

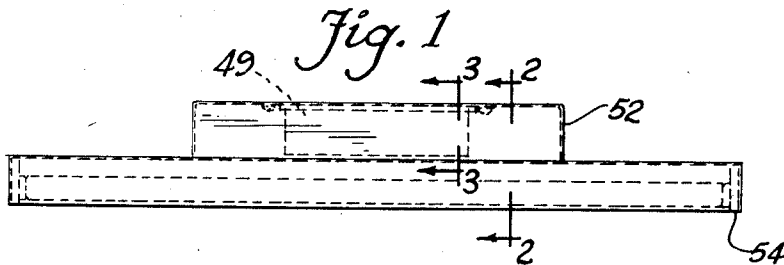
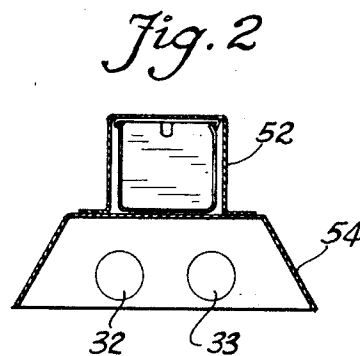
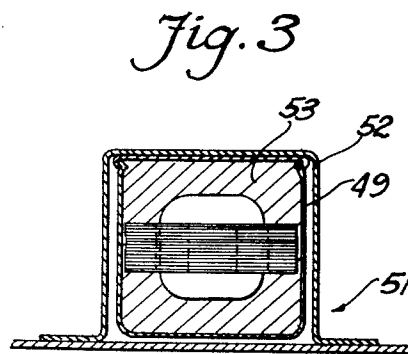
Sept. 10, 1957

J. G. SOLA
TRANSFORMER

2,806,199

Original Filed March 18, 1948

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4

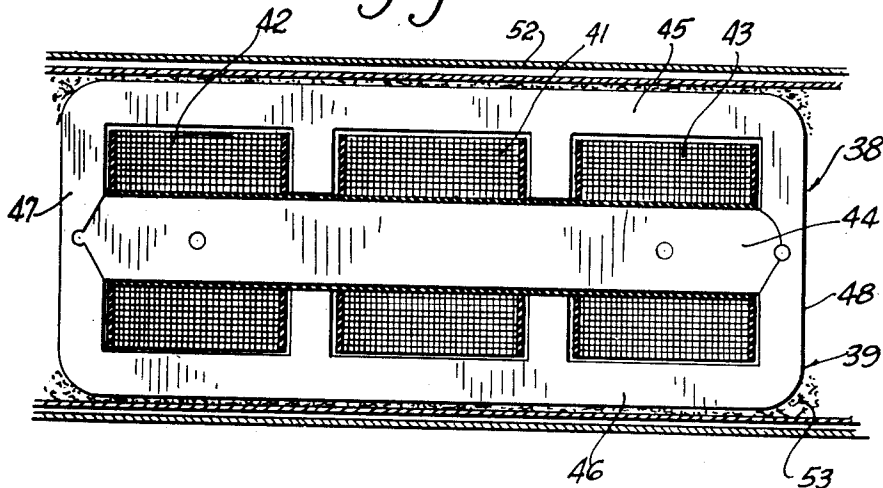
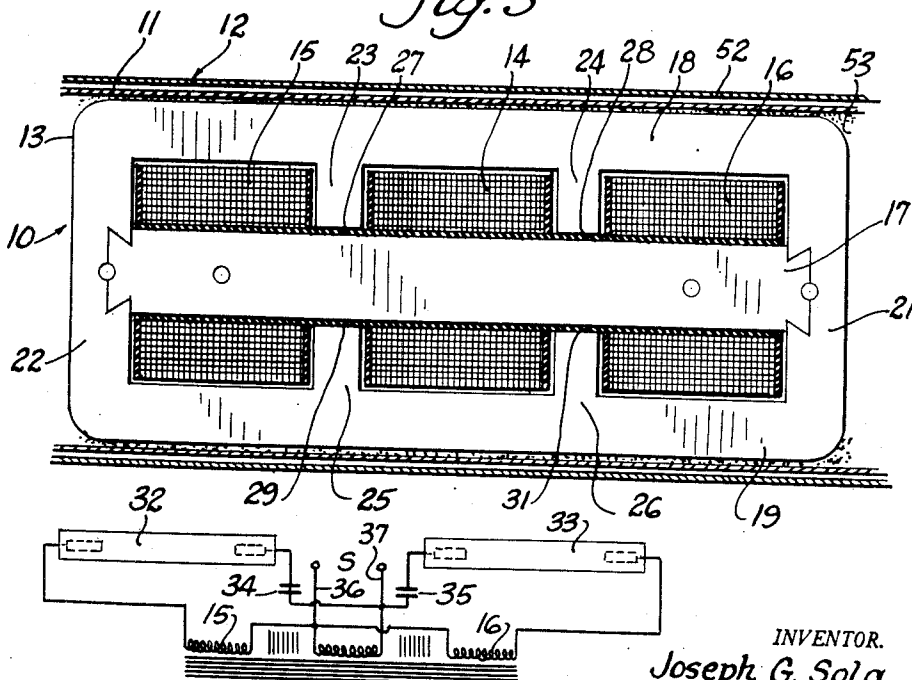


Fig. 5



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Fig. 6

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2,806,199

TRANSFORMER

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Continuation of abandoned application Serial No. 15,701, March 18, 1948. This application July 9, 1953, Serial No. 366,916

5 Claims. (Cl. 323—60)

This application is a continuation of the copending application Serial No. 15,701, of Joseph G. Sola, filed March 18, 1948, for Transformer, now abandoned.

This invention relates to high leakage reactance transformer and condenser combinations and methods wherein the condenser and one or more windings of the transformer are related for simulating a condition of series resonance, more particularly to such combinations and methods wherein the stray magnetic field surrounding the transformer core is substantially eliminated.

Stray magnetic fields surrounding transformers are objectionable in many instances, radio and television interference, improper instrument indications and noise being examples thereof. Particularly in the case of transformers and ballasts used with lighting fixtures, such as fluorescent or neon lights, the stray fields have been large and have been objectionable.

Lighting fixtures for fluorescent lamps usually have large flat metallic surfaces which may act as resonators to amplify sounds when set into vibration. Such surfaces may be set into vibration by direct coaction with the stray magnetic field of the transformer or ballast associated with the fixture, or indirectly by vibrations sympathetic to the vibrations of the transformer or ballast cores and their surrounding cases caused by magnetostriction or by the stray magnetic field on the cases. The noise or hum in the first instance may be of a frequency substantially equal to that of applied alternating voltage, but in either instance the fixture surfaces may be set into vibration at their own natural frequency. In some instances the fixture and transformer may vibrate into contact with each other after each is vibrating itself with consequent higher pitch and metallic-like sounds. Such sounds are undesirable, and particularly so where lighting fixtures are installed in relatively quiet places, such as offices and homes.

Accordingly, it is a further object of the invention to provide an improved high leakage reactance transformer for energizing discharge devices of the negative resistance type through a condenser of a predetermined character relative to the transformer wherein light fixture noise or vibration due to the transformer is substantially eliminated.

It is a further object of the invention to provide an improved high leakage reactance transformer for energizing a light of the negative resistance type through a condenser of a predetermined character relative to the transformer wherein the transformer stray field is substantially eliminated.

It is a further object of the invention to provide an improved transformer for use with a condenser of predetermined characteristics relative to the transformer wherein the condenser and one or more windings of the transformer are related to simulate a condition of series resonance having substantially no stray field surrounding the transformer.

While the invention has reference to lighting fixtures of the fluorescent type and is described in connection there-

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with, it will be understood that this is by way of example, the invention having reference to improved transformer constructions in connection with condensers of certain characteristics wherein the stray magnetic field of the transformer is substantially eliminated.

In carrying out the invention in one form, a high leakage reactance transformer is provided having a core having a flux generating portion with primary and secondary windings disposed thereon, and flux return portions. A condenser is connected to the secondary winding, and to the load, the condenser having a value such that the transformer and condenser are related for simulating a condition of series resonance. The flux return path of the transformer is increased in cross-sectional area relative to the cross-sectional area of the flux generating path.

For a more complete understanding of the invention reference should be had to the accompanying drawings in which:

Figure 1 is a side view of a fluorescent lamp fixture incorporating a transformer embodying the invention;

Fig. 2 is a sectional view taken substantially along line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken substantially along line 3—3 of Fig. 1;

Fig. 4 is a sectional view of a transformer not embodying the invention mounted in a fluorescent lamp fixture shown fragmentarily;

Fig. 5 is a view similar to Fig. 4 of a transformer embodying the invention; and

Fig. 6 is a schematic diagram of a transformer embodying the invention and condensers connected to a pair of fluorescent lamps.

Referring to Fig. 5 of the drawings, the invention is shown embodied in a transformer core and coils 10, mounted in a case 11, which in turn is mounted in a fluorescent lamp fixture 12, case 11 and fixture 12 being shown fragmentarily.

Core and coils 10 comprise a core 13 of a transformer steel assembled from individual laminations, a primary winding 14, and a pair of secondary windings 15 and 16. Core 13 includes a central leg 17, a pair of outer legs 18 and 19, and a pair of end legs 21 and 22, the end and outer legs being preferably stamped in one piece and assembled in a stack of necessary thickness. Central leg 17 is assembled in a stack and attached to the end legs by any suitable connection such as the illustrated dovetail joint.

Extending inwardly from outer legs 18 and 19 are shunt members 23, 24 and 25, 26, non-magnetic gaps 27, 28 and 29, 31 of predetermined length, being formed between the ends of the shunt members and the central leg. Shunt members 23, 25 and 24, 26 lie magnetically between primary winding 14 and secondary windings 15 and 16 respectively, the shunt members and the associated non-magnetic gaps defining high reluctance shunts. The high reluctance shunts define flux leakage paths for the primary and secondary windings thereby forming a high leakage reactance transformer.

The thickness of the lamination stack is the same for central leg 17 as for outer and end legs, but the transverse dimension or width of central leg 17 is less than half of the total transverse dimension or width of outer legs 18 and 19, and similarly for end legs 21 and 22. That is, the cross-sectional area of leg 17 which is in the center of coil 14 is of lesser cross-sectional area than the total of legs 18 and 19 or end legs 21 and 22 which may be termed the flux return path.

In one example of transformer embodying the invention and illustrated in Fig. 5, central leg 17 is approximately $1\frac{1}{8}$ " wide, whereas each of the outer legs 18 and 19 and end legs 21 and 22 are approximately $1\frac{3}{32}$ " wide, thereby making each of the outer and end legs

greater than one-half of the central leg by $\frac{1}{8}$ " in width. This is an increase of approximately 36 percent in the cross-sectional area of the flux return path. Shunt members 23, 24, 25 and 26 have a width equal to one-half the width of central leg 17 and consequently in the particular example may be approximately $\frac{1}{32}$ " wide.

In Fig. 6 a circuit diagram is shown wherein the transformer of Fig. 5 is connected to a pair of fluorescent lamps 32 and 33 which may be of the cold cathode type, for example, through condensers 34 and 35, the same reference characters being used in the two figures for corresponding parts. An alternating voltage source S of appropriate frequency and voltage, for example 60 cycles and 110 volts, may be connected to the primary winding 14, as shown, through conductors 36 and 37. Secondary winding 15 is associated with primary winding 14 in auto transformer relationship, one end of the secondary winding being connected to conductor 36, and the other end thereof being connected to fluorescent lamp 32, which in turn is connected to a condenser 34 and thus to conductor 37. Similarly, one end of secondary winding 16 is connected to conductor 36, and the other end thereof is connected to fluorescent lamp 33, which in turn is connected to a condenser 35 and thus to conductor 37. Windings 14, 15, and 16 are so wound and disposed on the core that the voltages are additive, as is well understood. While the primary and secondary windings have been shown in auto transformer relationship, it will be understood that this is exemplary and that other core and coil arrangements may be used without departing from the spirit and scope of the invention.

In my prior Patent No. 2,143,745, issued January 10, 1939, there is described and broadly claimed a constant voltage transformer capable of general application which employs a high reluctance magnetic shunt for effecting a relatively loose coupling between the primary and secondary sides in combination with a condenser connected in the secondary side which is in a relationship simulating series resonance, which combination serves to establish the total flux in the secondary portion of the transformer core greater than that in the primary portion of the core by an amount sufficient to cause a saturation effect in the secondary portion of the core, for maintaining the secondary voltage substantially constant over a wide range of primary voltages. The transformer disclosed in Figs. 5 and 6 of the present application employs certain of the basic principles set forth in this patent.

In my prior Patent No. 2,346,621, issued April 11, 1944, there is described and claimed an alternating current supply system embodying a transformer employing certain of the basic principles set forth in my Patent No. 2,143,745.

The transformer of Figs. 5 and 6 as to organization and operation follows the principles described in both my patents. The improvements thereover comprising the subject matter of the present invention will be more specifically pointed out subsequently in this specification.

According to the teachings of the patents referred to and applied to the present invention, when a voltage of desired value, for example 110 volts at 60 cycles, is applied to the terminals S, a voltage of sufficient magnitude to strike lamps 32 and 33 is produced. This voltage is principally the result of the turn ratio of the transformer, since before the lamps strike there is no current flowing in the secondary windings and consequently no condition simulating series resonance exists, the various legs of the transformer being in a relatively unsaturated condition. However, when the voltage across the lamps is sufficient to strike them, this being the sum of the primary and secondary voltage since these windings are connected in auto transformer relation and the lamps do in fact strike, a condition simulating series resonance immediately arises. The voltage across lamps 32 and 33 falls to the desired value due to their negative

resistance characteristic, whereas the voltages across windings 15 and 16 and corresponding condensers 34 and 35 rise to relatively higher values.

It is a characteristic of the transformers described in my patents and the present invention that when the condition simulating series resonance arises, the steel core of the transformer becomes saturated at least in certain portions thereof to a high degree, for example 105,000 lines of flux or more per square inch of cross section may be expected. Also under these conditions the secondary voltage of the transformer as well as the voltage across the condenser increases to rather high values which are considerably greater than that determined by the transformer turn ratio and are beyond the control of the primary voltage so to speak. Consequently, when a transformer and condenser of this character have been selected to operate any load, for example fluorescent lamps, the saturation condition of the transformer is no longer controllable by merely varying the primary voltage, the stable self-regulating secondary voltage, and consequently the saturation, being determined by the transformer and condenser characteristics.

In Fig. 4 there is illustrated a transformer core and coils generally similar to the core and coils shown in Fig. 5, but differing therefrom in that the total cross-sectional area of the outer legs is equal to the cross-sectional area of the central leg. In this regard the transformer of Fig. 4 differs from that of Fig. 5 and is substantially that shown in Fig. 3 of the Patent No. 2,346,621. Thus transformer 38 of Fig. 4, including a core 39, primary winding 41, and secondary windings 42 and 43, has a central leg 44 equal in transverse dimension to the central leg 17 of the transformer of Fig. 5, that is, equal to approximately $\frac{11}{16}$ ". Outer legs 45 and 46, as well as end legs 47 and 48, are equal to $\frac{11}{32}$ " in width, so that the total transverse dimension is $\frac{11}{16}$ ". The stack of punchings is, of course, the same for the central leg as for the remainder of the core. Primary winding 41 and secondary windings 42 and 43 may, in all respects, be substantially identical with corresponding windings in Fig. 5.

When the transformer of Fig. 4 is connected in circuit with fluorescent lamps, for example, and is operating under conditions simulating series resonance, the core portions including the central leg as well as the outer and end legs are saturated to a considerable degree, as has already been pointed out. Such saturations may reach 105,000 lines per square inch or more, with consequent large stray fields in air around the transformer core, since the permeability of transformer steel is considerably nearer that of air at these saturations than it is when the steel is relatively unsaturated. Under these operating conditions, primary winding 41 will have a relatively constant voltage applied to it, but the voltage across the secondary windings 42 and 43 is at a high value due to the conditions simulating series resonance. Because of the consequent saturation, considerable amounts of leakage flux flow through the various high reluctance shunt paths and the saturation conditions of the various parts of the transformer, that is the portion associated particularly with the primary winding and that associated particularly with the secondary winding, may not have the same conditions of saturation. So far as stray fields are concerned, this is of relative unimportance inasmuch as the portions of the core which are saturated the greatest will permit of substantial amounts of stray magnetic field.

In transformers such as the one illustrated in Fig. 4 where the cross-sectional area of central leg 44, which may be termed the flux generating path, and the cross-sectional area of legs 45 and 46, which may be termed the flux return path, are equal, the saturation condition of the core cannot be changed in sufficient measure merely by changing the dimensions of both the flux generating path and the flux return path. That is to say, if in the transformer of Fig. 4 the total cross-sectional area of

outer legs 45 and 46 (as well as the end legs) is increased, by the same factor as the cross-sectional area of the central leg 44 is increased, say for example 36 percent, and such a transformer is used with the same condenser and the same load circuit as was used before the change in the core dimensions was made, the core would be saturated to substantially the same percentage as existed before the core dimensions were changed. Some change in the total saturation may be accomplished by changing the condenser value provided sufficient voltage is obtained for striking the lamps, but even then the core will saturate to a very substantial degree and consequently will permit of substantial stray flux existing in the air surrounding the transformer.

It is well known in conventional transformers, that is, transformers operating with primary and secondary windings on a transformer steel core without the use of condensers and without embodying the principles set out in my patents, the degree of saturation in the transformer core is, of course, completely at the control of the transformer designer and under the control of the transformer operator merely by changing the primary or input voltage. That is to say, if a core of certain dimensions a smaller voltage is used, a lesser condition of saturation exists and vice versa. Consequently, in such a transformer if a condition of lesser saturation is desired, it is only necessary to change the dimensions of the core. In order that all portions of the core may operate at substantially the same flux density, the flux generating paths and the flux return paths are normally of equal cross-section.

Distinguished from this, in a transformer such as shown in Fig. 4 where the saturation condition is largely beyond control during the condition simulating series resonance, increasing the cross-sectional area of both the flux generating path and the flux return path is not productive of a significant change in saturation conditions such that stray magnetic fields may be eliminated. Increasing the transformer core dimensions in this transformer results merely in a heavier and larger transformer, but one still having a large stray field.

The prime distinction between the cores of Fig. 4 and Fig. 5 is that outer legs 18 and 19 and end legs 21 and 22 of Fig. 5 are greater in transverse dimension by $\frac{1}{8}$ " than the corresponding outer and end legs of the transformer in Fig. 4, the transverse dimensions of the center legs 17 and 44 being the same. That is, the cross-sectional area of the flux return path is increased relative to the cross-sectional area of the flux generating path.

It will be understood that while specific dimensions and dimensional differences have been given in one example, this is by way of example only and other dimensions may be used so long as the cross-sectional area of the flux return path is greater than the cross-sectional area of the flux generating path, the difference between these two being chosen such as to produce the desired conditions of low stray magnetism. Thus, it has been observed that a transformer such as shown in Fig. 4 has sufficient stray magnetic field surrounding it to cause loud humming when the transformer is mounted in a fluorescent lamp fixture. A transformer such as that shown in Fig. 5, when mounted in the same lamp fixture, will not produce an audible sound inasmuch as the saturation of the flux return path has been decreased, thereby largely eliminating the stray magnetic field and also reducing the effects of magnetostriction.

Under conditions of saturation, the magnetic reluctance of iron increases and under conditions of severe saturation it approaches the reluctance of an equivalent air path.

Referring to Fig. 5, it is understood, of course, that flux existing in central leg 17 must complete its pathway and consequently it returns through the end and outer legs and through the surrounding air, the percentages of flux returning through the legs and through the air being determined by the relative reluctances. As has already been pointed out in transformers such as that shown in

Fig. 4, when a condition simulating series resonance occurs, the transformer core saturates, and moreover increasing all the cross-sectional areas of the core does not significantly change the saturation condition. Likewise in the transformer shown in Fig. 5, saturation occurs when the transformer and condensers simulate a condition of series resonance. However, since central leg 17 is smaller in cross-sectional area than the total cross-sectional area of the outer legs 18 and 19, central leg 17 saturates to a greater degree than the outer legs. Since the magnetization curve of transformer steel bends rather sharply in the region of saturation and therefore the reluctance thereof increases rapidly, the reluctance of central legs 17 is considerably greater than that of the return legs 18 and 19. Consequently, the amount of flux existing in the magnetic circuit is largely determined by the dimensions of central leg 17 due to its condition of greater saturation. This same flux upon returning through legs 18 and 19 of greater cross-sectional area, consequently saturates these portions of the core to a lesser amount and may even not saturate them at all, thereby reducing or eliminating stray magnetic fields existing around the transformer. The cross-sectional dimensions of central leg 17 which saturates first is the prime factor in determining the amount of flux in the circuit, and is the factor which determines the stable self-regulating condition when this transformer is used in the circuit of Fig. 6.

The saturation condition of the transformer of Fig. 5 also is beyond the control of an operator and is not within the control of the primary voltage once a sufficient voltage has been applied to bring about a condition simulating series resonance. While the total reluctance of the magnetic pathway has been decreased by increasing the cross-sectional area of a portion thereof, the dimension of central leg 17 brings about the condition where the total saturation may lie between the cases where the transformer is that of Fig. 4 or one similar to Fig. 5 with all dimensions increased, but the flux saturating central leg 17 does not saturate legs 18 and 19. Thus in transformers embodying the principles of my patents and of the present invention, it is necessary to have the cross-sectional dimensions of the flux return path greater than the cross-sectional dimensions of the flux generating path in order to have any significant reduction in the saturation of the flux return path.

While in the particular examples given the cross-sectional area of the return path is approximately 36 percent greater than the flux generating path, which results in a condition of substantially no humming when the transformer is mounted in a fluorescent lighting fixture, satisfactory results may be obtained by increasing the flux return path cross-sectional area by as much as 50 percent without significantly increasing the size of the transformer. The cross section of the flux return path may be less than 36 percent greater than that of the flux generating path depending on the degree of saturation desired.

In using such transformers for fluorescent lamp fixtures, dimensions are of prime importance since the transformer must be designed to fit into the dimensions of the fixtures. The close proximity of the surfaces of the fixtures makes them susceptible to any stray magnetic field existing around the transformer which may set the fixture into vibration.

In Fig. 3 a transformer such as that shown in Fig. 5 is shown inside of a case 49, which unit then is assembled to a fluorescent lighting fixture 51 including a housing 52, which may contain the transformer as well as wiring and other equipment, for example. The transformer in Fig. 3 shows a core and coils inside of case 49 with insulating compound 53 filling the case so as to dampen vibrations of the case as well as to insulate. In Fig. 2 housing 52 is shown assembled to a reflector portion 54 adapted to house a pair of fluorescent lamps, which may be lamps 32 and 33 of Fig. 6. In order to provide for

greater heat transfer from the transformer to the housing 52, the transformer and case 49 are assembled in direct contact with the top of housing 52. Consequently, any vibrations of the case 49 are effectively transmitted to housing 52 and to the relatively large surfaces of reflector 54. Hence, it is of advantage to eliminate any stray magnetic fields as well as magnetostrictive effects to as great an extent as possible.

While a particular embodiment of the invention has been shown, it will be understood, of course, that the invention is not limited thereto, since many modifications may be made, and it is, therefore, contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

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

1. A resonant transformer and condenser combination for connection between a supply circuit of predetermined voltage and frequency and a load comprising a core having a central leg, two outer legs one each of which is disposed on each side of said central leg and a pair of end legs completing the magnetic path between the ends of said central and said outer legs, said central and said outer legs having primary and secondary winding portions, a primary winding disposed on the primary winding portion of said central leg, a secondary winding disposed on said secondary winding portion of said central leg, said primary and secondary windings being loosely coupled whereby a high leakage reactance is associated therewith and a condenser connected to said secondary winding and having a reactance relative to the reactance of said secondary winding at the frequency and voltage of such supply circuit such that a condition in the nature of series resonance exists in the completed circuit comprising said secondary winding and said condenser when such supply circuit is connected to said primary winding, the cross-sectional area of the secondary portion of said central leg having a value such as to produce during operation the saturation flux density necessary to such series resonance, and the total cross-sectional area of the secondary portions of said outer legs having a value substantially greater than that of said central leg so as to provide during the said operation a flux density in the secondary portions of said outer leg below saturation value with consequent avoidance of any substantial stray field surrounding said outer legs and maintenance of the saturation flux density in the secondary portion of said central leg.

2. A resonant transformer and condenser combination for connection between a supply circuit of predetermined voltage and frequency and a load comprising a core having a central leg, two outer legs one each of which is disposed on each side of said central leg and a pair of end legs completing the magnetic path between the ends of said central and said outer legs, said central and said outer legs having primary and secondary winding portions, a primary winding disposed on the primary winding portion of said central leg, a secondary winding disposed on said secondary winding portion of said central leg and connected in auto-transformer relationship to said primary winding, said primary and secondary windings being loosely coupled whereby a high leakage reactance is associated therewith and a condenser connected to said secondary winding and having a reactance relative to the reactance of said secondary winding at the frequency and voltage of such supply circuit such that a condition in the nature of series resonance exists in the completed circuit comprising said secondary winding and said condenser when such supply circuit is connected to said primary winding, the cross-sectional area of the secondary portion of said central leg having a value such as to produce during operation the saturation flux density necessary to such series resonance, and the total cross-sectional area of the secondary portions of said outer legs having a value substantially greater than

that of said central leg so as to provide during the said operation a flux density in the secondary portions of said outer leg below saturation value with consequent avoidance of any substantial stray field surrounding said outer legs and maintenance of the saturation flux density in the secondary portion of said central leg.

3. A resonant transformer and condenser combination for connection between a supply circuit of predetermined voltage and frequency and a load comprising a core having a central leg, two outer legs one each of which is disposed on each side of said central leg and a pair of end legs completing the magnetic path between the ends of said central and said outer legs, said central and said outer legs having primary and secondary winding portions, a primary winding disposed on the primary winding portion of said central leg, a secondary winding disposed on said secondary winding portion of said central leg, said primary and secondary windings being loosely coupled whereby a high leakage reactance is associated therewith and a condenser connected to said secondary winding and having a reactance relative to the reactance of said secondary winding at the frequency and voltage of such supply circuit such that a condition in the nature of series resonance exists in the completed series circuit comprising said secondary winding, said condenser and a load when such supply circuit is connected to said primary winding, the cross-sectional area of the secondary portion of said central leg having a value such as to produce during operation the saturation flux density necessary to such series resonance, and the total cross-sectional area of the secondary portions of said outer legs having a value substantially greater than that of said central leg so as to provide during the said operation a flux density in the secondary portions of said outer leg below saturation value with consequent avoidance of any substantial stray field surrounding said outer legs and maintenance of the saturation flux density in the secondary portion of said central leg.

4. A resonant transformer and condenser combination for connection between a supply circuit of predetermined voltage and frequency and a load comprising a core having a central leg, two outer legs one each of which is disposed on each side of said central leg and a pair of end legs completing the magnetic path between the ends of said central and said outer legs, said central and said outer legs having primary and secondary winding portions, a primary winding disposed on the primary winding portion of said central leg, a secondary winding disposed on said secondary winding portion of said central leg and connected in auto-transformer relationship to said primary winding, said primary and secondary windings being loosely coupled whereby a high leakage reactance is associated therewith and a condenser connected to said secondary winding and having a reactance relative to the reactance of said secondary winding at the frequency and voltage of such supply circuit such that a condition in the nature of series resonance exists in the completed series circuit comprising said secondary winding, said condenser, said primary winding and a load when such supply circuit is connected to said primary winding, the cross-sectional area of the secondary portion of said central leg having a value such as to produce during operation the saturation flux density necessary to such series resonance, and the total cross-sectional area of the secondary portions of said outer legs having a value substantially greater than that of said central leg so as to provide during the said operation a flux density in the secondary portions of said outer leg below saturation value with consequent avoidance of any substantial stray field surrounding said outer legs and maintenance of the saturation flux density in the secondary portion of said central leg.

5. A resonant transformer and condenser combination for connection between a supply circuit of predetermined voltage and frequency and a load comprising a core having a central leg, two outer legs one each of which is

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disposed on each side of said central leg and a pair of end legs completing the magnetic path between the ends of said central and said outer legs, said central and said outer legs having primary and secondary winding portions, a primary winding disposed on the primary winding portion of said central leg, a secondary winding disposed on said secondary winding portion of said central leg and connected in auto-transformer relationship to said primary winding, said primary and secondary windings being loosely coupled whereby a high leakage reactance is associated therewith an a condenser connected to said secondary winding and having a reactance relative to the reactance of said secondary winding at the frequency and voltage of such supply circuit such that a condition in the nature of series resonance exists in the completed series circuit comprising said secondary winding, said condenser, said primary winding and a load when such supply circuit is connected to said primary winding, the cross-sectional area of the secondary portion of said

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central leg having a value such as to produce during operation the saturation flux density necessary to such series resonance, and the total cross-sectional area of the secondary portions of said outer legs having a value approximately 36 to 50 percent greater than that of said central leg so as to provide during the said operation a flux density in the secondary portions of said outer leg below saturation value with consequent avoidance of any substantial stray field surrounding said outer legs and maintenance of the saturation flux density in the secondary portion of said central leg.

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