Aug. 13, 1957 E. A. HOBART ET AL 2,802,981

TRANSFORMER WELDER WITH ELECTRICALLY ADJUSTABLE LEAKAGE REACTANCE

Filed Dec. 23, 1953 2 Sheets-Sheet 1

Fig. 1.

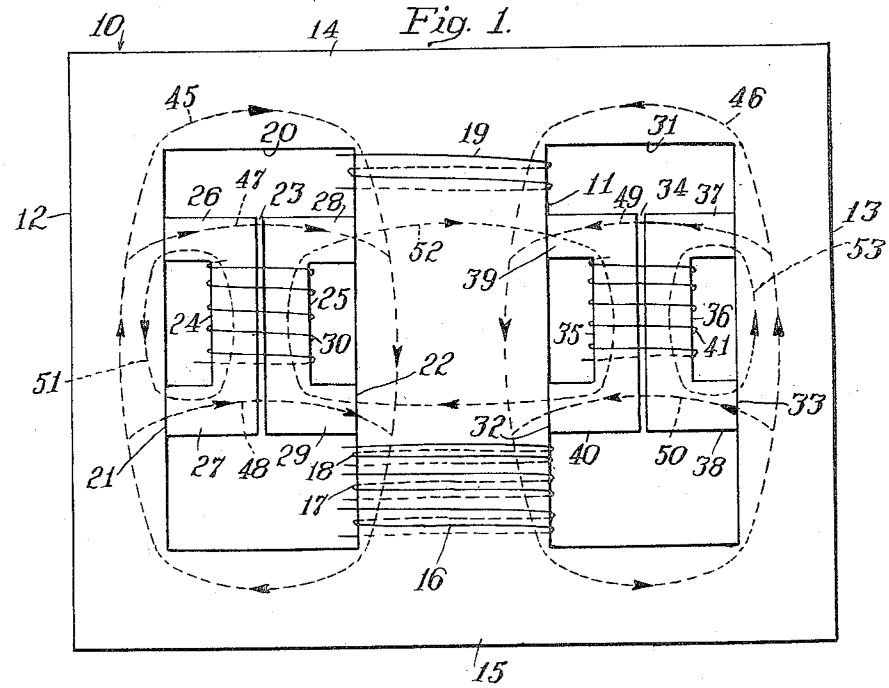
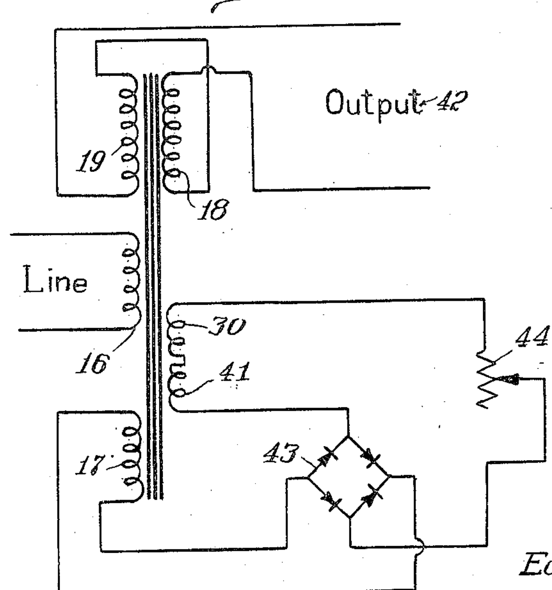


Fig. 2.



INVENTORS
Edward A. Hobart
John H. Blankenbuehler
BY and William R. Schober

Toulmin & Toulmin
ATTORNEYS

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Fig. 3.

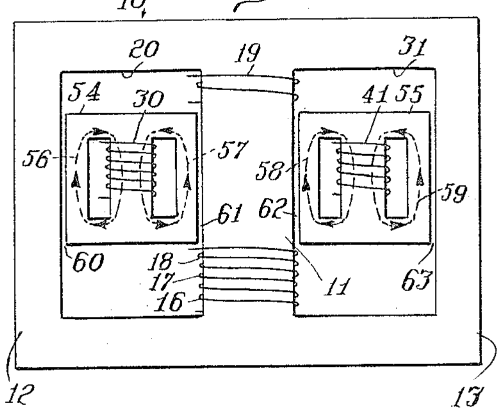


Fig. 4.

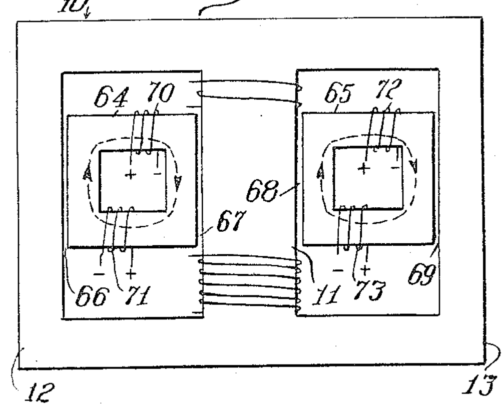


Fig. 5.

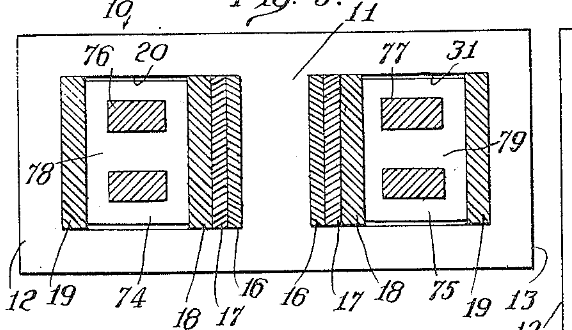


Fig. 6.

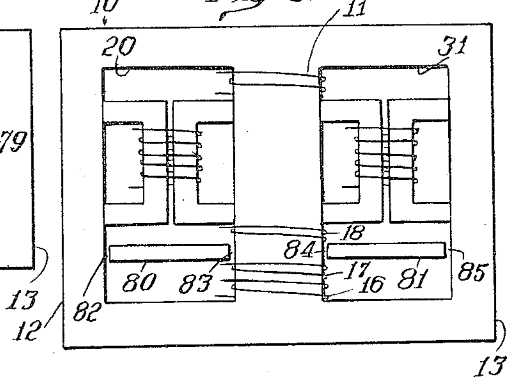


Fig. 7.

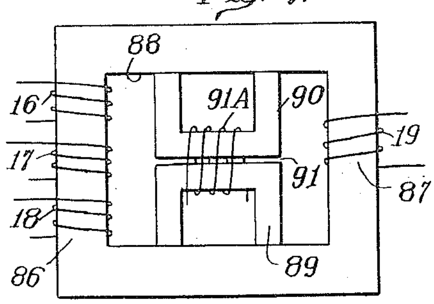
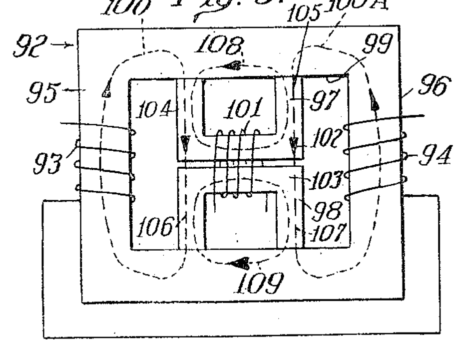


Fig. 8.



INVENTORS

Edward A. Hobart

John H. Blankenbuehler

BY and William R. Schober

Toulmin & Toulmin

ATTORNEYS

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TRANSFORMER WELDER WITH ELECTRICALLY ADJUSTABLE LEAKAGE REACTANCE

Edward A. Hobart, John H. Blankenbuehler, and William R. Schober, Troy, Ohio, assignors to The Hobart Brothers Company, Troy, Ohio, a corporation of Ohio

Application December 23, 1953, Serial No. 400,038

19 Claims. (Cl. 323—56)

Heretofore welding apparatus comprised a transformer for converting higher voltage down to the required voltage desirable for welding. In addition, means was provided to vary the amperes output of the transformer. This variable means was usually a reactor electrically connected to the transformer. With the apparatus of this type it was, therefore, necessary that two distinct electrical devices be utilized, namely, a transformer and a reactor.

As is well known in the art, the conventional core for a transformer comprises a plurality of substantially parallel legs having the ends thereof connected by end members. The entire core structure is made from a highly magnetic material and results in a core structure generally resembling a plurality of rectangles connected to each other along their longer sides. As current is passed through the primary winding, a magnetic flux is set up which passes through the leg carrying the primary winding and through a return path consisting of the adjacent leg and the end members connecting the ends of these legs. As this flux is common to the secondary winding which is usually around the same leg as the primary winding, it is referred to as mutual flux. Some of the mutual flux will pass through the relatively high reluctance space formed by the air space between the adjacent legs. This flux is termed leakage flux. As load current is increased on the secondary winding an increasing quantity of the mutual flux becomes leakage flux. This action produces the characteristic droop in secondary voltage as load current is increased.

In the present invention, leakage core members are placed in the path of the leakage flux. However, in order to prevent saturation of the leakage path through the leakage core members an air gap is placed in the leakage path. This air gap also prevents the leakage path from affecting the flux coupling between the secondary and primary windings at no load conditions to a degree sufficient to reduce the open circuit voltage.

This invention discloses the structure whereby the leakage flux from the secondary winding is utilized to control the load current. This means is in effect a saturable reactor combined with the structure of the transformer.

In addition to the necessary transformer, there was entailed the cost of providing a suitable reactor. The present invention has greatly simplified the existing welding apparatus and greatly reduced the cost thereof by disclosing a transformer structure in which the reactor is built upon the same transformer core of the step-down transformer. The welder of this invention is of the electrically adjustable leakage reactance type and comprises a conventional single phase magnetic transformer core. A group of windings comprising a primary and a plurality of secondary windings are wound around one of the legs of the magnetic core. Another secondary winding is wound around preferably the same leg carrying the aforementioned windings. Leakage path means are provided between adjacent legs and between said group

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of windings and the secondary winding. The various forms which the leakage path means may take will be subsequently pointed out in greater detail. An air gap is placed in said leakage path. A direct current control coil is wound around each leakage path means. This invention discloses that the control coil may be energized by one of the secondary windings on the transformer. A rectifier may be used to change the alternating current in the secondary winding to the direct current utilized in the control coil. Other methods by which direct current may be obtained for use in the control coils will be readily apparent to one skilled in the art.

The primary object of the invention is to provide a new electrically adjustable leakage rectance type of welding transformer.

Another object of the invention is to provide a welding transformer having control coils in which effectively no A. C. voltage is induced.

A further object of the invention is to provide a welding transformer whose open circuit voltage is effectively independent of the setting of the control rheostat.

An additional object of the invention is to provide a welding transformer whose secondary leakage reactance is sufficiently large to produce the drooping volt-ampere characteristic required of an alternating current welder and to provide control of this leakage reactance to permit adjustment of the welding current.

The invention will be better understood and additional objects will become readily apparent when reference is made to the following description and accompanying drawings, in which:

Figure 1 is a diagrammatic view showing the preferred form of the apparatus embodying this invention;

Figure 2 is a wiring diagram of the circuit utilized in this invention;

Figure 3 is a diagrammatic view of a modification of the invention in which the direct flux does not pass through the main transformer core;

Figure 4 is a diagrammatic view of a modification of the invention wherein a single window leakage path is provided;

Figure 5 is a partial sectional view showing the transformer coils being wound concentrically;

Figure 6 is a diagrammatic view showing a variation of the invention wherein additional leakage paths are inserted;

Figure 7 is a diagrammatic view showing the application of the invention to a core-type transformer; and

Figure 8 is a diagrammatic view showing the application of the invention to provide control of the impedance of a saturable reactor.

Referring back to the drawings, more particularly to Figure 1, wherein like reference numbers refer to same parts throughout the various views, **10** indicates generally a magnetic transformer core. The transformer core **10** comprises a center leg **11** and two outer legs **12** and **13**. The legs **11**, **12** and **13** are connected at the ends thereof by end pieces **14** and **15**. A primary winding **16** is wound around one end of the center leg **11**. Secondary windings **17** and **18** are also wound around the same end of the center leg **11**. An additional secondary winding **19** is wound around the other end of the center leg **11**.

Between the legs **11** and **12** there is a window **20** in which are mounted two leakage core members **21** and **22**. The leakage core members **21** and **22** are substantially C-shaped and are placed back to back within the window **20**. There is an air gap **23** between the back sides **24** and **25**, respectively, of the leakage core members **21** and **22**. The arms **26** and **27** of the leakage core member **21** are in contacting relationship with the outer leg 12. The arms 28 and 29 of the leakage core member 22 are similarly in contacting relationship with the center leg 11. A direct current control winding 30 is wound around the longer legs 24 and 25, respectively, of the leakage core members 21 and 22.

Between the legs 11 and 13 of the transformer core 10 there is a window 31 in which are mounted two leakage core members 32 and 33 which are similar in structure to the leakage core members 21 and 22. The leakage core members 32 and 33 are so mounted within the window 31 that there is an air gap 34 between the longer sides 35 and 36, respectively of the leakage core members 32 and 33. The arms 37 and 38 of the leakage core member 33 are in contacting relationship with the outer leg 13 and the arms 39 and 40 of the leakage core member 32 are in contacting relationship with the center leg 11. A direct current control coil 41 is wound around the longer legs 35 and 36, respectively, of the leakage core members 32 and 33.

Figure 2 which is a wiring diagram of the circuit involved in this invention serves to relate the various components as disclosed in Figure 1 to each other. From Figure 2 it will be seen that the secondary windings 18 and 19 form the output 42 of the transformer of this invention. It will also be seen that the secondary winding 17 serves to energize the control coils 30 and 41. The secondary winding 17 is connected to one side of a rectifier 43, and the other side of the rectifier 43 is connected to the control coils 30 and 41. A rheostat, indicated generally as 44, is inserted between the rectifier 43 and control coils 30 and 41 in order to vary the control current.

Referring back to Figure 1, the operation of the invention is as follows:

As current is passed through the primary winding 16 alternating current flux is set up, the paths of which are indicated as 45 and 46. It will be seen that leakage flux paths 47, 48, 49 and 50 are provided through the leakage core members 21 and 22 between the legs 11 and 12 and through the leakage core members 32 and 33 between the legs 11 and 13. As the load on the output windings 18 and 19 is increased, the M. M. F. of the secondary winding 19 will divert an increasing percentage of flux from the flux paths 45 and 46 to the paths 47 through 50.

When direct current flows through the control coils 30 and 41, direct fluxes 51, 52 and 53 are set up. As this direct current is increased the direct fluxes 51 through 53 tend to saturate the leakage paths used by the fluxes 47 through 50 in the direction shown in Figure 1. This direct saturation effectively reduces the leakage area provided by the paths 47 through 50 and thus serves to decrease the leakage reactance of the secondary winding 19. This action will provide an increase of load current for a given load voltage while retaining the drooping volt-ampere characteristic. It can be seen, therefore, that the magnitude of the control current determines the degree of saturation, and consequently the load current.

Saturation of the leakage paths 47 through 50 by the direct fluxes 51 through 53 would tend to increase the mutual fluxes 45 and 46 between the primary winding 16 and the secondary windings 18 and 19. This in turn would cause an increase in the open circuit voltage with an increase in the control fluxes 51 through 53. However, the open circuit voltage is held effectively constant by passing the direct fluxes 51 through 53 through the legs 11, 12 and 13 of the transformer 10, as shown in Figure 1. Thus, the mutual flux coupling the primary and secondary windings is virtually independent of the control current.

It is pointed out that since the axes of the control coils 30 and 41 are perpendicular to the direction of flow of the leakage fluxes 47 through 50 the voltage induced in the control coils 30 and 41 is negligible. It has also

been found that the self-induction of the secondary winding 18 is no affected to a noticeable degree by the leakage paths 47 through 50 and is, therefore, very low. It is possible to further control the total inductance in the secondary circuit by changing the ratio of turns in winding 19 to the turns in winding 18. The variation of this ratio would provide a coarse adjustment of load current.

While the form of the transformer as illustrated in Figure 1 is preferable, the invention need not be limited to this construction. The remaining Figures 3 through 7 illustrate some of the many modifications possible of the invention.

Figure 3 shows leakage core members 54 and 55 placed in the windows 20 and 31, respectively, of the transformer core 10. The leakage core members 54 and 55 are of substantially the same shape as the core 10. These core members 54 and 55 are so mounted that the legs thereof are parallel to the legs 11, 12 and 13 of the core 10. When the control coils 30 and 41 are energized direct current fluxes indicated by the paths 56, 57, 58 and 59 are set up wholly within the leakage core members 54 and 55. Thus, by providing return paths for the direct fluxes and placing the air gaps 60, 61, 62, and 63 between the return paths of the leakage core members 54 and 55 and the main core 10 no effective direct flux passes through the main transformer core.

If desired, a single window leakage path may be provided, as disclosed in modification of the invention illustrated in Figure 4. In Figure 4 the leakage core members 64 and 65 are substantially square-shaped with air gaps 66, 67, 68, and 69 between the return paths of the leakage core members 64 and 65 and the legs 11, 12, and 13 of the main core 10. In this modification the control coils 70, 71, 72, and 73 must be connected in such a manner so as to cancel the voltages induced in them.

Figure 5 discloses a modification of the invention wherein the transformer windings may be wound concentrically about the center leg 11 of the transformer core 10. The primary winding 16 is first wound around the center leg 11 and both secondary windings 17 and 18 wound concentrically about the primary winding 16. Leakage core members 74 and 75 are inserted in the windows 20 and 31, and the secondary winding 19 is then wound concentrically about the leakage core members 74 and 75 and the transformer windings 16, 17 and 18. The control coils 76 and 77 are then wound about the middle legs 78 and 79, respectively, of the leakage core members 74 and 75.

As illustrated in Figure 6, additional leakage paths may be inserted between the secondary windings 17 and 18. These additional leakage paths comprise bar-like members 80 and 81 which are inserted in the windows 20 and 31. Air gaps 82, 83, 84 and 85 are placed between the ends of the bar-like members 80 and 81 and the legs 11, 12 and 13 of the core 10, substantially as shown in Figure 6. By means of this modification, the slope of the volt-ampere characteristic may be changed.

As has been apparent, the transformers disclosed in Figures 1 through 6 are all of the shell type. Figure 7 discloses that the invention could also be applied to core-type transformers. In a core-type transformer the primary winding 16 and the secondary windings 17 and 18 are placed on the outer leg 86, and the secondary winding 19 mounted on the outer leg 87. In the window 88 a pair of leakage core members 89 and 90 are mounted. There is an air gap 91 between the backs of the leakage core members 89 and 90 and a control coil 91A is wound around said backs of the leakage core members 89 and 90. It should be noted that in this modification the open sides of the leakage core members 89 and 90 face the end pieces of the transformer instead of the legs about which the various windings are wound, as is the case in the invention disclosed in Figure 1.

Figure 8 discloses that this invention may also be used to provide control of the impedance of a saturable reactor indicated generally as **92**. The alternating current windings **93** and **94** are wound around the outer legs **95** and **96** of the saturable reactor **92**. Equal turns in the alternating current windings **93** and **94** set up equal alternating current fluxes, indicated as **100** and **100A** respectively, which flow through the leakage core members **97** and **98** located in the window **99** of the saturable reactor **92**. A direct current control coil **101** is wound around the back legs **102** and **103**, respectively, of the leakage core members **97** and **98**. No alternating voltage is induced in the control coil **101**, but a direct current flux **108** flows in both of the legs **104** and **105** of the core member **97** and another direct current flux **109** flows in the legs **106** and **107** of the core member **98**. Consequently, any change of current in the control coil causes a change in the total flux linking the alternating current coils **93** and **94**, and hence a change of inductance.

Referring back to the invention as illustrated in Figure 1 and to the many embodiments thereof, as illustrated in Figures 3 through 8, it can be seen that an air gap is provided in each one of these modifications in the path of the alternating current leakage flux flow. Under certain conditions it may be deemed desirable to omit this air gap altogether. However, it has been found that the air gap should not be placed in the path of the direct current control flux. If an air gap should be placed in the path of the control flux, the transformer will operate unsatisfactorily as compared to the construction where there is no air gap in the path of the control flux.

It will be understood that various modifications and arrangements in structure could be made without departing from the spirit of this invention, and accordingly it is desired to comprehend such modifications and substitutions of the equivalents as may fall within the scope of the appended claims.

Having fully described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. An alternating current transformer comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, a secondary winding around said center leg, a pair of C-shaped leakage core members placed back to back between adjacent legs and between said group and secondary windings, the tips of the ends of said C-shaped members in contact with the respective legs, additional leakage path means between adjacent legs, air gaps between the backs of said C-shaped members and between the ends of said leakage path means adjacent to said legs, and a control coil around the backs of each pair of leakage core members.

2. An alternating current transformer, comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, a secondary winding around said center leg, a leakage core member between adjacent legs and between said group and secondary windings, each leakage core member comprising a center and two outer legs having the ends thereof connected by end members, the outer legs of said core members being substantially parallel to the legs of said magnetic core, air gaps between the outer legs of said leakage core members and the adjacent legs of said magnetic core, and a control coil around the center leg of each leakage core member.

3. An alternating current transformer, comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a primary winding around said center leg, a plurality of secondary windings wound concentrically around said center leg, a pair of leakage core members mounted between adjacent legs of said magnetic core and the two outer secondary windings, each leakage core member having a center and two outer legs having the ends thereof connected by end members, the outer legs of each leakage core member being adjacent to the end members of said magnetic core, air gaps between the outer legs of each leakage core member and the adjacent end member of said magnetic core, and a control coil around the center leg of each leakage core member.

4. An alternating current transformer comprising a magnetic core with a center and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, a secondary winding around said center leg, a pair of C-shaped leakage core members placed back to back between adjacent legs and between said group and secondary windings, the tips of the ends of said C-shaped members in contact with the respective legs, bar means between adjacent legs and between the primary and the secondary windings in said group of windings to provide an additional leakage path means, air gaps between the backs of said C-shaped members and between the ends of said bar means adjacent to said legs, and a control coil around the backs of each pair of leakage core members whereby only an insignificant percentage of the total leakage flux through said leakage path means links the turns of said control coil.

5. An alternating current transformer comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a primary winding around said center leg, a plurality of secondary windings wound concentrically around said center leg, a pair of leakage core members mounted between adjacent legs of said magnetic core and the two outer secondary windings, each pair of leakage core members comprising a pair of C-shaped members placed back to back with the ends of the legs in contact with the adjacent end members, air gaps between the backs of each pair of leakage core members, and a control coil positioned around the adjacent backs of each pair of C-shaped leakage core members whereby only an insignificant percentage of the total leakage flux through said leakage core members links the turns of said control coil.

6. An alternating current transformer comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, a secondary winding around said center leg, a pair of C-shaped leakage core members placed back to back between adjacent legs and between said group and secondary windings, the tips of the ends of said C-shaped members in contact with the respective legs, additional leakage path means between adjacent legs, air gaps between the backs of said C-shaped members and between the ends of said leakage path means adjacent to said legs, and a control coil around the backs of each pair of leakage core members, each said control coil having its axis perpendicular to the direction of alternating current leakage flux flow.

7. An alternating current transformer, comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, a secondary winding around said center leg, a leakage core member between adjacent legs and between said group and secondary windings, each leakage core member comprising a center and two outer legs having the ends thereof connected by end members, the outer legs of said core members being substantially parallel to the legs of said magnetic core, air gaps between the outer legs of said leakage core members and the adjacent legs of said magnetic core, and a control coil around the center leg of each leakage core members, said control coil being so positioned that its axis is perpendicular to the direction of alternating current leakage flux flow.

8. An alternating current transformer, comprising a magnetic core having a center and two outer legs with end members connecting the ends of said legs, a primary winding around said center leg, a plurality of secondary windings wound concentrically around said center leg, a pair of leakage core members mounted between adjacent legs of said magnetic core and the two outer secondary windings, each leakage core member having a center and two outer legs having the ends thereof connected by end members, the outer legs of each leakage core member being adjacent to the end members of said magnetic core, air gaps between the outer legs of each leakage core member and the adjacent end member of said magnetic core, and a control coil around the center leg of each leakage core member, each of said control coils having its axis perpendicular to the direction of alternating current leakage flux flow.

9. A reactor to control the flow of current, said reactor comprising a magnetic core having a plurality of legs with end members connecting the ends thereof, a first winding about one leg, a second winding about another leg and connected to said first winding, leakage path means mounted between adjacent legs and between said end members whereby said leakage path means are in contact with said end members, an air gap in said leakage path means, a direct current control coil so positioned about said leakage path means that said air gap is not in the path of the control flux, said control coil further positioned on said leakage means whereby only a small percentage of the leakage flux through said leakage means links the turns of said control coil and the permeability of said leakage means is varied by the current flowing in said control coil.

10. An alternating current transformer, comprising a magnetic core having a center leg and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, an additional secondary winding around said center leg spaced from said group, a pair of magnetic leakage path means extending between the center leg and at least one of the outer of said legs engaging said center leg between said group of windings and said additional secondary winding, an air gap in each said leakage path means, and control coil means between said leakage path means magnetically associated therewith energizable to magnetize the leakage paths but so arranged that only an insignificant percentage of the total leakage flux through said leakage path means links the turns of said control coil.

11. An alternating current transformer, comprising a magnetic core having a center leg and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, an additional secondary winding around said center leg spaced from said group, means providing a plurality of spaced magnetic leakage paths between the center and the outer legs of the core, said means engaging the center leg between the said group of windings and said additional secondary winding and comprising a plurality of magnetic leakage core members, an air gap in each leakage path, and control coil means located between and pertaining to pairs of said leakage paths energizable for magnetizing said leakage paths but so located that only an insignificant percentage of the total leakage flux through said leakage path means links the turns of said control coil means.

12. An alternating current transformer, comprising a magnetic core having a center leg and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, an additional secondary winding around said center leg spaced from said group, means providing a pair of magnetic leakage paths between adjacent legs, each of said means comprising a pair of magnetic C-shaped leakage core members, said members placed back to back with the ends of the legs of the inner one thereof in contacting relationship with the said center leg between said group of windings and said additional secondary winding and with an air gap between the backs of said leakage core members, and a control coil around the backs of each pair of leakage core members.

13. A stationary induction apparatus, comprising a magnetic core having a plurality of legs with end members connecting the ends thereof, a group of windings comprising a primary and a plurality of secondary windings around one of said legs, an additional secondary winding spaced from said group of windings around said one of said legs, spaced magnetic members mounted between adjacent legs and between said group of windings and said additional secondary winding forming spaced magnetic leakage paths, an air gap in each magnetic member, and control coil means operatively associated with said leakage path means energizable for varying the saturation thereof, said control coil means being located between said leakage path means whereby only an insignificant percentage of the total leakage flux through said leakage path means links the turns of said control coil means.

14. A stationary induction apparatus, comprising a magnetic core having a plurality of legs with end members connecting the ends thereof, a group of windings comprising a primary and plurality of secondary windings around one of said legs, an additional secondary winding spaced from said group of windings around the said one leg, spaced magnetic leakage path means mounted between adjacent legs and engaging said one leg between said group of windings and said additional secondary winding, an air gap in each said leakage path means, a single direct current control coil means located between said leakage path means energizable for varying the saturation of said leakage path means, a rectifier having one side thereof electrically connected to one of the said secondary windings of said group of windings, said control coil means being electrically connected to the other side of said rectifier, and means to vary the magnitude of the control current, said control coil means being located between said spaced leakage path means in the region of the air gaps therein, and there being magnetic members extending between said leakage path means through said coil on opposite sides of said air gaps.

15. An alternating current transformer, comprising a magnetic core having a center leg and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, an additional secondary winding around said center leg spaced from said group, magnetic members forming pairs of leakage path means mounted between adjacent legs and engaging the center leg between said group of windings and said additional secondary winding, an air gap in each said leakage path means, and a control coil positioned in magnetizing relation to each pair of leakage path means but with the axis of said control coil being perpendicular to the direction of alternating current leakage flux flow.

16. An alternating current transformer, comprising a magnetic core having a center leg and two outer legs with end members connecting the ends of said legs, a group of windings around said center leg comprising a primary and a plurality of secondary windings, an additional secondary winding around said center leg, means providing a pair of spaced leakage paths between adjacent legs, each of said means comprising a pair of magnetic C-shaped leakage core members, said members placed back to back with the ends of the legs of the inner one thereof in contacting relationship with the center leg between said group of windings and said additional secondary winding, and with the backs of each pair of leak-

age core members spaced to provide an air gap in each leakage path, and a control coil positioned around the backs of each pair of leakage core members, each said control coil having its axis perpendicular to the direction of alternating current leakage flux flow.

17. In an alternating current induction apparatus; a magnetic core, a pair of serially connected windings mounted in spaced relation on said core, a magnetic leakage path associated with the core for each said winding, each said leakage path including an air gap, and electromagnetic means extending between said paths on opposite sides of the air gaps therein but forming a part of neither thereof energizable by direct current for varying the saturation of said paths thereby to vary the self-inductance of said windings.

18. In an alternating current induction apparatus; a magnetic core having leg means connected by end members, said leg means having a pair of serially connected windings mounted thereon in spaced relation, individual magnetic leakage paths formed between said leg means for each of said windings and said paths also being in spaced relation and each including an air gap, electromagnetic means extending between said paths on opposite sides of the air gaps therein, and means for variably energizing said electromagnetic means to vary the saturation of said paths and thereby vary the self-inductance of said windings.

19. In an alternating current induction apparatus; a magnetic core having spaced serially connected windings thereon, a magnetic leakage path associated with the core for each said winding and each said path including an air gap, electromagnetic means extending between said paths on opposite sides of the air gaps therein and forming with said paths closed magnetic circuits, each said circuit including at least a portion of each leakage path and at least a portion of said electromagnetic means, and means for variably energizing said electromagnetic means for varying the saturation of said leakage paths and thereby varying the self-inductance of said windings.

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