towards each other by means of bolts 9, all of the clamping structure, it being noted, being located wholly outside of the core structure of the transformer.

It is preferable to provide insulating sheets 10 between all of the faces of the clamping members and the core sections. It is to be noted also from Figures 2 and 3 that the L-shaped clamping members 8 extend over the ends 4 of the central core 3.

While it is preferable to slightly grind the portions 4 at the ends of the central core 3 and the adjacent portions of the outer cores 1, this grinding may be dispensed with if desired but, as stated, more accurate and smoother faces are provided by grinding at these contacting portions.

Also if it is desired, any oxide or scale that may be formed on the portions 4 and on the adjacent portions of the outer core 1 may be removed after annealing, though this is not usually found necessary. This oxide may be scraped off or brushed off but it is to be distinctly understood that no machining or working of the cores takes place after annealing and thus no stresses are imparted to the cores after annealing. Instead, the transformer is finished after annealing without any stresses being imparted to any core structure whatsoever and thus minimum reluctance of the core sections is obtained in the finished transformer.

In the form of the invention shown in Figures 4, 5 and 6 outer closed cores 11 are wound from magnetic ribbon and the central core 12 is also wound from magnetic ribbon. The central core is either cut in half or a portion is cut out so as to provide a central core of the shape shown in Figure 5 wherein the outer ends of the central core are cut off along the lines indicated at 13 in Figure 5.

The central core is, of course, held clamped during this cutting operation as in the case of the form previously described and the faces at the points 13 and the adjacent portions of the closed cores are ground to provide smooth surfaces. The central core 12 and the outer closed cores 11 are held clamped so as to retain their shape and are annealed. Thereafter the central core is either slipped through a preformed conducting winding 14, as the curved end portions 15 thereof do not extend beyond the outline of the central core, or, if desired, the central core may be placed in a winding lathe and the conducting winding 14 may be wound thereon, suitable insulation being provided in accordance with the usual practice.

All of the cutting and grinding is done prior to annealing and after annealing no further working either by machining, bending or in any other manner is done on any of the core structures, thereby avoiding stressing the core structures after annealing. During the annealing any wire

edges or burrs that may be left from the grinding or cutting are burned off, but if by chance any remaining burrs or wire edges should be left after annealing, these may be readily removed by means of a wire brush, or, in fact, they may be removed by a wire brush prior to annealing.

The final step in the manufacture of this form of the invention is to clamp the outer cores to the central core. This is readily accomplished in a simple way, for example by means of the end brackets 16 through which set screws 17 are threaded. These set screws bear against clamping plates 18 on opposite sides of the outer closed cores 11, suitable insulation being positioned between all portions of the clamping structure and the core structures as indicated at 19.

In order to prevent any possibility of the curved sections 15 opening out and losing their intimate contact with the adjacent portions of the closed cores 11, V-shaped clamping members 20 are provided at opposite ends of the transformer. These V-shaped clamping plates are forced inwardly by means of set screws 21 threaded into the brackets 16, the brackets themselves being held against opening outwardly by means of the bolts 22. It is also preferable to provide insulating sheets 23 between the ends 15 of the central core and the clamping members 20.

While it is not usually necessary, if it is desired any oxide that may be formed along the faces 13 of the end sections 15 of the central core and the adjacent portions of the closed outer cores 11 may be removed after annealing by scraping or by means of a wire brush or in any suitable manner, but no working of any of the core structures whatsoever is done after the annealing has been completed and thus the core sections are left in a wholly unstressed condition in the finished transformer.

In the form of the invention shown in Figures 7 and 8 the central core is formed by winding a closed core of magnetic ribbon as described in connection with the central core of Figures 1, 2 and 3. This wound magnetic ribbon is then cut in half and the two sections are arranged back to back to form the central core portion 24 provided with outwardly extending end portions 25 projecting outwardly in opposite directions at each end of the central core.

The outer cores are formed of wound magnetic ribbon and are cut in half and the two halves are separated. The half sections forming the outer cores are indicated at 26 and each is provided with inwardly projecting end portions 27 which are spaced apart, as shown most clearly in Figure 8. These end portions 27 about the side faces of the end portions 25 of the central core section and an edge to edge contact is obtained. It is preferable to grind the adjacent faces of the portions 25 and 27 to secure smooth even faces and an accurate edge to edge contact. After the grinding has been completed, all of the cores are annealed and any burrs or wire edges that may result from the grinding or cutting are burned off, but if by any chance any remaining burrs or wire edges should be left after annealing, these may be readily removed by means of a wire brush or, in fact, they may be removed by a wire brush prior to annealing.

It is not necessary to grind down the central portion of the central core 24 for it will be seen that in this form of the invention the outer cores do not cross over the curved portions at the outer ends of the central core, as in the case of Figure 1. Instead the outer cores terminate in the

portions 27, see Figure 8, which do not cross over the curved outer ends of the central core, see Figure 7.

The wound magnetic ribbons forming the outer and central cores are held clamped during the cutting, grinding and annealing portions as previously described. Obviously any oxide that may be formed on the ground faces may be scraped off if desired prior to assembly as previously described. It is to be distinctly understood, however, that no machining, bending or working of any of the core sections occurs after annealing.

While it is preferred to wind all of the core sections and cut certain of them in different forms of the invention, it is within the province of this invention to form all of the core sections, except the outer closed core sections of the first two forms of the invention, of stacked magnetic laminations which are shaped as required, though this is not the preferred form of the invention.

The central core 24 may be placed in an ordinary winding lathe and the conducting winding is wound thereon, suitable insulation being provided in the customary manner.

The several sections of the core may be clamped together in any desired way. For example, the L-shaped clamping members 8 may be employed which are drawn towards each other by means of the bolts 9, suitable insulation 10 being provided between the clamping members and the laminated core structure as described in connection with the form of the invention shown in Figures 1 to 3.

The material used in the making of the cores is any suitable magnetic ribbon. It is preferable to use silicon steel which may be either hot rolled or cold rolled as this material has been found highly efficient in the manufacture of these transformers or other electromagnetic devices of this general nature, such as chokes for instance.

In the forms of the invention shown in Figures 1, 2, 3, 7 and 8 the lateral edges of the laminations of the central core have an edge to edge contact with the adjacent edges of the outer cores. In the form of the invention shown in Figures 4, 5 and 6 the end edges of the laminations of the central core 12 have an edge to edge contact with the adjacent laminations of the outer closed cores 11. In all forms of the invention, therefore, this edge to edge contact is secured between the laminations of the central core and the laminations of the outer cores.

It is to be noted that in all forms of the invention the magnetic flux travels lengthwise of the magnetic ribbon in substantially all portions of the core structure and this is the path having minimum magnetic reluctance due to the manner in which the particles of the magnetic ribbon are orientated during their manufacture. However, there is a small portion of the path of the magnetic flux where the flux travels crosswise of the magnetic ribbon where it passes, for example in Figures 1, 2, 3, 7 and 8, from the end portions of the central core into the outer cores. This path of cross travel of the flux is very short and is confined to a very limited portion of the entire core structure. In the form of the invention shown in Figures 4, 5 and 6 there is no cross travel of the flux in the end portions 15 of the central core and there is a slight cross travel of the flux only in the outer closed cores 11 where the flux enters such outer cores. However, the path of cross travel of the flux is very short in all forms of the invention.

It will be seen, therefore, that transformers

and other electromagnetic devices have been disclosed by this invention which have a very small magnetic reluctance for the flux travel and which are extremely simple to make and which, in their preferred forms, utilize the advantages of wound magnetic cores formed from magnetic ribbon, though allowing the conducting winding to be wound in the ordinary simple manner without requiring any special processes for the winding of the conducting winding.

It is to be noted that the substantially edge to edge contact between the laminations of the central and outer cores materially reduces the reluctance of the magnetic path.

It will be seen further that transformers or other electromagnetic devices constructed in accordance with this invention may be made with a very small number of operations and in a very simple manner.

Wherever the expression "insulating paint" is used, it is intended to cover insulating paint, insulating varnish, or any other insulating compound. It is also to be understood that wherever the expressions "laminations" or "magnetic laminations" are employed, it is intended that these expressions shall not be limited to stacked laminations but shall include any laminated structure whether it is formed by winding a magnetic ribbon or by stacking magnetic laminations.

Although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting, as the invention may be variously embodied and is to be interpreted as claimed.

I claim:

1. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations, said central core having its ends located between the closed cores, the laminations of the central and closed cores being arranged with their edges in close juxtaposition and lying in parallel planes and with the longitudinal extent of the edges of the individual laminations of the central core substantially paralleling the longitudinal extent of the edges of the individual laminations of the outer cores at their area of juxtaposition.

2. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations, said central core having its ends located between the closed cores, the laminations of the central core having an edge to edge contact with the laminations of the closed cores with the contacting edges of the central and closed cores lying in parallel planes and with the longitudinal extent of the edges of the individual laminations of the ends of the central core substantially paralleling the longitudinal extent of the edges of the adjacent laminations of the outer cores.

3. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, a central core formed of magnetic laminations, said central core having its ends located between the closed cores, the laminations of the central core having an edge to edge contact with the laminations of the closed cores with the contacting edges of the central and closed cores arranged in substantial parallelism, and clamping means for spreading the ends of the central core and for maintaining an edge to edge contact be-

tween the laminations of the central and closed cores.

4. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations, the laminations at each end of the central core extending in opposite directions, said central core having its ends located between the closed cores, the edges of the laminations of the end portions of the central core and the adjacent edges of the outer cores being closely juxtaposed and lying in parallel planes with the longitudinal extent of the edges of the individual laminations of the ends of the central core substantially paralleling the adjacent longitudinal extent of the edges of the individual laminations of the outer cores, said central and closed cores being annealed and being free from any stresses produced by machining or other working after annealing.

5. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations, the laminations at each end of the central core being turned in opposite directions, the ends of the central core being positioned between the closed cores and the end portions of the laminations of the central core extending at substantially right angles to the adjacent laminations of the closed cores and having a substantial edge to edge contact with the adjacent laminations of the outer closed cores.

6. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central magnetic core formed of magnetic laminations with the laminations extending in opposite directions at each end to form end portions, the end portions of the central core being located between the closed cores, the laminations of the end portions of the central core having substantially an edge to edge contact with the adjacent laminations of the closed cores, the edges of the laminations of the end portions of the central core and the adjacent edges of the laminations of the outer cores lying in parallel planes and the longitudinal extent of the edges of the individual laminations of the end portions of the central core substantially paralleling the longitudinal extent of the adjacent edges of the individual laminations of the outer cores.

7. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations having projecting end portions parts of which are curved and the outer ends of which extend in opposite directions, the outer ends of the laminations of the central core being wider than the curved portions, the ends of the central core being located between the closed cores with the side edges of the outwardly extending portions of the ends of the laminations of the central core having an edge to edge contact with the laminations of the closed cores and with the curved portions of the ends of the central core out of contact with the laminations of the closed cores.

8. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central magnetic core formed of magnetic laminations with the laminations extending out-

wardly in opposite directions at each end to form end portions, the oppositely extending portions having a greater width than the remaining portions of the central core and being located between the closed cores, the side edges of the laminations of the oppositely extending portions at the ends of the central core having substantially an edge to edge contact with the adjacent edges of the laminations of the closed cores.

9. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central magnetic core formed of magnetic laminations with the laminations turned outwardly in opposite directions at each end to form end portions, the oppositely turned end portions of the central core being located between the closed cores with the ends of the laminations of the central core having substantially an edge to edge contact with the adjacent edges of the laminations of the closed cores.

10. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central core formed of magnetic laminations with the laminations extending outwardly in opposite directions at each end to form end portions projecting outwardly laterally beyond the main body of the central core, the oppositely extending end portions being located between the closed cores with the side edges of the laminations of the oppositely extending end portions having substantially an edge to edge contact with the adjacent edges of the laminations of the closed cores, the main body of the central core being joined to the oppositely extending end portions by curved portions and the curved portions of the central core being ground down on opposite sides between the oppositely extending end portions.

11. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, and a central magnetic core formed of magnetic laminations with the laminations extending in opposite directions at each end to form end portions, said central magnetic core being formed of two portions of a closed wound core of magnetic ribbon cut across with the two resulting portions arranged back to back to form the central core, the end portions of the central core being located between the closed cores, the laminations of the end portions of the central core and the laminations of the adjacent portions of the outer cores having their edges in close juxtaposition and lying in parallel planes with the longitudinal extent of the edges of the individual laminations of the central core substantially paralleling the longitudinal extent of the edges of individual laminations of the outer cores at their area of juxtaposition.

12. A core construction for an electromagnetic device comprising at least one outer closed, laminated, wound core formed of magnetic ribbon, and a central magnetic core formed of magnetic laminations with the laminations extending in opposite directions at each end to form end portions, the end portions of the central core being located in close juxtaposition to portions of the outer closed core and to one side thereof with the laminations of the end portions of the central core and the laminations of the adjacent portions of the outer core having their edges lying in parallel planes with the longitudinal extent of the edges of the individual laminations of the cen-

tral core substantially paralleling the longitudinal extent of the edges of the individual laminations of the outer core at their area of juxtaposition.

13. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, a central core formed of magnetic laminations, the laminations at each end of the central core being turned in opposite directions, the ends of the central core being positioned between the closed cores and the end portions of the laminations of the central core extending at substantially right angles to the adjacent laminations of the closed cores, and clamping means including a tapered member at each end of the central core for holding the end portions of the laminations at each end of the central core in position.

14. A core construction for an electromagnetic device comprising a pair of outer, closed, laminated, wound cores formed of magnetic ribbon, a central core formed of magnetic laminations, the laminations at each end of the central core being turned in opposite directions, the ends of the central core being positioned between the closed cores and the end portions of the laminations of the central core extending at substantially right angles to the adjacent laminations of the closed cores, and clamping means for holding the portions of the core together, said clamping means including main frame like means and tapered wedging means located at each end of the central core movable with reference to the main frame like means and bearing against the outwardly turned end portions of the central core.

15. A core construction for an electromagnetic device comprising a central core having a pair of sections formed of magnetic laminations with the end portions turned outwardly in opposite directions at each end of the central core and with the outer ends of the end portions spaced apart at each end of the central core, and an outer core structure formed of magnetic laminations with the side edges of the laminations of the outer core structure in close juxtaposition to the side edges of the outwardly turned ends of the central core, the edges of the outwardly turned end portions of the central core and the edges of the outer core structure lying in parallel planes with the longitudinal extent of the edges of the individual laminations of the outwardly turned end portions of the central core substantially paralleling the longitudinal extent of the adjacent edges of the individual laminations of the outer core structure.

16. A core construction for an electromagnetic device comprising a central core having a pair of sections formed of magnetic laminations with the end portions turned outwardly in opposite directions at each end of the central core and with the outer ends of the end portions spaced apart at each end of the central core, and an outer core structure formed of magnetic laminations with the side edges of the laminations of the outer core structure in contact with the side edges of the outwardly turned ends of the central core, the edges of the outwardly turned end portions of the central core and the edges of the outer core structure lying in parallel planes with the longitudinal extent of the edges of the individual laminations of the outwardly turned end portions of the central core substantially paralleling the longitudinal extent of the adjacent edges of the individual laminations of the outer core structure.

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