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STATIONARY INDUCTION ELECTRICAL APPARATUS

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2 Sheets-Sheet 1

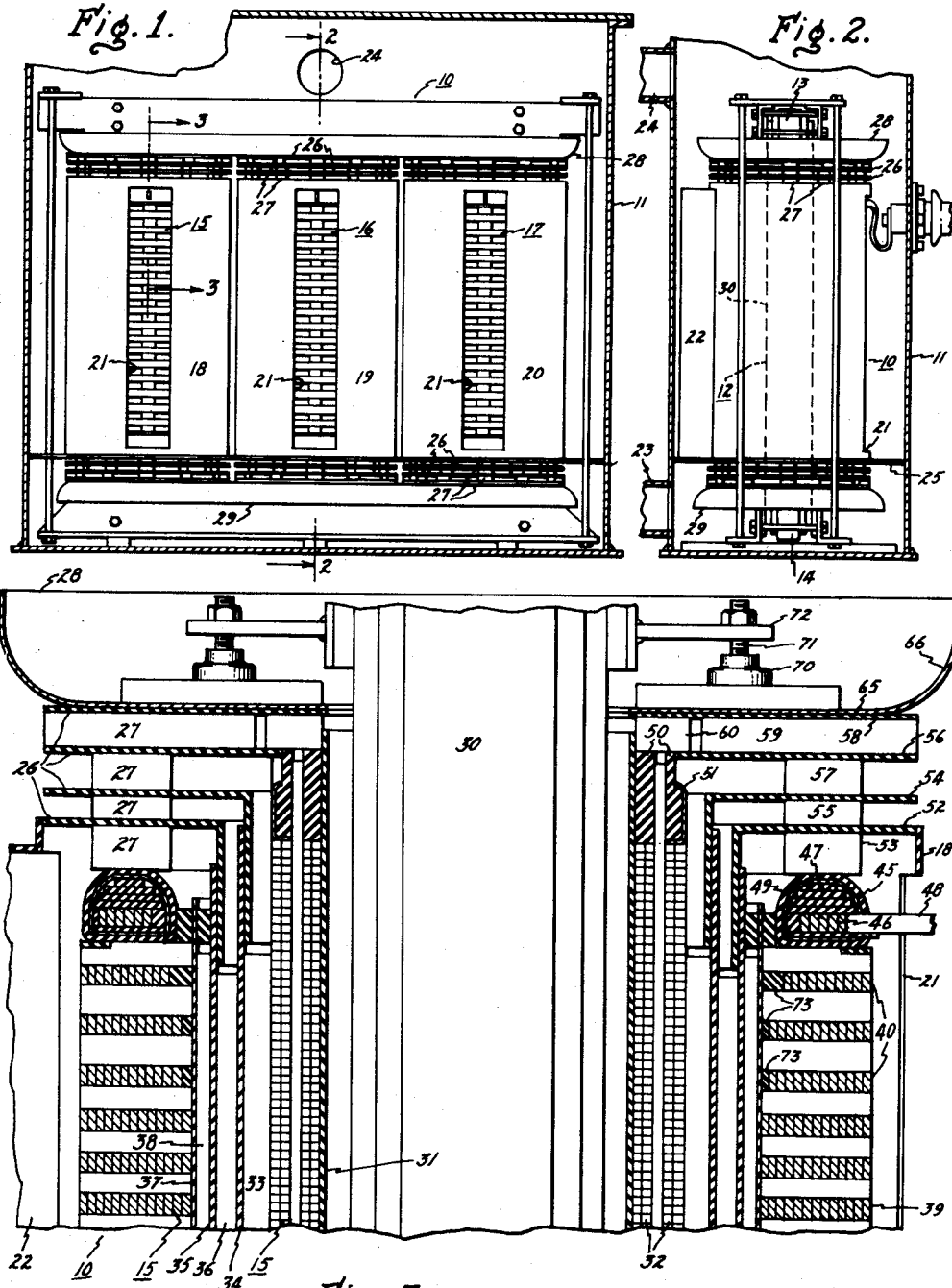


Fig. 3.

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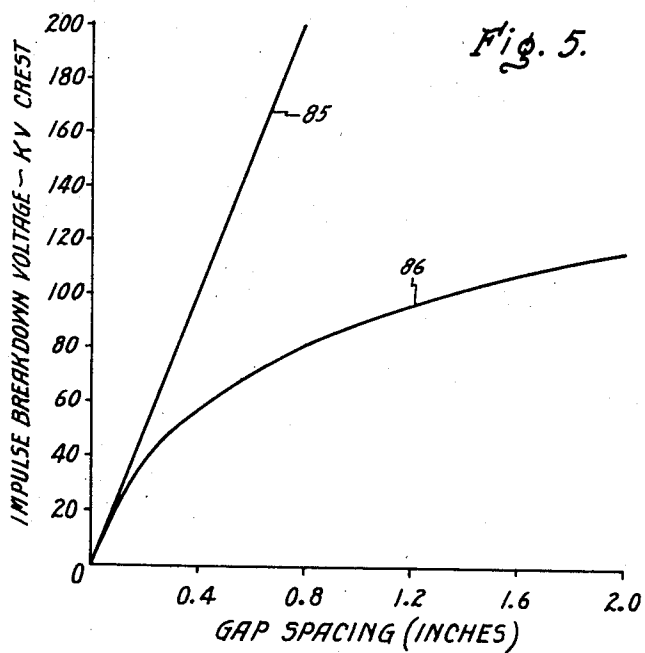
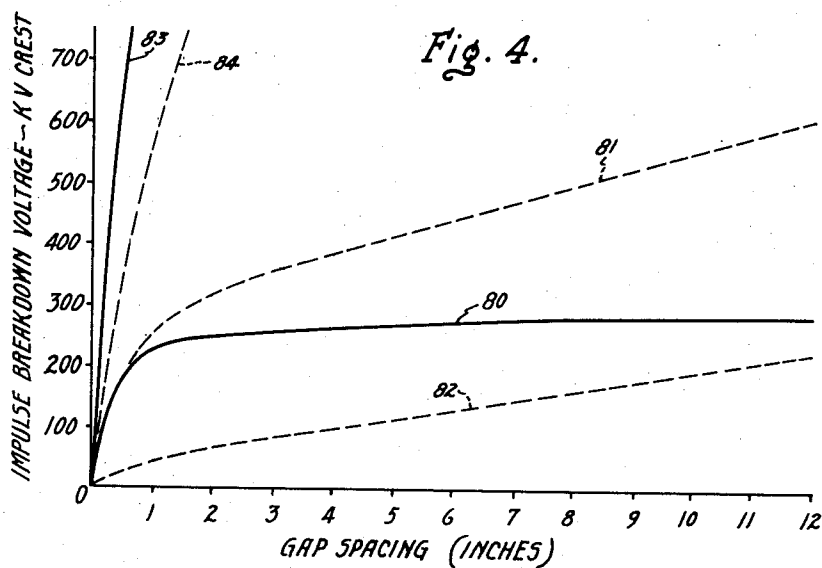
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2 Sheets-Sheet 2



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STATIONARY INDUCTION ELECTRICAL APPARATUS

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2 Claims. (Cl. 336—58)

This invention relates to stationary induction electrical apparatus, and more in particular to means for improving the dielectric strength of stationary electrical induction apparatus employing a halogenated fluid as a dielectric medium.

In the past it has been common to employ halogenated liquid compounds as dielectric medium in electrical apparatus, such as power transformers and the like, in order to provide improved insulation characteristics. A typical compound of this type is askarel, although recently gaseous compounds, such as sulphur-hexafluoride (SF_6), octafluoropropane (C_3F_8), and decafluorobutane (C_4F_{10}) have shown promising possibilities for such use.

In general it may be said that the dielectric strength of an insulating medium disposed between a pair of electrodes having different potentials increases proportionally with the increase of spacing between the electrodes. Although in the case of non-halogenated dielectric fluids some difference exists between the proportionality in uniform and non-uniform electric fields, there is still an appreciable increase in low frequency and impulse dielectric strength of the non-halogenated fluid with increases in electrode spacing in non-uniform fields.

This generalization has been found to hold true for halogenated fluid dielectrics in the case of uniform electrical fields, and also in the case of non-uniform electrical fields having a low frequency (e.g. 60 cycles per second). It has now been found, however, that the impulse strength of a halogenated fluid in a non-uniform electrical field does not increase appreciably with increases in electrode spacing beyond a certain distance. In the case of the previously mentioned halogenated fluids, this distance is about two inches.

Thus although better dielectric strength characteristics are obtained in electrical apparatus generally by the use of halogenated fluid dielectric compounds (as compared with non-halogenated compounds), the impulse strengths of the halogenated compounds in non-uniform fields cannot be appreciably increased by increasing the electrode spacing. In an electrical structure such as a transformer having a magnetic core and a plurality of windings, there are generally many places where the electrical fields are non-uniform, and as a result a serious limitation is placed upon the use of halogenated fluids in such transformers for high voltage applications.

It is therefore an object of this invention to provide means for improving the dielectric strength characteristics of stationary electrical induction apparatus immersed in a halogenated dielectric fluid medium.

Another object is to provide means for obtaining substantially uniform electrical fields in stationary electrical induction apparatus immersed in a halogenated dielectric fluid medium.

Still another object of this invention is to provide means in stationary electrical induction apparatus im-

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mersed in a halogenated dielectric fluid for simulating sphere gaps in regions of high electrical stress in order to increase the impulse dielectric strength of the dielectric fluid.

5 A further object is to provide shield means in a stationary electrical induction apparatus immersed in a dielectric fluid, the shield means being disposed in regions of non-uniform electrical fields in order to simulate sphere gaps and thereby increase the impulse dielectric strength of the dielectric fluid.

10 Briefly stated, in accordance with one embodiment of my invention, I provide a stationary electrical induction apparatus, such as the transformer or reactor, comprised of a magnetic core having at least one leg member adapted to receive electrical windings, the leg member being joined at its ends to yoke members. A high voltage winding is provided surrounding the leg member, and electrically insulated therefrom. In order to reduce the non-uniformity of the electrical fields between the high voltage winding and the yoke, I provide a shield extending in a plane perpendicular to the plane of the leg, and axially spaced from the end of the high voltage winding. The shield preferably extends in the plane at least as far as the radial outermost extremity of the high voltage winding, and the outermost edges of the shield is provided with a substantially uniform curvature away from the high voltage winding. The shield is electrically connected to the core. The entire apparatus is immersed in a halogenated dielectric fluid medium such as askarel or sulphur-hexafluoride.

I also prefer to provide an annular shield member at the ends of the high voltage winding. The annular shield member has semicircular cross section and the flat side of the annular shield member is disposed facing the high voltage winding. The annular shield member is electrically connected to an end turn of the high voltage winding, and may surround an end turn or turns of the high voltage winding.

15 In the modification of my invention wherein a low voltage winding is disposed between the winding leg and the high voltage winding, I prefer to employ an annular shield member at the ends of the low voltage winding. The low voltage annular shield member preferably extends from the radially outermost extremities of the low voltage winding, and is provided for at least a portion of its axial dimension with a substantially uniform curvature extending radially inward.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing,

Fig. 1 is a partially cross sectional view of a transformer embodying the shield means of my invention,

Fig. 2 is a partially cross sectional view along the lines 2—2 of the transformer of Fig. 1,

Fig. 3 is an enlarged partially cross sectional view along the lines 3—3 of the transformer of Fig. 1,

Fig. 4 is an impulse breakdown voltage versus gap spacing for askarel, and

Fig. 5 is an impulse breakdown voltage versus gap spacing for sulphur-hexafluoride.

Referring now to the drawings, and more in particular to Figs. 1 and 2, therein is illustrated a transformer 10 enclosed in a halogenated dielectric fluid filled tank 11. The transformer 10 has a magnetic core 12 comprised of upper and lower yoke members 13 and 14 respectively separated by three parallel winding leg members (one of which is shown by the dashed lines in Fig.

2). On the winding leg members are disposed three windings 15, 16 and 17.

The windings 15, 16 and 17 are surrounded by coaxial cylinders 18, 19 and 20 respectively of insulating material, the cylinders having axially extending openings 21 on one side of the windings and ducts 22 on the diametrically opposite sides of the windings. An external cooling and circulating system (not shown) of conventional type is provided to force the dielectric fluid to circulate into the bottom of the tank 11 through the inlet opening 23, upwardly through the ducts 22, axially and radially through the windings, through the cylinder openings 21 into the tank 11, and thence through the outlet opening 24 in the upper portion of the tank to the circulation system. A baffle 25 is provided to prevent passage of the fluid upwardly through the tank 11 bypassing the windings, and other baffle means may be provided in order to further direct the flow of fluid. For example, axial spacers in the windings may provide a zig-zag path for the fluid across the windings in the manner disclosed in U.S. Letters Patent No. 2,632,041 which issued on an application of W. J. Bilodeau and is assigned to the assignee of the present invention.

The ends of the windings are spaced from the core yokes 13 and 14 by means of annular insulating members 26 separated by insulating blocks 27. Shield members 28 and 29 are disposed in proximity to yoke members 13 and 14 respectively, and are also spaced from the respective ends of the windings 15, 16 and 17.

Referring now to Fig. 3, therein is illustrated an enlarged partially cross sectional view of a portion of the transformer of Fig. 1 taken along the lines 3—3. In Fig. 3 the windings and shield members are shown in section, while the core members are shown unsectioned for clarity. A core leg 30 is therein shown extending coaxially through the windings 15. An insulating winding cylinder 31 surrounds the core leg 30, and a low voltage winding 32 is wound on the cylinder 31. The low voltage winding is preferably a layer winding as illustrated in Fig. 3, and may be comprised of several radially spaced apart portions, although other types of windings may also be employed. Axially extending spacers 33 separate the radially outermost surface or extremity of the low voltage winding from a coaxial insulating cylinder 34. Another insulating cylinder 35 is radially spaced from the cylinder 34 by means of axially extending spacers 36, and a high voltage insulating winding cylinder 37 is radially spaced from the cylinder 35 by means of axially extending spacers 38. The high voltage winding 39 is preferably comprised of a plurality of axially separated disk-shaped coils and is coaxially mounted on the high voltage winding cylinder 37, each of the coils being comprised of a plurality of turns of insulated conductor strands.

An annular shield 45 is provided on the end of the high voltage winding, the shield being generally semi-circular in cross section with its flat side toward the high voltage winding. As shown in Fig. 3 the shield 45 may surround the endmost coil 46 of the high voltage winding, and may be comprised of a metallized tape wrapped around the endmost coil 46 and a plurality of annular members 47 of insulating material of decreasing radial dimension away from the high voltage winding and stacked on the endmost coil 46 of the high voltage winding. The shield 45 is connected to one turn of the endmost coil 46, such as the radially outermost turn connected to lead 48 as shown in Fig. 3. The shield 45 is surrounded by an insulating material 49, which may consist of an insulating tape wrapped therearound.

The low voltage windings 32 extend axially beyond the high voltage winding, and insulating cylinders 50 are provided abutting the ends thereof. The radially outermost insulating cylinder 50 is provided with an annular conducting shield 51 extending upwardly from the outermost extremity of the low voltage winding for a short

distance and thence radially inwardly with a substantially uniform curvature. The shield 51 may consist of a metallized surface on the outermost insulating cylinder 50.

An annular insulating plate 52 with a cylindrical extension on its radially inward edge extends between the respective ends of cylinder 35 and cylinder 18, and is axially spaced from the shield 45 on the end of high voltage winding 39 by insulating blocks 53. Annular insulating plate 54 is axially spaced from insulating plate 52 by means of insulating blocks 55, and has a cylindrical extension on its radially inward edge joining the insulating cylinder 34.

Another annular insulating plate 56 is spaced from the insulating plate 54 by means of insulating blocks 57, and extends inwardly to join the outermost of the insulating cylinders 50. Still another annular insulating plate 58 is provided extending at least from the outermost extremity of the low voltage winding to the outermost extremity of the high voltage winding, and is axially spaced from the plate 56 and cylinders 50 by radially extending insulating spacers 59 and 60 respectively.

The shield 28 has a flat central portion 65 lying in a plane perpendicular to the axis of the core leg 30, and a curved outer portion 66 extending with a substantially uniform curvature away from the high voltage winding. The flat central portion of the shield 28 extends at least between the outermost extremity of the low voltage winding to the outermost extremity of the high voltage winding, and has a central aperture through which the magnetic core extends. The flat central portion 65 of the shield 28 is held against the insulating plate 58 by a clamp means which may be comprised of blocks 70 having threaded extensions 71 bolted into angle members 72 of the core bracing assembly of the magnetic core 13. The clamping assembly provides axial forces to hold the low and high voltage windings in place.

In order to further simulate a rounded surface at the ends of the high voltage winding, and thus reduce the danger of sparkover between the ends of the high and low voltage windings, the several coils of the high voltage winding adjacent the ends of the winding have increasing radial spacing from the low voltage winding toward the end of the high voltage winding. This may be accomplished, as illustrated in Fig. 3, by providing annular insulated spacing members 73 of increasing radial thickness toward the end of the high voltage winding between the cylinder 37 and the inside edges of the coil 40 adjacent the end of the high voltage winding. The contour of the outside of the high voltage winding is not as important in regard to danger of sparkover, and may be straight as shown in Fig. 3.

Referring still to Fig. 3, there are several circulation paths for the dielectric fluid through the windings. A portion of the fluid is forced upwardly in the duct 22, and thence horizontally across the faces of the high voltage coils and out through the opening 21. Other portions of the fluid are forced upwardly between the insulating cylinders 35 and 37, between the insulating cylinders 34 and 35, between the low voltage winding and the cylinder 34, and between the radially spaced sections of the low voltage winding. The axially extending spacers 33, 36 and 38 preferably do not extend beyond the end of the high voltage winding, in order to reduce the stress on the dielectric fluid resulting in a difference in permittivity between the fluid and the solid insulation. This is especially important when gaseous insulation is employed.

Referring now to Fig. 4, the curves 80, 81 and 82 are impulse breakdown voltage versus gap spacing characteristics for askarel, 10-C oil, and air respectively using one-half inch square brass electrodes. The curves 83 and 84 are similar curves for askarel and oil respectively using 12.5 centimeter spherical electrodes. The voltage impulses were 1.5 microsecond in duration and were separated from each other by about 40 microseconds. From

these curves it may be seen that askarel has better impulse characteristics than oil with spherical electrodes, or in other words in a substantially uniform field, while oil has better impulse characteristics than askarel in the non-uniform field provided by the square electrodes. From this curve it may also be seen that the impulse strength of askarel does not increase appreciably for gap spacings above about two inches. Extension of the curves 80 and 82 indicates that a spacing of about 13 inches or greater, the impulse strength of air is better than that of askarel in a non-uniform electrical field. In Fig. 5 curves 85 and 86 illustrate the impulse breakdown voltage versus gap spacing characteristics for spherical and square electrodes respectively in sulphur-hexafluoride. This curve illustrates that sulphur-hexafluoride, like askarel, provides substantially no increase in impulse strength above about two-inch gap spacings in a non-uniform field, while the impulse strength is a linear function of the gap spacing in a uniform field.

In view of these characteristics of halogenated dielectric fluids, the present invention provides means for reducing the non-uniformity of the electrical field in high stress regions of stationary electrical induction apparatus in order to improve the impulse strength of the apparatus. Thus, in the transformer illustrated in Fig. 3, smooth contours have been provided on the core and windings by providing a dish-shaped shield adjacent the ends of the winding and electrically connected to the core, a semi-circular cross section annular shield on the ends of the high voltage winding, and a rounded annular shield on the ends of the low voltage winding. Further improvement results in increasing the radial spacing between the respective ends of the high and low voltage windings.

Although this invention has been disclosed with particular reference to a three phase transformer, it is obvious that the principles involved may be employed without departing from the spirit and scope of the invention in other stationary electrical induction apparatus such as single phase transformers.

It will be understood, of course, that, while the form of the invention herein shown and described constitutes a preferred embodiment of the invention, it is not intended herein to illustrate all of the possible equivalent forms or ramifications thereof. It will also be understood that the words used are words of description rather than of limitation, and that various changes may be made without departing from the spirit or scope of the invention herein disclosed, and it is aimed in the appended claims to cover all such changes as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A stationary electrical induction apparatus comprising an enclosed tank, a halogenated dielectric fluid within said tank, a magnetic core immersed in said fluid and having a plurality of parallel leg members at least one of which is adapted to receive electrical windings, said leg members being joined at their respective ends by a pair of yoke members, a low voltage winding surrounding said one leg member and insulated therefrom, a high voltage winding surrounding said low voltage winding and radially spaced therefrom, said high voltage winding being comprised of a plurality of axially spaced apart disk-shaped coils each having a plurality of individual turns, first annular shield means having a substantially semi-circular cross section mounted coaxially on one end of said high voltage winding and having its flat side toward said high voltage winding, said first annular shield means being electrically connected to a turn of the endmost coil on said one end of said high voltage winding, the several coils of said high voltage winding adjacent said one end having increasing radial spacing from said low voltage winding toward said one end of said high voltage winding, one end of said low voltage winding extending axially beyond said one end of said high voltage winding, a

second annular shield means mounted coaxially on said one end of said low voltage winding and connected to a turn on said one end of said low voltage winding, said second annular shield means having a cylindrical portion having one end adjacent said one end of said low voltage winding and extending coaxially from said one end of said low voltage winding and a curved portion extending a substantially uniform curvature extending radially inward from the other end of said cylindrical portion, and a dish-shaped shield member having a flat central portion and a curved outermost portion, said shield member being axially spaced from said annular shield means with said flat portion lying in a plane perpendicular to the axis of said leg member, said shield having an aperture through which said core extends, said shield member being electrically connected to said core, said flat portion extending at least from the radially outermost extremity of said low voltage winding to the radially outermost extremity of said high voltage winding, said outermost portion having a substantially uniform curvature away from said windings, said curvature of said outermost portion being less than the curvature of said first annular shield means, said annular shield means and dish-shaped shield and the increasing radii of said coils toward said one end of said high voltage winding being proportioned to provide a substantially uniform electrostatic field surrounding said high voltage winding.

2. A stationary electrical induction apparatus comprising an enclosed tank, a halogenated fluid within said tank, a magnetic core immersed in said fluid and having a plurality of parallel winding leg members joined at their respective ends by a pair of yoke members, a low voltage winding surrounding each of said leg members, a high voltage winding surrounding each of said low voltage windings and being radially spaced from their respective low voltage winding, said high voltage windings being each comprised of a plurality of axially spaced apart disk-shaped coils each having a plurality of individual turns, first annular shield means mounted coaxially adjacent each end of each of said high voltage windings, second annular shield means mounted coaxially adjacent each end of said low voltage windings, said first annular shield means each having a substantially semicircular cross section and being electrically connected to a turn of the respective end coil of said high voltage windings, said first annular shield means having their flat sides toward the ends of the respective high voltage windings, said second annular shield means each being electrically connected to a turn on the end of the respective low voltage winding and having a cylindrical portion having one end adjacent one end of said low voltage winding and extending from the radially outermost extremity of said respective low voltage winding and a curved portion extending from the other end of said cylindrical portion and having a substantially uniform curvature extending radially inwardly from said cylindrical portion and away from said low voltage winding, the several coils of said high voltage windings toward the ends of said high voltage windings having increasing radial spacing from their respective low voltage windings toward the ends of said high voltage windings, and a dish-shaped shield member having a flat central portion and a curved outermost portion disposed at each end of said windings and axially spaced from said annular shield means, said flat portions lying in planes perpendicular to the axes of said leg members and extending at least from the radially outermost extremities of said low voltage windings to the radially outermost extremities of said high voltage windings, apertures through said shield members through which said core extends, said shield members being electrically connected to said core, said outermost portions having substantially uniform curvature away from said windings and less than the curvature of said first annular shield means, said shield means and shield member and the inner radii of said high voltage windings being proportioned to provide a substantially

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uniform electrostatic field surrounding each end of each
of said high voltage windings. 2,153,090
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