

July 10, 1951

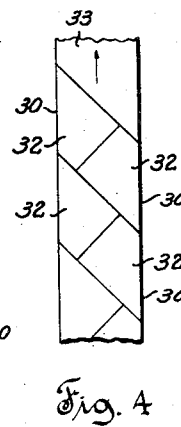
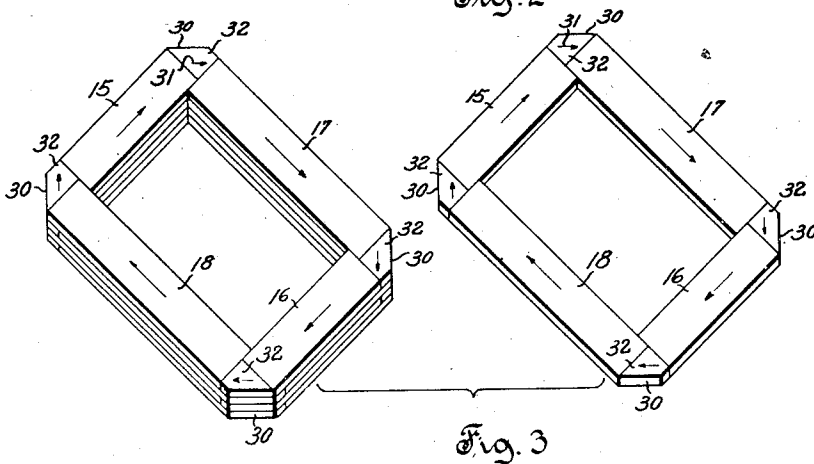
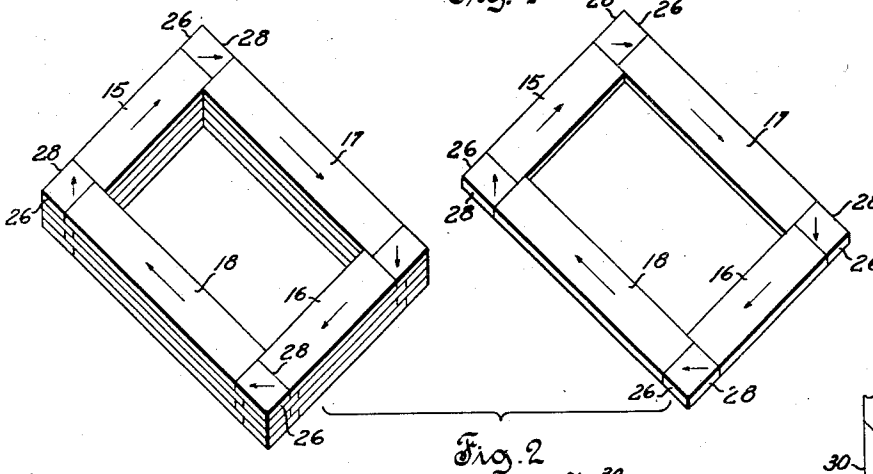
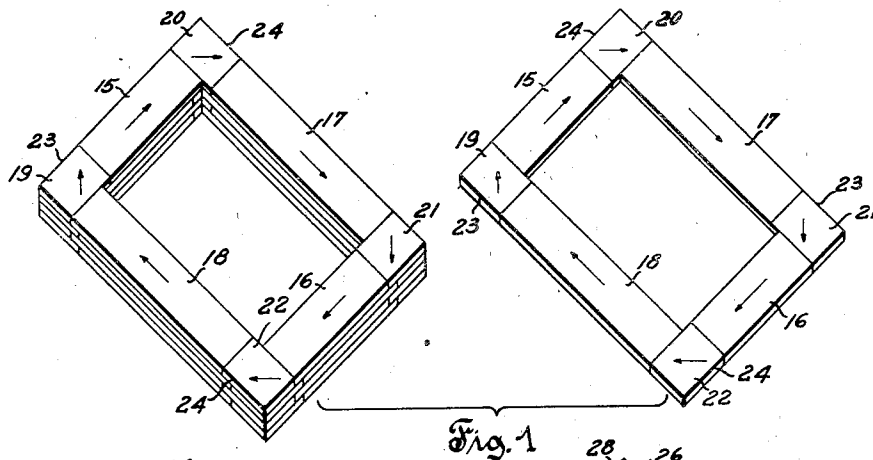
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2,560,003

MAGNETIC CORE COMPRISING LEG, YOKE AND CORNER LAMINATIONS

Filed Feb. 13, 1948

3 Sheets-Sheet 1



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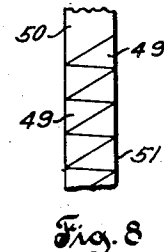
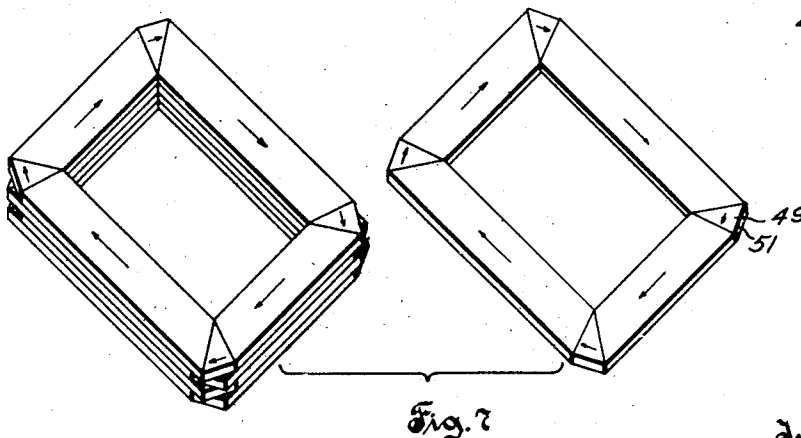
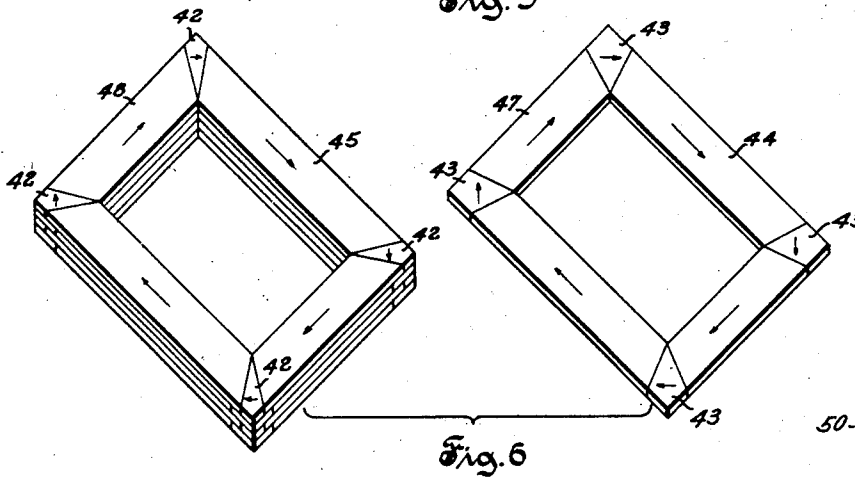
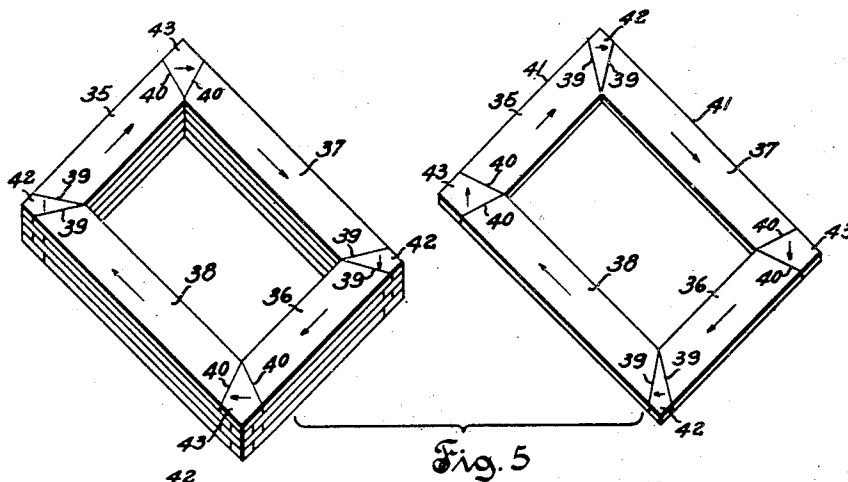
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3 Sheets-Sheet 3

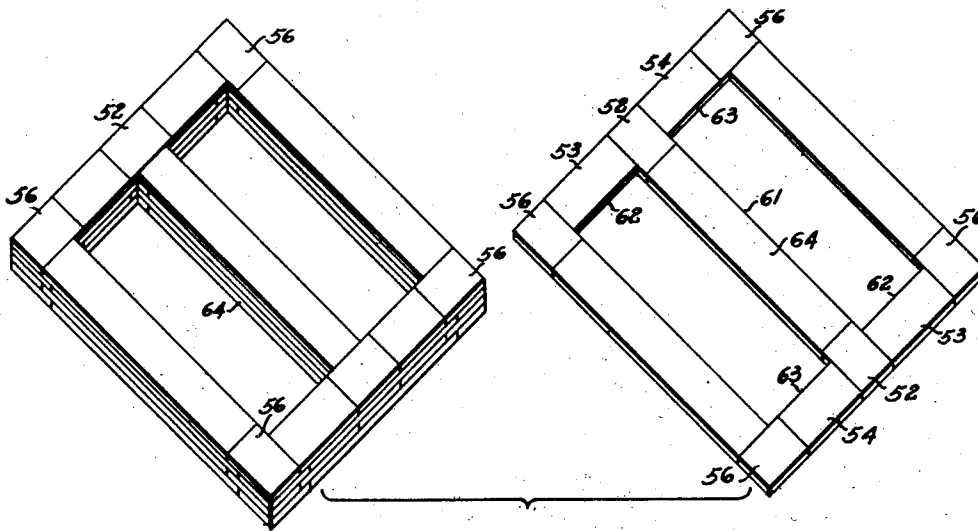


Fig. 9

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UNITED STATES PATENT OFFICE

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MAGNETIC CORE COMPRISING LEG, YOKE,
AND CORNER LAMINATIONS

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This invention relates to improvements in the manufacture and assembly of cores for use in electrical induction apparatus.

Magnetic material such as silicon steel, which has been cold reduced in the rolling process and then annealed shows evidence of substantial alignment of the grain structure. This results in improved magnetic characteristics. Steel so processed is said to have a preferred grain orientation having magnetic characteristics most favorable in the direction of elongation of the material during the rolling process.

The advantages of these improved magnetic characteristics have been incorporated into electrical induction apparatus design by cutting I-shaped laminations along the direction of the elongation of the material. The grain orientation is parallel to the longest dimension of each lamination. The magnetic flux flow in the greater part of the core structure is in the same direction. Thus in those portions of the core in which the flux or magnetic circuit is in the direction of the grain orientation the permeability is at its maximum value and the core losses at their minimum value. But where the flux flow traverses the direction of grain orientation the core losses are increased and the permeability is reduced. Hence the final limit of performance of induction apparatus made from grain oriented steel is determined by the proportion of the flux flow parallel and transverse to the grain of the magnetic steel used. Redesign of core structures is necessary to take advantage of grain oriented steel.

Conventional square cut laminations assembled in butt and lap fashion are satisfactory for cores formed from steel having random magnetic characteristics, hereafter called random steel. Such steel differs from grain oriented steel in that the magnetic properties do not vary as greatly in function of the angle which the magnetic flux makes with the direction in which the material has been elongated. These core arrangements using grain oriented steels result in transverse core losses which are much greater than with grain core losses.

Various methods have been proposed to minimize the cross grain losses. There are several suggestions for cutting the ends of lamination to form the joints at corners at an angle with the direction of grain orientation. This results in reducing the length of the paths of the transverse flux. The best condition which can be obtained results in the flux paths not being at more than 45° to the direction of grain orientation in each lamination.

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When the flux direction is approximately 25° to the grain orientation, the magnetic characteristics of the grain oriented steel are about the same as the magnetic characteristics of random steel. When the flux flow makes a greater angle with the grain orientation, the magnetic characteristics for the grain oriented steel may not be as good as the magnetic characteristics of random steel. The core losses then become greater. The permeability is not as good.

In accordance with the present invention, the paths of the flux flow in all parts of the magnetic circuit are controlled to produce a minimum of core losses. The extent to which the crystals of the steel have been oriented is considered when determining the maximum angle at which the flux may traverse the direction of grain to take advantage of the better magnetic properties of the grain oriented steel.

It is an object of the present invention to provide an assembled magnetic core in which the core losses are held at a minimum value for a predetermined flux density.

Another object of the invention is to provide a closed magnetic circuit in which the most favorable magnetic characteristics of the core laminations substantially conforms in direction to the magnetic flux.

Another object of the invention is to control the angle which the flux paths make with the most favorable magnetic direction of the core materials.

Still another object of the invention is to vary the transverse angle which the flux paths make with the direction of most favorable magnetic characteristics and to maintain that angle within the most efficient limits for the particular magnetic steel used.

The objects of this invention are preferably accomplished in a manner substantially as follows:

Laminations for leg, yoke and corner members are made from magnetic steel having most favorable magnetic characteristics in the direction of grain orientation. These laminations are assembled to form a core structure having most favorable magnetic characteristics substantially conforming to the magnetic circuit within the core. The corner arrangement of the core structure is formed of at least three laminations of such shape that a minimum of flux will cross the direction of grain orientation.

The invention will be better understood from the description of specific embodiments which

are explained in connection with the accompanying drawings, in which:

Fig. 1 is a perspective view of a two legged core assembled of rectangular laminations with rectangular corner pieces extending into the core legs and yokes, the top layer of laminations being shown removed from its normal position.

Fig. 2 is a view similar to Fig. 1 of a modified core arrangement in which the corner pieces are entirely outside the extended inner edges of the core.

Fig. 3 is a view similar to Fig. 1 of another modified core arrangement utilizing corner pieces of trapezoidal shape.

Fig. 4 is an enlarged view of strip material cut to form corner pieces for the core illustrated in Fig. 3 without waste of material.

Figs. 5, 6 and 7 are perspective views of further modified core structures provided with wedge shaped corner pieces.

Fig. 8 shows a manner of cutting the corner pieces for the core illustrated in Fig. 7 from a strip of material to avoid waste.

Fig. 9 is a perspective view of a three legged transformer core constructed in accordance with the teachings of this invention.

In Fig. 1 is shown a rectangular core construction of layers of a plurality of assembled laminations. Each layer of the core structure includes two yoke members 15, 16; two leg members 17, 18; and four corner pieces 19, 20, 21, 22. All of the laminations are of rectangular shape. The leg and yoke members have their most favorable magnetic characteristics lengthwise, that is parallel to their longest sides. The corner pieces may have their magnetic characteristics most favorable in a direction at an angle, preferably 45°, to their sides. These pieces are assembled between the ends of the leg and yoke members of each layer. The direction of most favorable magnetic characteristics of each lamination is indicated by an arrow.

The diagonally opposed corner pieces 19, 21 are positioned to have their longest dimension 23 parallel with the leg members. The two remaining corner pieces 20, 22 of each layer are positioned with the longest dimension 24 parallel with the yoke members. This arrangement of diagonal corner pieces is reversed in contiguous layers to permit the joints between the laminations of each layer to be overlapped by laminations of a contiguous layer. In a magnetic core assembled with at least 3 pieces of preferred oriented steel forming a corner, advantage is taken to the greatest possible extent of the most favorable magnetic characteristics of the material along the flux paths of the closed magnetic circuit formed by the core.

Figs. 2 and 3 show variations of the core arrangement of Fig. 1. In Fig. 2 the short side 26 of the corner pieces is shorter than the width of the leg or yoke members, and the long side 28 of the corner pieces has the same dimension as the width of the leg and yoke members. The corner pieces are arranged in the manner indicated with reference to Fig. 1 in order to have overlapped joints.

Fig. 3 shows leg and yoke members similar to those of the core illustrated in Fig. 2. The outer edge 30 of the corner pieces 32 is cut at an angle parallel to the direction of grain orientation represented by arrow 31. These pieces may be cut from strip material 33 without waste of the material as indicated in Fig. 4.

The two sides of the corner pieces which abut

the leg and yoke members are shown as having different dimensions. The sides of the pieces at each corner are oppositely arranged in contiguous layers so that the joints of one layer are overlapped by laminations of the next layer.

In Fig. 5 the leg members 37, 38 and yoke members 35, 36 are cut to form trapezoidal laminations which may be similar except for length, the leg members being longer than the yoke members. The ends 39, 40 of each lamination may make different angles with their base 41. In each stack of leg or yoke members the contiguous laminations are oppositely arranged. The ends of the contiguous members are thereby staggered since the ends do not make similar angles with the bases. The stacks of leg members are positioned so that their bases are at 90° from the bases of the laminations in the stacks of yoke members. The corners for the rectangular magnetic core are formed of the leg and yoke members with corner pieces 42, 43 inserted between the ends of the adjacent leg and yoke members. The butt joints between the corner pieces and the leg or yoke members are staggered and therefore overlapped.

In Fig. 6 the core structure shown has two kinds of isosceles trapezoidal leg members 44, 45 and two kinds of isosceles trapezoidal yoke members 47, 48. The differences in the two kinds of legs or yokes are in the angles which the ends make with the bases and in the length of the bases. The arrangement of dissimilar members in contiguous layers in the stacks of legs or yokes is therefore such as to have staggered ends to permit overlapping of the butt joints formed with the corner pieces.

The embodiment shown in Fig. 7 has leg and yoke members similar to those shown in Fig. 5. The complementary corner pieces 49 are cut in a triangular shape. In this core arrangement the leg, yoke and corner pieces are each of only one size and shape. In the contiguous layers each lamination is reversed to stagger the butt joints to be overlapped by a lamination in the next layer.

The grain orientation in the separate laminations in Figs. 5, 6 and 7 is similar to that of Fig. 1 and is represented by arrows.

The various modifications in Figs. 5, 6 and 7 permit control of the maximum angle which the flux will make with the grain orientation, herein called angle of transverse flux. In any one lamination the maximum angle of transverse flux is determined by the angle between the ends and the sides of the lamination. Where this angle is approximately 67°, the greatest angle of transverse flux in any lamination is approximately 23°. Therefore in these structures, advantage is always obtained from the improved magnetic characteristics of preferred oriented steel over random steel.

The triangular shaped corner pieces may be formed from strip material 50 as indicated in Fig. 8 without wasting material. The most favorable magnetic characteristics then are in a direction parallel to the side of the triangle which forms the outer edge 51 of the corner pieces, which is not exactly at 45° to the sides of the leg and yoke laminations.

The corner pieces in Fig. 7 may have any triangular shape so long as they form complementary pieces with the ends of the leg and yoke members. Although the bases of the trapezoidal leg and yoke members are shown as forming the outer edge of the core structure, they may be

reversed without departing from the invention. Then the base forms the inner edge of the core structure. The complementary corner pieces, triangular or of some other shape, would occupy a greater part of the corner, and the outer edges of the corner pieces would extend into the leg and yoke portions of the core structure.

The invention has been described in relation to core structures in which all of the laminations are made from strips of magnetic material having their most favorable magnetic characteristics in the direction in which the material has been elongated.

In core structures such as those shown, it may be desirable and advantageous to cut the corner pieces from steel having random magnetic characteristics. The cross sectional area perpendicular to the flux being greater in the corner pieces than in the legs and yokes, the flux density in the corner pieces is relatively low, and the core losses therein are limited to a reasonable value.

In the three legged core structure shown in Fig. 9 the four outer corner pieces 56 are similar in shape and arrangement to the corner pieces of Fig. 1. The sides 61 of the center leg member 64 are positioned at 90° with the sides 62 and 63 of yoke members 53 and 54 respectively. The adjacent ends of these three members about three sides of the rectangular insert 52. In one layer the insert is positioned with its long sides in alignment with the sides of the abutting yoke members, whereas in contiguous layers the insert is turned 90° and the long sides of the insert are in alignment with the sides of the abutting center leg member. Alternating the position of the inserts in each layer permits the butt joints between the members and the inserts in each layer to be overlapped by laminations of contiguous layers.

In the structure shown in Fig. 9 it is preferable to cut the inserts from random steel. The corner pieces may be either random or preferred oriented steel. It is preferable to cut the leg members and the yoke members from preferred oriented steel.

This invention has been described in what is considered to represent certain preferred embodiments. It is intended that the invention shall not be limited except by the appended claims which are intended to cover all such modifications as fall within the true spirit and scope of the invention.

It is claimed and desired to secure by Letters Patent:

1. A magnetic core having a closed magnetic circuit comprising abutting flat leg, yoke and corner laminations of magnetic steel assembled in stacks of superposed layers, said corner laminations between the adjacent ends of said leg and yoke laminations forming the corners of said core, the most favorable magnetic characteristics of said leg and yoke laminations being in their respective lengthwise directions displaced 90° from each other and the magnetic characteristics in any one of said corner laminations being at least as favorable in a direction substantially normal to the bisector of the angle between the lengthwise directions of the leg and the yoke laminations adjacent said one corner lamination as in any other direction.

2. A rectangular magnetic core comprising a plurality of layers of laminations, each of said layers including I-shaped leg and yoke laminations having their most favorable magnetic characteristics in their respective lengthwise direc-

tions, and corner laminations abutted against the ends of said leg and yoke laminations, each of said corner laminations having at least as favorable magnetic characteristics in a direction substantially normal to the bisector of the angle between the lengthwise directions of the leg and the yoke abutting the corner lamination as in any other direction.

3. A rectangular magnetic core comprising a plurality of layers of assembled laminations, each of said layers consisting of at least eight laminations, a first four of said layer laminations having their most favorable magnetic characteristics in their respective lengthwise directions, said first four laminations forming the legs and yokes of said core, the remaining said layer laminations inserted between and abutting the ends of said legs and the ends of said yokes to form corners of said core, the magnetic characteristics of one said corner laminations being at least as favorable in a direction substantially normal to the bisector of the angle between the lengthwise directions of the leg and the yoke adjacent said one corner as in any other direction.

4. A rectangular magnetic core having a closed magnetic circuit comprising a plurality of assembled laminations, said magnetic circuit including corner laminations and I-shaped leg and yoke laminations with the adjacent ends of said leg and yoke laminations abutted by said corner laminations, said leg and yoke laminations having their most favorable magnetic characteristics in their respective lengthwise directions, and the magnetic characteristics of each said corner lamination being most favorable in a direction substantially normal to the bisector of the angle between the lengthwise directions of the leg and yoke adjacent the corner lamination.

5. A magnetic core comprising a plurality of abutting flat laminations of magnetic steel assembled in stacks of superposed layers, said stacks arranged about a rectangular window and including legs, yokes and corners of said core, the magnetic characteristics of said legs and yokes being relatively highly oriented and being most favorable in their respective lengthwise directions and said corners of said stacks having substantially random magnetic characteristics.

6. A rectangular magnetic core comprising a plurality of layers of laminations, each of said layers including corner laminations and I-shaped leg and yoke laminations, the magnetic characteristics of said leg and yoke laminations being relatively highly oriented and being most favorable in their respective lengthwise directions, and said corner laminations inserted between and abutting ends of adjacent leg and yoke laminations, said corner laminations having substantially random magnetic characteristics.

7. A magnetic core having a closed magnetic circuit comprising a plurality of layers of laminations defining legs and yokes surrounding a rectangular window, each said layer including a three lamination corner arrangement, two of said three laminations having their most favorable magnetic characteristics in their respective lengthwise directions and positioned with their lengthwise directions at 90° to each other, the third of said three laminations positioned between and abutting the adjacent ends of said two laminations and the magnetic characteristics of said third lamination being most favorable in a direction substantially normal to the bisector of the angle between the lengthwise directions of said first two laminations.

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8. A magnetic core comprising a plurality of layers of assembled laminations, each of said layers formed of at least four rectangular laminations and at least four triangular laminations, said rectangular laminations forming legs and yokes of said core with their most favorable magnetic characteristics in their respective lengthwise directions, and said triangular laminations forming corners of said core inserted between and abutting the adjacent ends of said leg and yoke laminations, the direction of most favorable magnetic characteristics of one of said triangular laminations in one corner being substantially normal to the bisector of the angle between the lengthwise directions of the leg and yoke laminations at said one corner.

9. A magnetic core structure comprising a plurality of layers of assembled laminations, each of said layers including a corner lamination shaped as a triangle having all its angles not greater than 90° and at least two trapezoidal laminations which are positioned with their bases forming part of the outside edges of said core and positioned at 90° to each other forming a leg and a yoke of said core having their most favorable magnetic characteristics in their respective lengthwise directions, adjacent ends of said two trapezoidal laminations being abutted by the sides of said triangular lamination and the base of said triangular lamination forming two angles with said bases of said trapezoidal laminations with the most favorable magnetic characteristics of said triangular lamination in a direction sub-

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stantially parallel to the base of said triangular lamination.

10. A three-legged magnetic core comprising a plurality of layers of assembled laminations, each of said layers including two aligned yoke laminations, a leg lamination, and an insert lamination, said leg and yoke laminations having their magnetic characteristics relatively highly oriented with their most favorable magnetic characteristics being in their respective lengthwise directions with the lengthwise direction of said yoke laminations making an angle of 90° with the lengthwise direction of said leg lamination, adjacent ends of said yoke and leg laminations abutting said insert lamination and said insert lamination having substantially random magnetic characteristics.

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