

C. LE G. FORTESCUE.
TRANSFORMER.

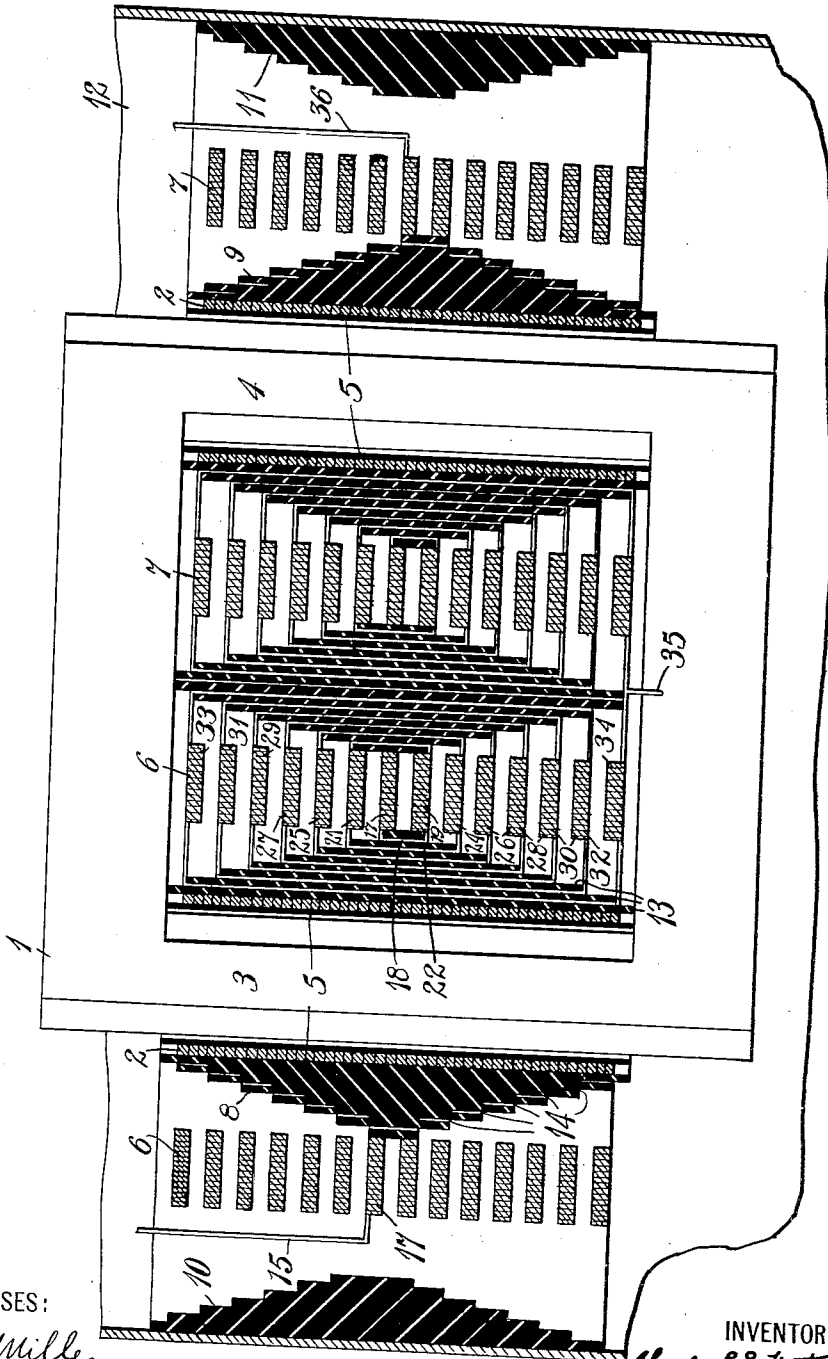
APPLICATION FILED OCT. 8, 1910. RENEWED AUG. 20, 1914.

1,129,474.

Patented Feb. 23, 1915.

3 SHEETS—SHEET 1.

Fig. 1.



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3 SHEETS—SHEET 2.

Fig. 2.

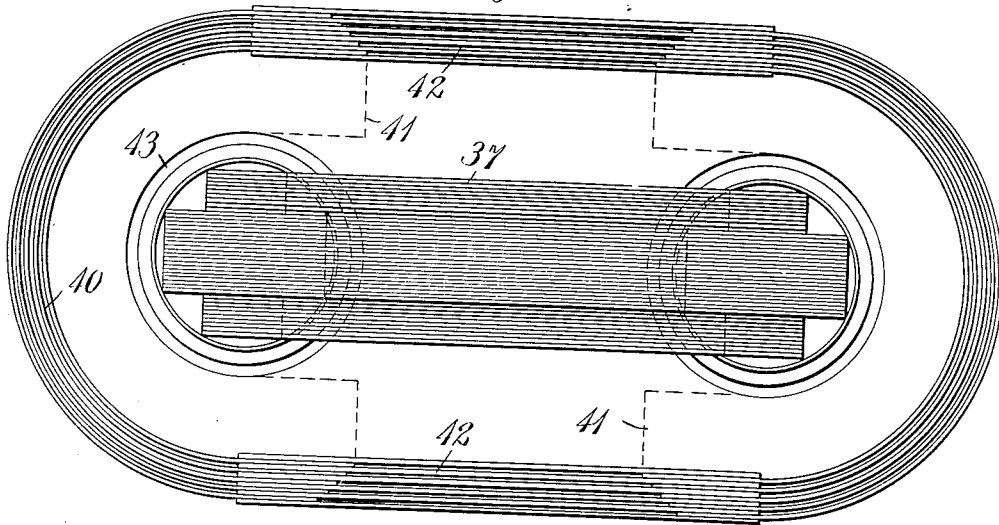
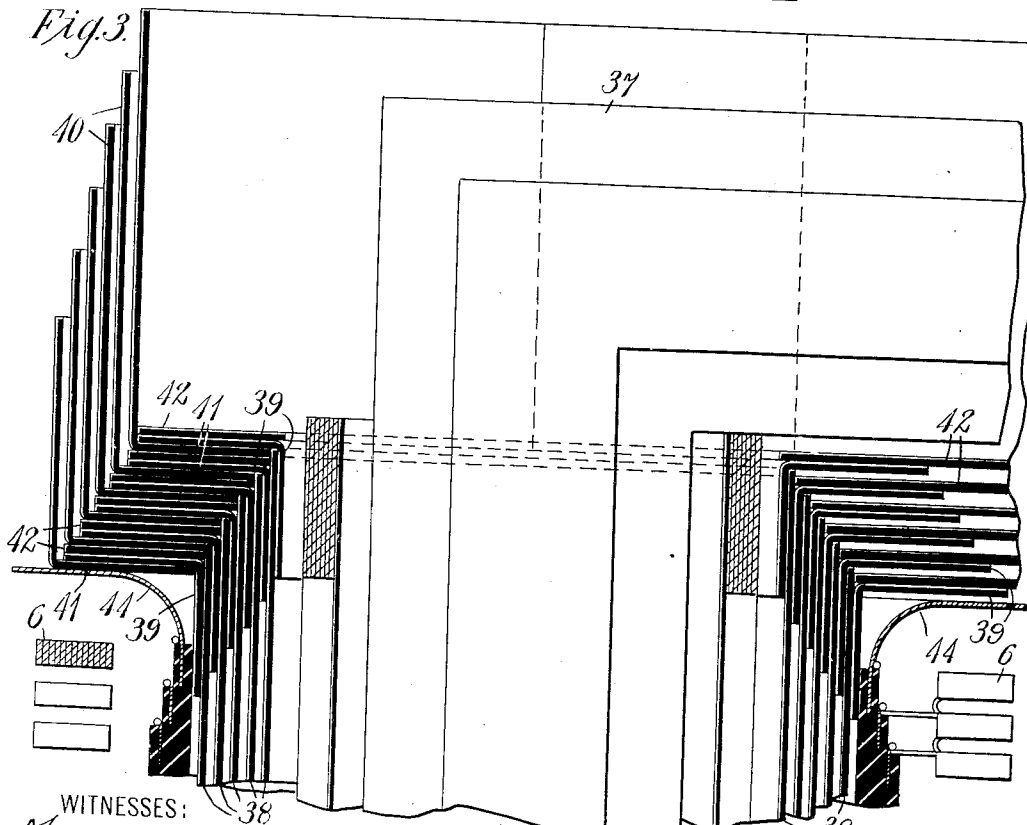


Fig. 3.



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3 SHEETS—SHEET 3.

Fig. 4.

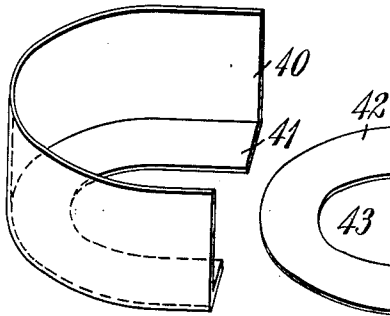


Fig. 5.

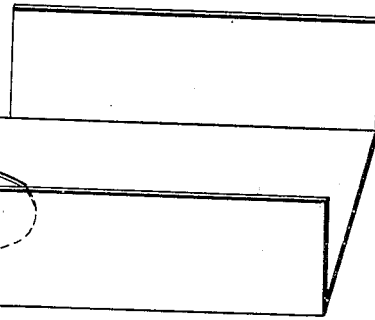


Fig. 6.

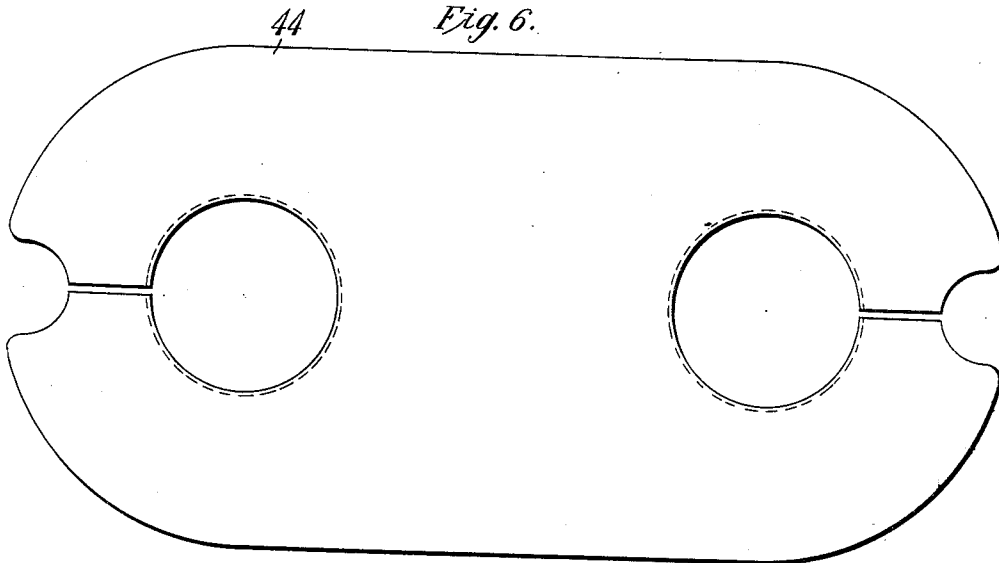
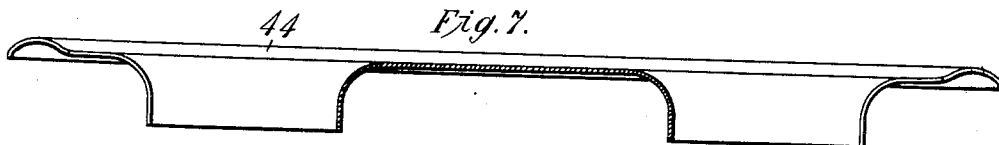


Fig. 7.



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UNITED STATES PATENT OFFICE.

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TRANSFORMER.

1,129,474.

Specification of Letters Patent.

Patented Feb. 23, 1915.

Original application filed August 2, 1909, Serial No. 510,854. Divided and this application filed October 8, 1910, Serial No. 586,099. Renewed August 20, 1914. Serial No. 857,774.

To all whom it may concern:

Be it known that I, CHARLES LE G. FORTESCUE, a subject of the King of Great Britain, and a resident of Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Transformers, of which the following is a specification, this application being a division of Case 2308, Serial No. 510,854, filed August 2, 1909.

My invention relates to electrical apparatus, and it has special reference to the windings and insulation of transformers which are adapted for use with very high-voltage circuits.

The general object of my invention is to provide such a winding and such an insulating structure that the stress exerted by the voltage of the coils shall be properly distributed through the insulation, with a view to reducing the space occupied by, and the manufacturing cost of high-voltage transformers and apparatus of this class.

My invention is applicable to all types of transformers but it is particularly adapted for application to transformers of the core type.

In my co-pending application, Serial No. 510,854, filed August 2, 1909, of which this application is a division, I have illustrated and described a transformer having a plurality of coils which are separated from the core member and from each other by insulation of the condenser type, the connections between coils being established through the condenser plates of the insulation. When a series of condensers are associated with a transformer in this manner, electric disturbances are liable to be introduced which, under certain conditions, may rupture the insulation that immediately surrounds the charged conductor.

According to the present invention there are no disturbances in the insulating structure resulting from the existence of capacities between the conductors that constitute a part thereof, because the potentials of said conductors are fixed at the values they would have if the surfaces of the parts to be insulated were extended infinitely, or as far as possible.

Figure 1 of the accompanying drawings is a sectional elevation of a transformer core and windings arranged and insulated in accord-

ance with my invention. Figs. 2 and 3 are respectively, a plan view and a sectional elevation of a portion of a transformer, a novel insulating structure for separating the coils from the core member, in all directions, being set forth. Figs. 4, 5, 6, and 7 are detail views of the structure shown in Figs. 2 and 3.

Referring to the drawings, the structure here shown comprises a substantially rectangular core member 1, a low-potential winding 2 that is divided into two groups of coils which surround two opposite legs 3 and 4 of the core member 1 and are separated therefrom by insulating sleeves 5, or by some other suitable means, a primary winding composed of two groups 6 and 7 of relatively flat coils, insulating sleeves 8 and 9 on the respective core legs, between the low and high-potential windings, and insulating barriers 10 and 11 that separate the high-potential windings from each other and from the walls of the tank or casing 12, in which the transformer is located. The core legs 3 and 4 may be of any suitable form, but are preferably cruciform in cross section, in order to economize space and to reduce the mean length of turn in the coils.

The insulating sleeves 8 and 9 are alike, each preferably comprising a plurality of insulating cylinders 13 and conducting rings 14. The conducting rings are of different diameters and are so located between the layers of insulation that their adjacent edges are in approximately the same plane. The insulating cylinders 13 are preferably of graded lengths, as shown in Figs. 1 and 3 of the drawings, although their lengths are not material, so long as the conducting rings are properly located and separated from each other.

If the lowest-voltage coils of the high-potential winding are grounded, they may be located very close to the core structure (see Fig. 1), but if the potential difference between these coils and the core is liable to be great, they should be separated or protected from the adjacent core legs, as shown in Fig. 3. The circuit connections for the primary windings are clearly shown in Fig. 1, to which special reference may now be had.

As here shown, a connection may be completed from a high-potential external circuit, through a conducting lead 15 to coil 17,

from which circuit is continued through conducting ring 18 of the bushing 8 to coil 19. From the outer turn of this coil, circuit is continued to connector 20, which is embedded in barrier 10, to the outer turn of coil 21. From the inner turn of coil 21, circuit is continued through connector 22, which joins together the rings that are adjacent to the respective edges of the middle ring 14, to coil 24 and from thence, circuit is similarly continued through coils 25 to 34, inclusive, the outer turn of the latter coil being grounded at 35. The outer turn of the corresponding coil of the group 7 is also grounded and circuit is completed between terminal 36 and the point 35, as already described for coil group 6.

The rings are connected to such intermediate points in the transformer winding that the potential of each is fixed at a value which corresponds to the potential of the same surface in a field which would exist between the high potential ring and the core member if their parts were concentric conducting cylinders of infinite length. In other words, such a distribution of potential is established over the surfaces of the insulating body that extend between the parts to be insulated as will produce substantially the same static field or stress distribution as would exist if the said parts were cylinders of infinite length or other surfaces of infinite area. In the case of cylinders of infinite length, the field or stress distribution between them follows the logarithmic law, and it is in accordance with this law that the potentials of the conductors are fixed in the insulating structures illustrated. It will, of course, be understood that the law according to which the potentials of the conductors adjacent to the surfaces of the insulating body are fixed, depends upon the shape of the surfaces of the parts to be insulated. For instance, the logarithmic law holds for concentric cylinders and the uniform law for parallel planes.

No conductor in the structure has a definite capacity to any other conductor, but its capacity is a function of its own potential and those of the remaining conductors. Consequently, its potential, as determined by its connection to the transformer winding, cannot be changed by resonance with the inductance of any portion of the winding of the transformer, because such a change would at once cause a change in capacity, which would at once destroy the requisite condition for resonance. Contiguous edges of adjacent rings are preferably in the same plane, in order to obtain the desired stress distribution in the insulation.

It is evident that insulating structures similar to the bushings 8 and 9 may be adapted for other windings and to polyphase transformers, and the coils may ob-

viously be arranged and connected in other relations to the insulating bushings or structures than those here illustrated without departing from the spirit of the invention.

In Figs. 2 and 3 a telescoping insulating structure is provided for completely separating the transformer coils from all parts of the core member, this structure being a modification of the insulating structure set forth in Patent No. 885,771, granted April 28, 1908, to the Westinghouse Electric & Manufacturing Co., upon an application filed by J. E. Mateer.

Referring specially to Figs. 2 and 7, inclusive, transformer coils 6 are separated from the core 37 by an insulating structure comprising a plurality of insulating cylinders 38, insulating collars 39 which are of angle-shape in cross section, segmental flattened cylinders 40 having flanges 41 that are interleaved with the collars 39, and plates 42 having holes 43 through which the core legs extend and which are so disposed between the flanges and the collars as to completely separate the coils from the core. The parts of the insulation are overlapped, as already pointed out, and, consequently, the surface leakage distances between the nearest coils and the transformer core is very great. The flattened cylindrical surfaces and insulating plates, and their form may be modified to accommodate any transformer tank or casing.

A metal plate 44 is so constructed and disposed as to prevent the formation of a corona at the outer corner of each of the end coils of the high voltage groups. Conducting cylinders and plates may be inserted between the corresponding insulating parts of the telescoping structure, and, when inserted, they should be interconnected according to their distance from the core and casing, in order to avoid the distortion of the stress distribution by the effect of the aforesaid grounded parts.

I claim as my invention:

1. In electrical apparatus, the combination with a magnetizable core, and a winding therefor, of an insulating structure disposed between said core and said winding and comprising an insulating body and a plurality of offset conducting rings having a straight line for the locus of their centers and connected to intermediate points in the winding.

2. In electrical apparatus, the combination with a magnetizable core and a winding therefor, of an insulating structure disposed between said core and said winding and comprising a plurality of concentric cylindrical sleeves of insulation and a series of conducting rings or short cylinders of different diameters arranged end to end, the axis of the insulating cylinders being a locus of the centers of the rings.

3. In electrical apparatus, the combination with a magnetizable core and a winding therefor, of an insulating structure disposed between said core and said winding and comprising a plurality of concentric cylindrical sleeves of insulation and a series of conducting rings or short cylinders of different diameters arranged end to end and connected to intermediate points in the winding, the axis of the insulating cylinders being a locus of their centers.

4. In a transformer, the combination with a substantially rectangular core, and a plurality of coils disposed upon the respective legs thereof, of an insulating structure comprising insulating cylinders and telescoping insulating angle collars, plates and segmental cylinders for separating the coils from the core member.

5. In a transformer, the combination with a substantially rectangular core and two groups of coils disposed upon the respective core legs, of a plurality of insulating cylinders disposed between the coil groups and the core legs on which they are mounted, insulating collars of angular section interleaved with the cylinders at their ends and projecting outwardly therefrom, flanged insulating plates, having holes through which the core legs project, interleaved with the outwardly extending annular projections from the collars, and flanged segmental cylinders interleaved between the outer ends of the plates and projecting upwardly to effectively separate the groups of coils from the core.

6. In electrical apparatus, the combination with a magnetizable core and a winding, of an insulating structure disposed between the core and the said winding and comprising a plurality of conducting rings or short cylinders of different diameters coaxially arranged end to end and embedded in the insulation.

7. An insulating structure comprising a sleeve of insulating material, and spaced conductors adjacent to the end faces only of the sleeve.

8. An insulating structure comprising a sleeve of insulating material that gradually decreases in external diameter from an intermediate point toward its ends, and spaced conductors adjacent to the end faces only of the sleeve.

9. An insulating structure comprising a sleeve of insulating material that gradually and similarly decreases in external diameter from an intermediate point toward its ends,

and spaced conductors adjacent to the end faces of the sleeve.

10. An insulating structure comprising a body of insulating material that gradually decreases in thickness from an intermediate point toward its ends, and spaced conductors adjacent to the end faces only of the said body.

11. An insulating structure comprising a body of insulating material that gradually and similarly decreases in thickness from an intermediate point toward its ends, and spaced conductors adjacent to the end faces of the said body.

12. The combination with two members to be insulated from each other, of an interposed insulating body, and spaced conductors adjacent to only the portions of the surfaces of the insulating body that extend between the said members.

13. An electrical device comprising a winding, an adjacent insulating structure that is tapered in opposite directions from an intermediate point, conducting rings adjacent to the tapered faces of the structure that are connected to the winding, and conductors extending through the structure and connecting corresponding rings at opposite ends thereof.

14. In electrical apparatus, the combination with a winding, of an insulating structure having similarly stepped ends, conducting rings adjacent to the steps in the insulating structure, and conductors extending through the insulating structure and connecting corresponding rings at opposite ends thereof.

15. In electrical apparatus, the combination with a winding, of an insulating structure having similarly stepped ends, and conducting rings adjacent to the steps in the insulating structure, the rings being of approximately the same widths as the steps.

16. An electrical device comprising a plurality of side-by-side coils, an insulating structure adjacent to the coils and composed of superposed layers of insulation of graded lengths, and conductors that are adjacent to the ends only of the respective layers and are connected to the coils.

In testimony whereof, I have hereunto subscribed my name this 23rd day of Sept., 1910.

CHARLES LE G. FORTESCUE.

Witnesses:

HELEN BURTON,
B. B. HINES.