United States Patent [19]

Miller et al.

[11] **3,851,287**

[45] **Nov. 26, 1974**

[54] **LOW LEAKAGE CURRENT ELECTRICAL ISOLATION SYSTEM**

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[73] Assignee: **Litton Systems, Inc.,** Bellwood, Ill.

[22] Filed: **June 6, 1973**

[21] Appl. No.: **367,584**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 224,878, Feb. 9, 1972, abandoned.

[52] **U.S. Cl.** **336/84,** 336/183, 336/212

[51] **Int. Cl.** **H01f 15/04**

[58] **Field of Search** 336/180, 84, 105, 107, 336/181, 183, 212

[56] **References Cited**

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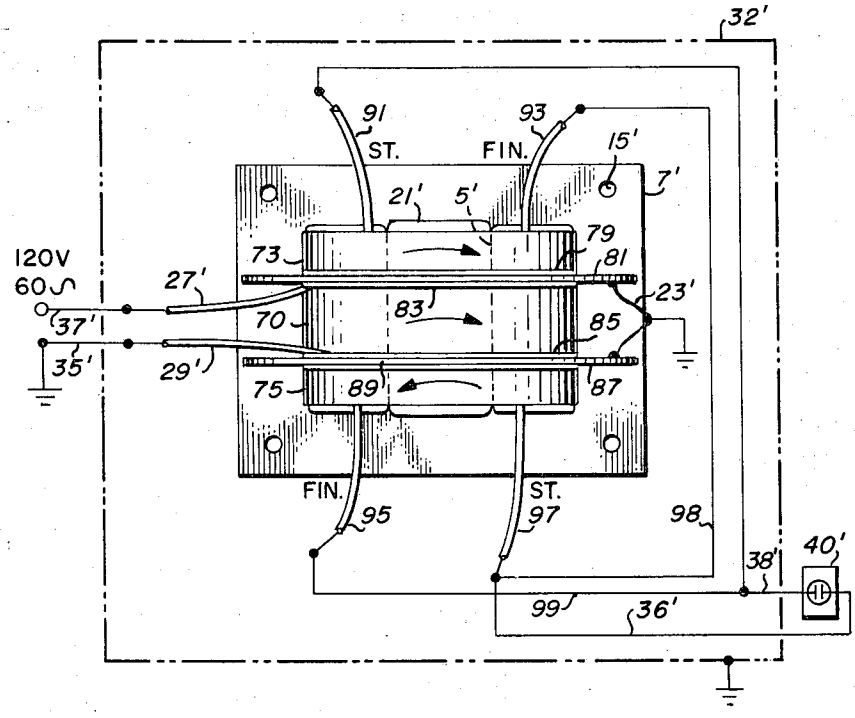
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Primary Examiner—Thomas J. Kozma
Attorney, Agent, or Firm—Ronald M. Goldman

[57] **ABSTRACT**

The disclosed invention presents an isolated electrical distribution system which includes at least a pair of power lines for providing a source of alternating voltage, one of the lines being connected to electrical ground, which are connected across the primary winding of an isolation power transformer, and at least a second pair of lines, neither of which is connected to said ground potential, wired to an electrical outlet or load and connected across the secondary winding of the transformer. The isolation transformer, housed in a metal enclosure, includes a magnetic core, a primary winding formed in a coil, a secondary winding formed in a separate coil with the coils mounted on the magnetic core on one side of the primary, with the turns of one coil wound in a clockwise direction relative to the core and the windings of the other coil wound in a counterclockwise direction relative to the core; another secondary winding formed in a separate coil and mounted on the core on the other side of the primary coil; and thin flat nonmagnetic metal shield members, each having a slot therethrough, are fitted over the magnetic core and sandwiched in between each of the two secondary coils and the primary coil. As described, leakage currents between the primary and secondary windings and between the secondary windings to ground is minimized with concurrent reduction in stray magnetic fields.

2 Claims, 20 Drawing Figures



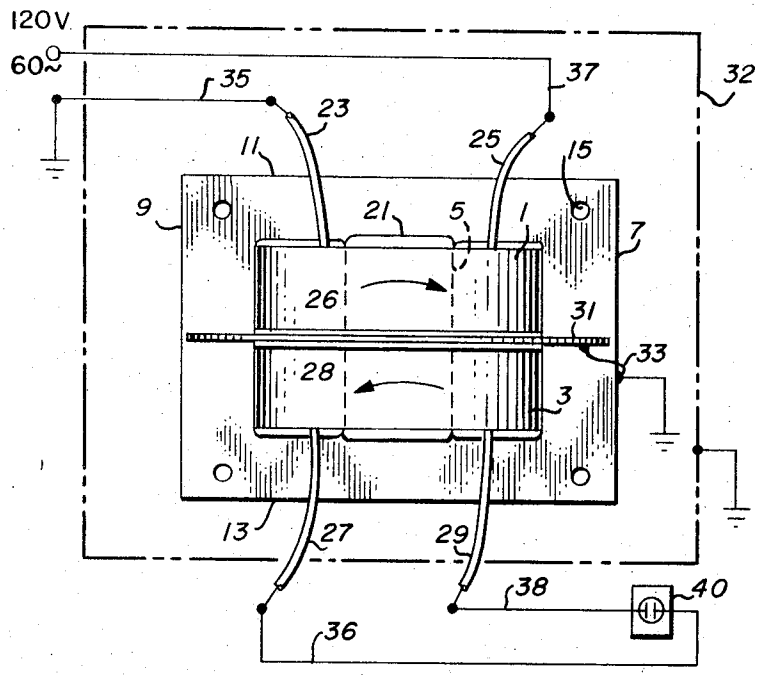


Fig_1

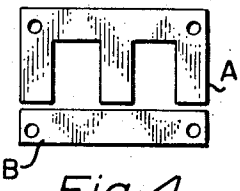


Fig_4

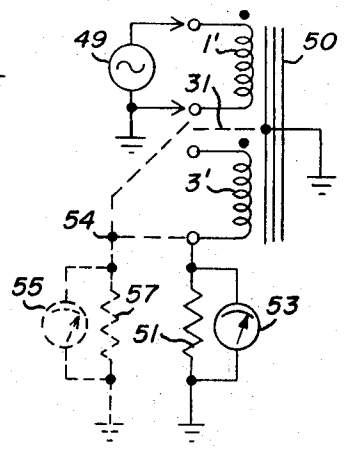


Fig_5

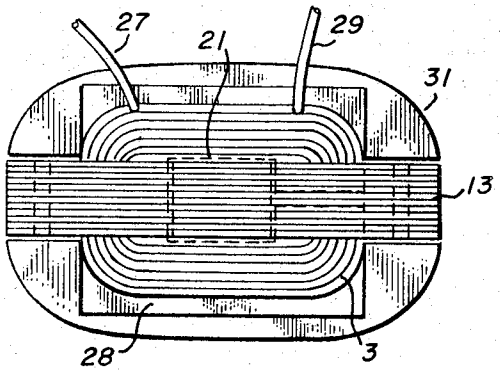


Fig_2

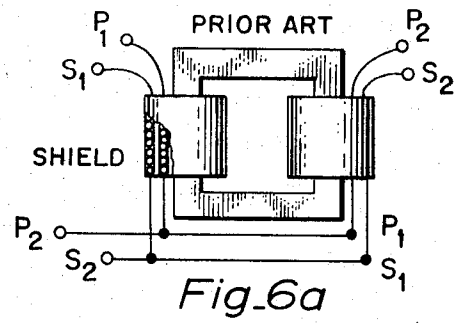


Fig_6a

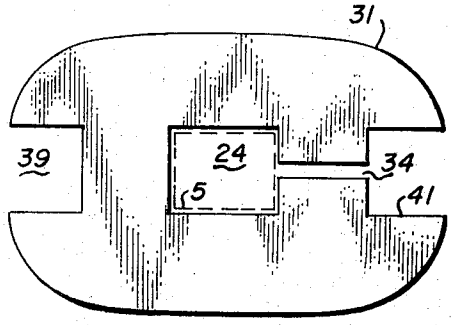


Fig_3

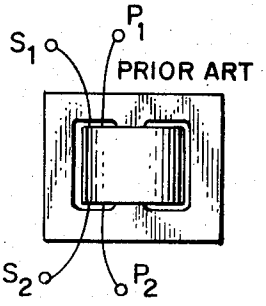


Fig_6b

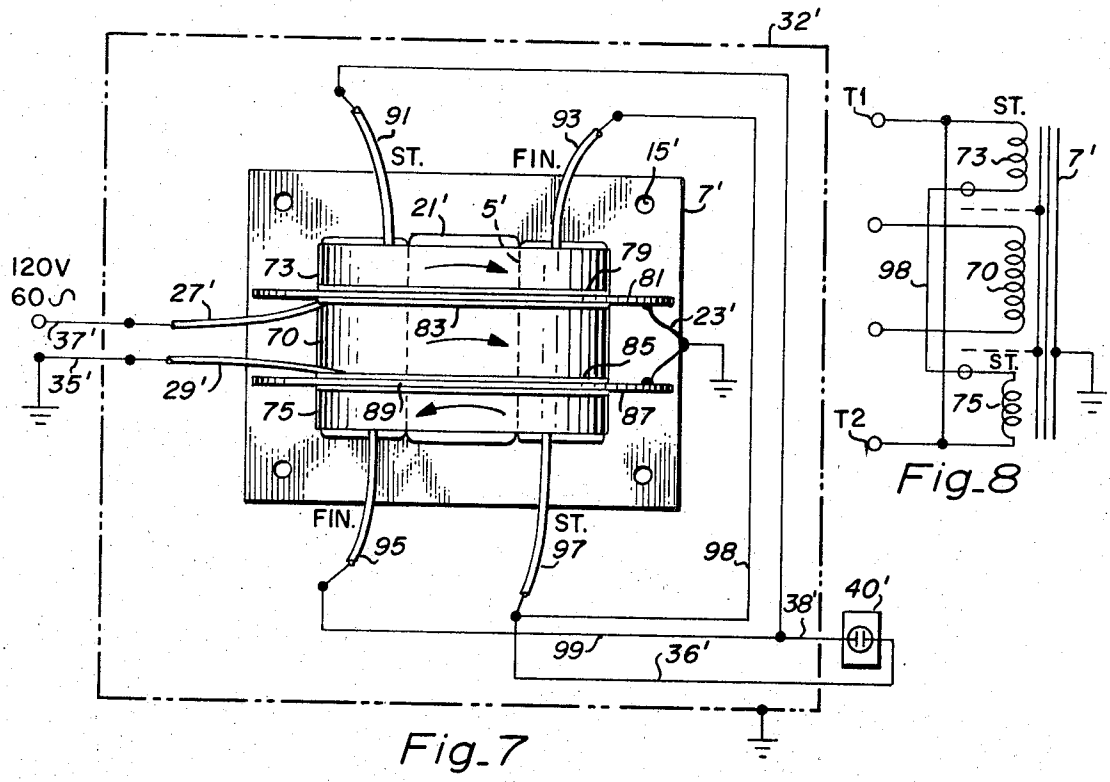


Fig_7

Fig_8

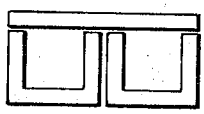


Fig_9a

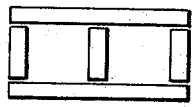


Fig_9b



Fig_9c

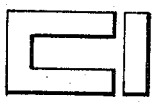


Fig_9d

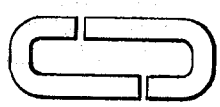


Fig_9e

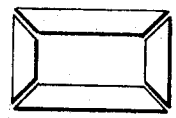


Fig_9f

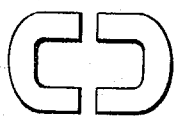


Fig_9g

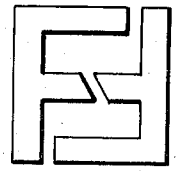


Fig_9h

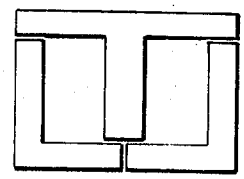


Fig_9i

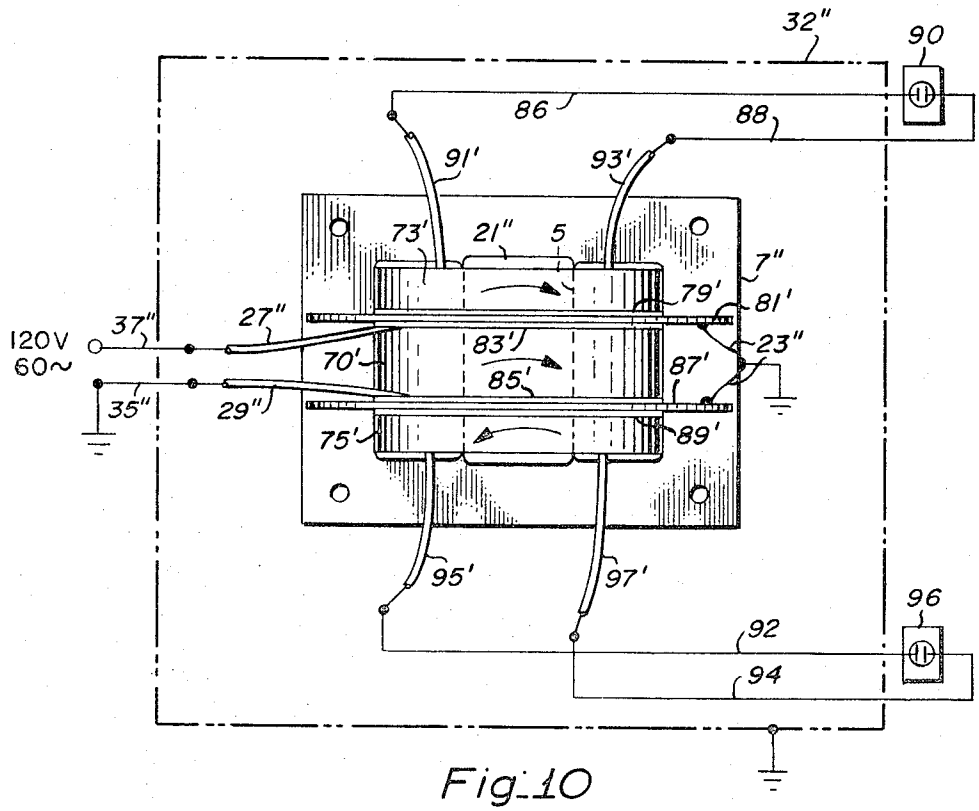

32"
90
86
88
91'
93'
73'
21"
5
7"
79'
81'
37"
27"
120V
60~
83'
23"
70'
87'
85'
35"
29"
75'
89'
95'
97'
96
92
94

Fig. 10

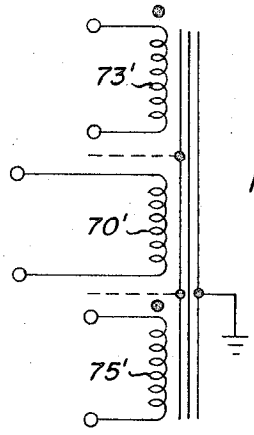

73'
70'
75'

Fig. 11

LOW LEAKAGE CURRENT ELECTRICAL ISOLATION SYSTEM

This is a continuation-in-part of our earlier filed application Ser. No. 224,878, filed Feb. 9, 1972 and now abandoned.

FIELD OF THE INVENTION

This invention relates to hospital electrical distribution system and, more particularly, to high power low leakage current isolation transformer and hospital type isolated electrical supply system combinations.

BACKGROUND OF THE INVENTION

Electrical AC distribution systems provide AC power from a source located at the power company over electrical lines which distribute the power to consumers at different locations. Electrical transformers are included in such a distribution system. The transformer is a well known electrical component by which AC electrical energy is coupled or transformed from one circuit at the transformer input to another coupled to the output by electromagnetic induction. Typically, the transformer includes at least a primary winding made up of a coil of wire, a secondary winding, also a coil of wire, inductively coupled together, and located physically on an iron core, the magnetic properties of which enhance the inductive coupling between the windings. Suitably a source of alternating voltage coupled to the primary winding is transformed and coupled by means of electromagnetic induction into an alternating voltage that appears across the secondary winding. The relationship between the magnitude of voltage applied to the primary and the voltage appearing at the secondary is primarily a function of the turns ratio of the windings, the number of turns of wire in the coil which makes up the primary as compared to the secondary. This and other factors affecting the design and operation of transformers are well known and explained in readily available literature.

One particular type of transformer is that in which the turns ratio, the number of turns in the secondary winding as compared to the number of turns in the primary winding, is equal approximately to one or two, whereby a voltage applied to the input or primary winding of that transformer is the same voltage which is produced at the secondary winding, or double that of the primary winding. This type of transformer permits a coupling of voltages and current from one circuit coupled to the primary winding to a second circuit coupled to the secondary winding, with no direct or DC current path between each primary and secondary circuits. Hence the transformer of this type serves to isolate electrically the first and second circuits and the transformer appropriately is referred to as an "isolation" transformer.

Isolation transformers have long found application for many different purposes as part of electrical AC distribution systems. One well-known and particularly critical application for isolation transformers is in combination with the electrical supply system of an operating room found in the modern hospital. For reasons hereinafter explained, the hospital operating room contains a special isolated electrical system. In this system the power available from the electrical utility companies is brought into the hospital via two or more lines and fed into an isolation transformer of the operating room supply. One of the utility company lines is always "grounded", i.e., connected in a direct current path with the earth. The output of the isolation transformer is thereupon fed to the numerous electrical distribution outlets found in the operating room. By connection to these outlets electrical and electronic instruments used in modern hospital operating rooms receive electrical power. Accordingly, isolation transformers must be capable of handling large amounts of AC power.

In addition to the aforementioned isolation system, a stranger to a modern operating room would find that the floors of the operating room are of metal construction and are electrically connected to neutral electrical potential, suitably ground or earth potential, as is the one electrical line from the power company. And all the room equipment is likewise in some manner in electrical contact with that metal flooring. Moreover, the operating personnel wear special electrically conductive foot coverings in order to prevent any build up of static electricity on the person, such as one commonly experiences by walking across rugs in dry weather.

The concept of metal flooring and other anti-static gear, as is known, was adopted because of the requirements of anesthesiology. In early hospitals the advent of modern anesthesiology was somewhat of a bane as well as a boon, in that the gases used for anesthetic are highly explosive. Thus the least spark such as could be caused by static electricity discharges between the surgeon's hand and the operating table ignited any gases that might have leaked from containers and accumulated. In the least, that was obviously undesirable.

With that problem solved, another was created. Since the flooring is electrically grounded, any equipment malfunction in the electrical outlets or equipment connected thereto, such as by insulation breakdown, could expose a "hot" AC line which when touched by one essentially "grounded" to the flooring would complete an electrical path from the hot line to ground through the person, resulting in shock or electrocution. This hazard is theoretically eliminated by the isolated electrical system. In being isolated, there is no direct current path or circuit from the electrical outlets to ground potential at the metal flooring.

As those in the field of electrical wiring are aware, there is often a difference in potential between electrical grounds because of a difference in location. Although in most applications proper electrical grounding of equipment is taken for granted, in fact persons may find in their household that an electrical sensation might be felt by touching an electrical stove at the same time that one touches a metal sink, assuming the two have not been grounded together to the same location. The electrical stove may be connected to the "ground" supplied by the electrical utility company, initially, while the sink is generally connected through the cold water pipes directly to the earth ground directly outside the house. Since the two different current paths to ground may have two different electrical resistances the potential or voltage across such resistances may differ slightly, resulting in a voltage difference between the two objects. Thus there are and can exist small differences in potential between ground, and these, in turn, can give rise to minute currents which, ordinarily, may be disregarded. However, with the sensitive equipment found in the modern hospital even minute differences must be avoided. Should one of two different ground connections become highly resistive or open, a

large current can flow between the two locations with resulting shock or electrocution if such current path is completed through a person.

Theoretically, the isolation transformer provides the isolation which breaks off or isolates the electrical ground supplied by the utility company as applied to the primary winding from the "ungrounded" lines of the operating room electrical system, coupled to the secondary winding. Like all physical things, however, isolation transformers depart to some degree from the ideal and although for most applications such departures may be disregarded, for hospital systems they must be maintained as close to the ideal as is permissible within the realm of present technology and closely monitored. The transformer primary and secondary windings are insulated from one another and from the magnetic iron core by isulating material. However even the best insulating material has some resistive leakage, however slight. And after years of service the insulation ages increasing resistive leakage current. In a transformer this insulation breakdown could permit noticeable resistive leakage currents between the primary and secondary windings and between each of those windings and the iron transformer core.

A second cause of inherent leakage currents, either between the primary and secondary windings or between either of those windings and the magnetic core to electrical ground, occurs due to electrostatic coupling. Effectively with any transformer there is some electrical capacitance, first, between the primary and secondary windings, and second, between each such winding and the iron core. While the inherent operation of the transformer at the 60-cycle frequencies usually found on the power lines relies upon magnetic induction action for coupling between the windings, it is apparent that there exists between the spaced electrically conductive materials of each of the primary and secondary windings and of the iron core some degree of electrical capacitance, however small. And, as is well known, alternating current does effectively pass through capacitance; the larger the capacitance, the more current which can flow therethrough.

With transformers, this property is referred to in the literature as "distributed capacitance," and is adequately there explained in greater detail should the reader wish to pursue same further.

Ideally, in an isolation transformer for hospital supply systems, this electrostatic coupling through distributed capacitance should be minimized. Typically, the leakage due to distributed capacitance is more predominant than that due to insulation resistance, resistive leakage. And, forturately, to some degree as the insulation ages and lowers in resistance its distributed capacitance, and hence capacitive leakage current, decreases to more than offset increased resistive leakage current.

A brochure published by the Sorgel Company of Milwaukee, Wisconsin, entitled "Hospital Isolating Panels," provides interesting insight into the foregoing problems of hospital supply systems. In addition, another brochure entitled "The Dynamic Ground Detector," published by the same company, makes mention of the requirements of a transformer in hospital isolated electrical systems, and depicts one such transformer. Quoting from the following brochure:

"The transformers, in all cases, should be of the isolating type and designed for low current leakage in the secondary winding. The capacitive current leakage of the secondary should not exceed 10 microamperes on units 5 KVA and smaller or 25 microamperes on units 15 KVA and larger. Transformers having higher current leakage values would limit the usable circuits in the total system.

"The present standard does not call for the isolating transformer to have an electrostatic shield between the primary and secondary windings, however most leading authorities have recommended the use of a shield. It seems likely that the new standards will require an isolating transformer with an electrostatic shield. From the practical viewpoint, it does complicate the problem of producing a low leakage transformer, as it represents an additional capacitive coupling to ground. It does, however, provide an additional margin of safety in preventing shorts between the primary and secondary. Perhaps an even greater contribution of the shield is that of providing a measure of protection against the coupling of harmonic distortions between the primary and secondary which might otherwise adversely effect sensitive electronic monitoring equipment."

An electrostatic shield between the primary and secondary windings of the transformer reduces not only 60 cycle AC coupling but minimizes coupling of any high frequency AC signals such as radio frequency signals that in some way get onto the power lines. The location of such a metal member is visualized in connection with the physical arrangement of the transformer elements.

Power transformers typically include the iron core which forms a closed magnetic circuit. The iron core is shaped into either the "core" or "shell" type, and contain different winding arrangements. In the core type the magnetic circuit resembles a rectangle, and the primary and secondary windings are generally placed on two opposed legs of top core. For efficiency of coupling, the primary and secondary may be "split" and a portion of each placed on each of the two opposed legs. In the shell type transformer, the magnetic core configuration resembles a rectangle with a center leg down the middle. The transformer windings are placed on the center leg, essentially remaining within the confines of the "window" formed on each side of the center leg by the outer legs of the rectangle, hence the term "shell." In either arrangement the primary and secondary windings are either formed one on ts of the other, termed "double wound," or are separately wound and placed side by side. In addition, with the core type transformer the primary and secondary windings may be split, that is, a coil on one leg includes a part of the secondary wound over a part of the primary winding in a double wound arrangement; a like coil arrangement is placed on the opposed leg and each of the remote portions of the same primary and secondary windings are placed in an electrical series circuit together. This latter arrangement is typical of the transformer in the aforecited Sorgel publication.

A metal barrier or shield is used in those transformer structures where it is desired to form or provide an electrostatic shield to prevent passage of high frequency electrical currents between parts. Such shields are commonly found in transformers of the double wound variety. The shielding is accomplished typically by placing a metal foil layer between the primary and

overwound secondary windings and electrically grounding that shield.

The use of a shield is also found in a low power ignition system transformer for reducing the coupling of high frequency energy generated in the ignition circuit and applied to the secondary winding to the primary winding. This is illustrated in U.S. Pat. No. 2,183,355, issued Dec. 12, 1939, to L. Mauerer. And a shield is used for a similar purpose in the transformer illustrated in U.S. Pat. No. 2,904,762, issued Sept. 15, 1959 to Schulz, on a type of power transformer.

OBJECTS OF THE INVENTION

Accordingly, it is a primary object of the invention to provide an improved isolated electrical distribution system for hospitals.

And it is a further object of the invention to provide a low leakage current isolation transformer of high efficiency suitable in combination with a hospital electrical supply system.

BRIEF SUMMARY OF THE INVENTION

An isolated electrical distribution system includes at least a pair of lines having applied thereto an alternating voltage, one of the lines being connected to ground, connected to the primary winding of an isolation transformer, and at least a second pair of lines, neither of which is connected to said ground, connected to the secondary winding of said transformer and to an electrical outlet load. The high power isolation transformer is located in a metal enclosure, suitably iron, and includes a magnetic core, a primary winding formed in a coil, a secondary winding formed in two coils mounted side by side on the magnetic core with the primary winding coil sandwiched between. Additionally a pair of thin, flat, nonmagnetic metal shield members, each having a slot therethrough, is fitted over the core; each one in between a respective secondary coil and the primary coil to form a physical barrier between said coils, and twin insulating spacers are provided between said metal shields and each said coils to form a closely packed sandwich of coils, spacers and shield. In accordance with the invention, the coils are oriented with the turns of one of the secondary coils wound in a clockwise direction with respect to the core leg and the turns of the other secondary coil wound counterclockwise, with the primary coil having its turns in one or other of such direction.

Those features which are believed to be characteristic of the invention, together with equivalents and substitutions of the elements therefor, and the accomplishment of the foregoing objects and advantages of the invention and additional advantages thereof, become more apparent from a consideration of the preferred embodiments of the invention as set forth in the following detailed description of the specification taken together with the figures of the drawings.

DESCRIPTION OF DRAWINGS

In the drawings:

FIG. **1** illustrates one view of an embodiment of the invention.

FIG. **2** illustrates a side view of the transformer construction used in the embodiment of FIG. **1.**

FIG. **3** illustrates a shield member used in the embodiment of FIG. **1.**

FIG. **4** illustrates a specific example of a magnetic lamination of the transformer used in the iron core of the transformer of FIG. **1.**

FIG. **5** illustrates schematically the transformer disclosed in FIG. **1** together with circuits for testing current leakage.

FIG. **6***a* and FIG. **6***b* represent core type and double wound shell type isolation transformer constructions commercially used in prior art hospital type isolated electrical supply systems.

FIG. **7** illustrates another embodiment of the invention.

FIG. **8** schematically illustrates the transformer included in FIG. **7.**

FIGS. **9***a* through *i* illustrate various lamination configurations.

FIG. **10** illustrates still another embodiment of the invention.

FIG. **11** illustrates schematically the transformer included in the embodiment of FIG. **10.**

DETAILED DESCRIPTION OF THE INVENTION

The top view of the transformer in FIG. **1** shows it to include a first coil winding **1** spaced side by side from a second coil winding **3** and mounted on the center leg **5** of a shell type transformer core. The magnetic iron core includes two side legs, **7** and **9,** and front and back legs, **11** and **13,** which form two windows, one on each side of the center leg. A large number of these laminations are stacked up together to form a transformer iron core. Suitable openings, **15,** extend through the stack of laminations to permit bolts, not illustrated, to clamp the individual laminations together mechanically into a single core. An insulating tube **21,** only partially visible in the figure, which fits around the center leg **5** and windings **1** and **3** fit over such insulation. Winding **1** is of conventional construction and consists of a plurality of layers of electrical wire wound around and along the core in a given direction, clockwise or counterclockwise, with each layer separated from the next adjacent layer suitably by a layer of insulating material until the requisite number of turns in the winding are formed and to form a spool with a central passage through which leg **5** extends. The two electrical leads **23** and **25** extend from coil **1** with lead **25** connected to the start of coil **1** and going to the first turn in the first layer most proximate the core and electrical lead **23,** finish lead, is attached to the last turn of wire in the coil. Winding **3** is similarly wound upon insulation tube **22,** only partially illustrated, and in this embodiment comprises the same number of turns and structure so that the turns ratio between coils **1** and **3** is one-to-one. Likewise coil **3** includes a start electrical lead **27** and a finish electrical lead **29.**

It is apparent that the winding **3,** which serves as the secondary winding, may contain double the number of turns if a two-to-one turns ratio is desired to double the voltage at the secondary.

Separating and fitted in between windings **1** and **3** is a thin flat metal member, **31,** which is also fitted over central leg **5,** which is better discussed hereinafter in connection with FIG. **3.** A pair of thin flat O-shaped insulating members **26** and **28** are fitted between metal member **31** and a respective one of the coils **1** and **3** to insure insulation therebetween. As is apparent, this forms a closely packed sandwich construction of coil **1,**

spacer **26**, shield **31**, spacer **28**, and coil **3** abutting the adjacent element

The secondary winding **3** is mounted on the center leg **5** in a manner which is magnetically opposite to that of primary winding **1**. That is, assuming the turns in the coil making up winding **1** are wound upon core tube **21** or leg **5** in a clockwise manner in the view of FIG. **1**, the turns of the winding **3** appear from the same view to be wound around insulating tube **22** or leg **5** in a counterclockwise manner. This is accomplished typically by winding both coils in the same direction but reversing one of the coils relative to the other prior to building up the laminations and completing the magnetic core.

A lead **33** electrically connects shield member **31** in circuit with the magnetic core at leg **7** to electrical ground potential as indicated by the symbol in the drawing.

The electrical utility lines which are provided by the power company provide connection to an alternating voltage source. The source is represented as the 120-volt 60-cycle AC in FIG. **1** connected via leads **35** and **37** to the leads **23** and **25** of the primary winding **1**. Lead **35** is connected electrically to ground potential as indicated by the symbol in the drawing.

The pair of electrical lines **36** and **38**, neither of which is connected to ground potential, are connected to the secondary winding output leads **27** and **29** and extend to various electrical outlets, not illustrated, in a hospital operating room for supplying AC to an electrical load represented by **40**.

The dash lines **32** symbolically denote a six sided metal housing or enclosure in which the transformer and usually monitoring instruments, not illustrated, or other electrical components common to hospital distribution systems are installed. This enclosure, sometimes referred to as a panel, usually contains a door or removable trim cover, is formed of 12 gauge steel. The enclosure is electrically grounded as illustrated in the figure.

For convenience, where an element appears in another figure it is given the same numerical designation. FIG. **2** illustrates a front side view of the transformer found in FIG. **1**. Visible in this view is the iron core leg **13**, coil **3**, leads **27** and **29**, the insulating tube **22** partially visible, O-shaped insulating spacer **28** and metal shield member **31**. As is apparent the view of the structural arrangements from the other end of the transformer would appear to be a mirror image of FIG. **2**. Note that member **31** completely obscures the coil **1** located on the other side.

The constructional detail of the metal shield member **31** is indicated in FIG. **3**. Member **31** is suitably of aluminum, is thin and flat but of a somewhat complicated geometry. This includes a central passage **32** through which the central leg **5** of the transformer of FIG. **1** extends and two cutaway end portions **39** and **41** with which to hook over the side core legs **9** and **7** in FIG. **1**. A slot **34** extends through the member, between passage **32** and an outer edge of the member **31**. This slot forms a gap and prevents a current path in the metal from encircling passage **24**. In the form illustrated the geometry is essentially a C-shaped member with a "hat" on the upper end of a "pedestal" at its bottom end, if analogy is appropriate. In its simplest form it is apparent that a simple C-shaped member, eliminating the ends which hook over core legs **9** and **7** of FIG. **1**, while less efficient would appear to suffice. As is indicated by dotted line **5'**, which represents the center leg of the transformer in FIGS. **1** and **2**, passage **32** is larger in cross section than core leg **5**, and in position on the leg the shield is placed so that the slot **34** is not "bridged" electrically by any part of the iron laminations which make up the center or outer core legs. This prevents the shield from acting as a single turn coil that is short-circuited. Other ways of maintaining slot **34** open are apparent to the reader.

FIG. **4** illustrates two individual laminations, A and B, which are commonly referred to as E-I laminations which is, by way of example, used to construct the magnetic core of FIG. **1**. Typically, the transformer core is built up by alternating the positions of E and I laminations so that the I of the next adjacent lamination would be situated over the back rib leg of the E lamination, A, and the next E lamination would be situated atop both the I lamination, **38**, and the stems of the E with the stems facing the opposite direction. And this is continued until the core is of the desired height.

A transformer construction of the embodiment of FIG. **1** constructed according to the teachings of this invention included a stack of laminations having a height of 1⅞ inches and length and width dimensions of 9⅜ and 11¼ inches, respectively. Coil **1** comprised approximately 78 turns of 9 sq. heavy armored Polythermaleze 2,000 wire and consisted of approximately four layers. The insulating tube comprised Nomex, well known insulating material, and the layer to layer insulation comprised "Quintex I." A like construction was used for the secondary winding **3**.

Basically, the transformer is put together in the conventional way by first forming the coils on suitable coil winding equipment. The coils are oriented as previously described, and the metal layer is sandwiched in between. Next, the magnetic lamination is built up by individually inserting E laminations through the coil, alternating in direction from the front to the back side, and also alternating placing I laminations down. When the stack is built up to the proper height, suitable bolts are inserted into the openings and the entire stack is fastened together. Typically, metal legs can be supported in place by means of the same bolts. In addition, conventional wedges of insulating material can be inserted in the slight gap or space between the center leg and the core tube to firmly fix the respective windings in place.

The operation of a transformer is well understood and need not be repeated here in detail. The voltage at the primary, 120 volts in the example, produces a current which induces a voltage in the secondary winding, equal approximately to the primary voltage multiplied by the turns ratio, which equals 1 in the example given and is also 120 volts AC.

The transformer is schematically illustrated in FIG. **5** with its core **50** and shield **31'** connected to ground. In testing the amount of leakage between the primary and secondary windings, leakage which includes both that due to the resistiveness of the insulation and that due to the coupling capacity, a source of alternating current, 49, is applied across the primary winding of the transformer and one end of the secondary winding is connected by means of a 500 ohm resistor, 51, to ground potential. A microvolt meter, **53**, is connected in parallel with resistor **51** to measure the small voltages that will be generated by the small currents flow-

ing through resistor **51.** Inasmuch as one side of the 60 cycle power supply by the utility company is connected to ground, the only path for current to flow is from the "hot" side of the source through the insulation, by capacitive or resistive current paths therethrough, to the secondary winding and from there through the load resistor **51** back to ground.

For measuring the leakage between the primary winding and ground and between the secondary winding and ground, the measuring circuit and load resistor represented by the dashed lines is, instead, used. A line, **54,** is connected between one side of each of the primary and secondary windings. This, in turn, is connected through a resistor, **57,** suitably 500 ohms to ground, and a microvolt meter, **55,** is connected across resistor **57** to measure voltages generated by leakage currents. A source of 60 cycle alternating current, **49,** is connected across the primary winding as in the preceding test.

The tests specified in FIG. **4** were made on the embodiment of FIG. **1.** These results are compared with like tests made on the double wound type isolation transformer of the prior art illustrated in FIG. **6***b* and the double wound split winding core type transformer of the prior art illustrated in FIG. a. a In the split winding arrangement of the prior art of FIG. **6***a*, one-half of the secondary winding and one-half of the primary winding are located on opposite legs of the magnetic core and the respective winding halves are connected together by means of the electrical leads in "series" or additive phase. And a metal shield is incorporated between each secondary winding half and each underlying primary winding half.

A comparison of results obtained from each type is reproduced:

TRANSFORMERS — 3 KVA — INSULATION NOMEX

LEAKAGE CURRENT	Pr (μA)		S (μA)		Pr — S (μA)	
	St.	Fin.	St.	Fin.	St.	Fin.
Invention FIG. 1	3.5	5.7	1.86	3.95	1.1	1.1
Prior Art FIG. 6(*a*)	65.0	65.0	7.0	7.0	70.0	70.0
Prior Art Double-wound FIG. 6(*b*)	12.4	23	16	11.8	29.4	34.8
Voltage Drop Across 500 ohm Resistor Millivolts						
Invention FIG. 1	1.75	2.85	.93	1.98	.55	.55
Prior Art FIG. 6(*a*)	32.5	32.5	3.5	3.5	35.0	35.0
Prior Art Double-wound FIG. 6(*b*)	6.2	11.5	8.0	5.9	14.7	17.4

It appears that the isolated electrical systems having isolation transformers of the type illustrated in the cited Sorgel Company publication as represented in FIG. **6***a* has poor results by comparison as a result of the included shields. This is consistent with the reasons attributed by the manufacture in the Sorgel publication.

As the foregoing results indicate, the isolated distribution system of the invention primarily due to the transformer construction has substantially less leakage current in all measurable respects, whether from the primary winding to ground, the secondary winding to ground, and between the primary to secondary winding, and even though a shield is included. All of the leakage currents are substantially below those levels desired in a hospital supply type isolation system, namely 10 microamps. This is true even though the transformer includes, essentially, a shield member **31** in FIG. **1** which would normally be expected to increase the capacitive coupling to ground and increase individual winding to ground leakage current as the prior art teaches. Accordingly, it is believed that some effects do occur by sandwiching the shield in between side by side primary and secondary windings on the transformer core which, though unexplained, do provide unexpected and highly desirable results.

Although in the abstract the use of a similar shield member and transformer construction appears in the prior art, particularly in U.S. Pat. NO. 2,183,355, issued Dec. 12, 1939, in which an ignition transformer is disclosed, a low power transformer used to step up and supply high voltage pulses to the secondary winding having widely spaced windings with shield member intended to isolate radio frequency energy generated in the load from passing back from the secondary windings to the primary windings and where normal current leakage is not a factor, we did not expect that a somewhat similar arrangement in which the shield is closely sandwiched between primary and secondary windings arranged side by side on a shell type transformer core to eliminate coupling radio frequency energy or other harmonics from the primary winding to the secondary winding to be useful and together with contraclockwise windings obtain low leakage currents in an isolation transformer of high power found in a hospital supply system.

In one specific example, a 250 VA, 60 Hz, 120 volt transformer constructed according to the teachings of the invention included a primary winding having 169 turns of wire and a secondary winding having 176 turns of wire, with the secondary winding mounted on the transformer core so that the turns of the winding were in the same clockwise direction, and with the shield grounded, and various leakage currents were measured as set forth in Row 2 of the chart hereinafter presented. By contrast with the secondary winding mounted on the core so that the direction of winding is opposite clockwise to that of the primary winding, the leakage currents set forth in Row 1 of the chart below presented were obtained. As is noted, the primary to secondary leakage decreased from 0.82 microamps to 0.06 microamps measured between the winding starts, and decreased from 1.6 microamps to 0.19 microamps measured between winding finishes:

	PRIMARY TO GRD.		PRIMARY TO SECONDARY		SECONDARY TO GRD.	
	P_{ST}	P_{FIN}	ST_S	FIN_S	S_{ST}	S_{FIN}
1	.42	.80	.82	1.6	.47	.57
2	.48	.82	.06	.19	.36	.69

FIG. 7 discloses another embodiment of the invention in which the transformer is of a slightly different configuration. For convenience where the elements in the embodiment of FIG. 7 are the same as that previously described and discussed in connection with the embodiment of FIGS. 1 through 5, they are similarly labeled with primed numerals. Further reference may be made to the preceding description of the preceding embodiment for the description and construction of such corresponding elements. A first coil of wire **70** forms a primary winding and consists of a suitable predetermined number of turns of wire which, by way of one specific example, can comprise 78 turns of 9 sq. heavy armored Polythermaleze 2,000 wire wound in four layers, is mounted on center leg 5' of magnetic core 5'. Coil **70** is wound with the turns in a clockwise direction as indicated by the arrow. A second coil of wire **73** forms a first secondary winding and is mounted at one end of leg 5' spaced from winding **70.** A third coil of wire **75** forms a second secondary winding and this coil is mounted on leg 5' at the other end of primary winding **70.** Suitably each of these secondary windings contains an equal number of turns of wire, with the number of turns in each coil being an integral multiple of those turns in the primary winding. By way of specific example, the turns ratio of each secondary to the primary can be 1 and, hence, the number of turns in each of the secondary windings is approximately 78. As indicated by the arrows in the figure the direction of the turns in coil **73** is clockwise whereas the winding direction of the turns in coil **75** is counterclockwise, so that the winding directions of the two secondary coils are contraclockwise relative to one another.

An insulator **79,** nonmagnetic metal shield **81,** and insulator **83** form a sandwich arrangement in between coils **73** and **70.** These insulators and the shield are identical to the insulator construction and shield construction of elements **26, 28** and **31,** discussed in connection with the preceding embodiments. Likewise another insulator **85,** shield **87,** and insulator **89,** is sandwiched in between the ends of coils **70** and **75.** Again these insulator elements and shield elements are identical in construction with corresponding elements **26, 28** and **31** of the preceding embodiments and function in the same manner. Shield **81,** shield **87** are joined by electrical wires **23'** in common with core 7' which in turn is connected to electrical ground potential as indicated by the symbol in the drawing.

The primary winding **70** includes two leads **27'** and **29'** connected to the ends of the coil. These are connected to a grounded AC line via leads **37'** and **35'.** Secondary winding **73** includes two leads **91** and **93** connected to the start (St.) and finish (Fin.) ends of the secondary coil **73,** respectively, and coil **75** includes leads **95** and **97** connected to the finish and start ends of secondary winding **75,** respectively. Secondary winding **73** is positioned on core 5' so that its windings are in the opposite winding direction as that of the other secondary coil **75.** Otherwise stated, given winding **75** wound in a clockwise direction, winding **73** would have its windings running in a counterclockwise direction. In so doing, the positive phase of coil **75** is at the start lead **95** while the positive phase end of winding **73** is at the finish lead **93.** The secondary windings are connected together so as to place them electrically in parallel with electrical lead **98** connected between lead **97** of winding **75** and to lead **93** of winding **73** and lead **91** connected to lead **95** by lead **99.** Hence, the full secondary voltage is produced by each of the two secondary windings and these are placed in parallel to provide the appropriate output voltage that appears across leads **98** and **99** which are conducted via leads **36'** and **38',** respectively, to outlet **40'** and with each secondary coil seeing approximately one-half the current to the load. This is in contrast to the single secondary winding **3** in the embodiment of FIG. **1.**

The dash lines **32'** symbolically denote a six sided metal housing or enclosure in which the transformer and usually monitoring instruments or other electrical components, not illustrated, common to hospital distribution systems are installed. This enclosure, sometimes referred to as a panel, usually contains a removable trim cover or door, and typically is of 12 gauge steel material. The enclosure is electrically grounded.

The construction of the transformer component of FIG. 7 is schematically indicated in FIG. **8** where identical numerals are used to denote the windings. As appears in this schematic drawing, secondary winding **75** has the turns wound in the direction opposite to that of secondary winding **73.** The symbol "St." located at one end of the respective windings symbolizes the start end of that winding with the unlabeled end being the finish end. The start end of winding **75** is connected to the finish end of winding **73** and the start end of winding **73** is connected electrically to the finish end of winding **75.** The windings are in parallel so that full output voltage appears across each winding and each winding sees one-half the load current taken from terminals T1 and T2. Other conventional connections can be substituted as is apparent to the skilled reader.

We have discovered that there is a significant advantage in employing the embodiment of FIG. 7 over that of FIG. **1,** even though the leakage current are lower in the case of the embodiment of FIG. **1.** In both systems the transformers are confined within the metal enclosures **32** or **32'.** It is found that the transformer in FIG. **1** allows considerable stray magnetic flux that is quite

intense and this stray flux couples or links to the metal walls of the enclosure. Through magnetic action the changing flux field causes the metal enclosure walls to vibrate and this in turn creates an annoying audible buzz. By contrast, the transformer of FIG. 7, although of the same power rating does not cause the metal enclosure walls to vibrate and create unduly loud noise. This we believe is due to the fact that the coils or windings, though also creating stray magnetic fields, are creating two separate stray fields which are opposite in direction and essentially cancel one another the farther one moves away from the transformer side, i.e., away perpendicular to the plane of the paper containing FIG. 7. Since practice requires a metal enclosure, this reduction in magnetic flux coupling thereto is in our opinion a significant advantage.

Other modifications are apparent to the reader. For example it is possible to locate both of the secondary coils on the same side of the primary coil with a single shield fitted between one end of the primary winding and the most adjacent one of the secondary windings. By way of further example, a four coil arrangement is possible with two primary coils and two secondary coils. In such an alternative, the two primary windings can be connected together in phase addition with the windings wound in opposite directions and likewise the two secondary coils are oriented on the core with the directions of turn winding contraclockwise and connected together in series additive phase. A shield and insulator arrangement would be placed between each coil set.

As was indicated heretofore in this specification, one lamination configuration which is used to form the magnetic core of the transformer in the embodiment of FIG. 1 and specifically illustrated in FIG. 4, is a conventional E-I lamination. However numerous ones of the other conventional lamination configurations thereof, less preferred, appear suitable as alternatives. Thus, FIGS. 9*a* through 9*j* illustrate some conventional configurations including FIG. 9*a*, the 2-U and I configuration; FIG. 9*b*, the stacked I configuration; FIG. 9*c*, the two wound core configuration; FIG. 9*d*, the U-I lamination configuration; FIG. 9*e*, the CC or JJ configuration; FIG. 9*f*, the long and short I configuration; FIG. 9*g*, a single wound core configuration; FIG. 9*h*, an FF configuration; and FIG. 9*i*, a T-L configuration.

FIG. 10 discloses another embodiment of the invention which contains a transformer similar in structure to the transformer incorporated in the embodiment of FIG. 7. For convenience, where the elements in the embodiment of FIG. 10 are the same as that previously described and discussed in connection with the embodiment of FIG. 7, they are similarly labeled with primed numerals. Further reference may be made to the preceding description of the embodiment of FIG. 7 for the description and construction of such corresponding elements. In this embodiment, each of the secondary windings 73' and 75' operate as individual isolated secondaries. Hence, each of the turns of wire in the coil forming such secondary winding comprises an integral number of turns of wire. Thus for a one-to-one turns ratio the output voltage across leads 95' and 97' in the case of winding 75' and leads 91' and 93' in the case of winding 73' would be the same as that applied to the input of primary 70', which is 120-volts in the illustrated example. Additionally for a transformer with a given power rating such as 1,000 volt-amperes, each of the secondary windings in this embodiment would be rated at half the full value, whereas in the embodiment illustrated in FIG. 7 the secondary windings were placed in series and each of the secondary windings was rated at full value, namely 1,000 volt-amperes in a 1,000 volt-ampere transformer to carry the full secondary load. Leads 95' and 97' of secondary 75' are connected via electrical leads 92 and 94 across an electrical outlet 96 for conducting the alternating voltages which appear across the secondary winding to outlet 96. The output leads 91' and 93' are connected via electrical leads 86 and 88 to electrical outlet 90 for conducting alternating voltages which appear across secondary winding 73' to electrical distribution outlet 90. As in the embodiment of FIG. 7 and as indicated by the arrows in this figure, the turns of wire comprising the coil 70' forming the primary winding are wound in a clockwise direction relative to the core leg 5'' and the turns of wire comprising secondary 73' are also wound in a clockwise direction relative to the core. The turns of wire comprising secondary coil 75' are wound clockwise relative to core leg 5'.

The dash lines 32'' symbolically denote the six sided metal housing or enclosure, previously referred to in the preceding embodiments, in which the transformer and usually monitoring instruments, not illustrated, common to hospital distribution systems are installed. This enclosure, sometimes referred to as a panel, usually contains a door and typically is of an iron material.

For convenience, a schematic illustration of the transformer of this embodiment is presented in FIG. 10. As is apparent, this schematic differs from the schematic of the transformer of FIG. 8 in that it omits the connection 98 joining the secondary windings in series in FIG. 8 and each secondary winding in FIG. 10 is double the number of turns in FIG. 8. In this system a somewhat different leakage current condition exists from that in the preceding cases. The leakage current between the aiding secondary and the primary winding is somewhat higher than that between the opposing secondary winding and primary. The leakage current between the opposing secondary and primary winding is relatively the same as in the preferred embodiment, and the leakage current between each secondary winding to ground are relatively equal. In this configuration two separate electrical distribution circuits are provided and can be individually monitored. Concurrently the benefits of low leakage current in each of these electrical isolation systems is obtained. If only one-half the load is taken from one receptacle, the stray magnetic field is insufficient to cause vibration of the cabinet. At full load, equally from each of the receptacles, the stray magnetic fields cancel, as in the embodiment of FIG. 7, and avoid the problem of enclosure vibration.

It is understood that the foregoing embodiments of the invention are presented solely for purposes of illustration and not by way of limitation, inasmuch as equivalents and substitutions for the elements thereof suggest themselves to one skilled in the art upon reading this specification.

Accordingly, it is specifically requested that the invention be broadly construed within the spirit and scope of the appended claims.

What is claimed is:

1. An isolated hospital electrical supply system with very low leakage current to electrical ground potential and low noise for transforming AC voltage from an electrically grounded source and providing ungrounded AC voltage so as to minimize the possibility of electrical shock of a patient who is in contact with said electrical ground of said grounded source and to minimize audible noise generation in the system comprising:

at least a first pair of lines for providing low frequency alternating voltage from an electrical utility line, one of said lines being electrically connected to ground potential;

an electrical outlet receptacle adapted for connection to electrical equipment;

at least a second pair of lines connected in circuit with said electrical outlet receptacle for conducting alternating voltage to said outlet receptacle, neither one of said second pair of lines being connected to said ground potential;

an isolation transformer located spaced from said outlet receptacle, said isolation transformer including:

a core of magnetic material;

a first coil of wire containing a first predetermined number of turns, N_p, comprising a primary winding;

a second separate coil of wire containing a second predetermined number of turns, N_{s1}, comprising a first secondary winding;

a third separate coil of wire containing a third predetermined number of turns, N_{s2}, comprising a second secondary winding, said third coil of wire being substantially identical with said second coil of wire and said second and third predetermined number of turns of wire being the same;

first and second nonmagnetic metal shields having a passage therethrough and a slot between said passage and an outer edge thereof;

said first, second and third coil being electrically insulated from said core and mounted on said core side by side and closely adjacent one another with said second coil located adjacent one side of said first coil and with said third coil located adjacent the remaining side of said first coil;

said second coil having the turns of wire therein wound in a clockwise direction as mounted on said core and said third coil having the turns of wire therein wound in a counterclockwise direction as mounted on said core;

and wherein the ratio, N_{s1}/N_p, is equal to a number less than 3 and at least 1, and wherein the ratio, N_{s2}/N_p, is equal to a number less than 3 and at least 1;

said first shield mounted on said core sandwiched between one side of said first coil and said second coil and said second shield mounted on said core sandwiched between the remaining side of said first coil and said third coil;

means electrically connecting the start end of one of said secondary windings to the finish end of the other and the finish end of said one secondary winding to the start end of said other secondary winding to place said secondary windings in parallel;

means connecting each of said shield members and said magnetic core electrically in common and to said ground potential;

means connecting said first pair of lines in circuit with said primary winding for supplying alternating voltage thereto; and

means connecting said second pair of lines in circuit across said secondary windings for coupling alternating voltages from said secondary windings to said outlet receptacle;

whereby low frequency AC leakage current between said first and second pair of lines and between said second pair of lines and ground potential is minimized;

a steel walled enclosure for housing electrical components, including said transformer, said enclosure being connected to electrical ground potential;

said transformer being located in said enclosure; and

means for extending said pair of lines through an enclosure wall into said enclosure.

2. An isolated hospital electrical supply system with very low leakage current to electrical ground potential and low noise for transforming AC voltage from a grounded source and providing ungrounded AC voltage so as to minimize the possibility of electrical shock of a patient who is in contact with said electrical ground of said grounded source and to minimize audible noise generation in the system comprising:

at least a first pair of lines for providing low frequency alternating voltage from an electrical utility line, one of said lines being electrically connected to ground potential;

first and second electrical outlet receptacle means adapted for connection to electrical equipment;

at least a second pair of lines connected in circuit with said first electrical outlet receptacle means for conducting alternating voltage to said outlet receptacle means, neither one of said second pair of lines being connected to said ground potential;

at least a third pair of lines connected in circuit with said second electrical outlet receptacle means for conducting alternating voltage to said outlet receptacle means, said second outlet receptacle means being isolated electrically from said first outlet receptacle means and neither one of said third pair of lines being connected to said ground potential;

an isolation transformer located spaced from said outlet receptacle, said isolation transformer including: a core of magnetic material;

a first coil of wire containing a first predetermined number of turns, N_p, comprising a primary winding;

a second separate coil of wire containing a second predetermined number of turns, N_{s1}, comprising a first secondary winding;

a third separate coil of wire containing a third predetermined number of turns, N_{s1}, comprising a second secondary winding, said third coil of wire being substantially identical with said second coil of wire and said second and third predetermined number of turns of wire being the same;

first and second nonmagnetic metal shields having a passage therethrough and a slot between said passage and an outer edge thereof;

said first, second and third coils being electrically insulated from one another and said core and mounted on said core side by side and closely adjacent one another with said second coil located adjacent one side of said first coil and with said third

coil located adjacent the remaining side of said first coil;

said second coil having the turns of wire therein wound in a clockwise direction as mounted on said core and said third coil having the turns of wire therein wound in a counterclockwise direction as mounted on said core;

and wherein the ratio N_{s1}/N_p is equal to a number less than 3 and at least 1;

said first shield mounted on said core sandwiched between one side of said first coil and said second coil and said second shield mounted on said core sandwiched between the remaining side of said first coil and said third coil;

means connecting each of said shield members and said magnetic core electrically in common and to said ground potential;

means connecting said first pair of lines in circuit with said primary winding for supplying alternating voltage thereto; and

means connecting said second pair of lines in circuit with the said first secondary winding for coupling alternating voltage from said first secondary winding to said first outlet receptacle means; and means connecting said third pair of lines in circuit with said second secondary winding for coupling alternating voltage from said second secondary winding to said second outlet receptacle means;

a steel walled enclosure for housing electrical components, including said transformer, said enclosure being connected to electrical ground potential;

said transformer being located in said enclosure;

and means for extending said pair of lines through an enclosure wall into said enclosure.

* * * * *

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,851,287 Dated November 26, 1974

Inventor(s) Charles Edward Miller and James Andrew Nuding

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 4, line 39, the word "top" should read -- the --.
In Column 7, line 55, the numeral "32" should read -- 24 --.
In Column 7, line 64, the word "of" should be -- and --.
In Column 9, line 25, the reference to "FIG. a.a" should read -- FIG. 6_a --. In Claim 1, column 15, line 54, the reference to "$N_{s1}lN_p$" should read -- N_{s1}/N_p --.

Signed and sealed this 18th day of March 1975.

(SEAL)
Attest:

RUTH C. MASON
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PO-1050
(5/69)

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