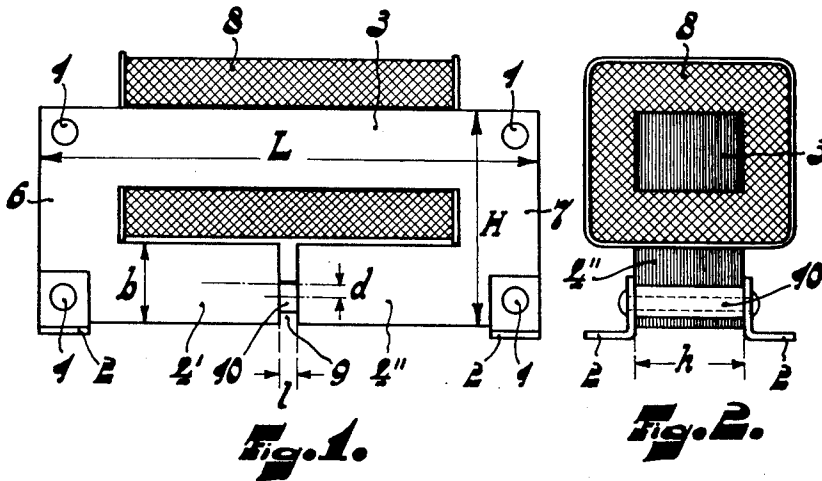
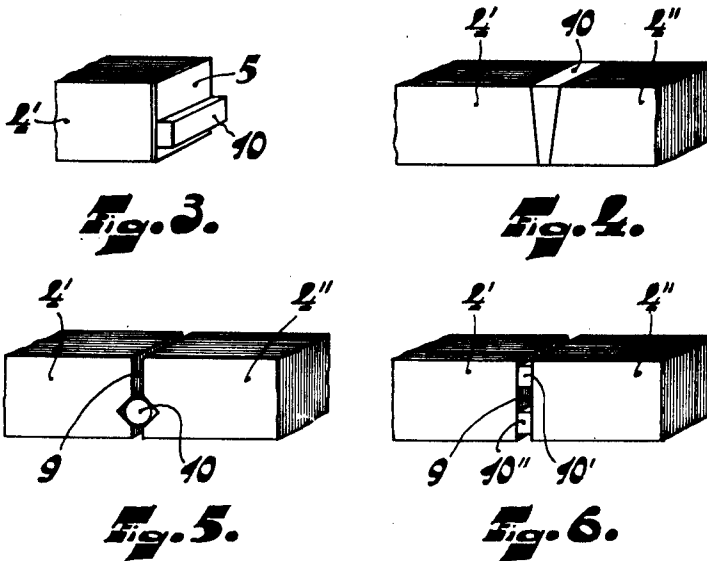


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TRANSFORMER OR CHOKE COIL OF THE  
CORE TYPE HAVING AN AIR-GAP  
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## TRANSFORMER OR CHOKE COIL OF THE CORE TYPE HAVING AN AIR-GAP

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This invention relates to transformers or choke coils of the closed core type having an air-gap in one limb.

It has been found that in such electromagnetic devices vibrations are produced in the core when the device is excited, which vibrations may be transmitted through the supporting members for the device to the mounting surface so that the mounting surface will emit the vibrations in the form of sound.

The object of this invention is to reduce the vibrations of the device.

According to the invention, this is accomplished by providing a non-magnetic member in the air-gap so disposed that the resultants of the reactive forces exerted by the non-magnetic member in the air-gap upon the two parts of the limb bounding the air-gap are acting on points in the plane passing through the center lines of the limbs, whereas the reactive forces act on points shifted from the center line of the limb comprising the air-gap in a direction remote from the window in the core.

Preferably, these points should be selected so that the amplitude of the vibrations to be attenuated is a minimum, which points may be readily ascertained experimentally.

In one embodiment of the invention, the air-gap and the non-magnetic member diverge towards the window.

In a further embodiment of the invention, a straight rod of non-magnetic material is employed, the axis of which is at right angles to the plane of the center lines of the core-sections. The rod may be cylindrical in shape and clamped between recesses provided in the terminal surfaces of the portions of the limb bounding the air-gap. The rod may be provided at about  $\frac{2}{3}$  of the width of the said portions of the limb, as viewed from the window.

Alternatively, two straight non-magnetic rods may be employed, the axes of which are normal to the plane of the center lines of the limbs, the rod provided on the side of the window consisting of material having a rigidity smaller than that of the other rod.

The non-magnetic member may also have a non-homogeneous constitution in the direction of the magnetic lines of force in the air-gap.

The invention will now be described in connection with the accompanying drawing, in which:

Fig. 1 shows a plan view of a choke coil according to the invention;

Fig. 2 shows an elevational view of the same choke coil;

Fig. 3 shows in perspective the non-magnetic member attached to a portion of the core;

Fig. 4 shows in perspective a portion of the core including the non-magnetic member;

Fig. 5 shows in perspective a portion of the core including a cylindrical non-magnetic member; and

Fig. 6 shows in perspective a portion of the core including two non-magnetic members.

Figs. 1 and 2 show a choke coil, the core of which is constituted by stacked, C-shaped layers of sheet-iron which are held together by bolts 1. The lower bolts also serve to secure L-shaped supporting members 2 to the assembly of sheet-iron plates. The sheet-iron plates constitute two horizontal limbs 3 and 4', 4'', respectively, and two vertical yokes 6 and 7. The upper limb 3 is provided with a winding 8 which, alternatively, may be provided on the other limb. The limbs 3, 4', 4'' and the yokes 6, 7 constitute the core of the choke coil. This circuit is closed by an air-gap 9 between the adjacent ends of the portions 4', 4'' of the core. In the air-gap there is provided a non-magnetic member in the form of a homogeneous rectangular rod 10.

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According to the invention, this rod is disposed in the air-gap in such manner that its axis at right angles to the sheet-iron layers lies lower than the common center line of the portions 4' and 4'' of the core. During operation, the rod exerts reactive forces upon the core portions, the resultants of which are located in the plane of the center lines of the core and which are exerted, at the level of the axis of the rod, parallel to the center lines of the portions 4', 4'' of the core. This asymmetric positioning of the non-magnetic member in the air-gap insures that vibrations of the ends of the portions 4' and 4'' of the core bounding the air-gap in the upward direction are prevented or at least materially reduced. Moreover, the non-magnetic member must have sufficient rigidity to withstand the forces exerted thereon.

In a specific example, the width  $b$  of the portions 4' and 4'' of the limb was 17 mms., the height  $h$  of the stack was 23 mms., the largest horizontal dimension  $L$  of the core portion was 105 mms. and the largest vertical dimension  $H$  was 45 mms. The length  $l$  of the air-gap, that is to say, the spacing between the core portions 4' and 4'', was 1.5 mms. The rod 10 was constituted by a brass plate of 23 x 5 x 1.5 mms. Upon variations of the magnetic inductance in the air-gap from 0 to 12,500 Gauss, the following largest vertical movements of the air-gap ends of the core portions 4', 4'' occurred as a function of the position of the rod 10 in the air-gap: with  $d=0$  mm.:  $\pm 0.14$  micron (in the upward direction); with  $d=6$  mms.:  $-0.11$  micron (in the downward direction); with  $d=3$  mms.: immeasurably small, that is to say, less than 0.01 micron, considering the sensitivity of the measuring equipment employed. Here  $d$  indicates how much the axis of the rod at right angles to the sheet-iron layers lies lower than the common center line of the portions 4' and 4'' of the core.

The rod 10 may be secured to the side of a vertical plate 5, for example, of hard paper (see Fig. 3) or, if desired, may be secured between two such plates so that the insertion of the rod at the correct position in the air-gap is facilitated. Insofar as the winding 8 is provided on the portions 4' and 4'' of the limb, this winding or its former may be used for fixing the said plates in position. By a suitable choice of the thickness of the plate or plates and of the rod in the direction of the magnetic lines of force in the air-gap, it is furthermore possible to vary the total rigidity of the non-magnetic member in the air-gap which, in this case, has a non-homogeneous constitution.

In the embodiment shown in Fig. 4, the non-magnetic member is wedge-shaped and the ends of the core portions 4' and 4'' of the core diverge accordingly in the upward direction; that is to say, towards the window. The resultants of the reactive forces exerted by the non-magnetic member upon the portions 4', 4'' of the core, in this case, do not pass through the center of gravity of the non-magnetic member in the air-gap, but pass through a point vertically underneath, since the rigidity of the filling in the narrow parts is greater than that in the wide parts.

In the embodiment shown in Fig. 5, the non-magnetic member has a cylindrical shape, the axis of which is at right angles to the sheet-iron layers. This axis is at about  $\frac{1}{3}$  of the height of the portions 4', 4'' of the core. The rod may be clamped between two V-shaped recesses provided in the air-gap ends of the portions 4' and 4'' of the core in order to secure the rod therebetween.

In the embodiment shown in Fig. 6, the non-magnetic member is constituted by two rods 10' and 10''. The upper rod 10' is of hard paper and the lower rod 10'' is of brass. In this case, the resultants of the reactive forces are not located midway between the rods but are shifted towards the brass rod 10'' of greater rigidity.

While the invention has thus been described with specific examples and applications, other modifications and applications thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding

on the core, a wedge-shaped non-magnetic member having a greater cross-sectional area on the side of the axis of the arm portions nearest the back leg portion than the cross-sectional area on that side of the axis remote from the back leg portion mounted within the air-gap and abutting the arm portions bounding the air-gap whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in a plane containing said axis.

2. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, a rectangular rod-shaped non-magnetic member mounted within the air-gap on that side of the axis of the arm portions bounding the air-gap which is remote from the back leg portion and abutting the arm portions bounding the air-gap whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in a plane containing said axis.

3. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, and a non-magnetic member mounted within the air-gap and abutting the arm portions bounding the air-gap, said non-magnetic member having an asymmetrical distribution of mass about a plane parallel to and including the axis of said arm portions, said non-magnetic member having a portion on the side of said axis remote from said back leg portion of greater rigidity than portions on the other side, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in the plane containing said axis.

4. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, said two coaxially-spaced arm portions having a central axis, a winding on the core, and a wedge-shaped non-magnetic member mounted within the air-gap and abutting the arm portions bounding the air-gap, said wedge-shaped member having a portion on the side of said axis of said arm portions remote from said back leg portion of greater rigidity than portions on the other side, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in a plane containing said axis.

5. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, and a rod-shaped non-magnetic member mounted within the air-gap and abutting the arm portions bounding the air-gap, said non-magnetic member being asymmetrically located with respect to a plane parallel to and including the axis of said arm portions and lying more on the side of said axis remote from the back leg portion than on the other side whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in the plane containing said axis.

6. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, a cylindrical non-magnetic member mounted within the air-gap and abutting the arm portions bounding the air-gap, said non-magnetic member having an asymmetrical distribution of mass about a plane parallel to and including the axis of said arm portions, said

member exhibiting greater rigidity on the side of said axis remote from said back leg portion than on the other side, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in the plane containing said axis.

7. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, a cylindrical non-magnetic member mounted within the air-gap the axis of which is located on the side of the axis of the arm portion which is remote from the back leg portion a distance equal to two-thirds of the width of the air-gap and which bears upon the arm portions bounding the air-gap, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to the axis of the arm portion and on the side thereof remote from the back leg portion and the resultants of the reactive forces are located in a plane containing the axis of the arm portions.

8. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, a first non-magnetic member of given rigidity mounted within the air-gap on the side of the axis of the adjoining arm portions remote from the back leg portion, a second non-magnetic member having a rigidity which is less than that of said first non-magnetic member mounted within the air-gap on that side of said axis nearest the back leg portion, said non-magnetic members together constituting a member asymmetrically bearing upon the arm portions bounding the air-gap, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in the plane containing said axis.

9. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air-gap therebetween, a winding on the core, a non-magnetic member mounted within the air-gap and having a variable cross-sectional rigidity with respect to a plane parallel to and including the axis of the arm portions and abutting the arm portions bounding the air-gap, said member having greater rigidity on the side of said axis remote from the back leg portion than on the other side, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to the axis of the arm portions bounding the air-gap and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in a plane containing said axis.

10. An inductor comprising a C-shaped magnetic core including a back leg portion and two coaxially-spaced arm portions defining an air gap therebetween, a winding on the core, a rod-shaped member eccentrically mounted within the air-gap with respect to a plane parallel to and including the axis of the arm portions and abutting the arm portions bounding the air-gap, said member lying more on the side of said axis remote from the back leg portion than on the other side, whereby the reactive forces exerted by the non-magnetic member, when the inductor is excited with an alternating current flowing through the winding, are exerted in a plane parallel to said axis and on the side thereof remote from the back leg portion, and the resultants of the reactive forces are located in the plane containing said axis.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |           |               |
|-----------|-----------|---------------|
| 1,654,097 | Shakelton | Dec. 27, 1927 |
| 2,136,895 | Sola      | Nov. 15, 1938 |
| 2,168,173 | Sabbah    | Aug. 1, 1939  |
| 2,265,700 | Outt      | Dec. 9, 1941  |
| 2,382,638 | Keiser    | Aug. 14, 1945 |