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(54) Transformer core support.

(57) During operation of a transformer having a core fabricated from a plurality of laminations, it is necessary to maintain compressive force on the core to prevent undesirable loosening and/or vibration of the laminations. Maintaining compressive force must be accomplished without establishing undesirable electrical flow paths through which current induced by magnetic flux flow in the transformer may flow. One such undesirable path may be created by encircling the mutual magnetic flux flow through the transformer with metallic components for maintaining compressive force on the core. In accordance with the present invention, a tensioning device (40) comprising an electrical insulative material urges a clamping device (12, 14) that straddles the core into compressive engagement with the core when the tensioning device is subjected to a predetermined amount of tension, without establishing undesirable electrical flow paths in the transformer. The tensioning device may include an aromatic polyamide and a turnbuckle and may be removably coupled to the clamping device for facilitating transformer coil repair and/or replacement. The tensioning device is preferably disposed in a window of a transformer.

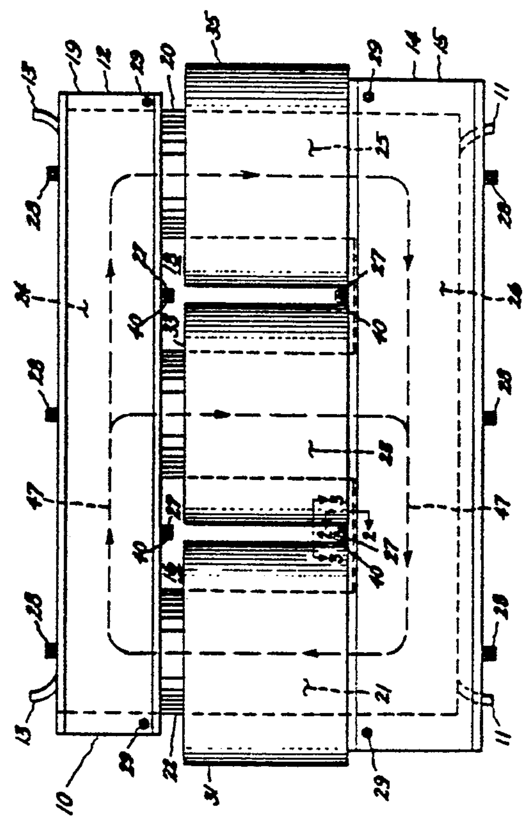

Fig. 1

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TRANSFORMER CORE SUPPORT APPARATUS

Background of the Invention

This invention relates to support apparatus for the core of a transformer and, more particularly, to support apparatus for securing laminations of the core against loosening or vibrating, especially in the window area of the core.

In one class of three phase transformers, the core is fabricated from a plurality of laminations which are appropriately shaped, registered and stacked to form the core. The core generally includes three parallel spaced apart legs having respective ends thereof connected by respective yokes. The space between adjacent legs and bounded in part by the yokes is known as a window. Generally at least two windings, which may be concentric with respect to each other, circumferentially surround each leg, are in magnetic flux communication therewith and pass through at least one window. During operation of the transformer, mutual magnetic flux is conducted between adjacent legs through portions of the yokes around the window between them.

A requirement of such transformers is that during operation sufficient clamping load be maintained on the core laminations to prevent them from loosening and/or vibrating due to magnetic forces, which result from eddy currents induced in the laminations during operation of the transformer. A particularly difficult area in which to maintain adequate clamping load is at the portion of the transformer window which is bounded by a yoke, since mutual flux of the transformer, i.e. flux flowing between legs through the yokes, must not be entirely encircled or surrounded by electrically conductive metallic components (such encirclement acts as a coil having a single turn, thus resulting in a relatively high current induced therein) because potentially heavy circulating currents will be induced in the components by the flow of mutual flux, which will result in generation of localized hot spots in the components with an attendent decrease of transformer efficiency and potential catastrophic damage to the components and core.

A previous core clamping method used metallic threaded bolts which pass through a hole in the core laminations. However, bolt holes through core members contribute to undesirable stresses and flux concentrations. One method for eliminating holes through the core involves using metallic yoke clamping channels, disposed on opposite sides of the yoke of the transformer, with metallic studs disposed around the outer periphery of the yokes and no direct clamping, such as metallic studs, in the window area. Thus, this method relies on clamping loads supplied by the clamping channels for supplying compressive loading in the window area. These clamping loads tend to decrease as the distance from a stud increases. This approach results in significant variation in compressive loads applied to core laminations with potential reduction in overall quality and operating efficiency of the transformer. It is desirable that surface stresses in laminations be minimized by using clamping methods which evenly distribute stresses.

In an attempt to provide more uniform clamping forces on the core, other core clamping devices have used threaded metallic studs with non-metallic washers, which are subject to compressive forces, placed under the nuts for isolating the stud from the metallic clamping channels. One problem associated with these devices is that under long term, heavy, often cyclic thermal loads, nonmetallic washers can deteriorate, leading to loss of core clamping load and increased core vibration. In addition, electrical insulation properties of non-metallic washers may be compromised by physical degradation, such as cracking, and/or by contamination, which may establish or faciliate formation of an electrical conductive path over the surface of the washer, wherein the path extends the relatively short distance from the metallic stud at the center of the washer to the channel at the outer periphery of the washer. In addition, it would be desirable to remove as many electrically conductive components as possible from between the coils, which generally have high voltage applied thereto during operation.

Accordingly, it is an object of the present invention to provide a clamping device for adequately clamping the laminations of a core of a transformer without entirely circling the mutual flux path with electrically conductive components, wherein the clamping device is able to withstand long term, heavy cyclic thermal loads without adversely affecting the device.

Another object of the present invention is to increase the electrical insulative path length of the clamping device over previously known devices.

Still another object is to remove electrically conductive objects from the vicinity of high voltage between the coils of a transformer.

Summary of the Invention

In accordance with the present invention, an electric transformer comprises a pair of legs each having a first and second end respectively connected by a first and second yoke, respectively, clamping means for straddling the first yoke and tensioning means coupled to the clamping means for urging the clamping means into compressive engagement with the first yoke, wherein the tensioning means include electrically insulative bridging means having a first and second end respectively coupled to the clamping means, such that the clamping means compressively engages the first yoke when the tensioning means is subjected to a predetermined amount of tension.

In another aspect of the present invention, for an electric transformer having a core fabricated from a plurality of laminations, tensioning means for compressing the laminations comprises clamping means for straddling the core and bridging means for urging the clamping means into compressive engagement with the core when the bridging means is subjected to a predetermined amount of tension, wherein the bridging means includes an electrically insulative material, such as a polyamide.

The features of the invention believed to be novel are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the detailed description taken in connection with the accompanying drawing.

Brief Description of the Drawing

Fig. 1 is a plan view of a three phase transformer including tensioning means in accordance with the present invention.

Fig. 2 is a view looking in the direction of the arrows of line 2-2 of Fig. 1 with coils removed.

Fig. 3 is a view looking in the direction of the arrows of line 3-3 of Fig. 1 with coils removed.

Fig. 4 is another embodiment of tensioning means in accordance with the present invention.

Detailed Description of the Invention

Referring to Fig. 1, a plan view of a three-phase transformer including support apparatus in accordance with the present invention is shown. Although the present invention will be described as it may be applied to a three-phase transformer, it is to be understood that the present invention is applicable to any transformer or other electrical device requiring a clamping force without adversely affecting flow of magnetic flux and without encircling a magnetic flux flow path with metallic structure. Transformer 10 comprises a core 22 and coils 31, 33 and 35. Core 22 includes three substantially parallel spaced apart legs 21, 23 and 25 and a pair of substantially parallel yokes 24 and 26 connected to respective ends of legs 21, 23 and 25. Yoke 24 magnetically couples one end of each leg 21, 23 and 25 and yoke 26 magnetically couples the other end of each leg 21, 23 and 25. Legs 21, 23 and 25 and yokes 24 and 26 are typically fabricated from a plurality of laminations 20 which are appropriately shaped, registered and stacked as is known in the art.

A pair of clamping channels 12, having one channel 19 thereof shown in Fig. 1, straddles yoke 24, and a pair of clamping channels 14, having one channel 15 thereof shown in Fig. 1, straddles yoke 26. Pairs of clamping channels 12 and 14 typically respectively comprise an electrically conductive material like a metal, such as iron or steel.

A window 16 is defined by spaced apart legs 21 and 23 and the portion of spaced apart yokes 24 and 26 therebetween. Likewise, a window 18 is defined by spaced apart legs 23 and 25 and the portion of spaced apart yokes 24 and 26 therebetween.

Coils 31, 33 and 35, corresponding to a respective phase of the transformer, respectively circumferentially surround legs 21, 23 and 25. Coils 31, 33, and 35 generally eaoh include at least two windings which may be conventionally designated as primary and secondary. A pair of coolant fluid inputs 11 and a pair of coolant fluid outputs 13 permit respective introduction and removal of coolant fluid, which is disposed in heat flow communication with core 22 for cooling core 22, if desired.

A plurality of blocks or flanges 28 are disposed at predetermined locations along the outer periphery of channel 15 and 19. Blocks 28 may be integral channel 15 and 19 or rigidly affixed thereto, such as by welding. A corresponding plurality of blocks or flanges (not shown) is predeterminedly disposed along the outer periphery of the other channel of pair of channels 12 and 14. Blocks 28 that are coupled to channels 15 and 19 and the corresponding blocks (not shown) coupled to the other member of pair of channels 12 and 14 each include a hole for receiving conventional tightening means, such as a metallic rod that is threaded at both ends to extend through the hole of block 28 and the hole of the corresponding block of the other member of pair of channels 12 and 14. The metallic rod is secured by a nut which engages block 28 and the corresponding blocks to forceably compress the respective outer portion of pair of channels 12 and 14 together, thereby respectively compressively sealing the laminations of yoke 24 and 26 therebetween. In a similar manner, holes 29 may be provided through channels 19 and 15 and the other channel of pair of channels 12 and 14 toward the inner side of the channel, outside legs 21 and 25 and near the end of each of the pair of channels 12 and 14 at respective ends thereof for receiving conventional tightening means, such as was described as being disposed in cooperation with blocks 28. Of course, a block 28 could be secured to respective ends of pair of channels 12 and 14 for clamping the ends of pair of channels 12 and 14 using conventional tightening means. In accordance with the present invention, respective tensioning means 40 are coupled to pair of channels 12 and 14 in windows 16 and 18.

It is not necessary that conventional threaded metallic rods, which are disposed in cooperation with blocks 28 and holes 29, be electrically insulated from pair of channels 12 and 14, if metallic structure, such as may include pair of clamping channels 12, one or more conventional rods in cooperation with block 28, and the tightening apparatus, such as tensioning means 40 in accordance with the present invention, that is disposed in windows 16 and 18 does not encircle mutual flux path 47 of transformer 10. The mutual flux path 47 of the transformer is shown by broken lines and is generally defined by portions of legs 21, 23 and 25 and yokes 24 and 26 surrounding windows 16 and 18. It is to be understood that at any predetermined instant the actual mutual flux flow direction along mutual flux path 47 may be opposed to the direction indicated by the arrows. In accordance with the present invention, it is preferred that tensioning means 40, which include an electrically insulative material, as explained in detail below, be appropriately disposed in windows 16 and 18. However, in certain transformer configurations it may be desired that blocks 28 with conventional threaded metallic rods either with or without insulating washers be disposed in windows 16 and 18, and tensioning means 40, in accordance with the present invention, be used at predetermined locations along the periphery of channel pairs 12 and 14 for maintaining adequate clamping forces on laminations 20 of core 22.

Restraining means 27, such as a block or flange, for fixedly securing tensioning means 40, are coupled to channel 15 and 19, or fabricated integral therewith, in the area of windows 16 and 18. Corresponding restraining means 27 are appropriately coupled to the other channels (not shown in Fig. 1) of pair of channels 12 and 14. Although restraining means 27 may be fixedly coupled to channel 15 and 19 respectively, such as by welding, or be integral therewith, it is preferable that at least one cooperating pair of restraining means 27 disposed in each of window 16 and 18, respectively, be removably coupled to pair of channels 12 and/or 14 in order to permit installation, removal and replacement of coil 31, 33 and/or 35 without disassembly of pair of clamping channels 12 and/or 14.

Referring to Fig. 2, a view looking in the direction of the arrows of line 2-2 of Fig. 1, with coils 31 and 33 removed for ease of illustration, is shown, but not necessarily to scale. A channel 17, the other member of pair of channels 14, is shown compressively engaging laminations 20 of yoke 26 and leg 21 of core 22. A similar channel (not shown) that is appropriately disposed with respect to core 22 and yoke 24 forms the other channel of pair of channels 12. Tensioning means or clamping device 40 comprises bridging means 37 and retaining means 30. Retaining means 30 and bridging means 37 are shown extending between respective restraining means 27, which are shown removably coupled to channel 15 and 17.

Retaining means 30 comprises a shank 32 having a cross member 34 fixedly secured to one end thereof and the other end thereof threaded for receiving a nut 36. Shank 32, cross member 34 and nut 36 may each be metallic. Alternatively, shank 32 may have an eye loop fixedly secured to the non-threaded end thereof. Thus, in these embodiments, retaining means 30 may be described as a T-bolt and eye-loop bolt, respectively. Restraining means 27 include a hole therethrough for receiving the threaded portion of shank 32 of retaining means 30. Restraining means 27 may be metallic and are removably secured to channel 15 and 17 of pair of channels 14 by fastening means 38. Fastening means 38 include an externally threaded member 44, which is fixedly coupled to restraining means 27 and extends through a hole 41 of channel 15, and a nut 39 for threadably engaging member 44 and abuttingly engaging channel 15 for removably securing restraining means 27 to channel 15. A recess or counter bore 43 may be provided in channel 15 for receiving nut 39 and preventing undesirable loosening thereof. Fastening means 38 is similarly secured to restraining means 27 and channel 17.

Bridging means 37 extends between channels 15 and 17 and is coupled at respective first and second ends thereof to retaining means 30 proximate channel 15 and retaining means 30 proximate channel 17. Bridging means 37 comprises arms 46 and 48 formed from a material which is electrically insulative, has high tensile strength, typically at least about 90,000 psi and preferably greater than that of restraining means 27 and retaining means 30, and good dimensional stability, that is, nearly zero elongation under tension. In other words, the material comprising bridging means 37 tends to rupture without elongating when subjected to a predetermined amount of tension. A material meeting these requirements for bridging means 37 is an aromatic polyamide. A preferred aromatic polyamide is poly (phenylenephthalamide), one example of which consists essentially of securing units of poly (1, 4-phenyleneterephthalamide), described as Kevlar by Gan et al, in Vol. 19 of the Journal Of Applied Polymer Science, pp. 69-82 (1975). Of course other synthetic or naturally occurring materials meeting the above requirements may be used.

Bridging means 37 may include a relatively thick strand of material, having a predetermined tensile strength, disposed in a single pass between respective restraining means 27 to form arms 46 and 48 and having the ends threof secured at a tie point 45, such as by fusing. Alternatively, bridging means 37 may include a plurality of strands of electrically insulative material each disposed in a single pass between respective restraining means 27. However, it is preferable that bridging means 37 include a relatively thin strand of material, having a predetermined tensile strength, interlaced in a plurality of passes and in a predetermined pattern between respective restraining means 27 so that arms 46 and 48 respectively include a plurality of segments of the strand of material. The ends of the strand are secured at tie point 45. When arms 46 and 48 of bridging means 37 include a plurality of strand segments, the plurality of strand segments may be impregnated with a curable solventless polyester resin, for tieing the strand segments together to prevent fretting or chafing and for augmenting the tensile strength of the plurality of strand segments.

When tensioning means 40 and restraining means 27 are operationally assembled, nuts 36 may be tightened to apply tension to tensioning means 40 which in turn applies tension to restraining means 27 and fastening means 38 for urging channels 15 and 17 together and thereby compressively engaging laminations 20 of yoke 26. The magnitude of the compressive force with which channels 15 and 17 engage core 22 may be appropriately adjusted by the degree of tightening of nuts 36.

Bridging means 37 also electrically insulates restraining means 27 and retaining means 30 which are coupled to channel 15 from retaining means 27 and retaining means 30 which are coupled to channel 17, thereby preventing entirely surrounding mutual flux path 47 (Fig. 1) with an electrically conductive material. Shank 32 of retaining means 30 may be made very short so as substantially to remove or minimize metallic structure between coils 31 and 33 (Fig. 1) of transformer 10, while also increasing the electrical insulative path length over prior devices.

Referring to Fig. 3, a view looking in the direction of the arrows of line 3-3 of Fig. 1, with coils 31 and 33 removed for clarity, is shown, but not necessarily to scale. Arms 46 and 48 of bridging means 37 are shown to include a plurality of segments of a strand of electrically insulative material, wherein each pass of the strand of material between opposing retaining means 30 is wrapped at least in part around respective shank 32 and cross member 34 before eventual joining of the ends of the strand at tie point 45. The weaving and wrapping of the strand of material around shank 32 and cross member 34 is made to ensure that bridging means 37 will be fixedly held between respective retaining means 30 and to able bridging means 37 to withstand tension applied thereto, without slipping off shank 32 and/or cross member 34. The plurality of strand segments forming arm 46 and 48 may be impregnated as hereinbefore described. The number of strand segments constituting arms 46 and 48 is predeterminedly selected to provide the desired tensile strength for arms 46 and 48, which is a function of the tensile strength of a single strand of material and may be determined by one of ordinary skill in the art without undue experimentation. Since bridging means 37 comprises electrically insulative material, current flow between opposing cooperating retaining means 30 through bridging means 37 is prevented.

During operation, nuts 36 are predeterminedly tightened, thereby placing bridging means 37 under a predetermined amount of tension and ultimately urging channels 15 and 17 into compressive engagement with core 22 for inhibiting vibration of laminations 20. Of course, only one nut 36 may be used, if desired, with the other retaining means 30 fixedly secured to restraining means 27.

Other tensioning means 40 disposed in windows 16 and 18 may be similarly configured and function analogously to tensioning means 40 described above.

Referring to Fig. 4, another embodiment of tensioning means 40 in accordance with the present invention is shown. Tensioning means 40 comprises spindle means 54, such as a cylindrical member, which may be fixedly or removeably coupled to clamping channel 15 as desired, and a turnbuckle 50 having a T-bolt 52 threadably secured to one end thereof with the other end of turnbuckle 50 threadably secured to a threaded shank 58 which is in turn fixedly secured to or integral with restraining means 56, such as a block or a flange. Restraining means 56 may be fixedly or removeably coupled to clamping channel 17 as desired. Spindle means 54 includes a groove or channel 55 disposed between the axial ends thereof and cut into the periphery thereof. Groove 55 is preferably annular in cross-section so as not to include any sharp edges. Tensioning means 40 further include bridging means 37, which include an electrically insulative material, and may be fabricated as hereinbefore described, secured to T-bolt 52 at one end thereof and disposed in groove 55 of spindle means 54.

In operation, turnbuckle 50 is tightened to apply a predetermined tension to bridging means 37, which in turn urges clamping channels 15 and 17 to compressively engage laminations 20 of core 22 as hereinbefore described.

Thus has been illustrated and described a clamping device for adequately clamping the laminations of a core of a transformer without entirely encircling the mutual flux path with electrically conductive components, wherein the device is able to withstand long term, heavy cyclic thermal loads without adversely affecting the device. Further shown and described is a clamping device which increases the electrical insulative path length over prior devices while removing electrically conductive objects from between the coils of the transformer.

While only certain preferred features of the invention have been shown by way of illustration, many modifications and changes will occur to those skilled in the art. It is to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

Claims

1. An electric transformer comprising:

a pair of spaced apart legs, each of the legs having a first and a second end;

a first yoke connected to the respective first ends of the pair of legs;

a second yoke connected to the respective second ends of the pair of legs, wherein the pair of legs and the first and second yoke are fabricated from a plurality of laminations, and whereby a window is defined between the pair of legs and the first and second yokes;

first clamping means for straddling the first yoke; and

first tensioning means coupled to said first clamping means for urging said first clamping means into compressive engagement with the first yoke;

wherein the first tensioning means include first electrically insulative bridging means coupled to the first clamping means, such that the first clamping means compressively engages the first yoke when the first bridging means is subjected to a predetermined amount of tension.

2. The transformer as in claim 1, further comprising:

second clamping means for straddling the second yoke; and

second tensioning means coupled to said second clamping means for urging said second clamping means into compressive engagement with the second yoke;

wherein the second tensioning means include second electrically insulative bridging means coupled to the second clamping means such that the second clamping means compressively engages the second yoke when the second bridging means is subjected to a predetermined amount of tension.

3. The transformer as in claim 1, further including retaining means coupled to said first bridging means and the first clamping means, said retaining means for supplying the predetermined amount of tension to said first bridging means.

4. The transformer as in claim 3, wherein said first tensioning means further include first restraining means fixedly coupled to said first clamping means, said first restraining means for coupling the retaining means to the first clamping means.

5. The transformer as in claim 3, wherein said first tensioning means further include first restraining means removeably coupled to said first clamping means, said first restraining means for coupling the retaining means to the first clamping means.

6. The transformer as in claim 4, wherein said first restraining means is integral said first clamping means.

7. The transformer as in claim 1, wherein said first tensioning means is disposed at least in part in the window.

8. The transformer as in claim 2, wherein said second tensioning means is disposed at least in part in the window.

9. The transformer as in claim 1, wherein the first bridging means comprises an aromatic polyamide.

10. The transformer as in claim 9, wherein the aromatic polyamide is fabricated in the form of a strand.

11. The transformer as in claim 9, wherein the first bridging means comprises a plurality of strands of an aromatic polyamide.

12. The transformer as in claim 10, wherein the strand is interlaced between predetermined portions of said first clamping means to form a first and second arm each including a plurality of portions of the strand.

13. The transformer as in claim 12, wherein the first and second arm is impregnated with a resin.

14. The transformer as in claim 13, wherein the resin include an epoxy.

15. The transformer as in claim 11, wherein the plurality of strands is impregnated with a resin.

16. The transformer as in claim 15, wherein the resin includes an epoxy.

17. The transformer as in claim 3, wherein the retaining means includes a turnbuckle.

18. The transformer as in claim 3, wherein the retaining means include a bolt and a nut.

19. The transformer as in claim 1, wherein the first bridging means comprises a material having a tensile strength of at least about 90,000 psi.

20. The transformer as in claim 19, wherein the material has good dimensional stability.

21. Tensioning means as in claim 20, wherein said electrically insulative material is fabricated in a strand.

22. Tensioning means as in claim 21, wherein said bridging means are coupled to a first and a second portion of said clamping means and further wherein said strand of said first material is disposed in a plurality of passes between said first and second portion of said clamping means.

23. Tensioning means as in claim 22, wherein the plurality of passes of said strand form a first and second arm and the first and second arm of said bridging means is impregnated with a resin.

24. Tensioning means as in claim 23, wherein said resin includes an epoxy.

25. Tensioning means as in claim 21, wherein said electrically insulative material includes an aromatic polyamide

26. In an electric transformer having a core fabricated from a plurality of laminations; tensioning means for compressing the laminations, comprising:

clamping means for straddling the core; and

bridging means coupled to said clamping means for urging said clamping means into compressive engagement with the core when said bridging means is subjected to a predetermined amount of tension, wherein said bridging means includes an electrically insulative material.

27. Tensioning means as in claim 26, further comprising retaining means coupled to said bridging means for applying the predetermined amount of tension.

28. Tensioning means as in claim 27, wherein said retaining means includes a turnbuckle.

29. Tensioning means as in claim 27, wherein said retaining means includes a bolt and a nut.

30. Tensioning means as in claim 27, wherein said electrically insulative material includes an aromatic polyamide.

31. Tensioning means as in claim 26, wherein the bridging means comprises a material having a tensile strength of at least about 90,000 psi.

32. Tensioning means as in claim 31, wherein the material has good dimensional stability.

33. Tensioning means as in claim 27, further including restraining means fixedly coupled to said clamping means, said restraining means for securing said retaining means to said clamping means.

34. Tensioning means as in claim 27, further including restraining means removeably coupled to said clamping means, said restraining means for securing said retaining means to said clamping means.

35. Tensioning means as in claim 33, wherein said restraining means is integral said clamping means.

36. Tensioning means as in claim 27, wherein said electrically insulative material includes an aromatic polyamide.

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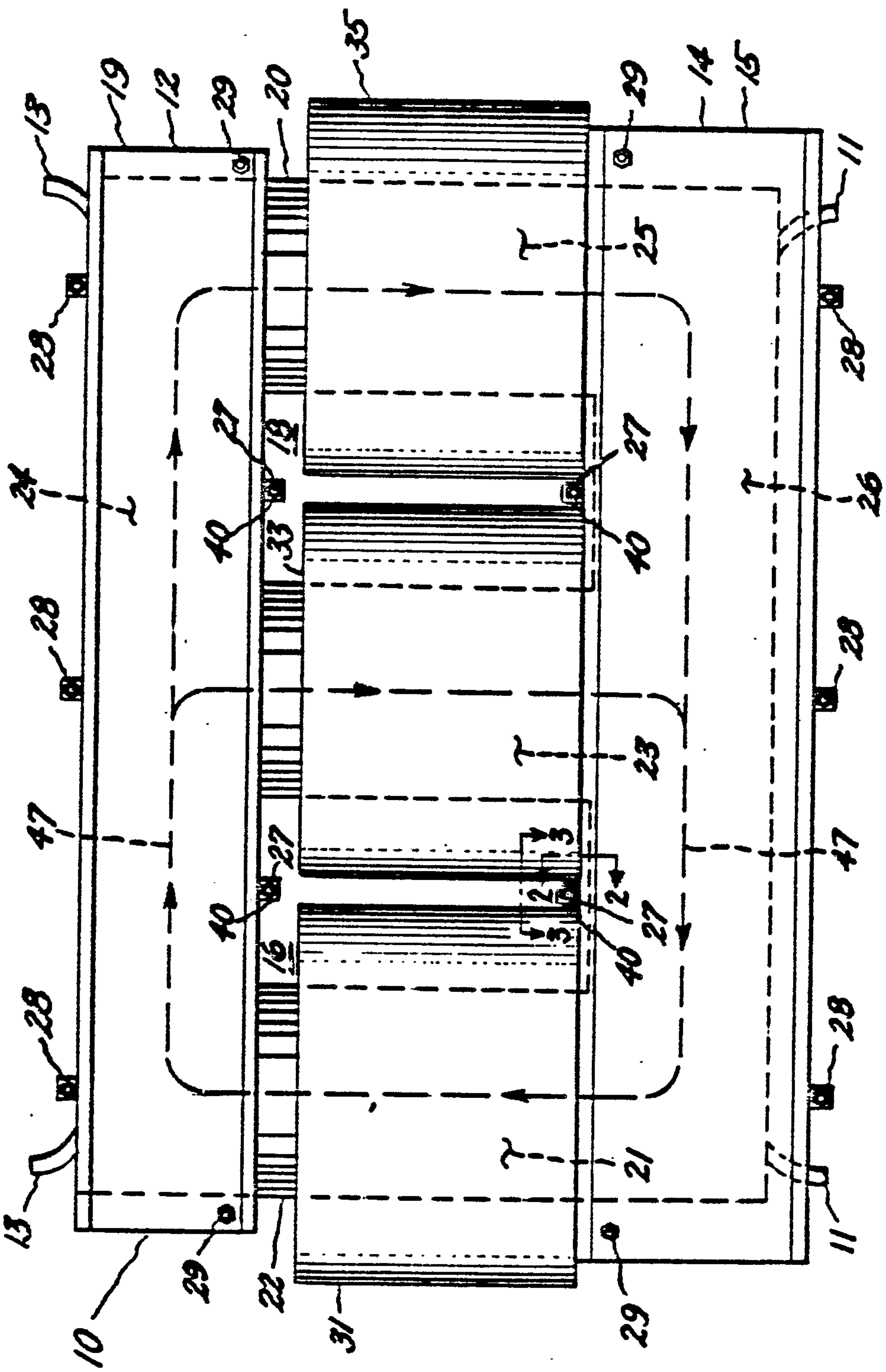

Fig.1

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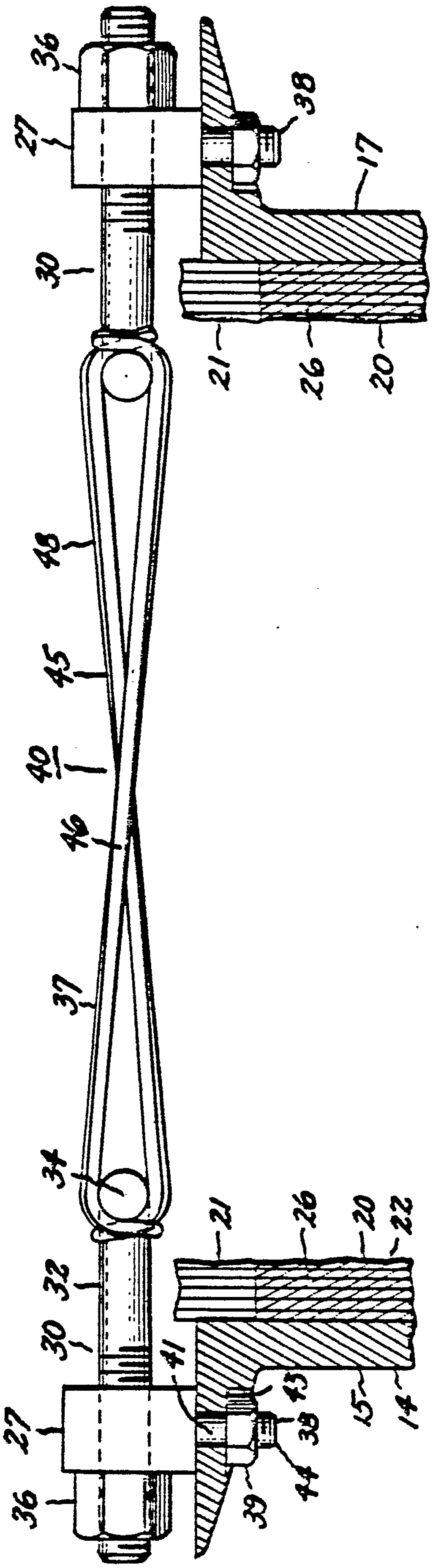

Fig. 2

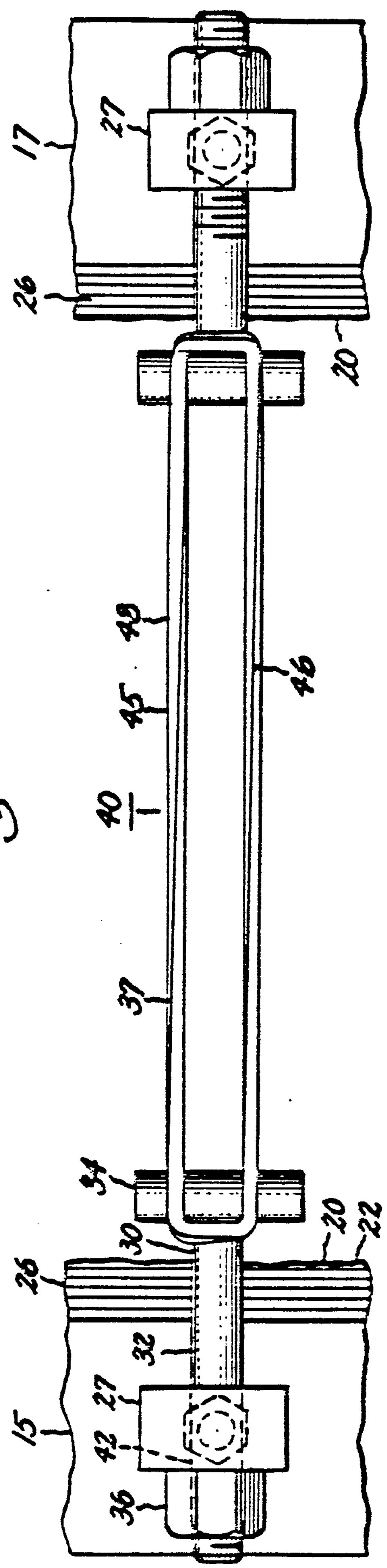

Fig. 3

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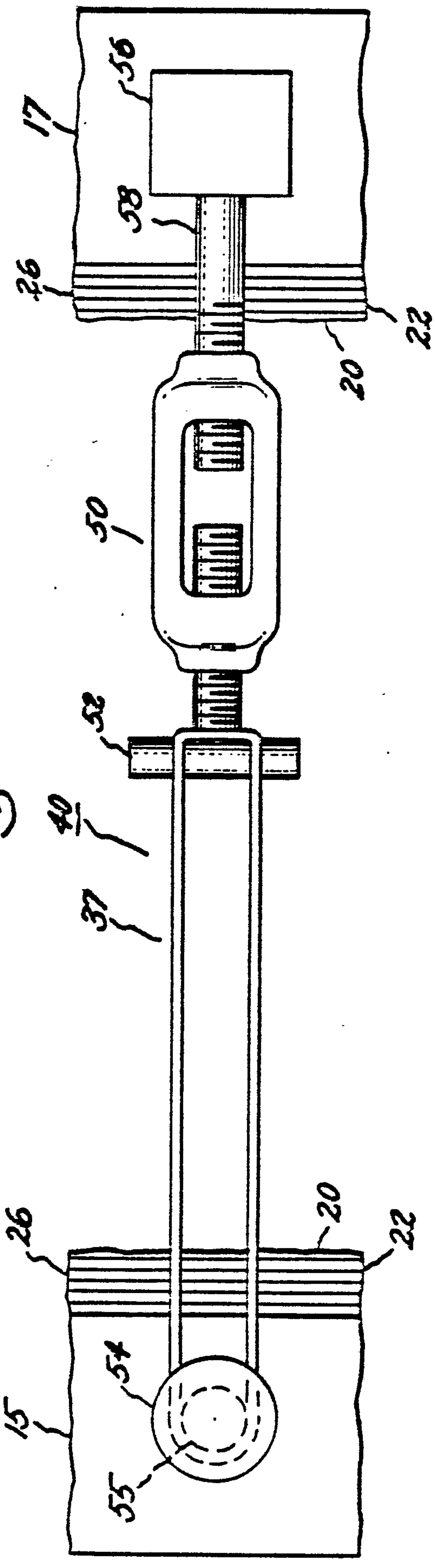

Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 87 10 4861

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.4)
A	DE-A-2 339 972 (BROWN, BOVERI) * Page 8; page 9, first paragraph * ---	1,2,7,8,26	H 01 F 27/26
A	DE-B-1 189 195 (VEB TRANSFORMATOREN- UND RÖNTGEN-WERK) * Column 3; column 4, lines 1-35 * ---	1-6,12,22,26,27	
A	GB-A-1 043 564 (LICENTIA) * Page 3, lines 8-17 * ---	9-16	
A	NL-A-7 102 086 (SMIT NIJMEGEN) * Figure 2 * ---	17	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US-A-3 082 390 (CUTLER-HAMMER) * Figure 6 * ---	18	H 01 F 27/00
A	GB-A- 566 642 (METROPOLITAN-VICKERS ELECTRICAL CO.) ---		
A	DE-B-1 233 484 (ELIN-UNION) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07-08-1987	VANHULLE R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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