June 23, 1964 C. E. DERBYSHIRE ETAL 3,138,774

ELECTRICAL INDUCTION APPARATUS WITH RESILIENTLY SUPPORTED MAGNETIC CORE

Filed Feb. 3, 1961

2 Sheets-Sheet 1

Fig. 1.

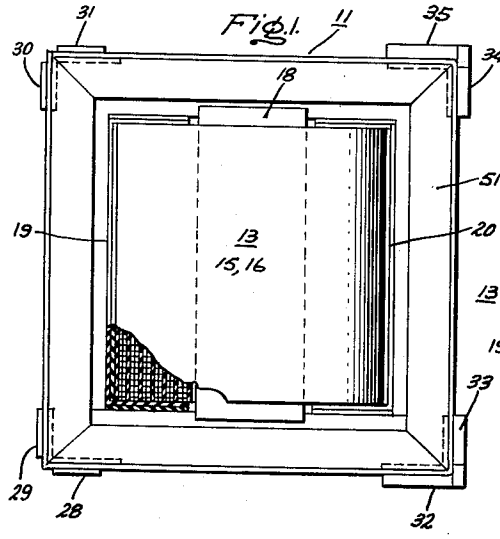


Fig. 2.

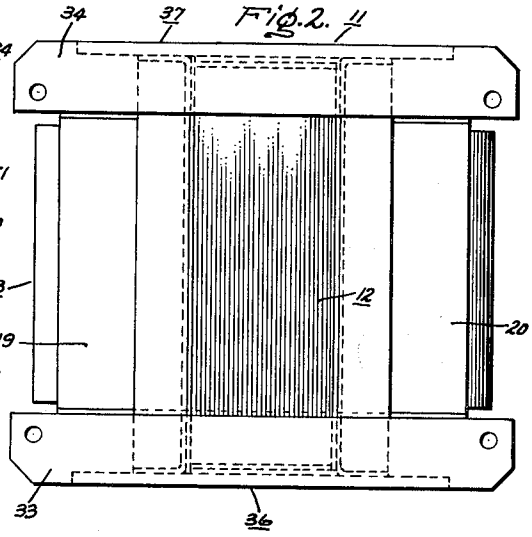
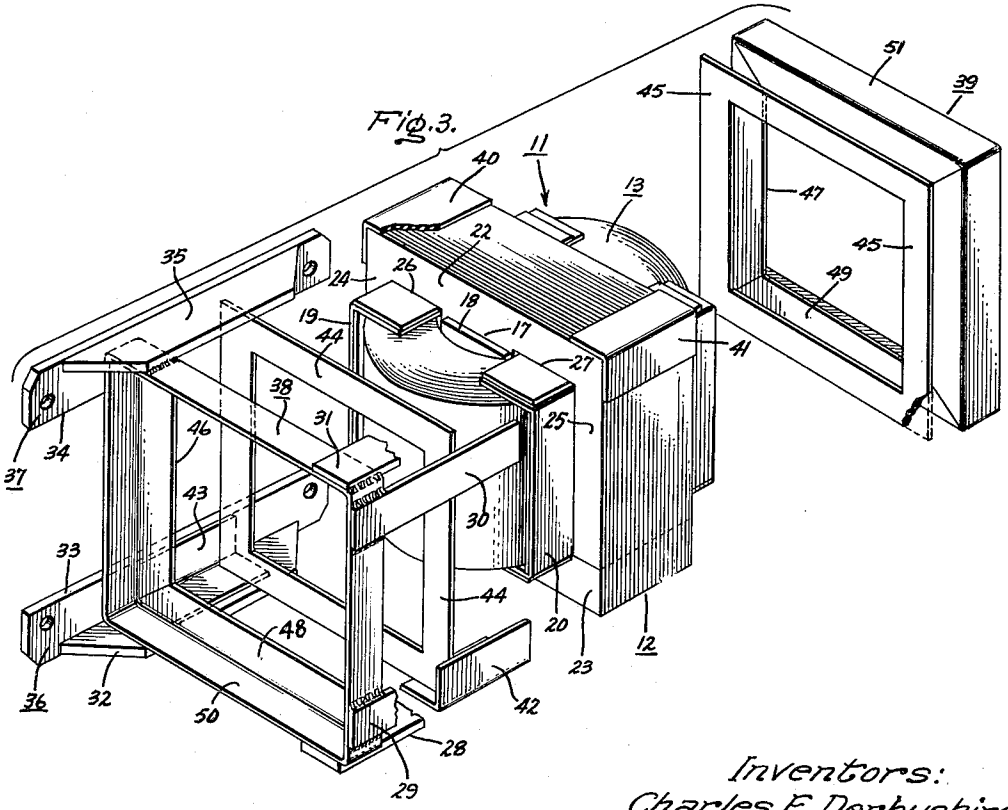


Fig. 3.



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2 Sheets-Sheet 2

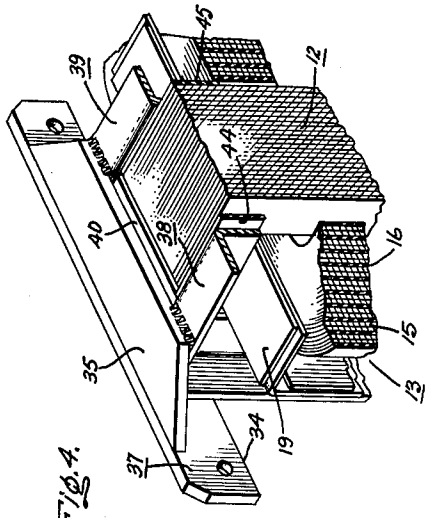


Fig. 4.

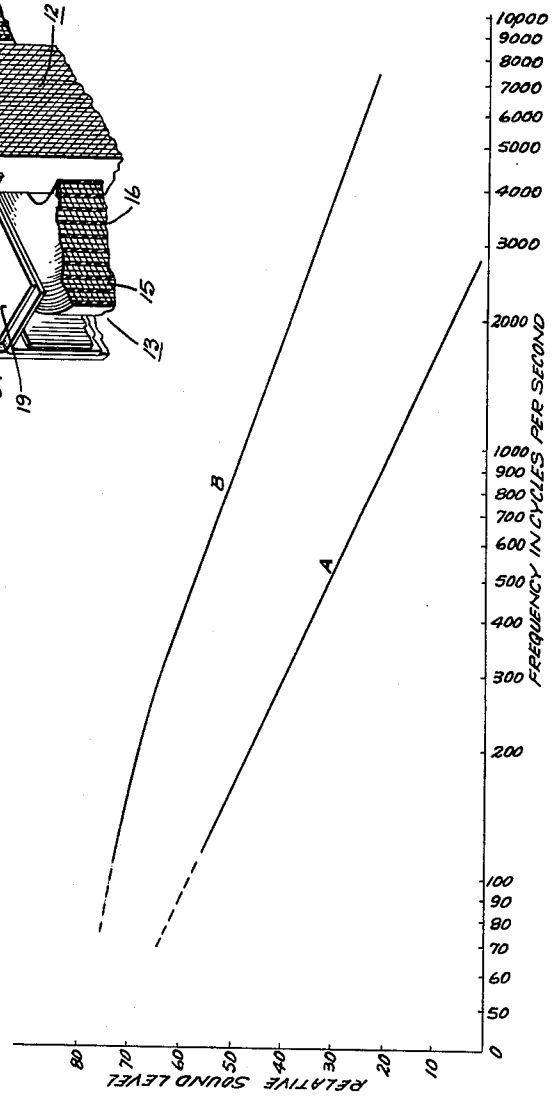


Fig. 5.

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ELECTRICAL INDUCTION APPARATUS WITH RESILIENTLY SUPPORTED MAGNETIC CORE

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This invention relates to electrical induction apparatus such as transformers and reactors, and more particularly to electrical induction apparatus employing laminated cores wherein vibrations resulting from magnetostriction are minimized.

In many applications where transformers and reactors are employed, it is desirable to minimize the effects of magnetostrictive deformations that take place in the laminations of the magnetic core of a transformer or reactor as the unit is energized from an alternating current power supply. It is well known that core laminations when magnetized undergo minute changes in size and shape, which often cause perceptible movements in the laminations. Therefore, the laminations are generally held in assembled relation by some suitable means. Even when the laminations of a magnetic core are firmly clamped in assembled relation, magnetostrictive deformations cause vibrations which are transmitted through the clamps and the structural frame of the apparatus to the surrounding media. In some instances the vibrations may interfere with other electrical apparatus. Frequently, audible humming may result from these vibrations, which is objectionable in some applications. For example, in the operating rooms of hospitals or in some military applications, the vibrations caused by magnetostrictive deformation of the laminated cores of transformers may cause difficulty.

Many different arrangements have been tried in the past to minimize the effects of magnetostriction in electrical induction apparatus such as transformers and reactors. A common method of reducing the effects of magnetostriction in the past has been to mount the apparatus on resilient supports so as to isolate the unit from the structure to which it was attached. Another method employed in the past has been to encapsulate the clamped core assembly in an asphaltic or resinous compound which serves to dampen the vibrations. However, these arrangements of the prior art have not sufficiently reduced the vibrations to a level where the apparatus is suitable for many special applications where vibrations above certain sound levels caused by the magnetostriction cannot be tolerated.

It is, therefore, an object of the invention to provide an improved electric inductive apparatus wherein the vibrations caused by magnetostriction are effectively minimized.

Another object of the invention is to provide an improved mounting and clamping frame for an inductive core and coil assembly wherein the core and coil assembly are effectively isolated from the mounting and clamping frame members.

In accordance with the invention we have provided an electrical induction apparatus wherein resilient spacers are interposed between the outer surfaces of a laminated magnetic core and the clamping elements and between the frame straps and the surfaces defined by the edges of the core laminations so as to prevent any metal-to-metal contact between the magnetic core and the clamping elements and between the magnetic core and the frame straps. The spacers provide a resilient suspension for the magnetic core and coil assembly thereby substantially isolating and dampening magnetostrictive vibrations originating in the magnetic core.

The subject matter which we regard as our invention is set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof, may be understood by referring to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a front elevation of an electrical induction apparatus in accordance with the invention;

FIG. 2 is a side elevation of the electrical induction apparatus shown in FIG. 1;

FIG. 3 is an exploded view of the electrical induction apparatus shown in FIGS. 1 and 2;

FIG. 4 is a fragmentary perspective view of the electrical induction apparatus shown in FIGS. 1, 2 and 3 cutaway to show the various components thereof in assembled relation; and,

FIG. 5 is a curve showing a plot of relative sound level versus frequency for a transformer incorporating the present invention and a comparable unit of the prior art.

As used herein, the term "electrical induction apparatus" includes transformers, chokes, saturable reactors, and other similar electrical devices having a flux conducting element. Referring now to the drawings and more particularly to FIG. 3, the flux conducting element of the transformer **11**, as herein described for the purpose of illustrating my invention, comprises generally a magnetic core **12** and a coil assembly **13**. The coil assembly **13** may be of any suitable design and may include a plurality of individual windings with leads (not shown) which may be provided for external connection to an electrical circuit.

In the illustrated exemplification of the invention the coil assembly **13** included a primary winding **15** and a secondary winding **16** inductively coupled on the central winding leg **17** of the magnetic core **12**. A wedge **18** is positioned between the central leg **17** and the inner portion of the coil assembly **13** to hold the coil assembly **13** in assembled relationship on the central winding leg **17**. A pair of channel-shaped insulators **19**, **20** made of an insulating material such as paper, are employed to provide corner insulation for the coil assembly **13**.

As is best illustrated in the exploded view shown in FIG. 3, the magnetic core **12** is comprised of E-shaped laminations **22** and I-shaped laminations **23**, the outer legs **24**, **25** of which are butted together to form a closed magnetic circuit. In the illustrative embodiment of the invention, alternate layers of E-shaped and I-shaped laminations **22**, **23** were inverted in order to provide an overlap for the butted joint. The outer legs **24**, **25** and the central winding leg **17** are spaced from each other so as to define coil receiving windows **26**, **27**. The coil assembly **13** is mounted on the center winding leg **17** by bringing alternate layers of E-shaped laminations **22** and I-shaped laminations **23** in assembled relation therein.

In accordance with the invention we have provided a mounting and clamping arrangement which includes frame straps **28**, **29**, **30**, **31** and **32**, **33**, **34**, **35**, the latter group of frame straps **32–35** forming a pair of mounting brackets **36**, **37** and six resilient spacers **40**, **41**, **42**, **43**, **44**, **45**. The clamping elements **38**, **39** are provided with a rectangular opening **46**, **47**, respectively, through which a portion of the coil assembly **13** extends. Clamping portions **48**, **49** and stiffener portions **50**, **51**, to which the frame straps **28**, **29**, **30**, **31** are attached, are provided on clamping elements **38**, **39**.

As will be seen in the exploded view in FIG. 3, four resilient spacers **40**, **41**, **42**, **43** are positioned so that when transformer **11** is assembled the spacers are interposed between frame straps **28–35** and the corners of the magnetic core **12**. Further, referring to FIG. 4, it will be seen that the two rectangular-shaped resilient spacers **44**, **45** are interposed between the clamping elements **38**,

39 and the outer laminations of the magnetic core 12 when the transformer 11 is assembled.

The resilient spacers 40–45 may be constructed of resilient materials such as, for example, synthetic or natural rubber which is capable of withstanding a compressive force without permanent deformation. The purpose of the spacers 40–45 is to provide a resilient or spring-like suspension for the magnetic core 12 and coil assembly 13. It will be noted that resilient spacers 44, 45 have a rectangular-shaped opening and general configuration that substantially conforms to the clamping portions 48, 49. It will be appreciated that the design and shape of the resilient spacers 40–45 can be varied as required. For example, if desired, spacers 40, 41, 42, 43 may be fabricated of separate pieces.

In order to provide a suitable mounting means for the transformer 11, as is best seen in the view shown in FIG. 1, four of the frame straps 32, 33, 34, 35 were made of a heavier metal plate than straps 28, 29, 30, 31. As shown in FIGS. 2 and 3, frame straps 33, 34 were drilled to provide suitable sized openings so that the transformer 11 may be attached to a wall or other mounting surface. It will be appreciated that the unit may be mounted in any position as may be required in a particular application.

Referring again to the exploded view of FIG. 3, the transformer 11 used to exemplify the invention was assembled in the following manner. The frame straps 28–35 were welded at one end thereof to the corners of the stiffener portion 50 of clamping element 38. Resilient spacer 44 was placed in position on clamping portion 48 of clamp element 38. The four resilient spacers 40, 41, 42, 43, the magnetic core 12 and coil assembly 13 were then inserted in assembled relationship within the structure formed by clamping element 38 and the frame straps 28–35. The other resilient spacer 45 was then placed in position over the top lamination of the magnetic core 12 and the other clamping element 39 was placed in position over the resilient spacer 45. The clamping elements 38, 39 were placed under compression by a clamp or other suitable means so that the clamping elements 38, 39 when rigidly secured to the frame straps 28–35 exert a compressive force against the resilient spacers 44, 45 and hold the laminations of the magnetic core 12 tightly in assembled relation as illustrated in the fragmentary view in FIG. 4. Thus, it will be seen that resilient spacers 40–45 are interposed wherever a part of the clamping elements 38, 39 or the frame straps 28–35 may come in contact with the magnetic core 12. The clamping element 39 was then welded to the other end of frame straps 28–35. It will be understood that the clamping elements 38, 39 may be fastened to the frame straps 28–35 by other suitable methods such as by bolting the straps 28–35 thereto.

It was found that when the laminations of the magnetic core 12 are held in a resilient suspension between the clamping elements 38, 39 and the frame straps 28–35, the noise level can be very significantly reduced as compared with arrangements heretofore used. A further advantage resulting from the resilient isolation of the magnetic core 12 was that magnetostrictive vibrations were effectively dampened and the effects of magnetostriction were thereby minimized.

In FIG. 5 we have shown the comparative sound level and frequency characteristics of a transformer employing the resilient suspension arrangement of the present inveniton as compared with a comparable arrangement of the prior art in which the magnetic core is held in assembled relation by a conventional metal-to-metal clamping frame. Curve A represents a plot of sound level versus frequency in cycles per second for transformed in accordance with the invention. Similar sound level measurements were taken of the same core and coil assembly in which the lamination were clamped with the same clamping frame as the transformer embodying the invention but without the resilient isolation arrangement of the present invention. A plot of the sound level versus frequency for the conventional arrangement is represented by curve B. As will be seen from curve A, it is possible at a frequency of 600 cycles per second to obtain a reduction of approximately 50 percent in the sound level above the zero point as compared with the corresponding value on curve B. The sound measurements upon which curves A and B are based were made in accordance with American Standards Association, Standard Z24. It will be seen from curves A and B that the resilient isolation of the magnetic core 12 in accordance with the invention makes it possible to significantly reduce the level of sound in a transformer or other electrical induction apparatus.

While the present invention has been described with reference to a specific exemplification thereof, it will be understood that numerous modifications may be made by one skilled in the art which are within the scope of this invention. It is to be understood, therefore, that we intend by the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electrical induction apparatus comprising a plurality of laminations disposed to form a magnetic core having a central winding leg and outer legs and forming a closed magnetic circuit, at least one coil assembly disposed on said central winding leg, said magnetic core having a pair of outer surfaces defined by the outer laminations of said core, said coil assembly being disposed about said central winding leg so as to extend outwardly from said surface, a pair of clamping elements adjacent to said outer laminations, a resilient spacer interposed between each of said clamping elements and said surfaces of said outer laminations, a plurality of straps disposed along the edges of said laminations and rigidly attached to said clamping elements to hold said clamping elements in compressive force exerting relationship with said laminations and said aforementioned resilient spacers, a plurality of resilient spacers interposed between said straps and the edges of said lamination stack, said straps maintaining alignment of said lamination stack and said resilient spacers providing a resilient suspension for said magnetic core and coil assembly and substantially isolating and dampening magnetostrictvie vibrations originating in said magnetic core.

2. An electrical induction apparatus comprising a magnetic core defining a closed magnetic circuit and having outer legs and a center winding leg forming coil receiving windows, said magnetic core being formed of a stack of laminations having a pair of outer surfaces defined by the outer laminations of the said stack; at least one coil assembly mounted on said central winding leg and disposed within said coil receiving windows; a pair of rectangular-shaped clamping elements, each having an opening therein to provide clearance for the portion of said coil assembly extending outwardly of said outer surfaces, a clamping portion and a stiffening portion extending at right angles thereof; said clamping elements being disposed at opposite ends of said stack of laminations; a resilient spacer interposed between each of the clamping portions of said clamping elements and said outer surfaces of siad stack of laminations; a plurality of straps extending vertically along the corners of said laminations and rigidly secured to said stiffening portions of the clamping elements and holding said clamping elements in compressive force exerting relationship against said resilient spacers and said stack of laminations; and resilient spacers interposed between said straps and said laminations, said resilient spacers substantially isolating said straps and said clamping elements from magnetostrictive vibrations occurring during operation and preventing metal-to-metal contact between said straps and said laminations.

3. The electrical induction apparatus set forth in claim 2 wherein said resilient spacers interposed between said clamping portion of said clamping element and said outer surfaces of said stack of laminations are rectangular in shape and conform substantially to the configuration of said clamping portion.

4. A transformer comprising a plurality of laminations disposed to form a magnetic core having a central winding leg and outer legs and forming a closed magnetic circuit, at least one coil assembly including a primary winding and a secondary winding inductively coupled therewith on said magnetic core, said magnetic core having a pair of outer surfaces defined by the outer laminations of said core, said coil assembly being disposed about said central winding leg and extending outwardly from said surfaces, a pair of clamping element disposed adjacent to the outer laminations, a resilient spacer interposed between each of said clamping elements and said outer surfaces of said outer laminations, a plurality of straps rigidly attached to said clamping elements to hold said clamping elements in compressive force exerting relationship with said laminations, at least two of said straps being adapted to serve as a mounting bracket, a plurality of resilient spacers interposed between said straps and the magnetic core, said resilient spacers interposed between said straps and magnetic core and between said clamping elements and said magnetic core providing a resilient suspension for said magnetic core thereby substantially isolating and dampening magnetostrictive vibrations originating therein.

5. A transformer comprising a stack of laminations forming a magnetic core defining a closed magnetic circuit, at least one coil assembly disposed on said magnetic

core and including a primary winding and a secondary winding inductively coupled thereon, said magnetic core having a plurality of sides defined by the edges of said laminations and a pair of outer surfaces defined by the outer laminations of said stack, a pair of clamping elements disposed adjacent to the outer laminations of the magnetic core, a resilient rubber spacer interposed between each of said clamping elements and said outer surfaces of said laminations, a plurality of frame straps extending along the edges of said laminations and secured to said clamping elements to hold said clamping elements in compressive force exerting relationship with said laminations and said aforementioned resilient rubber spacers, a plurality of resilient rubber spacers interposed between said straps and said sides of said magnetic core, said resilient rubber spacers being disposed so as to prevent metal-to-metal contact between the magnetic core and the clamping elements and between the magnetic core and the frame straps thereby providing a resilient suspension for the magnetic core and substantially isolating and dampening magnetostrictive vibrations originating in the laminations of the magnetic core.

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