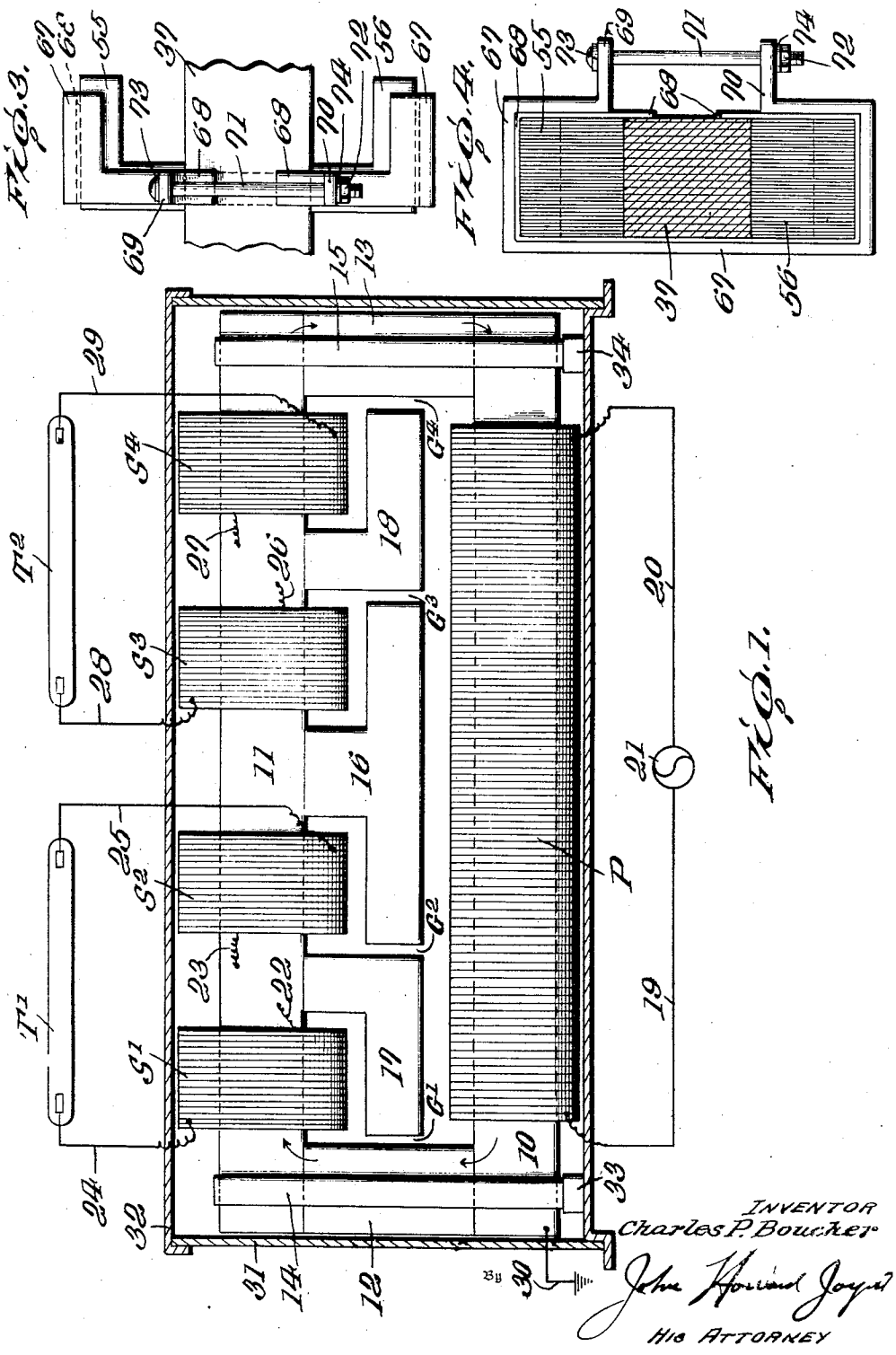
March 2, 1943. C. P. BOUCHER 2,312,868

TRANSFORMER

Filed May 1, 1940 2 Sheets-Sheet 1



March 2, 1943. C. P. BOUCHER 2,312,868

TRANSFORMER

Filed May 1, 1940 2 Sheets-Sheet 2

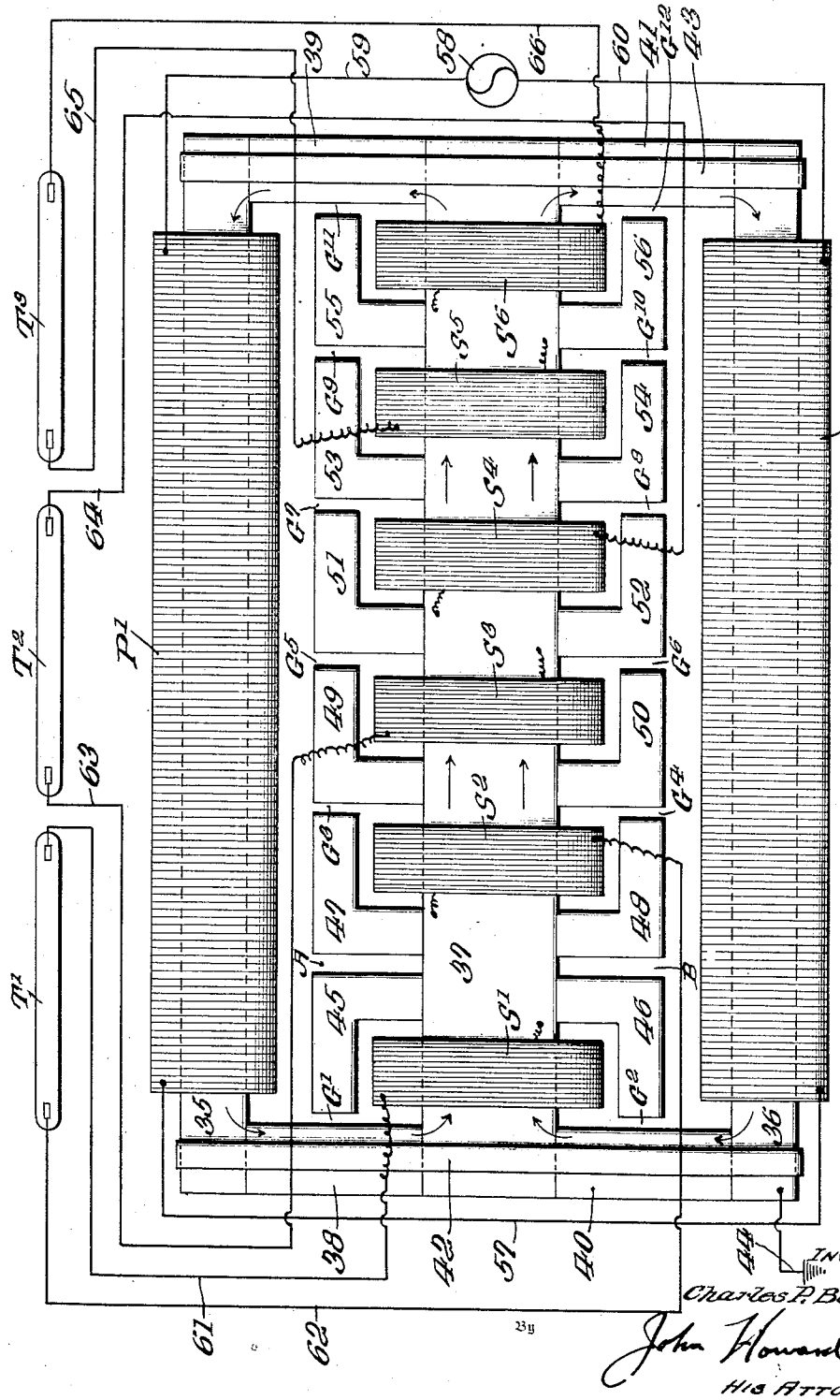


FIG. 2.

INVENTOR
Charles P. Boucher
By John Howard Joyce
HIS ATTORNEY

Patented Mar. 2, 1943

2,312,868

UNITED STATES PATENT OFFICE

2,312,868

TRANSFORMER

Charles Philippe Boucher, Paterson, N. J., assignor to Boucher Inventions, Ltd., Washington, D. C., a corporation of Delaware

Application May 1, 1940, Serial No. 332,813

5 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.

Still another object is to provide a transformer having shunt core members which can be manufactured inexpensively and which are so designed that after assembly the shunt paths of which they form parts will have the correct predetermined magnetic reluctances.

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

The invention accordingly consists in the combination of elements, features of construction and arrangement of parts, 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 a core-type transformer embodying certain features of my invention.

Figure 2 is a similar representation of a shell type transformer also embodying certain features of my invention.

Figure 3 is a detail view of one pair of the core shunt pieces used in the transformer of Figure 2, showing the means for securing them in position, and

Figure 4 is a side view of the parts shown in Figure 3.

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

As conducive to a more thorough understanding of my invention, it may be noted that in the operation of a luminescent sign employing one or more luminescent gas filled tubes high potential electrical energy is required. The desired high potential electrical energy ordinarily 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 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 often is necessary to use a plurality of luminescent tubes. Since the maximum voltage to ground permitted by the Fire Underwriters is approximately seven thousand five hundred volts, and consequently the maximum permissible voltage across any secondary circuit is approximately fifteen thousand volts, tubes whose striking potential is in the neighborhood of fifteen thousand volts may not be connected in a series circuit. Also, due to their different striking potentials and negative load operating characteristics they can not be operated in a parallel circuit. Accordingly, each tube must have its own separate transformer secondary winding. In order to avoid the high costs of transformer equipment and installation which would be incurred in using a separate transformer for each tube, transformers have been designed which have a plurality of secondary windings on one core.

In order that the current flowing through the secondary coil sections of such transformers may not exceed a maximum safe value, the transformers are provided with magnetic by-passes including air gaps of high reluctance through which the major portion of the energizing flux is shunted when current is flowing through the secondary coil sections. These by-passes have, in the past, been formed in a number of different manners. My invention has as one of its objects the provision of shunt paths which are so formed that many advantages are achieved in the manufacture and operation of the transformers in which they are incorporated.

In heretofore known and/or used multiple secondary circuit transformers, the shunt pieces have been formed either as integral parts of a core leg or as parts separate from the main core. Where the shunt pieces are integral parts of a core leg, their manufacture is expensive, because a special die must be used for each transformer having a different current output. Likewise, the manufacture of previously used shunt parts which are separate from the main core, and of transformers in which such parts are incorporated, has been attended with difficulties. This is due to the fact that such parts have been assembled in such a manner that the butt joint formed between the part and the main core was parallel to the flat surfaces of the air gap. Thus, when heavy pres-

sure was applied in order to secure a good butt joint, the length of the air gap was varied enough to make accurate control of the shunt path reluctance difficult, if not impossible. Moreover, a special die was necessary for each shunt part designed for a secondary of different current output. That was true because the part had to be varied in width or length in order to vary the reluctance of the air gap.

It is a further object of my invention, therefore, to provide a multiple secondary circuit transformer whose magnetic shunt parts may be made inexpensively, without requiring a new die for each transformer of different current output and yet which shunt parts will provide magnetic by-passes of the proper reluctance for all transformers of nearly the same rating in which they are used. Moreover, it is my aim to provide a transformer in which the reluctances of the magnetic shunt paths can be accurately controlled.

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 legs **10** and **11** interconnected at their ends by members **12** and **13**. Primary coil section P is mounted on the leg **10** and extends over substantially the entire length of that leg. Secondary coil sections S_1, S_2, S_3 and S_4 are mounted on the leg **11**. The core members are preferably formed of laminated magnetic steel and they are held together by core bands **14** and **15**, which are preferably of magnetic material. The core also includes a T-shaped shunt member **16** abutting the leg **11** at about its midpoint and two L-shaped shunt members **17** and **18** which abut the leg **11** on opposite sides of its midpoint. The secondary coil sections are mounted on the leg **11** in such a manner that a separate magnetic shunt path is formed around each coil section by the T-shaped member **16** and/or one of the L-shaped members **17** and **18**. The L-shaped member **17** extends closely toward but does not abut the leg **12**, forming therewith an air gap G_1 of high magnetic reluctance. Similarly air gaps G_2 and G_3 are formed between the T-shaped member **16** and the L-shaped members **17** and **18** respectively, and air gap G_4 is formed between L-shaped member **18** and the leg **13**. Where the secondary coil sections S_1, S_2, S_3 and S_4 are of like current and voltage ratings, the air gaps G_1, G_2, G_3 and G_4 have equal reluctances. This condition normally obtains where the loads of the coils are substantially equal. On the other hand, where the loads are unequal and the current and voltage demands on the secondary coils vary accordingly the air gaps are adjusted so that the power delivered by each coil section will correspond to the need of its load. The manner of securing the members **16**, **17**, and **18** in place is not shown in Figure 1 but is similar to that which will be described later in connection with Figures 3 and 4. Like the main core members, the shunt members are preferably made of laminated magnetic steel.

The primary coil P is energized through leads **19** and **20** from a suitable source of alternating current electrical energy **21**, such as a standard single-phase 60-cycle source of supply at 110 volts. As the current in the coil P rises and falls between a maximum positive and a maximum negative value in conformity with the alternations of the electromotive force impressed across its terminals, an alternating magnetomotive force is induced in the transformer core. This magnetomotive force causes the rise and fall of a magnetic flux which traverses the core and links the coil sections of the secondary windings.

The coil sections comprising one secondary winding have their one terminals grounded, the grounded terminals preferably being those whose grounding places the coils in series, their other terminals being connected across the load of the winding. With this arrangement, the voltage across the load is approximately double that across the terminals of any one coil section and yet the voltage to ground at no point exceeds the maximum safe value approved by the fire underwriters. Thus the coils S_1 and S_2 have their one terminals grounded to the core at **22** and **23** and their other terminals are connected across a negative load, such as the fluorescent luminous tube T_1 illustrated, by the leads **24** and **25**. Similarly the one terminals of the coils S_3 and S_4 are grounded to the core at **26** and **27** and their other terminals are connected across the terminals of the luminescent tube T_2 by the leads **28** and **29**. The core itself is preferably connected to ground, as at **30**.

The transformer preferably is enclosed in a casing **31** having a cover **32**. A suitable way of supporting the transformer in the casing is by resting it on the bases **33** and **34**, the bases in turn resting on the bottom of the casing. The casing preferably is then filled with an insulating compound to prevent the destructive effects of moisture and ozone on the core and coils.

As the flux induced in the main core by the flow of current in primary coil P rises and falls in value, electromotive forces are induced in the secondary coils. When the potential across the terminals of the tube T_1 is sufficient to ionize the gas therein, a current at once flows through the tube and its winding, which comprises coils S_1 and S_2. The current flowing through coils S_1 and S_2 sets up a magnetomotive force which opposes the coursing of the main flux. Accompanying this back magnetomotive force, a portion of the main flux is diverted around the coils S_1 and S_2 through a magnetic shunt path of high reluctance. Assuming that the flux is coursing in the direction of the arrows, as seen in Figure 1, that is, in a clockwise direction, at the moment under discussion, this shunt path will be from the leg **10** through leg **12**, air gap G_1, L-shaped member **17**, air gap G_2, T-shaped member **16**, leg **11** and leg **13**, back to leg **10** when the tube T_2 is not operating. All the main flux will still link the coil sections S_3 and S_4 at this time. Similarly, when tube T_2 becomes ionized, but tube T_1 has not yet become ionized, the main portion of the main flux will be diverted through a shunt path through leg **10**, leg **12**, leg **11**, T-shaped member **16**, air gap G_3, L-shaped member **18**, air gap G_4, and leg **13**, back to leg **10**. Thus the main flux will still be linking the coil sections S_1 and S_2. When both tubes become ionized, the major portion of the main flux will be diverted through a shunt path comprising leg **10**, leg **12**, air gap G_1, L-shaped member **17**, air gap G_2, T-shaped member **16**, air gap G_3, L-shaped member **18**, air gap G_4, leg **13** and back to leg **10**. Although in the conditions of operation set forth above the major portion of the main flux is by-passed around the secondary winding or windings, enough flux still links the coil sections of the operative winding or windings to maintain a steady flow of current through tubes T_1 and T_2.

It may happen that one secondary winding be-

comes grounded. Such a condition may be caused by the formation of a conductive film of moisture, atmospheric impurities, matted insect bodies, and the like between the terminals of the tube load or between terminals and a grounded part of the system. When such a condition exists, the operation of my transformer will be the same as that obtaining when the load is ionized and conductive while operating normally. Thus, if the tube T_1 is grounded, the current induced in its secondary coil sections S_1 and S_2 will generate a back magnetomotive force opposing the coursing of the main flux and causing it to seek a path of high reluctance through the magnetic shunt path, including leg 12, air gap G_1, member 17, gap G_2, member 16 and leg 11. Excessive current will therefore not be generated in the coil sections S^1 and S_2 and overheating of these coil sections, with consequent destruction of their insulation, will be prevented. The shunt construction provided for the coil sections S_3 and S_4 will likewise protect those coil sections from excessive current, and consequent overheating, if the winding which they form becomes grounded.

Where one winding becomes open-circuited, as for example, by the breakage of the tube or tubes in its load, the other winding will continue to operate normally. Thus, if the tube T_1 becomes broken, no current will flow in the coils S_1 and S_2 comprising its secondary winding. The main flux will continue to link those coils and also the coils S_3 and S_4 until the tube T_2 becomes ionized, as in normal operation. A similar condition will obtain if it is the tube T_2 which breaks, the other tube T_1 continuing to operate normally.

Where one of the coil sections becomes open-circuited, its whole winding will of course be inoperative but the other winding will continue to operate in a normal manner as is more particularly described in the preceding paragraph.

Should one coil, say the coil S_1, become grounded, its winding will be rendered inoperative but no dangerous condition of excessive current flowing through it will exist, and the other winding will continue to operate in a normal manner. The voltage induced in the other coil S_2 will be insufficient to ionize the gas in the tube T_1, hence no current will flow in tube T_1, or the coil S_2. The current in the grounded coil S_1 will not reach an excessive value because a counter magnetomotive force will be generated by that coil as the short-circuit current begins to flow in it. This back magnetomotive force diverts the main flux around the coil S_1 through a shunt path of high reluctance from leg 10 through leg 12, air gap G_1, L-shaped member 17, leg 11, and member 13 back to leg 10. Similarly, individual magnetic shunt paths are provided for each of the other coil sections and prevent an excessive short-circuit current from flowing in them should they become grounded. In fact, in my transformer the short-circuit current is about the same as the normal load current.

It will be understood that the operation of my transformer under the various conditions enumerated above will be the same during the other half cycle of the impressed electromotive force. The flux will then be coursing in a direction opposite to that indicated by the arrows, but the paths it follows will be identical for the same condition of operation. Due to persistence of vision, the luminescent tubes, which are rendered ionized and luminous 120 times a second where a 60 cycle source of electromotive force is used, will appear to be continually lighted.

From an inspection of Figure 1, it will be apparent that it is a very simple matter to vary the lengths of the air gaps. The legs 12 and 13 and the members 16, 17, and 18 can be moved either to the right or to the left a sufficient amount to vary the reluctances of the air gaps G_1, G_2, G_3, and G_4 as desired. Because of this, it is not necessary that members 16, 17 and 18 be made to different sizes for transformers of different ratings. For this reason, different dies are not needed for manufacturing the shunt parts for different transformers and thus an item of expense in manufacture is eliminated.

It will further be observed that in forming a tight butt joint between the members 16, 17, and 18 and the leg 11, the reluctance of the air gaps G_1, G_2, G_3 and G_4 is not varied since the force exerted to move the shunt members firmly against leg 11 is applied in a direction parallel to the surfaces of the air gap faces. The force used for this purpose is ordinarily between ten and forty tons and is necessary to crush the burrs of the laminations, the small imperfections due to cutting and dirt particles on the joint surface. Where the ordinary type of shunt part is used, the length of the air gap is frequently varied as much as 0.005 inch and its reluctance is changed accordingly. In practical construction and operation this constancy of air-gap in spite of differences in securing the shunt members is an exceedingly important factor. It assures controlled operation of the transformer.

My transformer has also many advantages in operation. A shunt path is provided for each secondary coil section, so that danger of overheating any coil section is avoided. Flexibility is thus achieved since any grouping of secondary coil sections is possible without danger of overheating. A high degree of efficiency is achieved since the flux by-passed around each secondary coil when there is current flowing through it nevertheless continues to link the as yet unoperated coil sections.

It will be understood that my transformer is capable of being modified in various ways. Thus, where the load of each secondary winding is grounded at its mid-point, the coil sections may be connected in opposition, a complete circuit being formed between each half of the load and the corresponding coil section. With such a connection, the grounding or open-circuiting of one coil section or of the half of the load corresponding to one coil section will not render the other coil section and its half of the load inoperative. With the coils connected in opposition, however, the maximum potential difference available for energizing a load is about seven thousand five hundred volts. Only tubes which are half or less than half the size of the largest tubes energizable by a series circuit can be used in such a circuit.

Also, as has been previously indicated, the coil sections may be connected in any grouping. Thus coil S_1 may be grouped with coil S_4 and coils S_2 and S_3 may be united to form the two secondary windings. It is also possible to form one winding of the coils S_1 and S_3 and the other of coils S_2 and S_4. A still further possibility is to have each coil constitute a complete and separate winding.

It is to be understood that my invention is not limited to a transformer having two secondary windings but may have only one or more than two windings, up to a reasonable number.

Where tube loads and coil sections of different voltage ratings are employed, the corresponding

air-gaps are adjusted to vary the reluctance of the shunt paths in accordance with the relative operating voltages of the various secondary coils. Thus, if the tube T_1 has a higher voltage rating than the tube T_2, the series-connected coil sections S_1 and S_2 will have a greater number of turns than the coil sections S_3 and S_4 and will operate at correspondingly higher voltages. In order that sufficient voltage may be induced in coil sections S_1 and S_2 to maintain the tube T_1 in an ionized condition after it has struck and current is flowing through the circuit, the air gaps G_1 and G_2 are adjusted so as to have a higher reluctance than the gaps G_3 and G_4. As has already been indicated, this is merely a matter of changing the relative positions of leg 12 and shunt members 17 and 16 to increase the lengths of air-gaps.

Considering now another embodiment of my invention, attention is directed to Figure 2 in which I have shown a shell type transformer embodying my invention. The transformer comprises a core with primary and secondary windings mounted on the core. The core comprises outer legs 35 and 36 and a centrally disposed core leg 37 parallel to the outer legs. Between the ends of the leg 35 and the ends of leg 37 are interposed short bars 38 and 39. Likewise, short bars 40 and 41 are positioned between the ends of leg 36 and the ends of leg 37. The parts are held in firmly abutting relationship by the core bands 43 and 42. The core preferably is grounded as at 44. Magnetic shunt paths of high reluctance are formed by the L-shaped members 45—46, 47—48, 49—50, 51—52, 53—54, and 55—56, which are so disposed as to abut the central core leg 37 at their one ends. Each L-shaped member extends around a secondary coil section and forms an air-gap with one of the short bars 38, 39, 40, and 41 or with the adjacent L-shaped member. The air-gaps so formed are indicated by the reference characters G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{11} and G_{12}, as shown in the drawings.

The members 45 and 47 may be placed in back to back relationship with a space A separating them, as shown, or if desired, they may be made in one T-shaped integral piece, or the member 45 may be turned around so that its tip will form an air gap with member 47. Likewise, the members 46 and 48 may be in back to back relationship and separated by a space B, as illustrated, or they may be integral, or member 46 may be turned around. Illustratively, the magnetic shunt pieces are secured to the central core leg 37 to insure silent operation in the manner shown in Figures 3 and 4. The shunt parts 55 and 56 illustrated are enclosed in a metal clamp 67, and insulating pad 68 being interposed between the clamp and the shunt parts. The clamp has two ears 69 and 70 drilled to receive a bolt 71. Washers 73 and 74 insulate the bolt head and the nut 72 from the ears 69 and 70. The nut 72 is turned until the clamp 67 holds the parts firmly together. It will be understood that any other suitable manner of securing the shunt parts to the core may be employed, the one shown being merely illustrative.

The primary winding consists of two elongated coil sections P_1 and P_2 connected in series by a lead 57 and mounted on the legs 35 and 36 respectively. These primary coils are energized from a source of alternating current electrical energy 58, such as a standard 110-volt 60-cycle source. through leads 59 and 60. The construction noted is compact and assures excellent transference of heat produced under operating conditions. Where desired, P_1 and P_2 may be connected in parallel.

Three secondary windings are formed by the coil sections S_1, S_2, S_3, S_4, S_5, and S_6, all of which are mounted on the central leg 37. Coils S_1 and S_2 connected together in series form one winding energizing the tube T_1 through leads 61 and 62. A second winding is formed by serially-connected coils S_3 and S_4 and energizes tube T_2 through leads 63 and 64. The third winding comprises series-connected coils S_5 and S_6 and energizes tube T_3 through leads 65 and 66. The secondary coils are preferably grounded at their interconnections. Where the load of a winding is grounded at its midpoint, however, the coils may be connected in opposition, a complete circuit than being formed including each half of the tube load and the corresponding secondary coil.

When the transformer is used indoors, it need not be enclosed in a casing. In outdoor use, however, a casing is necessary. For the sake of clarity in the drawing, none is shown in Figure 2, but a casing similar to the one shown in Figure 1 may be used where desired.

The operation of this transformer is similar to the operation of the transformer of Figure 1 which has already been described, with the exception that two main magnetic paths are provided and there are two magnetic shunt paths associated with each secondary coil section. Thus, assuming that the flux is coursing in the direction of the arrows, it will consist of two parts going from the legs 35 and 36 respectively, through the bars 38 and 40 respectively, into the central leg 37, where the two parts unite and link the secondary coils. At the right hand end of the member 37 the flux separates into two parts again, traversing the bars 39 and 41, respectively, and returning to the legs 35 and 36 respectively. In normal operation, as the tube T_1 becomes ionized and conductive due to the rising of the electromotive force induced in its secondary winding coil sections S_1 and S_2 under excitation of the primary winding by the potential impressed across its terminals, a counter magnetomotive force is generated by the current flowing in the coils S_1 and S_2. This forces the major portion of the main magnetic flux to seek a path of less reluctance. Two such paths are provided, from the leg 35 through bar 38, air-gap G_1, L-shaped member 45, leg 37, member 47, air-gap G_3, member 49, member 37, and bar 39, back to leg 35, and from leg 36 through bar 40, air-gap G_2, member 46, leg 37, member 48, air-gap G_4, member 50, member 37, and bar 41 back to leg 36. The flux at this time continues to link the other coil sections S_3, S_4, S_5, and S_6, but passes around the coils S_1 and S_2 as outlined above, so that an excessive current does not flow in those coils. Similarly, the coil sections comprising the other windings will be by-passed when their loads are operating. Should all the loads be operative at the same time, the major portion of the main flux will pass through two paths of high reluctance excluding the member 37 and including all the L-shaped shunt members and their associated air-gaps.

As explained more fully in connection with Figure 1, safe operation of the transformer will be assured under conditions of grounding or open-circuiting of a whole secondary winding or of one coil section of that winding.

As in the transformer shown in Figure 1, the shunt parts in the embodiment of Figure 2 need not be of a different size for each transformer which varies slightly in current output. The reluctance of the shunt paths readily can be varied simply by moving the parts to the left or right as shown in Figure 2. Thus, a special die is not necessary to make shunt parts for different transformers, and the expense of their production is minimized. An accurate adjustment of the reluctance of each shunt path is possible because, in tightening the butt joint between the shunt part and the main core member 37, any change of position of the shunt part will not vary the length and reluctance of the air-gap. Instead, such movement of the shunt part will be in a direction parallel to the surfaces of the air-gap. A further advantage of this transformer is that it can be assembled with facility. It is a simple matter to mount the various secondary coil sections and shunt pieces in their proper positions on the central leg 37 as a first step and then assemble the other parts about the leg 37.

Although I have illustrated a transformer having three secondary circuits, it is to be understood that any other number of circuits may be provided. Any number of secondary coil sections may be mounted on the core from one up to any reasonable number.

It will be seen that there has been provided in my invention a system and apparatus for the illumination of luminous tubes or for the operation of other negative loads in which the various objects hereinbefore set forth, together with many practical advantages, are successfully achieved. The apparatus includes simple parts which are inexpensively manufactured and which may be accurately assembled with a minimum of difficulty. The construction is compact. Extraneous magnetic flux leakage is low. Heat dissipation is high. Operation of the apparatus is characterized by safety, flexibility and efficiency.

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 drawings, is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A constant current transformer comprising, in combination, a main magnetic core having two leg portions, a primary winding mounted on one leg portion, two or more secondary windings mounted on the other leg portion, and shunt core portions spaced between coil sections and cooperating therewith, said shunt core portions comprising a T-shaped magnetic shunt core portion and two or more L-shaped magnetic shunt core portions abutting said main core portion at their one ends and forming air-gaps of high reluctance at their other ends with each other and with said core, the surfaces of said air-gaps being perpendicular to the joints between said main core portion and said shunt core portions.

2. In electrical transformer apparatus of the character described, in combination, a primary winding, one or more secondary windings each comprising two coil sections, a core interlinking said primary winding and secondary coil sections and including interiorly thereof L-shaped portions which form a magnetic circuit of high reluctance around each of said secondary coil sections, and individual clamping means for the one ends of each of said L-shaped portions, maintaining the same in abutting relation with a portion of the core, at least one of said shunt core portions forming at its other end air gaps with a portion of the core and with another shunt core portion to provide a series shunt path around a pair of secondary coil sections as a group for the main portion of the magnetic flux.

3. In electrical transformer apparatus of the character described, in combination, a core type transformer core; an elongated primary winding mounted on one leg of said core; one or more secondary windings mounted on the opposite leg of said core, each of said secondary windings comprising two coil sections having their one terminals grounded to place said coil sections in series; and L- and T-shaped magnetic shunt parts, abutting a portion of the core and spaced between adjacent secondary coil sections and extending substantially but not completely around said coil sections, thereby forming magnetic shunt paths of high reluctance which exclude the coil sections when they are operating under closed-circuit or short-circuit conditions.

4. A constant current transformer comprising, in combination, a main magnetic core portion, a primary winding mounted on said core portion, a plurality of secondary coil sections mounted on said core portion, a plurality of magnetic shunt core portions located interiorly of the main magnetic core and between said primary and secondary coil sections and abutting said main core portion at their one ends and forming individual shunt paths around said coil sections, said shunt core portions forming with their other ends a series magnetic path with included air-gaps to shunt the principal portion of the magnetic flux around the secondary coil sections as a group.

5. A constant current transformer comprising, in combination, a main magnetic core portion, a primary winding mounted on said core portion, a plurality of secondary coil sections mounted on said core portion having their one terminals grounded, a magnetic shunt portion abutting the main magnetic core and extending inwardly of the main magnetic core and around at least one of the secondary coil sections and forming a shunt path around said section with an included air-gap, and at least one other magnetic shunt portion abutting the main magnetic core and extending inwardly of the main magnetic core and around another secondary coil section and forming with the first-mentioned shunt core portion and the main magnetic core a magnetic path with two included air-gaps to shunt the principal portion of the magnetic flux around both coil sections and thereby regulate the current of the two secondary coil sections as a group.

CHARLES PHILIPPE BOUCHER.