

Dec. 17, 1946.

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2,412,914

MAGNETIC CORE

Filed May 7, 1942

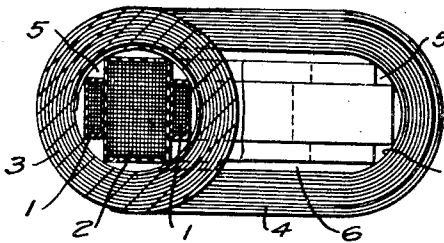


Fig. 1.

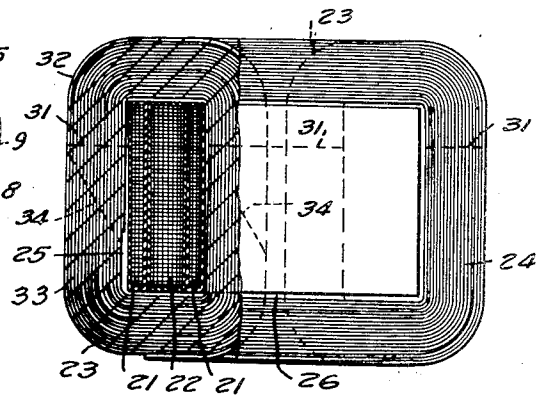


Fig. 3.

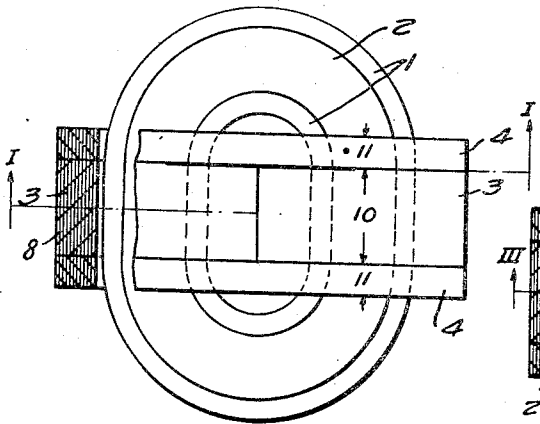


Fig. 2.

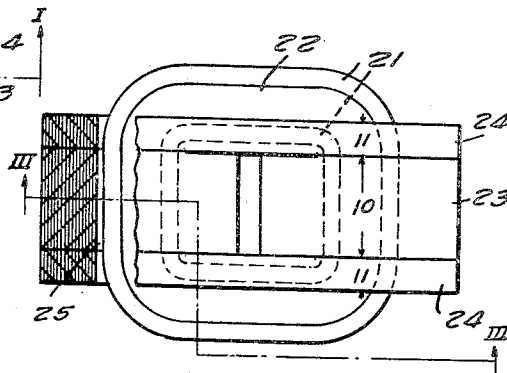


Fig. 4.

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## UNITED STATES PATENT OFFICE

2,412,914

## MAGNETIC CORE

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Application May 7, 1942, Serial No. 442,058

7 Claims. (Cl. 175-356)

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Our invention relates to electrical induction apparatus such as transformers and, particularly, to the core or magnetic circuit structure thereof.

Years of research in magnetic sheet steel have resulted in the development of cold rolled steels having preferred orientation of the axis of easiest magnetization of the crystal grains of the material in the direction of rolling. The permeability in the direction of rolling of such cold rolled steel is considerably higher at operating densities, say, 13 to 17 kilogausses, than the permeability of commercial grades of hot rolled silicon steel at the same densities. The permeability in other than the rolling direction is considerably lower than the permeability in the rolling direction. Likewise, the watts loss per unit volume or per unit weight at operating densities, when magnetized in the direction of rolling, is lower than for commercial grades of hot rolled silicon steel at the same density.

To effectively utilize such material in a transformer core, it is necessary that the direction of magnetic flux coincide substantially with the rolling direction at all parts of the core. This can readily be done by forming the core of a ribbon of sheet steel having preferred orientation of the grains in the direction of rolling of the strip, that is, in the direction in which the lines of magnetic flux pass through the strip. The loops of magnetic material comprising the core structure may be made up by winding a continuous strip of material flatwise to give the desired dimensions, the loop being cut to provide butt joints at suitable places to form separable core sections that fit over the copper circuit conducting windings.

Various arrangements of this type of wound core loops have been devised to accomplish this result, and at the same time to secure desirable dimensional relations between the iron and copper circuits comprising the core and coil assemblies. These arrangements are very desirable from the standpoint of the transformer builder in that it is not necessary to use dies which are expensive and which must be changed when the design of the apparatus is modified.

However, these prior art designs have, in general, certain objections due to the necessity of forming butt joints in the magnetic circuit which increase the exciting current or magnetizing current required and further because the arrangements of the core parts are such that the entire magnetic circuit must be operated at the same density. It is a general experience in the design and manufacture of transformers that it is desirable to operate those portions of the magnetic circuit around which the copper or current conducting circuit is wound at a higher flux density than the remaining portion of the magnetic circuit, thus reducing the amount of

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copper required in the core and coil assembly structure. The cross-section of that portion of the magnetic circuit exterior to the window of the coil may be made greater than the cross section of the winding leg of the core that is within the coil window. This increasing of the cross-sectional area exterior to the coil window is termed "widening."

It is an object of the invention to provide electrical induction apparatus comprising core and coil assemblies in which the harmful effects of the joints in the magnetic circuit are minimized.

It is a further object of the invention to provide a greater cross-sectional area of the core at points not surrounded by the associated electrical circuit conductor, thereby reducing the flux density at such portions of the magnetic circuit.

Other objects and advantages of the invention will be apparent from the following description taken from certain preferred embodiments thereof, reference being had to the accompanying drawing, in which:

Figure 1 is an elevational view, partly in section, along the line I—I in Fig. 2 of a core and coil assembly constructed in accordance with the invention;

Fig. 2 is a plan view, partly in section, of the assembly shown in Fig. 1;

Fig. 3 is an elevational view, partly in section, taken along the line III—III of Fig. 4; and

Fig. 4 is a plan view, partly in section, of the coil and core assembly shown in Fig. 3.

Referring to the drawing, Figs. 1 and 2 illustrate a single phase transformer coil and core assembly employing two secondary winding coils 1 on opposite sides of a primary winding coil 2, these windings or coils being formed of an electrical circuit conductor and being inductively related through a core structure comprising two loops 3 of magnetic material shown as being circular in form and extending through the central opening or window in the coil structure, so as to form closed magnetic circuits about the circuit conductor of the coils. The core structure also includes closed magnetic circuit looping portions 4 having an elongated window 6 and closing two opposite sides of the electrical coils. Each of the core loops are formed from a ribbon of magnetic sheet steel wound flatwise to the desired dimension, the window 5 of the circular loops 3 being of a size suitable to accommodate the coils 1 and 2. The elongated loops 4 are made up of a similar number of turns of ribbon sheet steel and so arranged as to have an inner curved surface 8 and an outer curved surface 9 at the two opposite ends which correspond in curvature to the inner and outer surfaces of the core loops 3. As shown in Fig. 2, the core loops 4 are placed on

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opposite sides and closely adjacent to the two loops 3 which are positioned in alignment so as to make a substantially unitary structure, the outer end portions of the core having a width corresponding to the width 10 of the loop 3 plus the width 11 of each of the two longer loops 4. Thus, the cross-section of the portions of the core structure remote from the window of the conducting coil is widened or increased in cross-sectional area so that the flux density in these portions of the core structure is less than in the portions passing through the window of the coils.

The structure shown in Figs. 3 and 4 corresponds, in general, to that shown in Figs. 1 and 2 except that the core loops 23 which extend through the windows in the copper conducting primary coil 22, and secondary coils 21 is rectangular in section so that the three enclosed circuit conducting coils may be formed of the same width from top to bottom. In this construction also, the windows 25 of the core loops 23 are more completely filled with the copper conducting coils so that there is less waste space of the window area. This is also true of the windows 26 of the outer elongated loops 24 which, like the loops 4 in Figs. 1 and 2, extend about two opposite sides of the circuit conducting coils and are placed closely adjacent to the two loops 23 which are positioned in alignment.

The core loops are formed by winding a continuous strip of magnetic material as above described, which material may be cut as shown by the horizontal lines 31 in Fig. 3 to form upper and lower core sections 32 and 33 that may be suitably assembled about the coil structure. If desired, the core loop may be cut along other lines than 31, such as along the sloping lines 34. By cutting the core to provide greater area of gap at the butt joint, the reluctance of the joint is reduced.

It will be appreciated that one or more wound core loops may be used in one core and coil assembly and that there may be a single coil as in a reactor or primary and secondary windings as in the typical transformer assembly. It will also be appreciated that the widening groups of layers of magnetic material may be added to one or both sides of the core loops. These widening groups of layers may be formed as continuous loops as illustrated, or they may be discontinuous adjacent the ends of the winding legs of the core loops, if desired.

It will be apparent to those skilled in the art that modifications in the structure and the arrangement of the parts may be made within the spirit of our invention, and we do not wish to be limited other than by the scope of the appended claims.

We claim as our invention:

1. In a single phase core and coil assembly, in combination, an electrical circuit conductor forming an electrical coil having a window extending therethrough, a core of magnetic material comprising layers of magnetic material extending through the window in said coil and forming two main closed magnetic circuit loops about opposite sides of the electrical coil, said magnetic circuit loops comprising turns of magnetic sheet material wound flatwise layer upon layer, each successive layer being about the others with the inner layer outlining the opening in the core loop and the outer layer outlining the core loop, said two loops being arranged with corresponding flat faces in alignment, and two additional groups of layers of magnetic material for widening the core sec-

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tion exterior to the window extending along the aligned faces of the main core loops on opposite sides thereof and on the outside of the electrical coil, forming two closed magnetic circuit loops enclosing two opposite sides of the electrical coil, said two closed magnetic circuit loops having their outer peripheries remote from the coil window aligned with the outer peripheries of the adjacent portions of the first named loops, each widening core loop comprising turns of magnetic sheet material wound layer upon layer, each successive layer being about the other turns of the loop, the turns of layers of magnetic sheet material in the separate core loop parts of the magnetic circuit being in the same plane throughout the greater portion of the main core loop part that is outside of the window of the circuit conducting coil with edges of the turns of the widening core parts closely adjacent opposite edges of the turns of the main core loop part on the opposite sides thereof to provide a low reluctance area between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop and the widening core loop parts.

2. In a single phase core and coil assembly, in combination, an electrical circuit conductor forming an electrical circuit conducting coil having a window extending therethrough, a core of magnetic material comprising two main core loops of magnetic material each wound flatwise layer upon layer and extending through the window in the coil, the two loops being arranged with their opposite flat faces in alignment and having the same cross-sectional areas throughout their lengths, and two additional widening core loops of magnetic material wound flatwise layer upon layer and extending about opposite sides of the electrical coil adjacent the first two main core loops each with one face against one of the opposite flat faces of the two main core loops, said two widening core loops having the same outer and inner dimensions as the opposite outer end portions of the two main core loops and positioned adjacent the first two named loops with the outer and inner surfaces of the end portions remote from the coil window in alignment, the turns of layers of magnetic sheet material in the widening core loop parts being in the same plane throughout the greater portion of the main core loop parts that are outside of the window of the circuit conducting coil, with edges of the turns of the widening core parts closely adjacent opposite edges of the turns of the main core loop parts on the opposite sides thereof to provide a low reluctance area between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop parts and the widening core loop parts.

3. In a single phase core and coil assembly, in combination, an electrical circuit conductor forming an electrical circuit conducting coil having a window extending therethrough, a core of magnetic material comprising two main loops of magnetic material each wound flatwise layer upon layer and extending through the window in the circuit conducting coil, the two main loops being arranged with their opposite flat faces in alignment and having the same cross-sectional areas throughout their lengths, and additional magnetic material comprising widening strips for increasing the cross-sectional area of the path of the magnetic flux in the portion of the magnetic circuit path outside of the window of the electrical circuit conducting coil above the cross-

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sectional area of the portion of the magnetic circuit path extending through the coil window, said widening strips comprising layers of magnetic material positioned flatwise with their edges adjacent the edges of the two core loops, said widening strips having the same outer and inner dimensions as the portions of the two named loops exterior to the coil window, and positioned adjacent the two named loops, the turns of the layers of magnetic sheet material in the widening strips being in substantially the same plane as the turns in the main core loops throughout the greater portion of the main core loop parts that are outside of the window of the circuit conducting coil, with edges of the turns of the widening core parts closely adjacent opposite edges of the turns of the main core loop parts on the opposite sides thereof to provide a low reluctance area between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop parts and the widening core loop parts.

4. In a core assembly, in combination, a core comprising two main core loops of magnetic material each wound flatwise layer upon layer, the two main core loops having the same cross-sectional areas throughout their lengths with their opposite flat faces in alignment, and two additional widening core loops of magnetic material wound flatwise and extending adjacent the first two core loops each with one face against one of the opposite flat faces of the first two named core loops, said two widening core loops having the same outer and inner dimensions as the opposite outer end portions of the two main core loops and positioned adjacent the two main core loops with the outer and inner surfaces of the end portions remote from the winding leg in alignment, the turns of the layers of magnetic sheet material in the widening strips being in substantially the same plane as the turns in the main core loops throughout the greater portion of the main core loop parts that are outside of the window of the circuit conducting coil, with edges of the turns of the widening core parts closely adjacent opposite edges of the turns of the main core loop parts on the opposite sides thereof to provide a low reluctance area between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop parts and the widening core loop parts.

5. In a single-phase core assembly, in combination, a core comprising a plurality of main core loops of magnetic material each wound flatwise layer upon layer, the main core loops being arranged with opposite flat face surfaces in alignment and having the same cross-sectional areas throughout their lengths, and means for increasing the cross-sectional area of the path of the magnetic flux in the portion of the main core magnetic circuit paths that are physically remote from each other comprising additional layers of magnetic material wound flatwise layer upon layer and extending adjacent the flat face surfaces of the portions of the first named loops and forming a closed loop structure aligned with the outer portions of the first named loops, the turns of additional layers of magnetic material being in substantially the same plane as the turns in the main core loops throughout the greater portion of the main core loop parts that are outside of the window of the circuit conducting coil, with edges of the turns of the additional layers of magnetic material closely adjacent edges of the turns of the main core loops to provide a low reluctance area between them.

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6. In a single-phase core and coil assembly, in combination, an electrical circuit conductor forming an electrical coil having a window extending therethrough, and a magnetic structure comprising a main core loop part of magnetic material wound flatwise layer upon layer, each successive layer being about the others with the inner layer outlining the opening in the core loop and the outer layer outlining the core loop, the core loop extending through the window in said electrical coil and forming a closed magnetic circuit about the circuit conductor of the coil, and additional turns of magnetic sheet material also wound flatwise layer upon layer, each successive layer being about the others to form a widening core loop part for increasing the cross-sectional area of the path of the magnetic flux in the portion of the magnetic circuit path outside of the window of the electrical circuit conducting coil above the cross-sectional area of the portion of the magnetic circuit path extending through the coil window, and forming a closed loop of magnetic material enclosing both the opposite sides of the electrical coil, the turns of layers of magnetic sheet material in the separate core loop parts of the magnetic circuit being in the same plane with the edges of the turns of the widening core part closely adjacent edges of the turns of the main core loop part throughout the greater portion of the main core loop part that is outside of the window of the circuit conducting coil to provide a low reluctance between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop and the widening core loop parts.

7. In a single-phase core and coil assembly, in combination, an electrical circuit conductor forming an electrical coil having a window extending therethrough, and a magnetic structure comprising a main core loop part of magnetic material wound flatwise layer upon layer, each successive layer being about the others with the inner layer outlining the opening in the core loop and the outer layer outlining the core loop, the core loop extending through the window in said electrical coil and forming a closed magnetic circuit about the circuit conductor of the coil, and two additional widening core loop parts for increasing the cross-sectional area of the path of the magnetic flux in the portion of the magnetic circuit path outside of the window of the electrical circuit conducting coil above the cross-sectional area of the portion of the magnetic circuit path extending through the coil window, each widening core loop comprising turns of magnetic sheet material wound layer upon layer, each successive layer being about the other turns of the loop, the turns of layers of magnetic sheet material in the separate core loop parts of the magnetic circuit being in the same plane throughout the greater portion of the main core loop part that is outside of the window of the circuit conducting coil with edges of the turns of the widening core parts closely adjacent opposite edges of the turns of the main core loop part on the opposite sides thereof to provide a low reluctance area between the main and widening core loop parts to permit the flow of magnetic flux freely between the main core loop and the widening core loop parts.

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