Dec. 17, 1957 G. SCARPA 2,817,066

ELECTRIC TRANSFORMER

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Fig. 1

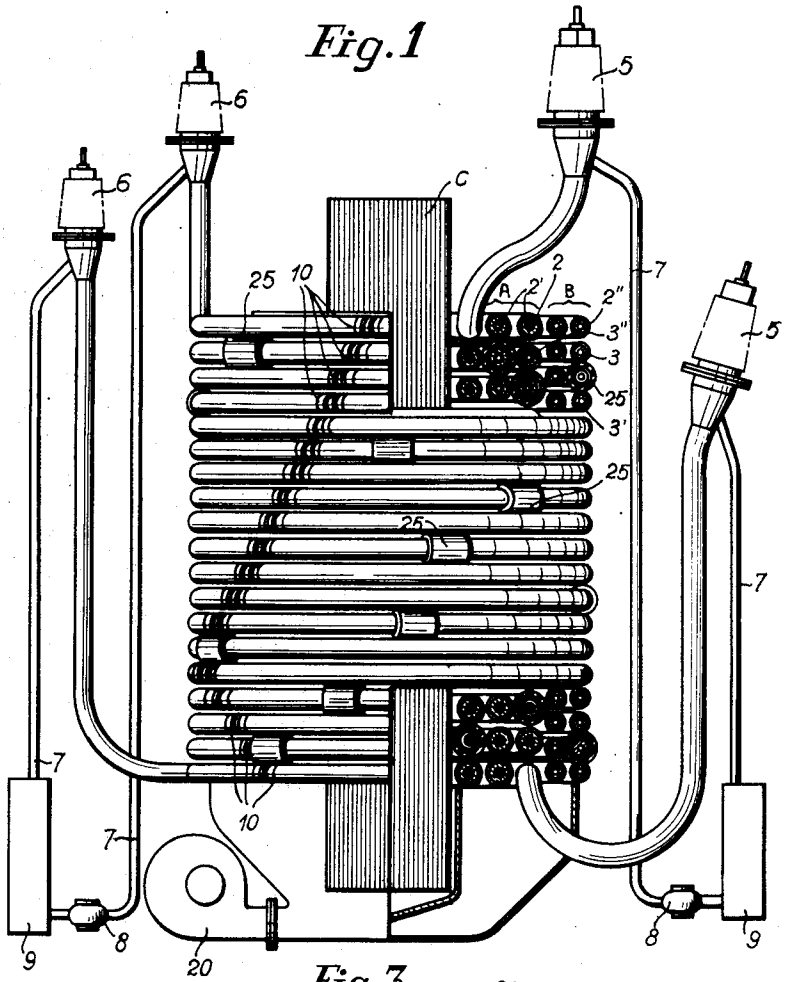
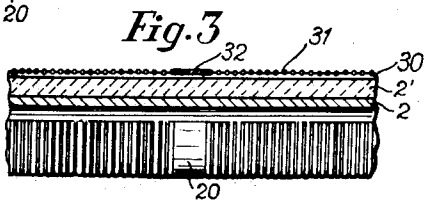


Fig. 3



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Fig. 5

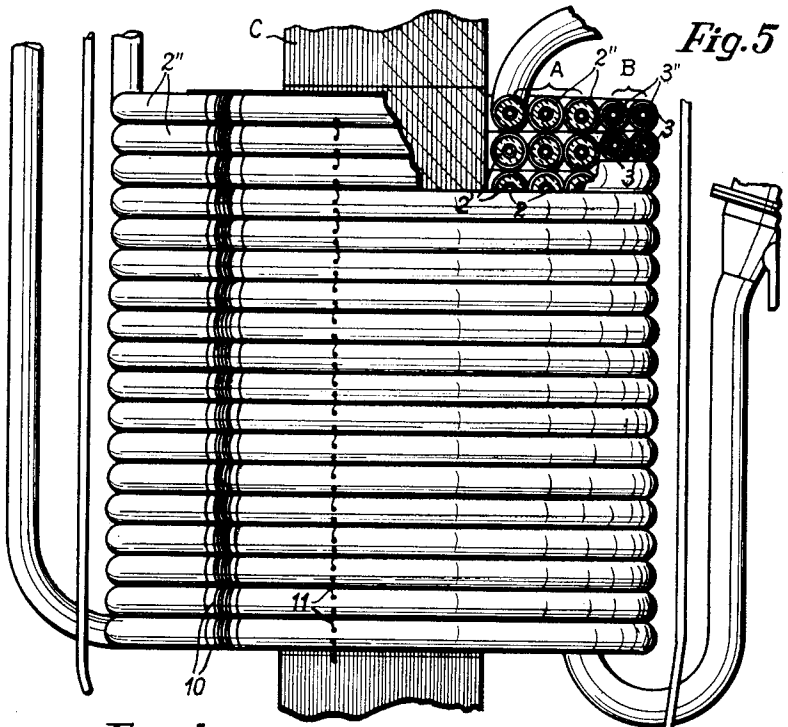


Fig. 4

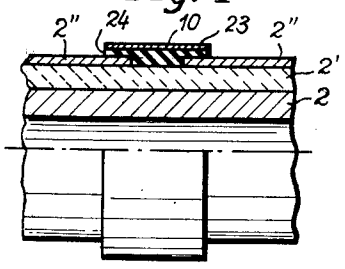
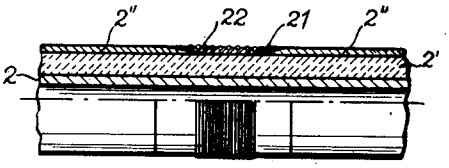


Fig. 2



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ELECTRIC TRANSFORMER

Giuseppe Scarpa, Milan, Italy

Application August 11, 1954, Serial No. 449,071

Claims priority, application Italy October 27, 1950

7 Claims. (Cl. 336—84)

This application is a continuation-in-part of my co-pending application Serial No. 209,927 filed February 8, 1951, now abandoned.

This invention relates to improvements in electric transformers.

More particularly, the present invention is especially well suited for transformers for high power systems and high voltage transformers of the type in which it is desired to eliminate the large quantity of oil and casing therefor usually required for satisfactory insulation and cooling of the coils of the transformer windings.

The principal object of this invention is to provide a transformer of the type referred to above which is capable of satisfactorily withstanding the action of electrical or arc discharges between adjacent turns and adjacent coils of the transformer windings, respectively, as occur in known transformers in the presence of steep-front voltage waves, such as atmospheric discharges, etc.

A further object of this invention is to provide a transformer of the type referred to above in which the insulation surrounding the conductors from which the turns and coils are made operates under exactly defined electric field conditions, permitting the use of layers of insulating material of reduced thickness for insulating the coil conductors, and permitting very high operating voltages for the transformer without any risk of deterioration of the transformer insulation or of discharges between the turns or coils, respectively.

A further object of this invention is to provide a transformer of the type referred to above in which the conductors and the insulation thereof are efficiently protected against attack by atmospheric agents, such as moisture, corrosive fluids, etc.

Yet another object of the present invention is to provide an improved transformer of the above character which is of simple design and construction, economical to manufacture and highly efficient in the accomplishment of its intended purpose.

Still another object of this invention is to provide a transformer of the type referred to in which the risk of fire in the insulation is minimized.

It may be broadly stated that transformers, more particularly transformers for high power systems, presently manufactured, on any principle whatever, afford satisfactory results in respect of insulation between the high-voltage winding and ground and between high-voltage and low-voltage windings. Most accidents occurring in transformers are due either to discharges between the individual turns of some coils, at times of the first or of the next coil when the turns of the first coils are highly insulated, or in discharges between the individual coils.

Attempts have been made to obviate these serious drawbacks due to extra-steep-front waves by increasing the insulation between the turns of the end coils. However, if the construction is of the conventional type, it is not convenient, from an economical standpoint, to make the insulation between the turns of the whole winding of a size

such as to resist all over-voltages which may occur during operation.

An attempt has been made to overcome this difficulty by the so-called anti-resonating transformers, in which suitable screening modifies the capacity between the coils, in order to improve voltage distribution when a steep-front wave is applied to the transformer. This is an expensive arrangement which does not, however, fully solve the problem as the present arrangement does. The present arrangement moreover dispenses with the large volume of oil required by large transformers.

The present arrangement is extremely simple and fully meets the desired operating requirements. From an economical standpoint, it is more particularly useful with very high-tension transformers. By way of a rough approximation, the economical limit of use, which is related to the voltage of the winding at the highest voltage, is usually within ranges between 7,500 kva. and 33 kv. at 60,000 kva. and up to 220 kv.

The fundamental principle of the novel construction is to use for both high- and low-voltage windings actual lead-sheathed cables, instead of ordinary insulated conductors, presently employed for the conduction of electric power. This fully avoids any insulation between the individual turns and individual coils, and leaves a uniform insulation throughout the length of the winding between the high-voltage side and ground.

In windings of this type, the outer portions of all the turns are grounded, so that the windings need no longer be submerged in oil or enclosed in a casing, and they can therefore be left exposed.

The lead sheathing of the cable must, of course, be interrupted at each turn. All resulting sections should be grounded.

Cooling of the winding, which is very extensive, may take place naturally or by blowing air into the clearances left between the layers of the cables, and may even be supplemented, if necessary, for example in case the windings are formed by lead sheathed cables the core of which has the form of a hollow conductor by circulating by means of a pump the oil contained within the cable through a cooler.

This invention provides an electric transformer, more particularly a high-powered high-tension transformer, in which the dielectric strength, i. e. the resistance against sparking through the dielectric between the turns, equals the dielectric strength between the winding and ground throughout the winding.

The above objects are obtained by employing high-tension electric cables of the known type in the windings, in which the conductors are insulated by means of oil-impregnated paper and in which the outer metal sheathing of said cables is grounded and subdivided into sections to avoid the formation of a second winding.

In order to further obtain the above objects, the heat evolved by the winding is dissipated by the usual ventilation and forced air draft means and, in addition, when cables having cores in the form of tubular conductors are used by causing oil to be circulated within the tubular conductor forming the cable core, the oil being cooled, as described hereinafter, by circulating it through a suitable heat exchanger.

In accordance with the present invention, there is provided an electric high-voltage transformer comprising a central core, a high-voltage winding wound concentrically about said core and a low-voltage winding wound about said high-voltage winding and concentrically about said core. Each of said windings includes a central conductor, insulation material of oil-impregnated paper surrounding said conductor, a non-magnetic metallic sheathing disposed about and encompassing said insulation material, said metallic sheathing being subdivided into sec-

tions and said sections defining a gap therebetween whereby to avoid the formation of a closed turn or winding.

In addition to the above, the present invention contemplates means for dispersing heat generated in said windings both in case the cable employed for forming the windings has a solid core or a tubular core.

The above and other objects of this invention will be understood from the following description referring to the accompanying drawings which show by way of example the preferred embodiments of the improved transformer and the preferred mode of practicing the invention.

In the drawings:

Fig. 1 is a diagrammatic view of a transformer construction, partially in elevation and partially in section.

Fig. 2 is a sectional view of a constructional detail of the transformer shown in Fig. 1.

Fig. 3 is a sectional view of a modification of the constructional detail of Fig. 2.

Fig. 4 is a sectional view of a further modification of the constructional detail of Fig. 2.

Fig. 5 is a modification of the transformer construction of Fig. 1.

As shown in the drawings, A denotes the high-voltage cable or winding, B the low-voltage cable or winding and C the core on which the windings A and B are concentrically arranged.

The windings A and B are each formed of a conventional cable provided with an external metallic sheathing, for instance of lead of the type employed for the transmission of high-voltage electric power. The windings A and B comprise a tubular central conductor **2** and **3**, respectively, disposed within an annular layer of insulating material **2'** and **3'**, respectively, made for example of oil-impregnated paper or synthetic resins such as polyethylene. The preferred polyethylene is a synthetic resin known under the trade name "Araldite." The layers of insulating material **2'** and **3'** are protected by a metallic sheath **2''** and **3''**, respectively, of non-magnetic metal, such as lead, or a coil or non-magnetic wire or tape. The use of these electric cables fully avoids any insulation between the individual turns and individual bobbins, a single insulation being provided which is the same throughout the length of the winding between the high voltage winding and ground.

The reference numeral **5** denotes high-voltage terminals and the reference numeral **6** denotes low-voltage insulators, respectively.

Oil flows through the inner bore of the tubular conductors **2** and **3** forming the core of the cables pertaining to the windings A and B in order to dissipate the heat generated in the windings. The oil circulation is maintained by pumps **8** connected by conduits **7** to the end of each winding. Heat exchangers **9** acting as oil coolers are connected in the oil circuits. Cooling of the transformer windings A and B can be completed by supplying an air jet supplied by a blower **20** and directed upwardly through the gaps between the concentric turns. Since, in a winding of the type refered to, the external portion of all the windings is grounded, the windings need no longer be immersed in oil or enclosed in a casing and can remain freely exposed to air. Of course, the metal sheathing of the cables should be interrupted, as described hereinafter, at each turn and all the resulting sections should be grounded. The cooling of the winding, of which the surface is quite extensive, may take place naturally, as explained hereinbefore, for air may freely circulate through clearances left between the cylindrical layers of the cables or, as in the example shown, it may be supplemented, if necessary, by circulating the oil contained within the cable through a cooler or heat exchanger, as hereinbefore described.

The reference numeral **10** denotes gaps or interruptions in the metallic sheathing of the cable forming the high-voltage winding A which may be obtained, for instance,

by removing a portion of said sheathing **2''** and **3''** of the end of each turn and filling the resulting groove with a band or layer of insulating material **21**, such as vulcanized synthetic rubber, which may be externally reinforced at will by an encircling non-magnetic wire winding **22**, such as non-magnetic steel wire (Fig. 2). The process followed for forming these interruptions or gaps **10** is not, however, a part of this invention.

The wire winding or lashing **22** serves as a reinforcement and maintains the distribution of the electric field at the gaps unaltered. The insulation between the lead and metal sheathing is called upon to withstand the full voltage applied, but this occurs under accurately defined electric field conditions, so that highly reduced thicknesses are sufficient, such as employed in cables. For instance, 16 mm. are sufficient for 220 kv. operation, and any risk of discharges between the turns or the coils, as occur in conventional transformers with very steep front waves, are avoided.

Fig. 4 illustrates metal bushings **23** which can be superposed on the gaps **10** and extend beyond the edges of the sections of the cable sheathing or divided cable sheathing and separated from said edges by an insulating layer **24**. The gaps **10**, as illustrated in Fig. 1, can be distributed in a spiral formation about the axis of the core C or in non-alignment relative to each other to prevent the sheathings **2''** and **3''** on the cables of windings A and B from forming closed turns. Alternatively, the gaps **10** can be aligned with one another in a vertical direction, as illustrated in Fig. 5. In this modification, the successive turns of the windings might rest upon one another and be spaced in a radial direction. In addition, the turns may even be closely adjacent in a radial direction, provided the gaps in all the turns of the transformer windings are arranged in the same radial plane. However, it is more convenient to space the turns forming the windings A and B both in a radial and vertical direction. The turns of the windings A and B are not actually all in contact with one another but can be spaced by about one or more millimeters because this space is necessary for the overthickness formed by the material covering the metal sheathing at the points where the latter is interrupted.

When the turns are spaced in a radial and vertical direction, the gaps **10** do not necessarily have to be aligned with one another. The gaps in the cable sheathing can be provided at equal distances such that they are somewhat smaller in length than the circumference of the outer turns and somewhat greater in length than the internal turns.

The spacing, more particularly in a vertical direction, of the successive turns can be obtained by providing at the surface of the metallic sheathing of the cables forming the windings equally spaced bushings **25** (Fig. 1) of insulating material or by winding thereon steep-pitched coils made from insulating tape or cord, in order to form gaps which also improve air circulation, and hence the cooling of the winding.

All the sections of the metallic cable sheathings forming the windings A and B are grounded by equipotential connections **11** connected between the individual sections of said sheathings.

Fig. 3 shows a modification of the structure of the cable sheathing and gap **10**. In this modification, the insulating layer **2'** has superposed thereon a waterproof layer of synthetic rubber **30** on which a spiral of non-magnetic steel wire **31** is wound, the gap in the spiral being filled by a bandage or wrapping **32** made of vulcanized rubber-impregnated fabric.

The advantages of the transformer in accordance with the present invention are chiefly the fact that it can be constructed for high voltages and high power systems without immersing the windings into an insulating liquid, while discharges between the turns at any point of the winding in the presence of voltage waves having a steep front are avoided.

While there has been shown what is at present considered to be the preferred embodiments of the present invention, it is apparent that many changes and modifications may be made therein without departing from the invention and it is therefore intended in the accompanying claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

This of course leaves unaltered all the above explained advantages of the described transformer even in case the transformer windings are made of electric conductors having a solid instead of a tubular section.

The only difference between a transformer of the latter type and the transformer as described would reside in the cooling system which should be adapted accordingly.

In fact, it will be obvious that in this case cooling by means of oil circulating within the conductor would be out of the question, for it would not be admitted by a non-tubular conductor, and an arrangement would conveniently be made for implementing cooling by means of air jets forced through the clearances between the turns of the windings.

What I claim and desire to secure by Letters Patent is:

1. In an electric high-power high-voltage transformer, high-voltage and low-voltage windings, respectively, including turns formed by electric cables comprising an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, said metallic sheathing being subdivided into sections, said sections defining a gap therebetween and adjacent turns being electrically insulated from one another to avoid the formation of closed turns or windings of said metallic sheathing, adjacent sections of said sheathing being further grounded for maintaining them always at the same ground potential, and means for cooling said windings upon operation of the transformer.

2. In an electric high-power high-voltage transformer, high-voltage and low-voltage windings, respectively, including turns formed by electric cables comprising an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, and adjacent turns being electrically insulated from one another said metallic sheathing being subdivided into sections, each of the subdivisions of said metallic sheathing being substantially of one turn in length and the adjacent sections being grounded for maintaining them at the same ground potential, and means for cooling said windings upon operation of the transformer.

3. In an electric high-power high-voltage transformer, high-voltage and low-voltage windings, respectively, formed by electric cables comprising an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated conductor, said sheathing being divided into sections of substantially one turn length, the sheathings of each turn of said windings being close to the sheathing of the turns adjacent thereto of said windings and being interrupted by a gap, all gaps so formed being aligned in a plane extending through the axis of the transformer and on the same side of the axis of the transformer, the sheathing of each turn of said windings being grounded for maintaining them at the same ground potential, means being further provided for cooling said windings upon operation of the transformer.

4. In an electric high-power high-voltage transformer, comprising a central core, a high-voltage winding and a low-voltage winding wound concentrically about said core, each of said windings including an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, said sheathing being divided into sections of substantially one turn length, the sheathings of each turn of said windings being close to the sheathings of the turns of said windings adjacent thereto and being interrupted by a gap, all gaps so formed being situated in the same radial plane projecting outwardly from the axis of said concentrically wound windings of the transformer, the sheathings of each turn of said windings being grounded for maintaining them at the same ground potential, means being further provided for cooling said windings upon operation of the transformer.

5. In an electric high-power high-voltage transformer, comprising a central core, a high-voltage and a low-voltage winding wound concentrically about said core and comprising each at least one row of superimposed turns and including an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, in each row the sheathing of each turn being close to the sheathings of the turns adjacent thereto and pertaining to the same row, said rows of superimposed turns being radially spaced therebetween, the metallic sheathing of each turn of each row being further interrupted by a gap, all gaps in each row of turns being aligned along a line parallel to the common axis of said high-voltage and low-voltage windings, the sheaths of each turn of said windings being grounded for maintaining them at the same ground potential, means being also provided for cooling said windings upon operation of the transformer.

6. In an electric high-power high-voltage transformer, comprising a central core, a high voltage winding and a low-voltage winding wound concentrically about said core and comprising each at least one row of superimposed turns and including an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, in each row the sheathing of each turn being spaced from the sheathing of adjacent turns pertaining to the same row, said rows of superimposed turns being radially spaced therebetween, the metallic sheathing of each winding being subdivided into sections, and said sections defining a gap therebetween, the sheaths of each section being grounded for maintaining them at the same ground potential, and means being also provided for cooling said windings upon operation of the transformer.

7. In an electric high-power high-voltage transformer, comprising a central core, a high-voltage and a low-voltage winding wound concentrically about said core and comprising each at least one row of superimposed turns and including an insulated central conductor and a non-magnetic metallic sheathing enclosing said insulated central conductor, in each row the sheathing of each turn being spaced from the sheathing of the adjacent turns pertaining to the same row, said rows of superimposed turns being radially spaced therebetween, the metallic sheathing of each turn being interrupted by a gap, said gaps being arranged in each row in spiral relation, the sheaths of each turn being grounded for maintaining them at the same ground potential, and means being also provided for cooling said windings upon operation of the transformer.

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