Oct. 31, 1961 J. E. L. ROBINSON 3,007,124

LAMINATED MAGNETIC CORES FOR STATIC ELECTRICAL APPARATUS

Filed March 17, 1958 2 Sheets-Sheet 1

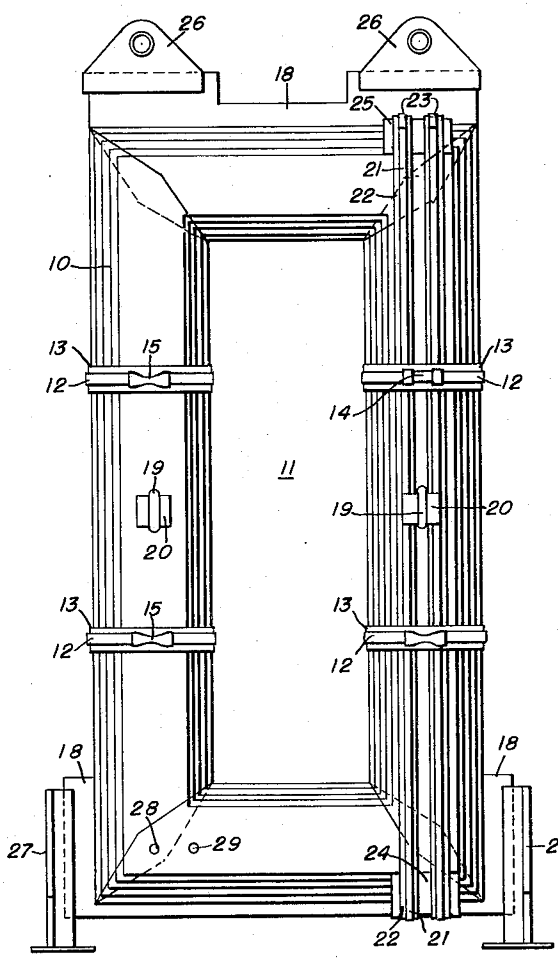

FIG. 1

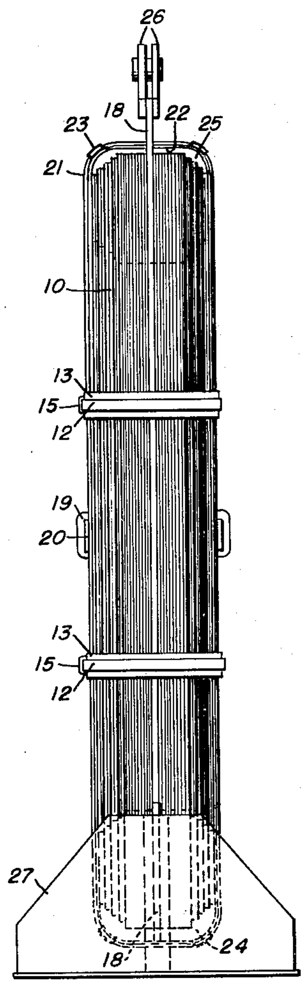

FIG. 2

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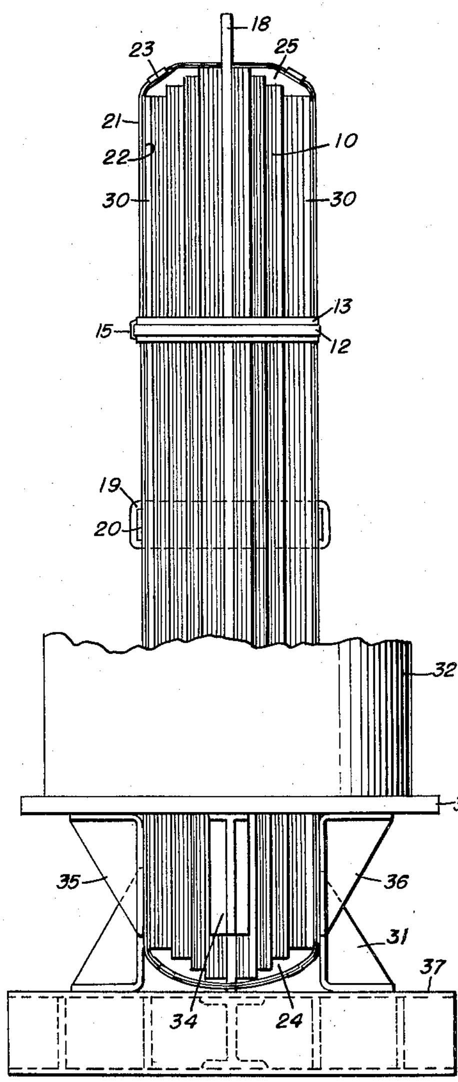

FIG. 3

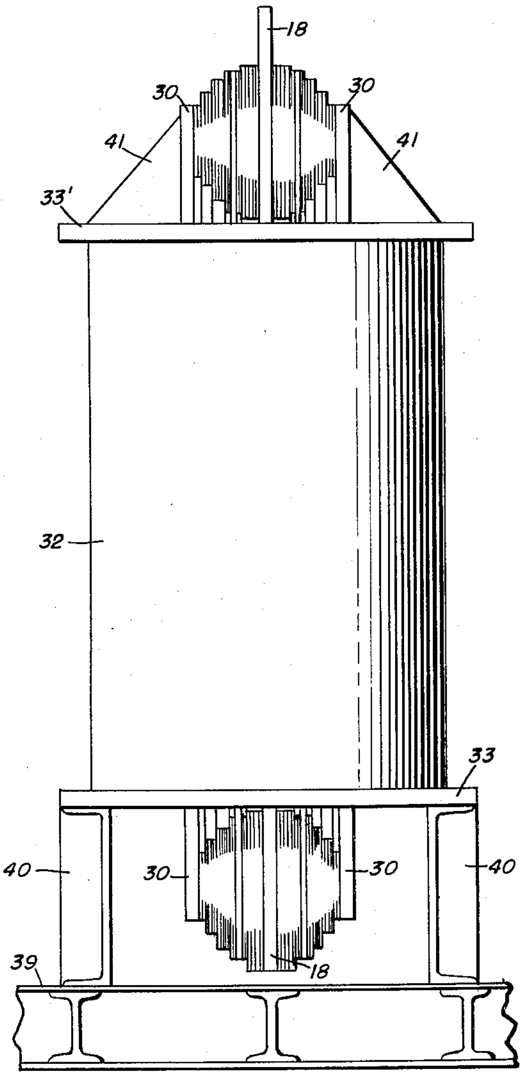

FIG. 4

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LAMINATED MAGNETIC CORES FOR STATIC ELECTRICAL APPARATUS

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This invention relates to laminated magnetic core structures for static electrical apparatus.

Such core structures having vertical legs and horizontal yokes are normally supported from the bottom or from the top or from the bottom and the top by supports which consist of clamps or brackets fitted to the top and bottom yokes respectively and which may be interconnected by means of tie or stay bars for added strength these being disposed either inside or outside the electrical winding. The electrical windings are normally supported by the clamps, and are usually restrained from movement by similar supports or clamps fastened rigidly to the core. In some cases the tie bars or core limbs impose an axial compressive stress on the windings.

The laminated core limbs themselves are normally held together by means of adhesives between the laminations, or organic or synthetic tapes wrapped around the limbs, or by means of a series of bolts with, especially in the larger cores, plates to distribute the force over a reasonably large area. The number and size of the bolts increases as the size and weight of the core increases and they are fitted through holes punched in the laminations. While such holes have a relatively small effect on the magnetic characteristics of a core constructed from laminations of hot-rolled steel which has sensibly omnidirectional magnetic properties, their presence nevertheless affects its properties detrimentally.

In a core constructed from laminations of grain-oriented steel the bolt holes become of greater importance as they cause in their vicinity a considerable deviation of the flux from the optimum magnetic path parallel to the direction of rolling of the steel which results in increased losses and magnetising current.

Losses may also occur at the corners of cores, which losses may be reduced by making the joint with some form of mitring or offsetting which ensures that the flux is kept substantially parallel to the optimum direction of magnetisation. In such constructions the amount of overlap between leg and yoke laminations is small and there is a resultant lack of rigidity.

Another disadvantage of known constructions is that vibrations of the laminations due to magnetostriction generate noise when the transformer is in operation.

An object of the present invention is to provide a laminated magnetic core structure having vertical legs in which the number and size of the holes through the laminations for supporting purposes are reduced to a minimum without reducing the rigidity of the core structure.

Another object is to provide such a core structure in which the clamping pressure on the laminations is more evenly distributed than with bolted structures as hitherto known.

A further object is to provide such a core structure in which the noise caused by vibration in operation of the laminations due to magnetostriction is considerably reduced.

In accordance with the invention, a laminated magnetic core structure for static electrical apparatus includes one or more vertical leg members and associated horizontal yoke members, the said members being constructed from laminations of magnetic material, wherein the laminations of each leg member are held together and to a non-magnetic supporting framework by at least one non-short-circuiting band around said leg member.

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The laminations of the leg member may be supported from said framework at substantially the nodal points of lengthwise magnetostrictive vibration of those laminations, and may elsewhere be only lightly clamped to the framework by said band or bands, the laminations of the yoke members being supported by the leg members.

Said band may be of metal, with a transverse portion of insulation to prevent the band from acting as a short-circuited winding, the band being insulated from the laminations of the core structure.

In the accompanying drawings,

FIGURE 1 shows in elevation a core structure according to the invention,

FIGURE 2 is an end view of the core shown in FIGURE 1, and

FIGURES 3 and 4 are end views of a transformer having modified forms of core structure according to the invention.

In carrying out the invention in accordance with one form by way of example, see FIGURES 1 and 2, a magnetic core structure for a transformer is built from laminations **10** of magnetic material to form two horizontal yokes and two vertical legs surrounding a rectangular window **11**.

The laminations of the leg members are held together by four metal bands **12** perpendicular to the leg axes and insulated from the laminations by layers **13** of thin, tough, but flexible insulating material. Each of the bands has interposed a transverse insulating section, one of which is shown at **14**, to prevent the band from acting as a short-circuited winding; in the other three bands the insulating section is out of view. The two ends of each band are joined by a crimped sleeve, as shown for three of the bands at **15**, the band being placed in tension by the use of a suitable tensioning device; in the fourth band the crimped sleeve is out of view.

The core structure includes a non-magnetic electrically resistive steel framework plate **18**, made for example from the material known by the registered trademark "Nomag." This material, as manufactured and sold by Ferranti, Limited, of England, is a cast iron alloy of the austenitic type having a soft grey iron base to which has been added sufficient nickel and manganese to render the alloy non-magnetic, and having an electrical resistance of the order of 150 micro-ohms per centimeter cube. This plate is of appreciable thickness compared with the laminations but is of the same shape as the core as a whole and is inserted among the laminations as shown in FIGURES 1 and 2. The laminations of the leg portions are supported from the frame by insulated keys **19** suitably attached to the frame and positioned approximately to correspond with the centre of he leg laminations. Narrow slots punched in the laminations allow the keys to pass through them, the laminations being retained on the keys by wedges **20** extending through slots in the keys.

The laminations are also held to the frame by the bands **12**, which pass around the assembly of the leg laminations and the corresponding parts of the frame. The weight of the laminations is supported almost wholly by the keys **19**; the bands **12** and wedges **20** mainly serve to hold the laminations and frame firmly together, and therefore only lightly clamp the laminations to the frame. By "lightly" clamped, as used throughout this specification, is meant that the bands are tight enough to hold the laminations firmly to the framework but not tightly enough to restrict magnetostrictive vibration of the laminations relative to the frame in the direction of the length of the leg laminations.

The laminations of the bottom yoke member are supported at each end by the leg members. Two different forms of such support are shown in FIGURE 1. The right-hand end of the yoke, as depicted, is carried by a pair of vertical straps 21 encircling the right-hand leg lengthwise. Each strap is insulated from the lamination by sheet material 22 (which may be the same as the material 13) and is provided with a suitable insulating section 23 (FIG. 2); section 23 is inserted to prevent the straps acting as short-circuited windings, since it found in practice that an E.M.F. is induced in the straps. Where the straps pass under the bottom yoke laminations, suitably shaped wooden blocks 24 are interposed between the laminations and the straps so that the weight of each lamination is taken by the straps. Similar blocks 25 are provided where the straps pass over the top yoke laminations. Hence the weight of the bottom yoke is carried by the top yoke which in turn is supported by the legs, the weight of substantially the whole magnetic core being thus carried by keys 19 from the framework. The use of such a framework allows eyes 26 to be provided to enable the whole assembly of the transformer to be lifted.

An alternative method of supporting the bottom yoke member from the leg members, depicted in FIGURE 1 in respect of the left-hand end of the yoke, will be described later.

Feet 27 (which may be detachable) are provided to allow the framework to stand.

Referring to FIG. 3, the framework shown includes additional stiffening plates 30 located between the clamping bands 12 and the outermost laminations. These additional plates are provided with slots to correspond with the keys 19 and are secured to the central plate 18 of the framework by way of the keys 19 and to each other by means of a pedestal 37 and girder members 31.

The electrical windings 32, shown cut away, are supported on each leg between two horizontal annular rings, of which only the lower, 33, is shown, each of which rings 33 is supported from the framework 18 and 30 at four points of attachment, of which three 34, 35, and 36 are shown; two of these are on the central frame 18 (only one, 34, being shown in the figure) and two of which, 35 and 36, are carried on the stiffening plates 30.

The framework 18, 30, carries the weight of the magnetic core and that of the winding 32 and stands on pedestal 37, but may, alternatively, be suspended from the top.

FIGURE 4 shows an arrangement in which the lower ends of the windings 32 rest on the ground or tank bottom 39 on suitable girder supports 40, the framework 18, 30, being supported by the upper ends of the windings 32 by way of the upper annular ring 33^1 and the members 41, and the magnetic core being carried in turn by the framework through keys at the central points of the legs. In this arrangement the weight of the core structure puts the windings in compression. This construction possesses the advantages of allowing any shrinkage in the winding to be taken up automatically, and of causing any residual vibrations in the framework and core assembly to be damped out by the winding, which in this respect acts as a spring.

In an alternative method of supporting the bottom yoke member (see FIGURE 1) thin insulated rods or pins are inserted through the laminations of each leg and bottom yoke where they overlap at a joint as shown for example at 28, and the laminations of the bottom yoke member are pinned together as shown at 29. Both these pins pass through the framework plate 18 by holes large enough to clear the pins so that none of the weight of the yoke laminations is taken by the yoke portion of the frame. As each pin 28 passes through the laminations where they are closely interleaved the pin is subjected to only a very slight bending moment; furthermore, the pin is not in appreciable tension since it does not serve to clamp the laminations together, which function is performed by the bands 12. Hence the pins need only be of very small diameter, and accordingly the holes punched for them in the laminations are of negligible size (compared with the bolt holes through the laminations of prior constructions) and so do not interfere appreciably with the magnetic flux path. It is not necessary to provide pins for the joints between the top yoke and the legs.

Core structures in accordance with the invention show considerably reduced iron losses and require less magnetising current than those previously known. This is because the method of support employed obviates the need for holes through the laminations other than the two slots through which pass keys 19 and, where the bottom yoke is supported by pins rather than straps, the negligibly small holes for such pins, whilst providing a core structure of at least the usual rigidity and with a more evenly distributed clamping pressure. Furthermore, the fact that the laminations of the leg members are supported from the frame at substantially only their centres, which are the nodal points of lengthwise magnetostrictive vibration of those laminations, the bands being not too tight to prevent such vibration relative to the framework, results in a considerable reduction in the noise due to such vibration. The fact that both yoke members are supported only by the leg members without themselves being secured direct to the frame also serves to free the leg members for such lengthwise vibration, with consequent reduction of noise.

The invention is applicable to any arrangement or construction of the magnetic laminations and for any kind of single-phase or polyphase systems. In some polyphase designs of transformer the core includes one or more vertical members which act as flux paths without actually carrying windings. It will of course be understood that the expression "vertical leg members" as used throughout this specification includes such members, which require to be attached to the frame by the combination of keys at the nodal points and bands elsewhere exactly as in the case of the embodiment first described.

In the case of cores having the plane of the laminations at right angles to the plane of the window or windows there is a marked increase in rigidity because the stiffness of the framework members complements that of the laminations.

For core constructions of the smaller size the supporting bands may take the form of a length of insulating tape, which may be wound in spiral form. For such transformers it may not be necessary to supply keys to take the weight of the stampings, which may be supported from the framework solely by the bands, whether of metal or of insulating material.

What is claimed is:

1. A laminated magnetic core structure for static electrical apparatus comprising a supporting framework, vertical leg members and associated horizontal yoke members, said members being constructed from laminations of magnetic material, means for supporting the laminations of each leg member from said framework at substantially the nodal points of lengthwise magnetostrictive vibration of those laminations, means for supporting the laminations of the yoke members from the leg members, and non-short-circuiting bands lightly clamping the laminations of the leg members together and to said framework at points other than said nodal points.

2. A core structure as claimed in claim 1 wherein each of said bands is of metal with a transverse portion of insulation to prevent the band from acting as a short-circuited winding, the band being insulated from the laminations of the core structure.

3. A core structure as claimed in claim 1 wherein the laminations in a bottom yoke member are supported by at least one non-short-circuiting strap from a top yoke member.

4. A core structure as claimed in claim 1 wherein the laminations in a bottom yoke member are supported by at least one rod or pin inserted through the laminations

of that yoke member and a leg member where they overlap at a joint.

5. A core structure as claimed in claim 1 wherein said framework is supported by the upper end of a core winding or windings the lower end or ends of which are supported from the ground, whereby the winding structure is subjected to compression by the weight of the core structure.

6. A core structure as claimed in claim 1 wherein the material of said framework is substantially non-magnetic.

7. A core structure as claimed in claim 1 wherein the material of said framework is electrically resistive.

8. A laminated core structure for static electrical apparatus comprising a substantially rectangular assembly of horizontally spaced vertical leg members and upper and lower horizontal yoke members, each of which members is formed of laminations of magnetic material, a supporting framework of substantially the same shape as said assembly of leg and yoke members, at least one non-short-circuiting band surrounding each of said leg members and the corresponding portion of said framework and holding the laminations of said leg member together and to said framework, means for supporting the laminations of each of said leg members from said framework at substantially the nodal points of lengthwise magnetostrictive vibration of said laminations, and means for supporting the laminations of said yoke members from said leg members.

9. A core structure as claimed in claim 8 wherein the means for supporting the laminations of said leg members includes insulated keys fixed to said framework and passing through openings in said laminations.

10. A core structure as claimed in claim 8 wherein the ends of the laminations of said lower yoke member overlap the lower ends of the laminations of said leg members, and the means for supporting the laminations of said lower yoke members consists of pins passing through the overlapping portions of said laminations.

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