

June 6, 1933.

F. S. SMITH

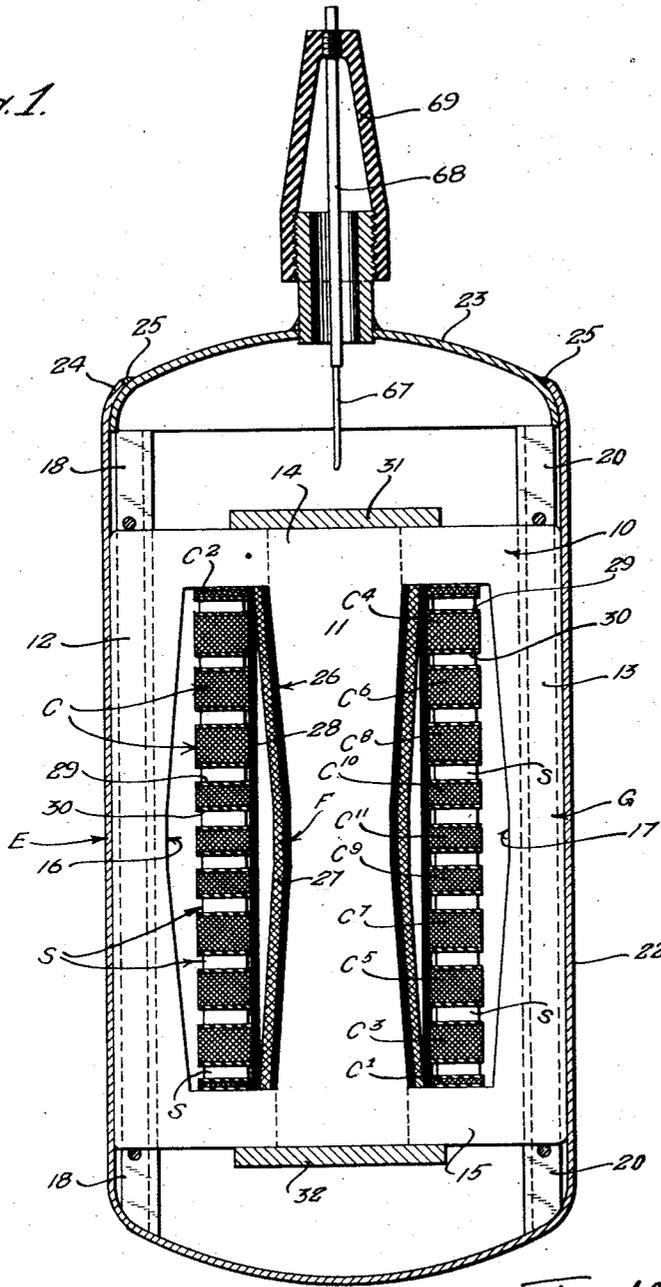
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TRANSFORMER CONSTRUCTION AND ART OF PRODUCING THE SAME

Filed Jan. 26, 1931

3 Sheets-Sheet 1

Fig. 1.



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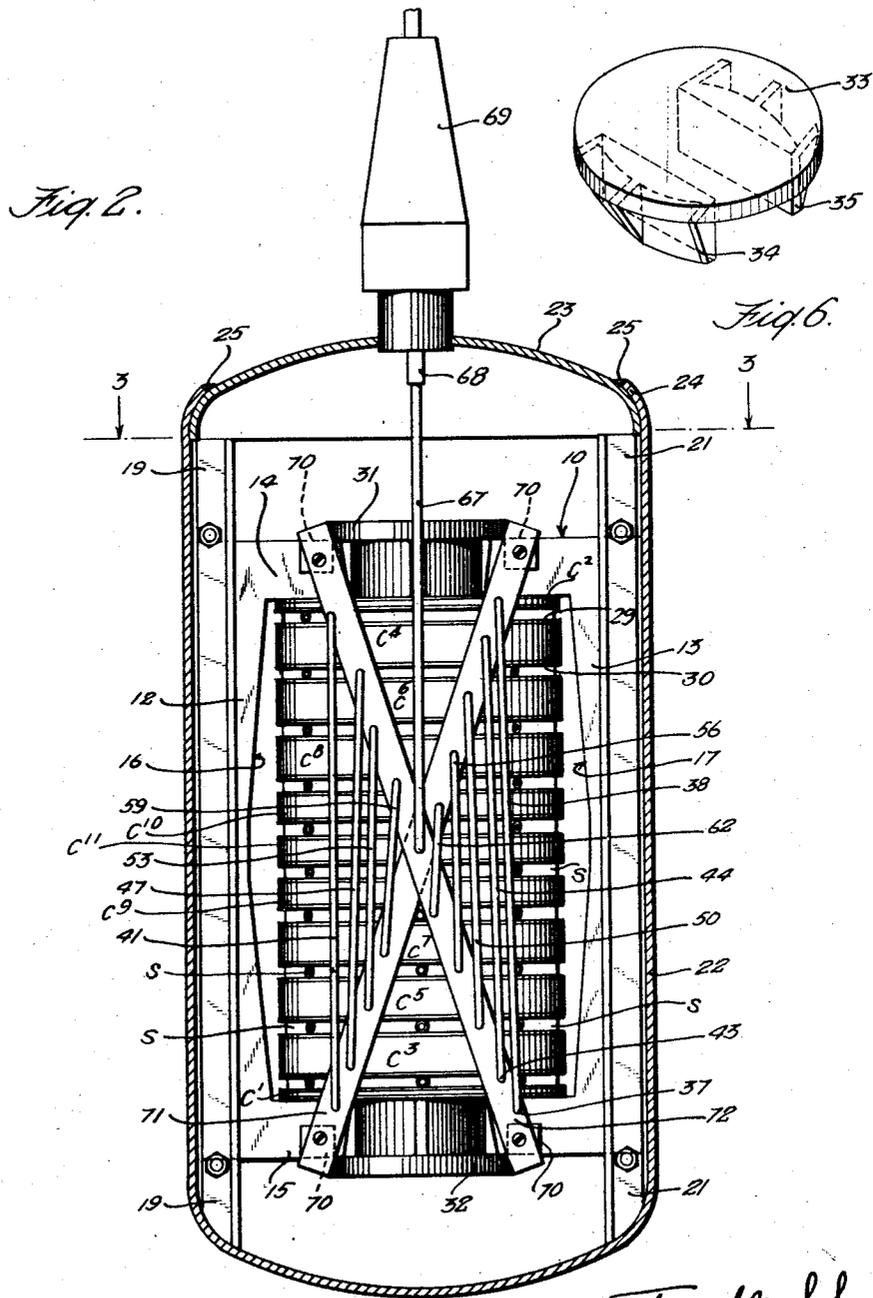
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3 Sheets-Sheet 3

Fig. 3.

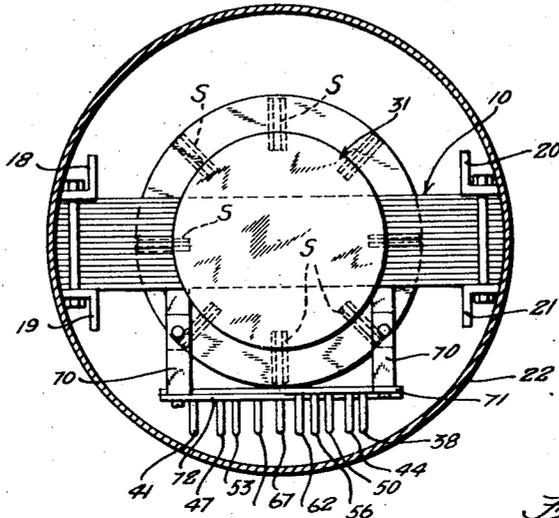


Fig. 4.

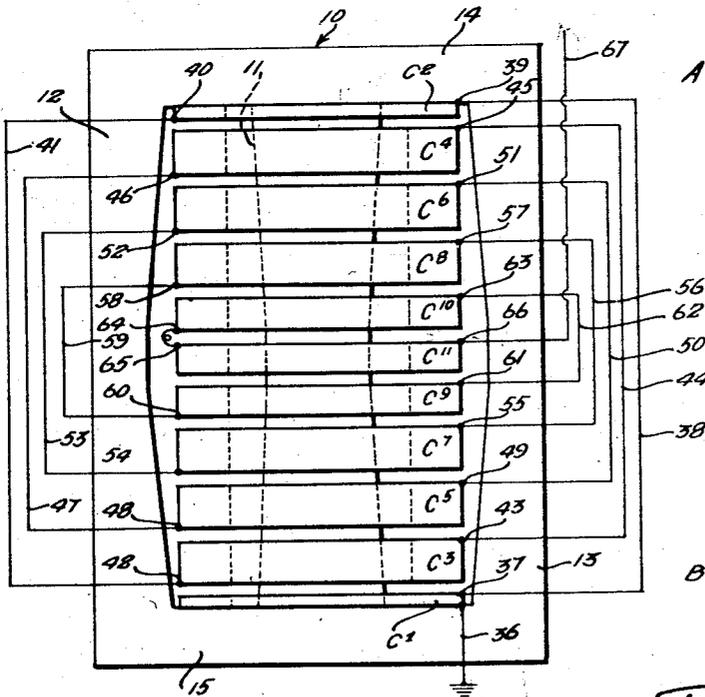
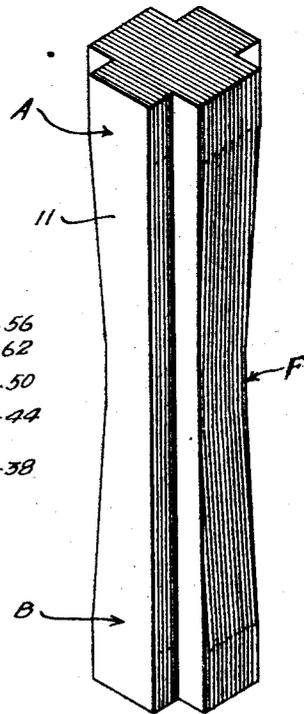


Fig. 5.



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TRANSFORMER CONSTRUCTION AND ART OF PRODUCING THE SAME

Application filed January 26, 1931. Serial No. 511,307.

This invention relates to transformers construction and to the art of producing the same.

One of the objects of this invention is to provide a transformer construction capable of operation at relatively high potentials, having a high efficiency of operation, and capable of effecting a regulation much better than has heretofore been possible to achieve. Another object of this invention is to provide a transformer construction in which inefficient flux densities in the iron magnetic circuit may be avoided without impairment of other advantages. Another object is to provide a transformer construction of short mean length of winding turn and short magnetic circuit with more compactness of construction, lighter weight, greater efficiency of insulation, and lower cost of production. Another object is to provide a transformer construction in which a high degree of closeness of inter-linkage of the magnetic circuit with the windings may be achieved in order thereby to greatly improve the regulation of the transformer. Another object is to provide a transformer construction of the above-mentioned nature for achieving such objects as those noted above but without restricting or limiting unduly the potentials which may be employed. Another object is to achieve a transformer construction in which a high efficiency of insulation may be achieved with a lowering of the electro static capacity without complicating the construction and without increasing the cost of manufacture, and to achieve a construction by which rapid assembly and manufacture may be carried on. Another object of this invention is to provide a method of constructing and winding transformers which may be readily and inexpensively carried on in practice and with thoroughly dependable results. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts and in the several steps and relation and order of each of the same to one or more of the others all

as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is shown an illustrative embodiment of the mechanical features of my invention,

Figure 1 is a vertical sectional view of a complete transformer;

Figure 2 is a front elevation of the completely assembled transformer, portions of the casing or tank being broken away to show certain features of the interior construction more clearly;

Figure 3 is a sectional view as seen along the line 3—3 of Figure 2;

Figure 4 is a diagrammatic view showing the relation of the sections of the high tension winding to the core and shows diagrammatically a preferred embodiment of the connection of these sections;

Figure 5 is a perspective view on a smaller scale of a portion of the magnetic circuit of the transformer, and specifically is a perspective view of a leg of the transformer core in one stage of the construction of the transformer, and

Figure 6 is a perspective view of one of the coil supports.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Referring now to the drawings and more particularly to Figure 1, I have provided a transformer core indicated generally at 10 and illustratively of the shell type; preferably this core 10 comprises a middle leg 11 about which the windings are received and preferably two end legs 12 and 13 spaced horizontally therefrom. These legs are inter-connected at their upper and lower ends by the horizontal members generally indicated at 14 and 15, thereby forming two core windings generally indicated at 16 and 17. It will be understood that, while I have illustrated only two outer core legs 12 and 13, the shell type of transformer core may be embodied to have, for example, four outer core legs, if desired, with corresponding upper and lower cross-members to inter-con-

nect magnetically the various outer core legs with the middle or central core leg 11.

The transformer core 10 is made up of sheet metal laminations but the sheet metal strips of which the middle leg 11 is made are shaped so that they are narrower at substantially their central portion than at their outer end portions, the intervening portions being of progressively greater width as the respective end portions are approached. The shape thus given the laminations of which the core member 11 is made is well indicated in Figure 1, and the resultant tapering upwardly and downwardly from the center of the width of the laminations and hence in the thickness of the core member 11, as viewed in Figure 1, is preferably such that the shape of the individual laminations is defined by straight lines, thereby making it feasible to rapidly shear or stamp the laminations to the desired shape.

The outer core legs 12 and 13 are also made up of sheet metal laminations and these are preferably shaped substantially as indicated in either Figures 1 or 4, it being noted that the outer side edges of these members are straight, while the inner edges, that is, the edges that face toward the middle core leg 11, are tapered both in an upward and downward direction from substantially the midpoint thereof and to a degree commensurate with the tapering which is given the middle core leg 11. This tapering of the laminations of the core legs 12 and 13 is also preferably a straight line taper so that the laminations may be rapidly and inexpensively sheared or stamped with inexpensive tools. The upper and lower cross-members 14 and 15 are made up of laminations substantially rectangular in shape, it being understood that the laminations of all of the several core parts, formed and shaped as above described, may be assembled in the usual manner of assembling a laminated transformer core so that existing facilities for manufacture may thus be made use of in constructing the transformer core embodying the features of my invention. The assembled laminations may be clamped together in any suitable manner and preferably are clamped together by the vertically extending pairs of angle irons more clearly shown in Figure 3; thus, the angle irons 18 and 19 may clamp together the left-hand end of the core 10 and the angle irons 20 and 21, also extending vertically, may clamp together the right-hand portion of the transformer core 10. Suitable bolts may be used to co-act with these angle irons to securely clamp the parts of the core together.

The horizontal dimension of the core 10, as viewed in Figure 1, is preferably such that the core 10 may be snugly received within a tank or container 22, preferably cylindrical, and of appropriate length in a

vertical direction. Moreover, the clamping angle irons 18, 19, 20 and 21 are preferably of such a length, as will be clearly seen from Figure 1, that they may be snugly received between the bottom and top members of the tank 22, the transformer core and its associated parts carried thereby, and to be more clearly described hereinafter, being thus snugly housed and held within the tank 22. More specifically, the top or closing member 23 of the tank 22 will be seen to have its peripheral edge portion inserted into the upper peripheral rim portion 24 of the container 22 and is made to rest upon the upper ends of the vertically extending clamping angle irons. The peripheral edge portion 24 of the container 22 is thereupon bent inwardly and substantially over and upon the closure member 23 of the tank, and the two parts welded together, as is indicated at 25, whereby the casing 22 is hermetically sealed, for a purpose to be more clearly described hereinafter. By this construction, it will be seen that the transformer core and its associated parts are securely housed and held within the container 22.

The various portions of the core 10 may be of cruciform cross-section and this is preferably the case with respect to the middle leg 11 about which the windings are received. In Figure 5 I have illustrated in perspective the double tapered and modified cruciformed core leg 11 as it is, in accordance with my invention, first assembled preliminary to its association and assembly with the remaining core members hereinabove described, with the laminations of which its own laminations are inter-leaved, as will be understood by those skilled in the art. After the laminations of the core leg 11 are first assembled in the form shown in Figure 5, they are clamped together in any suitable manner and the assembled core leg 11 is then mounted to be rotated about its longitudinal axis by any suitable means, for example, in a lathe and, while being rotated, I wind thereupon and throughout a range extending substantially between the points A and B of Figure 5, a cord or a tape, such as jute or cotton which is impregnated with uncured phenolic condensation product. This winding of the thus impregnated yarn, in one or more layers, provides a covering for the core 11 which will follow the general double tapered contour of the core 11. The core 11 with the wound and impregnated cord thereon is then placed in a bakelizer or appropriate vessel in which it is preferably subjected to an air pressure of from 100 to 200 pounds per square inch and simultaneously heated to about 150° centigrade; this treatment is continued for a period of about twenty minutes and upon its completion, the phenolic condensation product with which the jute or yarn is impregnated is

cured and forms a substantially rigid and solid tube-like covering for the irregularly shaped core leg 11, and has an appearance and physical properties closely analogous to laminated bakelite as the latter is commonly known.

Upon this rigid covering, indicated at 26 in Figure 1, which will thus be seen to have also excellent dielectric properties, there is then wound the low tension winding in one or more layers, and in Figure 1 this winding is indicated at 27 as being wound in a single layer. The winding 27 will thus be seen to be given a contour substantially identical with that of the core leg 11 and will, furthermore, be seen to be not only well insulated from the core 11 by the intervening dielectric covering 26, but also supported and protected by the covering 26 against the otherwise sharp corners or edges of the cruciformed core leg 11 (see Figure 5).

With the core 11 thus prepared and with the low tension winding 27 thereabout, it may now be assembled with respect to the remaining portions of the transformer core 10 and also with respect to the high tension winding.

The high tension winding consists of an appropriate number of coil sections, all of which are preferably of identical dimensions when viewed as shown in Figure 3; preferably these coil sections are annular in shape, as will be clear from both Figures 1 and 3, and when placed about the core leg 11, which, as will be clear from the foregoing, has its longitudinal axis substantially coincident with the axis of the cylindrical tank 22, will thus be substantially concentrically positioned within and with respect to the tank 22.

Preferably, also, these coil sections of the high tension winding are of substantially the same number of turns in order that there be effective at each substantially the same voltage, but certain buffer coils, to be more clearly described hereinafter, are preferably of a lesser number of turns and embody turn and/or layer insulation greater than in the remaining coil sections.

The coil sections, generally indicated in Figure 1 at C, are supported about a substantially cylindrical sleeve 28 made of solid dielectric material, such as bakelized paper for example, this sleeve 28 having a length sufficient to be snugly received between the upper and lower cross-members 14 and 15 of the transformer core 10, and has an inside diameter sufficient to permit the sleeve or tube 28 to be slid over the core leg 11 and to provide a relatively small annular space between its upper and lower ends and the upper and lower ends respectively of the low tension winding 27, the latter being, as will be clear from Figure 1, of greatest lateral dimension or diameter at its upper and lower

ends. The coil sections C may be separately wound and thereupon assembled about the sleeve 28, or they may be directly wound about the sleeve 28 and assembled with respect to the transformer core as a single unit with the sleeve or tube 28 itself.

Each coil section is wound between or positioned between two annular members of solid dielectric material, such as bakelite, and as typical of this preferred construction, it might be pointed out that above and below each coil section C of Figure 1, there are provided the washer-like members 29 and 30. Each coil section C, with its respective confining members 29 and 30 of solid dielectric material, is spaced from an adjacent and similar coil section by spacing members, indicated at S in Figure 1, which extend radially (see Fig. 3) and which are preferably of tubular cross-section. The purpose and functioning of these spacing members S will be more clearly set forth hereinafter.

The uppermost and lowermost coil sections as indicated in Figure 1, may conveniently be insulated from the upper and lower cross-members 14 and 15 of the transformer core 10 by simply the confining annular solid dielectric members respectively at the outermost faces of these end coils, and in order to form a rigid support for the stack of high tension coil sections, there are attached to the upper and lower cross-members 14 and 15 of the core, two members 31 and 32 respectively, and preferably made of a non-magnetic material, such as brass, for example. In Figure 6, I have illustrated the member 31, to which the lower member 32 is identical, in perspective, and it will be seen to include a disk-like portion 33 adapted to rest upon the outer face of the end member 14 so that the two spaced depending portions 34 and 35 thereof, each substantially in the shape of a segment of a circle, will project downwardly on either side of the cross-member 14 of the core, and in a direction toward the stack of high tension coil sections. The depending portions 34 and 35 of the member 31 are of such a length so that their lower faces fall into substantially the same plane with the underface of the cross-member 14 of the core 10, and against which latter face the stack of coil sections abuts. Any suitable means may be used to secure the members 31 and 32 to the transformer core. Thus, the stack of high tension coil sections may be well supported substantially throughout their entire peripheral extent not only against their own weight but also against any mechanical stresses that may be set up by reason of any electrical phenomena due to current changes through the windings.

The outer diameter of the coil sections C (see Figure 1) is, as has already been noted,

substantially the same for all of the coil sections so that the peripheral faces or edges of the coils C are in substantial alignment and successive coil sections will be seen to be progressively spaced in a lateral direction both from the outer core legs 12 and 13 and from the middle core leg 11 with its low tension winding 27, but at progressively varying distances. The inside diameter of the coil section C is also preferably the same for all of the coil sections, thus making it possible to greatly simplify manufacture in that all of the coil sections are of substantially the same dimension.

The coil sections C are interconnected in a manner so that the average potential of any one coil section is substantially proportional to its spacing in a lateral direction from the primary winding 27 and the middle core leg 11 on the one hand and from the outer core legs 12-13 on the other hand, and in order to illustrate this preferred mode of interconnection of the coils, it will be assumed that the end coil C¹ is a buffer coil like one of those above-mentioned and is grounded and is wound with extra turn and/or layer insulation and has sufficient turns to have induced therein a voltage of 7,000 volts, assuming the low tension winding to be wound for 100 volts, and that the middle or high voltage buffer coil C¹¹ (see now Fig. 4) is wound to have sufficient turns to have induced therein a voltage of 3,000 volts. Let it further be assumed that, intermediate of the upper coil C² and the high voltage buffer coil C¹¹ there are four coil sections C⁴, C⁶, C⁸, and C¹⁰, each having sufficient turns to permit of the application to each of a potential of 10,000 volts or to have induced therein, for a low voltage winding voltage of 100 volts, a voltage of 10,000 volts. Intermediate of the lower buffer coil C¹ and the high voltage buffer coil C¹¹ there are likewise four coils C³, C⁵, C⁷ and C⁹, each wound for 10,000 volts.

Referring again to Figure 4, one terminal of the buffer coil C¹ is grounded to the transformer core or to the steel casing 23, as is diagrammatically indicated at 36, the disk 30 of solid dielectric material that is interposed between the coil C¹ and the transverse member 15 of the core and the supporting member 31 being of sufficient thickness safely to insulate this buffer coil from the cross member 15 of the core. The terminal 37 of the coil C¹, this terminal being, in operation of the transformer, at a potential of about 7,000 volts, is connected by a conductor 38, supported in a manner hereinafter described, to the upper or lower voltage terminal 39 of the upper coil C², the solid dielectric member 29 interposed between the coil C² and the upper cross member 14 of the core and the supporting member 31 being of sufficient thick-

ness safely to insulate the section C² from these parts for at least a voltage of 17,000 volts. Though the coil C² is a 10,000-volt coil, its other terminal 40 will be at a potential of 17,000 volts and this terminal is connected by conductor 41 to the lower voltage terminal 42 of the 10,000-volt coil C³. The higher voltage terminal 43, now at a potential of 27,000 volts, is connected by conductor 44 to the uppermost terminal 45 of the 10,000-volt coil C⁴. The terminal 46 of the latter coil, at a potential of 37,000 volts is connected by conductor 47 to the lower voltage terminal 48 of the 10,000-volt coil C⁵.

The other terminal 49 now at a potential of 47,000 volts, is connected by conductor 50 to terminal 51 of an upper coil section C⁶ whose other terminal 52, now at a potential of 57,000 volts, is connected by conductor 53 to the terminal 54 of a lower coil C⁷.

The other terminal 55 of coil C⁷, at a potential of 67,000 volts, is connected by conductor 56 to terminal 57 of an upper coil C⁸, the other terminal 58 of which, now at a potential of 77,000 volts, is connected by conductor 59 to terminal 60 of a lower coil C⁹.

The other terminal 61, now at a potential of 87,000 volts, is connected by conductor 62 to the terminal 63 of an upper coil C¹⁰ whose other terminal 64, at a potential of 97,000 volts, is connected to the terminals 65 of the high voltage buffer coil C¹¹, the other terminal 66 of which, now at a potential of 100,000 volts, is connected by conductor 67 to the outlet conductor 68 of a suitable high voltage terminal generally indicated at 69.

Referring again to Figure 4, and bearing in mind the manner of connecting the different coil sections as immediately above outlined in detail, it will be noted that the coil connections are such that, considering the high tension winding as a whole, the end sections or coils (C¹ and C²) of the winding which are closely adjacent the core cross members (14 and 15) and which rest in the narrowest end portions in the core windows 16 and 17 are relatively the lowest voltage coil sections of the winding; from these end coils or end sections, the potential gradient of the winding increases substantially in proportion as the width of the core windings 16 and 17 increases, terminating in the buffer coil C¹¹ which is centrally positioned and hence is positioned in the widest portions of the core windows and which, though the potential across its terminals 65 and 66 is only 3,000 volts, is at a potential, with respect to the core and low tension winding, of substantially 97,000 to 100,000 volts.

The low tension winding 27 (see also Fig. 1) conforms to the shape of the middle core

leg 11 and will be seen to be spaced away from the sections of the high tension winding by distances that are substantially proportional to the relative potentials of the coil sections of the high tension winding.

As above noted, the tank or casing 22 is hermetically sealed and it contains a suitable gas under pressure, such as nitrogen under a pressure on the order of fifteen atmospheres; preferably, where there are substantial heat losses to be dissipated, the gas under pressure comprises a mixture of nitrogen and helium, the helium having greater thermal conductivity than the nitrogen. This gas under pressure fills the spaces between the coil sections above-described, the solid dielectric material, the low tension winding, and the core portion and I am enabled, by the coaction of this gaseous dielectric under pressure with such features as those above described, to achieve many thoroughly practical advantages. For example, because of the high dielectric strength of the above-mentioned illustrative gaseous dielectrics, I am enabled to make the core windows 16 and 17 of much smaller dimensions than would otherwise be possible. Thus the spacing from the core legs 12 and 13 of the outer peripheral portions of the coil sections C may be considerably lessened while the spacing between the inner peripheries of the aligned coil sections C and the low tension winding 27 or even also the middle core leg may be still further diminished by the unique coaction of this gaseous dielectric with certain solid dielectric material already above described. For example, referring to Figure 1, the space between the inner peripheries of the coil sections C and the low tension winding 27, varying as it does in width in accordance with the potentials along the high tension winding, will be seen to be occupied by a layer of solid dielectric material, made up of the solid dielectric sleeve 28, and a layer of gaseous dielectric under pressure which fills the space between the sleeve 28 and the low tension winding 27.

These two dielectrics will be seen to be in series in the field of the potential difference or differences existing between any coil section and the low tension winding. The permittivity of the solid dielectric material, where it is of bakelite, is 5 or above, while the permittivity of the gaseous dielectric under pressure is 1. These dielectrics, in series, distribute the potential stress between a coil section and the low tension winding inversely as their permittivities and because of this high ratio of permittivities and of the high dielectric strength of the gaseous dielectric, I am enabled to make the solid dielectric of minimum thickness and the over-all spacing vastly smaller than would otherwise be possible. Moreover, I am enabled, due to such features as those above-mentioned, to sim-

plify the manufacture and minimize the expense by making it possible to maintain a uniform thickness of solid dielectric material in the sleeve 28, as the potential gradient along the inner periphery of the high tension winding with respect to the low tension winding 27, is substantially uniform. Considering briefly the insulation of the high tension coil sections from the middle core leg 11, it will be noted that the solid dielectric material 26 and 28 (see Fig. 1) and the intervening space of gaseous dielectric under pressure are in series with each other.

Considering now certain other advantages that I am able to achieve by reason of such features as those above-mentioned, I might note that the cross-sections of the core members at the points indicated in Figure 1 at E, F and G are such that there exists, at these portions, the maximum flux density during the operation of the transformer. If there are two outside core legs such as the core legs 12 and 13, the cross section of each core leg, as at E and G, respectively, will be about one-half of the cross-section of the middle core leg 11 at F; this fraction will be one-quarter where there are four core legs employed. In either case, however, it will be noted that the cross-sectional area, due to the shaping of the core windows 16 and 17, increases in both an upward and downward direction from the points E, F and G. The flux densities existing in these sections of greater cross-section will therefore be lower and thus the iron losses are correspondingly diminished. Furthermore, the shaping of the core windows 16 and 17, as above described, gives the core such a conformation that the latter, assuming the path of any single flux line, very closely approaches that path and, considering all of the flux lines, the core very closely approximates the shape of the field of flux. Flux or magnetic leakage is thus greatly minimized and a very highly efficient linkage between the low tension winding and the high tension winding (or vice versa) results, giving very close ratio of transformation, a feature of importance particularly when the apparatus is to be used as an instrument transformer. These advantages, moreover, will be seen to be achieved without requiring very material departure from existing or known methods of building up laminated transformer cores. In fact, the laminations may be easily sheared to the right shape and though certain of the laminations are other than rectangular or L-shaped (due to the above-described shaping of the core windows 16 and 17), the method of assembly of the laminations may proceed in the usual or the known way.

As above described, spaced coil sections C are separated from each other by tubular spacers S extending radially (see Fig. 3)

and suitably distributed throughout the circular extent of the individual coils; these spacers S are made of a suitable solid dielectric such as bakelite, and, in being tubular, have not only a very high mechanical strength, thus making it possible to use a lesser number, but also coact in a unique way with the gaseous dielectric under pressure. In this latter connection, it might be noted that the possible leakage path from one coil section to another by way of the surface of a tubular separator S must be around or along the curved exterior surface of the separator and hence along a path much in excess of the shorter straight line distance between any two spaced adjacent coil sections. Such excessively long possible surface leakage path is, however, contacted by the gaseous dielectric under pressure, and, where that pressure is on the order of fifteen atmospheres, it requires a voltage many times in excess of that necessary to cause actual surface leakage in the absence of the gaseous dielectric under pressure. Thus I am enabled in a simple and inexpensive manner to more closely space the coil sections while effectively minimizing the possibility of surface leakage. Such closer spacing of coil sections makes it possible also to still further shorten up the magnetic circuit.

Furthermore, any straight line drawn through one of these separators and from one coil section to another must pass through both gaseous dielectric and solid dielectric; hence these two dielectrics are also in series in the field of highest voltage gradient between adjacent coils and due to this series relation I am able still further to minimize the dimensions of the spacers S and achieve a still further close spacing of the coil sections C.

Secured by suitable brackets 70 (see Figs. 2 and 3) to the upper and lower cross members of the transformer core are two diagonally extending members 71 and 72 (see Fig. 2) each made of solid dielectric material such as laminated bakelite or the like. These members 71 and 72 are held at their upper and lower ends by the brackets 70 which are dimensioned so as to hold the members 71 and 72 spaced laterally from the stacked coil sections C (see Fig. 3) and to hold these members, moreover, along the line of a chord of the circle represented by the surrounding tank 22.

The conductors which connect the various coil sections together and which have been described in detail above in connection with Figure 4 are preferably substantially U-shaped and may conveniently take the form of copper rods or tubes of suitable cross-section. These U-shaped conductors have their legs passed through and supported by these cross members 71 and 72 of solid die-

lectric material and in Figure 2 these connecting conductors are shown extending vertically but spaced laterally in the same order in which they appear, reading left to right, in Figure 4, and they appear, when viewed from above in Figure 2, as shown in Figure 3. Thus these U-shaped connecting conductors appear in the order of conductors 41, 47, 53, 59, 67, 62, 56, 50, 44 and 38, reading in a direction left to right in Figure 3.

It will be noted, however, that the potential of these conductors, relative to the transformer casing 22, increases in a direction reading from conductor 41 to the end conductor 67 and from the conductor 38 to the same end conductor 67, and that the spacing of these conductors from the wall of the casing 22 varies progressively with the potential difference existing between the conductors and the casing itself. By the use of the gaseous dielectric under pressure, I am enabled to make this spacing much smaller than would otherwise be the case.

Returning now to Figure 2, a further advantage of this distribution of the connecting conductors may be pointed out. As above pointed out, I am enabled to make the spacing between adjacent coil sections relatively small, due to a number of coacting features which I have mentioned above. However, the leakage path along the dielectric supporting members 71 and 72 and between the points where these connecting conductors pass through the dielectric supports 71 and 72, due to the lateral displacement of connecting conductors, is materially greater than the actual spacing between any two adjacent coil sections. For example (comparing Figure 2 with Figure 4) the spacing between the coil terminal 37 of the lowermost buffer coil C¹ (this terminal 37 has been above-assumed to be at a potential of 7,000 volts) vertically from the terminal 43 (at a potential of 27,000 volts) of the coil section C³ next to the buffer coil C¹ is the same as the vertical spacing between the two coil sections C¹ and C³, but the length of the leakage path along the solid dielectric member 72 and between these terminals 37 and 43 is materially greater than this vertical spacing, due to the lateral displacement of the connecting conductors. Moreover, the surface of the solid dielectric support 72 is contacted by this gaseous dielectric under pressure and, due to this feature, the lateral spacing between the connecting conductors need not be as great as it would have to be otherwise, for, as above pointed out, the coaction of the gaseous dielectric under pressure with the surface of a solid dielectric, such as bakelite, is such that, to effect surface leakage between two conductors, a very much greater voltage must exist between these conductors than is necessary

if the gaseous dielectric under pressure were absent. Or, for a given potential corresponding to which it is desired to prevent surface leakage, a very much shorter spacing of the conductors is possible where the solid dielectric surface is contacted by the gaseous dielectric under pressure than is necessary with the use of solid dielectric alone. This difference in the spacing where the gaseous pressure is on the order of fifteen atmospheres may be as high as one-tenth.

It might also be pointed out that the spacings of the high tension winding from the low tension winding and from the vertically extending core legs provide adequate channels for the convection currents of the gaseous dielectric under pressure, the latter taking up the heat losses and giving the latter up to the walls of the steel casing, thus preventing undue temperature rises during the operation of the apparatus.

The compactness of arrangement of the coil sections of the high tension winding with respect not only to each other but also to the low tension winding and to the core, made possible by the use of the gaseous dielectric under pressure and particularly by the coaction thereof with solid dielectric material, all as above pointed out, achieves a further advantage of substantial practical importance. In this connection, it might be noted that the construction of the steel tank or casing 22 that I prefer to employ is a pressed steel tank that is therefore seamless excepting for the welded joint between the casing and the cover member. A pressed steel casing is far preferable to a casing of other construction in view of its low cost, its strength and hence its adequate capacity safely to withstand the high pressures to which it is subjected by the gaseous dielectric. However, the diameter to which pressed steel casings of this kind are commercially made is limited but because of the above-mentioned compactness of arrangement that I am enabled to achieve, I can still operate within the confines of pressed steel casing of a diameter now commercially practicable. I wish it to be understood, however, that my invention is not to be limited, unless otherwise expressed in the following claims, to a transformer encased in a pressed steel casing for, in so far as many features of my invention are concerned, I may use a casing other than of pressed steel.

It will thus be seen that there has been provided in this invention an art and apparatus in which the several objects hereinabove noted, as well as many thoroughly practical advantages, are successfully achieved. It will be seen that the art is capable of being rapidly and inexpensively carried on in practice and that the apparatus lends itself to rapid and inexpensive manufacture and is well adapted to meet the varying require-

ments and conditions met with in practice. It will be seen that an unusually high efficiency of linkage of magnetic flux with the turns of the windings is achieved, that core losses are greatly minimized not only because of the possibility of operating at lower average flux densities, for a given mean length of winding turn, but also because of the fact that it is possible to make the magnetic circuit somewhat shorter. It may further be noted that such thoroughly practical advantages as these make it possible for the construction to meet the precision exacting requirements of an instrument transformer.

As many possible embodiments may be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. The herein described art which consists in building up a core leg of laminations shaped so that the insulating core leg is of varying cross-section, winding a fibrous yarn or string impregnated with phenolic condensation product about the core leg, subjecting the core and impregnated yarn wound thereon to heat and pressure to cure said phenolic condensation product, and winding wire thereon to form a winding.

2. The herein described art which consists in assembling laminations of transformer metal to form a core leg of cruciform cross-section, winding a fibrous yarn or string impregnated with phenolic condensation product about the core leg, subjecting the core and impregnated yarn wound thereon to heat and pressure to cure the phenolic condensation product, and associating a winding with respect to said core leg.

3. The herein described art which consists in forming a core of varying cross-section, covering said core with uncured phenolic condensation product, and curing the phenolic condensation product.

4. The herein described art which consists in forming a core of varying cross-section, applying thereto uncured phenolic condensation product, curing the phenolic condensation product and winding wire about the core and on top of the cured phenolic condensation product to form a coil.

5. The herein described art which consists in forming a laminated core leg of a cross-section varying so that the core leg tapers in two directions, applying uncured phenolic condensation product to the core leg, curing the phenolic condensation product, and winding wire thereabout to form a coil.

6. The herein described art which consists

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in forming a laminated core leg of such varying cross-section that the core leg is tapered, applying uncured phenolic condensation product thereto, curing the phenolic condensation product, and surrounding the core leg with a coil.

7. In transformer construction, in combination, a core leg built up of laminations each having a shape so that the cross-section of said core leg varies, a winding about said core leg and conforming substantially to the shape of the latter, and a continuous sheath of unbroken solid dielectric material interposed between said winding and said core leg.

8. In transformer construction, in combination, a core leg built up of laminations shaped so that the core leg is substantially tapered, a winding about said core leg and conforming to the shape thereof, and an unbroken layer of solid dielectric material interposed between said core leg and said winding.

9. In transformer construction, in combination, a core leg built up of laminations, said core leg having a shape such that it tapers in two directions, a winding about said core leg and conforming substantially to the shape thereof, and a layer of cured phenolic condensation product interposed between said core leg and said winding.

10. In transformer construction, in combination, a core leg built up of laminations, said core leg having a shape such that it tapers in two directions, a winding about said core leg and conforming substantially to the shape thereof, and an unbroken sheath of solid dielectric material interposed between said core leg and said winding.

11. In transformer construction, in combination, a transformer core having a middle leg and side legs spaced therefrom but connected therewith by core cross members, said core legs being shaped to provide therebetween core windows of varying width, each core window having its greatest width at a point intermediate of said core cross members, a low tension winding about said middle core leg and conforming substantially to the shape thereof, a high tension winding about said middle core leg, said high tension winding being made up of a plurality of coil sections of substantially the same dimensions, said coil sections being substantially aligned within said core windows and spaced from the sides of the latter at varying distances, and means connecting said coil sections so that the respective potentials thereof are substantially proportional to the respective spacings of the coil sections from said low tension winding and from said side core legs.

12. In transformer construction, in combination, a transformer core having a middle leg and side legs spaced therefrom but con-

nected therewith by core cross members, said core legs being shaped to provide therebetween core windows of varying width, each core window having its greatest width at a point intermediate of said core cross members, a high tension winding about said middle core leg, said high tension winding comprising a plurality of coil sections of substantially the same radial dimensions and substantially aligned in said core windows, means grounding one terminal of said high tension winding, means substantially alternately connecting said coil sections above and below said intermediate point and so that coil sections of relatively lowest potential are in the narrowest portions of said core windows, coil sections of relatively highest potential are in the portions of greatest width of said core windows, and coils of intermediate potential are intermediate of the narrowest and widest portions of said core windows, and a low tension winding coating with said core.

13. In transformer construction, in combination, a transformer core having a middle leg and side legs spaced therefrom but connected therewith by core cross members, said core legs being shaped to provide therebetween core windows of varying width, each core window having its greatest width at a point intermediate of said core cross members, a low tension winding wound directly upon and insulated from said middle core leg and assuming substantially the contour thereof, a plurality of coil sections about said middle core leg and having substantially similar radial dimensions, said sections passing through said core windows, and means connecting said coil sections so that the sections at the narrowest portions of said core windows are of lower potential than the sections at portions of said core window of greater width.

14. In transformer construction, in combination, a transformer core having a core window of varying width, a high tension winding linked with said core and comprising a plurality of spaced coil sections of substantially similar radial dimensions, a low tension winding linked with said core, and means connecting said coil sections so that the sections passing through narrower portions of said core window are of a lower voltage than coil sections passing through wider portions of said core window.

15. In transformer construction, in combination, a high voltage winding having portions of differing potential, a low voltage member in the form of a low voltage winding, a core member with which said windings coat, and means for insulating said high voltage winding from one of said members, said means including a layer of solid dielectric material and a layer of gaseous dielectric under pressure, the thickness of said

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last-mentioned layer varying in thickness substantially in proportion to the potential of said portions of said winding.

16. In transformer construction, in combination, a high voltage winding for a transformer made up of a plurality of coils positioned in spaced relation one above the other, a plurality of substantially radially extending members of solid dielectric material interposed between adjacent coils for holding the latter in spaced relation, and a fluid dielectric in which said coils and said members are immersed, said members being so shaped that the surface leakage path from one coil to another is longer than the distance between the two spaced coils.

17. In transformer construction, in combination, a high voltage winding for a transformer made up of a plurality of coils positioned in spaced relation one above the other, a plurality of substantially radially extending members of solid dielectric material interposed between adjacent coils for holding the latter in spaced relation, and a fluid dielectric in which said coils and said members are immersed, said members having a cross-section of such configuration that the insulation in the path of any voltage gradient between adjacent spaced coils is made up of the solid dielectric material of the member in series with said fluid dielectric.

18. In transformer construction, in combination, a high voltage winding for a transformer made up of a plurality of coils positioned in spaced relation one above the other, a plurality of substantially radially extending members of solid dielectric material interposed between adjacent coils for holding the latter in spaced relation, and a fluid dielectric in which said coils and said members are immersed, said members being tubular in cross-section and said fluid dielectric contacting both the interior and exterior surfaces thereof.

19. In transformer construction, in combination, a high voltage winding for a transformer made up of a plurality of coils positioned in spaced relation one above the other, a plurality of substantially radially extending members of solid dielectric material interposed between adjacent coils for holding the latter in spaced relation, and a gaseous dielectric under pressure in which said winding and said members are immersed, each of said members being so shaped that the shortest possible leakage path from one coil to another is along a surface contacted by said gaseous dielectric under pressure and is longer than the shortest distance between adjacent spaced coils.

20. In transformer construction, in combination, a transformer core having a middle leg and side legs spaced therefrom but connected therewith by core cross members,

said core legs being shaped to provide therebetween core windows of varying width, each core window having its greatest width at a point intermediate of said core cross members, a high tension winding about said middle core leg, said high tension winding comprising a plurality of coil sections of substantially the same radial dimensions and substantially alined in said core windows, means grounding one terminal of said high tension winding, means substantially alternately connecting said coil sections above and below said intermediate point and so that coil sections of relatively lowest potential are in the narrowest portions of said core windows, coil sections of relatively highest potential are in the portions of greatest width of said core windows, and coils of intermediate potential are intermediate of the narrowest and widest portions of said core windows, a low tension winding coacting with said core, and a saddle associated with each core cross member and rigidly secured with respect thereto for engaging respectively the endmost coil sections.

21. In transformer construction, in combination, a transformer core having a core window of varying width, the narrowest portion of said core window being adjacent a core cross member, metallic means held in fixed relation to said cross member and projecting away therefrom, a high tension winding linked with said core and comprising a plurality of coil sections of substantially similar radial dimensions and passing through said core window, an endmost coil section being engaged by said means, and means connecting said coil sections so that the sections passing through narrower portions of said core window are of lower voltage than coil sections passing through wider portions of said core window.

22. In transformer construction, in combination, a transformer core having a core window of varying width, a high tension winding passing through said core window and shaped and having such a voltage gradient therealong that portions of different potentials of said winding extend through portions of said core window of widths varying substantially with said potentials, said core having a greater cross-sectional area at portions thereof adjacent narrower portions of said core window than the cross-section thereof adjacent wider portions of said core window.

23. In transformer construction, in combination, a casing of substantially circular cross-section, a transformer mounted therein having a core with a high voltage winding thereabout and made up of a plurality of coil sections, said winding being spaced from said casing, a fluid dielectric in said casing, and a plurality of conductors interconnecting said coil sections, said conductors

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being spaced from each other substantially along a chord of the circular inside periphery of said casing.

24. In transformer construction, in combination, a casing of substantially circular cross-section, a transformer mounted therein having a core with a high voltage winding thereabout and made up of a plurality of coil sections, said winding being spaced from said casing, a fluid dielectric in said casing, solid dielectric means supported substantially between said winding and the casing, and a plurality of conductors supported by said solid dielectric means and interconnecting said coil sections, the points of support of said conductors in said solid dielectric means being spaced so that the possible leakage path therebetween is greater than the spacing between adjacent conductors.

25. In transformer construction, in combination, a casing of substantially circular cross-section, a transformer mounted therein having a core with a high voltage winding thereabout and made up of a plurality of coil sections, said winding being spaced from said casing, a fluid dielectric in said casing, solid dielectric means supported between said winding and said casing and extending substantially along a chord of the circular cross-section of said casing, and a plurality of conductors interconnecting said coil sections and supported thereby along substantially a chord of said cross-section, conductors of higher potential being supported by said solid dielectric means at substantially central portions of said chord and conductors of lower potential being supported at outer ends thereof.

26. In transformer construction, in combination, a casing of substantially circular cross-section, a transformer mounted therein having a core with a high voltage winding thereabout and made up of a plurality of coil sections, said winding being spaced from said casing, a fluid dielectric in said casing, a plurality of conductors interconnecting said coil sections, said conductors being spaced from each other substantially along a chord of the circular inside periphery of said casing and conductors of higher potential being at portions intermediate of said chord, and solid dielectric means supporting said connecting conductors at points so displaced from each other that the possible surface leakage path along said solid dielectric means and from one conductor to another is greater than the spacing between said one conductor and said other conductor.

27. In transformer construction, in combination, a casing of circular cross-section and adapted to withstand relatively high pressures; a transformer therein including a transformer core having a core window of varying width, a high tension winding linked with said core and comprising a plu-

rality of coil sections of substantially similar radial dimensions, and a low tension winding linked with said core, said high tension winding having its axis extending in the same direction as the axis of said casing; a gaseous dielectric under pressure within said casing; a plurality of conductors connecting said coil sections so that the sections passing through narrower portions of said core window are of lower voltage than coil sections passing through wider portions of said core window; said conductors being arranged relative to the circular cross-section of said casing so that the gaseous dielectric under pressure between conductors of higher voltage and the inside coil of said casing is of greater thickness than the gaseous dielectric under pressure between conductors of lower voltage and the inside wall of said casing.

28. In transformer construction, in combination, a casing of circular cross-section and adapted to withstand relatively high pressures; a transformer therein including a transformer core having a core window of varying width, a high tension winding linked with said core and comprising a plurality of coil sections of substantially similar radial dimensions, and a low tension winding linked with said core, said high tension winding having its axis extending in the same direction as the axis of said casing; a gaseous dielectric under pressure within said casing; a plurality of conductors connecting said coil sections so that the sections passing through narrower portions of said core window are of lower voltage than coil sections passing through wider portions of said core window; and solid dielectric means contacted by said gaseous dielectric under pressure and supporting said connecting conductors at points so spaced from each other that the possible surface leakage path along said solid dielectric means and from one conductor to another is of greater length than the shortest distance between said one conductor and said other conductor.

29. In transformer construction, in combination, a casing of circular cross-section and adapted to withstand relatively high pressures; a transformer therein including a transformer core having a core window of varying width, a high tension winding linked with said core and comprising a plurality of coil sections of substantially similar radial dimensions, and a low tension winding linked with said core, said high tension winding having its axis extending in the same direction as the axis of said casing; a gaseous dielectric under pressure within said casing; a plurality of conductors connecting said coil sections so that the sections passing through narrower portions of said core window are of lower voltage than coil sections passing through wider portions

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- of said core window; solid dielectric means contacted by said gaseous dielectric under pressure and supporting said connecting conductors at points so spaced from each other that the possible surface leakage path along said solid dielectric means and from one conductor to another is of greater length than the shortest distance between said one conductor and said other conductor, and said connecting conductors being arranged with respect to the inside wall of said casing so that the gaseous dielectric under pressure between conductors of higher voltages and the inside wall of said casing is of greater thickness than the gaseous dielectric under pressure between conductors of lesser voltages and the inside wall of said casing.
- 5 30. The herein described art which consists in covering a core with uncured phenolic condensation product and curing said condensation product. 70
- 10 31. The herein described art which consists in covering a core, covering said core with uncured phenolic condensation product and curing said condensation product. 75
- 15 32. In transformer construction employing a core, the art comprising covering the core with uncured phenolic condensation product and curing said condensation product. 80
- 30 33. In transformer construction, in combination, a winding the potential of which varies along its length, and a surrounding dielectric of gas under pressure, said dielectric varying in thickness in accordance with the electric potential to which it is subjected. 85
- 35 34. In transformer construction, in combination, a winding the potential of which varies along its length, and a surrounding dielectric of gas under pressure whose thickness changes along the length of said winding. 100
- 40 35. In transformer construction, in combination, a winding forming a cylinder the potential of which changes along its length and an included cylindrical sheath of gaseous dielectric under pressure whose thickness changes along the length of the winding. 105
- 45 36. In transformer construction, in combination, a winding forming a cylinder the potential of which changes along its length, and a dielectric comprising a gaseous envelop surrounding said winding both interiorly and exteriorly thereof, the thickness of said dielectric changing along the length of said winding. 110
- 50 37. In transformer construction, in combination, a high potential winding forming a cylinder the potential of which varies along its length and an insulating envelop comprising a gaseous dielectric under pressure whose thickness varies in accordance 115
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- 60 125
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with the potential along the length of said winding.

In testimony whereof, I have signed my name to this specification this 22nd day of January, 1931.

FRANKLIN S. SMITH.