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Fahrner

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[54] **ROTARY POWER TRANSFORMER**

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[52] **U.S. Cl.** **323/53**; 323/60; 336/120; 336/178
[51] **Int. Cl.**[2] **H01F 39/00**
[58] **Field of Search** 336/117, 118, 119, 120, 336/178; 323/60, 53

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[57] **ABSTRACT**

This invention relates to a Rotary Power Transformer, wherein Primary and Secondary windings on a laminated ferromagnetic core are provided, the construction permitting one winding to be rotatable with respect to the remainder of the transformer. This makes possible electrical energization of a rotatable load from a stationary source of electric power, without slip rings or sliding contacts being used. In the application of the invention to a transformer, a laminated ferro-magnetic core having a divided core leg with an air gap between core leg portions is used. A rotatable winding, secondary as a rule, is mechanically coupled to a rotatable hollow shaft passing through the core leg portions and air gap for accommodating leads between the secondary winding and rotatable load, the shaft and load being rotated by some independent means such as a motor. The primary winding is stationary, surrounds the secondary winding, but clears the same for relative rotation. The transformer functions in conventional fashion independently of secondary winding rotation. Any desired power level may be handled by suitable transformer design.

6 Claims, 7 Drawing Figures

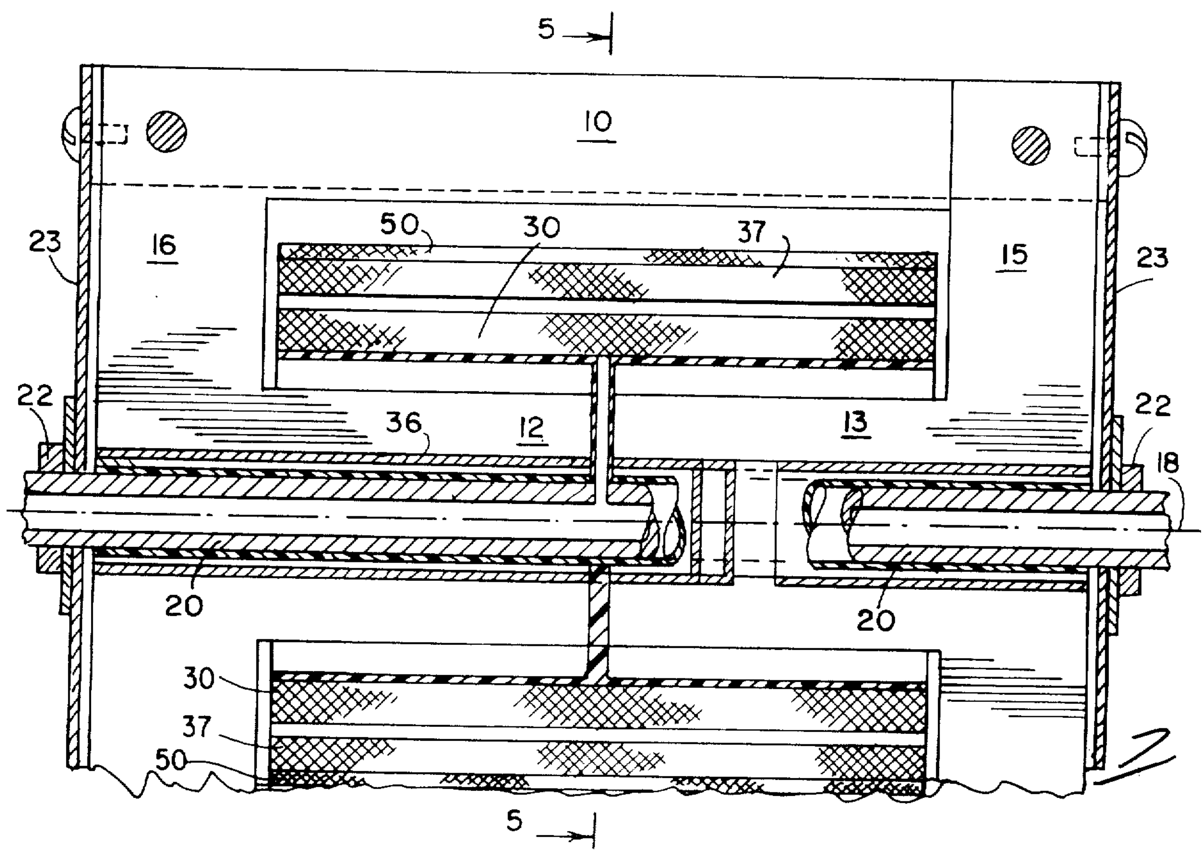


FIG. 1

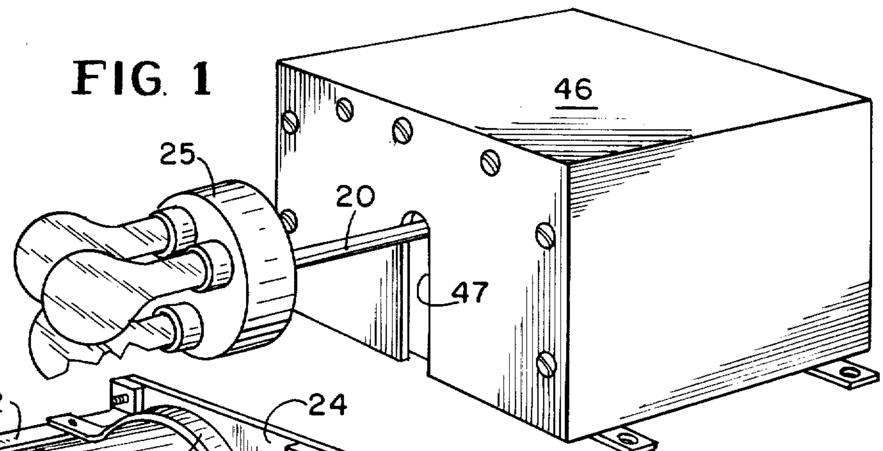


FIG. 2

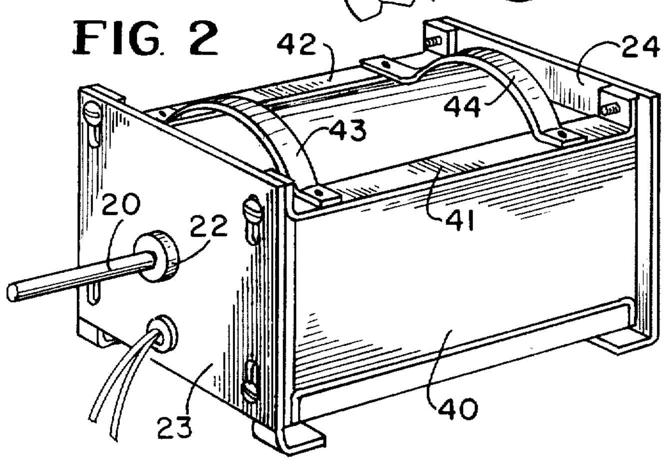


FIG. 3

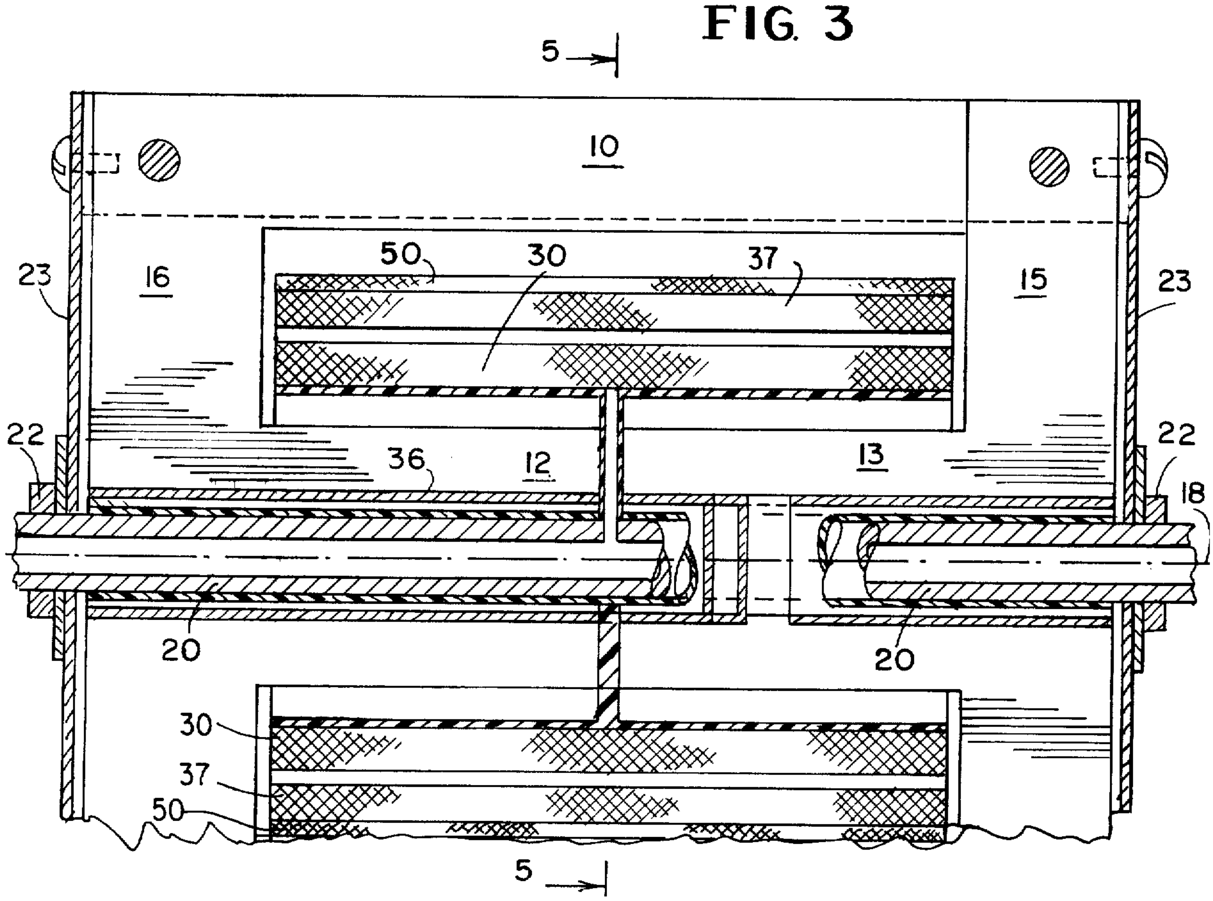


FIG. 7

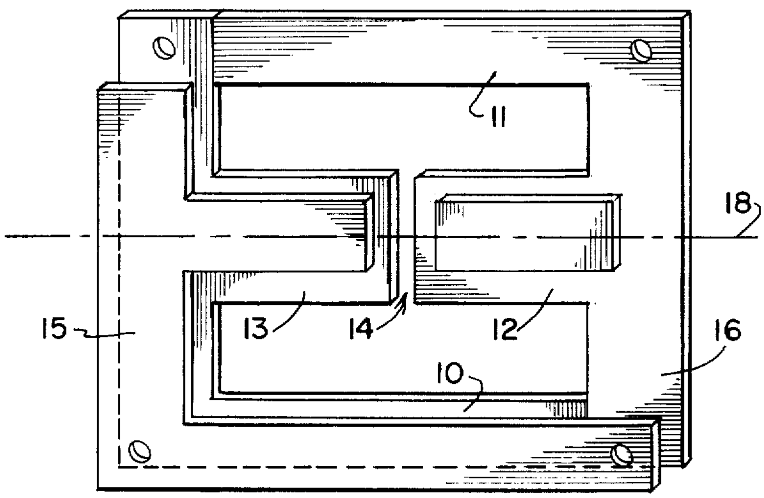


FIG. 6

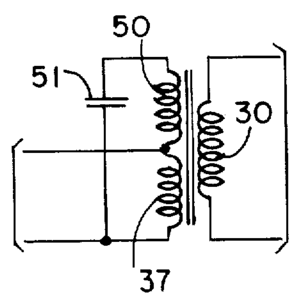
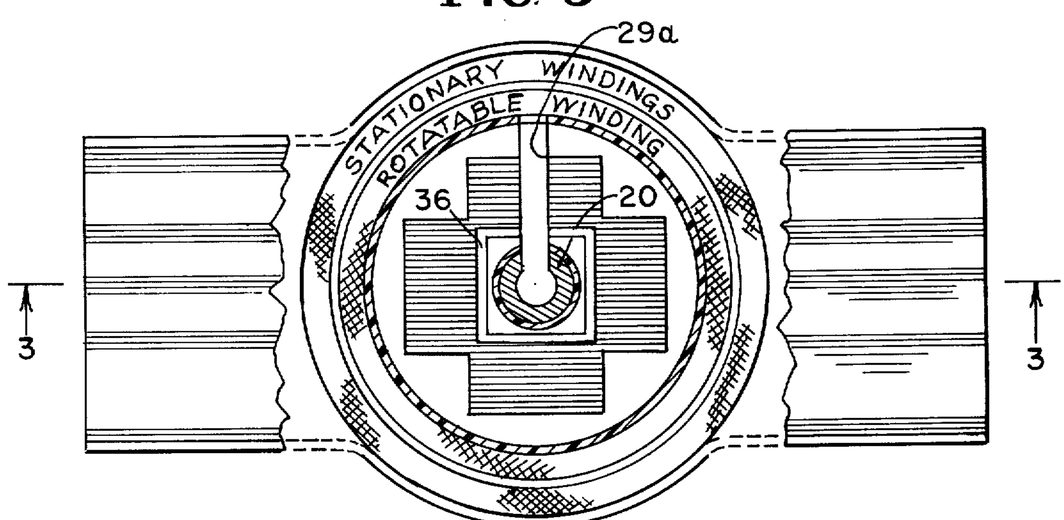


FIG. 5



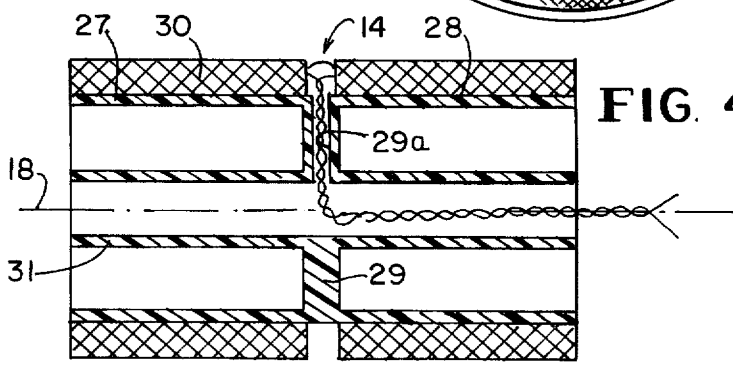


FIG. 4

ROTARY POWER TRANSFORMER

GENERAL DESCRIPTION OF THE INVENTION

This invention relates to a rotary power transformer wherein primary and secondary windings are electromagnetically coupled together by a ferro-magnetic laminated core and is endowed with the characteristic of rotary movement of one winding with respect to the other winding without the use of sliding contacts such as slip rings. The new transformer permits direct wire connections between the rotatable transformer winding and a rotatable load. The transformer embodying the invention is in practice and in theory a true transformer in that primary and secondary windings are coupled through a ferro-magnetic core to handle any desired level of power characteristic generally of iron core type of power transformers. For convenience, the primary winding will be designated as the stationary energizing winding to which a fixed alternating current source can be connected and the secondary winding is that winding in which potentials are induced by true transformer action and has currents flow in the secondary in accordance with winding and load parameters. The transformer embodying the present invention functions as a transformer at desired power levels for which the transformer is designed, irrespective of rotation or lack of rotation of the secondary winding. The transformer action is independent of any relative rotary movement between the transformer windings. It is understood that the secondary winding may be stationary and primary winding may be rotatable if the energizing source of power happens to be rotatable.

The transformer embodying the present invention has a ferro-magnetic core of flat laminations for providing almost all of a magnetic circuit. An essential feature of the magnetic circuit is a core leg divided into two physically separate leg parts having an air gap therebetween, with transformer windings over the leg parts and gap. The secondary winding is within a primary winding assembly and extends about the two leg portions and air gap. Leads from said secondary winding extend through the air gap into an axially disposed hollow rotatable shaft. The secondary winding is rotatably coupled to the hollow shaft. The divided core leg parts, preferably equally long, are stationary within the secondary winding and are parts of an otherwise generally conventional laminated ferro-magnetic transformer core. Disposed about the secondary winding and clearing the same is a stationary primary winding assembly.

The cross section of the divided leg parts is preferably cruciform in shape, although a simple rectangular shape may be used. A generally cruciform shape, however, is preferred for higher efficiency. The two leg portions separated by an air gap may be, as an example, part of a shell-type of transformer core, although a simple core type may be used. A stationary frame construction is provided for supporting the stationary parts of the complete transformer and carries suitable bearings in which the centrally disposed rotable tubular shaft is carried.

The appropriate core stack laminations are suitably fabricated to accommodate the rotary shaft with sufficient clearance through the stack. The transformer structure may be mounted in a suitable casing or housing. The rotatable shaft, coupled to the rotatable secondary winding structure, may be secured in any desired fashion to a suitable rotatable electric load such as a revolving sign. The transformer secondary structure, together with the leads within the tubular rotatable shaft and the load, with thus be connected together for rotation. The other end of the tubular shaft may be solid. Either end may be mechanically coupled to an electric motor or other means for rotating the the secondary winding assembly and load, it being understood that conventional mechanical engineering design will determine shaft dimensions, bearings, etc. The stationary part of the transformer can be handled in conventional fashion.

Insofar as transformer windings and transformer core design are concerned, conventional transformer theory and design may generally be applied with some allowance for the presence of the air gap between the two portions of the divided core leg and clearance for rotating parts. Insofar as transformer ratio is concerned, it is possible to have any value. The nature of the load may vary from relatively low voltage loads to moderately high potentials.

The air gap between the opposed leg portions of the core is required for mechanical considerations in connection with coupling of the secondary winding structure to the hollow shaft. The distance between the opposed ends of the divided leg portions may be quite small and in practice may be of the order of about one-eighth of an inch or more. The air gap should be large enough to accommodate the rotary physical structure between the secondary winding structure and the hollow shaft including insulated wire extending from the secondary winding structure to the hollow shaft. It is preferred to have the air gap centrally located between two equal leg portions.

The speed of rotation of the secondary winding system may range over wide limits, depending upon mechanical considerations. The power level may range from any desired minimum, practically about 200 or 300 watts, up to levels in the kilowatt range.

It is understood that the nature of the bearing support for the rotary shaft will depend upon load factors and may involve such considerations as end thrust bearings, conventional sleeve bearings, or the like, none of which will have any substantial effect on the transformer structure itself. Insofar as the nature of clearance between the relatively movable parts of the transformer are concerned, this will depend upon such factors as desired efficiency of the transformer, and generally mechanical factors such as vibration, desired thickness of solid insulation, speed of rotation, cost and the like.

By virtue of this construction, substantially all leakage lines of force from the magnetic field of the divided leg will link the windings and maximize efficiency. The magnetic core laminations may utilize various shapes of laminations, such as for example, "E," "F," "T," "L" and "I" to provide for butt edges or overlapping between separate parts of a single lamination layer. In accordance with general transformer practice, it is desirable to have the unavoidable minute air gaps between opposing lamination edges in core layers randomly disposed along various parts of the ferro-magnetic circuit to avoid accumulation of minute air gaps at any one particular part of the stack. It is understood, of course, that the essential air gap between opposing ends of the divided leg portions is not included in this avoidance. It is possible to have an E type of lamination for some layers, F shaped parts may be used in other layers, I may be used, the objective being to avoid superimposing any air gaps between separate pieces of a lamination layer at any particular part of the stack. Inasmuch as this is conventional transformer practice, no detailed description thereof is necessary.

Due to the selection of a cruciform cross section of the leg portions within the secondary winding, care will have to be exercised in stacking laminations to provide the cruciform section. This may be accomplished by having different widths of laminations as will be evident later in connection with the description of the structure. In addition, modification of some laminations will be necessary for accommodating the rotary shaft. Generally, it is preferred to have hollow square tubes extending through stack parts on each side of the air gap with the rotatable shaft within such rectangular tubes. By providing such a square tube within each stack part on opposing sides of the air gap, the positioning of the stack laminations will be facilitated, the outer surface of the square tube providing stops for edges of such laminations.

In accordance with customary transformer practice, where laminations are used, the entire stack will generally be divided into two complementary stack portions to permit the disposition of all windings over the core leg parts and thereafter to interleave such stack parts so that a complete laminated stack over the windings is provided. Before the stack is assembled, however, the leads for the secondary should be threaded into the hollow circular shaft to be available for final connection to a rotary load. The ends of the tubular shaft extend beyond the transformer proper and are mounted in bearings supported in a frame construction in which the entire transformer structure is rigidly secured.

It is normally desirable to improve the power factor of the transformer and to this end, a supplemental primary winding is disposed over the energizing main primary winding proper, such supplemental winding usually having smaller gauge wire and more turns than the primary winding proper. The supplemental winding is connected in series with a capacitor and the two are connected across the energized primary winding. The power factor correction is desirable because of the air gap between the opposed, divided core leg portions. The two series connected windings constitute a stationary primary winding assembly.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a transformer embodying the invention disposed within a housing, the transformer shaft for rotating the winding being shown coupled to a rotatable load such as an assembly of incandescent lamps, the view not showing a driving motor for rotating the transformer shaft;

FIG. 2 is a perspective view of the transformer illustrated in FIG. 1, removed from its housing and free from the rotatable load;

FIG. 3 is an elevation on an enlarged scale of a transformer embodying the present invention with parts cut away to illustrate certain structural details thereof;

FIG. 4 is an elevation of a section of a double ended bobbin for carrying the rotary secondary winding together with the mechanical coupling to the rotatable shaft to illustrate the manner in which the leads from the rotatable secondary are taken to the interior of the rotatable shaft;

FIG. 5 is a transverse view along line 5—5 of FIG. 3, showing a laminated leg about which the secondary rotates;

FIG. 6 is a diagrammatic illustration of the transformer windings together with a supplemental primary winding and capacitor for improving power factor; and

FIG. 7 is a plan view of a core stack for the new transformer.

DESCRIPTION OF THE PREFERRED SPECIES

As illustrated in the drawings and described with reference to the drawings, a shell type of ferro-magnetic core is disclosed. It is understood, however, that except for the divided core leg about which the transformer windings are positioned, the ferro-magnetic core may assume any one of a number of shapes, the characteristics of which and the advantages of which are well known in the transformer art and may be adopted for reasons generally independent of the application of the invention to provide a new transformer. Before beginning the detailed description of the transformer embodying the present invention, it will be helpful to consider initially the structural details of a ferro-magnetic stack consisting of flat laminations.

Thus, referring to FIGS. 3 and 7, a shell type of transformer core is illustrated wherein leg **10** at one side and leg **11** at the other side has therebetween a divided transformer leg having portions **12** and **13** provided with air gap **14** therebetween. Sides **15** and **16** of the magnetic core completes the ferro-magnetic path. The construction of the divided ferro-magnetic leg consisting of portions **12** and **13** with air gap **14** therebetween is essential to the practice of this invention. Otherwise leg **10** or leg **11** may be omitted, in which case core sides **15** and **16** would be limited in length to joining the divided leg and the remaining leg together, with suitable increases in lamination widths. However, from a structural angle and maximize transformer efficiency, the generally shell-type core is preferred. A properly dimensioned shell-type transformer core minimizes leakage of magnetic flux from the core. Centerline **18** extends longitudinally of the divided leg and normal to air gap **14** to indicate an axis of rotation about which the rotatable portions of the transformer turn.

This centerline will naturally pass through the thickness of the stack at core sides **15** and **16**, as well as along divided leg portions **12** and **13** and through air gap **14**. The air gap functions to permit leads to go from a secondary which is normally disposed around divided leg portions **12** and **13** and extend radially to centerline **18** and then parallel to the centerline toward the end of a rotatable shaft to be described later. It is, therefore, necessary to provide clearance openings in the entire stack and divided leg portions and through air gap **14**. The air gap **14** between divided core portions **12** and **13** should be just large enough to permit a physical coupling member to extend from the rotatable shaft about centerline **18** radially outwardly to a cylindrical bobbin member which extends about leg portions **12** and **13** and has sufficient clearance to permit rotation of the rotary member about divided core leg portions **12** and **13**. All ferro-magnetic portions of the entire core are stationary. Rotation of a cylindrical secondary assembly is possible with respect to the outer surfaces of divided core leg portions **12** and **13** on the one hand and the outer space about centerline **18** extending through the entire transformer core and the hollow shaft about centerline **18**, which hollow shaft must pass through the entire transformer core stack, and beyond the same.

For production purposes, it is impractical to make divided leg portions **12** and **13** circular in section. Because of the necessity for the rotary portion of the secondary assembly to operate, and to provide maximum magnetic efficiency, it is preferred to have the ferromagnetic divided core portions **12** and **13** shaped as illustrated in FIG. **5**, to provide a cruciform shape which will clear the cylindrical inner surface of the secondary rotatable winding assembly. The cruciform shape of the leg portions **12** and **13** as well known and widely used in conventional transformers where windings are prepared on cylindrical bobbins, there being no necessity for any rotational characteristics. The advantages of a cruciform core leg section principally relate to the fact that the number of different sized laminations insofar as the width is concerned, is reduced to two and thus makes the assembly of laminations into a stack possible with minimum trouble and minimum stack sizes and lamination widths. Theoretically, a large number of laminations having graduated leg widths could be used to provide a generally circular or cylindrical leg or core section. In practice, the cost of manufacturing and assembling such a stack would be prohibitive and would more than outweigh any possible improvement in the overall efficiency of the transformer. This is particularly true in the transformer embodying the present invention since clearances for the rotating shaft are also necessary.

The windows in the stack between end legs **10** and **11** on the one hand, and the central divided leg portions **12** and **13** on the other hand, provide room for both secondary and primary winding assemblies and must also include clearance for rotation of the secondary winding assembly about the divided core leg portions on the one hand and within the stationary primary winding on the other hand. Insofar as the primary winding assembly is concerned, the inside surface thereof considered as a unitary assembly, must be smooth and have sufficient clearance with respect to the outside of the secondary winding assembly for rotation of such secondary winding assembly. The outside of the primary winding assembly (including an auxiliary winding) will, of course, be within the window between the end legs **10** and **11** on the one hand, and the outer surface of the rotatable secondary winding assembly. It will be necessary to anchor the primary winding assembly within the windows to rigidly retain such winding assembly in position and permit free rotation of the secondary winding assembly. To this end, spacer bars and metal curved straps as illustrated, for example, in FIG. **2**, may be used for firmly maintaining and locking the primary winding assembly in position.

Center line **18** is the center line for rotatable hollow shaft **20** which in practice will normally extend not only through an appropriate tunnel through the stack of laminations, but beyond so that a rotatable load for the transformer secondary can be carried by and rotated with such hollow shaft **20**. In practice, hollow shaft **20** will be mounted within bearings **22** carried by end plates **23** and **24** adjustably secured to a frame construction illustrated in FIG. **2**, to permit centering of hollow shaft **20** for free rotation of the secondary assembly within the transformer. Hollow shaft **20** may carry a load such as incandescent lamps mounted on base **25**, illustrated in FIG. **1**, and may also be rotated by a suitable mechanism (not shown) such as an electric motor, for example, which may be directly or indirectly coupled to hollow shaft **20** for rotating the same.

Referring to FIGS. **3** and **4**, a unitary construction which, in effect, comprises two cups back-to-back is provided for rotation about divided core leg portions **12** and **13** and extending across air gap **14** forms a portion of the rotatable secondary winding assembly. This construction may comprise two separate cups back-to-back, or an integral construction, and has radial clearance openings **29a** through the dividing walls of the two cup-shaped portions to permit secondary winding insulated wire leads to extend radially from outside of the cups to the interior of tube **20** through at least one aperture in the tube wall. The wire leads extend along said shaft for connection to the secondary load. Cup-shaped portions **27** and **28** function as a bobbin with coupling portion **29** extending radially inwardly and may consist of a strong plastic or other non-metal about whose outer surface is wound secondary winding **30.**

The thickness of secondary winding **30** will be determined by available design space and the electrical details such as the amount of wire, size and the like will be determined by generally conventional transformer design practice. The outer surface of secondary winding **30** should be smooth and in the event that rotation of the entire winding and shaft assembly is at a substantial speed, then it may be necessary to consider dynamic balance of the rotatable assembly to insure against excessive vibration. The secondary winding should extend for the full length of the cupped construction and the secondary winding should be so constructed to withstand the affect of centrifugal force thereon. The wire layers may be held tightly in position by suitable means such as cements and the like. It may be desirable for leads from the secondary winding to be in the form of flat strips covered with a layer of suitable insulation to minimize undesirable bulges and it may be desirable for the sake of balance to take one secondary lead from one side of the secondary support cup-shaped member and the other lead from a diametrically opposite point of the cup-shaped secondary support. Instead of a solid cup bottom construction for joining cups **27** and **28** back-to-back, it is possible to use a spoke construction. In all cases, it is necessary to provide a good mechanical coupling between cups **27** and **28** on the one hand and hollow shaft **20** on the other hand, so that the shaft can rotate the cup structure without danger or damage. Centrally disposed sleeve portions **31** within each cup portion are provided for hollow shaft **20** to be snugly disposed to insure good coupling. Sleeve portions **31** should not interfere with the secondary leads.

Since hollow shaft **20** must have a tunnel through the entire stack along center line **18** as illustrated in FIGS. **5** and **7**, it is preferred to have coaxial rigid tubes **35** and **36** disposed on opposite sides of air gap **14** and extending to the very outer edges of the laminations define such tunnel. These tubes are of plastic or other suitable material. Tubes **35** and **36** are preferably square, so oriented as to have the sides parallel and perpendicular, respectively, to the laminations to thus provide a stop against which laminations may rest. Square tubes **35** and **36** are just enough larger than hollow shaft **20** so that lateral centering of hollow shaft **20** and the secondary rotatable assembly may be accomplished. Hollow shaft **20** itself must be sturdy and may be of steel, or any other rigid strong material.

It is evident from the geometry of the construction that specially shaped laminations, or portions of laminations, may be necessary in that part of the stack immediately at square tubes **35** and **36**, particularly where the edge of a lamination encounters the square side of such a tube. The special shapes required for laminations to accommodate the square tube will generally be limited to the stack region bordering upon the square tubes. By designing the relative dimensions of the laminations (not including thickness) and the square tube portions, the number of laminations requiring special fabrication may be reduced to a relatively low proportion. It is evident that a wide variety of lamination shapes such as previously noted may be used. When a substantial production run of transformers embodying the present invention is necessary, standardized lamination shapes required for various portions of the stack may be used. The laminations have generally conventional shapes readily available on the market and will be useful in those stack portions not required to accommodate square tubes **35** and **36.** A generally conventional primary winding structure **37** of cylindrical shape is provided about, but clearing rotatable secondary **30.**

In order to assemble a complete transformer, the entire lamination stack is divided into two stack portions which may be interleaved as in conventional transformer practice after the winding assemblies have been positioned over the divided core leg. Thus, for example, stack leg portions **10** and **11** may be separable along a plane perpendicular to the stack as seen in FIG. 7, and passing through air gap **14.** It is also possible to locate the plane or planes of separation at other regions. As is well known, the stack portions have their individual laminations overlapping with respect to what has been called a plane of stack separation, with alternate laminations extending beyond the plane of separation to one side and interleaved when assembled with a similar stack with laminations extending to the other side. In general, separating the entire stack of laminations for accommodating the placement of the rotatable secondary and stationary primary windings can follow conventional lines, this procedure being simplified by the fact that divided core leg portions **12** and **13** are always separated.

Following conventional procedure in transformer assembly, the various laminations are generally provided with holes therethrough at various places to accommodate bolts for rigidly securing a stack after assembly and after the windings have been in place, to form a rigid magnetic core of ferro-magnetic laminations. As previously pointed out, it is preferred to have the ends of lamination parts (not including leg portions **12** and **13**) arranged so that the edges of laminations coming together will be staggered over the core stack. Where oriented transformer steel is used, it may be desirable to arrange the transformer lamination parts so that the lines of magnetic flux extend along the direction of orientation for the most part.

After the transformer laminations and rotatable parts are assembled, it is preferred to provide a strong frame for securing the stack and rotatable portions of the system as well as the stationary primary winding structure in position to prevent any shift, particularly of the stack and primary winding. To this end, a rigid frame structure including side plates **40** and end plates **23** and **24** is provided. Side plates **40** have retaining strips **41** and **42** and straps **43** and **44** secured to lock the primary winding firmly into position, as shown in FIG. **2,** both at the top and bottom of the frame. As pointed out previously, end plates **23** and **24** have elongated bolt holes to provide a limited degree of adjustment in all directions so that the rotatable portion of the transformer may be supported in bearings **22** and properly centered for free rotation. Bolts or suitable means for locking the end plates in proper position are provided. Bearings **22** may be of any suitable type and may have means for lubrication. Housing **46** over the transformer illustrated in FIG. **2,** may be provided and such housing may have slots **47** on opposite walls of the housing to accommodate shaft ends when positioning the transformer illustrated in FIG. **2,** within the housing.

Due principally to the air gap in the magnetic circuit, it is desirable to improve the power factor of the transformer. Accordingly, an auxilliary winding **50** is connected in series with capacitor **51** across the energizing power source in shunt to the primary winding. The auxilliary winding **50** may have more turns of substantially finer wire gauge than the principal primary. Auxilliary winding **50** is preferably disposed over the principal primary winding.

What is claimed is:

1. A transformer having a ferro-magnetic laminated core including a leg having two aligned leg portions with an air gap therebetween, a cylindrical secondary winding structure positioned over said two leg portions and air gap so that it is rotatable about the same, a shaft within passages through said aligned leg portions and through said air gap and extending through passages in said magnetic core and beyond the core, means in said air gap securing said secondary winding structure to said shaft, said secondary winding having leads extending therefrom and passing radially in said air gap to said shaft, at least part of said shaft being hollow from said air gap region to an end of said shaft, said shaft at the region of said air gap having at least one opening through its wall to the interior thereof, said secondary winding leads extending through the shaft wall to the interior thereof and thence to the end of the hollow shaft portion for connection to a rotatable electric load, a stationary primary winding having a cylindrical interior surface disposed about said secondary winding and clearing the same to permit relative rotation thereof, both of said windings lying over the leg portions and air gap, means for retaining said core structure and primary winding rigidly in stationary position, bearing means supported by said stationary structure for rotatably supporting the shaft, said bearing means and support therefor having means for adjusting said shaft means to center the rotatable portions of the transformer for free rotation, whereby a relatively stationary electric power source may be metallically connected to the primary winding for energizing the same and the electric power in said secondary winding may be directly connected to a rotatable electric load without interposition of sliding contacts between relatively rotatable parts.

2. The construction according to claim **1,** wherein the leg portions of the divided leg are shaped to provide a cruciform section for improving efficiency.

3. The construction according to claim **1,** wherein the secondary winding structure includes a bobbin having the general shape of two cylindrical cups in back-to-back relation, said cup bottoms being shaped to accommodate the rotatable shaft therethrough, said cups being large enough to clear the outside of the divided magnetic leg portions about which said cups are adapted to rotate, said cups also having small sleeve portions through the rotatable shaft passes, said sleeve portions being short enough and thin enough to secure firm adherence to the rotatable shaft but clearing the opposed stationary surfaces of the core leg portions.

4. The construction according to claim 1, wherein passages for the rotatable shaft are square in section within the transformer core structure, said passages being defined by square tubes extending through the lamination portions only, the orientation of said square tubes being such that two opposed tube sides are parallel to the length of laminations while the remaining two opposed tube sides are perpendicular to the edges of laminations, said tubes providing stop limits for the ends or sides of laminations, said square tubes being large enough with respect to the diameter of the shaft so that sufficient clearance is provided to permit centering of such shaft with respect to the entire transformer construction.

5. The construction according to claim 1, wherein means are provided for power factor correction, said means including an auxiliary primary winding disposed over the first named primary winding and connected through a capacitor across the primary winding.

6. The construction according to claim 1, wherein a frame construction is provided for rigidly supporting the core and primary winding structure in rigid relation to each other and wherein end plates adjustable secured to said frame are provided for supporting bearings through which the rotatable shaft ends pass, said adjustment permitting proper centering of the rotatable portion of the transformer with respect to the stationary portion of the transformer.

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