Nov. 19, 1946. E. FRIES 2,411,370

TRANSFORMER WITH VARIABLE SECONDARY REACTANCE

Filed June 14, 1943 2 Sheets-Sheet 1

Fig. 1

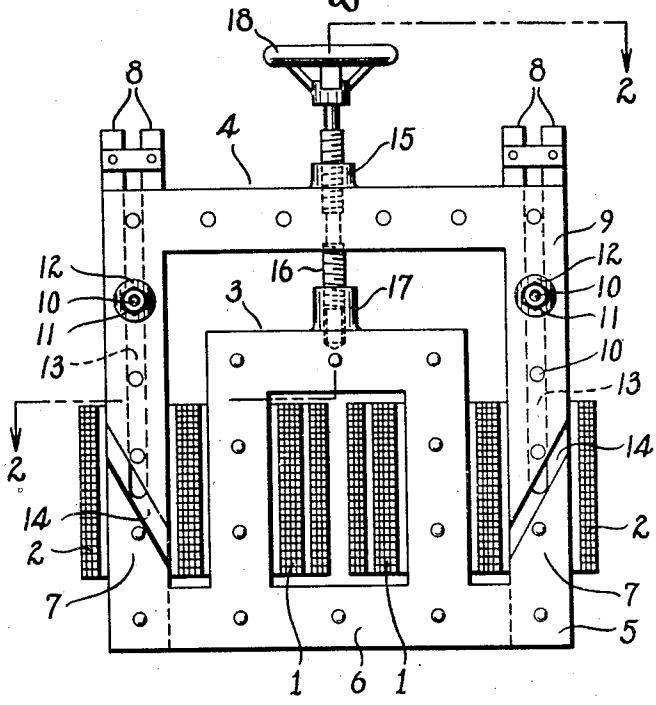
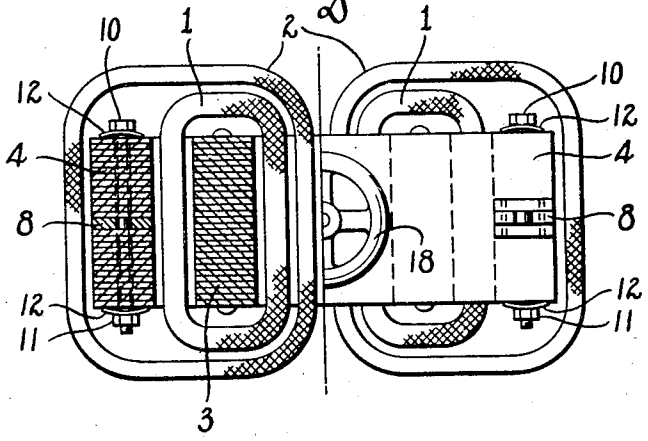


Fig. 2



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Fig. 3

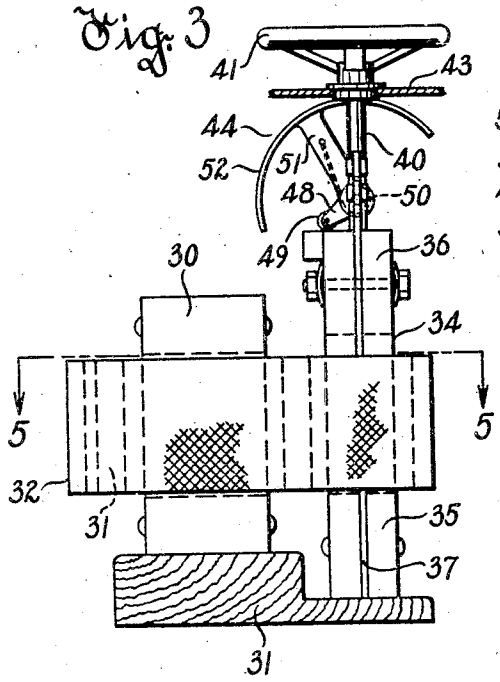


Fig. 4

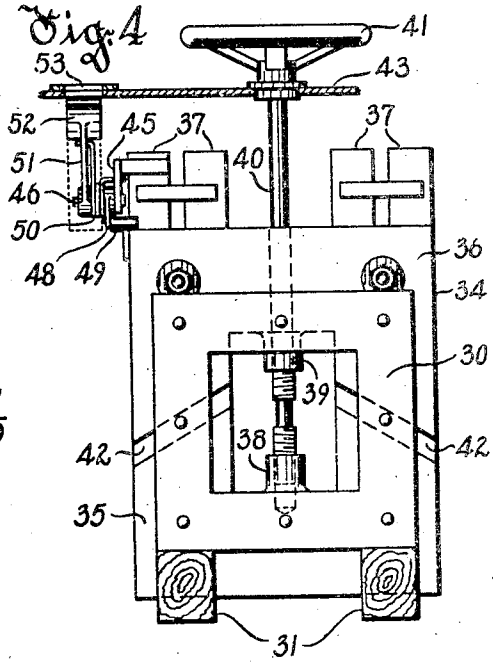
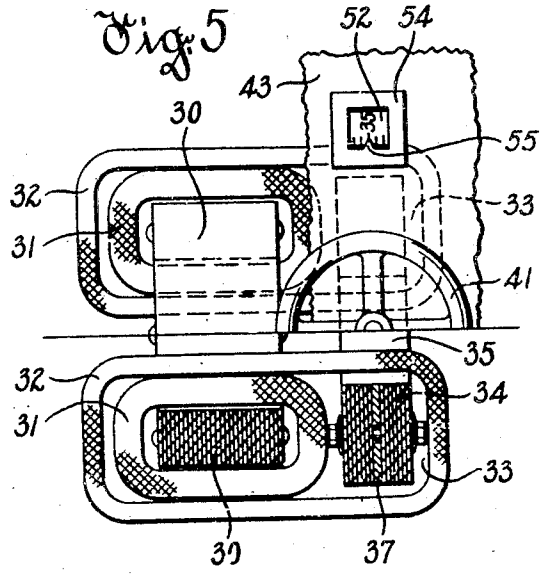


Fig. 5



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TRANSFORMER WITH VARIABLE SECONDARY REACTANCE

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In Switzerland July 6, 1942

9 Claims. (Cl. 171—119)

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The present invention relates to transformers with variable reactance and is particularly applicable to transformers for welding or the like in which the reactance of the secondary circuit is variable within wide limits.

The reactance component of transformers which determines the ratio of the primary and secondary voltage for different load currents has in the past been made regulable by inserting iron laminations into the leakage path of the primary magnetic flux, that is in shunt with the main flux path. For heavier sections of the magnetic circuit thin sheets were assembled in a known manner to form stacks of laminations. The magnetic forces exerted on these stacks may be very high, in which case they must be mounted very solidly in order to avoid noises and vibrations.

This is not too difficult for a constant reactance which permits of stationary mounting of the stacks. However, if a reactance which is adjustable within a wide range is required, it is necessary to provide a variable air gap in the shunt magnetic path. It is structurally difficult to provide for adjustment of the air gap between wide limits in a simple and inexpensive manner, if vibrations and noises in the apparatus are to be avoided. Such vibrations are disturbing and may in time lead to the destruction of the apparatus.

An object of the present invention is to provide simple means for varying the air gap in the path of the secondary magnetic flux of transformers having a high reactance which is adjustable within wide limits, without producing excessive noises or vibrations.

Another object is to provide in a transformer with primary and secondary windings, a magnetic core which is inductively coupled with the secondary winding of said transformer only and which is provided with a variable air gap.

Another object is to provide a unitary structure of a transformer and a reactor, the reactor being inductively coupled with the secondary windings of the transformer only and having an adjustable reluctance.

Another object is to provide a high reactance transformer having primary and secondary windings, a primary core inductively interlinked with the primary and the secondary windings, and a secondary core having a variable reluctance and interlinked with the secondary winding only.

Another object is to provide a transformer and a variable reactor with a primary winding inductively mounted on the core of said transformer and a secondary winding inductively interlinked

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with both the core of the transformer and the variable reactor.

Other objects and advantages will hereinafter appear.

The preferred form of the invention provides transformer cores of rectangular cross section and rectangular coils. The transverse interspace between the primary and secondary coil is enlarged on one side and a secondary core with an adjustable air gap and inductively interlinked with the secondary coil only, is inserted into this enlarged space. This leakage or secondary core consists of a stationary part and a movable part, having an air gap between them. The stationary part is fixedly connected with the main transformer core or its support and projects axially into the aforementioned interspace from one end of the coils. The movable part which completes the secondary core is inserted from the other end. This latter part is arranged to be moved in and out of the coil by a simple mechanism in such a manner that the air gap is approximately at the central transverse plane of the coils. In case of a two coil single phase core type transformer the leakage core comprises two opposed U-shaped parts, while for three phase transformers the leakage comprises two opposed E-shaped parts, in which case the increased distance between the primary and secondary coils is preferably arranged on the narrow side of the rectangular coils. The stationary secondary core part has at each pole at least one guide bar and the corresponding movable part is pressed against this bar, but so that it is still possible to slide it relative thereto. The pressure is preferably exerted by spring discs.

The accompanying drawings are illustrative of two embodiments of the invention. In the drawings,

Fig. 1 is a vertical section of the embodiment of the invention in a single phase transformer.

Fig. 2 is a top view and partially a cross-section along the lines 2—2 of Fig. 1.

Fig. 3 is a side view of a modification of the transformer illustrated in Fig. 1.

Fig. 4 is a front view of Fig. 3, while

Fig. 5 is a top view, partially in section along the lines 5—5 of the transformer shown in Figs. 3 and 4.

Referring to Figs. 1 and 2, the same illustrates a single phase transformer having two primary coils 1, two secondary coils 2, and a closed main magnetic laminated core 3.

The coils are rectangular in shape and the transverse distance between the coils 1 and 2 is

increased at one side thereof to provide a space for a laminated secondary core 4, which is coplanar with the core 3 and comprises a U-shaped stationary part 5, the center section 6 of which is common with one leg of the main core 3. The vertical legs 7 of the stationary part 5 are provided at their center with flat magnetic or non-magnetic guide bars 8 and a movable U-shaped part 9 of the secondary core is arranged to straddle these guide bars and to slide longitudinally thereon. The movable part 9 is provided with insulated bolts 10 provided with nuts 11 and interposed spring washers 12 to hold the laminations together and press them against the guide bars. The bolts 10 are arranged to move in slots 13 of the guide bars, to permit movement of the part 9 relative to the stationary part and thereby vary air gaps 14 between adjacent limbs of the respective parts.

To provide for adjustment of the air gap the movable part 9 has fixed thereto a tapped boss 15 which engages a threaded shaft 16. A second tapped boss 17 is attached to the core 3. The threads in the two bosses and the coacting threads of the shaft are in opposite directions, so that upon turning of the shaft 16 by the handwheel 18 attached to its upper end the movable part 9 is moved toward or away from the stationary part, to thereby vary the air gap 14 and thus the reluctance of the leakage core and the reactance of the secondary coils.

In order to provide for a more gradual adjustment of the leakage reactance the air gap may be arranged as shown at an angle to the direction of movement of the movable part. However the air gap may be of any other desired shape and it may partially be bridged by a magnetic shunt such as the guide bars 8 if they are made of magnetic material.

The apparatus functions in the following manner: When the primary coils are connected to an alternating current source a current flows therethrough which induces a flux in the main magnetic core 3. This flux in turn induces an electromotive force in the secondary coils 2 in the usual manner. If now the circuit of the secondary coils is closed through a translating device as for instance a welding machine, a current flows in the secondary winding. This current induces a secondary flux which passes through the core 3 in a direction opposite to that of the primary flux. An additional flux is induced in the secondary core 4, the two secondary fluxes being so related that they jointly are proportional to the counter electromotive force induced in the secondary winding.

The lower the reactance of the leakage core relative to the reluctance of the main core the greater is the proportion of the total secondary flux which passes through the secondary core. The reluctance of the secondary core is largely determined by the length of the air gap 14 so that by increasing the air gap the secondary flux is reduced and vice versa. Thus by moving the part 9 up and down relative to the part 5 the secondary counter-electromotive force is varied to thereby vary the net or output secondary voltage of the transformer. The secondary or leakage flux varies with the current flowing in the secondary winding so that for any given adjustment of the air gap 14 the secondary voltage decreases with increasing current, as is desirable for a welding transformer or the like. On the other hand, the open circuit voltage of the transformer is only slightly affected by the reluctance

of the secondary magnetic circuit and hence by the length of the air gap 14. It is thus possible by adjustment of the air gap to adjust the secondary terminal voltage for any given current within very wide limits.

Referring now to Figs. 3, 4, and 5, the same illustrates a transformer having a primary closed magnetic core 30 which is fixedly mounted on a support 31 by any suitable means (not shown). The two vertical limbs of the core 30 are each provided with a primary coil 31 and a secondary coil 32. In one direction the inside cross-sectional dimension of the secondary coil is made considerably greater than the corresponding outside cross-sectional dimension of the coil 31, to provide for a space 33 into which projects the vertical limbs of a secondary core 34 having a stationary U-shaped part 35 and a movable U-shaped part 36. The part 35 is fixed to the base 31 and its two limbs are preferably provided at their center with guide bars 37 which are arranged and constructed similarly to the guide bar 8 of Fig. 1. The movable U-shaped member 36 is preferably arranged similar to the part 9 of Fig. 1, so as to straddle the guide bars 37. The laminations of the member 36 are clamped together and against the guide bars 37 in the manner shown in Fig. 2 for the part 9. A threaded boss 38 is fixed to the center limb of the member 35 and a similar boss 39 to the member 36. The two bosses are threaded in opposite directions and engage cooperating screw threads of a shaft 40 provided with a handwheel 41. By turning the handwheel in one direction or the other the member 36 is moved relative to the member 35 in the manner aforedescribed in connection with Figs. 1 and 2 to vary an air gap 42 therebetween.

The entire apparatus is preferably enclosed in a casing of which only a portion of the top is shown at 43. The shaft 40 extends through the casing and the handwheel 41 is arranged outside thereof. In order to indicate the position of the member 36 an indicator 44 is provided. The same comprises a bracket 45 which is fixed to one of the guide bars 37 or any other stationary part of the apparatus and is provided with a horizontal axle 46. Mounted on said axle is a bell crank lever having an arm 48 which is provided with a roller 49 which engages the top surfaces of the member 36. The bell crank is biased in a counterclockwise direction by a spring 50. A second arm 51 of the bell crank carries a circular segment 52. The cover 43 is provided with a window 54 through which the circular segment 52 can be observed. The window is provided with a pointer 55. The outer circumference of segment 52 is provided with indicia which may be in terms of the reactance of the secondary circuit or in terms of the welding current for which the reactance is to be adjusted. If the member 36 is moved up and down by operation of the handwheel 41 the bell crank is rotated in a clockwise or counterclockwise direction respectively, so that different indicia corresponding to the position of the member appear at the window opposite the pointer 55. In this manner the adjustment of the reactor is facilitated from the outside.

While the drawings show only a single guide bar 8 and 37, respectively, at each leg of the reactor, it is obvious that a multiplicity of such guide bars may be employed. This is particularly advantageous if the structure is very large in the direction transversely to the laminations, that is if it comprises a large number of laminations. By providing more than one guide bar the pres-

sure on the laminations is better equalized, thereby reducing the amount of noise and vibration incident to the magnetic effects in the laminated structure.

The apparatus shown is capable of many modifications, for instance, the invention may be used with a three phase transformer and three phase reactor, whereby the transformer is provided with three limbs and three sets of primary and secondary coils and the two halves of the reactor each comprise an E-shaped frame, each leg of the E projecting into the space between the corresponding primary and secondary coils.

What I claim as new and desire to secure by Letters Patent is:

1. A transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed primary magnetic core, a primary winding of substantially rectangular transverse cross-section inductively mounted on said core in fixed relation thereto, a secondary winding of substantially rectangular transverse cross-section telescoped over said primary winding and mounted in fixed relation to said primary winding and said core, and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of said primary winding, a secondary magnetic core arranged to pass axially through the space between said walls of the primary and secondary windings so as to be inductively interlinked with said secondary winding only, said secondary core comprising a part mounted stationary with respect to said windings and another part which is movable relative to said stationary part to interpose a variable air gap in the path of the flux induced in said parts by said secondary winding, said air gap being located near the transverse central plane of said secondary winding, a guide bar fixed to one of said parts, means attached to said other part and arranged to hold the latter in resilient sliding engagement with said bar, and means to reciprocate said movable part on said guide bar for varying the length of said air gap.

2. A single phase transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed rectangular primary magnetic core, a pair of primary and a pair of secondary coils, one of said primary and one of said secondary coils being mounted on one and the other primary and secondary coil being mounted on the other of two opposite side members of said rectangular core, said coils being of substantially rectangular transverse cross-section with each secondary coil telescoped over the respective primary coil and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary coil, a rectangular secondary magnetic core arranged with its opposite side members passing axially through the space between said walls so as to be inductively interlinked with said secondary coil only, said secondary core comprising a U-shaped part mounted stationary with respect to said coils and an inverted U-shaped part which is movable relative to said stationary part to interpose variable air gaps between the respective opposed pole faces of said parts, and said air gaps being located near the transverse central plane of said secondary coils, and means to reciprocate said movable part relative to said stationary part to vary the length of said air gaps.

3. A single phase transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed rectangular primary magnetic core, a pair of primary and a pair of secondary coils, one of said primary and one of said secondary coils being mounted on one and the other primary and secondary coil being mounted on the other of two opposite side members of said rectangular core, said coils being of substantially rectangular transverse cross-section with each secondary coil telescoped over the respective primary coil and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary winding, a rectangular secondary magnetic core arranged with its opposite side members passing axially through the space between said walls so as to be inductively interlinked with said secondary coil only, said secondary core comprising a U-shaped part mounted stationary with respect to said coil and an inverted U-shaped part which is movable relative to said stationary part to interpose a variable air gap between the respective opposed pole faces of said parts and said air gaps being located near the transverse central plane of said secondary coils, a guide bar fixed to each of the side members of said stationary part, means attached to the side members of said movable part and arranged to hold the latter in resilient sliding engagement with said bar, and means to reciprocate said movable part relative to said stationary part to vary the length of said air gap.

4. A single phase transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed rectangular primary magnetic core, a pair of primary and a pair of secondary coils, one of said primary and one each of said secondary coils being mounted on one and the other primary and secondary coil being mounted on the other of two opposite side members of said rectangular core, said coils being of substantially rectangular transverse cross-section with each secondary coil telescoped over the respective primary coil and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary coil, a rectangular secondary magnetic core arranged with its opposite side members passing axially through the space between said walls so as to be inductively interlinked with said secondary coil only, said secondary core comprising a U-shaped part mounted stationary with respect to said coils and an inverted U-shaped part which is movable relative to said stationary part to interpose variable air gaps between the respective opposed pole faces of said parts, and said air gaps being located near the transverse central plane of said secondary coils, and means to move said movable part relative to said stationary part to vary the length of said air gaps, said means comprising a screw tap attached to said stationary part and a screw tap attached to the movable part, said taps having their threads in opposite directions and a shaft provided with threads cooperating with said taps and with a handwheel whereby rotation of said handwheel in opposite directions affords relative movement between said parts to thereby adjust the length of said air gap.

5. A single phase transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed rectangular primary magnetic core, a pair of primary and a pair of secondary coils, one of said primary coils and one

of said secondary coils being mounted on one and the other primary and secondary winding being mounted on the other of two opposite side members of said rectangular core, said coils being of substantially rectangular transverse cross-section with the secondary coil telescoped over the respective primary coil and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary coil, a rectangular secondary magnetic core arranged with its opposite side members passing axially through the space between said walls so as to be inductively interlinked with said secondary coil only, said secondary core comprising a U-shaped part mounted stationary with respect to said coil and an inverted U-shaped part which is movable relative to said stationary part to interpose a variable air gap between the respective opposed pole faces of said parts, and said air gaps being located near the transverse central plane of said secondary coils, a guide bar fixed to each of the side members of said stationary part, means attached to the side members of said movable part and arranged to hold the latter in resilient sliding engagement with said bar, and means to move said movable part relative to said stationary part to vary the length of said air gaps, said means comprising a screw tap attached to said stationary part and a screw tap attached to the movable part, said taps having their threads in opposite directions, and a shaft provided with threads cooperating with said taps and with a handwheel whereby rotation of said handwheel in opposite directions affords relative movement between said parts to thereby adjust the length of said air gap.

6. A transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed primary magnetic core having a plurality of legs, a primary winding for each of said legs and inductively encircling the same, a secondary winding for each of said legs and encircling the same and the respective primary winding and having its inner circumferential wall spaced from the outer circumferential wall of the respective primary winding, a secondary magnetic core having a leg for each of said secondary windings, each of said last named legs being provided with an adjustable air gap and being arranged to pass axially through the space between the walls of the respective primary and secondary windings, and means to vary the length of said air gaps.

7. A transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed magnetic core having a plurality of legs, a primary winding of substantially rectangular transverse cross-section for each of said legs and inductively encircling the same, a secondary winding of substantially rectangular cross-section for each of said legs telescoped over the respective primary winding and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary winding, a secondary magnetic core having a leg for each of said secondary windings, said secondary core being closed save for a variable air gap in each of said last named legs, said last named legs being arranged to pass axially through the space between the walls of the respective primary and secondary windings, and said air gaps being located near the transverse central plane of said secondary windings, and means to vary the length of said air gaps.

8. A transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed primary circuit having a plurality of legs, a primary winding of substantially rectangular transverse cross-section for each of said legs and inductively encircling the same, a secondary winding of substantially rectangular transverse cross-section for each of said legs telescoped over the respective primary winding and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary winding, a secondary magnetic core having a leg including a variable air gap for each of said secondary windings and being arranged to pass through the space between the respective walls of the primary and secondary windings, said air gaps being located near the transverse central plane of said secondary windings and extending between two planar pole faces parallel with each other and at an angle to said plane and means to vary the length of said air gaps.

9. A transformer providing for adjustment of its secondary reactance within wide limits, comprising, a closed primary magnetic core having a plurality of legs, a primary winding of substantially rectangular transverse cross-section for each of said legs and inductively encircling the same in fixed relation thereto, a secondary winding of substantially rectangular transverse cross-section for each of said legs and telescoped over the respective primary winding and mounted in fixed relation thereto and having one side of its inner circumferential wall spaced a substantial distance from the outer circumferential wall of the respective primary winding, a secondary magnetic core having a leg for each of said secondary windings and arranged to pass axially through the space between the walls of the respective primary and secondary windings, said secondary core comprising a part mounted stationary with respect to said windings and another part which is movable relative to said stationary part to interpose variable air gaps in the path of the flux induced in said parts by said secondary windings, said air gaps being located near the transverse central plane of the respective secondary windings, and means to move said movable part relative to said stationary part to vary the length of said air gaps.

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