Dec. 17, 1946. A. G. GANZ 2,412,609

HIGH VOLTAGE TRANSFORMER

Filed Jan. 15, 1944

FIG. 1

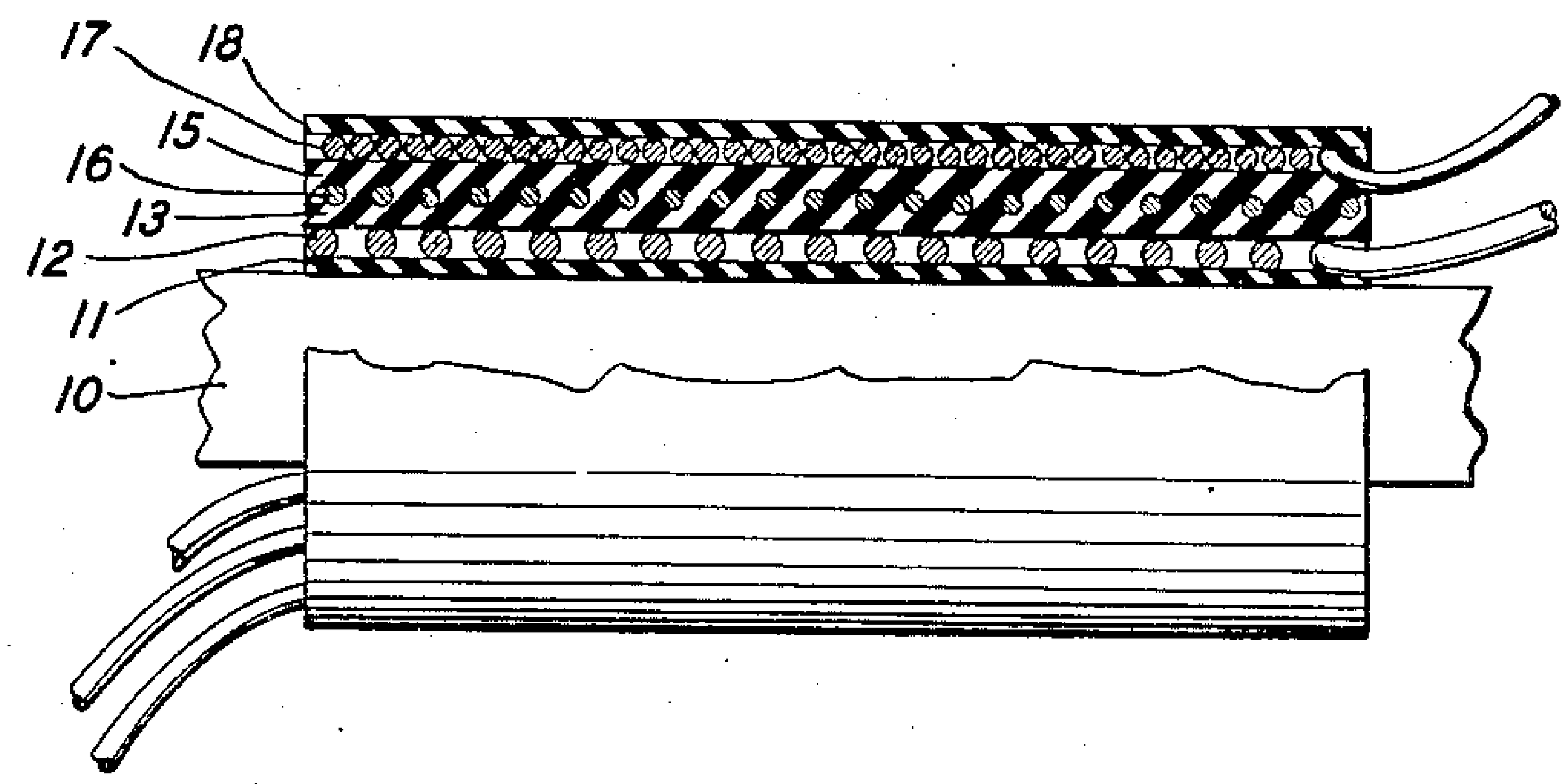


FIG. 2

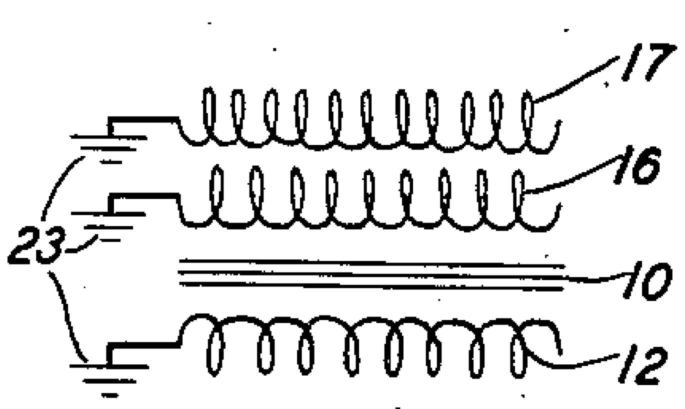


FIG. 3

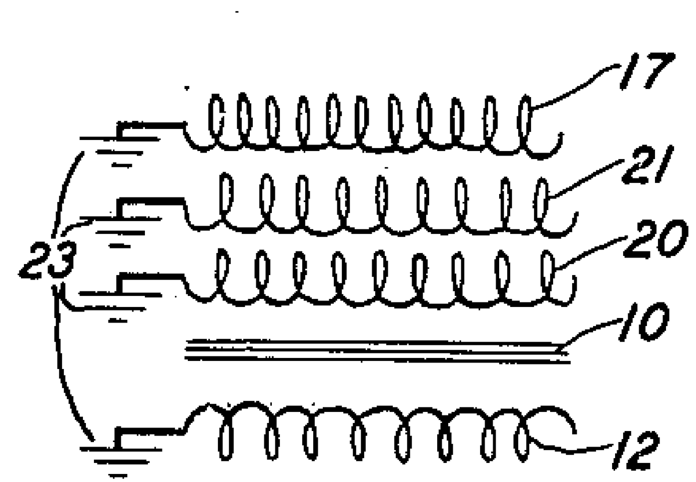


FIG. 4

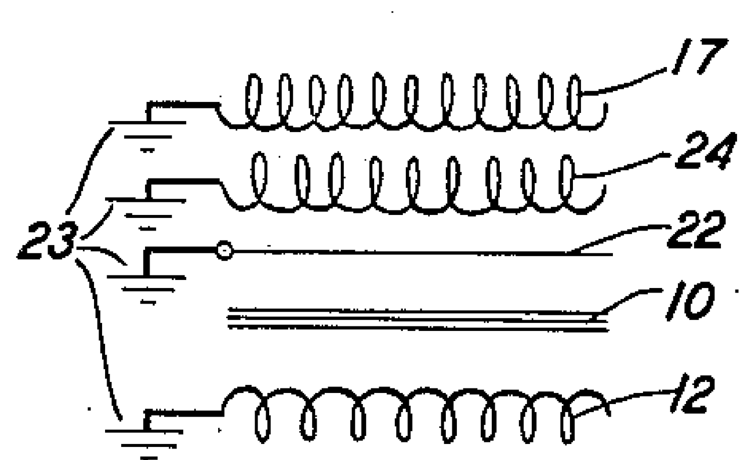
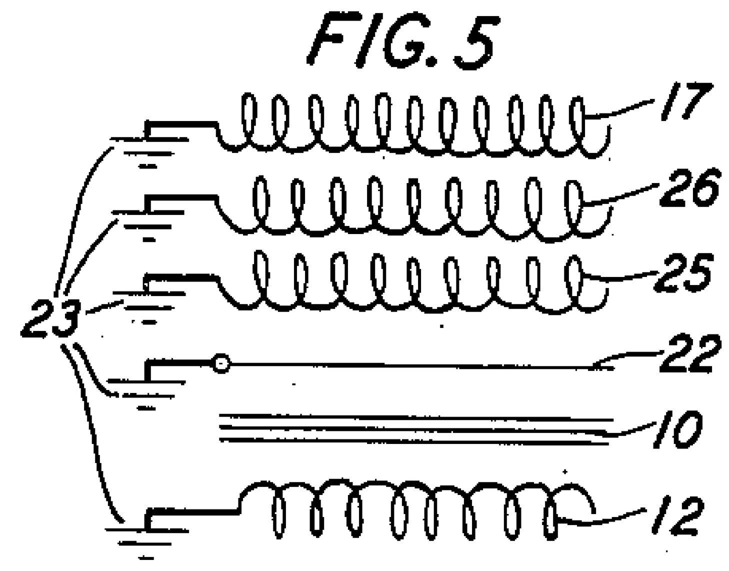


FIG. 5



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HIGH-VOLTAGE TRANSFORMER

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7 Claims. (Cl. 175—356)

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This invention relates to transformers and particularly to transformers subjected to high voltages.

In high voltage transformers the insulation between windings is of considerable importance in insuring against transformer failure in service. Increasing the amount of insulation between the windings is one way of obtaining a high safety factor, but increasing the insulation increases transformer size and cost and reduces the transformer efficiency, particularly where a wide band of frequencies is transmitted. Where space is limited and weight must be a minimum, as for example in airplanes, means for increasing the effectiveness of insulation is especially valuable since it reduces the amount that would be required.

An object of the present invention is a high voltage transformer in which the thickness of insulation between windings is reduced while still retaining a high safety factor.

Another object of the invention is a high voltage transformer having a high efficiency and which is of small size and low weight in relation to the voltage and power involved.

A further object of the invention is to increase the uniformity of the potential gradient across the insulation between the windings of a high voltage transformer.

In one embodiment, this invention comprises a single layer auxiliary winding between a single layer secondary winding and a single layer primary winding of the transformer. This auxiliary winding is open-circuited. When the primary winding is subjected to a voltage, there is induced in the auxiliary winding a voltage dependent upon the number of turns of the auxiliary winding. If the auxiliary winding is located between the secondary winding and the primary winding at a proper position determined by the number of turns therein, the insulation is effectively divided into two sections, each of which is subjected to only a fraction of the original voltage. The potential gradients throughout the insulation will, therefore, be maintained more nearly uniform.

The invention will be better understood from the following description in connection with the attached drawing, in which:

Fig. 1 is a partial section of a simplified form of transformer embodying the invention;

Fig. 2 is a schematic circuit of the transformer of Fig. 1;

Fig. 3 is a schematic circuit of a transformer in which two auxiliary windings are used;

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Fig. 4 is a schematic circuit of a transformer showing the arrangement when a grounded shield and one auxiliary winding are used; and

Fig. 5 is a schematic circuit of a transformer showing the arrangement when a grounded shield and two auxiliary windings are used like parts in the different figures having like indicia.

The simplified form of the invention shown in Fig. 1 shows a part of the core 10 which may be of any magnetic or non-magnetic material and the core form may be of any type. Insulation 11 is placed on core 10 and single layer primary winding 12 of N_p turns is wound thereon. Insulation 13 is placed on winding 12 and single layer auxiliary winding 16 of N_a turns is wound thereon. Additional insulation of thickness equal to 13 is placed on auxiliary winding 16 and single layer secondary winding 17 of N_s turns is wound thereon, over which is placed insulation 18. The auxiliary winding 16 is thus located half way between windings 12 and 17. The left ends of the windings are at ground potential.

When a voltage is applied to primary winding 12 there are induced in auxiliary winding 16 and secondary winding 17 voltages dependent upon the voltage of winding 12 and the ratio of turns between winding 12 and the respective windings.

If the number of turns of winding 16 is equal to $\frac{1}{2}(N_s+N_p)$, the voltage induced in winding 16 will be the average of that in winding 12 and that induced in winding 17. Furthermore, each turn of winding 16 will then have a potential equal to the average of that in the nearest primary and secondary turns. These potentials are the same as would exist theoretically at the location of the auxiliary winding turns in an absolutely uniform dielectric without any auxiliary winding. Since dielectric materials in practice are not uniform, the potentials at these points would ordinarily depart from the ideal values, resulting in excessive gradients in portions of the insulation. Thus the auxiliary winding by maintaining the mid-section of the insulation at the proper potentials provides more nearly uniform potential gradients throughout the insulation. This increases the effectiveness of the insulation and permits a substantial reduction in its thickness without decreasing the safety factor.

More than one auxiliary winding may be used if desired. If two auxiliary windings are used and are spaced at equal intervals between the primary winding having N_p turns and the secondary winding having N_s turns, then the number of turns in that winding which is nearer the primary winding should be equal to $\frac{1}{3}(2N_p+N_s)$

and the number of turns in the auxiliary winding nearer the secondary winding should be equal to $\frac{1}{3}(N_p+2N_s)$. In this way the potential gradient will be maintained substantially uniform throughout the insulation.

A transformer having two auxiliary windings is illustrated schematically in Fig. 3. In this case the number of turns in auxiliary winding 20 may be equal to $\frac{1}{3}(2N_p+N_s)$ and be spaced from winding 12 one-third the distance between windings 12 and 17, while the number of turns in auxiliary winding 21 may be equal to $\frac{1}{3}(N_p+2N_s)$ and be spaced from winding 12 two-thirds of the distance between windings 12 and 17.

In Fig. 4 there is illustrated the arrangement when an electrostatic shield is used. As is usual in such cases, shield 22 is shown grounded at 23. Since the shield is at ground potential and the primary winding 12 is the low potential winding, the potential gradient between winding 12 and shield 22 is not of major importance. Auxiliary winding 24 is, therefore, positioned with reference to the shield 22 and high voltage winding 17 and should have one-half the number of turns of winding 17 if spaced from shield 22 one-half the distance between shield 22 and winding 17.

If two auxiliary windings and a shield are used, the distance between the shield and the high voltage winding controls and the auxiliary windings may be spaced at equal intervals between the shield and the high voltage winding. The auxiliary winding nearer the shield should have one-third and the other auxiliary winding two-thirds the number of turns of the high voltage winding.

Fig. 5 is a schematic of a transformer having an electrostatic shield 22 and two auxiliary windings 25 and 26 located between primary winding 12 and secondary winding 17. Auxiliary winding 25 should have one-third the number of turns of secondary winding 17 and be spaced from shield 22 one-third the distance between the shield and winding 17 while auxiliary winding 26 should have two-thirds the number of turns of winding 17 and be spaced from shield 22 two-thirds the distance between the shield and winding 17.

In the drawing all of the windings are shown with one terminal connected to ground. The grounded terminal for the primary and secondary windings is not essential and may be omitted if desired. However, the connection to ground of one terminal of the auxiliary winding or windings is preferable to insure that the auxiliary winding does not float.

The invention may also be applied to configurations other than cylindrical windings. The turns of the auxiliary winding or windings may be embedded in the insulation of a coil of any structure to fix the potentials at particular points within the body of the insulation to predetermined values. By these means the potential gradients may be controlled so as to avoid excessive values.

The present invention is of particular value where the voltage developed across the secondary winding is of the order of 10,000 volts or higher.

It is desired to point out also that the potential gradient may be controlled to give any desired values. If for any reason it is desired that the potential gradient be other than uniform, the position and number of turns of the auxiliary windings may be arranged accordingly.

The invention may be carried out in other specific ways than those herein set forth without

departing from the spirit and essential characteristics of the invention and the present embodiment is, therefore, to be considered in all respects as illustrative and not restrictive and all changes coming within the meaning and equivalency range of the appended claims are to be embraced therein.

What is claimed is:

1. A high voltage electrical transformer comprising a primary winding, a secondary winding, insulation separating said windings, and means for insuring a substantially uniform potential gradient between said windings, said means comprising an open circuited auxiliary winding placed between said primary and secondary windings and insulated therefrom, the number of turns in said auxiliary winding being such as to cause to be induced in each elementary portion of said auxiliary winding a potential which is substantially the same as would exist at the relative location of said portion in an absolutely uniform dielectric in the absence of said auxiliary winding.

2. A high voltage electrical transformer comprising a primary winding, a secondary winding, insulation separating said windings, and means for insuring a substantially uniform potential gradient in said insulation, said means comprising an open circuited auxiliary winding located between said primary and secondary windings, the relation of the number of turns in said auxiliary winding to the number of turns in said other windings determining the distance between said auxiliary winding and said other windings.

3. A high voltage electrical transformer comprising a primary winding, a secondary winding adapted to have developed across its terminals an alternating current voltage at least of the order of 10,000 volts, insulation separating said windings, and an open-circuited auxiliary winding located substantially half way between said primary and secondary windings, the number of turns in said auxiliary winding being substantially equal to one-half the sum of the number of turns in said primary and secondary windings.

4. A high voltage electrical transformer comprising a primary winding, a secondary winding, insulation separating said windings, and a plurality of open-circuited auxiliary windings between said primary and secondary windings, said auxiliary windings having different numbers of turns, the auxiliary winding having the larger number of turns being positioned nearer said secondary winding.

5. A high voltage electrical transformer comprising a primary winding, a secondary winding, a grounded electrostatic shield therebetween, an open-circuited auxiliary winding and insulation separating said shield and windings, said auxiliary winding having about one-half the number of turns of said secondary winding and being positioned about half-way between said shield and said secondary winding.

6. A high voltage electrical transformer comprising a primary winding, a secondary winding, insulation separating said windings, and a plurality of open circuited auxiliary windings between said primary and secondary windings, the number of turns of said auxiliary windings and their location in reference to said primary and secondary windings being determined by the potentials which would exist in an absolutely uniform dielectric at the positions of said auxiliary windings.

7. A high voltage electrical transformer com-

prising a single layer primary winding, a single layer secondary winding surrounding said primary winding and spaced therefrom, insulation between said windings, and means for insuring a substantially uniform potential gradient between said windings, said means comprising an open-circuited single layer auxiliary winding spaced between said primary and said secondary windings and insulated therefrom, one end of said auxiliary winding being substantially at ground potential, the number of turns in said auxiliary winding being such as to cause to be induced in an elementary portion of said auxiliary winding a potential which is substantially the same as would exist at the relative location of said portion in an absolutely uniform dielectric in the absence of said auxiliary winding.

ALBERT G. GANZ.