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[54] **MAGNETIC METAL DEFECT-DETECTING APPARATUS**

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[51] **Int. Cl.** **G01r 33/12**

[58] **Field of Search** .... 324/34 ST, 37, 40

[56] **References Cited**

UNITED STATES PATENTS

1,893,074	1/1933	Drake	324/37
3,469,440	9/1969	Lofgren	324/34 X
3,495,166	2/1970	Lorenzi et al.	324/37
3,593,120	7/1971	Mandula, Jr.	324/37

FOREIGN PATENTS OR APPLICATIONS

847,661	8/1952	Germany	324/37
5,638	2/1971	Japan	324/37

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[57] **ABSTRACT**

A magnetic metal defect-detecting apparatus comprising a cross-shaped magnetic core assembly prepared from two pairs of magnetic pole members providing two pairs of magnetic poles intersecting each other at right angles and each fitted with a caster at the end; a first and a second coil wound about the two pairs of magnetic pole members; and a power supply device for supplying the first coil with single phase alternating current of positive half wave and the second coil with single phase alternating current of negative half wave, thereby alternately applying each of two magnetic fluxes in perpendicularly intersecting directions.

6 Claims, 6 Drawing Figures

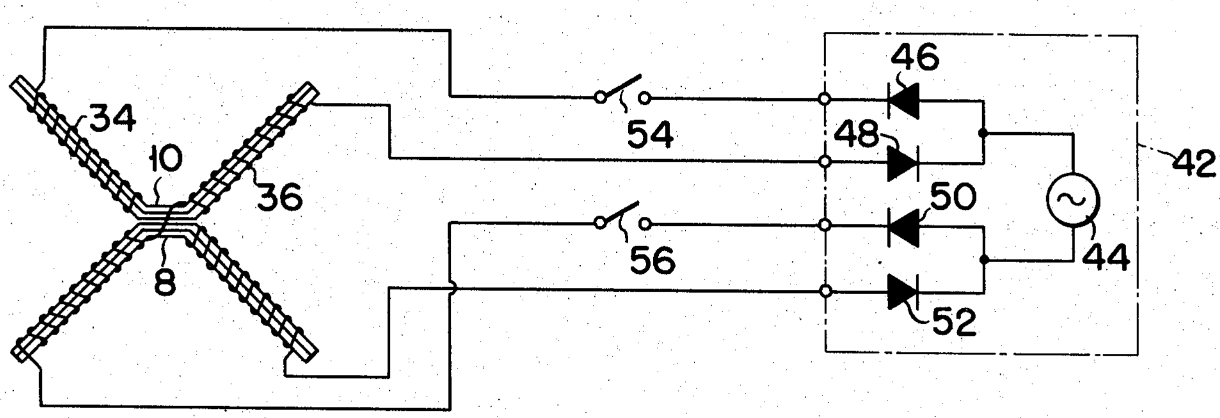


FIG. 1

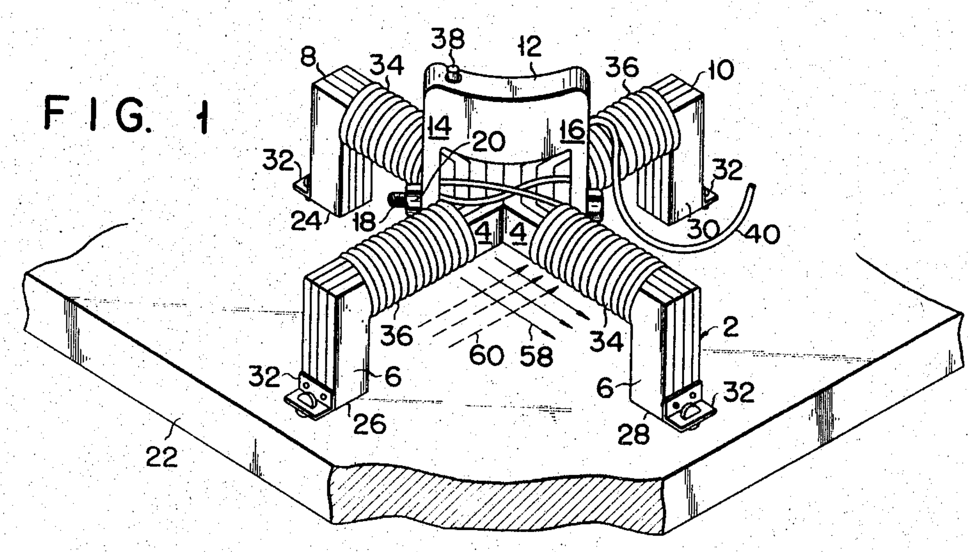


FIG. 2

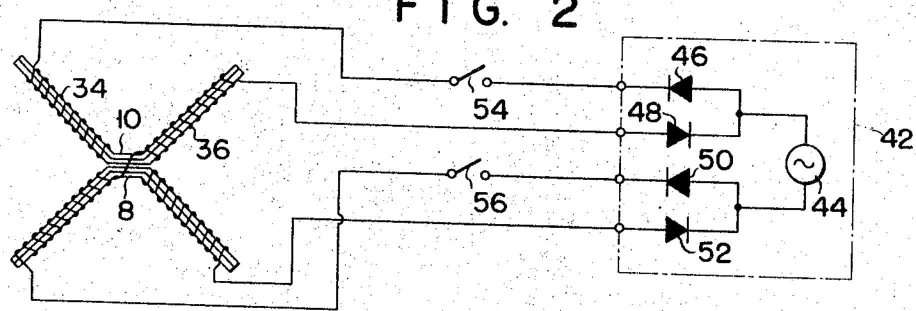


FIG. 4

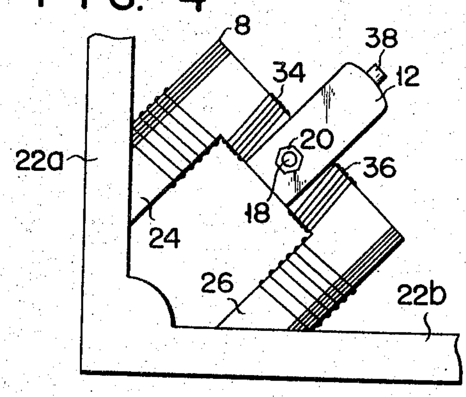


FIG. 3

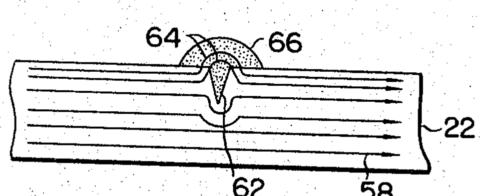


FIG. 5

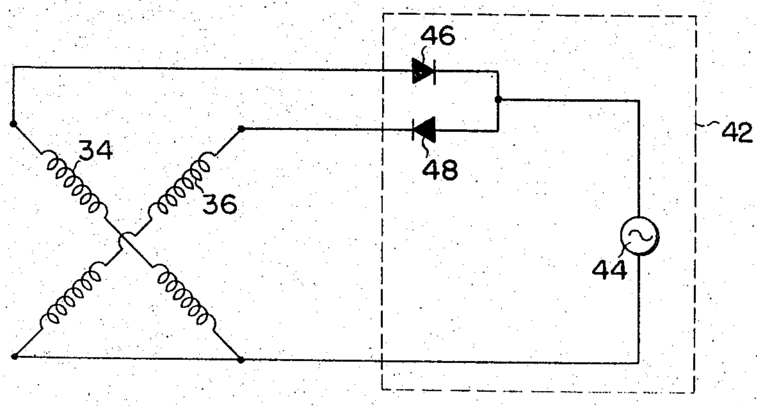
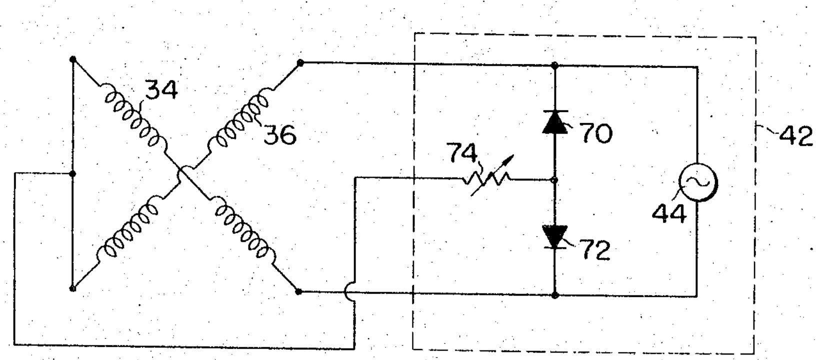


FIG. 6



MAGNETIC METAL DEFECT-DETECTING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to a magnetic metal defect-detecting apparatus designed alternately to apply each of two magnetic fluxes to a magnetizable test material in perpendicularly intersecting directions.

A known process of magnetically detecting any defect in magnetizable metal material being tested consists in spreading powders of magnetizable metal material over the surface of said test material before it is magnetized by a magnetic field generator. If, in this case, the magnetized test material is free from any defect, then magnetized metal powders will be uniformly distributed in the direction in which a magnetic flux is applied. If, however, the test material has a defect, then a leakage magnetic flux will be released to the outside from the surface of that part of the test material which contains the defect, causing the magnetized powders spread on the test material to be concentrated on said surface. Therefore, observation of the distributed condition of the magnetized metal powders can detect a defect in the test material.

A conventional magnetic field generator used in the magnetic detection of a defect in magnetizable metal material generally includes a U-shaped electromagnet provided with two opposite magnetic poles. When such an electromagnet is placed on a piece of magnetizable material being tested, then a magnetic flux passes through that part of the test material which is defined between the two opposite poles of the electromagnet. The magnetic flux is directed along a line connecting the magnetic poles. If, therefore, the test material contains an elongate defect extending perpendicular to the axis of the magnetic flux, then a leakage magnetic flux resulting from the defect will have a sufficiently high density to cause a large amount of magnetizable metal powders spread on the test material to be absorbed to the surface of that part of the test material which contains the defect. In the above-mentioned case, therefore, a defect can be detected very sensitively. Where, however, an elongate defect extends along the axis of the magnetic flux, then a leakage magnetic flux delivered from the defective portion of the test material will have such a low density as to attain the absorption of only a small amount of magnetizable metal powders, presenting difficulties in detecting the defect. To date, therefore, the same portion of the test material which is supposed to contain a defect has been subjected to a detecting operation by applying a magnetic flux derived from the above-mentioned U-shaped electromagnet at least once in each of the perpendicularly intersecting directions. Such a two-fold application of a detecting operation with respect to each supposedly defective part of a test material does not indeed raise any important problem in the case where the test material has a relatively small area of such defective portion, but proves a considerably time-consuming work in the case where the defective portion is very large as in the welded part of steel plates used in, for example, shipping. Particularly where a large electromagnet is used, an operator is fatigued by its heavy weight, possibly resulting in a careless detecting work and in consequence the omission of a serious defect.

It is accordingly the object of this invention to provide a magnetic metal defect-detecting apparatus capable of effecting a relatively easy defect detecting operation in two mutually perpendicular directions by a single step with little fatigue to an operator.

SUMMARY OF THE INVENTION

According to an aspect of this invention, there is provided a magnetic metal defect-detecting apparatus comprising a cross-shaped magnetic core assembly including two pairs of magnetic pole members providing two pairs of magnetic poles intersecting each other; a first and a second coil wound about the two pairs of magnetic pole members; and a power supply device including a source of single phase alternating current; and at least a pair of rectifiers coupled to the power supply device for supplying the first coil with single phase alternating current of positive half wave and the second coil with single phase alternating current of negative half wave, thereby alternately applying each of two magnetic fluxes in intersecting directions.

According to another aspect of the invention, there is provided a magnetic metal defect-detecting apparatus wherein the end of each magnetic pole member of the cross-shaped magnetic core assembly is fitted with a caster so as to facilitate the handling of said detecting apparatus which is of relatively great weight.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an oblique view of the magnetic metal defect-detecting apparatus of this invention;

FIG. **2** is a circuit diagram of the detecting apparatus of FIG. **1**;

FIG. **3** presents the manner in which the magnetic detection of a metal defect is effected by spreading magnetizable metal powders over the surface of a piece of metal material being tested;

FIG. **4** is a side view of a modification of the magnetic metal defect-detecting apparatus of the invention;

FIG. **5** is a circuit diagram of a power supply device modified from FIG. **2**; and

FIG. **6** is a circuit diagram of a metal defect-detecting apparatus according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1,** a cross-shaped magnetic core assembly **2** comprises a combined pair of laminated core sections **8** and **10,** each of which is formed by superposing a plurality of silicon steel plates **6** whose bridging sides **4** are bent substantially at right angles at the center. The bent portions of the core sections **8** and **10** are pressed against each other between the support poles **14** and **16** of a handle **12** and fixed in place by a bolt **18** penetrating the core sections **8** and **10** and support poles **14** and **16** and a corresponding nut **20.** Integrally formed at the respective ends of the core sections **8** and **10** are two groups of magnetic pole members **24–26** and **28–30,** each of which partly extends toward a piece of magnetizable metal material being tested, for example, a steel plate **22.** The magnetic pole members **24–26** and **28–30** are each fitted at the lower end with a caster **32** so as to move freely over the surface of said steel plate **22** in a state almost abutting against said surface. The bridging sides **4** of the magnetic pole members **24** and **28** facing each other across the joint of the core sections **8** and **10** are respectively wound with an exactly half portion of a first exciting coil **34.** Similarly, the bridging sides **4** of the magnetic pole members **26** and 30 facing each other across the joint of the core sections 8 and 10 at right angles to the first mentioned magnetic pole members 24 and 28 are respectively wound with an exactly half portion of a second exciting coil 36. The exciting coils 34 and 36 are each connected at one end to two cores of a 4-core power supply cable 40 through the respective contacts of a 2-contact push-button switch 38 mounted on the handle 12, and at the other end to the remaining two cores of said cable 40. This 4-core cable 40 is connected to a power supply device 42 shown in FIG. 2.

In FIG. 2, the power supply device 42 consists of a source 44 of single phase alternating current and four diodes 46, 48, 50 and 52. One end of said single phase A.C. source 44 is connected to one end of the coil 34 through the anode and cathode of the diode 46 as well as one contact 54 of the 2-contact switch 38. The other end of said power source 44 is connected to the other end of the coil 34 through the cathode and anode of the diode 52. Said one end of the power source 44 is also connected to one end of the coil 36 through the cathode and anode of the diode 48. Said other end of the power source 44 is also connected to the other end of the coil 36 through the anode and cathode of the diode 50 and the other contact 56 of the 2-contact switch 38.

Where, in the magnetic metal defect-detecting apparatus of this invention arranged as described above, the push-button 38 is depressed by gripping the handle 12, current of positive half wave is supplied from the single phase A.C. source 44 to one exciting coil 34 through the diodes 46 and 52, then the magnetic pole members 24 and 28 indicate, for example, the N and S poles respectively. As the result, a magnetic flux 58 passes through the steel plate 22 in the direction of solid line arrows shown in FIG. 1, namely, from the magnetic pole member 24 (N pole) to the magnetic pole member 28 (S pole). In the succeeding half cylce of single phase alternating current, current of negative half wave is conducted from the A.C. source 44 to the other exciting coil 36 through the diodes 48 and 50, causing the magnetic pole members 26 and 30 to indicate the N and S poles respectively. Accordingly, a magnetic flux 60 runs through the steel plate 22 in the direction of broken line arrows shown in FIG. 1, namely, from the magnetic pole member 26 (N pole) to the magnetic pole member 30 (S pole). When, therefore, powders of magnetizable metal material are spread on the surface of the steel plate 22 being tested, and a cross-shaped magnetic core assembly 2 is placed thereon, and, under this condition said steel plate 22 happens to contain a defect intersecting either of two magnetic fluxes applied at right angles, then a leakage magnetic flux appears at said defective portion and powders of magnetizable metal material previously spread on the surface of the steel plate 22 are concentratedly absorbed to the surface of said defective portion. For example, if the steel plate 22 contains a defect 62 intersecting a magnetic flux 58 passing therethrough at right angles, as illustrated in FIG. 3, then a leakage magnetic flux 64 appears at the spot of said defect 62. As the result, powders 66 of magnetizable metal material spread on the surface of the steel plate 22 are concentratedly attracted by said leakage magnetic flux 64. Further, a leakage magnetic flux representing a vector sum of the magnetic fluxes 58 and 60 takes place with respect to a defect obliquely intersecting either of said fluxes 58 and 60. Therefore, powders of magnetizable metal material are similarly attracted by said leakage magnetic flux denoting a vector sum, thereby carrying out the detection of a defect. Accordingly, it is possible to detect any defect occurring in that part of the steel plate 22 in which there is placed the cross-shaped magnetic core assembly 2 of this invention. The magnetic core assembly 2 whose two groups of magnetic pole members 24–26 and 28–30 are fitted with casters 32 can be freely rotated over the surface of the steel plate 22 when the handle 12 of said assembly 2 is gripped by an operator's hand, thereby causing either of the magnetic fluxes 58 and 60 perpendicularly to intersect any defect contained in the steel plate 22. Therefore, only one rotation of the cross-shaped magnetic core assembly 2 on the surface of the steel plate 22 is sufficient to detect its defects extending in all directions at once with a highest possible sensitivity.

In the foregoing embodiment the two core sections 8 and 10 were fixed at the joint by the bolt 18 and nut 20. However, said core sections 8 and 10 may be made rotatable in a vertical direction about the bolt 18. This arrangement can cause the casters fitted to the ends of the magnetic pole members 24–26 and 28–30 always to contact the surface of the steel plate 22 even when said surface is slightly uneven, thereby enabling a uniform strength of magnetization to be always applied to the steel plate 22 by the magnetic fluxes 58 and 60.

The above-mentioned embodiment relates to the case where an attempt was made to detect a defect included in the plane section of the steel plate 22. However, the magnetic metal defect-detecting apparatus of this invention can be applied in detecting any defect contained in the angular welded section of two pieces of the steel plate 22 or the angular bent section of a single piece thereof. FIG. 4 illustrates said application, the same parts thereof as those of FIG. 1 being denoted by the same numerals. In this case, a magnetizable test material is supposed to be two steel plates 22*a* and 22*b* welded together on the edge at right angles. The magnetic pole members 24 and 26 constituting one section of the cross-shaped magnetic core assembly 2 are cut obliquely at the end so as to contact the inner surfaces of the steel plates 22*a* and 22*b* welded together at right angles. Though not shown, the magnetic pole members 28 and 30 are likewise obliquely cut at the end. The cross-shaped magnetic core assembly 2 thus constructed can easily detect a defect present in the angular section of a test metal material.

The foregoing embodiment relates to the case where there was used a cross-shaped magnetic core assembly 2 constructed by joining two core sections, each of which was formed of a plurality of laminated steel plates. Obviously, it is possible to use a cross-shaped magnetic core assembly 2 formed into an integral body. The power supply device 42 of FIG. 2 consisted of four diodes 46, 48, 50 and 52. However, it is possible to connect, as shown in FIG. 5, one end of the power source 44 to one end of the coils 36 and 38 respectively through two diodes 46 and 48 of the indicated polarity and connect the other ends of the coils 36 and 38 jointly to the other end of the power source 44. Still, this invention can be operated with the same effect. This arrangement only requires two diodes as compared with the circuit of FIG. 2, attaining simple construction and low cost.

The foregoing description was given on the premise that a steel plate being tested was already shown to have a property of retaining a relatively small amount of residual magnetism. Where, however, a steel plate happens to have a property of retaining a large amount of residual magnetism, two magnetic fluxes some times fail to be applied alternately in either of two directions intersecting each other exactly at right angles. Where, in FIG. **1**, for example, current of positive half wave runs through the coil **34** to provide a magnetic flux **58**, some amount of residual magnetism resulting from a magnetic flux **60** created by current of negative half wave introduced immediately before still remains in a steel plate **22** in the same direction as that in which the magnetic flux was previously applied. As the result, a separate magnetic flux caused by said residual magnetism is mixed with the magnetic flux **58** in the vector form, thus giving rise to the growth in the steel plate **22** of a new composite magnetic flux acting in an intermediate direction between those in which the magnetic fluxes **58** and **60** were applied. Conversely where current of negative half wave passes through the coil **36**, then the resultant magnetic flux **60** is mixed with a residual magnetism derived from the previously applied magnetic flux **58** to provide a new composite magnetic flux, which also acts in an intermediate direction between those in which the magnetic fluxes **58** and **60** were applied. Therefore, these two composite magnetic fluxes intersect each other at acute angles.

FIG. **6** shows the arrangement of another embodiment of this invention which enables two magnetic fluxes to be applied in directions intersecting each other exactly at right angles even when a steel plate being tested has a property of retaining a relatively large amount of residual magnetism. Referring to FIG. **6**, one end of the single phase A.C. source **44** is connected to one end of the coil **36** and also to the cathode of a diode **70**. The other end of said A.C. source **44** is connected to one end of the coil **34** and also to the cathode of a diode **72**. The anodes of the diodes **70** and **72** are jointly connected to one end of a variable resistor **74**, the other end of which is connected to the junction of the coils **34** and **36**.

In the arrangement of FIG. **6**, where the current used has a positive half wave, a main current runs through the coil **36**, variable resistor **74** and diode **72** in the order mentioned and at this time a side current also passes from the coil **36** to the coil **34**. Conversely where current of negative half wave is applied, a main current is conducted through the coil **34**, variable resistor **74** and diode **70** and simultaneously a side current is introduced from the coil **34** to the coil **36**. Namely, in the case of positive half wave current, the coil **36** is supplied with a main current and the coil **34** is supplied with a side current which travels in an opposite direction to that in which a main current flows through said coil **34** in the case of negative half wave current. Accordingly, a residual magnetism resulting from a magnetic flux created by a main current passing through the coil **34** in the case of negative half wave current is offset by a magnetic flux caused by a side current conducted through the coil **34** in the case of positive half wave current. Similarly, a residual magnetism originating with a magnetic flux provided by a main current introduced through the coil **36** in the case of positive half wave is extinguished by a magnetic flux created by a side current flowing through the coil **36** in the case of negative half wave current. In this case, proper adjustment of the capacity of the variable resistor **74** enables a side current to have a sufficient magnitude to eliminate any amount of residual magnetism.

What we claim is:

1. A magnetic metal defect-detecting apparatus comprising:

- a cross-shaped magnetic core assembly including two pairs of magnetic pole members providing two pairs of magnetic poles intersecting each other;
- a first and a second coil wound about the two pairs of magnetic pole members;
- a power supply device including a source of single phase alternating current;
- at least one first rectifier connected in series between the source of single phase alternating current and the first coil in the forward direction with respect to the positive half wave of the single phase alternating current for supplying the first coil with single phase alternating current of positive half wave; and
- at least one second rectifier connected in series between the source of single phase alternating current and the second coil in the forward direction with respect to the negative half wave of the single phase alternating current for supplying the second coil with single phase alternating current of negative half wave;
- thereby alternately applying each of two magnetic fluxes in intersecting directions.

2. A detecting apparatus according to claim **1** wherein the cross-shaped magnetic core assembly comprises two pairs of magnetic pole members, each of which is fitted with a caster at the end thereof.

3. A detecting apparatus according to claim **2** wherein the cross-shaped magnetic core assembly comprises a first laminated core section bent substantially at right angles; a second laminated core section bent substantially at right angles and so positioned relative to the first laminated core section as to cause the outside of the bent portion to abut against that of the bent portion of the first laminated core section; a joining means for assembling the mutually abutting bent portions of the first and second laminated core sections into a cross-shaped magnetic core; and a handle attached to the magnetic core by the joining means.

4. A detecting apparatus according to claim **1** wherein the respective ends of the two pairs of magnetic pole members are located so as to substantially contact the surface of a test piece of metal material.

5. A detecting apparatus according to claim **1** wherein the respective ends of the two pairs of magnetic pole members are located so as to contact the inner surfaces of two test pieces of metal material joined on the edge at right angles.

6. A detecting apparatus according to claim **1** wherein the first and second coils are connected together at one end, and including:

- a first rectifier and a second rectifier, the first and second rectifiers having cathodes which are connected to respective corresponding terminals of said single phase alternating current source and anodes which are connected together; and
- a variable resistor which is connected between the junction of the anodes of the first and second rectifiers and the junction of the connected together ends of the first and second coils;
- the other ends of the first and second coils being connected to said corresponding terminals of said single phase alternating current source.

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