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(54) **Transformer cores.**

(57) A method of manufacturing transformer cores of either the continuously wound or cut wound type using electrical steel strip having approximately a linear taper. By selecting a suitable taper, a hexagonal (or higher order) approximation of a circular cross-section for the legs of the cores is available. Two complementary core strips can be cut from a single rectangular stock strip in a scrapless manner.

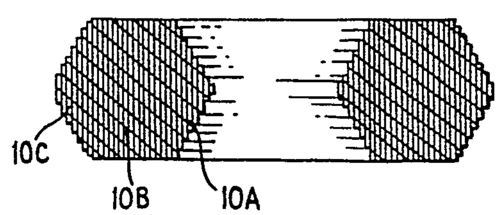

FIG.1A

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Croydon Printing Company Ltd.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to transformer cores of the wound core type and is suitable for either single phase or three phase transformers.

(2) Description of the prior art

There are a multitude of existing designs, which can be broadly catergorized as rectangular or cruciform. After examination of these existing types, it was considered that the cruciform types were philosophically superior, but the rectangular types embodied production advantages, including simplicity.

BRIEF SUMMARY OF THE INVENTION

The object of the present invention is to improve upon these existing cores.

It is a preferred object to be able to produce a cruciform-like circular core cross-section.

It is a further preferred object to produce the cores without a large number of different widths of electrical steel strip being required.

A preferred feature of the present invention is the use of tapered electrical steel strip to produce a hexagonal or better approximation to circular cross-section for those portions of the core under the windings to enable the production of cores of near optimum geometry as a straight forward procedure.

Other objects of the present invention will become apparent from the following description.

In the broad aspect, the present invention resides in a method of manufacturing a transformer core from electrical steel strip including the step of:

cutting at least a portion of the strip with non-parallel sides.

Preferably the portion of the strip is cut with an approximately linear taper.

In another aspect, the present invention resides in a transformer constructed using the method.

The invention, in its preferred simplest form, is the hexagonal form approximation, which can be achieved in either of two ways, both using a single width size of conventionally slit steel strip, which is then specially slit. For scrapless production of cores two identical cores can be slit from the normal parallel sided strip in such a manner that the tapered pieces are complementary to each other. Two identical tapered strips can readily be cut from a suitable rectangular piece by cutting it at an appropriate angle.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS.

To enable the invention to be fully understood, a number of preferred embodiments will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a front view of a single phase core of substantially hexagonal cross-section;

FIG. 1A is a cross-sectional view taken on line 1A-1A of FIG. 1;

FIG. 1B shows the cutting plan of the strip for the core of FIG. 1;

FIG. 2 is a cross-sectional view of a modified form of the core of FIG. 1;

FIG. 2A shows the cutting plan of the strip for the core of FIG. 2;

FIG. 3 is a front view of a single phase shell type core;

FIG. 3A is a cross-sectional view taken on line 3A - 3A of FIG. 3;

FIG. 4 is a front view of a three phase "delta" core;

FIG. 4A is a cross-sectional view taken on line 4A - 4A of FIG. 4;

FIG. 5 is a cross-sectional view of a three-phase star core;

FIG. 5A is a view of an assembled layer of the core of FIG. 5; and

FIG. 5B is a plan view of the strips for the assembled layer of FIG. 5A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The production of the tapered electrical steel strip is implemented by a suitable slitting machine. Because the angle of taper is so small e.g. less than 1^{o}, the axis of the slitting rollers is set perpendicular to the strip of electrical steel, and the necessary taper is achieved by forcing the rollers across the sheet. The need for precise control of the positioning of the slitting rollers means that the slitting machine is best built with a single pair of rollers for the slitting operation. This means that it only has to accomodate the width of steel needed for the largest core to be cut by the method. The details of the method are most easily illustrated by a description of the relevant parts of the machine. After dereeling, the strip is passed through a pair of plain rollers, comprising a driven roller to control the speed of the strip, and its idler. The strip then passes through two guides with tungsten carbide wear parts which control its lateral position, and then through a second pair of rollers similar to the first. The second idler is identical to the first, but the other roller is machined to have a circumference which matches the number of pulses per revolution of the pulse generator (shaft encoder) that it drives. This unit thus measures the length along the strip as it is fed through, and the slitting roller assembly is immediately adjacent to it. The slitting rollers are mounted on a very rigid frame, and can be set so that they are pre-loaded to minimize deflection and with the desired amount of over-lap. The roller frame is wider than the strip, since it must be able to move back and forth across the strip. The frame is mounted on a machine bed and driven by a worm drive from a direct current motor geared down by a large amount because of the slow travel required. Included in this assembly is a second shaft encoder with its own small roller which enables the position of the slitting rollers to be known and controlled. The control system for the slitting roller assembly is straightforward in that the motion of the slitting rollers sideways across the strip is directly proportional to the length of strip passing through. This can be implemented by ordinary logic and servosystem components, but is better and simpler done by a microprocessor based computer which may control the rest of the machine. Thus the tapered strip required for the core designs can readily be produced.

Referring to FIGS. 1, 1A and 1B, the core 10 which is continuously wound, has a substantially hexagonal cross-section as shown in FIG. 1A comprising a section 10A of increasing width, a central section 10B of maximum width, and a section 10C of decreasing width.

Referring to FIG. 1B, section 10A is wound from strip 11A which is cut from a rectangular stock strip 12, the strip 10A having a linear taper from a substantially zero width upto the width of the stock-strip 12.

Section 10B is wound from a strip 11B cut from a length of the stock strip 12 and has parallel sides.

Section 10C is wound from a strip 11C cut from stock strip 12 and has a linear taper from the width of the stock strip 12 down to substantially zero width. As the strip 11A, 11C are of the same width, they can be cut from lengths of stock strip 12.

In the modified form of the core illustrated in FIGS. 2 and 2A, the core 20 has a section 20A of increasing width and a section 20B of decreasing width. The sections both have a maximum width equal to the maximum width of the core and a minimum width equal to one-half of the core, the sections 20A, 20B being wound from strips 21A, 21B respectively from rectangular stock strip 22 which has a width equal to 1.5 times the maximum width of the core 20. As the strips 21A, 20B are complementary, two transformer cores 20 can be cut from a single length of stock strip 22 without scrap. The single phase shell-type core 30 of FIGS. 3 and 3A has a pair of core frames 31A each with a cross-section which is substantially identical with an isosceles trapezium. When the two frames are placed back-to-back, the central leg is substantially hexagonal in cross-section (as shown in FIG. 3A). Each frame can be wound from a single strip of increasing width, such as strips 21A, 21B shown in FIG. 2A. As these strips are complementary, the core 30 can be produced from a single piece of rectangular stock strip i.e. strip 22.

The three-phase delta core 40 shown in FIGS. 4 and

4A comprises three frames 41 each conjoined at their sides to the other two frames, the legs of the core having a substantially hexagonal cross-section. Each frame 41 is continuously wound from a section 42 of fixed width (equal to 0.5 times the diameter of the leg) cut from a length of rectangular stock strip of that width, and then a section 43 of decreasing width. As the sections 43 of two of the frames can be complementary, they can be cut from rectangular stock strip having a width equal to 0.5 times the diameter of the core legs. The core 40 is assembled by placing the frames 41 in the configuration shown in FIGS. 4 and 4A and securing the frames together.

FIGS. 5, 5A and 5B show a three-phase "star" or "Y" core 50 with legs of substantially hexagonal cross-section. The core 50 comprises three frames 51A, 51B, 51C each of substantially C-shape in side view.

Each frame 51A, 51B, 51C is formed from a series of lamination lengths A,B,C respectively cut from a tapered strip 53.

The strip 53 is of increasing taper to form section 52A of each frame and of decreasing taper to form section 52B and may be cut as shown in FIG. 2A.

Lamination lengths A.B.C are cut to selected length of square-ended strip 53 with two cuts at 60° to the longitudinal axis of the strip 53. This cutting step for most size cores can ignore the taper on the layers which come from the tapered strip because of the small angle of taper.

Each layer is formed as shown in FIG. 5A where the angled cut ends of each lamination length are butted to the side of adjacent strip adjacent its free ends.

The method of assembling a star core is to lay together all the laminations so that one joint (e.g. the bottom joint) is assembled and the core has the appearance of three radial arms. The joint is clamped and the lamination lengths A,B, C are bent upward until they are perpendicular to the plane of the joint. The lengths are secured and then the top joint is sequentially folded together. The electromagnetic properties of the joint are best when each layer is rotated one third of a turn from the previous layer, that is when piece A of FIG. 5A is placed on each core leg in turn. This joint is applicable not only to cores with tapered strip, but to any core of this type, also known as Y (wye) cores. The section labelled E can be seen to protrude from the joint, but there is no advantage to be gained by removing it.

All of the new core designs, being of the wound core type, require annealing after they have been cut and formed to shape.

By using the tapered strip to form the cores, which can be continuously wound (except for the star core 50 of FIGS. 5, 5A and 5B), the transformer designer can achieve great flexibility in design. By careful selection of the taper of the electrical strip, he can achieve almost any core cross-section which he may require and can almost achieve the theoretically optimum circular cross-section. For simplicity, the hexagonal cross-section as an approximation of the circular cross-section is readily achievable.

The invention, in addition to its application as a means of producing the hexagonal form approximation, can in an analogous fashion to the cruciform case, be used to produce octagonal or higher order even regular sided approximations to a circular cross-section. However, for each pair of sides in excess of six an additional size of parallel strip is required to allow scrapless production of the core.

Various changes and modifications may be made to the methods described without departing from the scope of the present invention.

CLAIMS

1. A method of manufacturing a transformer core from electrical steel strip including the step of:

cutting at least a portion of the strip with non-parallel sides.

2. A method as claimed in claim 1 wherein:

the portion of the strip is cut with an approximately linear taper.

3. A method as claimed in claim 2 wherein:

two tapered core strips are cut from a parallel side portion of electrical steel strip, the tapered core strips being complementary to each other.

4. A method as claimed in claim 3 wherein:

the parallel side portion has a width of approximately 1.5 times the width of the core section; and

the tapered core strips have a width of approximately 0.5 times the width of the core section.

5. A method as claimed in claim 2 for cutting a core with a core section of substantially hexagonal cross-section and further including:

cutting a first portion with a taper of increasing width; and

cutting a second portion with a taper of decreasing width, the length of the second portion being greater than the length of the first portion.

6. A method as claimed in claim 5 wherein:

the electrical strip section has a width of approximately 1.5 times the width of the core section; and the minimum widths of the first portion and the second portion are approximately equal to 0.5 times the width of the core section.

7. A method as claimed in claim 6 and further including:

cutting a third portion with substantially parallel sides to be interposed between the first portion and the second portion, the third portion having a width equal to the maximum width of the core section.

8. A method as claimed in any one of claims 1 to 7 wherein the core is continuously wound from the electrical strips.

9. A method as claimed in claim 2 for a delta core comprising the conjunction of three frames and have three vertical leg sections of substantially hexagonal cross-section including:

cutting a first portion for each frame with substantially parallel sides, said first portion being of a width substantially equal to 0.5 times the diameter of the leg sections of the core; and

cutting a second portion for each frame with an increasing or decreasing taper.

10. A method as claimed in claim 2 for a star or Y-core comprising three frames each of substantially C-shape in side view and substantially hexagonal in cross-section, the frames being arranged at substantially 120° apart, including:

cutting a first portion of increasing taper from a minimum width to a maximum width;

cutting a second portion from a maximum width to a minimum width;

cutting each portion into a plurality of lamination lengths, each group of three lamination lengths being separated from the adjacent group at each end by a cut at substantially 90° to its longitudinal axis, each said group forming a layer of the core, with the three lamination lengths in the group being separated from each other by cuts at substantially 60° to the longitudinal axis;

butt joining the ends of two of the lamination lengths cut at substantially 60° to the sides of a third lamination length cut substantially 90° adjacent the ends of the third lamination length to form a lamination layer; and assembling the lamination layers to form the assembled core.

11. A transformer core formed by the method as claimed in any one of Claims 1 to 10.

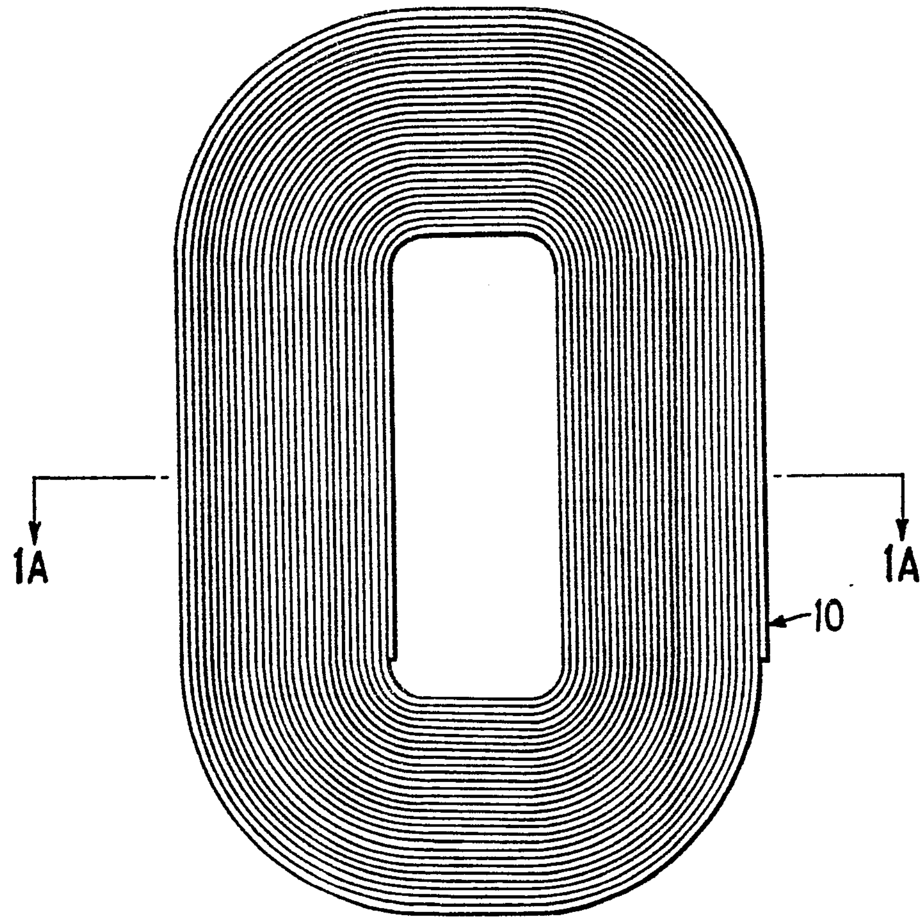

FIG.1

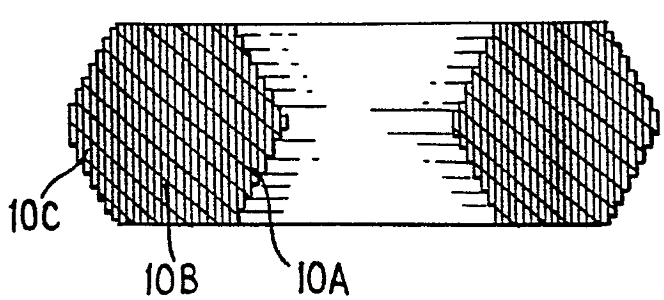

FIG.1A

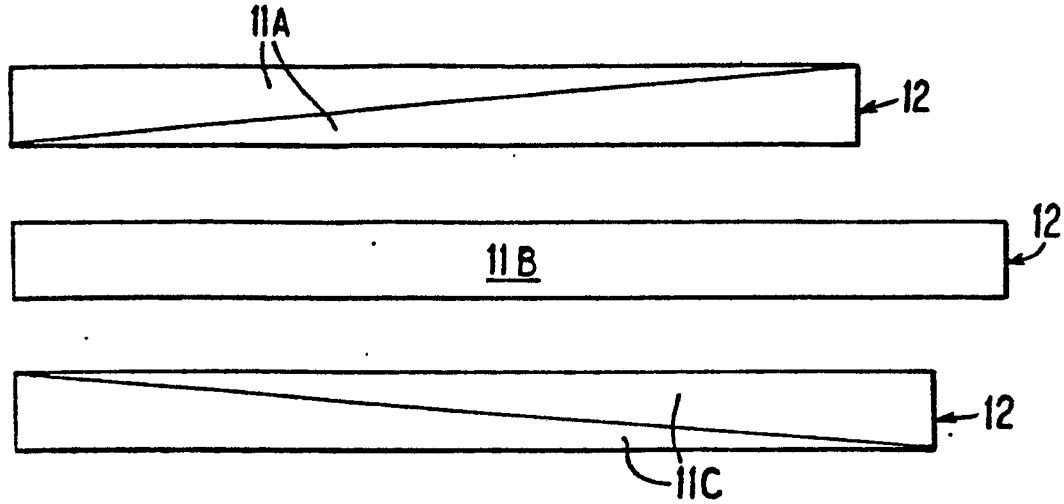

FIG.1B

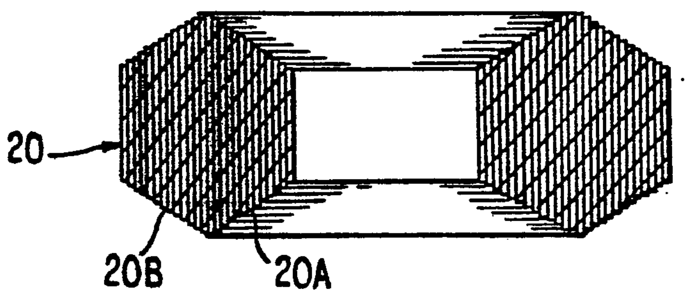

FIG. 2

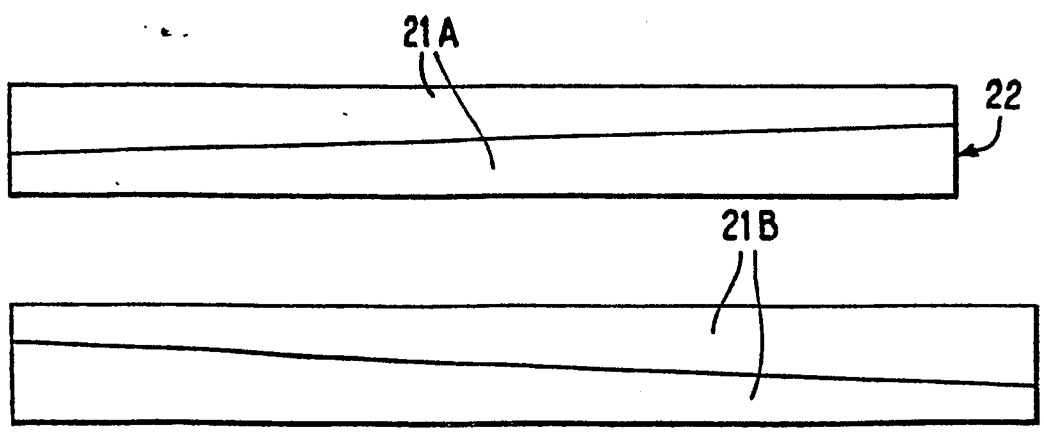

FIG. 2A

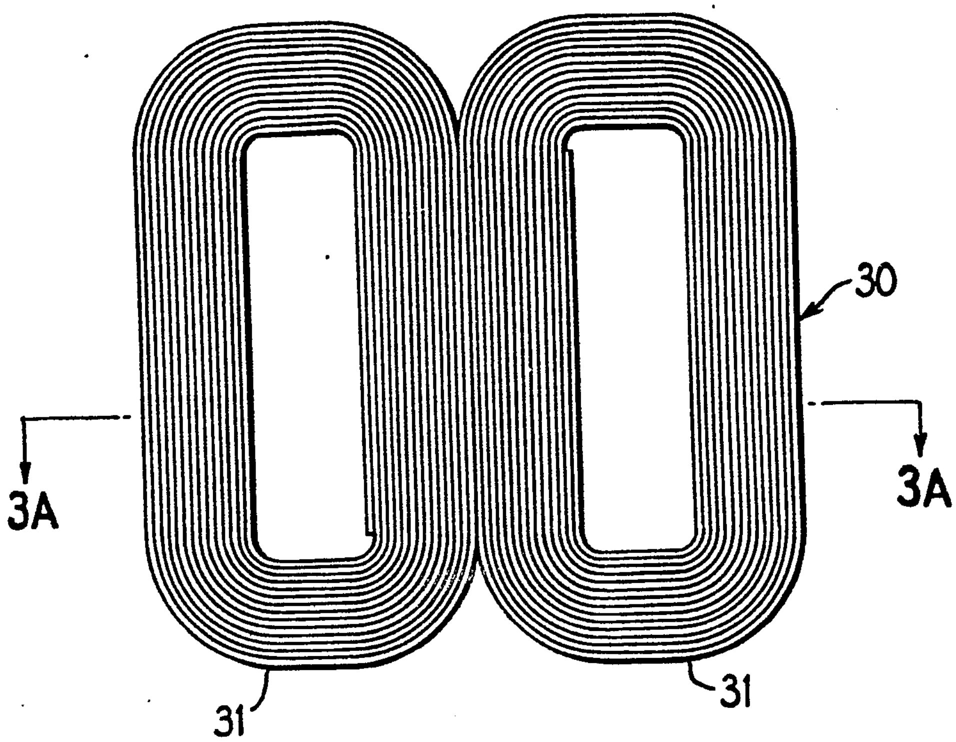

FIG. 3

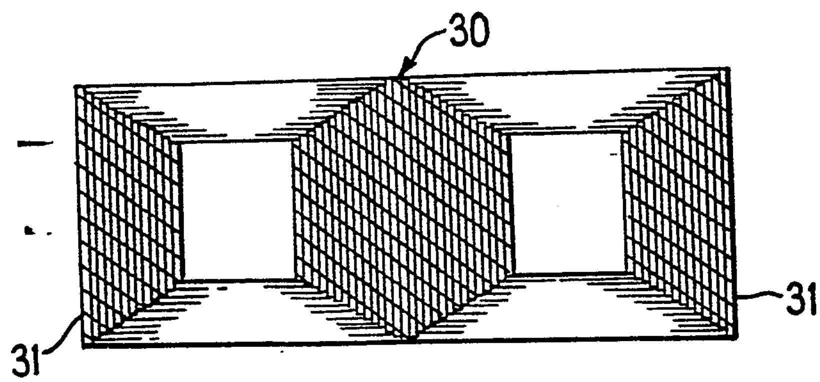

FIG. 3A

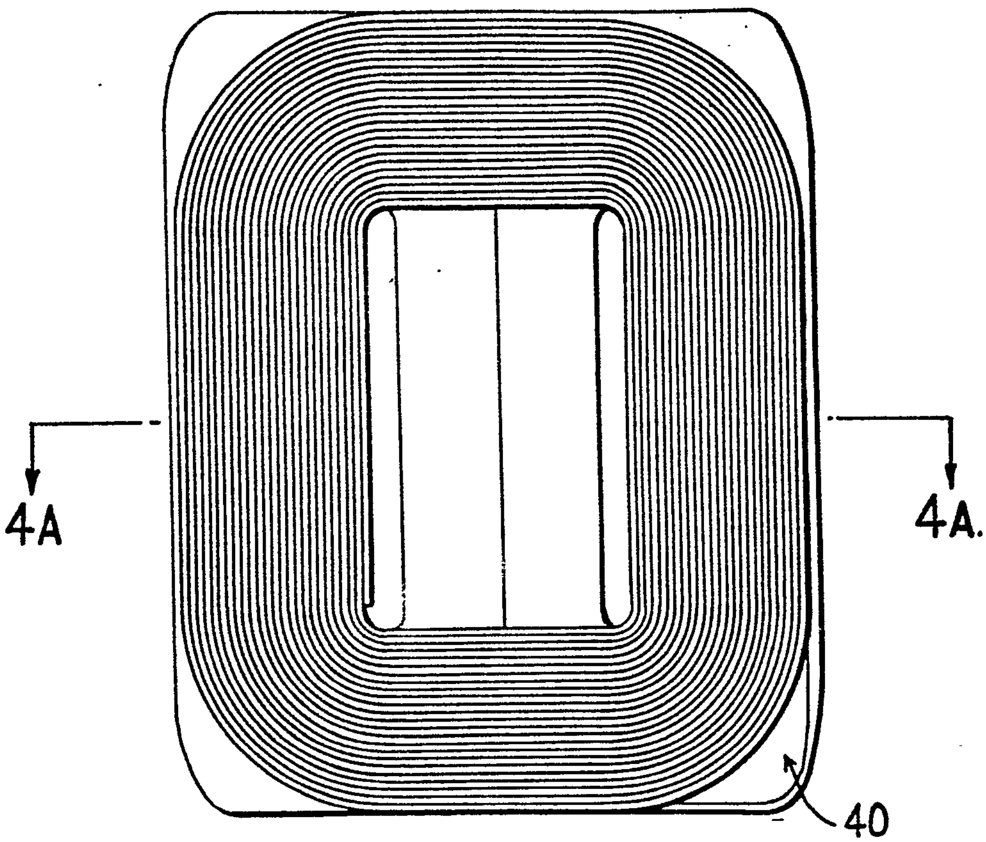

FIG.4

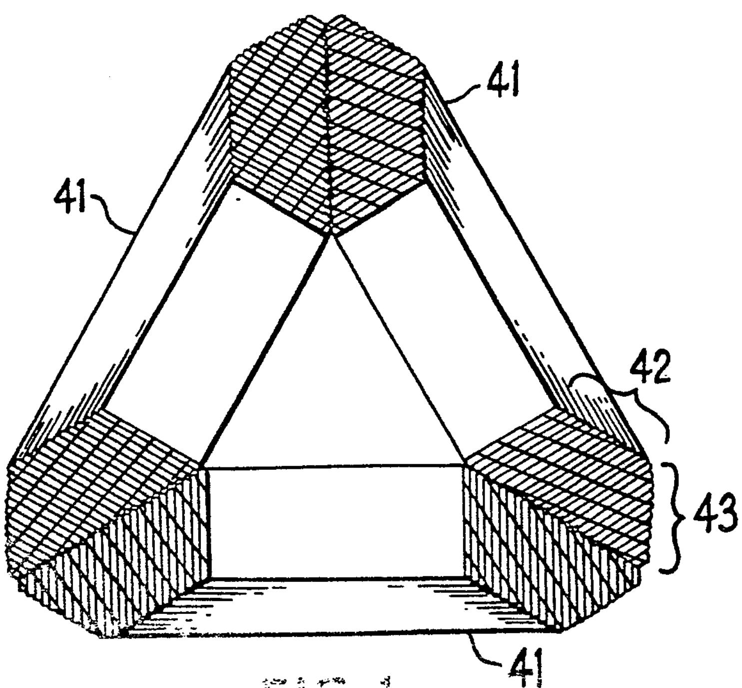

FIG. 4A

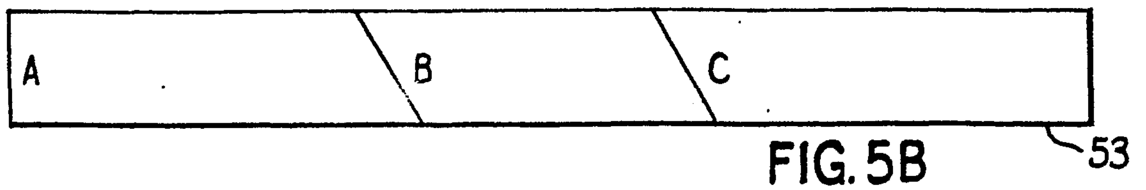

FIG. 5B

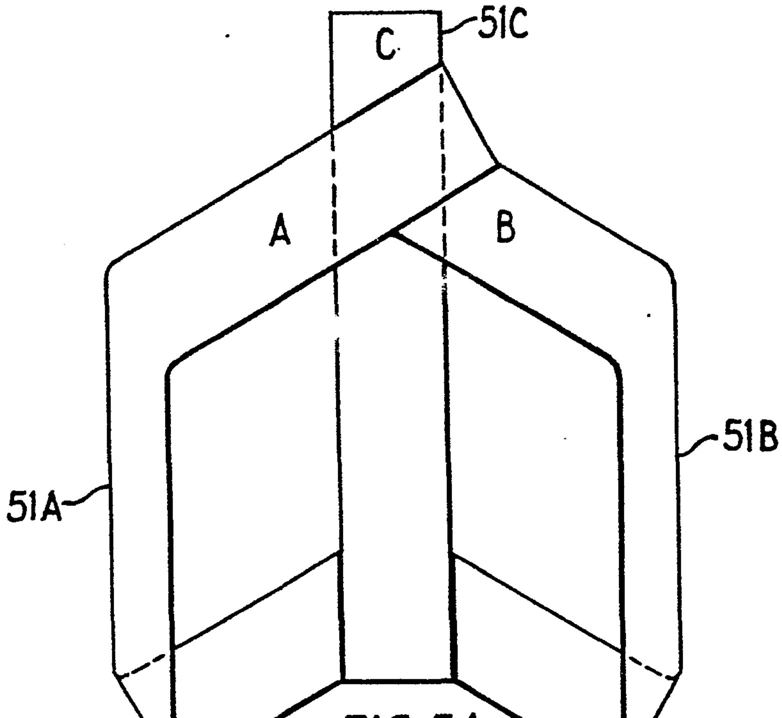

FIG.5A

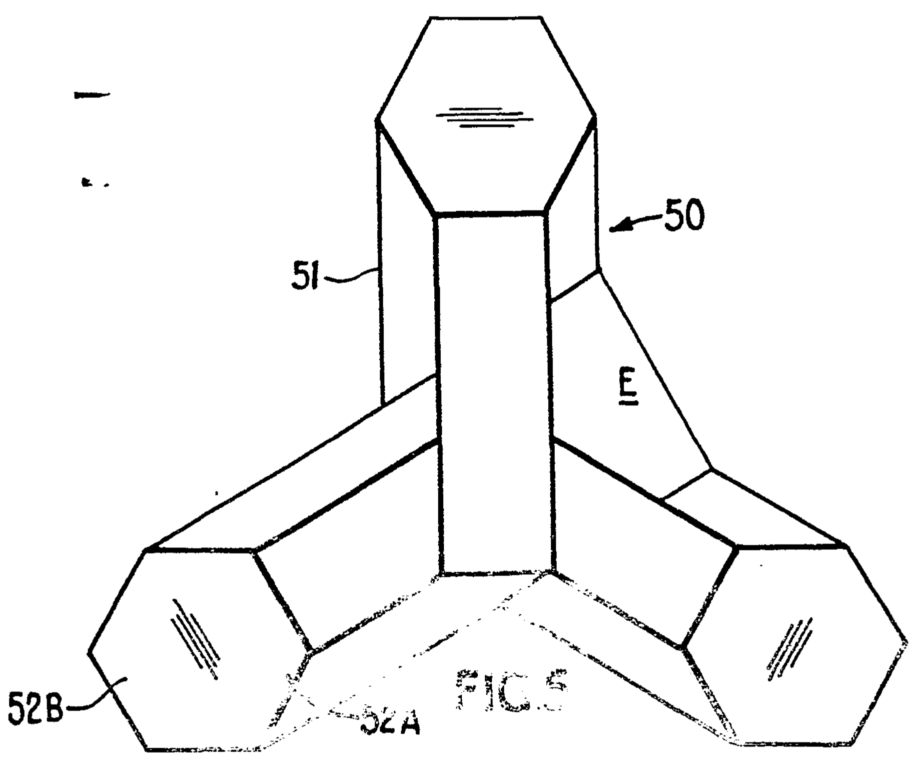

FIG.5

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Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 79 30 2237

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	DE - B - 1 011 056 (LICENTIA) * Column 2, lines 21-44 * --	1-3,5, 8,9,11
X	US - A - 2 366 071 (GENERAL ELECTRIC) * Page 2, left-hand column, lines 62-75, right-hand column lines 1-14 * --	1-3,7, 8,11
X	DE - A - 2 702 455 (ANDREEU GENNADIJ BORISOVITSCH) * Page 9 * --	1-3,8, 9,11
X	FR - A - 1 107 583 (COMPAGNIE ELECTRO-MECANIQUE) * Page 2, right-hand column, paragraphs 5,6; page 3, left-hand column, paragraphs 1,2 * --	1-6, 8,11
	GB - A - 524 285 (THOMSON-HOUSTON) * Page 2, lines 5-11 * --	7,8
	GB - A - 662 915 (WESTINGHOUSE) * Page 7, lines 120-130; page 8, lines 1-19 * --	10
A	GB - A - 692 845 (A.S.E.A.)	
A	FR - A - 1 333 285 (AUGIER)	
A	US - A - 2 458 112 (LINE MATERIAL COMP.)	

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CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

H 01 F 41/02
H 01 F 27/24

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

H 01 F 41/02
H 01 F 27/24
H 01 F 3/04
H 01 F 33/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	07-01-1980	VANHULLE

EPO Form 1503.1 06.78

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EUROPEAN SEARCH REPORT

Application number
EP 79 30 2237

-2-

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	DE - C - 691 531 (A.E.G.)		
A	FR - A - 2 287 760 (INGENIERIA ELECTRICA INDUSTRIAL)		
A	GB - A - 830 094 (BROWN BOVERI)		
A	GB - A - 708 995 (THOMSON-HOUSTON)		

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)