July 15, 1969 H. J. SMITH 3,456,223

VOLTAGE STABILIZING TRANSFORMER WITH VARIABLE AIR GAP CHARACTERISTICS

Filed Sept. 15, 1967 2 Sheets-Sheet 1

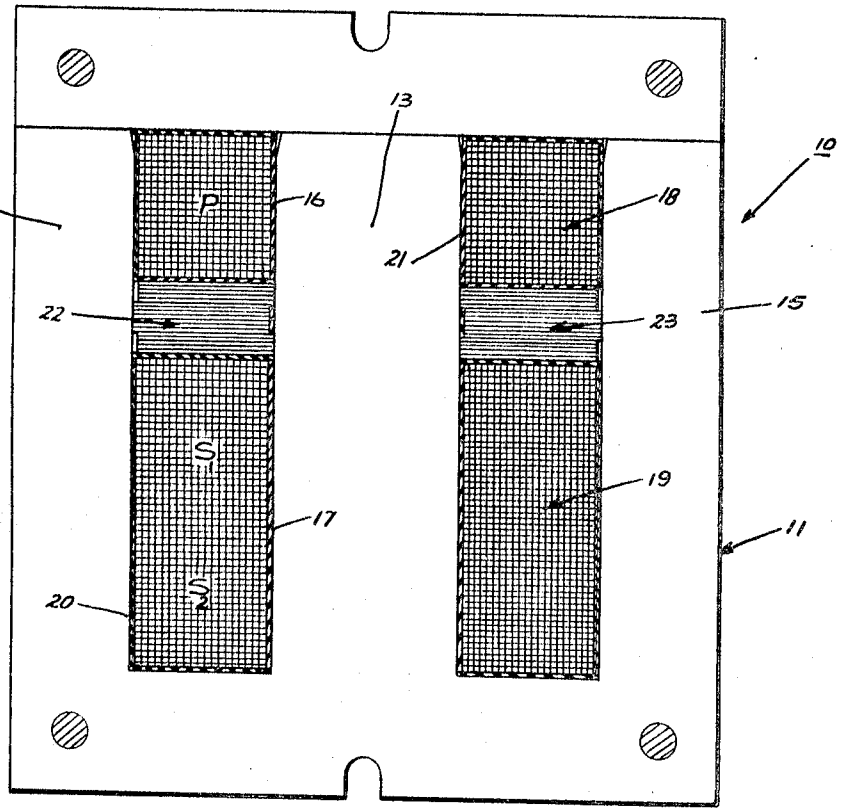


Fig. 1

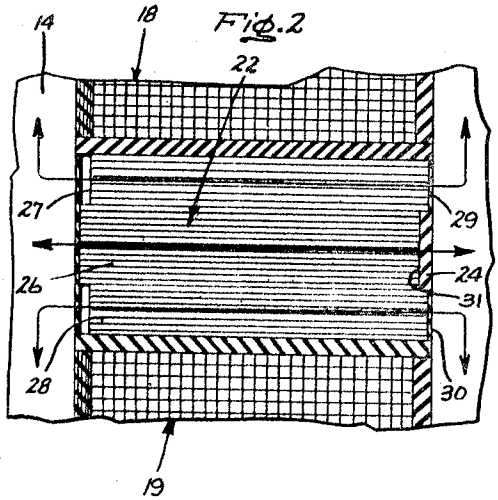


Fig. 2

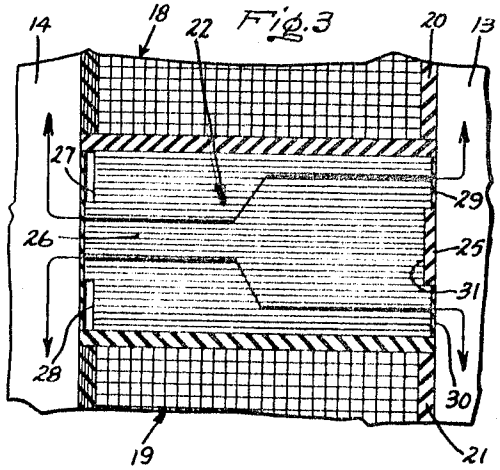


Fig. 3

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Fig. 4

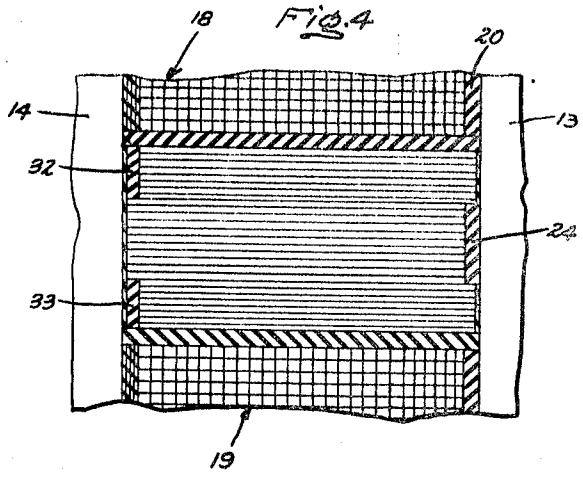


Fig. 6

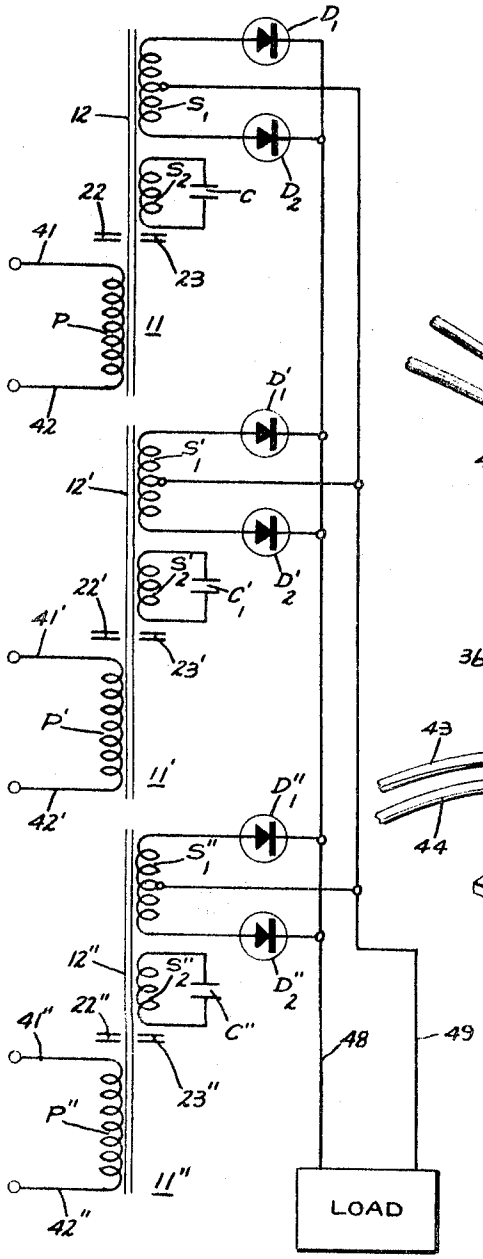
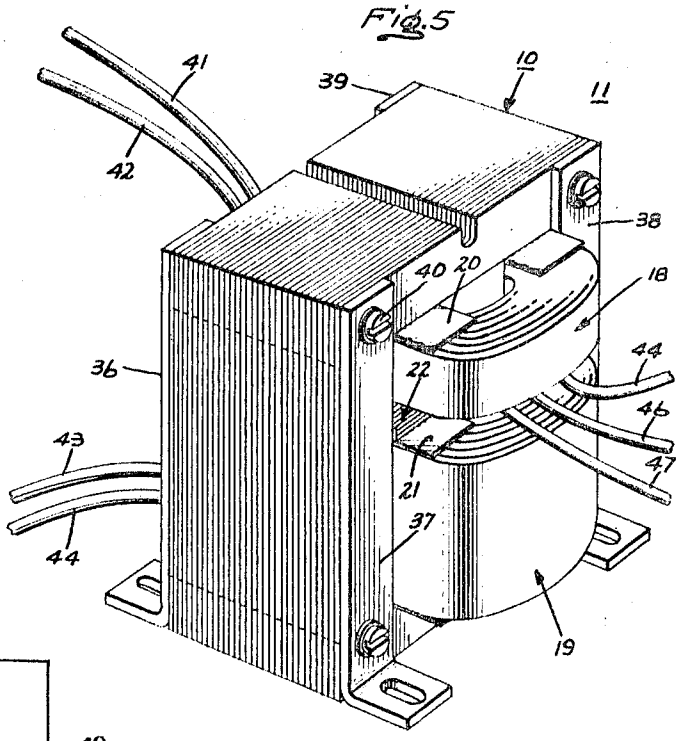


Fig. 5



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VOLTAGE STABILIZING TRANSFORMER WITH VARIABLE AIR GAP CHARACTERISTICS

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U.S. Cl. 336—165 9 Claims

ABSTRACT OF THE DISCLOSURE

A voltage stabilizing transformer having a magnetic core formed of interleaved E and I-shaped laminations forming a close magnetic circuit with a center winding leg and outer legs. A pair of coil assemblies are mounted on the center winding leg. Magnetic shunts comprised of rectangular-shaped laminations are inserted in the coil receiving windows by skewing and are disposed between the coil assemblies in staggered array to define a single juxtaposed shunting section and a pair of offset shunt sections at one end and to define a single offset shunt section and a pair of juxtaposed shunt sections at the other end. The offset shunt sections provide a predetermined gap between the shunt and the magnetic core, and the juxtaposed shunt sections bridge the gaps formed by the offset shunt sections. At relatively low load currents the juxtaposed shunt sections provide a path for the magnetic flux through the shunt while at high load currents both the offset and juxtaposed shunt sections provide a path for the flow of magnetic flux through the shunt to aid in the stabilization of the output voltage over a wide range of loads.

Background of the invention

This invention relates to transformers and more particularly to a transformer for use in voltage stabilizers for maintaining a substantially constant output voltage over a wide range of variations in the input voltage and load.

The transformers utilized in voltage stabilizers are of the high leakage reactance type and are used in conjunction with a capacitor connected in parallel across a secondary winding or a part thereof. Such voltage stabilizers function as a nonlinear ferroresonant circuit. The capacitor draws a leading current from the secondary winding thereby causing the core of the high leakage reactance transformer to operate in the saturated region or, in effect, as a saturable reactor having a fixed volt-second capacity. As long as the volt-second capacity of the secondary winding remains fixed, the output voltage will not be affected by variations in the input voltage. The output voltage is essentially a function of the frequency, the saturation flux density, reactor turns and effective area of the core.

Although conventional voltage stabilizing transformers compensate for changes in the input voltage, it is highly desirable in certain applications, such as computer power supplies, that the voltage in alternate half cycles has essentially the same shape over a wide range of loads, for example, from 10 percent to 110 percent of the rated load current of the voltage stabilizer. In these applications of voltage stabilizers the output voltage is usually rectified, and it is desirable, if not necessary, that the symmetry of the waveform be maintained without exceeding a certain specified percentage of ripple.

As used herein, percentage of ripple is equal to 100 multiplied by the ratio of the peak-to-peak value of the ripple voltage to the average value of the total output voltage. By way of illustration, in the above-described computer application of the voltage stabilizing transformer, it was required that the percentage of ripple over the 10 percent to 100 percent load range not exceed 15.

Accordingly, the general object of the present invention is to provide an improved voltage stabilizing transformer incorporating the foregoing features.

A specific object of the invention is to provide a voltage stabilizing transformer for use in conjunction with a capacitor and a rectifier wherein the symmetry of the output voltage waveform of alternate half cycles is essentially maintained over a wide range of loads.

It is another object of the invention to provide an improved voltage stabilizing transformer for use in conjunction with a capacitor and rectifier wherein the symmetry of the output voltage waveform is maintained over a wide range of load changes without excessive ripple.

Summary of the invention

In one form of my invention I have provided an improved voltage stabilizing transformer with a staggered magnetic shunt arrangement. The voltage stabilizing transformer includes a magnetic core defining a closed magmagnetic shunt arrangement. The voltage stabilizing transouter legs. A first coil assembly including at least a primary winding is mounted on the central winding leg, and a second coil assembly including at least one secondary winding is also mounted on the central winding leg. At least one magnetic shunt is interposed between the first and second coil assemblies and between the center winding leg and one of the outer legs of the magnetic core.

In accordance with an important aspect of the invention, the magnetic shunt is comprised of a stack of laminations of magnetic material preferably rectangular in shape. The laminations are arranged in staggered array to form at least one juxtaposed shunt section and one offset shunt section at each end of the magnetic shunt. The offset shunt sections provide a predetermined gap between the shunt and the magnetic core while the juxtaposed shunt sections bridge the gaps. The juxtaposed shunt sections are adapted to provide an essentially low reluctance path for magnetic flux through the magnetic shunts at relatively low load current levels, and both the juxtaposed shunt sections and offset shunt sections come into play at higher load current levels.

In accordance with another aspect of the invention, at least one gap spacer may be employed to position the laminations in offset relationship thereby to form the offset shunt sections with a precisely spaced air gap.

An important advantage of the improved voltage stabilizing transformer is that it is possible to economically achieve symmetry in the waveform of the output voltage at loads as low as 10 percent of rated load capacity. Also, the improved staggered shunt arrangement is readily adapted to standard transformer manufacturing techniques.

The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof, may be better understood by referring to the following description taken in connection with the accompanying drawings:

Brief description of the drawings

FIGURE 1 is a plan view, partially in section of the magnetic core and coil assembly of an improved voltage stabilizing transformer which may be used in carrying out one form of my invention;

FIGURE 2 is an enlarged partial view of the shunt shown in the left-hand window space of the transformer of FIGURE 1 with the directional lines indicating the course of the flux path through the magnetic shunt at relatively heavy loads;

FIGURE 3 is a view corresponding to the view of FIGURE 1 illustrating the course of the flux path through the magnetic shunt at relatively light loads;

FIGURE 4 is an enlarged partial view corresponding to the views of FIGURES 2 and 3 illustrating another shunt arrangement in accordance with the present invention;

FIGURE 5 is a perspective view of the voltage stabilizing transformer incorporating the staggered shunt arrangement as shown in FIGURES 2 and 3; and

FIGURE 6 is a schematic circuit diagram showing the application of the voltage stabilizing transformer in a three-phase voltage stabilizing system.

Description of the preferred embodiments

Referring now more specifically to the drawings, I will now describe the magnetic core and coil assembly **10** of this high leakage reactance transformer **11** embodying one form of my invention and shown in FIGURE 5. The magnetic core and coil assembly **10** includes a magnetic core **12** formed of suitable magnetic material. As is best seen in FIGURES 1 and 6, the magnetic core **12** is formed of a stack of relatively thin E-shaped and I-shaped laminations, alternately stacked as is well known in the art, to provide an interleaved core structure.

The magnetic core **12** includes a center winding leg **13** and outer legs **14, 15** which define windows **16, 17** for receiving coil assemblies **18** and **19** respectively. It will be seen that the coil assemblies **18** and **19**, a cross-sectional view of which is shown in FIGURE 1, are mounted on the center winding leg **13**. Coil assembly **18** contains a primary winding P and coil assembly **19** contains the secondary windings S_1 and S_2. The primary and secondary windings P_1, S_1, and S_2 are insulated from the magnetic core **12** by suitable insulation **20, 21**.

In order to provide the desired loose coupling between the primary winding P and secondary windings S_1 and S_2, magnetic shunts **22, 23** are inserted between the coil assemblies **18** and **19**. In the exemplification of my invention, each magnetic shunt **22, 23** was constructed of essentially I-shaped laminations having a width of 1.036 inches, a length of 4 inches and a stack height of 0.5 inch. The stack height of the magnetic core **12** was approximately 3.90 inches. It will be appreciated that the total width of the coil receiving windows **16, 17** is 1.062 inches, leaving a clearance 0.022 of an inch for the magnetic shunts **22, 23**.

With more specific reference now to FIGURES 2 and 3, I will now describe the staggered shunt arrangement as shown therein. Since the magnetic shunts **22** and **23** are of identical construction, specific reference will be made only to magnetic shunt **22**. It will be noted that the stack of laminations which form magnetic shunt **22** are arranged in staggered array to form three groups of laminations. This staggered array of laminations defines a juxtaposed shunt section **26** and a pair of offset shunt sections **27, 28** at the left end of the magnetic shunt **22** or the end adjacent to the outer leg **14** of magnetic core **12**. At the right end of the magnetic shunt **22** or the end adjacent to the center winding leg **13**, the staggered array of rectangular-shaped laminations defines a pair of juxtaposed shunt sections **29, 30** and a single offset section **31**. The offset shunt sections **27, 28** and **31** provide a predetermined gap between the shunt **22** and the magnetic core **12** while the juxtaposed shunt sections **26, 29** and **30** bridge the gaps.

In the illustrative embodiment of my invention, gap spacers **24** and **25** are used to achieve the desired staggered arrangement of the shunt laminations. It was found that when the primary winding is energized, the outer groups of shunt laminations were magnetically attracted to the center winding leg and that after the varnish treatment they remained in this position. The coil design in the exemplification of the invention was controlled so

that the shunts **22, 23** are snugly but not tightly held between the coil assemblies **18, 19**.

Two additional gap spacers **32** and **33** may be used to insure that the desired air gap is maintained. It will be appreciated, of course, that the use of a gap spacer is not essential to practice of the invention. The stack of shunt laminations may be preformed and riveted or glued prior to insertion between the coil assemblies **18, 19**.

The gap spacers used in the illustrated embodiments of the invention shown in FIGURES 2, 3 and 4 were made of flexible asbestos paper treated with silicon resin. It will be understood that other nonmagnetic materials may be used to provide the desired gap spacing. In the process of manufacture the gap spacer **24** is held in position on the shunt stack by means of electrical insulating tape. A tape made from the condensation product of terephthalic and ethylene glycol was used and had a thickness of approximately 0.001 of an inch.

An important advantage of the staggered shunt lamination arrangement is that the shunts can be readily assembled in the transformer **10**. During manufacture, the magnetic core **12** and coil assemblies **18, 19** are loosely assembled without the shunts **22, 23**. Before inspection between the loose coil assemblies **18, 19**, the shunt lamination stack is slightly skewed to facilitate its entry into the window space and the skewed shunt lamination stacks are then inserted. With the shunts in position, the laminations of the magnetic core **12** are tightly assembled. As the assembly is tightened, the skew is removed. The primary winding P is energized, and the laminations of the shunts **22, 23** are aligned essentially as shown in FIGURES 2 and 3, the shunt laminations being electromagnetically attracted to the center winding leg **13**. If the magnetic shunts **22, 23** are too tightly held between the coil assemblies **18** and **19**, it may be necessary in some instances to tap the magnetic core laminations lightly to insure that the two outer groups of shunt laminations are properly aligned in staggered array with respect to the center group.

In FIGURE 5 I have illustrated a complete assembly of the voltage stabilizing transformer utilizing the staggered shunt arrangement. Only one of the shunts **22** is shown in the view of FIGURE 5. The laminations of the magnetic core are secured in assembled relation by four mounting brackets **36, 37, 38** and **39** held compressively against the laminations of the magnetic core **12** by bolts **40**. To prevent grounding of the coil conductors of the coil assemblies **18, 19**, it will be seen that the insulation **20, 21** projects outwardly beyond the magnetic core **12**. Leads **41, 42** extend from coil assembly **18** for connection to the alternating current supply, and leads **43, 44** are brought out from coil assembly **19** for connection to the capacitor C, as shown in FIGURE 6. Three leads **45, 46**, and **47** are brought out from secondary winding S, for connection to a pair of diodes D_1 and D_2 and for making a connection with the center tap of the secondary winding.

Referring now to FIGURE 6, I have shown therein a schematic circuit diagram of a voltage stabilizer adapted for connection to a three-phase system for supplying a stabilized voltage output across supply lines **48** and **49**. Since the three transformers used in this system are of the same construction, I have identified the corresponding parts of the other two transformers with single and double prime reference numerals. As will be seen from the schematic circuit diagram, the primary winding P is adapted for connection across a pair of input terminal leads **41, 42** and is inductively coupled on the magnetic cores with secondary windings S_1 and S_2 but will be generally passed in through the shunt as shown in FIGURE 3. At high flux densities (relatively high loads), the lines of flux will bridge the air gaps and will travel generally along the directional lines as shown in FIGURE 2. With a transformer embodying the staggered shunt arrangement of my invention, it was found that for light

loads as low as 10 percent of the rated load, it was possible to obtain an output voltage having a symmetrical wave shape in alternate half cycle without exceeding a 15 percent ripple. Also, for heavy loads as high as 110 percent of the rated load, it was still possible to obtain an output voltage having the desired symmetrical wave shape characteristics without exceeding a 15 percent limit of ripple.

In order to provide the voltage stabilizing action, a capacitor C is connected across the secondary winding S_2 to draw leading current so that the portion of the core **12** on the secondary winding S_1 will be operated in the saturated region. A pair of diodes D_1 and D_2 are connected in circuit with secondary winding S_1 and to provide a full-wave rectified DC current across lines **48, 49.**

It was found that during operation of the transformer **12** that at low flux densities (relatively light loads) the greater portion of the flux will not traverse the air gaps.

From the foregoing description of the various structural features and the operation of the illustrated embodiment of the invention, it will be seen that I have provided an improved voltage stabilizing transformer having a staggered shunt that provides a variable reluctance path for a leakage flux passing through the shunt. Stable output voltage without excessive ripple over a wide range of load changes is thereby achieved.

It will be appreciated that although in the illustrated exemplifications of the principles of my invention a laminated shunt was utilized, it will be appreciated that other arrangements may be utilized to provide the desired variable reluctance path.

While I have shown and described various embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention. It is therefore intended in the appended claims to cover all such changes and modifications that fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A voltage stabilizing transformer for use in a voltage stabilizer comprising: a magnetic core defining a closed magnetic circuit and including a center winding leg and a pair of outer legs spaced therefrom, said outer legs and said center winding leg defining coil receiving windows, a first coil assembly mounted on said central winding leg and disposed within said coil receiving windows, said first coil assembly including at least a primary winding, a second coil assembly mounted on said central winding leg and disposed within said coil receiving windows, said second coil assembly including at least one secondary winding, at least one magnetic shunt interposed between the first and second coil assemblies and between the center winding leg and one of the outer legs, at least one shunt formed of essentially rectangular-shaped laminations in staggered array to define a juxtaposed shunt section and a pair of offset shunt sections at one end and further to define an offset shunt section and a pair of juxtaposed shunt sections at the other end, said offset shunt sections providing a predetermined gap between the shunt and magnetic core, and said juxtaposed shunt sections bridging said gap.

2. The voltage stabilizing transformer of claim **1** wherein a gap spacer of nonmagnetic material is disposed between at least one offset shunt section and one of the legs of said magnetic core and between a pair of said juxtaposed shunt sections.

3. The voltage stabilizing transformer of claim **1** wherein a gap spacer of nonmagnetic material is disposed between each of the offset sections and the legs of the magnetic core.

4. A voltage stabilizing transformer for use in a voltage stabilizer comprising: a magnetic core, a primary winding disposed on said magnetic core and adapted to be supplied from an alternating voltage source, at least one secondary winding disposed on said core, at least one magnetic shunt comprised of a stack of laminations positioned between said primary and secondary winding, said stack of laminations being staggered to define a juxtaposed shunt section and an offset shunt section at each end thereof, each of said offset shunt sections defining a predetermined gap between an end of the magnetic shunt and an adjacent portion of the magnetic core, said juxtaposed shunt sections bridging said gap to provide an essentially low reluctance path for magnetic flux through said magnetic shunt, and said offset shunt sections providing a relatively high reluctance path for magnetic flux through said shunt.

5. The voltage stabilizing transformer of claim **4** wherein at least one gap spacer of nonmagnetic material is interposed between one of said offset shunt sections and the magnetic core.

6. The voltage stabilizing transformer of claim **4** wherein a gap spacer of nonmagnetic material is interposed betwen each of said offset shunt sections and the magnetic core.

7. A voltage stabilizing transformer for use in a voltage stabilizer comprising: a magnetic core formed of a plurality of interleaved E and I-shaped laminations forming a pair of outer legs and a center winding leg, a first coil assembly including at least a primary winding and mounted on said center winding leg, a second coil assembly including at least one secondary winding and mounted on said center winding leg, a pair of magnetic shunts disposed between said first and second coil assemblies, each of said magnetic shunts comprising a stack of laminations, said stack of laminations defining at each end thereof at least one juxtaposed shunt section and one offset shunt section, said offset shunt section providing a predetermined gap between said magnetic core and shunt, and said juxtaposed shunt sections briding said gap.

8. The voltage stabilizing transformer of claim **7** wherein a gap spacer of nonmagnetic material is interposed betwen at least one of said shunt sections and a leg of said magnetic core.

9. The voltage stabilizing transformer of claim **7** wherein a gap spacer of nonmagnetic material is interposed between each of said offset shunt sections and the magnetic core.

References Cited

UNITED STATES PATENTS

1,895,231	1/1933	Pearson et al.	336—165
2,553,596	5/1951	Mann	336—165 XR
2,568,553	9/1951	Mauerer	336—165 XR
2,996,656	8/1961	Sola	336—165 XR
3,278,878	10/1966	Callucci	336—178 XR
3,360,753	12/1967	Wroblewski	336—178 XR

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