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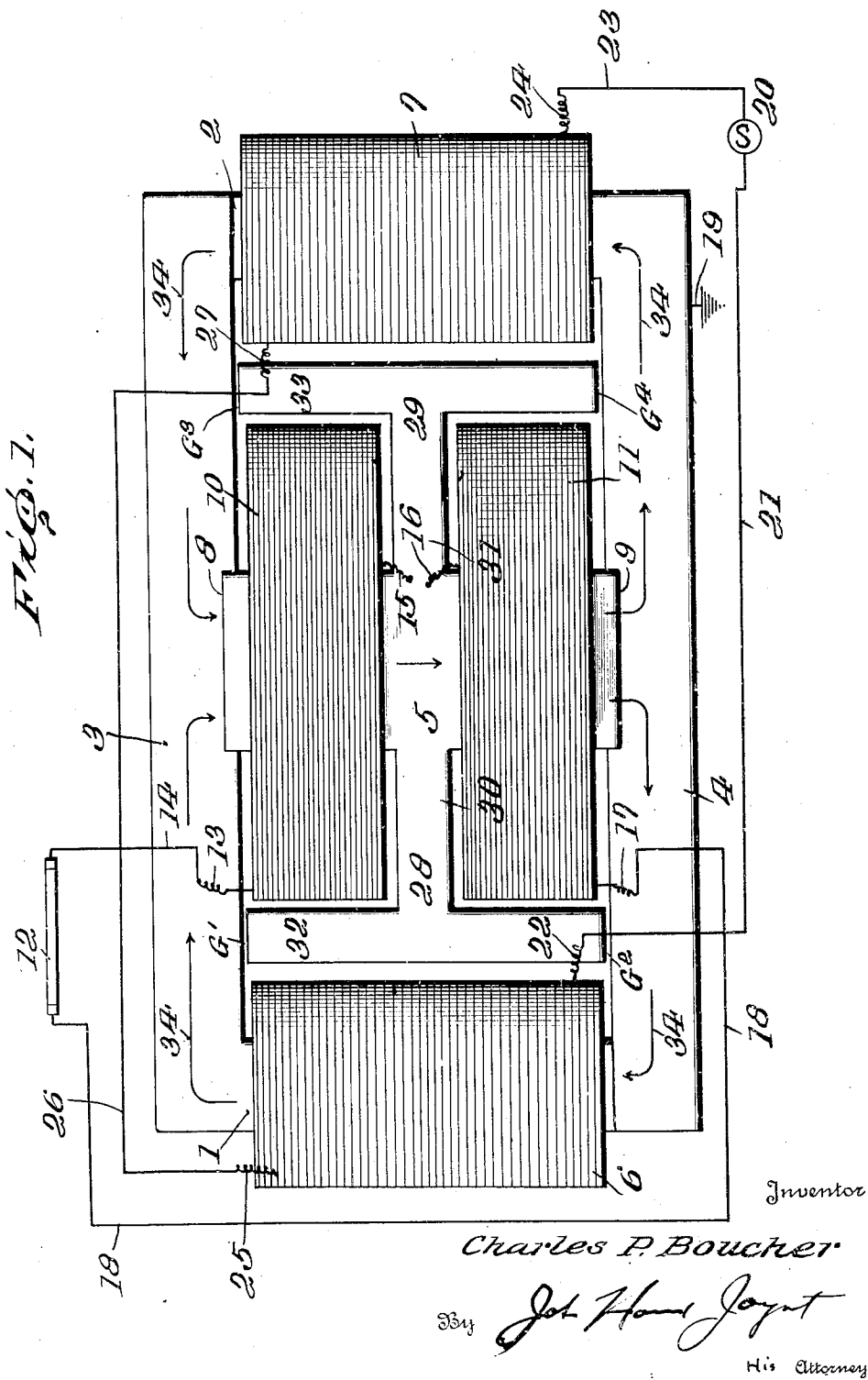
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2,292,923

TRANSFORMER

Filed Jan. 31, 1939

3 Sheets-Sheet 1



Aug. 11, 1942.

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TRANSFORMER

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FIG. 2.

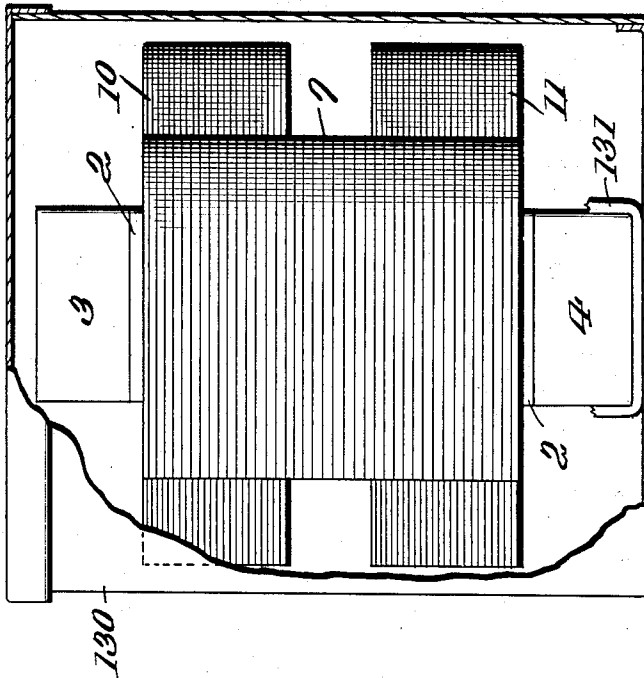
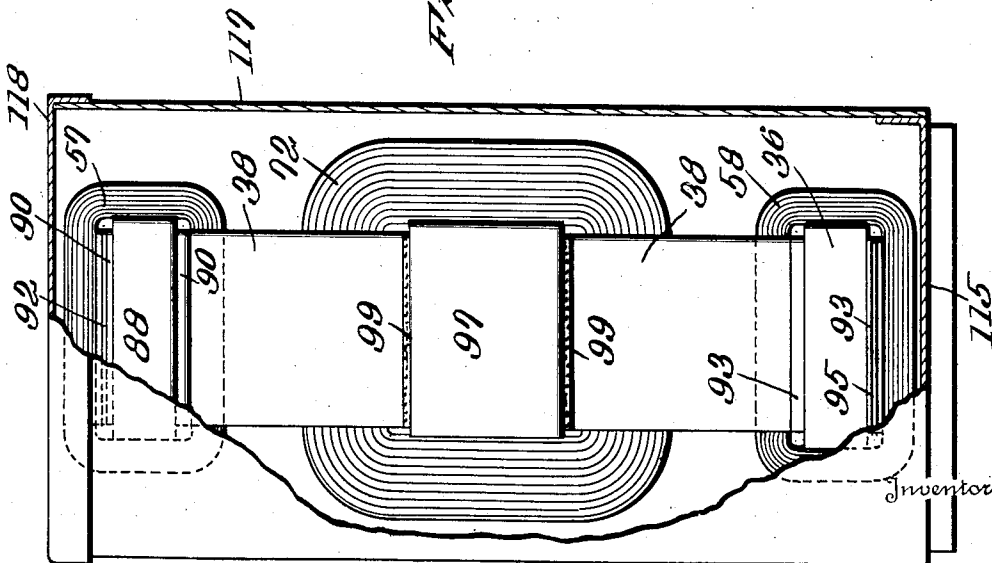


FIG. 4.



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2,292,923

TRANSFORMER

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Application January 31, 1939, Serial No. 253,867

9 Claims. (Cl. 171-119)

This invention relates to negative load transformers, and more particularly concerns transformers suitable for energizing luminous display signs employing gaseous discharge tubes as the luminous elements.

One of the objects of my invention is to provide simple, practical and thoroughly reliable transformer apparatus which is well adapted to withstand the many varying conditions of load and whole or partial short-circuit encountered in actual practical use.

Another object is the provision of power transformer apparatus which is exceedingly compact, highly efficient and particularly economical in construction, installation, and operation, enjoying low copper and iron losses, a high rate of heat dissipation and good operating power factor.

Another object is the provision of a transformer employing a casing of minimum size and consequently requiring a minimum of insulating compound and yet which gives rise to but a minimum of magnetic flux leakage from core to casing, and minimum magnetic disturbance between primary and secondary windings.

Other objects will be obvious in part and in part pointed out hereinafter.

The invention accordingly consists in the combination of elements, features of construction and arrangement of parts, and in the several steps and the relation of each of the same to one or more of the others as described herein, the scope of the application of which is indicated in the claims at the end of the specification.

In the accompanying drawings,

Figure 1 is a diagrammatic representation of transformer apparatus embodying certain features of my invention,

Figure 2 is a view of the transformer of Figure 1, as seen from the right, as positioned within its casing, parts of which are broken away,

Figure 3 is a diagrammatic representation of a double transformer in accordance with my invention in which the casing is broken away disclosing certain features of construction, and

Figure 4 is a view of the transformer of Figure 3, as seen along the line A—A.

Like reference characters denote like parts throughout the several views of the drawings.

As conducive to a clearer understanding of certain features of my invention, it may be noted at this point that in the operation of a luminescent sign or display employing one or more luminescent gas filled tubes of desired size and configuration high potential electrical energy is required. Ordinarily, the desired high potential

electrical energy is supplied by alternating-current transformer apparatus connected to a standard single phase sixty cycle source at either one hundred and ten volts or two hundred and twenty volts. The high potential electrical energy supplied the tubes has a maximum value of about fifteen thousand volts across the terminals of the tubes or about seven thousand five hundred volts to ground. This is approximately the maximum value permitted by the Fire Underwriters.

In the operation of even a single luminous sign or display, it frequently is necessary to use a plurality of luminescent tubes, and to energize these tubes by a corresponding plurality of transformers, so that the energizing potential will not exceed values specified by the Fire Underwriters. It is apparent, therefore, that the use of a number of individual transformers in the operation of a single sign or display results in a rather costly installation. Not only is equipment cost excessively high, but the separate charges made for connecting each such transformer to the alternating current source of supply results in a high labor charge.

In heretofore known transformers which are designed for operating a luminescent sign or display, these objections are alleviated in part by splitting the secondary winding into two parts and grounding the midpoints to the transformer core. Each such coil section then develops one-half of the total potential of the winding. In this manner, while the potential applied across the terminals of a tube may amount to fifteen thousand volts, for example, the potential to ground never exceeds seven thousand five hundred volts.

In the operation of transformers of the general type mentioned in the foregoing, it is found that the size of the necessary transformer equipment and its attendant great weight often constitute serious objections, extremely difficult to overcome. When core type transformers are used, with their long magnetic paths, it is extremely difficult, if not altogether impossible, to provide a light and small transformer which at the same time, has a high operating efficiency. By consequence, units are produced employing large quantities of iron and consequently having low power factors; and where compactness is attempted, inadequate heat dissipation results.

One of the outstanding objects of my invention, therefore, is the provision of transformer apparatus which further alleviates these difficulties, giving a single, light, compact, inexpensive

unit of high efficiency, high operating power factor, and effective heat dissipation.

It will be readily appreciated that in energizing luminous displays of considerable size, a number of transformer units must be employed. Since each such unit involves a considerable expense, including both initial cost, maintenance, and labor, it is apparent that any reduction in first cost, as by decreasing the quantity of iron employed or increasing efficiency of operation, is of the utmost importance. One manner of accomplishing this desired end is by minimizing core loss, at the same time, retaining proper magnetic circuit relations, however. In this manner, the power factor is increased to some extent and the operating efficiency improved. At the same time, the amount of iron employed is reduced and initial costs of the installation lowered.

A further important object of my invention therefore is to reduce the amount of iron employed, and to improve the power factor under normal operation.

Another difficulty encountered in the prior art is the cumbersome construction of transformers because of waste space between the transformer proper and its casing. Heretofore, ample space between transformer and casing is required to prevent undue magnetic disturbance by the casing. In such a construction, many disadvantages are encountered, among which the cost of the surplus iron in the casing, the cost of the large quantity of compound with which voids in the casing are filled, excessive weight, excessive space for installation and the like.

Important features of my invention therefore are to ensure a snug fit of the transformer in its casing, with resulting savings in casing construction and quantity of compound used, and yet to minimize fringing or leakage of flux from the magnetic circuit to the transformer casing.

It may be noted at this point that, in general, a so-called double transformer, that is, a transformer having several separate and independent secondary circuits, one form of which I have shown in Figures 3 and 4, is more economical than a single transformer, or one having a single complete secondary winding or circuit, an embodiment of which is illustrated in Figures 1 and 2. This is because the double transformer performs the function of two single transformers while costing considerably less than two such devices in matters of construction, installation and operation. A complete line of transformers, however, requires both types. In these, there are certain special core parts which are similar in function. Savings in manufacturing costs are possible through modifying the constructions of each to permit interchangeability of certain core parts.

Accordingly, a feature of my invention is the production of a leg construction, with which may be formed one or more magnetic shunts, which leg construction is adapted to receive the secondary windings, and which leg construction can be employed at will in either a single or a double transformer.

Referring now to the practice of my invention and directing attention to Figure 1, it will be seen that my transformer consists of a core comprising two outermost legs 1 and 2 interconnected at their ends by inter-connecting members 3 and 4. Between the members 3 and 4 is disposed a central leg 5. The outermost legs 1 and 2, inter-connecting members 3 and 4, and central leg 5, are all formed of a suitable mag-

netic material, such as iron. These elements, together, form a principal magnetic path of shell-like form.

Central leg 5 is secured to connecting members 3 and 4 in desired suitable manner, as by press fit at 8 and 9. The inter-connecting members 3 and 4 are secured to outermost legs 1 and 2 in desired similar manner. This construction ensures a flow of magnetic flux which is unimpeded at the joints of the several parts of the core construction.

About external leg 1 is mounted a suitable primary coil section 6, while about external leg 2 is mounted in desired suitable manner a primary coil section 7. These two coil sections are connected together in series to form the primary winding. Of course, if desired, these coil sections may be connected together in parallel. It is to be kept in mind that when the primary coil sections are connected in series, only one-half of the voltage is impressed across each and a heavy current using coarse wire is employed, thereby lowering the production costs of the transformer. With parallel connection of the separate coil sections of the primary winding, full voltage is impressed across the terminals of each coil and a greater quantity of finer wire must be used. The parallel connection is advantageous, however, in case there is some slight difference in the reluctance of the two parallel magnetic paths, as by some inequality in the length of the air gaps in the shunt magnetic paths to be described, hereinafter. In such a case, the relative amounts of current drawn by the two primary coil sections in parallel connection will be automatically adjusted to give compensating magnetomotive forces. The net result of such a connection is to ensure rather uniform concentrations of flux throughout the core despite irregularities in core construction or assembly. In general, therefore, series connection of the coil sections of the primary winding produces a comparatively inexpensive transformer, while parallel connection gives rise to a more flexible magnetic field.

Coil sections 6 and 7 of the primary winding are energized from a suitable source of alternating current 20, such as a standard single-phase 60 cycle, source of supply at 110 volts. The connection is through conductor 21 and pig-tail 22 to coil 6, and conductor 23 and pig-tail 24 to coil 7. Coils 6 and 7 are interconnected by pig-tail 25, conductor 26, and pig-tail 27.

Mounted on the central leg 5 are secondary coil sections 10 and 11, forming the secondary winding, and while these secondary coil sections may be connected in any desired suitable manner, they are illustrated as connected in series with the inter-connection grounded to the core. Thus the magnetic flux interlinking these coils generates an induced electromotive force of say, 7500 volts in each section, which is approximately the maximum value of potential to ground permitted by the Fire Underwriters, while the total voltage of the winding, as applied to a load 12, is say 15,000 volts.

It will be noted that to this end and in order to connect the secondary coil sections in series, coil section 10 is connected through pig-tail 13 and conductor 14 to one terminal of luminescent tube 12, while its other end is connected through pig-tail 15 to the core. Similarly, the winding 11 is connected through pig-tail 16 to the core, and through pig-tail 17 and conductor 18 to the other terminal of tube 12. The core is conveniently

grounded at 19. It is at once apparent that while no voltage produced is at a potential difference with respect to the ground greater than 7500 volts, nevertheless the potential difference impressed across the tube terminals is 15,000 volts.

Referring back to the construction of the core of my transformer, extending off of the central part of the central leg 5 are the substantially T-shaped magnetic shunts indicated broadly by the numerals 28 and 29, respectively. These shunts have their leg portions 30 and 31 secured in any suitable manner, as by press fit or by being formed integrally with the central leg 5. The leg portions 30 and 31 extend on opposite sides of the central leg 5, and lie in the plane of the shell formed by the outermost legs 1 and 2 and inter-connecting members 3 and 4. The portions of the shunts are substantially parallel with the inter-connecting core members. The head portions 32 and 33 of the T-shaped members 28 and 29 extend at right angles to the said leg portions, still in the plane of the said shell, and extend substantially parallel to the external legs 1 and 2, to points just short of connecting members 3 and 4, forming therewith short-air-gaps, of comparatively high magnetic reluctance, G1, G2, G3, G4. Air-gaps G1 and G2 are approximately equal in length and air-gaps G3 and G4 are also substantially equal in length. Such construction assures paths of equal reluctance through each T-shaped member. Furthermore, gaps G1 and G3 are approximately of the same lengths as gaps G2 and G4, since the parallel paths across gaps G1 and G3 and across gaps G2 and G4 should have substantially the same magnetic characteristics to ensure the development of desired electromotive forces in coil sections 10 and 11.

It is to be noted that long parallel magnetic paths of low reluctance are provided by the outermost legs 1 and 2, the inter-connecting members 3 and 4, and the central leg 5, while short magnetic paths of much greater magnetic reluctance are provided between leg 1, a small portion of each inter-connecting member 3 and 4, and head portion 32, with air-gaps G1 and G2 included therein; and leg 2, small portions of inter-connecting members 3 and 4, and head portion 33, with air-gaps G3 and G4 included. A number of magnetic paths of intermediate lengths and intermediate reluctances are each provided by a reduced length of one of the inter-connecting members 3 and 4, one-half the head portions 32 or 33, the leg portions 30 or 31, and one-half the central leg 5, the flux returning through the full length of the other of the two inter-connecting members 3 and 4.

Now, when say sixty-cycle current from source of supply 20 is impressed on the primary conductors 21, 23, voltage rises from zero to its maximum value, falls back to zero, rises to its maximum value in the opposite direction and falls back to zero some sixty times per second. In so doing, a current flow takes place, which induces a flux in the magnetic core which rises to a maximum, falls through zero to a minimum in the opposite direction passing through sixty cycles per second.

It is necessary for the flux generated by the primary coils to flow in the same direction through the central leg 5, otherwise, there would be substantially no flux passing through this leg. To this end the primary coil sections 6 and 7 are connected in proper manner to give opposing or bucking magneto-motive forces. For a

particular instant, the flux is in the direction of the arrows 34; the direction of flux, of course, reversing 120 times per second for 60 cycle current. As shown, both upper terminals of the coils are connected together, while the bottom terminals are connected through conductors 21 and 23 to the source of supply 20. It may be noted here that the central leg 5 is dimensioned so that the flux density is substantially uniform throughout the principal magnetic path, that is, the cross section of this leg is substantially double that of the external legs 1 and 2 and the connecting members 3 and 4, all of which have approximately the same cross-section.

The magnetic flux, coursing through the path of central leg 5, changing direction and value some 120 times per second, links the turns of the secondary coil sections 10 and 11, and produces therein induced electromotive forces which rise to a maximum in one direction, fall back to and through zero to a maximum in the opposite direction some sixty cycles per second. This induced voltage is impressed on load 12, and since the secondary coil sections are wound so that the instantaneous voltage in the coil section 10, say, adds to that in coil section 11, the 7500 volts developed in each coil section gives a total of 15,000 volts secondary winding output across the tube terminals with but 7500 volts to the ground.

As the secondary voltage starts to build up, it reaches in value the potential necessary to ionize the gas filling of the luminescent tube 12 and strike a diffused arc across its terminals, which value is sometimes known as the "striking potential" of the tube. The diffused arc thus formed continues while the voltage increases to its maximum value and then falls away to a point where it no longer is able to maintain the arc, that is, until its "extinguishing potential" is reached. Tube 12 then is de-energized and remains so until the voltage, building up in the opposite direction, again reaches a striking potential, the tube, however, now being energized in the opposite direction. Thus the tube is alternately energized and extinguished some 120 times per second. Due to the persistence of vision, however, the effect to the observer is that of continued light emission from the tube 12.

As stated previously, upon passage of current through the coil sections 6 and 7 of the primary winding, a flux is caused to course through the magnetic circuits of least reluctance. In the instant that the flow of flux is in the direction of arrow 34, one such circuit may be traced, up from external leg 1, part of inter-connecting member 3, down through central leg 5, and back through part of inter-connecting member 4 to leg 1. Another such circuit may be traced, up from outermost leg 2, along part of inter-connecting member 3, down through central leg 5, and back through part of inter-connecting member 4 to leg 2. Of course, during the next half cycle, the direction of coursing of flux through the complete magnetic circuit traced is in the opposite direction. Because of the high reluctance of the magnetic path across any of the air-gaps G1, G2, G3 or G4, substantially no magnetic flux courses through the head portion 32 and 33 of the magnetic shunts 28 and 29.

Shortly after current flow is started in the primary coil sections, the voltages induced in the secondary coil sections reach a value sufficient to ionize the gas in tube 12, whereupon a glow discharge takes place therein, rendering said tube luminous and suddenly conductive. A flow

of excessive current in secondary winding 10—11 upon the tube 12 suddenly becoming conductive (the tube being essentially non-conductive in the unionized condition, as indicated) is effectively prevented by a change in the coursing of the magnetic flux through the transformer core and a resultant change in the flux interlinking the primary and secondary windings. As a current begins to flow in secondary coil sections 10 and 11 comprising the complete secondary winding, back magnetomotive forces are produced which buck the magnetomotive forces established by a flow of current in primary winding 6 and 7. As a result, the major part of the magnetic flux coursing through the core from coil 6, say, passes from core leg 1 along a shunt path of high reluctance across air-gaps G1 and G2 and head member 32. Similarly, that from coil 7 goes from core leg 2 across air-gaps G3 and G4 and the head portion 33 of shunt 29. The portion of the total magnetic flux which courses through the major lengths of inter-connecting members 3 and 4 and central leg 5 is adequate, however, to induce electromotive forces in coil sections 10 and 11 sufficient to maintain a current flowing through tube 12 in its ionized condition.

Any coursing of the magnetic flux across the portions 30 and 31 of shunt sections 28 and 29 is effectively prevented by the balanced reluctance of these paths across these portions because of the equivalence of the air-gaps and by a balance of the magnetomotive forces of secondary coil sections 10 and 11, tending to send the magnetic flux through these portions of the core. It is evident that inasmuch as the coil sections 10 and 11 are of identical ratings (they have the same number of turns of wire) and having the same current flowing through them, the magnetomotive forces produced by this flow of current are the same for each coil section.

The luminous condition of the tube 12 persists until the potential output of secondary winding 10—11 falls to a value insufficient to maintain the ionized condition of the tube. At this time the tube becomes suddenly un-ionized and non-conductive and current ceases to flow in the secondary winding and its back magnetomotive force suddenly falls to zero. The magnetic flux now tends to course through inter-connecting members 3 and 4 and central leg 5 through the paths of low reluctance. Because of the comparatively high reluctance of the magnetic paths through air-gaps G1 and G2, and G3 and G4, no flux appears in the head portions 32 and 33 at this time.

With the continued change in the magnitude and direction of the magnetic flux coursing through the transformer core and interlinking the primary and secondary coil sections, the electromotive forces induced in the coil sections comprising the secondary windings 10—11 fall through zero and rise in the opposite directions, causing the output potential of the secondary winding representing the difference between these induced electromotive forces to reach again a value sufficient to establish an ionized condition. The gas column present in tube 12 renders the tube conductive and luminous and again the flow of excess current in the transformer secondary winding is effectively prevented by the appearance of back magnetomotive forces causing in the secondary winding 10—11, the major part of the magnetic flux to flow from core legs 1 and 2 respectively along the shunt paths of high reluctance across air-gaps G1 and G2 and

head portion 32, on the one hand, and across air-gaps G3 and G4 and head portion 33, on the other hand.

Since the output potential of the transformer secondary winding 10—11 reaches a maximum twice for each cycle of the source 20 of alternating current electrical energy, the tube 12 becomes luminous twice for each complete cycle of the source, or one hundred and twenty times a second where a sixty cycle source of supply is employed. As has already been suggested, due to the persistence of vision the luminescent tube appears to give forth a continuous glow, which for a neon tube is red orange in color.

Where, by chance, a short-circuit occurs across the output terminals of the transformer secondary winding 10—11 as a result, for example, of the establishment of a conductive film of dirt along the exterior of tube 12 or a grounding of both tube terminals through insects packing themselves about the same, current begins to flow in coil sections 10 and 11 as the induced electromotive force rises from a zero value. The back magnetomotive forces created by this flow of current in these coil sections cause the main body of magnetic flux from core legs 1 and 2 respectively to course through the shunt paths of high reluctance, including air-gaps G1 and G2 and head portion 32 for the one, and air-gaps G3 and G4 and head portion 33 for the other. That portion of the magnetic flux which courses through the inter-connecting members 3 and 4 and the central leg 5, thereby interlinking the primary and secondary windings, is insufficient to induce such electromotive force in coil sections 10 and 11 as to cause an excessive flow of current through these coil sections. The value of the current flowing under short-circuit conditions is substantially the same as that flowing during the conductive period of the luminous tube 12 because the impedance of the circuit is about the same under both conditions. Neither current is sufficient to cause substantial heating and consequent damage to the windings.

Where only one of the secondary winding coil sections becomes grounded in operation, for example section 10, the current immediately begins to flow in this section as soon as the induced electromotive force begins to rise in value from the assumed zero. Corresponding to this flow of current a back magnetomotive force is created which opposes the normal coursing of magnetic flux through the inter-connecting member 3 and the top part of central leg 5. In the coil section 11, however, no current flows as the electromotive force induced in this coil section rises from the zero value. Ordinarily, the striking potential or potential at which the luminescent tube becomes ionized and conductive is so high that the potential induced in but one of the coil sections is wholly insufficient to establish the ionized conductive condition. As a result of the failure of a current to flow in coil 11, this coil section creates no back magnetomotive force to oppose the normal coursing of magnetic flux through inter-connecting member 4 and the bottom part of central leg 5.

With the total back magnetomotive force opposing the normal coursing of the magnetic flux through the core reduced to one-half the value present under normal operating conditions, or conditions of full short-circuit, as indicated above, the current flowing through coil section 10 would tend to rise to an excessive value but for the peculiar constructions of the transformer

core. Under the assumed conditions of the grounding of coil 10 and the open circuit operation of coil 11, a large portion of the magnetic flux is shunted around coil section 10 by way of the top parts of the T-shaped members 28 and 29, the magnetic flux passing from inter-connecting member 3 in parallel paths across air-gaps G1 and G3, top parts of head sections 32 and 33, and leg portions 30 and 31, uniting at the central part of central leg 5 and continuing there-through, the paths again separating at the bottom of leg 5 and returning to outermost core legs 1 and 2, on which are mounted the primary coil sections 6 and 7, through inter-connecting member 4. It will be seen that the flux passes between coil sections 10 and 11, and includes and links the one coil 11 operating under open-circuit conditions but excludes the other coil section 10 operating under short-circuit conditions.

The reluctance of this magnetic path is intermediate the reluctance of the long path of low reluctance including both secondary winding coil sections and the short path of high reluctance across four air-gaps excluding both coil sections. The total reluctance of the two shunt magnetic paths is largely made up of the reluctance of the two or four air-gaps included therein. The parallel shunt paths, then under the assumed condition of short-circuit operation of coil section 10 and open-circuit operation of coil section 11 include two air-gaps, and, therefore, has a reluctance of approximately one-half of that encountered in normal operation where the major portion of the magnetic flux courses along parallel paths including four air-gaps.

The halving of the reluctance of the shunt magnetic path corresponding to the halving of the back magnetomotive force created by the flow of current in the secondary winding results in a current of about the same magnitude as under load and full short-circuit conditions. In effect, the construction of the core and its placement with respect to the coil sections of primary and secondary windings prevents the current flowing in the grounded coil section from rising to the excessive values which otherwise would be realized. Damage to the coil as a result of grounding is thus effectively prevented in a simple, direct and highly efficient manner.

It will be understood that where single-coil short-circuit conditions are reversed and coil 11, for example, is operating under short-circuit conditions, and coil 10 is operating under open-circuit conditions, the magnetic paths of intermediate reluctance include the short-portions of inter-connecting member 4, the air-gaps G2 and G4, the lower parts of head portions 32 and 33, the leg portions 30 and 31, joining at the central part of central leg 5, and extending through the upper portion of said leg 5, where the paths again separate, coursing through connecting member 3 to outermost core legs 1 and 2. The major part of the flux normally coursing through the coil sections 11 and 10, being directed to include the coil section 10 and exclude the coil section 11. Under these conditions of operation the remaining portion of the total magnetic flux, or that portion which includes the short-circuited coil section 11, is insufficient to induce an electromotive force in this coil section which is great enough to cause an excessive flow of short-circuit current.

An important feature of my invention can best be realized, in connection with Fig. 1, by noting that the general contour of my new transformer

assembly is substantially that of a rectangle, which is substantially completely filled. Thus coils 6 and 7 fit snugly in spaces provided respectively therefor between the core portions comprising outermost leg 1, inter-connecting members 3 and 4, and head portion 32, on the one hand, and outermost leg 2 and inter-connecting members 3 and 4, and head portion 33, on the other hand. Similarly, coils 10 and 11, respectively, fit snugly in the core spaces provided therefor between interconnecting member 3, leg portions 30 and 31, and head portions 32 and 33, on the one hand, and inter-connecting member 4, leg portions 30 and 31, and head portions 32 and 33 on the other hand. There is substantially no unused space in this construction. Compound necessary to fill the interstices is reduced to a minimum in quantity. The length of the magnetic paths and consequently the amount of core iron is minimized. The shell type of construction employed and the peculiar shunt construction used assures a minimum flux leakage, thus permitting a closely fitting casing. For example, I have found that a transformer according to my present invention can be enclosed in a container of only 145 cubic inches capacity, while in the case of a simple core-type construction, of the same secondary core cross-section, and same secondary output, a container of 240 cubic inches content is required. Moreover, the primary copper employed is reduced thirty per cent, the total iron employed is reduced fifteen per cent and the total weight is reduced thirty per cent.

Another feature of my novel transformer construction, as already pointed out, is that rapid dissipation of heat is realized. This is had because the two primary coils are of comparatively low depth. This construction gives rise to rapid heat dissipation, permitting higher primary currents without danger of overheating or charring of insulation. Where desired, this heat dissipation is facilitated by placing connecting members 3 and 4 in contact with the transformer casing 130 (see Figure 2) conveniently through a steel binding member 131.

As a modification of my single transformer described above, I contemplate a double transformer, that is a transformer having more than a single complete secondary circuit. Such a construction is illustrated in Figures 3 and 4 of the drawings to which attention is now directed. The double transformer of Figures 3 and 4 fundamentally is but a development of the single transformer shown in Figures 1 and 2. Instead of a single central leg, there are employed two central core legs 39 and 40 disposed one after the other, each with the corresponding T-shaped magnetic shunts associated therewith, and each having mounted thereon the two coil sections of separate and independent secondary windings. For convenience of illustration, the major axis has been shown as shifted through 90°. Further, the showing of the construction of Figures 3 and 4 has been amplified over that of Figures 1 and 2, in order to depict accurately the close interrelation between the transformer and its associated casing, and also in order to illustrate the manner in which the various parts of the transformer are clamped and wedged in place.

In the embodiment of Figures 3 and 4, outermost core legs 35 and 36 are provided, interconnected adjacent their ends, in order to form a closed magnetic path, by members 37, 38 and mid-member 141. This interconnection may be

of any suitable type, such as a press-fit, clamping or the like.

Joining the midpoints of the inter-connecting members 37 and 38, and disposed in the prolongation of each other, in the plane of the shell formed by the outermost legs 35 and 36 and the inter-connecting members 37, 38 and 141 are two central legs 39, 40, each of which is substantially identical to the central leg 5 of the single transformer construction illustrated in Figures 1 and 2. The single central leg element, which conveniently is composed of a stack of iron laminations, is the same for both the single and double transformers, one being used for the single transformer and two for the double. A very material reduction in production costs results from this ingenious conception, since one stack is sufficient for both.

Referring now more particularly to the core construction, the free ends of the central legs 39 and 40 are connected together by a transverse mid-inter-connecting member 141 which conveniently is formed of laminated sheet iron. Member 141 extends in opposite directions from the median line of legs 39 and 40, in the plane of the shell, to points just short of external legs 35 and 36, respectively. Central leg 39 is secured to outermost inter-connecting member 37 and mid-inter-connecting member 141, respectively. Similarly, central leg 40 is secured to inter-connecting member 38 and mid-inter-connecting member 141 in any suitable manner, as by press fits at 41, 42, 44 and 43 respectively.

Just as in the case of the central leg 5 of the transformer of Figures 1 and 2, the central leg 39 is provided with centrally disposed, outwardly extending magnetic shunt members 45, 46, of substantially T-shape, with their respective leg portions 47, 48 lying in the plane of the shell, substantially parallel to the connecting member 37, and with the respective head portions 49 and 50 terminating short of and lying parallel with respect to outermost legs 35 and 36. The said head portions 49 and 50 extend in opposite directions from the leg portions, to points just short of the inter-connecting member 37 at one end, and just short of the mid-member 141 at the other end. Similarly, the other central leg 40 is provided with two T-shaped magnetic shunts 51 and 52, the leg portions 53 and 54 of which are connected with the central leg 40 and extend parallel to the inter-connecting member 38, and the head portions 55 and 56 of which terminate short of and are parallel with the respective outermost legs 35 and 36. The ends of the shunt head portions 55 and 56 terminate just short of inter-connecting member 38 and mid-member 141, respectively.

Mounted on one outermost leg 35 is a primary coil section 57, which together with the corresponding primary coil section 58 on the other outermost leg 36, constitutes the complete primary winding of the transformer. While the primary winding of the transformer of Figures 1 and 2 is illustrated as having the coil sections connected in series, here, by contrast, the coil sections are shown as connected in parallel relationship. Thus the primary coils here are wound for twice the voltage of the transformer of Figures 1 and 2, and a much finer wire is employed. While such construction is more costly, it has the advantage, as explained hitherto in connection with the transformer of Figures 1 and 2, that where there is some slight difference in the reluctance in the two parallel magnetic paths

energized by the primary winding (as by some inequalities in the length of air-gaps in the shunt paths), the relative amounts of current drawn by the two primary coil sections will be automatically adjusted to give compensating magnetomotive forces. The net result of such parallel connection, therefore, is to assure rather uniform concentrations of flux throughout the core despite minor irregularities in the core construction. Accordingly, the right hand terminal of primary coil section 57 is connected through pig-tail 59 and lead 60 to one terminal of a suitable alternating current source of electric supply 61, while the left hand terminal of this coil section 57 is connected by pig-tail 62 and lead 63 to the other terminal of said source of supply. In similar manner, coil section 58 likewise is connected to the supply source 61, by pig-tail 64 and lead 65 connecting the right hand terminal of the coil section to the one terminal of supply source 61, while the left hand terminal of the coil section 58 is connected by the pig-tail 66 and lead 67 to the other terminal of the said supply source.

It will be seen that two principal and parallel magnetic paths of substantially the same magnetic characteristics are provided. One of these is from the one outermost leg 35, the upper halves (as seen in Figure 3) of the inter-connecting members 37 and 38, and through central legs 39 and 40 and the mid-inter-connecting member 141. The other of said parallel circuits is from the other outermost leg 36, through the lower halves (as seen in Figure 3) of the inter-connecting legs 37 and 38, and through the central legs 39 and 40, and the mid-member 141. The coil sections comprising the primary winding are so connected that the flow of magnetic flux coming from both of the parallel magnetic paths is through central legs 39 and 40 in the same direction for a particular instant. Otherwise, the flux would be confined to a path of outermost legs 35 and 36 and interconnecting members 37 and 38 with no flux coursing through central legs 39 and 40. To this end the terminals of the primary coil sections 57 and 58 have been so connected to the same source of supply 61 that the instantaneous direction of magnetic flux through the magnetic circuits may be conceived of as in the direction of the arrows 68. Of course, in the next half cycle of the alternating current supply, the direction of the flux is in the direction opposite to the arrows 68. Thus the flux courses the parallel magnetic paths in each opposite direction once for each complete alternation or cycle of the alternating current source of electric supply.

Considering now the construction of the secondary windings of my transformer, on the central leg 39 are mounted the coil sections 69 and 70 of one complete secondary winding. These coil sections are disposed on opposite sides of the median line constituted by leg portions 47 and 48 of the T-shaped magnetic shunt members 45 and 46. Similarly, coil sections 71, 72 of a second complete secondary winding are mounted on the central leg 40, one on each side of the median line formed by the leg portions 53, 54 of the T-shaped magnetic shunt members 51, 52.

Now, attention being directed for the moment to the secondary winding constituted by coil sections 69 and 70, the common ends or terminals of these two coil sections are grounded to the core, as through pig-tails 73, 74 respectively, the core being grounded to the earth at any convenient point 75. This places the coils in series,

their phase relationships being such that their induced potentials are additive. The free terminal of the one coil section is connected to the one terminal of a suitable load, such as gas-filled luminous discharge tube 76, while the free terminal of the other coil section is connected to the second terminal of said load. Conveniently, the free terminal of coil section 69 is connected through pig-tail 77 and lead 78 to one terminal of tube 76, while the free terminal of coil section 70 is connected through pig-tail 79 and lead 80 to the second terminal of this tube. The total maximum potential impressed across the terminals of the load, therefore, will be 15,000 volts, for a maximum of 7500 volts per coil, while at the same time the potential to ground never exceeds 7500 volts.

Similarly, the coil sections 71 and 72, comprising the second complete secondary winding, are connected in a series relation, this being accomplished by grounding unlike terminals of the coil sections to the transformer core through pig-tails 81 and 82, respectively, and by connecting the free terminals of said coil sections through pig-tail 83 and lead 84, and pig-tail 85 and lead 86, respectively, to opposite terminals of the tube 87.

It will be interesting to observe at this point, the manner in which the magnetic flux courses the magnetic path during the various conditions of operation. During no-load conditions, that is, prior to the establishment of the ionized, conductive conditions in tubes 76 and 87, when alternating current begins to flow through the primary winding, setting up a changing magnetic flux, this flux courses through the main or principal magnetic paths, previously traced, and interlinks the primary winding with both of the separate secondary windings. During this time, while a voltage is induced in the secondary windings, it is not yet of value equal to the striking potential of the respective tubes 76 and 87. Accordingly, no current flows through the secondary coil sections and no back magnetomotive force is set up to impede the coursing of the magnetic flux through the principal magnetic circuit. It is apparent that under the described conditions the flux courses over parallel long magnetic path of low reluctance. At this time practically none of the flux appears in the short magnetic paths comprised, one by the one outermost leg 35, a short part of inter-connecting member 38, air-gap G6, head portion 55, air-gap G5, mid-member 141, air-gap G2, head portion 49, air-gap G1, and a small part of inter-connecting member 37, back to outermost leg 35; and the other by the other outermost leg 36, a short part of inter-connecting member 38, air-gap G8, head portion 56, air-gap G7, mid-member 141, air-gap G4, head portion 50, air-gap G3, and a small part of inter-connecting member 37, back to the outermost leg 36.

Intermediate the two extremes of long magnetic paths of low reluctance and short magnetic paths of high reluctance, are a number of paths of intermediate lengths and intermediate reluctances, constituted by various lengths of the central core legs 39, 40, the magnetic shunts 45, 46, 51, 52, and air-gaps G1 to G8, all as will more fully appear hereinafter.

Because the coil sections 69 and 70 are of substantially the same electrical characteristics (they have the same number of turns) the air-gaps G1, G2, G3 and G4 are made uniform in length. The reluctance of the various parallel magnetic paths will be uniform, and the distribution of flux through the core likewise is symmetrical and uniform. Similarly, because the coil sections 71 and 72, supplying the tube 87, are of substantially the same electrical rating (they likewise have the same number of turns) the air-gaps G5, G6, G7 and G8 are made the same length, so that the reluctance of the various magnetic paths will be uniform.

There is no necessary relation between the four air-gaps associated with secondary winding 69—70 and the four air-gaps associated with winding 71—72, because the magnetic shunts with which the first set of air-gaps is associated are designed for operation of tube 76, while the magnetic shunts with which the second set of air-gaps is associated are designed for operation of tube 87. These tubes conceivably may have appreciably different electrical characteristics. As a practical matter, however, the tubes 76 and 87, forming parts of the same luminous sign, are usually of approximately the same length and of the same electrical characteristics. Accordingly, therefore, from a practical standpoint, and without appreciable sacrifice of efficiency, all air-gaps are made the same length.

Excessive flow of current, following ignition of the tubes, ignition and extinguishment taking place simultaneously in both tubes, since the tubes have substantially the same electrical characteristics, is prevented as in the single transformer described above. As soon as current flows in the secondary windings, back magnetomotive forces are created which buck the magnetomotive forces established by the primary winding. Considering for the moment the second complete secondary winding, consisting of the series-connected coil sections 71 and 72, these back magnetomotive forces oppose the passage of magnetic flux through central leg 40, and cause the main portion of the flux from the primary coil section 57 to course through a short length of the inter-connecting member 38, the air-gap G6, the head portion 55, air-gap G5, to mid-inter-connecting member 141. Similarly, the main portion of the flux from the primary coil section 58 courses through a short portion of inter-connecting member 38, air-gap G8, head portion 56, air-gap G7, to the mid-member 141. Now, if a discharge has not yet been struck in tube 76, or if there is no second load, the first complete secondary winding consisting of coil sections 69 and 70 is operating under open-circuit conditions. Under such conditions, no counter magnetomotive forces are established in the central leg 39, and the main flux will course along mid-inter-connecting member 141 and thence through central leg 39, splitting at connecting member 37 to return to the outermost legs supporting the primary coil sections. Operation of but a single load is possible without objectionable effect on my double transformer.

Where a discharge has been struck across the tube 76 and current begins to flow in coil sections 69 and 70, a back magnetomotive force is set up, bucking the flow of the main flux along the central leg 39. Accordingly, the main portion of this flux, considering now that which is established by primary coil section 57, will course across the mid-member 141, air-gap G2, head section 49, air-gap G1, a short portion of connecting member 37, and back to outermost leg 35. Similarly, the major part of the flux produced by coil section 58 will course across mid-member 141, gap G4, head section 50, gap

G3, a short portion of the connecting member 37, and back to outermost leg 36. Of course, enough flux will course through central legs 40 and 39 to maintain sufficient voltage to preserve the conductive and luminescent condition.

As soon as the voltage falls to a point where it is no longer sufficient to maintain the discharge across the tubes 76 or 87, the gas therein suddenly becomes un-ionized, discharge ceases, and open-circuit conditions maintain. Currents no longer course the transformer secondary windings, and the back magnetomotive forces no longer exist. Consequently, the main bodies of flux resume their circuits over the long magnetic circuits of low reluctance, down through the central legs 40 and 39. During the next half cycle, or one-one hundred and twentieth of a second in the case of a sixty cycle source of electric current supply, the main streams of flux reverse in direction, and flow in directions opposite to those given above.

Now let us assume that tube 87 becomes short-circuited for some unknown reason. In the absence of provision to the contrary, excessive current flow would result, occasioning overheating and charring in the insulation of the turns of the secondary coil sections 71 and 72, and eventually producing breakdown of these coil sections. With my construction, however, as soon as the short-circuit conditions maintain, increased current flows tend to occur in coil sections 71 and 72, and back magnetomotive forces are produced just as in the case of normal load conditions. The main fluxes therefore divert along the short magnetic paths of high reluctance 38, 55, G5 and 141; and 38, G8, 56, G7 and 141, already described. The portions of the main bodies of flux still coursing through central leg 40 is enough to produce a current flow in winding 71—72 substantially commensurate with that maintaining during normal current flow.

Assume now that only one of the coil sections is short-circuited, for example, section 72, the coil section 71 not being short-circuited, however. Excessive current flow tends to occur in coil section 72, a tendency which is effectively inhibited however, due to the fact that the resulting back magnetomotive force causes the main portion of the primary flux to thread, in the case of the flux induced by primary coil section 57, a short portion of inter-connecting member 38, air-gap G6, the right-hand end (as seen in Figure 3) of head portion 55, leg portion 53 to the center of central leg 40; and in the case of flux induced by primary coil section 58, a short portion of inter-connecting member 38, air-gap G8, the right hand end of head portion 56, the leg portion 54 to the center of central leg 40. Thus practically all the flux by-passes the short-circuited coil section 72. Since the voltage produced by coil section 71 above is insufficient to strike a discharge across tube 87, this coil section operates under open-circuit conditions. Inasmuch as no current flows, no back magnetomotive force maintains. Therefore, the main flux continues on down through the central leg 40, to the left in Figure 3 and back through parallel paths to complete the magnetic circuit. Upon reversal of the direction of the primary flux, the path of the flux is the same. The shunting of the magnetic flux results in a decrease in the electromotive force induced in the short-circuited coil and a consequent limitation of the current flow to a value substantially equal to that of load conditions for reasons which are particularly given above in de-

scribing the operation of the transformer of Figures 1 and 2.

If now it is the coil section 71 which is short-circuited, then it is the coil section 72 which operates on open-circuit conditions, since the developed voltage of this coil section is insufficient to strike an arc across tube 87. Under these conditions, the magnetic flux is shunted around the short-circuited section. Thus, the flux coming in opposite directions along inter-connecting member 38, as indicated by arrows 68, unite at the right-hand end of central leg 40 and flow unobstructed to the center of this leg 40 where, impeded by the back magnetomotive forces induced by current flow in the coil 71, the flux splits, one main part coursing through leg portion 53, the left hand section of head portion 55, air-gap G5, to mid-member 141; the other main part coursing along leg-portion 54, the left-hand section of head portion 56, air-gap G7 and mid-member 141. It will be understood that the same paths are traversed where the flux is proceeding in a reversed direction. Here again the current of the short-circuited coil is limited to safe operating values.

In the cases assumed above, further passage of the magnetic flux from the mid-inter-connecting member 141, of course, depends upon the load conditions of the secondary winding 69—70. Assuming a flux in the direction of the arrows 68, the flux will continue to inter-connecting member 37 along either the central leg 39 of low reluctance, or the shunt paths of high reluctance and including air-gaps G2 and G4, and G1 and G3, respectively, depending upon whether open-circuit or load conditions maintain, that is, whether the tube 76 is de-energized or energized just as in connection with the conditions of secondary winding 71—72 discussed above. Where load or short-circuit current flows in a coil section, the magnetic flux is shunted around that section.

While, as a matter of convenience in describing the operation of my transformer apparatus, the various stages in the operation of the two luminescent tubes 76 and 87 and the possibilities attending this operation are treated separately, each without special regard to the operation of the other, it will be understood that under actual operating conditions both luminescent tubes are rendered conductive and luminous at about the same instant and at about the same instant become non-conductive and non-luminous. During these brief periods when the tubes are in their non-conductive states, the complete path of the total magnetic flux courses along the entire lengths of outermost legs 35 and 36, inter-connecting members 37 and 38, and central legs 39 and 40, completing the magnetic circuit. During the periods when tubes 76 and 87 are in their conductive conditions, however, the major part of the magnetic flux courses along the least reluctant magnetic paths, which includes short sections of inter-connecting members 37 and 38, and head portions 49 and 55, and the included air-gaps G1, G2, G5 and G6, for one path; and head portions 50 and 56 and air-gaps G3, G4, G7 and G8, for the other path; the remaining portion of the magnetic flux continuing along the long path of low reluctance and interlinking the primary, and secondary windings.

Where either or both of the secondary windings are short-circuited, as a result of a dirty condition of either or both of these tubes as indicated above, the total path of magnetic flux

is substantially the same as that of the flux under the conditions of operation existing during the conductive periods of both tubes. Where, however, but a single coil section of one of the secondary windings is grounded, the complementary coil section being open-circuited, the path of the major portion of the magnetic flux is shunted around this grounded section including the open-circuited section but excluding the grounded section. This path varies in length to include both coil sections of the other secondary winding during the non-conductive periods of the tube which that winding energizes and to exclude these coil sections during the conductive periods of the tube, or during short-circuit conditions prevailing at these sections. Under these operating conditions the path of the remaining portion of the magnetic flux includes and interlinks the primary winding with the various coil sections of the secondary winding but the amount of this flux is insufficient to result in the flow of an excessive current in any of these coil sections as more particularly indicated in the foregoing. Protection of the transformer windings, therefore, is assured.

It is to be noted at this point that in my electrical transformer apparatus only a single primary winding and a single core structure are employed. The total magnetic flux is created by the one primary winding, and by way of the single core structure, serves to link and energize both secondary windings. This construction, of course, effects a direct saving in construction over heretofore known transformer apparatus. It is to be particularly noted, however, that these savings in iron, for the core, and copper for the primary winding, do not result in a loss in operating efficiency or, of greatest importance, in a risk of damage to any coil of the secondary windings as a result of accidental grounding of such a coil. Especially is it to be noted that protection of the secondary winding coil sections is achieved without necessity for increasing the size of wire over that normally necessary to handle the operating current of the luminescent tubes. These savings and economies in the construction of a single piece of apparatus requiring but a single connection to a source of supply energy are of the greatest practical importance in the operation of a maximum length of luminescent tubes by a single piece of apparatus.

As a further feature of my invention, structural means are employed for clamping and silencing the parts of my transformer. It will be recalled that upon the establishment of the magnetic flux in a core structure of laminated iron sheets, each of extreme thinness, in order to minimize eddy current losses, the rapidly changing flux tends to give rise to mechanical movement of the iron sheets or plates themselves, accompanied by an objectionable buzzing noise known as chattering. To avoid this movement and its resulting noise, the plates are firmly clamped against each other in a simple and effective manner. Furthermore, the several parts of the transformer core are firmly wedged together in abutting relation to prevent movement of said parts relative to each other.

To the foregoing end, a metallic tightening band 88 fits snugly about the joints of the one outermost leg 35 with interconnecting members 37 and 38, while band 89 secures adjacent ends of the other outermost leg 36 and its cooperating inter-connecting members 37 and 38. Band 88 is tightened by a wedge 90 at one end, electric

insulating pads 91 and 92 spacing the tightening band 88 from the leg 35. Similarly, band 89 is tightened by wedge 93, the band being spaced from outer leg 36 by insulating pads 94 and 95.

Silencing clamps 96 and 97 respectively fit about the lamina comprising into-connecting members 37 and 38, being separated therefrom by insulating pads 98 and 99, respectively. Similarly, the T-shaped member 45 is silenced by clamp 100 with its insulating pad 101, T-shaped member 46 is silenced by clamp 102 with its insulating pads 103, T-shaped member 51 is silenced by silencing clamp 104 with its insulating pad 105, while T-shaped member 52 is silenced by clamp 106 with its insulating pad 107. In like manner, mid-inter-connecting member 141 is silenced, at one end by clamp 108 with its insulating pad 109, and at its other end by clamp 110 with its insulating pad 111.

The joints 42 and 43 between central legs 39 and 40 and the mid-member 141, joints previously referred to as conveniently being of a pressed type, may be of a different type. Where desired, the central legs and the mid-members may be securely clamped in place by means such as holding plates 112 on opposite sides of the joints, engaging the ends of legs 39 and 40, the plates 112 being securely held by convenient means such as headed bolt 113 and insulating washers 114.

As a further structural feature of my invention, the transformer is housed in a casing illustrated as comprised by a mounting plate 115 having legs 116, a body portion 117, and a cover 118.

One of the important features of my invention is the manner in which the transformer proper is constructed in relation to its casing or housing, and in the manner in which the transformer is housed in the said casing. Ordinarily, unless special provisions are employed, a considerable amount of flux leaks from the core of a transformer to the surrounding casing, representing a net loss of energy and deleteriously affecting the operation of the transformer. Particularly is this true of a core type of transformer, where the magnetic path is comparatively long, and the construction is quite open. Especially, in such a transformer, is "fringing" or leakage of the flux to the casing likely to occur at the air-gaps which are provided in the magnetic shunts. At these air-gaps there is the tendency of some of the flux to spread out in fanlike fashion, the outer fringe of which is likely to leak to the casing, rather than to course directly across the air-gaps.

To minimize the fringing effect, I have disposed all magnetic shunts internally of the shell comprised by the outermost legs 35, 36 and inter-connecting member 37 and 38. Thus an important feature of my invention may be said to consist of a shell-type transformer, of either the single or the double type, in which all magnetic shunts are disposed internally of the principal magnetic path. This construction permits intimate association of transformer and casing without appreciable flux leakage. The transformer assembly is seen to fit very snugly in the casing. Additionally, and as pointed out hitherto, the primary and secondary coil sections fit snugly in the spaces provided therefor in the various parts of the core structure, leaving a minimum of air-pockets or voids. Thus substantially all available space within the outer confines of the transformer is utilized, and a small compact construction of relatively large power

output, results. Material economies are effected as savings in copper and iron of the transformer construction, in a reduction of flux leakage to casing during operation, in the construction of the casing itself, and in the amount of compound employed to fill the transformer casing. Furthermore, it will be noted that insofar as is possible, intricate core shapes have been avoided, so that these parts may be stamped out or otherwise formed, with a minimum of scrapping of waste iron.

As a still further feature of my invention, it is noted that the primary coil sections 57 and 58 are of the same shallow construction as in the single transformer of Figures 1 and 2. The coil sections lie closely adjacent the walls of the casing, providing very effective dissipation of the heat generated in these coils. Furthermore, it is to be noted that these primary coil sections are comparatively remote from the secondary coil sections 69, 70, 71 and 72, with the iron of the magnetic shunts interposed between these coils. The secondary coil sections are thus substantially completely shielded from the primary coil sections, thus reducing interference effects to a minimum. The greatest dimension of the primary coil sections is seen to extend along the outer legs, while the greatest dimension of the secondary coil sections is seen to extend at right angles to the central legs.

Thus, it will be seen that there has been provided in my invention an electric transformer in which the many objects hereinbefore noted, together with numerous practical advantages, are successfully achieved.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiments hereinbefore set forth, it will be understood that all matter described herein, or shown in the accompanying drawings, is to be interpreted as illustrative, and not in a limiting sense.

I claim:

1. Transformer apparatus, comprising a shell-like core comprising outermost core legs, inter-connecting members between said outermost core legs and a central leg between said outermost legs; primary coil sections mounted on said outer legs; secondary coil sections mounted on said central leg; magnetic shunt legs included in said core construction and extending off of said central leg in opposite directions at a point between secondary coil sections and terminating just short of said inter-connecting members, to form shunt paths around said coil sections with included air-gaps adjacent said inter-connecting members and interiorly of the main magnetic circuit; and a casing fitting snugly about the transformer core and the said coil sections, the disposition of the casing with respect to said coil sections, magnetic shunt legs, outer legs and said inter-connecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on the transformer operation.

2. Double transformer apparatus, comprising a core having a pair of outermost legs, and members interconnecting said outermost legs, and two central legs, disposed in the prolongation of each other and between and substantially parallel with said outermost legs; primary coil sections on said outermost legs; and secondary coil

sections of independent secondary windings on each of said central legs; said core including a mid-inter-connecting member disposed between said central legs and terminating at each end just short of said outermost legs, and magnetic shunt legs off each of said central legs between coil sections comprising a secondary winding and terminating, at one end of each said shunt, just short of the said mid-member and said inter-connecting members to form shunt magnetic leakage paths of high reluctance.

3. A double transformer apparatus, comprising a core having outermost legs and inter-connecting members forming an approximately rectangular shell, central legs disposed in the prolongation of each other and substantially parallel to said outermost legs; primary coil sections mounted on said outermost legs; and secondary coil sections of a complete secondary winding on each of said central legs; said core including a mid-inter-connecting member disposed between said central legs and terminating just short of said external legs, and T-shaped shunt members fast with each said central leg, through the leg portions of said T-shaped members, and projecting outwardly from the central part of the corresponding central leg on opposite sides thereof in the plane of said shell at points between the coil sections of a secondary winding and with the head portions of the T-shaped members disposed substantially parallel with, internally of, and spaced relation with said external legs, one end of each said portion terminating just short of the corresponding inter-connecting member, and the other end of each said head portion terminating just short of said mid-member, to form leakage paths of high reluctance about said secondary coil sections.

4. Double transformer apparatus, comprising outermost core legs, members inter-connecting said legs near the ends of the latter, primary coil sections disposed on said outermost legs, with their greatest dimension extending along said legs, central core legs disposed in the prolongation of each other and abutting said inter-connecting members and substantially parallel to said outermost legs, a mid-member disposed between said central legs and terminating just short of said outermost legs, coil sections of a separate secondary winding mounted on each of said central legs with their greatest dimension extending at right angles to the same, and magnetic shunt legs extending off each of said central legs at points between said coil sections and terminating just short of said inter-connecting members and said mid-member, to form magnetic leakage paths around said coil sections, the said secondary coil sections being substantially free from magnetic interference from the primary coil sections.

5. Transformer apparatus, comprising a shell-like core having outermost legs, inter-connecting members abutting said outermost legs, and a central leg between said outermost legs likewise abutting said inter-connecting members; primary coil sections mounted on said outermost legs; and spaced secondary coil sections mounted on said central leg; said core including like T-shaped shunt members extending off of said central leg in opposite directions at a point between said secondary coil sections and terminating just short of said inter-connecting core members, to form leakage paths with included air-gaps; and a casing fitting snugly about the transformer core and the said coil sections, the dis-

position of the casing with respect to said coil sections, shunt members, outermost legs and interconnecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on the transformer operation.

6. Transformer apparatus, comprising a shell-like core having outermost legs, inter-connecting members abutting said outermost legs, and a central leg between said outermost legs likewise abutting said inter-connecting members; primary coil sections mounted on said outermost legs; a pair of spaced secondary coil sections connected together in series with the common connection grounded positioned on said central leg; said core including like magnetic shunt legs extending off of said central leg in opposite directions at a point between said secondary coil sections and terminating just short of said inter-connecting core members, to form symmetrical leakage paths with included air-gaps; and a casing fitting snugly about the transformer core and the said coil sections, the disposition of the casing with respect to said coil, magnetic shunt legs, outermost legs and said inter-connecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on transformer operation.

7. Transformer apparatus, comprising a shell-like core comprising a pair of outermost legs and members interconnecting said outermost legs near the ends of the same; a pair of primary coil sections disposed on said outermost legs, with their greatest dimension extending along said legs; a central leg included in said core construction being disposed interiorly of said outermost legs substantially parallel thereto and across said inter-connecting members; secondary coil sections connected together in series and mounted on said central leg with their greatest dimension extending at right angles to said latter; a pair of magnetic shunt legs also included in said core construction and extending in opposite directions off of said central leg, between adjacent secondary coil sections and between said primary and secondary coil sections, and terminating just short of said connecting members, to form magnetic shunt paths, whereby the said secondary coil sections are substantially free from magnetic interference from the primary coil sections; and a casing fitting snugly about the transformer core and the said coil sections, the disposition of the casing with respect to said coil sections, magnetic

shunt legs, outermost legs and said inter-connecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on the transformer operation.

8. Double transformer apparatus, comprising a shell-like core having outermost legs, members inter-connecting said legs, and two central legs, disposed in the prolongation of each other and substantially parallel of said outer legs; two secondary coil sections mounted on each of said central legs; said core including like magnetic shunt legs off opposite sides of each of said central legs at points between said two coil sections mounted on that leg to form symmetrical shunt magnetic paths around said coil sections; and a casing fitting snugly about the transformer and the said coil sections, the disposition of the casing with respect to said coil sections, magnetic shunt legs, outermost legs and said inter-connecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on the transformer operation.

9. Double transformer apparatus, comprising outermost core legs, core members inter-connecting said legs near the ends of the same, a pair of primary coil sections disposed on said outermost legs, two central core legs disposed in the prolongation of each other between said inter-connecting members and substantially parallel to said outermost legs, two pair of series-connected coil sections of two separate secondary windings one pair being mounted on each of said central legs, magnetic shunt core legs extending off each of said central legs; at points between the coil sections of each pair of secondary coil sections and lying between said primary and secondary windings to provide symmetrical shunt magnetic paths around said coil sections; and a casing fitting snugly about the transformer core and the said coil sections, the disposition of the casing with respect to said coil sections, magnetic shunt legs, outermost legs and said inter-connecting members contributing to said snug fit and giving balanced magnetic conditions within the transformer and conditions tending to minimize leakage of magnetic flux to said casing, and minimizing the fringing of magnetic flux at the air-gaps and the effect of the casing on the transformer operation.

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