Dec. 9, 1958 A. L. HORELICK ET AL 2,864,065

CORE CONSTRUCTION FOR TRANSFORMERS

Filed Aug. 5, 1955 3 Sheets-Sheet 1

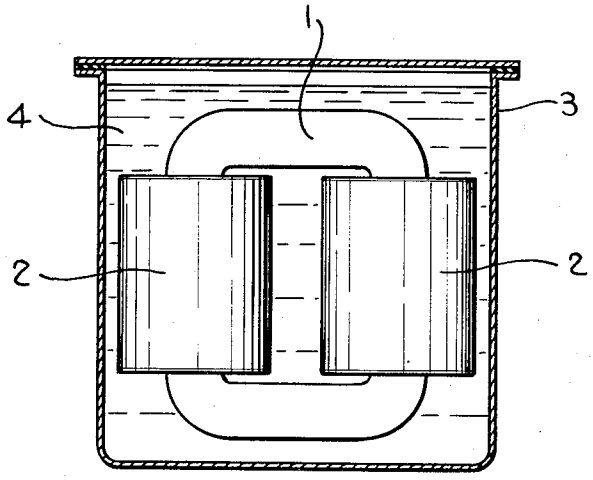


FIG. 1

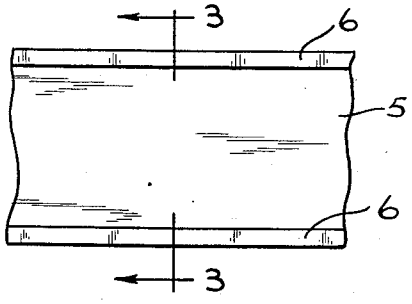


FIG. 2

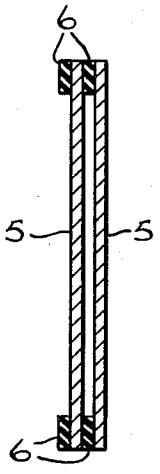


FIG. 3

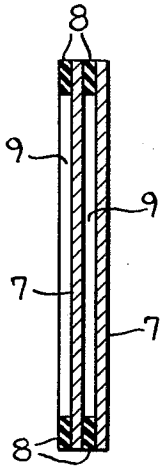


FIG. 5

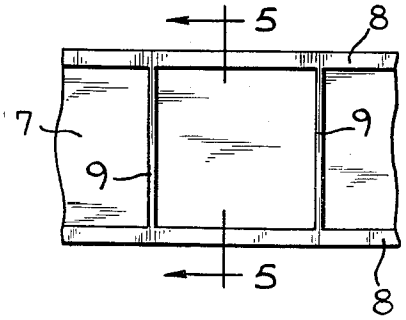


FIG. 4

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CORE CONSTRUCTION FOR TRANSFORMERS

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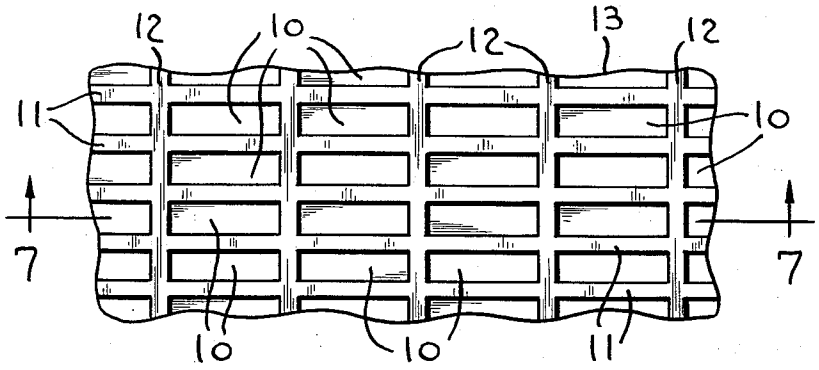


FIG. 6

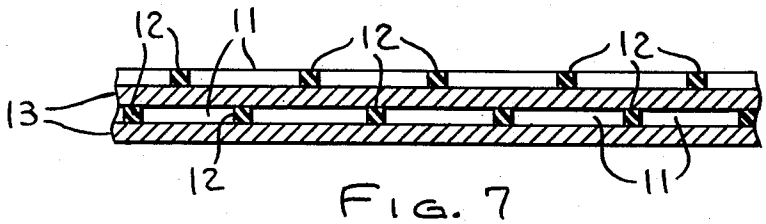


FIG. 7

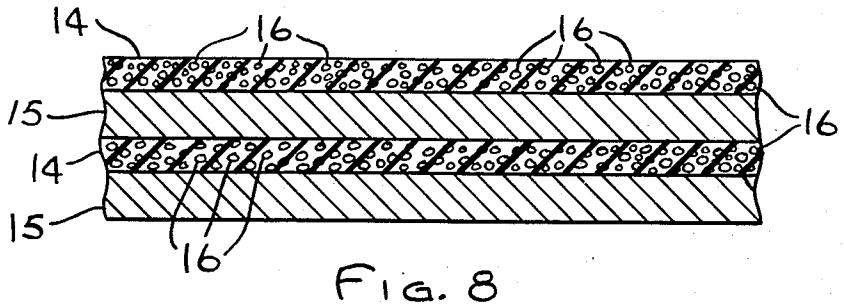


FIG. 8

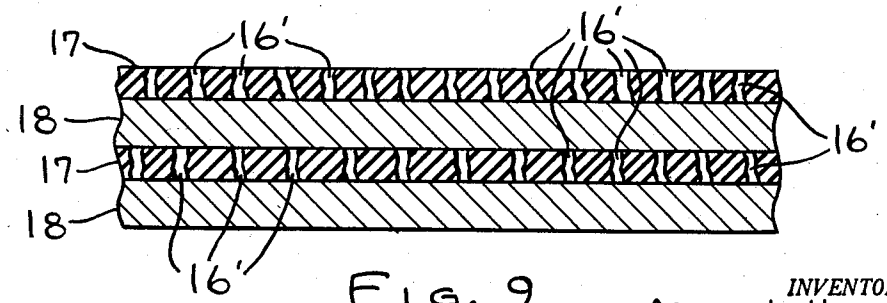


FIG. 9

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CORE CONSTRUCTION FOR TRANSFORMERS

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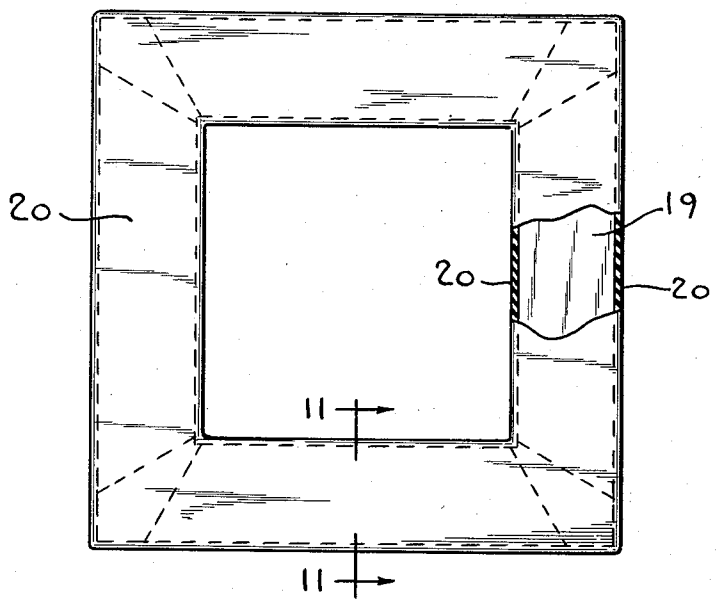


FIG. 10

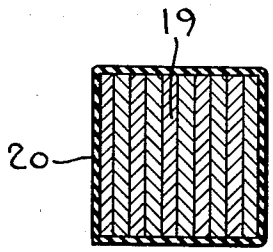


FIG. 11

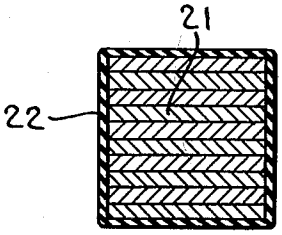


FIG. 13

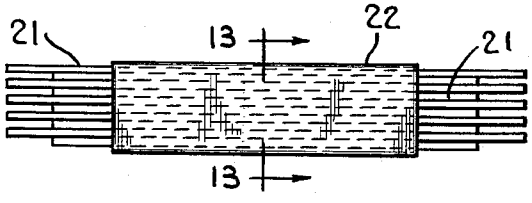


FIG. 12

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2,864,065

CORE CONSTRUCTION FOR TRANSFORMERS

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Application August 5, 1955, Serial No. 526,629

4 Claims. (Cl. 336—100)

This invention relates to transformers, and is particularly directed to the core structure of transformers.

It is the usual practice in transformer core construction to employ cold rolled silicon steel for the laminations. This cold rolled silicon steel has the grain oriented in the direction of the length of the lamination and it is usually finished so as to have a very hard and thin insulating coating. This material is quite expensive, and in order to reduce the weight of the transformer and economize on the core material, it has become the regular practice to work the cores at a high magnetic density thus securing a reduction in size, weight, and cost for any given size of transformer.

One of the results of the increased flux density is an increase in the production or generation of sound energy. The transformers are customarily mounted within a tank and surrounded with oil and it has been found that the sound energy is transmitted through the oil to the tank or outer casing, and in many instances this noise has been so great as to cause complaints to be registered from nearby householders or others in the vicinity of the transformer.

This invention is designed to avoid the above noted defects, and the primary object of this invention is to provide a construction of transformer core which materially reduces the noise or hum from the transformer.

From extensive research it has been found that the noise is transmitted in the form of sound waves within the audible range and having a frequency equal to that of the alternating current or some multiple thereof. It has also been found that most of the noise is transmitted from the laminations through the oil to the tank and from the tank through the air to the nearby residents.

It has further been found from these experiments that most of the sound energy is produced by the relative motion of the laminations with respect to each other and with respect to other portions of the transformer structure. The noise, whether in a stacked core or in a wound core transformer, results from the minute motion of different parts of the transformer, particularly from the motion of the laminations. This motion is produced primarily by magnetostriction and is also produced by the attempt of the laminations to align themselves with the magnetic flux. It has been found that sound energy is transmitted from the oil between successive laminations to the body of the oil surrounding the core and then to the tank and from the tank to the surrounding air.

It has been found that due to the vibratory motion of the laminations in directions at right angles to their planes, that there is a minute and rapid pumping of the oil into and out of the space between successive laminations at frequencies equal to or some multiple of that of the alternating current. Thus energy in the form of moving liquid is transmitted to the main body of oil and from the oil to the tank.

In greater detail, objects of this invention are to provide a core construction in which the oil is prevented from entering either the space between all laminations or the space between certain groups of laminations, and in which the space between successive laminations is filled with gas such for example as air or any desired gas.

Further object of this invention is to provide gas cushions between laminations so as to provide yielding energy-absorbing cushions for the laminations and thus prevent the motion of laminations from being transmitted to succeeding laminations as well as preventing the transmission of the vibratory motion of the laminations to the main body of oil and also to absorb the work being done by the moving laminations by means of the energy-absorbing gas between laminations and thus prevent the energy of the vibrating laminations from escaping the core in the form of liquid in motion.

Embodiments of the invention are shown in the accompanying drawings in which:

Figure 1 is a sectional view showing one form of the transformer enclosed in a tank and immersed in oil.

Figure 2 is a fragmentary face view of one of the laminations of the transformer core showing one form of the invention.

Figure 3 is a sectional view on the line 3—3 of Figure 2.

Figure 4 is a face view of a lamination of a transformer showing a further form of the invention.

Figure 5 is a sectional view on the line 5—5 of Figure 4.

Figure 6 is a fragmentary face view of a lamination of a transformer core showing a further form of the invention, such view being drawn to a greatly enlarged scale.

Figure 7 is a sectional view on the line 7—7 of Figure 6.

Figure 8 is a fragmentary sectional view through a few laminations of a transformer core showing a further form of the invention, such view being very much enlarged.

Figure 9 is a view similar to Figure 8 showing a still further form of the invention.

Figure 10 is a view of an assembled transformer core showing a still further form of the invention.

Figure 11 is a sectional view on the line 11—11 of Figure 10.

Figure 12 is a side elevation of one leg of a transformer core showing a further form of the invention.

Figure 13 is a sectional view on the line 13—13 of Figure 12.

In all forms of the invention shown in the accompanying drawings, the views have been very much exaggerated in order to bring out the different features of the invention. None of the views are to be interpreted as showing exact proportions or the exact relative proportions of different parts of the transformer core.

Referring to Figure 1 it will be seen that the transformer core is indicated by the reference character 1 and the primary and secondary windings by the reference character 2. This transformer is mounted in any suitable manner within a tank or housing 3 and is submerged in oil as indicated by the reference character 4. The term "oil" is used in a generic sense to indicate any insulating and cooling liquid.

It has been found that in the usual transformer constructions that the sound energy or sound wave is transmitted through the oil to the tank due to the vibratory motion of the laminations of the core. The vibrations of the laminations of the core are produced primarily by magnetostriction in which the actual physical dimensions of the laminations are altered. Usually in cold rolled oriented grain silicon steel the laminations elongate in the direction of the orientation of the grain. This alteration is minute but nevertheless it is sufficient to cause relative motion between the laminations themselves and between the laminations and other portions of the core structure. In addition to this, there is motion imparted to the laminations due to the fact that the laminations tend to align themselves with the flux thus producing motion of the

laminations as the magnetic flux varies due to the cyclic changes of the alternating current.

Extensive tests have known that the motion of the laminations occurs for each half cycle of the alternating current flux and therefore produce sound waves of a frequency equal to double the fundamental frequency of the alternating current or some harmonic multiple of the frequency or a mixture of several of these frequencies. The natural result is the generation of sound waves well within the audible range. The sound waves or sound energy it has been found, is transmitted to the outer casing or tank by means of the oil. The oil is pumped in and out from between the laminations no matter how closely they may be stacked in transformers as heretofore constructed.

This invention contemplates the provision of cushioning gas pockets between successive laminations and the preventing of the entrance of oil into the space between successive laminations. The pockets of gas, such as air for instance, sealed or permanently trapped between the laminations prevents the entrance of oil into such space and it has been found that this greatly decreases the amount of sound energy that is transmitted to the oil. These gas pockets serve to cushion and dampen the motion of the laminations and materially prevent the transmission of motion from one lamination to another and also enormously reduces the transmission of sound waves or sound energy through the medium of the oil to the surrounding tank.

Any suitable material may be used to seal or close the space between successive laminations. Some examples of material that may be used are set forth in the U. S. patents to James G. Ford No. 2,372,074 of March 20, 1945, for Bonded Laminated Magnetic Material, and 2,579,560 of December 25, 1951, for Bonded Magnetic Core Structure. For certain forms of the invention foamed or cellular plastic resin such as styrene foam commonly sold under the trade name of "Styrafoam" could be used. Further, a material generally known as cellular rubber commonly sold by numerous producers as "foam-rubber" or "sponge-rubber" could be used. For other forms of the invention a homogeneous sealing strip means for providing gas entrapped areas as illustrated in Figures 2 through 7, inclusive, may be accomplished by the use of a synthetic Buna rubber compound that is well known in the industry as "nitrile." These examples are not intended as limiting but illustrative of suitable materials that could be used.

In the form of the invention shown in Figures 2 and 3 a lamination of the magnetic core is indicated by the reference character **5**. Where used in a wound core transformer as illustrated in Figure 1, the material may be applied at the margins of the laminations as indicated at **6** in Figures 2 and 3. It is to be understood that the drawings are very much enlarged and do not show the relative proportion of the parts. The lamination as prepared in Figures 2 and 3 with the sealing material along the marginal edges is wound into a closed core as indicated in Figure 1, and it will be seen that as the surrounding laminations are wound in place, a small gas space is provided between each successive lamination or convolution. The gas space is sealed at its extreme inner and outer ends by transversely extending sealing material not shown.

For either a wound or stacked type of transformer core the invention shown in Figures 4 and 5 may be employed. This structure is similar in many respects to that shown in Figures 2 and 3. The laminations are indicated by the reference character **7** and each lamination is provided with sealing material **8** along its marginal edge. These marginal strips of sealing material are joined by relatively small transverse strips of sealing material **9** which are fairly closely spaced and provide completely sealed spaces between successive laminations.

It is apparent from the immediately above description of the structure shown in Figures 4 and 5 that this construction may be used for a wound type of transformer core or for a stacked type.

It is obvious also that instead of having a single space or gas pocket extending from adjacent one marginal edge of a lamination to adjacent the other marginal edge, that a multitude of gas pockets or spaces may be provided transversely as well as longitudinally of the laminations. For example, as shown in the greatly enlarged views Figures 6 and 7 it will be seen that a multitude of pockets are provided and are indicated by the reference character **10** and are formed by longitudinal sealing strips **11** joined by transversely extending sealing strips **12** so as to form a large number of gas pockets between the marginal edges of the laminations instead of a longitudinally arranged series of single gas pockets as previously described. Obviously the laminations indicated by the reference character **13** in Figures 5 and 6 may be used in either a stacked core or a wound core.

In the form of the invention shown in Figure 8 the sealing material is formed as a continuous sheet or layer **14** between successive laminations **15**. This material is a sealing material which is a cellular structure in which many gas pockets **16** are formed in any suitable manner. For example, in this particular form of the invention, the cellular foamed material such as that previously described and commonly sold under the name of "Styrafoam" could be used, or a cellular rubber such as that commonly sold under the descriptive names of "foam-rubber" or "sponge-rubber" could be used. In this last described form of the invention shown in Figure 8 the pockets are not closed on their inner and outer sides by successive lamination, but are closed in themselves or in other words are formed as a cellular structure in the sealing material itself, each pocket being completely sealed.

Figure 9 is intended to show the sealing material **17** having an irregular surface providing openings such as shown at **16'**. These openings may extend completely through the sealing material as shown, and may open on both sides thereof, or the openings may extend only part way through the sealing material. In either case the sealing of the openings or gas pockets **16'** is completed by the laminations. This figure is intended to show the sealing material with an irregular surface so as to provide in conjunction with the laminations sealed gas pockets.

In the form of the invention shown in Figures 10 and 11 the entire core structure, indicated generally by the reference character **19**, is coated after it is completely assembled. The coating is of sealing material indicated by the reference character **20**. The sealing completely covers all portions of the core including their overlapped corners as well as throughout their entire body portion. Obviously this form of the invention could be applied to a wound core as well as the stacked core shown in Figure 10.

In the form of the invention shown in Figures 12 and 13 a single leg of the core is shown and the magnetic laminations indicated by the reference character **21** are staggered, so as to provide overlapping at their ends in the usual manner, and each separate leg is coated or enclosed by the sealing material **22**. Obviously after the core has been completely formed by assembling the individually coated or encased legs of the core, the overlapping joints may be sealed by applying sealing material. During the coating operation for the individual legs of the core before they are assembled, the portions which would constitute the interfitting or overlapped portions, may be masked to prevent the sealing material from filling the space between the end portions of alternate laminations.

It is to be distinctly understood that the terms "air pockets" or "gas pockets" are used synonymously.

In each form of the invention it will be seen that the space between successive laminations of the magnetic core is provided with sealed pockets formed by the sealing material either alone or by the sealing material in conjunction with the adjacent magnetic laminations. Also

it is to be understood, particularly for the forms of the invention shown in Figures 4 through 9 that the sealing material may be applied only to alternate laminations and may be carried on both sides of these alternate laminations, the laminations in between the alternate coating laminations being uncoated, or the material may be applied to one side only of each lamination as described above.

In all forms of the invention, however, the gas pockets form cushioning pockets which have the two main functions of cushioning the motion of the laminations and preventing, to a great degree, the transmission of motion from one lamination to the next adjacent lamination. The other main function of the cushioning gas pocket is to exclude the oil from between successive laminations to thereby prevent the transmission of the motion of the laminations to the surrounding oil. Thus, though the motion of individual laminations cannot be stopped, the transmission of energy to the oil directly from the vibrating laminations of the magnetic core is prevented. This prevents to a very marked degree the transmission of sound energy through the oil to the surrounding tank of the transformer.

The sealing material may be applied to the laminations in any suitable manner. In the forms of the invention shown in Figures 4, 5, 6 and 7 the material may be applied to the laminations by means of rollers and the rollers may be suitably shaped or embossed to produce the pattern shown in such figures. In all cases the material is bonded or otherwise firmly secured to the laminations.

It is to be understood that the gas pockets or gas cushions may be provided between each of the successive laminations throughout the entire core structure or may be provided between certain selected laminations as desired or found most expedient.

A few of the many forms that the invention may take have been shown in the disclosure. However, it is to be understood that many other shapes of gas pockets could be employed and therefore although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting as the invention may be variously embodied and is to be interpreted as claimed.

We claim:

1. In a transformer construction, a tank, a body of oil in said tank, a core construction immersed in said oil and comprising a plurality of elongated laminations of magnetic material, and sealing means extending longitudinally of the laminations and having transversely extending portions joining the longitudinally extending portions and forming with the laminations completely sealed cushioning gas pockets between successive laminations, cushioning and energy absorbing gas in said pockets, said sealing means preventing the entrance of oil into the spaces between successive laminations, whereby the transmission of sound energy from the laminations through the oil to the tank is reduced.

2. In a transformer construction, a tank, a body of oil in said tank, a core construction immersed in said oil and comprising a plurality of elongated laminations of magnetic material, and sealing means extending longitudinally of the laminations and having transversely extending portions joining the longitudinally extending portions and forming with the laminations cushioning gas pockets between successive laminations for preventing the entrance of oil into the spaces between successive laminations, cushioning and energy absorbing gas in said pockets, the cushioning gas pockets being arranged in rows both longitudinally and laterally of the laminations, the laminations themselves constituting walls of the pockets for direct contact with the gas in the pockets, whereby the transmission of sound energy from the laminations through the oil to the tank is reduced.

3. In a transformer construction, a tank, a body of oil in said tank, a core construction immersed in said oil and comprising a plurality of elongated laminations of magnetic material, and sealing means between successive laminations, said sealing means having a multitude of closed cellular cushioning gas pockets both longitudinally and laterally of the laminations.

4. In a transformer construction, a tank, a body of oil in said tank, a core construction immersed in said oil and comprising a plurality of elongated laminations of magnetic material, and sealing means between successive laminations, said sealing means having a multitude of openings, cushioning and energy absorbing gas in said openings, said openings being closed at their ends by the faces of the laminations, the laminations themselves constituting walls of the pockets for direct contact with the gas in the pockets.

References Cited in the file of this patent

UNITED STATES PATENTS

2,261,983	Ford	Nov. 11, 1941
2,579,560	Ford	Dec. 25, 1951

FOREIGN PATENTS

642,433	Germany	Mar. 5, 1937