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ELECTRICAL TRANSFORMER APPARATUS

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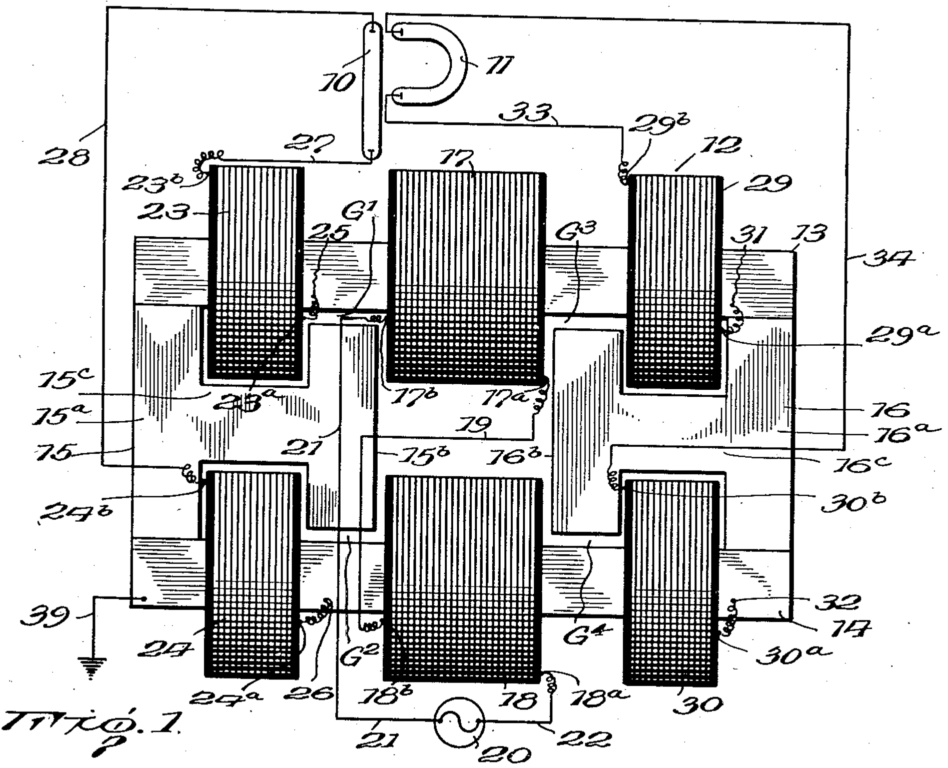

Fig. 1.

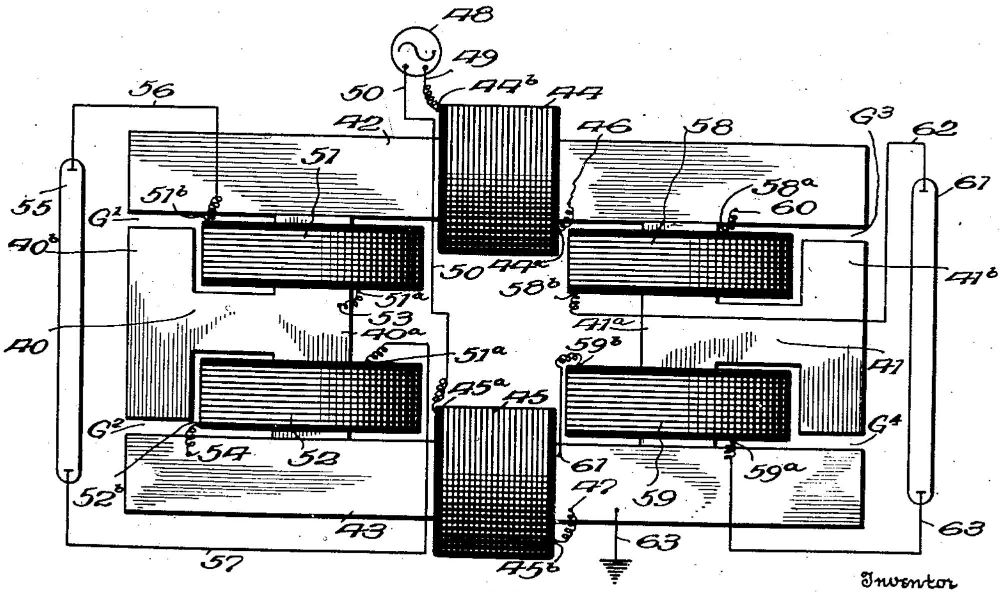

Fig. 2.

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ELECTRICAL TRANSFORMER APPARATUS

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5 Claims. (Cl. 171—119)

This application is a division of my co-pending application Serial No. 41,476 filed September 20, 1935, and entitled Electrical transformer apparatus, and the invention relates to electrical transformer apparatus and more particularly to electrical transformer apparatus having a high leakage reactance under instantaneously applied loads as employed in the operation of a luminescent tube system.

One of the objects of my invention is to provide simple, practical and thoroughly reliable transformer apparatus for the operation of a maximum length of luminescent tube with a minimum expense of transformer investment and installation charge.

Another object is the provision of compact, inexpensive and highly efficient transformer apparatus of the character indicated which is peculiarly adapted to withstand the varying conditions encountered in actual practical use, including short-circuiting and grounding of the whole or the parts of the apparatus, without damage to the apparatus and the consequent necessity for shut-down, replacement and/or repairs.

Another object of my invention is the provision of transformer apparatus of the character described which lends itself to rapid, efficient and economical production employing a minimum of different parts and requiring a minimum of skill in construction, installation and repair.

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, the scope of the application of which is indicated in the following claims.

In the accompanying drawing Figure 1 is a diagrammatic representation of my transformer apparatus as employed in the operation of two luminescent tubes, and

Figure 2 is a diagrammatic representation of a modified form of my transformer apparatus.

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 which is approximately the maximum value permitted by the fire underwriters.

In the operation of a single sign or luminous display, it is frequently necessary to use a plurality of luminescent tubes and energize these tubes by way of a corresponding plurality of transformers in order that the energizing potential may not reach values in excess of those specified by the underwriters. 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 the cost of equipment excessively high but the separate charges made for connecting each transformer to the alternating-current source of supply results in an objectionably high labor charge.

In heretofore known and/or used transformers designed for operating a luminescent sign or display, these objections are alleviated somewhat by constructing the secondary winding of the transformer in two coil sections connected together, each wound to give a maximum potential of about seven thousand five hundred volts, and grounding the interconnection between coil sections. In this manner the potential applied across the terminals of a tube may amount to fifteen thousand volts, for example, while the potential to ground never exceeds seven thousand five hundred volts. In even the moderately large luminescent signs several of these transformers are required in order to energize the complete display.

One of the outstanding objects of my invention is the provision of transformer apparatus which further alleviates these difficulties giving a single, compact, inexpensive unit requiring but a single connection to the source of supply and yet giving efficient and thoroughly reliable operation of a luminescent tube display or sign.

It may be noted further that in the operation of a luminescent tube system of the character indicated the system is subjected to a wide variety of weather conditions, including fog, rain, sleet, hail and ice in the presence of dirt, grit, mild sulphur bearing agents in industrial centers and salty agents near the seashore. In addition, such a luminescent tube system and apparatus is subjected to a certain amount of shock and vibration. Furthermore the luminescent tubes, being mounted in exposed positions, are subject to masses of insects packing themselves around the tube electrodes and in between the electrodes and the supporting structure thus providing a conductive path around a tube.

Under these conditions of operation the luminescent tubes frequently become short-circuited from terminal to terminal, or from terminal to ground, by way of a conductive film of dirt and moisture of an acid or salty character extending from tube to support or by way of the mass of insects packed about a tube terminal or electrode.

Under the conditions of short-circuit certain of the heretofore known and/or used transformer apparatus, unless specially designed to accommodate an excess current, is inclined to excessive heating resulting in the ultimate charring and burning of insulation and the destruction of the transformer apparatus necessitating shut-down, replacement and/or repair. This situation is especially prevalent in certain heretofore known and/or used transformer apparatus having the high potential secondary winding grounded at a mid-point. When a luminescent tube energized by such transformer apparatus gets but one terminal grounded as indicated above, excessive current is inclined to flow in one half of the secondary winding while no current flows in the other half of the winding. The flow of excessive current damages the winding unless the transformer is initially designed to carry this heavy current, this design, of course, requiring larger and heavier coils at considerable increased expense.

Accordingly, another of the outstanding objects of my invention is the provision of transformer apparatus which is inexpensive in construction, employing windings of minimum necessary current-carrying capacity at minimum cost, and yet which is of such construction as to reliably withstand the many varying conditions encountered in actual practical use.

Referring now more particularly to the practice of my invention, attention is directed to Figure 1 of the drawing wherein, illustratively, two luminescent gas filled tubes 10 and 11 comprising a single luminous display in the form of the letter P are supplied with high potential alternating-current electrical energy from transformer apparatus generally indicated at 12, which in turn is energized in a manner more particularly described hereinafter.

In order that a maximum length of luminescent tubing may be energized by a minimum investment of transformer apparatus, the apparatus 12 preferably comprises what is essentially a double transformer having two separate high potential output circuits and a single low potential input circuit. Transformer 12 consists of a laminated iron core structure comprising linear parallel members 13 and 14 with closing H-shaped members 15 and 16. The H-shaped members are provided with the long leg portions 15*a* and 16*a* which abut linear core members 13 and 14, preferably at the extreme ends thereof. The H-shaped members are also provided with short leg portions 15*b* and 16*b* positioned in the same plane with linear core members 13 and 14 and tend to abut these members at points intermediate their ends. As the result of the foreshortening of the leg portions 15*b* and 16*b* of the two H-shaped members, air-gaps G1 and G2 are provided between 15*b* of the H-shaped member 15 and the respective linear core members 13 and 14 and similar air-gaps G3 and G4 are provided between leg 15*b* of the H-shaped member 16 and the respective linear members 13 and 14. Air-gaps G1 and G2 are approximately equal in length and air-gaps G3 and G4 are also about equal in length. Such construction assures paths of equal reluctance through each H-shaped core member. While there is no necessary relation between the lengths of air-gaps G1 and G3, for example, and between G2 and G4, these gaps are usually approximately equal because of the substantially equal ratings of the two luminescent tubes 10 and 11.

It is to be noted that a long magnetic path of very low reluctance is provided between the full lengths of the linear core members 13 and 14 and the long legs 15*a* and 16*a* of the two H-shaped members. A short magnetic path of high reluctance is provided by a somewhat reduced length of linear members 13 and 14 and either one of the short core legs 15*b* and 16*b* of the two H-shaped members and the air-gaps G1 and G2, or G3 and G4, respectively included therewith. A number of magnetic paths of intermediate lengths and intermediate reluctances are each provided by a slightly reduced length of one of the linear core members 13 and 14 and the one half of the long leg portions of the H-shaped core members 15 and 16 and the opposite half of the short leg portions of these members including a single air-gap.

Positioned on the linear core members 13 and 14 is a primary winding preferably comprising two coil sections. Conveniently, one coil section 17 is positioned on core member 13 near the middle thereof while the other coil section 18 is mounted on core member 14 near its middle. The one terminals 17*a* and 18*b* of these coil sections are interconnected by a conductor 19, placing the coil sections in a series-aiding magnetic relationship. The other terminals 17*b* and 18*a* of these coil sections are connected to a single phase source of alternating-current electrical energy 20 by way of conductors 21 and 22, respectively.

One complete secondary winding comprising two coil sections is positioned on the transformer core with these coil sections, 23 and 24, preferably mounted on linear core members 13 and 14, respectively, near the left ends thereof as seen in the drawing, the coil sections linking the core through the spaces provided between these core members and the upper and lower U-shaped parts of the H-shaped core member 15, these parts, of themselves, largely linking the coil sections. The coil sections 23 and 24 are placed in series relationship by grounding their one coil terminals 23*a* and 24*a* to the core as at 25 and 26, respectively. The other terminals of the coils, 23*b* and 24*b*, representing the output terminals of secondary winding 23—24, supply high potential alternating-current electrical energy to luminescent tube 10 by way of the respective conductors 27 and 28.

Similarly, another complete secondary winding consists of the two coil sections, 29 and 30, respectively mounted on the right ends of linear core members 13 and 14 and linking these core members through the spaces provided between these members and the upper and lower U-shaped parts of the H-shaped core member 16, these parts largely linking the coil sections. The coil sections 29 and 30 are placed in series relationship by grounding their one terminals 29*a* and 30*a* to the core as at 31 and 32, respectively. The other terminals 29*b* and 30*b*, comprising the output terminals of the complete secondary winding 29—30, supply high potential electrical energy to luminous tube 11 by way of conductors 33 and 34, respectively.

In order that the potential of no coil section may reach an excessively high value to ground the core 13—15—14—16 is preferably connected to ground as generally indicated at 39. Because of the grounding of their one terminals to the grounded core the output terminals of the various high potential secondary winding coil sections are limited to a value of potential to ground which is equal to the output potential of the one coil section to which the terminal is connected. In no case may the potential to ground amount to that of a complete secondary winding. This construction gives a direct saving in insulation costs and maintains the possible value of potential to ground within safe limits and yet permits a desired high value across the output terminals of the transformer apparatus.

The coil sections 23 and 24 comprising one secondary winding are of like current and voltage ratings, while the coil sections 29 and 30 comprising the other secondary winding are also of like ratings in order to give balanced operation as appears more fully hereinafter. The ratings of coil sections 23 and 24 are dependent upon that of luminescent tube 10 which they are designed to operate, while the ratings of coil sections 29 and 30 are dependent upon that of tube 11. There is no relation between the ratings of the two secondary windings, that is, for example, between coil 23 taken from the one secondary winding and the coil section 29 taken from the other winding, or between 24 and 30, although in general these various coil sections are of approximately the same ratings.

Ordinarily, in the design of a luminescent sign or display, the complete display is made up of a number of individual luminescent tubes or series of tubes of various configurations which are as near the same total length as is conveniently practicable. In energizing two tubes comprising a part of such a display the secondary windings of my transformer apparatus are preferably of about the same voltage rating as a matter of convenience in production of the apparatus, although better results in operation are achieved where the ratings of the secondary windings conform exactly to the ratings of the individual luminescent tubes which they are intended to operate.

It is to be noted at this point that my transformer apparatus is exceedingly compact and rugged in construction. The various secondary winding coil sections snugly fit within the spaces provided for them by the opposite U-shaped openings in the H-shaped core members. Similarly, the two coil sections comprising the primary winding snugly fit within the space provided between the short leg portions of the H-shaped members. With this construction a minimum amount of iron is required in the core, thus effecting a very real and direct economy. Furthermore, with this construction the overall dimensions of the transformer apparatus is reduced to a minimum. The cost of the enclosure for the transformer apparatus and the packing and shipping costs incident to the transportation of a large number of the units is thus effectively minimized.

In the operation of two luminescent tubes with my transformer apparatus, as alternating-current electrical energy is supplied the primary winding 17—18, a magnetomotive force is developed causing a magnetic flux to course around the transformer core path of lowest reluctance as indicated above. This path is through linear core member 13, the long leg of the H-shaped member 15, linear member 14, the long leg of the H-shaped member 16 and back through member 13, where the magnetomotive force, resulting from a flow of current in the primary winding, acts in a counter-clockwise direction. Upon a reversal of the magnetomotive force, as a result of the current supplied the winding being reversed in direction as the source of supply passes through its cycle of alternations, the magnetic flux courses through the core of the transformer apparatus in a clockwise direction, that is, through linear core member 13, the long leg 16a of H-shaped member 16, linear core member 14 and the long leg 15a of H-shaped member 15 and back to member 13. 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 short legs 15b and 16b of the two H-shaped core members.

As the magnetic flux acting under the impulse of the magnetomotive force created by the flow of exciting current in primary winding 17—18 courses through the transformer core, first in a counter-clockwise direction and then in a clockwise direction, rising to a maximum and falling to zero in each of these directions, electromotive forces are induced in the transformer secondary coil sections 23 and 24 comprising one secondary winding as well as in the coil sections 29 and 30 comprising the other secondary winding. These electromotive forces are inclined to rise to peak values in a positive direction, fall to zero and rise to peak values in a negative direction, then to zero, sixty times every second corresponding to the alternations in the exciting current and the magnetic flux.

Coil sections 23 and 24 as indicated above are placed in series on the transformer core so that as the electromotive force induced in coil 23, for example, is rising to a maximum value in a positive direction the electromotive force induced in coil 24 is rising to a maximum in a negative direction. The value of the potential difference appearing across the output terminals of the secondary winding 23—24 is therefore equal to the difference between the values of the electromotive forces induced in the individual coils 23 and 24 with respect to their ground connections.

Similarly, as the electromotive force induced in coil section 29 tends to rise to a maximum in a positive direction with respect to ground, the electromotive force induced in coil section 30 tends to rise to a maximum in a negative direction. As a result of coil sections 29 and 30 being placed in series the potential difference appearing across the output terminals of the secondary winding 29—30 is equal to the difference between the values of the electromotive forces induced in each coil.

It is to be noted that as the potential is rising to a maximum in coil 23, for example, it is also rising to a maximum in coil 29 so that the potential difference between the output terminals of these coils is substantially negligible where coils of the same rating are employed. Similarly, as the potential of coil 24 with respect to ground rises to a maximum in a negative direction the potential of coil 30 likewise rises to a maximum in the negative direction so that the potential difference appearing across the output terminals of these coils is substantially negligible.

As the potential difference appearing across the output terminals of secondary winding 23—24 increases, either as a result of the electromotive force of positive potential being induced in coil

23 and one of negative potential being induced in coil 24, or vice versa, a value is soon reached which is sufficient to establish an ionized condition in the gas column present in luminescent tube 10.

A luminescent gas filled tube of the character indicated is non-conductive and non-luminous until a sufficiently high potential is applied across its terminals. When this value is reached the gas present in the tube suddenly becomes ionized and electrically conductive, the gas giving forth a luminous glow.

The flow of excessive current in secondary winding 23—24 upon the sudden rendering of tube 10 electrically conductive (the tube being essentially non-conductive in the un-ionized condition as indicated) is effectively prevented by a sudden change in the coursing of magnetic flux through the transformer core and interlinking the primary and secondary windings. As a current begins to flow in secondary coils 23 and 24 comprising the secondary winding, back magnetomotive forces are produced which buck the magnetomotive forces established by a flow of current in primary winding 17—18 with the result that the major portion of the magnetic flux coursing through the core passes along a shunt path of high reluctance across air-gaps G1 and G2 and the short leg 15*b* of the H-shaped core member. The portion of the total magnetic flux which courses through the linear core members 13 and 14 and the long leg 15*a* of the H-shaped member is adequate, however, to induce electromotive forces in coil sections 23 and 24 sufficient to maintain a current flowing through the tube 10 in its ionized condition.

Any coursing of the magnetic flux across the bar portion 15*c* of the H-shaped core member is effectively prevented by the balance reluctance of either path across this portion because of the equivalence of the air-gaps and by a balance of the magnetomotive forces tending to send the magnetic flux through this portion of the member. Inasmuch as the coil sections 23 and 24 are of identical ratings (they have the same number of turns of wire) and have 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 tube 10 persists until the potential output of secondary winding 23—24 falls to a value insufficient to maintain the ionized condition of the tube as a result of a falling of the electromotive forces induced in coil sections 23 and 24 by virtue of the changing magnetic flux in the transformer core caused by the source of alternating-current supply continuing through its cycle of alternations. At this time the tube becomes suddenly un-ionized and non-conductive and current ceases to flow in the secondary winding and the back magnetomotive forces suddenly fall to zero. The magnetic flux tends to course through linear core members 13 and 14 and the long leg of H-shaped section 15 through the path of low reluctance. Because of the comparatively high reluctance of the magnetic path through the air-gaps G1 and G2 substantially no flux appears in the short leg 15*b* of the H-shaped core member 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 windings, the electromotive forces induced in the coil sections comprising the transformer secondary winding 23—24 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 again reach a value sufficient to establish an ionized condition. The gas column present in tube 10 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 the major portion of the magnetic flux to flow along the shunt path of high reluctance across air-gaps G1 and G2 and the short leg of H-shaped core member 15.

Since the output potential of the transformer secondary winding 23—24 reaches a maximum twice for each cycle of the source of alternating-current electrical energy, the tube 10 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. 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.

It will, of course, be understood that luminescent tube 11 operates in a manner exactly similar to that of tube 10 in accordance with variations in the output potentials of the secondary winding 29—30 and its related magnetic circuit including linear core members 13 and 14 and the H-shaped core member 16 with its short leg 16*b* providing a shunt path of high reluctance around this winding.

Where, by chance, a short-circuit occurs across the output terminals of the transformer secondary winding 23—24 as a result, for example, of the establishment of a conductive film of dirt along the outside of the tube 10, current begins to flow in coil sections 23 and 24 as the induced electromotive force rises from a zero value. The back magnetomotive forces created by this flow of current in these coil sections causes the main body of magnetic flux to course through the shunt path of high reluctance including the short leg of core member 15 and the associated air-gaps G1 and G2. That portion of the magnetic flux which courses through the linear core members 13 and 14 and the long leg of core member 15, thereby interlinking the primary and secondary windings, is insufficient to induce such electromotive forces in coil sections 23 and 24 as to cause an excessive flow of current through these coil sections. The value of the current flowing under short-circuited conditions is substantially the same as that flowing during the conductive period of the luminescent tube. Neither is sufficient to cause substantial heating and consequent damage to the winding.

Where only one of the secondary winding coil sections becomes grounded in operation, for example 23, the current immediately begins to flow in this coil section as soon as the induced electromotive force begins to rise from the assumed zero value. Corresponding to this flow of current a back magnetomotive force is created which opposes the normal coursing of magnetic flux through linear core member 13 and the long leg of H-shaped member 15. In the coil section 24, however, no current flows as the electromotive force induced in this coil 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 only 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 24, the coil creates no back magnetomotive force to oppose the normal coursing of magnetic flux through linear core 14 and the long leg of H-shaped core member 15.

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 short-circuit, as indicated above, the current flowing through coil section 23 would tend to rise to an excessive value but for the peculiar construction of the transformer core. Under the assumed conditions of the grounding of coil 23 and the open-circuit operation of coil 24, a large portion of the magnetic flux is shunted around coil 23 by way of the H-shaped core section 15, the magnetic flux passing from linear core member 13 across the single gap G1 down through the upper part of the short leg 15*b* of the H-shaped member, then across this member by way of the bar portion 15*c* and down through the lower part of the long core leg 15*a* to linear core member 14; thus passing between coil sections 23 and 24 including and linking the one coil 24 operating under open-circuit conditions but excluding the other coil section 23 operating under short-circuit conditions.

The reluctance of this magnetic path is intermediate the reluctances of the long path of low reluctance including both secondary winding coil sections and the short path of high reluctance across two air-gaps excluding both coil sections. The total reluctance of the two shunt magnetic paths is largely made up of the reluctance of the one or two air-gaps serially included therein. The shunt path then under the assumed conditions of short-circuit operation of coil 23 and open-circuit operation of coil 24 includes the one air-gap 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 a path including two air-gaps.

The halving of the reluctance of the shunt magnetic path corresponding to the halving of the back magnetomotive forces created by the flow of current in the secondary winding prevents the current flowing in the grounded coil section from rising to the excessive values which otherwise would be reached. 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 coil 24, for example, is operating under short-circuit conditions and coil 23 is operating under open-circuit conditions the magnetic path of intermediate reluctance includes the linear core member 13, the upper part of the long leg portion 15*a* of H-shaped member 15, the bar portion 15*c*, the lower part of the short leg 15*b* of this member, the air-gap G2 and linear core member 14, the major portion of the magnetic flux coursing between coils 23 and 24 thus including the coil 23 and excluding coil 24. Under these conditions of operation the remaining portion of the total magnetic flux, or that portion which includes the short-circuited coil section 24, is insufficient to induce an electromotive force in this coil section which is great enough to cause an excessive short-circuit current.

Furthermore, it will be understood that in the operation of the luminescent tube 11 that portion of my transformer apparatus including secondary winding 29—30 and the interlinking core 13—16—14 operates in a manner similar to that portion including secondary winding 23—24 and interlinking core 13—15—14 more particularly discussed above. Thus, under normal operating conditions of tube 11 the total magnetic flux courses along the path of low reluctance including and interlinking coil sections 29 and 30 during those brief periods of time when the tube is in an un-ionized non-conductive condition and then, for the most part, along the shunt path of high reluctance excluding both of these coil sections during the ionized conductive condition of the tube. Under possible short-circuit operating conditions, the major portion of the magnetic flux courses along the short path of high reluctance excluding coil sections 29 and 30, thereby preventing the flow of an excess current in these coil sections.

Similarly, under the possible operating conditions of one coil section being grounded and the other being substantially open-circuited, the major portion of the magnetic flux courses along a path of intermediate magnetic reluctance, including core members 13 and 14 and the H-shaped member 16, and passes between the coil sections 29 and 30 by way of the bar portion 16*c* of the H-shaped member and across one of the air-gaps G3 and G4 including and interlinking the coil section operating under open-circuit conditions but excluding and passing around the short-circuited coil section to effect a limitation in the amount of magnetic flux linking the short-circuited coil section, and thereby preventing the rise of current in this section from reaching an excessive value.

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 10 and 11 and the possibilities attending this operation are treated separately, each without special regard to the operating 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 those 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 linear core members 13 and 14 and the long leg portions of the H-shaped members 15 and 16 effecting the closure of the magnetic circuit. During those periods when tubes 10 and 11 are in their conductive conditions, the major portion of the magnetic flux courses along the shortest possible magnetic path which includes only the middle portions of linear core members 13 and 14 and the short leg portions of H-shaped core members 15 and 16 and the included air-gaps G1 and G2, and G3 and G4, 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 magnetix 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 non-conductive periods of the tube. 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 above.

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.

Where desired the highly beneficial operating characteristics of my transformer apparatus are achieved by modifying the construction of the apparatus as by mounting the secondary winding coil sections on the long leg portions of the H-shaped core members and, further, by positioning these H-shaped members with respect to the linear parallel members so that the long leg portions of H-shaped members are intermediate the ends of the parallel members and the short legs of the H-shaped members are inclined to abut the ends of the linear members, being separated therefrom only by the desired air-gaps.

Thus referring to Figure 2 of the drawing, the H-shaped members **40** and **41** are assembled with respect to the linear parallel core members **42** and **43** with their long leg portions **40***a* and **41***a* abutting the core members **42** and **43** intermediate their ends. The short leg portions **40***b* and **41***b* of the H-shaped members are positioned adjacent the ends of the linear core members forming therebetween the air-gaps **G1** and **G2** for the one short leg and the air-gaps **G3** and **G4** for the other short leg. The air-gaps **G1** and **G2**, as well as the air-gaps **G3** and **G4**, are substantially equal in length.

Mounted on linear core members **42** and **43** are the respective primary coil sections **44** and **45** comprising the primary winding with their one terminals **44***a* and **45***b* connected together, as by being grounded to the core as indicated at **46** and **47** respectively, placing the coils in a series-aiding relationship, and with their other terminals **44***b* and **45***a* connected to a source of alternating-current electrical energy **48** by way of the respective conductors **49** and **50**.

The secondary winding coil sections **51** and **52** comprising one secondary winding are mounted on opposite ends of the long leg portion **40***a* of H-shaped core member **40**, the coil sections linking the main magnetic circuit through the spaces provided between opposite halves of the H-shaped member and the adjoining linear core members. It is to be noted that the opposite halves of the H-shaped member, of themselves, largely link the coil sections. The one terminals **51***a* and **52***b* are grounded to the core as at **53** and **54** (the core itself is connected to ground as generally indicated at **63**) placing the coils in series, while the other terminals **51***b* and **52***a* supply high potential electrical energy to luminescent tube **55** by way of the respective conductors **56** and **57**.

Similarly, the secondary winding coil sections **58** and **59** comprising the second secondary winding are mounted on opposite ends of the long leg **41***a* of the H-shaped core member **41**. These coil sections link the main magnetic circuit through the spaces provided between the opposite portions of the H-shaped core member and the adjoining linear members, the opposite portions of the H-shaped member largely linking the coil sections. The one terminals **58***a* and **59***b* are grounded to the core as at **60** and **61**, placing the coil sections in series. The other terminals **58***b* and **59***a* of these coil sections supply high potential electrical energy to luminescent tube **61** by way of conductors **62** and **63**.

In the operation of my modified transformer apparatus, during those periods where luminescent tubes **55** and **61** are in their un-ionized non-conductive states, the magnetic flux interlinking the primary and secondary windings courses along the short path of low reluctance including the middle portions of linear core members **42** and **43** and the long leg portions of H-shaped members **40** and **41**. During those brief periods when either or both of the luminescent tubes are in their ionized conductive condition, the major portion of the magnetic flux courses along a long shunt path of high reluctance around and excluding the coil sections comprising the secondary windings which supply high potential electrical energy to the tube or tubes in the conductive state. During the conductive state of tube **55**, for example, the major portion of the magnetic flux coursing through linear core sections **42** and **43** passes across air-gaps **G1** and **G2** and through the short leg **40***b* of the H-shaped core member associated with coil sections **51** and **52**. Similarly, during the conductive periods of the luminescent tube **61**, the major portion of the magnetic flux coursing through linear core member **42** and **43** passes across air-gaps **G3** and **G4** and through the short leg of H-shaped member **41**. The remaining portion of the magnetic flux, or that portion interlinking the primary winding **44—45** with the secondary windings **51—52** and **58—59**, is adequate, however, to maintain an induced potential in both of these coils sufficient to maintain a flow of current through the luminescent tubes and preserve brilliant operation.

In the event of a short-circuit occurring across the terminals of either luminescent tube, the coursing of the magnetic flux through the core of the transformer apparatus is substantially the same as it is during the conductive periods of both tubes. The amount of current flowing in the transformer secondary windings in this condition of operation is about the same as that encountered under normal operating conditions. Under neither condition does this current rise to such excessive values as to cause objectionable heating and damage to the coils.

In the event that only one coil section of a secondary winding becomes grounded, the flow of an excessively high current in this coil section is effectively prevented, in a manner more particularly described above, by the major portion of the magnetic flux coursing along a path of intermediate reluctance provided between the coil sections of the secondary winding by the bar portion of the H-shaped member upon which these sections are mounted. This path extends around and excludes the short-circuited section and includes and links the complementary open-circuited section. The portion of the total magnetic flux that interlinks the primary winding with the short-circuited coil section is substantially the same as that interlinking these two under normal operating conditions or under short-circuited operating conditions of the entire secondary winding. In all instances the electromotive forces induced in the secondary winding are not so great as to cause the flow of an excessively high current in the coil sections of this winding. In these instances the flow of current is about the same.

While, as illustrative of my invention, transformer apparatus employing a primary winding comprising two coil sections, one of which is mounted on each of the two linear core members of the apparatus is specifically described, it will be understood that good results are achieved where only a single primary coil section mounted on either of these core members is employed. Such a form of construction permits a direct saving in the cost of the primary winding, although a slight increase in the overall width of the transformer apparatus accompanies this modification.

Likewise, while as illustrative of my invention, H-shaped transformer core members having long and short leg portions of equal widths are indicated it will be understood that where desired the short leg portions may be either of greater widths or lesser widths. In fact, in order to gain a maximum compactness in construction and employ a minimum amount of core material consistent with good operating characteristics, the short leg portions of the H-shaped members are preferably made of a lesser width than the long leg portions, the relation between the widths of the two leg portions, or sectional areas, since the thickness of the member is constant, being in accordance with the relation between the total magnetic flux and that major portion which is shunted around and about the coil sections during certain of the operating conditions indicated above.

Thus it will be seen that there has been provided in this invention transformer apparatus in which the various objects hereinbefore noted, together with the many practical advantages thereof, are successfully achieved. It will be seen that my transformer apparatus is exceedingly compact and rugged in construction and that it lends itself to inexpensive and efficient commercial production and installation, employing a minimum of different shaped core members and requiring a minimum of expensive dies, tools and equipment in its construction. It will be seen, further, that my transformer apparatus permits the energization of a greater length of luminescent tubes than heretofore known transformer apparatus without at the same time encountering excessively high output potentials from terminals or conductors to ground, or risking damage to the secondary windings in the event of accidental grounding of either one or both coil sections of these windings.

While best results in my transformer apparatus are achieved where two secondary windings are employed, it will be understood that certain advantages and economies in construction, installation and operation are realized where transformer apparatus employing but a single secondary winding comprising two coil sections and but a single H-shaped core member is used. Such transformer apparatus is exceptionally compact and yet, because of the peculiar core construction and the relation of this core to the secondary winding, is fully protected from damage under the various conditions encountered in use. The compactness and coil protection feature assures an inexpensive, efficient and thoroughly reliable piece of apparatus.

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

I claim:

1. In electrical transformer apparatus of the character described, in combination, a primary winding, a secondary winding comprising two coil sections, and a core including an H-shaped portion one leg of which is included in a short main magnetic circuit of low reluctance interlinking primary and secondary windings, with the secondary coil sections being mounted on the upper and lower portions of said leg and the other leg and bar of which provide magnetic shunt paths of increased length and increased reluctance between and outwardly around said secondary winding coil sections during closed-circuit operation of the same.

2. In electrical transformer apparatus of the character described, in combination, a primary winding, a secondary winding comprising two coil sections serially connected together, and a core including an integral H-shaped portion one leg of which is included in a short main magnetic circuit of low reluctance interlinking said primary and secondary windings, with the secondary coil sections being mounted on said leg with the bar of the H-shaped portion intervening and the other leg and bar of which provides magnetic shunt paths of increased length and increased reluctance between and outwardly around said secondary winding coil sections during closed-circuit operation of the same.

3. In electrical transformer apparatus of the character described, in combination, a core including an integral H-shaped portion with the one leg thereof completing a short closed magnetic circuit of low reluctance and with the other leg thereof a long shunt circuit of high reluctance, a secondary winding comprising two serially connected coil sections mounted on said one leg of said H-shaped portion with the bar thereof intervening and with the mid-point of the winding grounded to said core, and a primary winding mounted in another portion of

said core symmetrically with respect to said secondary winding.

4. In electrical transformer apparatus of the character described, in combination, a primary winding, a plurality of secondary windings each of which includes two secondary winding coil sections connected in series with the series connection grounded, and a core interlinking said primary and secondary windings and establishing therebetween a magnetic path of low reluctance, said core including core shunt means for establishing a magnetic path of increased length and of increased reluctance excluding any one coil section of said plurality of secondary windings upon short-circuit operation of said one coil section.

5. In electrical transformer apparatus of the character described, in combination, two linear core members spaced in parallel relationship, two substantially H-shaped core members each having a long leg portion so positioned as to abut the linear core members intermediate the ends thereof to effect a closed magnetic circuit and each having a short leg portion so positioned as to form a shunt path and effect a lengthening of the magnetic circuit, a primary winding mounted on one of said linear core members, and two secondary windings each comprising two like coil sections mounted on said H-shaped core sections, each of said coil sections being mounted on a long leg portion of said H-shaped core members.

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