

[72]	Inventors	Saul Bennon; William D. Albright, Muncie, Ind.
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[73]	Assignee	Westinghouse Electric Corporation Pittsburgh, Pa.

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Primary Examiner—Thomas J. Kozma

Attorneys—A. T. Stratton, F. E. Browder and D. R. Lackey

**[54] ELECTRICAL INDUCTIVE APPARATUS HAVING
MAGNETIC SHIELDING LOOPS
5 Claims, 3 Drawing Figs.**

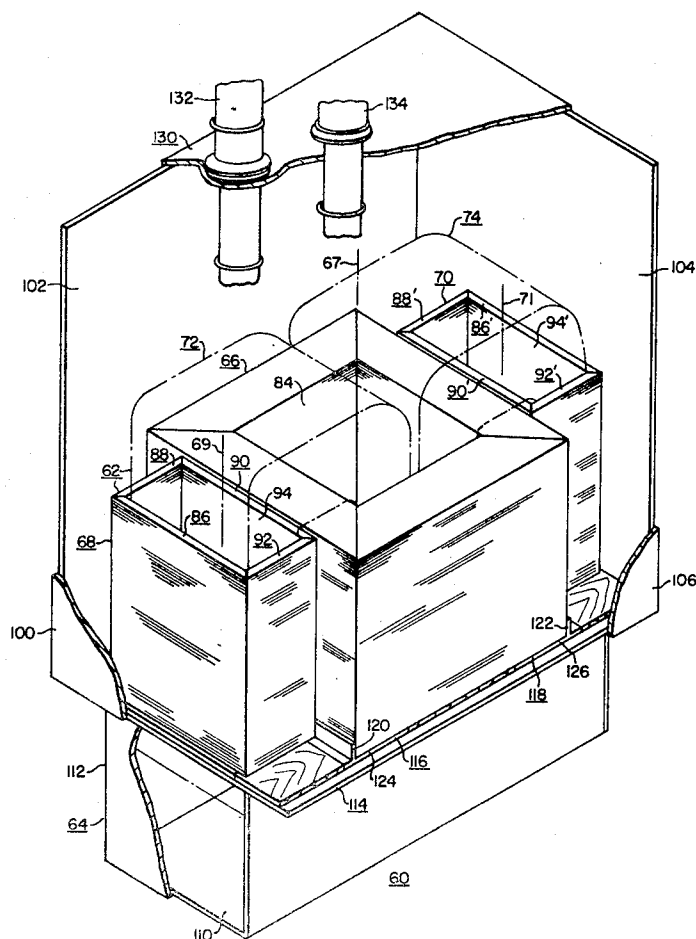
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[51]	Int. Cl.....	H01f 15/04, H01f 27/24
[50]	Field of Search.....	336/84, 212, 214, 215, 92, 90

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ABSTRACT: Single-phase electrical inductive apparatus including a magnetic core structure having a main core loop and first and second shielding loops, with the first and second shielding loops being disposed on opposite sides of the main core loop. The main core loop is formed of stacked magnetic laminations having a width dimension A , and the first and second shielding loops are formed of stacked magnetic laminations having a width dimension less than $A/3$. Electrical winding means are disposed to encircle the main core loop and first shielding loop, and the main core loop and the second shielding loop. The magnetic core structures and winding means are disposed in a tank having bottom and sidewall portions, with the magnetic core structure being oriented in the tank to magnetically shield the sidewall portions of the tank from the electrical winding means.



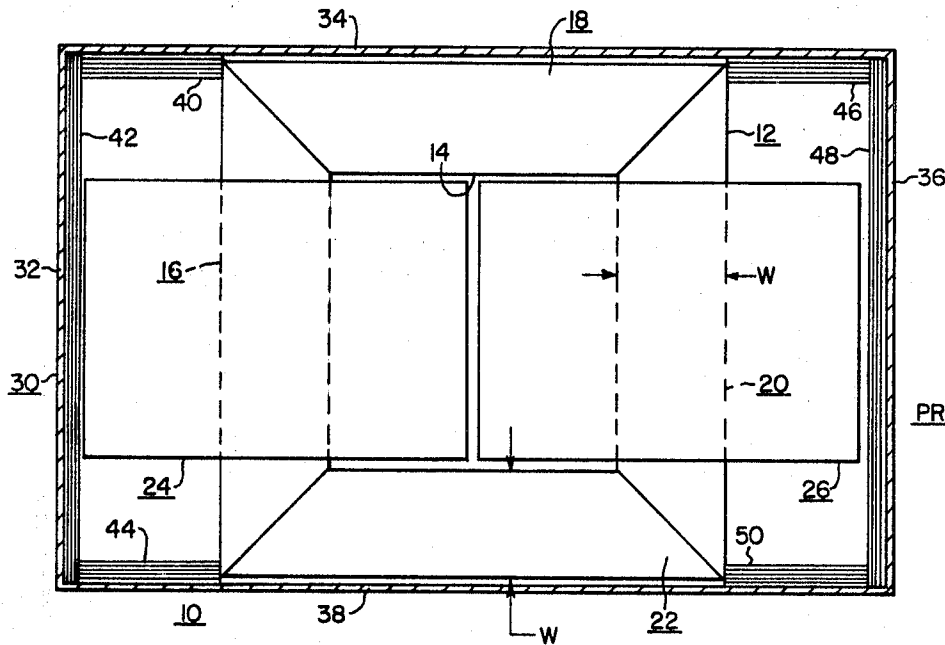


FIG. 1.
PRIOR ART

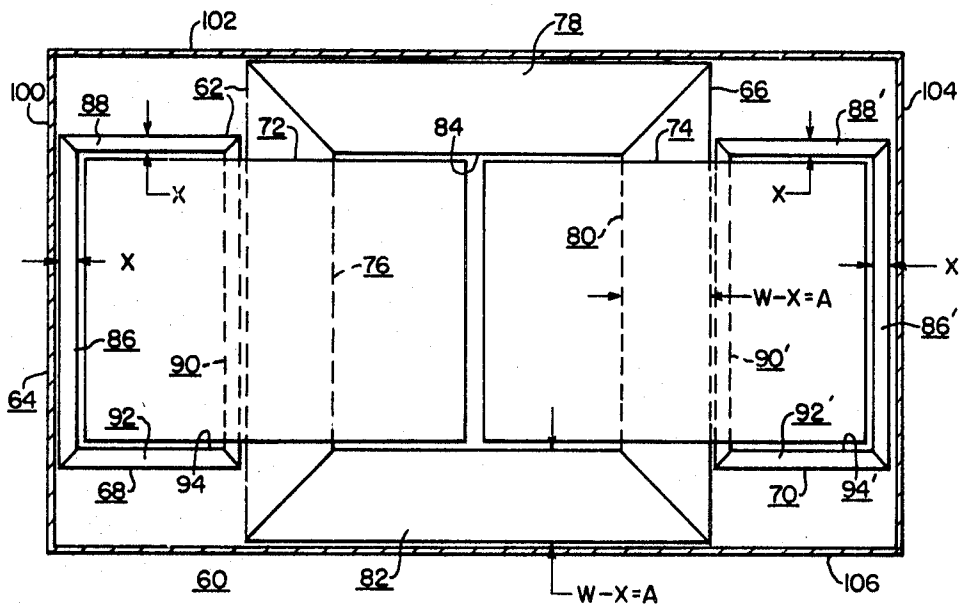
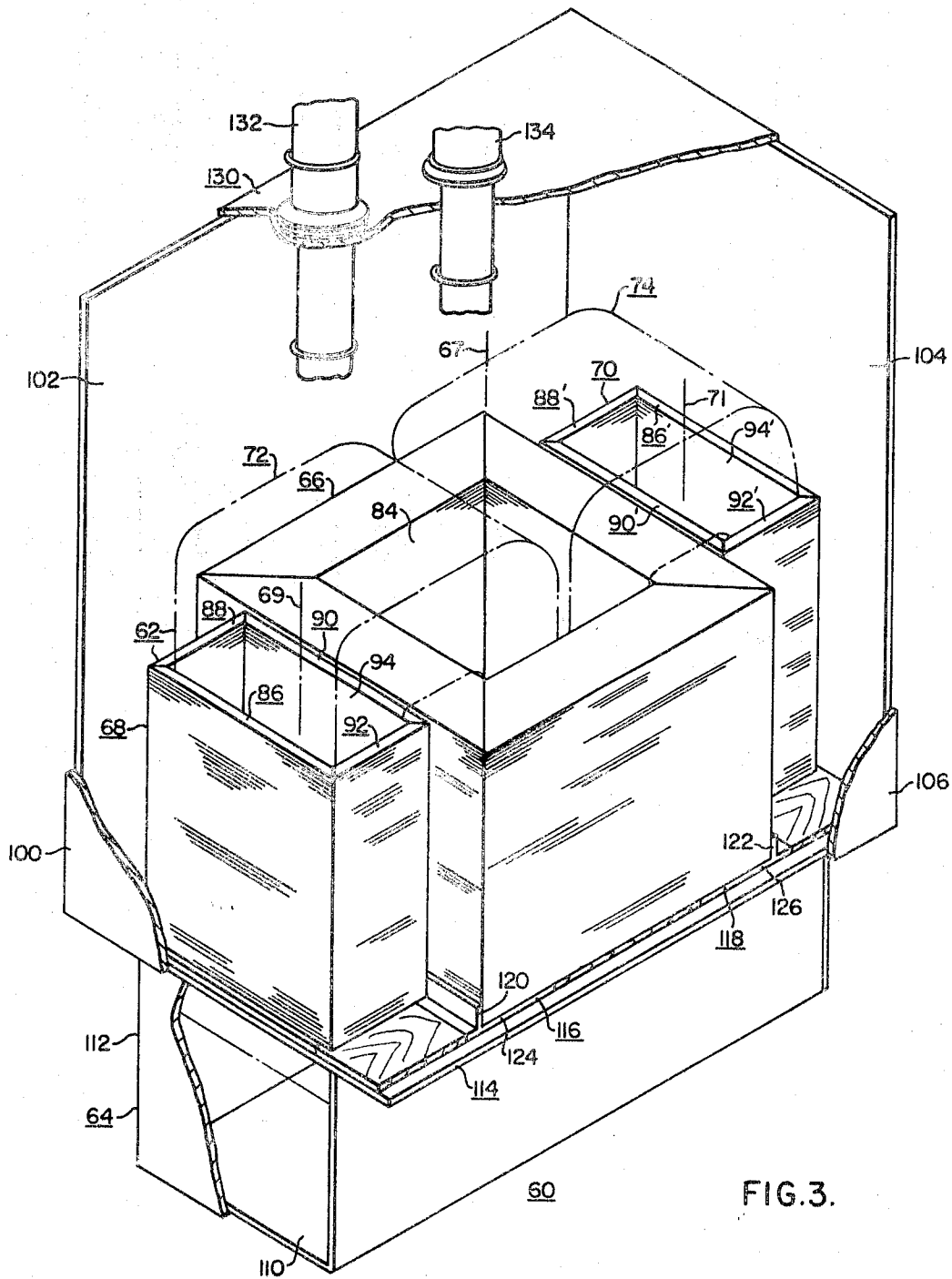


FIG. 2.

WITNESSES

Theodore F. Wrobel
James H. Young

INVENTORS
Saul Bennon and
William D. Albright
BY *Donald R. Lackey*
ATTORNEY



ELECTRICAL INDUCTIVE APPARATUS HAVING MAGNETIC SHIELDING LOOPS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to single-phase electrical inductive apparatus, such as power transformers and reactors.

2. Description of the Prior Art

Single-phase electrical inductive apparatus of the shell-form type, such as transformers, are conventionally constructed with two core loops placed side-by-side, with the windings encircling the adjacent portions of the two core loops. A more effective utilization of core material may be made in some applications by using two winding assemblies disposed on a single core loop, but when this construction is applied to high KVA ratings, severe heating of the tank walls is experienced adjacent the portions of the windings or coils not magnetically shielded by the magnetic core. Thus, additional magnetic shields are required between portions of the windings and tank walls, adding to the total weight of magnetic material required, and since the magnetic shields are extremely costly to assemble and fix to the tank walls, they virtually offset the advantages of using the single core loop. Further, shields fixed to the tank walls are not desirable from the standpoint of maintaining control of the flux. It is not really known where the flux is going, as the reluctance of the path they provide is not as low as desired. Thus, some flux may still go through the tank walls, resulting in losses therein.

SUMMARY OF THE INVENTION

Briefly, the present invention is new and improved single-phase electrical inductive apparatus which utilizes a single main core loop with two separate winding assemblies disposed on different leg portions of the core loop. Tank wall heating is prevented by first and second discrete magnetic low reluctance shielding loops which separate the winding assemblies from the tank walls, and which additionally encircle a winding assembly. Thus, the magnetic shielding loops, in addition to shielding the tank walls, carry useful magnetic flux, with a good control of where the flux is going, enabling the width of the laminations in the main core loop to be reduced, compared with similarly rated electrical inductive apparatus where the shielding loops are not linked to the windings in a low reluctance manner. Further, the shielding loops are constructed and assembled similar to a magnetic core, with the main core and shielding loops being supported by T-beams. Thus, the assembly cost is substantially lower than that of similarly rated apparatus which requires shielding bundles to be attached to the tank sidewalls.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG 1 is a plan view of single-phase electrical inductive apparatus constructed according to the teachings of the prior art;

FIG. 2 is a plan view of single-phase electrical inductive apparatus constructed according to the teachings of the invention; and

FIG. 3 is a perspective view of the electrical inductive apparatus shown in FIG. 2.

DESCRIPTION OF PREFERRED EMBODIMENTS

Electrical inductive apparatus of the shell-form type conventionally utilizes a magnetic core structure having two spaced vertical openings therein for each electrical phase. The electrical windings of a phase encircle the leg formed by the two spaced vertical openings. Thus, the magnetic core structure completely surrounds the winding assemblies, shielding the tank sidewall portions from stray magnetic flux. The top

and bottom portions of the tank are not as closely spaced to the exposed portions of the winding, and hence are not usually subjected to excessive eddy current heating.

Certain economies may sometimes be realized in single-phase electrical inductive apparatus, by using a single core loop having a single vertical opening, with two separate winding assemblies disposed on opposite leg portions thereof. The coils of the two winding assemblies are interconnected in series, or in parallel, as desired. With this arrangement, however, two of the tank sidewalls are no longer shielded from the winding assemblies, resulting in severe eddy current heating of these wall portions when the MVA rating of the apparatus is increased above about 100. The tank sidewalls exposed to the stray magnetic field from the windings may be shielded by attaching bundles of magnetic laminations to the tank walls, but this arrangement is time consuming and costly, in addition to providing poor control of flux, offsetting the advantages of changing from the two core loops to a single core loop.

Fig. 1 is a plan view of single-phase electrical inductive apparatus 10 constructed according to the teachings of the prior art, such as a transformer or reactor, including magnetic core 12 which is a single loop having four sides or portions 16, 18, 20 and 22, defining a single vertical window or opening 14. Magnetic core 12 is constructed of a plurality of superposed or stacked layers of metallic, magnetic lamination.

Inductive apparatus 10 includes first and second winding assemblies 24 and 26, respectively, which encircle opposite sides or leg portions of the magnetic core 12, such as portions 16 and 20, respectively. If conventional shell-form practice is used, the coils of winding assemblies 24 and 26 will be axially spaced, but they may be concentrically disposed, if desired. If inductive apparatus 10 is a transformer, the high voltage coils of the two winding assemblies are connected in series or in parallel, as are the low voltage coils, as required by the specific application.

The magnetic core structure 12 and assembled winding assemblies 24 and 26 are disposed in a metallic tank or enclosure 30 having sidewall portions 32, 34, 36 and 38. The tank 30 closely conforms to the magnetic core-winding assembly in order to reduce the size, weight and cost of the apparatus. However, it will be noted from FIG. 1 that sidewall portions 32 and 36 are not shielded from the winding assemblies 24 and 26, such as they would be in conventional shell-form construction having two core loops, thus requiring that the exposed tank walls be magnetically shielded, at least in the higher MVA ratings. Bundles or stacks 40, 42 and 44 of magnetic laminations are disposed about and fixed to the tank walls, such as by welding, adjacent winding assembly 24, and similar bundles or stacks 46, 48 and 50 of magnetic laminations are disposed about and fixed to the tank walls adjacent the winding assembly 26. These shielding bundles add additional weight and cost to the apparatus. It requires considerable assembly labor and time to assemble and consolidate the laminations into bundles, and then fix the bundles to the tank walls, and their only useful function is to prevent excessive heating of the tank walls. Further, they are undesirable from the designer's viewpoint, as control of the flux is not as predictable. Therefore, in single-phase electrical inductive apparatus using shell-form, or quasi shell-form construction, it is a close question whether the construction of FIG. 1 has any advantages over using two core loops, which inherently shields the tank walls from the windings.

FIGS. 2 and 3 are plan and perspective views, respectively, of single-phase electrical inductive apparatus 60 constructed according to the teachings of the invention, which construction enables the two separate winding assembly approach to be economically used. The disclosed arrangement utilizes the tank wall shields to also carry useful magnetic flux, i.e., magnetic flux which links the windings with a low reluctance path. Thus, the shields may be constructed and supported by more conventional transformer assembly practice resulting in savings in assembly time and cost. The low reluctance shielding loops also provide better control over the flux, than

separate bundles of laminations attached to the tank walls. With the tank shields carrying useful flux, the cross-sectional area of the four side portions of the main core loop may be substantially reduced, which more than offsets the additional iron required to provide the complete shielding loops. Thus, the advantages of a single core loop with two winding assemblies is preserved, without the problems of excessive tank wall heating, and loss of flux control, even at large power ratings.

More specifically, FIG. 2 is a plan view of single-phase electrical inductive apparatus 60, such as a transformer or reactor, having a magnetic core-winding assembly 62 disposed in a tank or enclosure 64. Magnetic core-winding assembly 62 includes a magnetic core structure having a main core loop 66 and first and second discrete shielding loops 68 and 70, respectively, and first and second winding assemblies 72 and 74, respectively. The main magnetic core loop 66 has a plurality of vertically stacked layers of magnetic laminations, which are assembled to provide a substantially rectangular magnetic core having four side portions 76, 78, 80 and 82, which define a vertical opening or window 84. The winding assemblies 72 and 74 are disposed about portions 76 and 80, respectively, of the magnetic core, and they may be of conventional shell-form construction, i.e., having a plurality of axially spaced coils, or they may be of concentric construction. The high voltage coils of the two winding assemblies are connected in series or in parallel, as are the low voltage coils, as required by the application.

The first and second shielding loops 68 and 70 are of similar construction, each being formed of a plurality of vertically stacked layers of assembled magnetic laminations. Each layer of laminations includes at least four laminations, assembled and stacked to provide four side portions, such as portions 86, 88, 90 and 92 in loop 68, which define a single vertical opening 94. Since shielding loop 70 is of like construction, like reference numerals are used to indicate like components in the loop 70, with the addition of a prime mark. Thus, shielding loops 68 and 70 may be quickly and easily stacked, in a manner similar to the main core 66.

Shielding loops 68 and 70 are placed immediately adjacent opposite sides of the main core loop 66, with the center lines of their openings 94 and 94' being parallel with, and in the same plane as the center line of the opening 84 in the main core loop. The opening 84 in the main core loop is sized to receive both winding assemblies 72 and 74, while openings 94 and 94' are sized to receive winding assemblies 72 and 74, respectively.

It is important that the width of the laminations which make up the shielding loops have a predetermined relationship with the width of the laminations of which the main core loop is formed. The approximate criterion is that the width of the shielding loop laminations should not exceed one-third of the width dimension A of the laminations of the main core loop, and preferably should not exceed $A/4$. The minimum dimension of the shielding loop laminations is a practical one, rather than theoretical, as there is a minimum width below which the laminations would be difficult to handle and stack.

The advantages of the construction shown in FIG. 2, over the prior arrangement of FIG. 1, may be better understood by considering an example. Assuming that the width of the laminations of which the core 12 of FIG. 1 is formed is W , the width of the laminations of which core 66 of FIG. 2 is formed is A , and the width of the laminations of which the shielding loops 68 and 70 are formed is X , for similarly rated electrical inductive apparatus, the width of the laminations of core loop 66 may be reduced compared to the width W of core loop 12, by the dimension X . Thus, $A = W - X$. The shielding arrangement of the prior art example of FIG. 1 provides three sides of a shielding loop, on each side of the main loop. By adding additional iron, complete loops may be formed to link the winding and provide low reluctance paths. The requirement of additional iron to form the low reluctance shielding loops about the windings, is offset by the fact that it allows a substantial reduction to be made in the iron of the main core loop, since

the shielding loops now carry useful flux which links the windings. Not only are the leg portions 76 and 80 reduced with by the dimension X , but the connecting portions 78 and 82 are also reduced by the dimension X . The total iron weight of a transformer constructed according to the teachings of the invention is less than the weight of a similarly rated transformer constructed with shielding bundles attached to the walls. In addition, to this savings in weight and cost, the invention provides better control of the flux, less tank wall heating, and a substantial savings in manufacturing cost, as discrete bundles of shielding laminations are not required, nor is the time consuming operation of fixing them to the tank walls required.

The savings in iron may be illustrated by an example, wherein the magnetic core 12 of FIG. 1 uses 32 inches wide laminations, has an opening about 80 inches square, and an outer dimension about 144 inches square, the core 12 weighs 246,000 and the shields, using 4 inches wide laminations, weigh a total of 24,000 pounds for an overall total of 270,000 pounds of iron. For a similarly rated transformer, the main core 66 of FIG. 2 may be reduced in size, to an outer configuration which is about 132 inches square, and may be reduced to a weight of about 197,000 pounds, using the same stack height as core 12 of FIG. 1. Using 6 inches wide laminations in the shielding loops, the shielding loops would weigh a total of 64,000 pounds, making a total iron weight 261,000 pounds. Thus, a savings of 9,000 pounds of steel is realized.

The orientation of the main and shielding loops in the casing or tank 64, wherein the center line of their openings are perpendicular to the bottom of the casing, completely shields the vertical sidewall portions 100, 102, 104 and 106 of the tank 64 from the windings, thus eliminating tank wall heating as a problem, even at high MVA ratings. This orientation of the core loops is also easy to manufacture, since the vertical stack height of the main core loops is the same. This may be more readily appreciated by examining the perspective view of electrical inductive apparatus 60 shown in FIG. 3, which is partially cut away, wherein the center lines 67, 69 and 71 of the main loop 66 and the shielding loops 68 and 70 are perpendicular to the bottom portion 110 of the tank 64.

More specifically, FIG. 3 illustrates electrical inductive apparatus 60 disposed in tank 64, which may be of a form-fitting style, having a bottom portion 112 sized to receive the lower extensions of the winding assemblies 72 and 74, and an outwardly projecting flanged portion 114 sized to support the outer stacked portions of the main core loop 66 on two opposite sides thereof, and sized to support the outer stacked portions of the first and second shielding loops 68 and 70 on the remaining two sides of the flanged portion 114. Tank 64 then has an upper portion which extends vertically upwardly from the outermost edges of the flanged portion 114. Off-center T-beams 116 and 118 support the winding leg portions of the main core loop and shielding loops. The upwardly extending portions 120 and 122 of the T-beams 116 and 118, respectively, are placed offcenter on their supporting plates 124 and 126, respectively, due to the differences in the widths of the main and shielding loop laminations, and instead of the offcenter T-beam being a detriment, it provides a wedging effect which improves the lateral support for the main core loop.

Tank 64 is filled to a predetermined level with a fluid insulating and cooling fluid, such as mineral oil, with the level being selected to completely immerse the magnetic core-winding assembly 62. Tank 64 is completed by a cover 130, through which the electrical bushings may extend, such as bushing assemblies 132 and 134.

In Summary, there has been disclosed new and improved single-phase electrical inductive apparatus, such as transformers or reactors, which divides the winding portion of the apparatus into first and second sections, and disposes the winding sections on different legs of a single main core loop. Tank wall heating is eliminated by utilizing first and second low reluctance shielding loops which link the first and second winding sections, respectively, providing good flux control

through the low reluctance paths, for a portion of the flux in the main core loop. Thus, the shielding loops carry useful flux linked with the windings, in addition to shielding the walls of the tank. Since the shielding loops carry useful flux, the size of the main core loop may be reduced, to more than offset the additional iron required in the complete shielding loops. The invention also provides the advantage of good flux control, and lower manufacturing cost, compared with similarly rated apparatus of the prior art which utilizes a single core loop and magnetic shielding bundles placed about the exposed tank walls.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings, shall be interpreted as illustrative, and not in a limiting sense.

We claim:

1. Single-phase electrical inductive apparatus, comprising: a magnetic core assembly having a main core loop and first and second shielding loops;
said main core loop having a plurality of superposed layers of metallic laminations, each having a width dimension A, with each of said layers including a plurality of laminations assembled to provide a closed magnetic loop and define a substantially vertical opening therein;
said first and second shielding loops each having a plurality of superposed layers of metallic laminations having a width dimension less than $A/3$, with each layer including a plurality of laminations assembled to provide a closed magnetic loop and define a substantially vertical opening therein,
said first and second shielding loops being disposed adjacent opposite sides of said main core loop, with the axes of the

openings in said first and second shielding loops being parallel with the axis of the main core loop, and in the same plane;

first and second electrical winding means disposed to encircle said main core loop and said first shielding loop, and said main core loop and said second shielding loop, respectively, to provide a magnetic core-winding assembly;

a tank including sidewall and bottom portions;

said magnetic core-winding assembly being disposed in said tank, and oriented with the axes of the openings in the main core loop and the first and second shielding loops perpendicular to the bottom portion of said tank, to dispose the main core loop and first and second shielding loops between said first and second electrical winding means and the sidewall portions of said tank.

2. The electrical inductive apparatus of claim 1 wherein the width of the laminations of the first and second shielding loops is less than $A/4$.

3. The electrical inductive apparatus of claim 1 including first and second T-beams, each having a base and vertical portion, disposed to support and space the stacked laminations of the main core loop and adjacent stacked laminations of the first and second shielding loops.

4. The electrical inductive apparatus of claim 3 wherein the vertical portion of the T-beams which separate the main core loop from a shielding loop is disposed offcenter on the base portion, to accommodate the different width dimensions of the laminations of the main core loop and shielding loops.

5. The transformer of claim 1 wherein the vertical stack height of the first and second shielding loops is the same as the vertical stack height of the main core loop.

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