

July 21, 1959

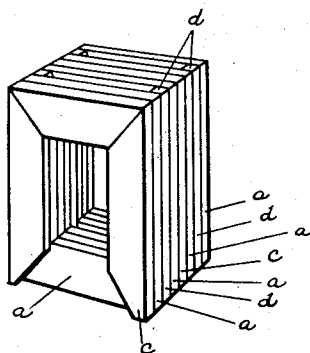
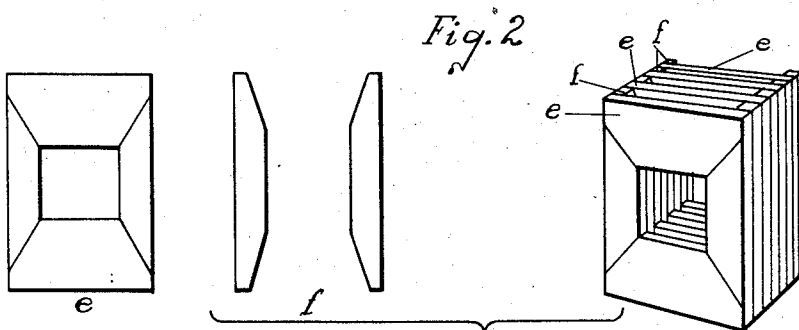
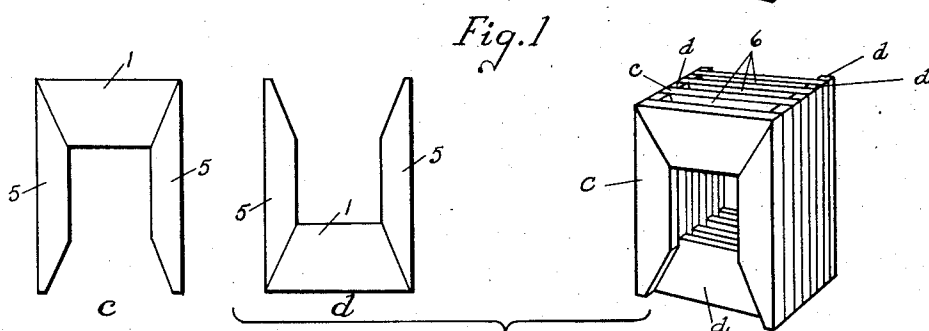
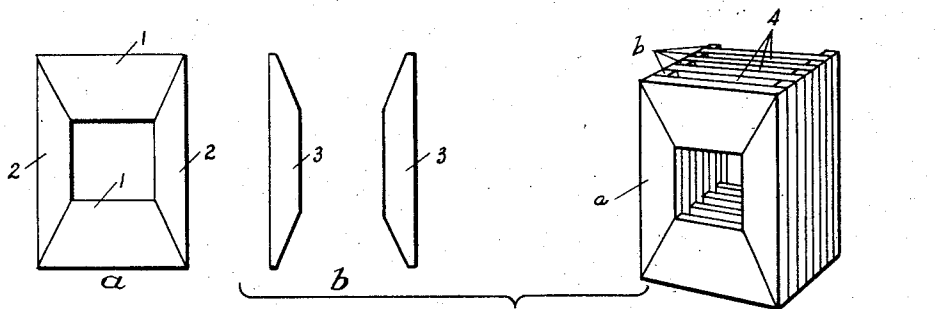
M. I. ZWELLING

2,896,181

MAGNETIC CORE

Filed Nov. 18, 1952

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

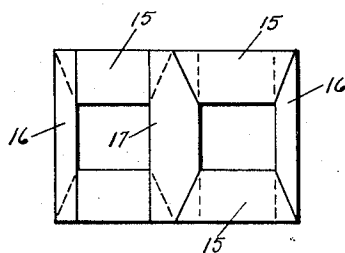
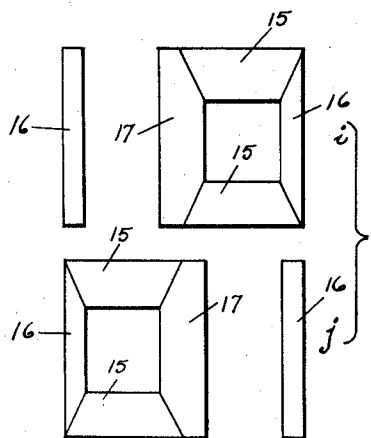


Fig. 5

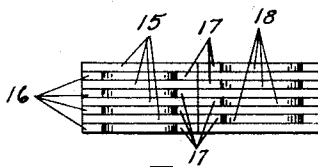


Fig. 6

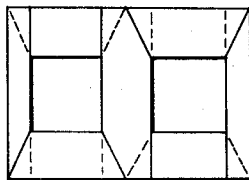
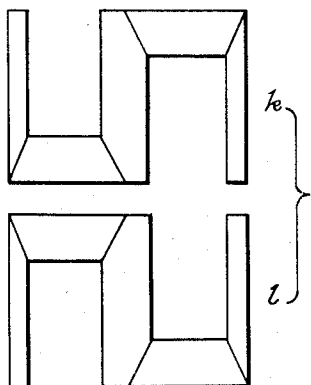


Fig. 7

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3 Sheets-Sheet 3

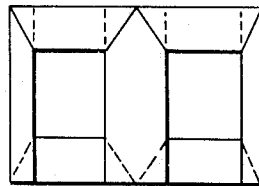
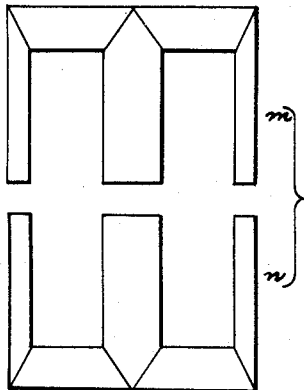


Fig. 8

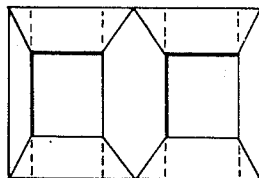
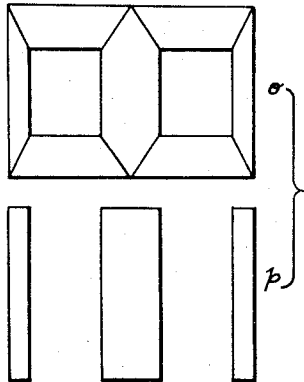


Fig. 9

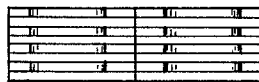


Fig. 10

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2,896,181

MAGNETIC CORE

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Application November 18, 1952, Serial No. 321,229

6 Claims. (Cl. 336—217)

This invention relates to stacked cores for electrical induction apparatus such as transformers.

In electrical induction apparatus a coil is wound around a core leg to magnetize the core, and the magnetizing force required to accomplish this is determined by the reluctance in the core structure.

Reluctance in the core is caused by several things: Among them are the steel itself, air gaps that may be present, and the design of the core for ease of flux flow. Oriented steel is more conductive to flux flow in one direction than hot rolled steel. An air gap sets up great reluctance and must be reduced to a minimum by providing close fitting joints. It is also desirable to keep the number of joints to the minimum possible coordinated with the grain direction or flux path of oriented steel. The shape of these joints is another important factor in reducing the resistance to flux flow.

In the copending application of Oliver G. Attewell, Serial No. 303,232, filed August 8, 1952, and assigned to the same assignee as this invention, a remarkable new discovery is revealed relative to the advantages of a long diagonal joint. It is explained in said application that by having the length of a diagonal butt joint two or three times the width of the steel, that the flux can flow across the joint with less reluctance because flux lines pass the air gap at different intervals of time.

It is also important to maintain the same area of steel in cross section on each side of the core for uniformity of coil design and balanced operation. It is generally desirable that the yoke sections be at least of an area equal to the leg sections so that the density will be uniform throughout the core. Sometimes the core is so designed that the yoke sections have a greater area than the leg sections so that the yokes will operate at a lower density. While this reduces the overall losses, it increases the cost. A core whose yoke sections are equal in cross sectional area to the leg sections is usually considered to be the most economical design.

However, usually, cores made from single width strips suffer from poor cooling facilities as it allows so little space for oil circulation. There are some single width strip cores of a cruciform shape which provide channels around the core for the oil to circulate freely and these are superior to rectangular cores with no circulatory facilities. The proposed core has channels throughout the yoke sections for oil to move freely which provides for better overall cooling.

It is the object of this invention to provide a stacked core utilizing the advantages of a long diagonal cut at the corners.

Another object of this invention is to provide a stacked core with great cooling facilities by using steel strips of varying widths but maintaining the same area in core cross section.

A further object of this invention is to provide a stacked core of magnetic steel with the yoke strips being twice the width and half the number of the leg strips.

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Another object of this invention is to provide a stacked core with cooling spaces between the strips of the yoke portion while maintaining the same cross sectional area in yoke and leg portions.

And another object of this invention is to provide a stacked core with lower reluctance than any stacked core now made so that the core can be magnetized with less magnetizing force.

Other objects will appear from time to time in the course of the specification and claims.

I illustrate several embodiments of this inventive idea in the accompanying drawings in which:

Fig. 1 is one method of making this core assembled of alternate layers of "a" and "b."

Fig. 2 is a second method of forming this core assembled of alternate layers of "c" and "d."

Fig. 3 is a third method of cutting the laminations "e" and "f" and then assembling them in alternate order.

Fig. 4 is a fourth variation for cutting the laminations with the yoke section one and one third times the leg section in width and then assembling three yoke sections to four leg sections.

Figs. 5, 6, 7, 8, 9, and 10 illustrate my inventive idea adapted to a shell-type core.

Fig. 5 is a shell-type core composed of layer designs "i" and "j" stacked in alternate order.

Fig. 6 is a top view of Figs. 5 and 7.

Fig. 7 is a shell-type core composed of layer designs "k" and "l" stacked in alternate order.

Fig. 8 is a shell-type core composed of layer designs "m" and "n" stacked in alternate order.

Fig. 9 is a shell-type core composed of layer designs "o" and "p" stacked in alternate order.

Fig. 10 is a top view of Figs. 8 and 9.

This invention utilizes the superior performance record of a butt joint that has a length that is greater than the width of the steel strip and applies it to a stacked core. Since stacked cores have joints substantially in their corner and excessive joints are undesirable, it is at the corner joints that I use a long diagonal cut. However, where a leg and yoke are in right angular relationship, in order to give the leg portion a long diagonal cut the adjoining yoke will have to be cut from considerably wider strip material.

In order to maintain the same cross sectional area on each side of the core and also to use the long diagonal butt joint, I designed a stacked core with the yoke laminations twice the width of the leg laminations and then used only half as many laminations in the yoke as in the leg allowing an air space the width of a lamination next to each yoke lamination. This proportion gives a diagonal cut on the leg lamination that is 2.24 times the width of the leg. The diagonal cut of the yoke lamination is only slightly greater than the width of the yoke.

A core can also be designed with yoke laminations three times the width of the leg laminations, and to maintain the same cross sectional area in yoke and leg, one third as many laminations can be used in the yoke as in the leg. The desirable arrangement for a core of this proportion is to leave two lamination spaces between each lamination.

Other ratios between the width of the yoke and leg may also be used. However, it is preferable to have the cross sectional area of the yoke strips balance the cross sectional area of the leg strips. Fig. 4 illustrates an example of this in which the width of the yoke is one and one third times the width of the leg. The diagonal corner joint has a length approximately one and two thirds the width of the leg. To achieve the balanced cross sectional area in yoke and leg this core is composed of three yoke sections to four leg sections. It can be constructed of laminations of similar design to laminations "a," "c," and

"d" of Figs. 1 and 2 with an "a" lamination alternating with a "c" and "d" lamination. As many "a" laminations are used as "c" and "d" laminations combined.

Referring to the Figs. 1, 2, and 3, it can be seen that there are various ways of arranging the laminations using wider and fewer yoke portions than leg portions. In Fig. 1, the yoke 1 is twice the width of the legs 2. The end of the legs adjoining the yokes are cut in a long diagonal to make a mitered corner joint with the yoke and combined they form lamination "a." Lamination "b" consists of two leg sections cut angularly on the inner side at both ends so that the angularly cut end will lap over the mitered joint of lamination "a" when assembled as shown at the right of Fig. 1 with the "a" and "b" lamination alternating to form the core. This provides an arrangement of laminae in which the yoke occurs in alternate laminations leaving an air space between the laminations in the yoke. These air spaces 3 provide excellent cooling means as the transformer oil can circulate faster and more easily through the core.

In Fig. 2, U-shaped laminations "c" and "d" are identical but are assembled with the yoke portions on alternate ends. The yoke is the same shape as the one used to make the core of Fig. 1, and the legs 5, where they meet the yoke, are cut in a long diagonal to form a mitered corner with the yoke. The other end of the legs 5 are cut angularly so that they will parallel and overlap the joint between yoke and leg of adjacent laminations. Cooling channels 6 between the yoke laminations are staggered in the opposing yoke sections.

Fig. 3 illustrates a third manner of cutting the corner angles and can be used when a greater overlap at the corner joint is desired between adjacent laminations. Lamination "e" has its corner joint extending angularly from the inner corner of the core to a point below the outer corner on the side of the core. Lamination "f" has similar angles on the ends of the inner leg sections that parallel and overlap the corner angles of lamination "e." The angular cuts of the legs of lamination "f" extend from a point above and below respectively the inner core corners to a point inside the outer core corners on the top and bottom sides. With this design, greater overlap is obtained between adjacent joints while maintaining the same amount of circulatory space.

If other ratios between the width of leg and yoke are used, various arrangements of laminations can be utilized to maintain substantially the same cross sectional area in yoke and leg strips. Fig. 4 is an example of a core in which the width of the yoke strips are one and one third times the width of the leg strips. With this ratio, it takes three yoke strips to provide the equivalent cross sectional area of four leg strips. By using yoke and leg designs similar to laminations "a," "c," and "d" and using the same number of "a" laminations as "c" and "d" laminations combined, a balanced core is obtained. However, this core design does not provide the circulatory channels of the cores illustrated in Figs. 1, 2, and 3.

In all of the above core designs the cut ends of adjacent laminations are in staggered relationship or so arranged that the joints and ends of adjacent laminations are not in register. This makes a stronger core structurally and a better performing core electrically. It is stronger structurally because the lapped position of the butt joints and the ends of the adjacent laminations causes the laminations to perform a holding or clamping action on each other. The electromagnetic performance is so excellent because of utilizing the advantages of the long diagonal butt joint, which allows greater length of path for the flux to flow across the joint. This prevention from crowding at the joint is a great aid to better flux flow. The flux flow also benefits by the lapped position of the ends adjacent to the butt joints.

Although I show the leg ends angularly cut in laminations adjacent to the butt joints, the leg ends could be straight. However, by cutting them angularly, I am able

to reduce the core weight and at the same time increase the size of the cooling channels.

This novel idea for a stacked core structure can be applied to a shell-type core. Four different design arrangements are illustrated in Figs. 5, 7, 8, and 9. The core of Fig. 5 is composed of alternate layers of laminations "i" and "j." The upper and lower leg portions 15 of the core are twice the width of the two outer side leg portions 16 but there are only half as many upper and lower leg portions 15 as there are outer side leg portions 16. The center leg 17 is the same width as the upper and lower legs 15 but there are as many laminations in the center leg 17 as in the outer side leg portions. This provides the same cross sectional area in the center leg as in the combined cross sectional area of the two outer legs, and also the same cross sectional area in each outer side leg as in the upper or lower legs. This balance of cross sectional area provides an economical use of the steel while the long diagonal joint at the corners provides excellent performance. Air spaces 18 between the laminations 15 are indicated in the top view of the core, Fig. 6.

Fig. 6 is also the top view for Fig. 7. Laminations "k" and "p" assembled in alternate order form Fig. 7. In Fig. 8 the core is composed of alternative layers of laminations "m" and "n" while Fig. 9 is composed of alternate layers of laminations "o" and "p." A top view of Figs. 8 and 9 is shown in Fig. 10.

This method of constructing a core can be applied to three phase cores and any of the designs shown for the shell type core can be adapted to a three phase core by making the center leg the same cross sectional area as the outer legs. Instead of a wide center leg as used in the shell-type core, the same width center leg as outer legs can be used for a three phase core.

The term lamination has been used throughout as one thickness of oriented steel. However, sometimes when the laminations are extremely thin, it is practical to form a core using several laminations together as a group or layer. It is to be understood that the same principles of design can be applied to the group or layer as to the single lamination.

In all of the core structures illustrated in the accompanying drawings, it can be seen that the utmost advantage is taken of the long diagonal butt joint. In order to benefit from the superior flux flow that exists when the flux is not crowded at the butt joints, I provide in my preferred embodiment a diagonal cut on the leg portion that has a length more than twice the width of the leg. To achieve this, I use laminae in the yokes or upper and lower legs that are twice the width of the laminae in the side legs. By using top and bottom laminae only in alternate laminations a uniform cross sectional area can be maintained throughout the core. This balanced cross sectional area prevents variance in flux density with consequent economic loss. The air spaces between the laminae in the upper and lower legs or yokes provides a great cooling factor because the transformer oil can circulate more thoroughly through the core.

In comparative tests made with this core, the electrical performance was excellent, proving superior to stacked cores now in common use.

I claim:

1. In an electrical apparatus, a magnetic core structure comprising leg members and yoke members substantially at right angles to each other forming a closed magnetic circuit about a rectangular window, the leg and yoke members being built up of layers of laminations having preferred grain orientation parallel to the length thereof, odd-numbered layers consisting of two leg laminations and two yoke laminations, even-numbered layers consisting of two leg laminations, said yoke laminations being at least twice as wide as said leg laminations, the yoke and leg laminations of said odd-numbered layers having adjoining edges forming substantially mitered butt joints adjacent the corners of the core structure, the leg lamina-

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tions of said even-numbered layers extending between and overlapping the yoke laminations of said odd-numbered layers, said butt joints having a length at least twice as great as the width of said leg laminations, said joints being contiguous uncut portions of leg laminations of said even-numbered layers.

2. A substantially rectangular laminated magnetic core including a yoke portion and a leg portion substantially at right angles relative to each other and each comprising a plurality of stacked laminations having a preferred grain orientation lengthwise thereof, certain of said laminations in said yoke portion being spaced laterally relative to each other to provide passageways affording circulation of a coolant through said yoke portion, certain of the laminations of said leg and yoke portions being disposed in planes common thereto and laminations in said leg portion disposed between said certain laminations of said leg portion extending to a position between said spaced yoke laminations in overlapping relation thereto, the laminations in said yoke portion being substantially wider in dimension than the laminations in said leg portion, the total cross-sectional area of the laminations in said yoke portion being at least equal to the total cross-sectional area of the laminations in said leg portion, said certain laminations in said leg and yoke portions having adjacent edges extending in a general direction diagonally relative to the periphery of the core in butt joint relation and of a length at least twice the width of the laminations in said leg portion, the butt joints between said certain laminations being contiguous to surfaces of adjacent laminations in said leg portion extending in overlapped relation to the laminations in said yoke portion.

3. A magnetic core for electrical apparatus including yoke portions and at least two leg portions at substantially right angles thereto forming a closed magnetic circuit surrounding at least one rectangular window, said core being built up of a plurality of layers of laminations of magnetic material, each lamination having a preferred grain orientation lengthwise thereof, each layer having leg laminations along each of said leg portions and certain layers including yoke laminations, certain of said yoke laminations being in spaced relation relative to each other whereby spaces are provided for circulation of coolant through said yoke portions, the laminations of said yoke portions being substantially wider in dimension than the laminations of said leg portions and the total cross sectional area of the laminations in each of said yoke portions being at least equal to the total cross sectional area of the laminations in each of said leg portions, said yoke laminations having edges adjoining edges of adjacent coplanar leg laminations in said certain layers and forming butt joints at the substantially right angle junctures between said yoke and leg portions, the leg laminations in layers adjoining said certain layers overlapping the yoke laminations in said certain layers, each of said butt joints having a length at least $5/3$ times as great as the width of said leg laminations and being overlapped by a contiguous lamination of an adjacent layer.

4. A stacked, substantially rectangular laminated magnetic core including a leg portion and a yoke portion at substantially right angles relative to each other and each comprising a plurality of laminations of magnetic material, each lamination having a preferred grain orientation lengthwise thereof, the laminations of said yoke portion being substantially wider than the laminations of said leg portion and the total cross-sectional area of the laminations in said yoke portion being at least equal to the total cross-sectional area of the laminations in said leg portion, certain of the laminations of said yoke portion being spaced relative to each other whereby spaces are provided for circulation of coolant through said yoke portion, coplanar laminations of said yoke and leg portions having generally mitered butt joints between ends at the substantially right angle juncture between said yoke and leg portions, each butt joint having a

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length at least twice as great as the width of the laminations of said leg portion and being overlapped by the contiguous lamination of an adjacent layer.

5. A magnetic core for electrical apparatus including yoke portions, a central leg portion and two outer leg portions connected at substantially right angles to said yoke portions forming a closed magnetic core having two windows, said core being built up of a plurality of layers of laminations of magnetic material, each lamination having a preferred grain orientation lengthwise thereof, each layer having leg laminations along each of said leg portions and certain layers including yoke laminations, certain of said yoke laminations being in spaced relation relative to each other whereby spaces are provided for circulation of coolant through said yoke portions, the laminations of said yoke portions being substantially wider in dimension than the laminations of said outer leg portions and the total cross-sectional area of the laminations in each of said yoke portions being at least equal to the total cross-sectional area of the laminations in each of said outer leg portions, said yoke laminations having edges adjoining edges of adjacent coplanar leg laminations in certain layers and forming butt joints at the substantially right angle junctures between said yoke and leg portions, the leg laminations in layers adjoining said certain layers overlapping the yoke laminations in said certain layers, each of said butt joints having a length at least $5/3$ times as great as the width of said leg laminations in said outer leg portions and being overlapped by a contiguous lamination of an adjacent layer.

6. A magnetic core for electrical apparatus including upper and lower yoke portions and at least two leg portions at substantially right angles thereto forming a closed magnetic circuit surrounding at least one rectangular window, said core being built up of a plurality of layers of laminations of magnetic material, each lamination having a preferred grain orientation lengthwise thereof, each layer having leg laminations along each of said leg portions, given layers including a yoke lamination in said upper yoke portion and other given layers including a yoke lamination in said lower yoke portion, certain of said yoke laminations being in spaced relation relative to each other whereby spaces are provided for circulation of coolant through said yoke portions, the laminations of said yoke portions being substantially wider in dimension than the laminations of said leg portions and the total cross-sectional area of the laminations in each of said yoke portions being at least equal to the total cross-sectional area of the laminations in each of said leg portions, said yoke laminations having edges adjoining edges of adjacent coplanar leg laminations in each said given layer and forming butt joints at the substantially right angle junctures between said yoke and leg portions, the leg laminations of successive layers being dissimilar and overlapping the yoke laminations in said given layers, each of said butt joints having a length at least $5/3$ times as great as the width of said leg laminations and being overlapped by a contiguous lamination of an adjacent layer.

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