

[54] STATIONARY INDUCTION APPARATUS
HAVING SOUND ATTENUATING CORE
CLAMPING MEANS

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[58] Field of Search 336/92, 100, 210, 94, 5, 10

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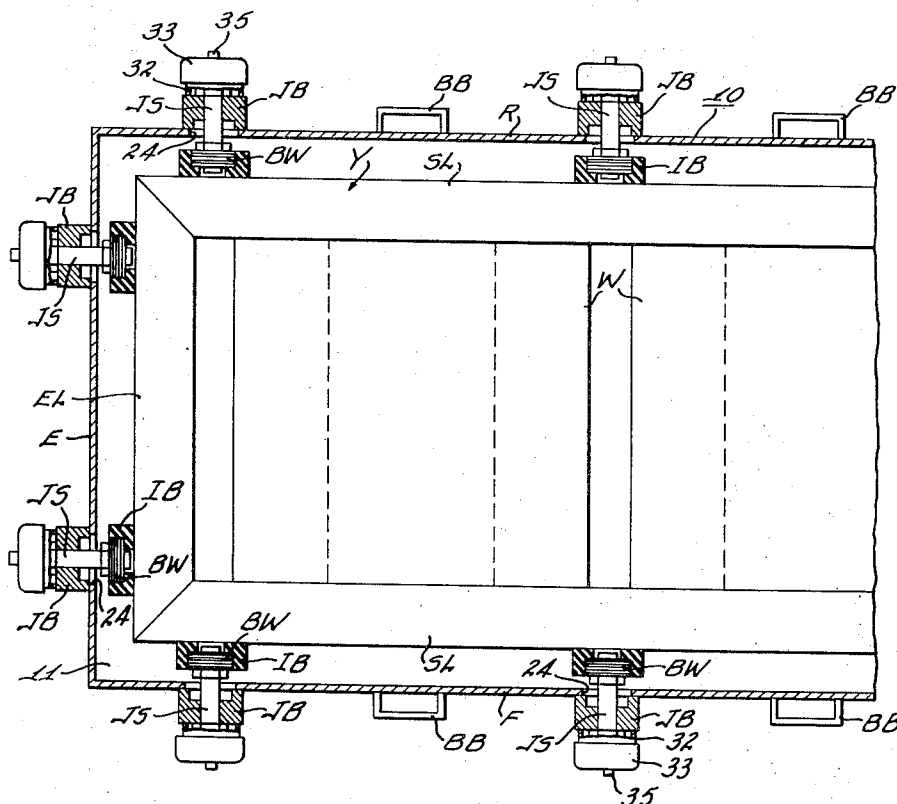
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[57] ABSTRACT

A shunt reactor has adjustable, spring-loaded jack-screw core clamping means which attenuate vibratory forces transmitted from the magnetic core to the tank walls and permit adjustment of core clamping pressure from the exterior of the tank.

15 Claims, 4 Drawing Figures



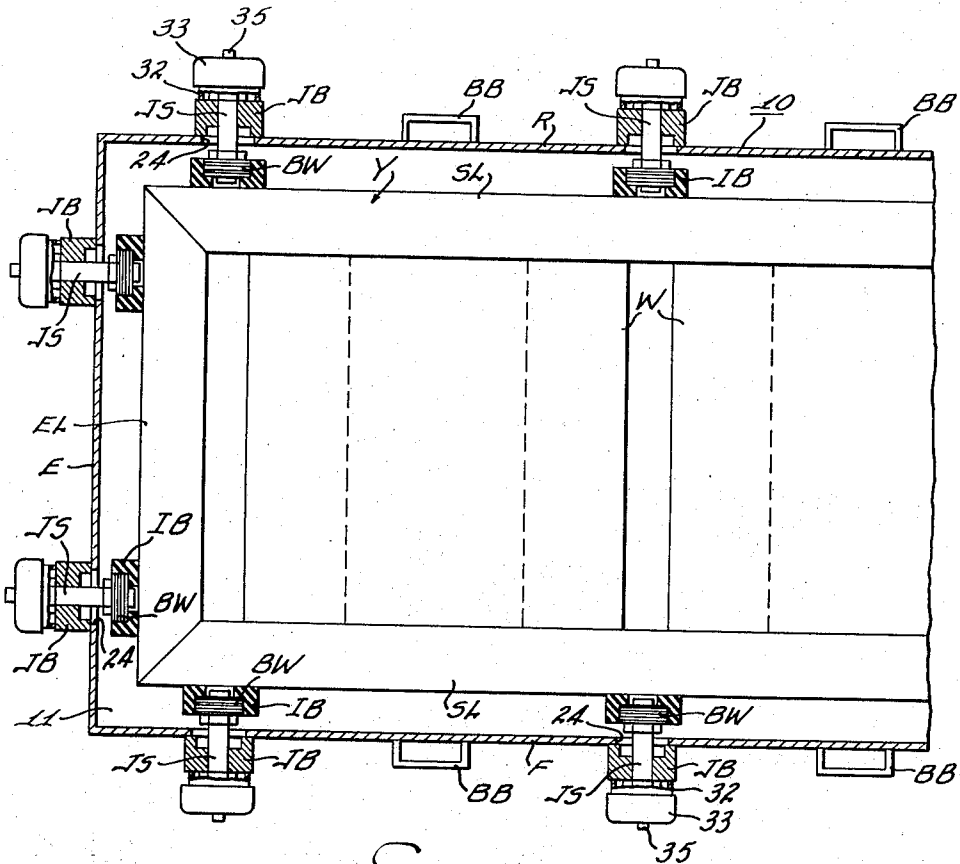


Fig. 2

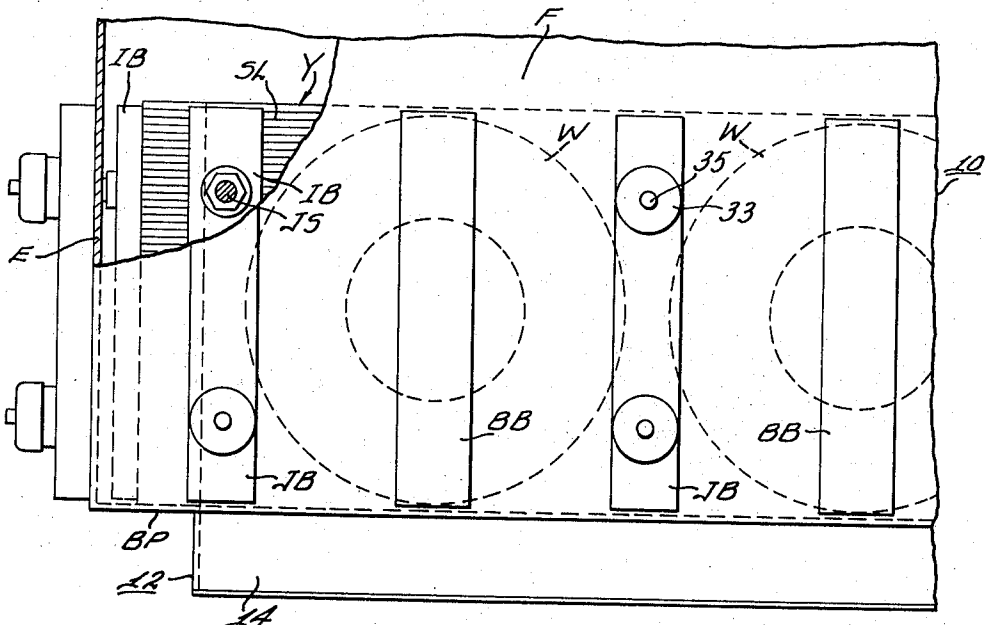
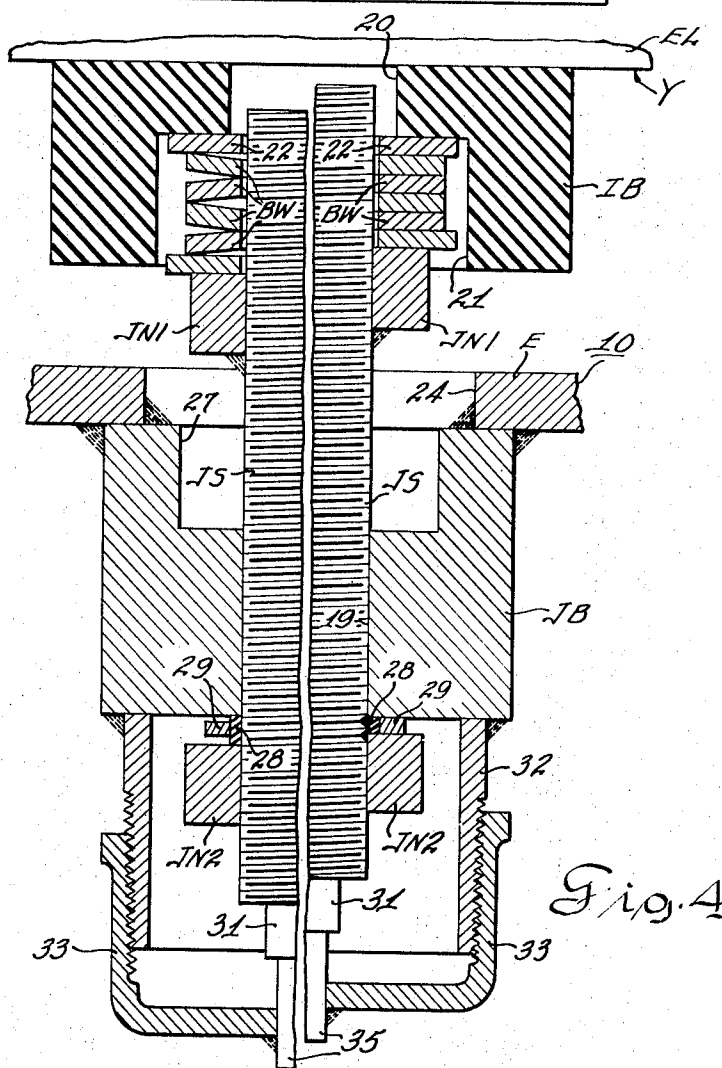
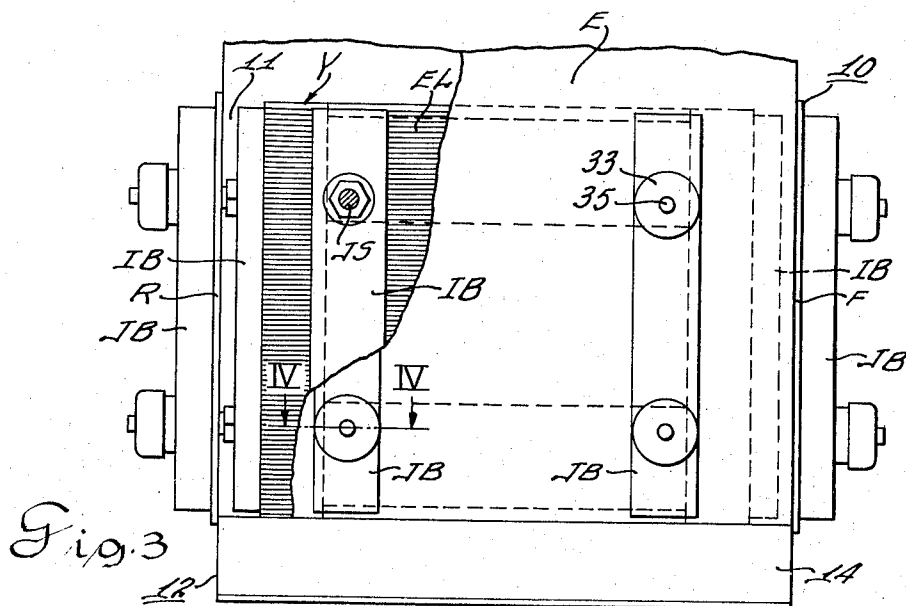


Fig. 1



STATIONARY INDUCTION APPARATUS HAVING SOUND ATTENUATING CORE CLAMPING MEANS

This invention relates to stationary induction apparatus and in particular to the reduction of the amplitude of vibrations and the attenuation of sound emanating from oil-filled stationary induction apparatus.

BACKGROUND OF THE INVENTION

Modern electrical power transmission and distribution practices necessitate the installation of stationary induction apparatus of considerable size in locations where the vibration and noise emanating therefrom may be a source of annoyance. With the increasing consciousness of the public regarding "noise pollution," it has become increasingly more important for design engineers to control the noise output and reduce the magnitude of vibrations from stationary induction apparatus. Magnetostriction of the core steel lamination is responsible for most of the noise emitted by stationary induction apparatus.

Such prior art stationary induction apparatus as the oil-filled shunt reactor disclosed in U.S. Pat. No. 3,466,582 to W. C. Sealey et al. has a rectangular yoke of magnetic laminations surrounding the reactor coil which may emit sufficient noise as to be objectionable. Vibrations exist in the reactor magnetic yoke due to magnetostriction, but the principal cause of noise and vibration is the expansion and contraction of the core at double line frequency due to magnetic forces. The reactor coil has no magnetic core leg extending through its window, the yoke laminations are in planes parallel to the coil axis, and the flux density in the air gap is a maximum opposite the coil axis and diminishes toward the radially outer portions of the coil. The magnetic yoke laminations are attracted toward the reactor coil by the magnetic flux and then repelled in what appears to be an oil pumping action, and in prior art structures the magnetic yoke transmitted the vibratory forces to the tank walls and resulted in high vibrational amplitudes with a consequent high level of noise. Such high vibrational amplitudes often resulted in metal fatigue and weld leaks in prior art stationary induction apparatus.

Further, although shell type transformers are known which have adjustable jackscrew means for clamping the magnetic core laminations, such prior art structures do not permit adjustment of the core clamping pressure from the exterior of the tank.

SUMMARY OF THE INVENTION

Core clamping means for stationary induction apparatus in accordance with the invention has spring-loaded jackscrews engaged within threaded holes in opposed tank walls and resilient compression means reacting between the jackscrews and the adjacent magnetic core laminations to attenuate vibratory forces transmitted from the core to the tank walls and thus reduce the output noise and vibration level. The jackscrews can be adjusted from the exterior of the tank to regulate core clamping pressure. The invention is preferably embodied in a polyphase shunt reactor with a plurality of cylindrical coils having parallel horizontal axes transverse to the front and rear walls of a rectangular tank and a rectangular magnetic core surrounding the coils. Heavy vertical jack bars affixed to the front and rear walls outward from the coils have

threaded holes which receive jackscrews having a tool engaging end exterior of the tank and a circumferential flange interior of the tank bearing against a spring disc washer which reacts against the side legs of the magnetic core. Preferably a heavy insulating member abuts against the core side leg opposite each jack bar and has a counterbore which freely receives the spring disc washer. Jack bars are also affixed to the tank end walls so that such jackscrew and spring disc washer means resiliently clamp the core end legs to a desired pressure adjusted from the exterior of the tank and to attenuate vibratory forces transmitted from core to tank walls, and vertical bracing members are welded to the tank front and rear walls between the jack bars to further attenuate radiated sound and reduce the vibrational amplitudes.

OBJECTS OF THE INVENTION

Accordingly it is an object of the invention to provide improved stationary induction apparatus which obviates the above disadvantages of the prior art and reduces the vibrational amplitude and noise output level of the apparatus.

Another object of the invention is to provide stationary induction apparatus having improved resilient magnetic lamination clamping means which substantially attenuates transmission of vibratory forces from the laminations to the tank walls and substantially reduces the amount of metal fatigue and the number of weld leaks which occurred due to the high amplitude of vibrations in prior art apparatus.

A further object of the invention is to provide stationary induction apparatus having improved magnetic lamination clamping means which permits clamping pressure to be adjusted from the exterior of the tank.

Still another object of the invention is to provide an oil-filled shunt reactor having a magnetic yoke surrounding the reactor coil and improved core clamping means which minimizes transmission of forces from the yoke to the tank walls resulting from cyclic magnetic attraction of the steel laminations to the reactor coil and permits adjustment of the core clamping pressure from the exterior of the tank.

DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the invention will be more readily apparent from the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 a front view of a shunt reactor embodying the invention with a portion of the tank front wall cut away to illustrate the internal reactor construction;

FIG. 2 is a plan view of the shunt reactor of FIG. 1 with the cover removed;

FIG. 3 is an end view of the shunt reactor shown in FIGS. 1 and 2 with a portion of the end wall cut away; and

FIG. 4 is a view taken along line 4-4 of FIG. 3 and showing the compressed and uncompressed positions of the spring-loaded jackscrew clamping means in the right and left halves of the view respectively.

DETAILED DESCRIPTION

Referring to the drawing, a three-phase shunt reactor embodying the invention may include an elongated metallic tank 10 containing a dielectric cooling and insu-

lating fluid such as oil in which are immersed three generally cylindrical shunt reactor phase coils W with parallel horizontal axes transverse to the longitudinal dimension of tank 10 and a rectangular core, or yoke Y surrounding coils W and comprising a stack of magnetic side laminations SL and end laminations EL disposed in horizontal planes parallel to the axes of coils W and so that the axial ends of the coils W are closely adjacent the side laminations SL to straighten the magnetic flux lines within the coils W. Each coil W may include a plurality of electrically connected but axially spaced coaxial annular pancake windings (not shown) and have a nonmagnetic core, i.e., the coil window does not contain any magnetic laminations. Rectangular magnetic yoke Y may comprise a stack of horizontal magnetic laminations with each layer comprising a pair of side laminations SL extending parallel to the tank front and rear walls and a pair of end laminations EL extending parallel to the tank end walls and with the abutting ends of the side laminations SL and end laminations EL mitered and offset in adjoining layers to define a closed magnetic path of low reluctance surrounding coils W.

The total magnetic flux in yoke Y in a maximum opposite the axis of each coil W and diminishes toward the upper and lower edges of the stack of laminations, and spaces (not shown) may be disposed between certain layers so that the cross sectional area of the magnetic steel laminations per inch of stack height is a maximum midway of the height of each coil and decreases toward the coil extremities as disclosed in the aforesaid U.S. Pat. No. 3,466,582 to W. C. Sealey et al., having the same assignee as this invention.

Tank 10 may have a bottom plate BP supported on and welded to a base 12 of structural beams 14, steel front and rear walls F and R extending longitudinally of the tank 10 and welded to bottom plate BP, and steel end walls E welded to bottom plate BP and to front and rear walls F and R. The yoke side laminations SL are preferably spaced from the tank front and rear walls F and R, and the yoke end laminations EL are spaced from the tank end walls E.

The steel yoke laminations are cyclically attracted magnetically toward the reactor coils W and released in a manner which appears to establish a pumping action in the oil, and the forces resulting from such pumping action in prior art apparatus were transmitted from the core laminations through the core clamping means to the tank walls and set up high amplitude vibrations therein which emitted objectionably high audio noise and often caused metal fatigue and insulating oil leaks. In accordance with the invention, these forces are substantially attenuated in the core clamping means. Four heavy-in-cross section (e.g., 2.75 inches X 4 inches) vertically extending steel jack bars JB are preferably affixed by welding to the exterior of each of the tank front and rear walls F and R at horizontally spaced positions radially outward from the coils W, and two such steel jack bars JB are preferably affixed to each tank end wall E. Three elongated vertical reinforcing members BB which may be of channel cross section are affixed to the exterior of each of the tank front and rear walls F and R opposite the axis of the coils W. A vertically elongated heavy-in-cross section insulating bar IB (for example, 2 inches X 5 inches in cross section) is disposed interiorly of tank 10 against the stack of yoke laminations opposite each jack bar JB so that a space

exists between each insulating bar IB and the tank wall opposite it. The insulating bars IB are preferably of a suitable high strength, low loss material which is compatible with oil, such as the dielectric laminate sold under the mark PERMALI by Permali Inc. of Mt. Pleasant, Pennsylvania, or, alternatively, they may be of high strength, impregnated wood laminate material.

Jackscrews JS extend through aligned apertures in each jack bar JB, in the corresponding tank wall F, R or E, and in the insulating bar IB opposite the jack bar. Preferably two jackscrews JS are engaged within the threaded holes 19 in each jack bar JB at vertically spaced positions outward from each coil W as best shown in FIG. 3. A clearance hole 20 (See FIG. 4) is provided in each insulating bar IB for the end of each jackscrew JS, and a counterbore 21 in insulating bar IB registering with clearance hole 20 freely receives a washer 22 surrounding jackscrew JS, spring disc washers BW surrounding jackscrew JS, and a heavy hexagon jam nut JN1 threaded on and welded to jackscrew JS to form a circumferential flange on jackscrew JS so that spring disc washers BW react between insulating bar IB and jam nut JN1.

Each tank wall F, R and E has an opening 24 for each jackscrew JS which is sufficiently large to freely receive jam nut JN1. Each jack bar JB has a threaded hole 19 for each jackscrew JS and a counterbore 27 from the interior of the tank registering with threaded hole 19 and of sufficient size to freely receive jam nut JN1.

A heavy hexagonal jam nut JN2 is threaded on each jackscrew JS exterior of tank 10 with a suitable resilient O-ring jacket seal 28 such as the series 7500 O-ring thread seal commercially available under the mark PARKER from the Parker Seal Company of Culver City, California, compressed between the jack bar JB and the jam nut JN2. An annular washer 29 surrounding jackscrew JS and O-ring seal 28 between jack bar JB and jam nut JN2 prevents outward expansion of seal 28, and the seal 28 prevents leakage of oil 11 out of tank 10 past jackscrew JS. A square head 31 provided on jackscrew JS exterior of tank 10 permits engagement with a tool to turn jackscrew JS. A tubular pipe nipple 32 is secured to jack bar JB in surrounding relation to jackscrew JS by suitable means such as welding, and a cup-shaped pipe cap 33 may be threaded on pipe nipple 32 to provide an additional seal to prevent oil leaks in the event that the thread seal 28 malfunctions. A locking pin 35 extends axially through an opening in pipe cap 33 and is welded thereto after pipe cap 33 is threaded on pipe nipple 32 to prevent outward movement of jackscrew JS relative to jack bar JB.

In operation, the square head 31 of jackscrew JS is engaged with a tool from the exterior of the tank 10 and turned relative to jack bar JB until the desired clamping force is exerted through spring disc washers BW against the yoke laminations. Any movement of jackscrew JS in an inward direction resulting from turning it in threaded hole 19 in jack bar JB is transmitted through jam nut JN1, spring disc washer BW, washer 22, and insulating bar IB to clamp the yoke lamination with a force depending on the degree of compression of spring disc washers BW. The clamping force on the yoke laminations SL and EL can thus be adjusted from the exterior of tank 10. Since jackscrew JS is held from movement outward of the tank by engagement of its external threads within threaded hole

19 in jack bar JB, any movement of the yoke laminations in a direction away from reactor coil W is transmitted through insulating bar IB to further compress spring disc washer BW against internal jam nut JN1 which is secured to jackscrew JS, thereby attenuating the outwardly directed force and minimizing the amplitude of vibrations in the tank wall tending to emit audio sound. When the yoke laminations are attracted and move toward coil W, the insulating bar IB follows such lamination movement and permits the spring disc washer BW to expand.

The left half of FIG. 4 illustrates the uncompressed position of spring disc washer BW, and the right half shows the compressed position after jackscrew JS has been turned relative to jack bar JB to compress spring disc, or Belleville washer BW so that it clamps the yoke lamination with the desired pressure. After the desired core clamping pressure has been attained by turning jackscrew JS to the compressed position shown in the right half of FIG. 4, the pipe cap 33 is threaded tightly on pipe nipple 32 and locking pin 35 is welded to pipe cap 33 in a position wherein it abuts against the end of jackscrew JS to thereby prevent movement of jackscrew JS relative to jack bar JB and thus prevent undesired change of core clamping pressure. It will be appreciated that change of pressure to which the yoke laminations are clamped can easily be accomplished from the exterior of tank 10, and without breaking any tacking welds, by merely unscrewing pipe cap 33, engaging square head 31 of jackscrew JS with a tool and turning jackscrew JS relative to jack bar JB to thereby vary the degree of compression of Belleville washers BW.

The spring disc washers BW expand as the yoke laminations are cyclically attracted by magnetic forces toward coils W and are compressed as the laminations move away from the coils W to attenuate the vibratory forces transmitted to the tank walls F, R and E, and the heavy-in-cross section steel bars JB and the bracing members BB reinforce the plate tank sidewalls and further reduce the amplitude of vibrations in and the level of sound emitted from the walls of tank 10. The reduction in the amplitude of vibrations accomplished by the disclosed adjustable, spring-loaded jackscrew core clamping means also results in substantial reductions in this amount of metal fatigue and in the number of weld leaks compared to prior art apparatus.

Although the preferred embodiment has been illustrated and described as clamping core laminations in a direction parallel to the plane of the laminations, it will be appreciated that the invention is also applicable to the clamping of magnetic laminations in a direction perpendicular to the plane of the core laminations in a manner which permits adjustment of the clamping pressure from the exterior of the stationary induction apparatus.

While only a single embodiment of my invention has been illustrated and described, many modifications and variations thereof will be readily apparent to those skilled in the art, and consequently it should be understood that I do not intend to be limited to the particular embodiment shown and described.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An electrical reactor comprising, in combination, a rectangular tank, a dielectric insulating and cooling

fluid within said tank, an electrical coil immersed in said insulating fluid with its axis horizontal and transverse to the longitudinal dimension of said tank, a magnetic yoke comprising a stack of magnetic laminations in horizontal planes immersed in said insulating fluid in surrounding relation to said coil and having a pair of side legs closely adjacent the axial ends of said coil and also adjacent to but spaced from a pair of opposed sidewalls of said tank, a pair of vertically extending jack bars affixed to the exterior of each of said opposed tank sidewalls at positions radially outward from said coil, each jack bar having a pair of vertically spaced threaded holes therethrough in alignment with clearance holes in the corresponding tank sidewall, a jackscrew engaged within each of said threaded holes and having a tool engaging end exterior of said tank, a vertically extending insulating member immersed in said insulating fluid opposite each said jack bar in abutting relation to the corresponding magnetic yoke side leg, resilient compression means reacting between each jackscrew and the corresponding insulating member, and means for sealing between each jackscrew and the threaded hole in which it is engaged, whereby the clamping pressure on said magnetic yoke may be adjusted from the exterior of said tank.

2. An electrical reactor in accordance with claim 1 wherein said resilient compression means includes a spring disc washer surrounding said jackscrew and reacting at one end against said insulating member and at its opposite end against a circumferential flange on the jackscrew.

3. An electrical reactor in accordance with claim 1 wherein said insulating member is a vertically extending insulating bar having a counterbore opposite each jackscrew freely receiving said spring disc washer.

4. An electrical reactor in accordance with claim 3 and including a threaded pipe nipple welded to the jack bar in surrounding relation to each jackscrew, a pipe cap threadedly engaging said pipe nipple, and a locking pin affixed to said pipe cap and projecting inwardly from said pipe cap in alignment with and adapted to abut against the end of said jackscrew, whereby an additional seal is provided to prevent leakage of said insulating fluid from said tank and undesired change in core clamping pressure is prevented.

5. An electrical reactor in accordance with claim 3 wherein each said means for sealing includes a nut threaded on the jackscrew exterior of said tank, a resilient O-ring gasket surrounding said jackscrew and compressed between the jack bar and said nut, and an annular washer surrounding said O-ring gasket between the jack bar and said nut.

6. An electrical reactor in accordance with claim 3 wherein said jack bar has a counterbore from the interior of said tank coaxial with each said threaded hole and which freely receives said circumferential flange on said jackscrew.

7. An electrical reactor in accordance with claim 2 which is polyphase and has a plurality of coils with horizontal parallel axes immersed in said insulating fluid and surrounded by said magnetic yoke and each of said opposed tank sidewalls has one of said vertically extending jack bars welded to the exterior thereof between each pair of adjacent coils and also radially outward of the end coils, and each of said opposed tank sidewalls also has a vertically extending reinforcing bar

welded to the interior thereof opposite the axis of each of said coils.

8. An electrical reactor in accordance with claim 7 wherein said opposed sidewalls are the front and rear walls of said tank and said magnetic yoke has a pair of end legs adjacent to but spaced from the end walls of said tank and said tank also has a pair of said vertically extending jack bars affixed to each of said tank end walls with said threaded holes therethrough receiving said jackscrews and with spring disc washers surrounding each jackscrew reacting between said circumferential flange on said jackscrew and one of said insulating members abutting against one of said end legs of said magnetic yoke.

9. Stationary induction apparatus permitting adjustment of core clamping pressure from the exterior thereof comprising, in combination, a tank, a dielectric insulating and cooling fluid within said tank, an electrical coil immersed in said insulating fluid, a magnetic core comprising a stack of laminations immersed in said insulating fluid and inductively linked with said coil and having portions adjacent to but spaced from a pair of opposed walls of said tank, a pair of heavy-incross section elongated jack bars affixed in spaced relation to the exterior of each of said opposed walls and having a plurality of spaced threaded holes therein each of which is in alignment with a clearance hole in the corresponding tank wall, a jackscrew engaged within each of said threaded holes and having a tool engaging end exterior of said tank, resilient compression means immersed in said insulating fluid and reacting between each said jackscrew and the adjacent portion of said magnetic core, and means for sealing between each jackscrew and the threaded hole in which it is engaged.

10. Stationary induction apparatus in accordance with claim 9 wherein each said resilient compression means includes a spring disc washer surrounding the jackscrew within said tank and reacting at one end against a circumferential flange on said jackscrew.

11. Stationary induction apparatus in accordance with claim 10 and including an elongated insulating bar immersed in said insulating fluid parallel to and opposite each said jack bar and being in abutting relation with said adjacent portion of said magnetic core and having a counterbore therein opposite each jackscrew freely receiving the end of said spring disc washer.

12. Stationary induction apparatus in accordance with claim 11 and including a threaded pipe nipple welded to the jack bar in surrounding relation to each jackscrew, a pipe cap threadedly engaging said pipe nipple, and a locking pin affixed to said pipe cap and projecting inwardly therefrom in alignment with and adapted to abut against the end of axial jackscrew, whereby an additional seal is provided to prevent leakage of said insulating fluid from said tank and undesired change in core clamping pressure prevented.

13. Stationary induction apparatus in accordance with claim 11 wherein said jack bar has a counterbore from the interior of said tank coaxial with said threaded hole which freely receives said circumferential flange on said jackscrew, and each said means for sealing includes a nut threaded on said jackscrew exterior of said tank, a resilient O-ring gasket surrounding said jackscrew and compressed between said nut and the jack bar, and an annular member surrounding said O-ring gasket between said jack bar and said nut.

14. Stationary induction apparatus in accordance with claim 13 wherein said tank is rectangular and said opposed walls are the front and rear walls thereof and said magnetic core also has portions adjacent to but spaced from the end walls of said tank and said apparatus also has a pair of said jack bars affixed to each of said tank end walls with said threaded holes therein receiving said jackscrews and with spring disc washers surrounding each jackscrew reacting between a circumferential flange on the jackscrew and one of said insulating bars abutting against said magnetic core portion adjacent said end wall.

15. Stationary induction apparatus in accordance with claim 14 where said apparatus is polyphase and has a plurality of said coils with horizontal parallel axes transverse to said front and rear walls and said magnetic core is also rectangular and surrounds said plurality of coils and has a pair of side legs adjacent to but spaced from said tank front and rear walls and a pair of end legs adjacent to but spaced from said tank end walls, and wherein said apparatus has reinforcing bars welded to said tank front and rear walls at positions between said jack bars to further attenuate the amplitude of vibrations and the level of audio noise emitted by said apparatus.

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