

March 29, 1966

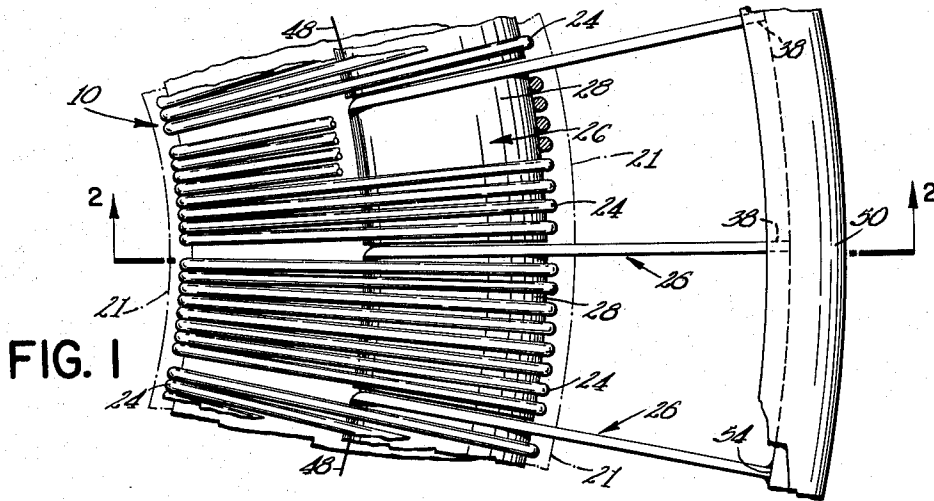
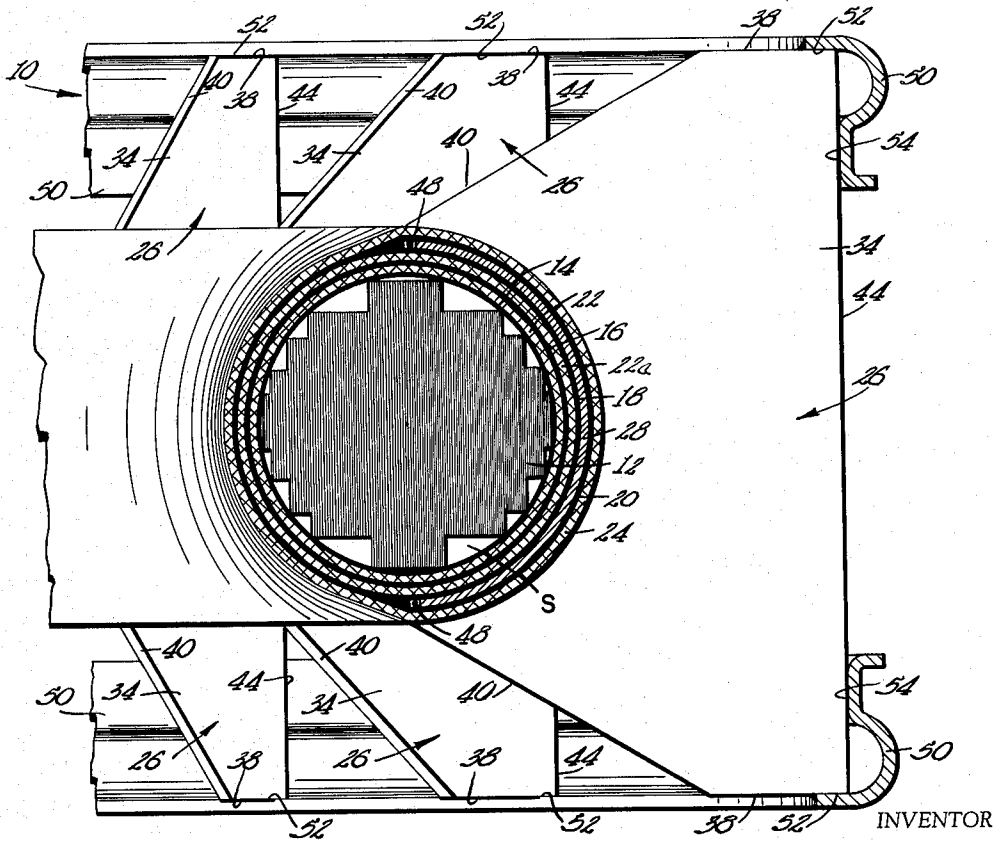
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3,243,744

TOROIDAL CORE ELECTRICAL TRANSFORMER WITH COOLING FINS

Filed Aug. 3, 1960

5 Sheets-Sheet 1



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TOROIDAL CORE ELECTRICAL TRANSFORMER WITH COOLING FINS

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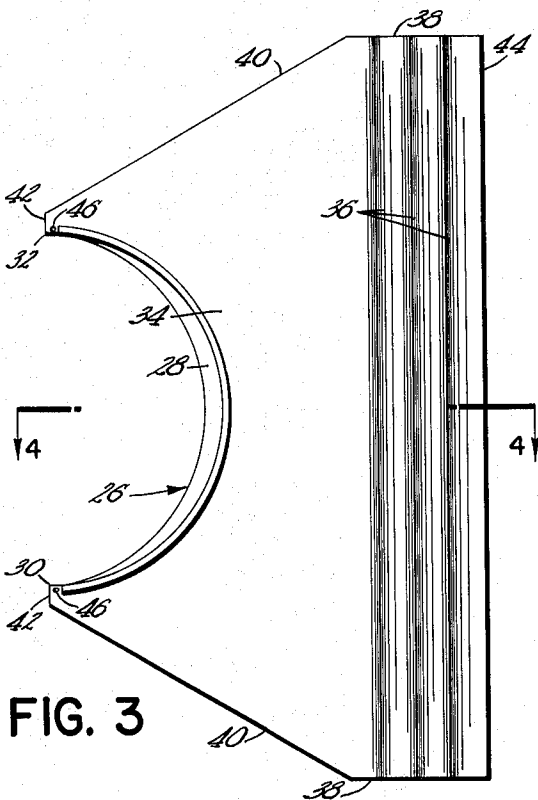


FIG. 3

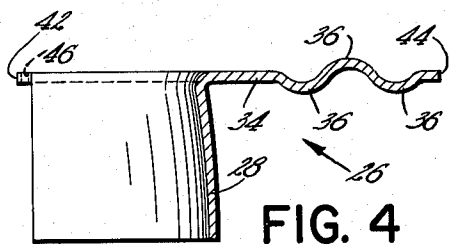


FIG. 4

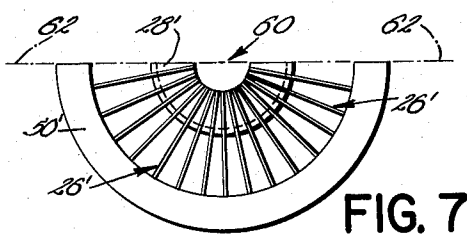


FIG. 7

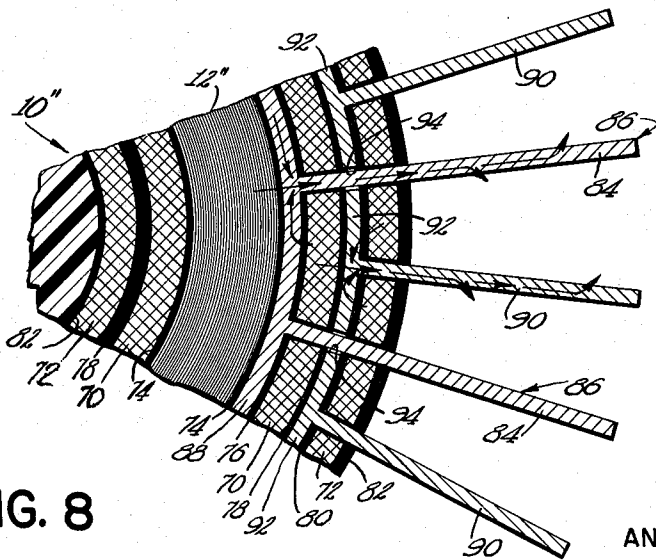


FIG. 8

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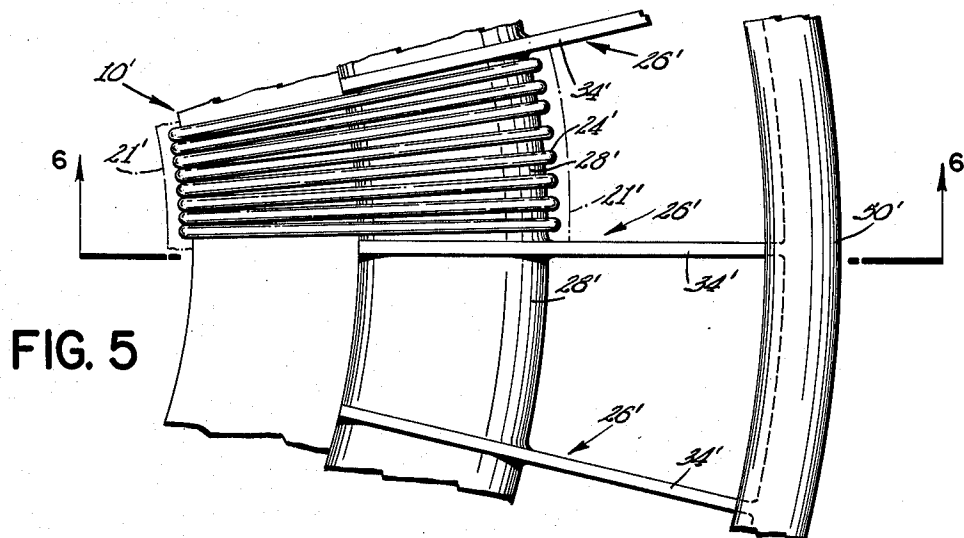
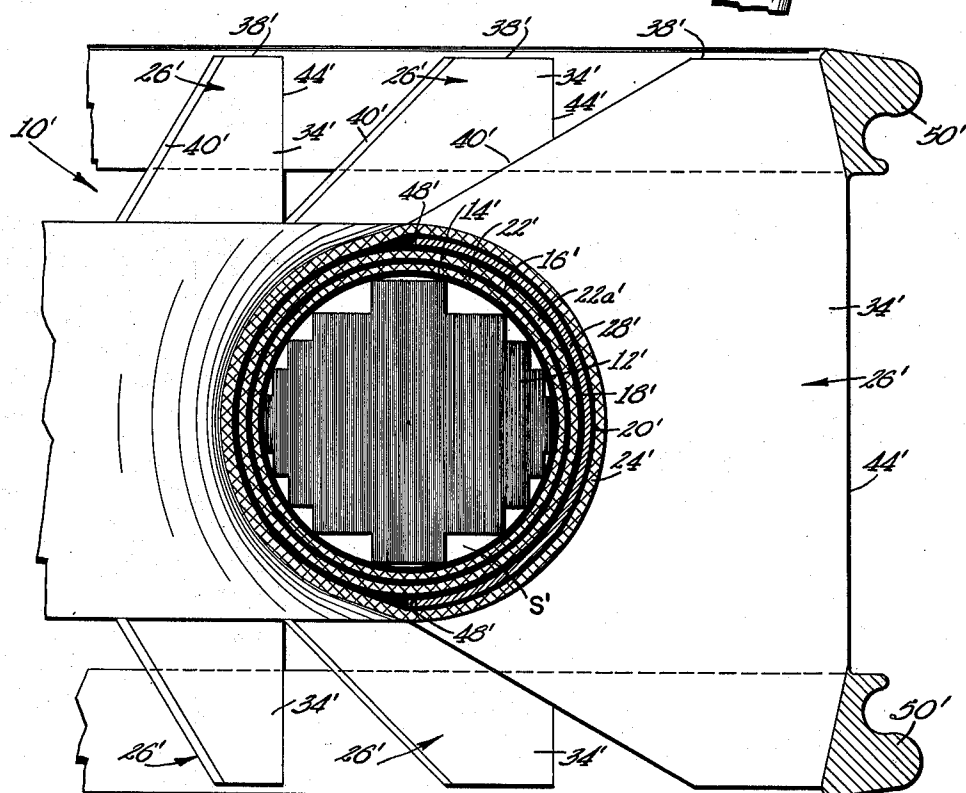
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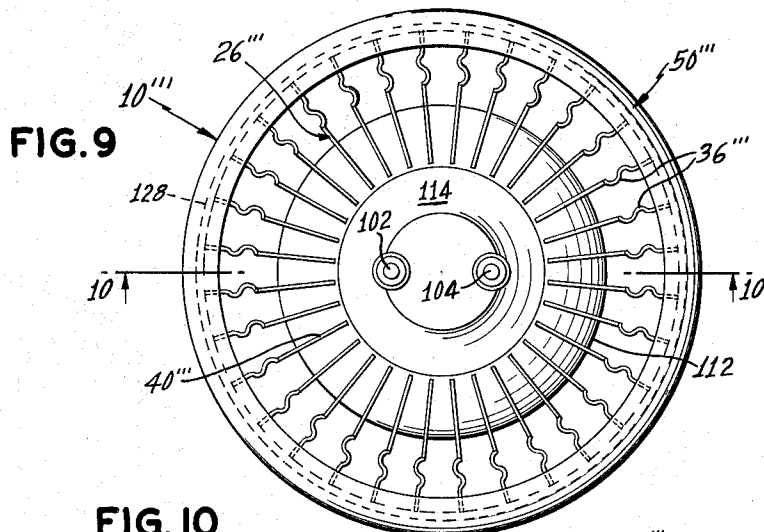
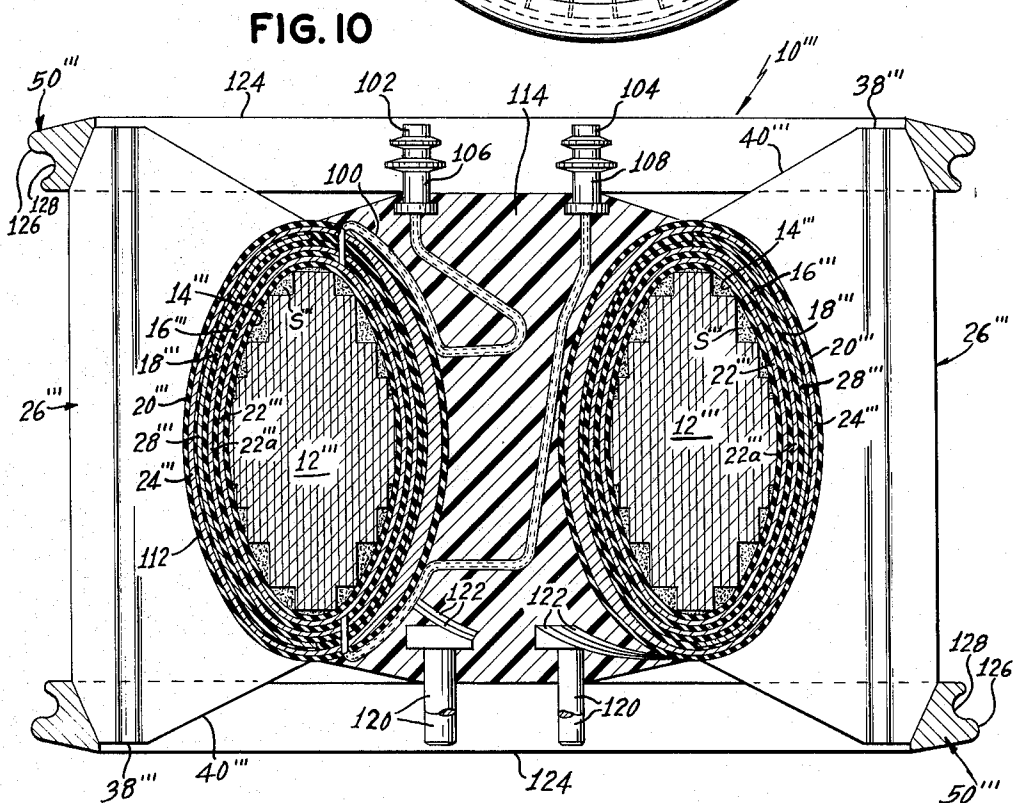
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TOROIDAL CORE ELECTRICAL TRANSFORMER WITH COOLING FINS

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TOROIDAL CORE ELECTRICAL TRANSFORMER WITH COOLING FINS

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FIG. 11

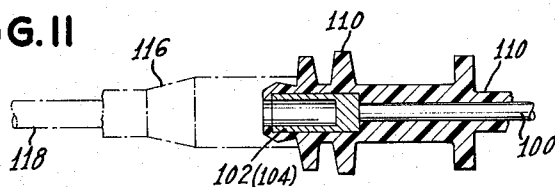
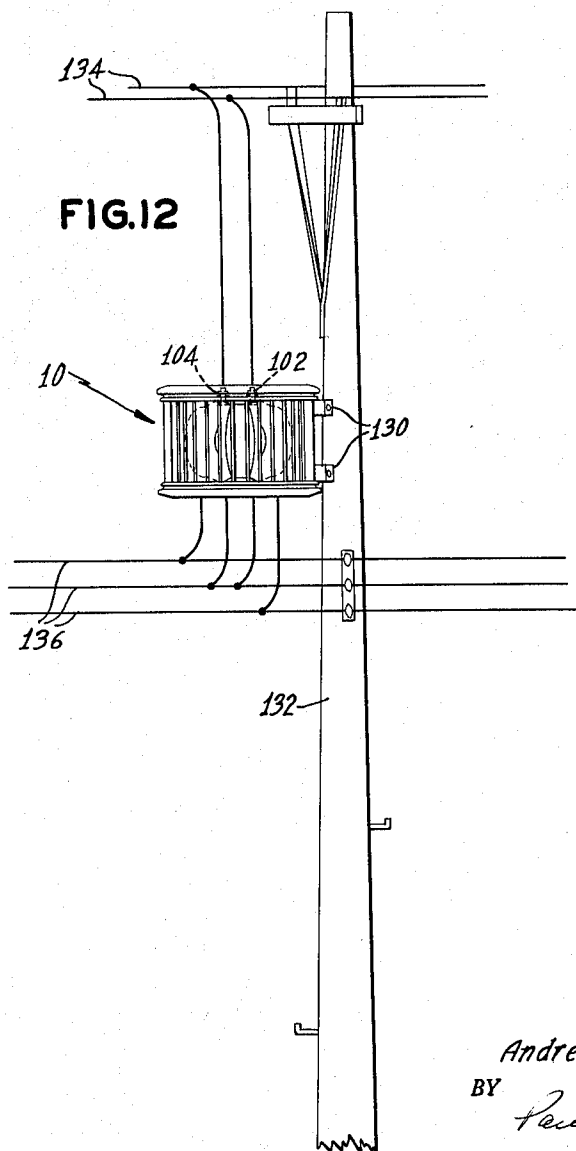


FIG. 12



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TOROIDAL CORE ELECTRICAL TRANSFORMER WITH COOLING FINS

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6 Claims. (Cl. 336-61)

This invention relates generally to an electrical transformer and more particularly to a new construction thereof providing improved cooling and mounting means.

The present invention applies especially to dry-type transformers of toroidal configuration, but certain of its aspects are not limited thereto. In such transformers, the heat generated by the magnetic flux in the core and the heat developed by the electrical current in the windings, flows outward and is dissipated in the ambient atmosphere. Such heat flow is accompanied by temperature rise in the insulation of the windings. The temperature rise is an important limiting factor in the loading of the winding and limits the selection of insulation materials usable therein to a relatively expensive group. More particularly, the heat generated in the inner winding combines with the heat generated in the core and this cumulative heat quantity flows across the insulation between the inner and outer windings into the latter subjecting such insulation to a heat rise corresponding to this cumulative effect. Similarly the heat generated in the outer winding adds to the heat generated in the core and the inner winding and this heat quantity subjects the insulation surrounding the outer winding to a corresponding heat rise. The temperature differential between the core and outer surface of the transformer approximately corresponds to the sum of the temperature increase across the insulating layers (the temperature difference across the windings is neglected) and one important object of the present invention is to obtain a substantial reduction in this temperature differential so that a transformer with a given insulation may be more heavily loaded or, for a given loading, a lower cost insulation may be used. Pursuant to this object of the present invention a novel arrangement is provided for dissipating heat from between the windings and/or between the core and inner winding to the ambient atmosphere, resulting in a cooler operating transformer having the attendant advantages aforementioned. Accordingly, the present invention paves the way for higher rated dry-type transformers than was heretofore possible.

Yet another object of the present invention is the provision of a generally improved electrical transformer of novel and economical design and construction which is particularly well-suited to dissipating heat resulting from inherent losses within the transformer and which is eminently suitable for its intended purpose.

Another important object of the present invention is the provision of an arrangement for mechanically protecting the transformer and its components in storage and while being transported. A related feature resides in novel transformer structure effective for facilitating the mobility and transporting of the transformer.

In an illustrative embodiment of the present invention in its various aspects, a toroidal transformer is provided with a plurality of cooling fins in a novel arrangement relative to the windings. Additionally one form of the illustrative transformers is provided with novel coaxial rings spaced apart so as to generate an imaginary protective cylinder for the transformer. As a further feature, the terminal bushings that project from the illustrative encapsulated coil body are disposed within a protected space. A further specific feature of the invention resides in the integration of the aforementioned transporting and protective rings with cooling fins projecting from

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the transformer body. A still further feature resides in forming the rings in a manner to receive a rope, or the like, to facilitate handling and installation of the transformer.

5 A further feature of the invention resides in the provision of a double-ended transformer having the primary high-voltage terminals at one end and the low-voltage terminals at the opposite end. Such transformer structure is suitable for mounting with the high-voltage terminals at the top and readily accessible for connection to over-head power lines and with the low-voltage secondary terminals at the bottom, accessible for the low voltage connection.

Yet another object of the present invention is the 15 provision of a dry-type distribution power transformer of generally improved designed and construction.

Other features, objects, and advantages of the present invention will become apparent as the description thereof proceeds when considered in connection with the accompanying illustrative drawings in which:

FIGURE 1 is a fragmentary plan view of a transformer embodying features of the present invention;

FIGURE 2 is a vertical sectional view taken along the line 2-2 of FIGURE 1;

FIGURE 3 is a side elevational view of a modified form of cooling fin;

FIGURE 4 is a sectional view taken on the line 4-4 of FIGURE 3;

FIGURE 5 is a view similar to FIGURE 1 showing a modified form of transformer cooling arrangement;

FIGURE 6 is a vertical sectional view taken along the line 6-6 of FIGURE 5;

FIGURE 7 is a plan view of a ring and cooling fin casting unit, utilized in pairs in the embodiments of FIGURES 5 and 6;

FIGURE 8 is a fragmentary view showing still another modified form of transformer cooling arrangement, said view being shown in horizontal section;

FIGURE 9 is a plan view of yet another embodiment of the invention in certain of its aspects;

FIGURE 10 is a section view taken along the line X-X of FIGURE 9 showing the general construction of a transformer fabricated according to the teachings of the present invention;

FIGURE 11 is an enlarged fragmentary sectional view showing a terminal and bushing of the primary winding in the transformer of FIGURES 9 and 10 connected to a plug-in connector illustrated in phantom; and

FIGURE 12 is a view showing mounting of the transformers hereinbefore described.

Referring to the drawings, and more particularly to FIGURES 1-4 thereof, there is shown a dry-type electrical transformer 10 of toroidal configuration characterized by the improved cooling and mounting arrangement to be described in detail below. The transformer comprises a core 12 of any suitable design and construction and formed of any suitable magnetic material, such as silicon steel. In the illustrated embodiments, the core 12 is formed of strip stock wound to form stacked layers of laminations and to assume an overall annular or toroidal configuration. The groups of layers are of overall reduced width at increments spaced from the center of the core so that the latter may be of the generally circular cross-section shown in FIGURE 2. Surrounding the core are spaced layers 14, 16, 18 and 20 of insulation, the inner winding which is composed of two spaced layers 22 and 22a, and the outer single layer winding 24. The inner winding layers 22 and 22a are disposed between the insulation layers 14 and 16, and 16 and 18, respectively, whereas the outer winding layer 24 surrounds insulation layer 18. Either winding may be

the high-voltage winding with the other being the low-voltage winding. The high voltage winding is the inner winding of the illustrate embodiment.

Pursuant to certain aspects of the present invention, the temperature differential between the core and the outer surface of the transformer is substantially reduced, there being provided an arrangement for dissipating heat from between the windings and/or between the core and inner winding. More particularly, there is provided a series of uniformly spaced radially extending cooling fins 26 (FIGURES 3 and 4) which may be formed of any suitable non-magnetic material having good thermal conduction properties, such as aluminum. The cooling fins conduct the heat, from the heat path defined between the inner and outer windings, to the ambient atmosphere. Each cooling fin 26 comprises an inner arcuate part or extension 28 which is disposed in the heat path between the inner and outer windings. Inner part 28 conforms to the configuration of the windings and extends transversely substantially to the adjacent cooling fin 26. In a longitudinal peripherally extending direction between terminal points 30 and 32, the part 28 extends for approximately 180 degrees of the core and windings, as best shown in FIGURE 2. Extending, substantially at right angles, from part 28 is a web 34 which conducts the heat from part 28 through the outer winding to the ambient atmosphere. The web or part 34 presents a substantial surface area to the atmosphere for the heat dissipating function. Web 34 is of plate-like construction and may be corrugated as indicated at 36 for increasing the surface area and strengthening. The web 34 enlarges in area from arcuate part 28 to the opposite edges 38, there being defined the opposite diagonal edges 40 between edges 38 and inner edges 42. The outer edge of cooling fin 26 is defined by edge 44. A pair of small apertures 46 are disposed in the region of points 30 and 32 for a purpose which will be apparent from the description which follows.

A series of convolutions of the winding layer 24 extend around part 28 and aid in retaining the individual cooling fins 26 in position. Such fins are collectively retained in assembled relation, to form a frame for the transformer by binding wires 48 which extend through a companion series of apertures 46 and by the external assembly rings 50. More particularly, one binding wire 48 extends through one series of apertures 46 at one diametrical position of the body of the transformer and the other binding wire 48 extends through the other series of apertures 46 at the opposite diametrical position. The rings 50 are laterally spaced at the opposite ends of the fins and surround the latter, said rings having inner surfaces 52 and 54 which are welded to the edges 38 and 44, respectively of the fins. In this manner the rings 50 are rigidly united to form a supporting frame for the transformer.

It will be understood that the parts 28 of the fins collectively form a surface area of substantial proportions blanketing approximately one-half the heat path defined between the inner and outer windings. The heat dissipating surface area of the fins substantially increases away from the body of the transformer to effectively dissipate the heat conducted along the fins to the ambient atmosphere. The heat generated in the core and inner winding, instead of streaming into the outer winding, streams into parts 28 and is dissipated to the atmosphere by the fin parts 34. Thus this heat will not traverse the insulation of the outer winding.

It may be observed that the heat transfer portions 28 are in extended area opposition to only the outer half of each turn. Resistance heating occurs throughout the whole turn. This suggests the possibility of inadequate dissipation of the heat that develops in the inside half-turns and the corresponding possibility of an excessive temperature rise in the inside half-turns. However, this does not occur. The heat developed in the inside half-

turns is effectively transferred by conduction along the turn itself (being a good heat conductor such as copper or aluminum) to the outer-half turn where it is dissipated by transfer to the aforementioned cooling fin assembly.

The insulation is traversed by only a portion of the heat generated in the outer winding because only a portion of such heat will flow inwardly into the parts 28 of the fins. Parts 28 are disposed between the insulation layers 18 and 20 as shown in FIGURE 2. The radially extending spaced fins define grooves for the winding of the outer layer 24, said grooves guiding the winding operation and also serving as supports for said layer thus increasing the short circuit strength thereof. The space S defined between the core and insulation layer 14 may be filled with sand or any other suitable material. The completed transformer is encapsulated, as shown in FIGURE 10, by a technique not forming a part of the present disclosure.

Referring to FIGURES 5-7, there is shown another transformer which is similar to the above described embodiment and differs therefrom in the respects to be pointed out in detail below. Parts of transformer 10' corresponding to transformer 10 are denoted by the same reference characters primed. In transformer 10' the cooling fins 26' and assembly rings 50' are formed as integrally cast units rather than individual units to facilitate manufacture and assembly, the cooling fins functioning in the manner aforescribed. The cooling fins and assembly rings are formed as a pair of cast units 60 (FIGURE 7) which are suitably united along the diametrical parting line 62 over the inner winding. Each unit thus consists of one-half the requisite number of fins 26' and one-half the circumferential extent of the rings 50'. The assembled units 60 define a peripherally continuous arcuate part 28', which corresponds collectively to parts 28 previously described, the part 28' being disposed in the heat path between the inner and outer windings and extending for approximately 180 degrees thereof. Extending from part 28' are fin parts or webs 34', which conduct the heat from the core and inner winding and part of the heat of the outer winding to the atmosphere. Thus the problem of individual cooling fin orientation and assembly are eliminated pursuant to the instant embodiment 10' which retains all of the functional advantages aforesaid. It will be understood that the cooling fins and assembly rings may be formed individually and suitably united or formed as a plurality of sectional units united by welding, or in any other suitable manner.

With reference to FIGURE 8, there is shown another transformer 10'' which is generally similar to the previous embodiments, differing therefrom in the respects now to be described, the same parts being designated by the same number double primed. In transformer 10'' cooling fins extend in the heat path defined between the core 12'' and inner winding 70 as well as in the heat path defined between the inner winding 70 and outer winding 72, so that there is a resulting heat transfer from the core and winding independent of each other to further reduce the operating temperature of the transformer. Extending around the core and windings are the insulation layers 74, 76, 78, 80 and 82. The cooling fins extending in the heat path between the core and inner winding correspond to the arrangement of transformer 10', i.e., the cooling fins 84 are parts of integrally cast units 86 united as aforescribed. More particularly, the fins 84 have a peripherally continuous arcuate part 88 disposed in said heat path, the heat from the latter being conducted from part 88 to the fins for dissipation in the atmosphere. The cast units 86 are shown without rings 50', it being understood that such rings may be provided, if desired.

Disposed between each pair of adjacent fins 84 is an individual cooling fin 90 for conducting heat from the heat path between the inner and outer windings to the atmosphere. Each winding fin 90 includes an arcuate

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part 92 which extends in the heat path between the inner and outer windings for conductive heat therefrom along the fins for dissipation in the atmosphere. The cooling fins 90 thus are generally similar to the fins 26 of the transformer 10, the parts 92 of fins 90 being symmetrically disposed with respect to the fins. It will be noted that the parts 92 are spaced from each other to define a passage 94 for the extension therethrough of the fins 84. The fins 84 extend to the ambient atmosphere between convolutions of the inner and outer windings, and the fins 90 extend to the ambient atmosphere between convolutions of the outer winding. In practice, the inner winding is wound around part 88, the fins 84 defining grooves for the winding operation. The outer winding is wound around parts 92 to retain the fins 90 in position. Heat generated from the core and inner winding is conducted to the atmosphere by fins 84 and heat generated from the inner and outer windings is conducted to the atmosphere by fins 90 as indicated by the arrows.

Referring to FIGURES 9 through 11 there is shown still another embodiment of the transformer which is similar to the above described embodiments and differs therefrom in the respects to be pointed out in detail below. Parts of transformer 10'' corresponding to transformer 10 are denoted by the same reference characters triple primed. The transformer comprises a toroidal core 12''' of any suitable design and construction and formed of any suitable magnetic material, such as silicon steel. Surrounding the core are spaced layers 14'', 16'', 18'', and 20''' of insulation, the inner winding which is composed of two spaced layers 22''' and 22a'', and the outer single winding layer 24''. The inner winding layers 22''' and 22a'' are disposed between the insulation layers 14'' and 16'', and 16'' and 18'', respectively, whereas the outer winding layer 24'' surrounds insulation layer 18''. At least layer 18''' is formed as a cast-in-situ unitary and continuous polymerized covering, additional to any insulation on the individual turns of wire. The high-voltage winding is the inner winding of the illustrated embodiment. The space between the core and layer 14''' of insulation is filled with a suitable filler material S''' such as sand.

The inner winding is formed by the continuously wound conductor 100 having formed plug-in terminals 102 and 104 at the opposite ends thereof laterally encased within the projecting bushings 106 and 108, respectively. Said bushings have integral circular ribs, as shown, and are formed of plastic insulating material or encapsulant as a continuation of the encapsulating layer 110 of the conductor 100. More particularly, the encapsulation 110 about the high-voltage leads 100 and terminals 102 and 104 extends continuously from the continuous uninterrupted encapsulating layer 112 which covers the winding 24''' to effectively shield this winding and its terminals against outside influences, such as moisture, chemical contaminants, etc. A preferred material for this purpose is silicon rubber because of its excellent insulation resistance, its ability to withstand high temperatures, its flexibility, and its adaptability of the casting procedure such as here involved.

The bushings and terminals of the high-voltage winding are fixed in position at one side of the transformer unit 10''' by being imbedded in the filler material 114, said bushings and terminals projecting beyond the transformer body. The material 114 which fills the body space of the transformer is selected from suitable materials such as epoxy resin and the like and is positioned by known methods such as casting. The terminals are adapted for plug-in connection with a complementary male plug-in type connector 116 (FIGURE 11) of any well-known type, at the end of a cable 118.

Projecting at the opposite sides of the transformer unit 10''' are low-voltage terminals 120 of the outer windings, the latter being formed in two sections with a pair of terminals 120 for each section. The terminals 120 are

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fixed in position by the cast filler 114 in the manner of bushings 102, 104. The terminals 120 are suitably secured to the proper conductors 122 of the outer windings, as by brazing or welding. The method of forming the inner winding has been described heretofore, it being understood that either or both windings may be formed in like manner. After the transformer has been assembled as hereinbefore described, a molding operation may be carried out in any well-known manner to encapsulate the transformer conductors and terminals so as to form an integral unit such as by spraying or dipping in known materials such as silicone rubber.

Referring once again to FIGURES 9 through 12, another feature of the present invention relates to the protection of the transformer and its components in storage or transport and for providing for the ready mobility and maneuverability thereof. The rings 50''' have a common axis coincident with the axis of the core, said rings generating an imaginary protective envelope for the transformer and its projecting components, including bushings 106, 108 and the low-voltage terminals 120. More particularly, the fins 26''' are of diverging configuration away from the core and extend laterally of the transformer beyond the projecting components 106, 108, 120 thereof, the rings 50''' being disposed at the ends of the fins laterally beyond said projecting components. Expressed differently, the outer peripheral edges 124 of the rings are disposed in a plane laterally beyond the plane of the projecting components so as to protect the latter when the transformer is supported on its side or when other apparatus or materials are stacked thereon. This lateral disposition of the rings also protects the projecting components during the transporting or maneuvering of the transformer thereon. The transformer is readily moved or transported on the rings 50''' which serve as wheels for rolling the transformer, the rings being radially outermost of the transformer. The external arcuate edge 126 of the rings define the rolling edges thereof and the imaginary cylinder generated between such edges defines a protective peripheral enclosure for the transformer 10'''.

Laterally adjacent to edges 126, inboard thereof, are peripherally extending grooves 128 which are adapted to receive a rope or chain which is trained around the rings to facilitate maneuvering of the transformer unit. Close control can thus be achieved in the handling of the unit by means of ropes, or the like, trained around the rings in grooves 128.

From the above it will be apparent that the rings on which the transformer unit may be facily rolled or maneuvered generates an imaginary protective envelope for the transformer and its projecting bushings terminals, said rings being radially and laterally outermost of the unit.

Referring more particularly to FIGURE 12 therein may be seen how the transformer 10 is adapted to be mounted by standard clips 130 to the distribution pole 132. The clips are bolted to the transformer at points convenient therefor before or after the clips are secured to the pole. In the drawing it may be seen that the transformer is mounted with the high-voltage bushings 102, 104 uppermost, thus being conveniently located for attachment of the high-voltage lines 134 thereto. In addition the low-voltage connections are made beneath the transformer, so that these service wires 136 may be easily drawn therefrom.

Double ended construction of power transformers is novel and results in the attainment of hitherto unattainable advantages. As for example, a transformer fabricated according to the teachings of the present invention produces a separation between the high-voltage and low-voltage lines not possible before without additional expensive structure. Additionally, it simplifies the installation of the transformer, and increases the safety of the installing and maintaining personnel. The open con-

struction of the transformer produces a self-cleansing effect when subjected to natural rainfall.

Various additional modifications of the above described embodiments of the invention will readily occur to those skilled in the art, and therefore the invention should be broadly construed in accordance with its full spirit and scope.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An electrical transformer comprising a toroidal magnetic core and heat generating windings thereon arranged as inner and outer layers of current-carrying convolutions having layers of insulation between the layers of convolutions, said magnetic core being of circular cross section as viewed in a plane containing the toroidal axis, and means for conducting heat to the ambient atmosphere comprising a series of heat conducting members each having a first metal portion extending along the core locally and confronting at least one of said layers of convolutions, said first metal portions being of semi-circular cross section and disposed to confront the peripherally outward portion of said toroidal core, said members each having another metal portion extending integrally from said first portion and disposed radially outward so as to extend between adjacent convolutions of at least one of said layers into the ambient atmosphere.

2. An electrical transformer comprising a magnetic core of toroidal configuration having a heat generating winding thereon, and a series of arcuately spaced metal cooling fins extending generally radially from said winding to the ambient atmosphere, said fins having portions extending to the interior of said winding and being in intimate heat transfer relationship therewith, said cooling fins also having substantial areas, respectively, exposed to the ambient atmosphere, means interconnecting the radially outermost extremities of said cooling fins at points spaced axially so as to constitute a cylindrical structure having an axis coincident with the axis of said core and defining a rolling surface for the transformer.

3. An electrical transformer comprising a toroidal core and heat generating windings extending therearound disposed as inner and outer layers of current carrying convolutions and layers of insulation between said layers of convolutions, and means for conducting heat to the ambient atmosphere comprising a first series of heat conducting members each having a first portion extending locally along the core and disposed between said core and the innermost layer of said convolutions and each having another portion integral with said first portion and extending radially outward between convolutions of all said layers and through said layers of insulation, and a second series of heat conducting members each having a first portion extending locally along the core between inner and outer layers of said convolutions and said second members each having another portion integral therewith and disposed to extend radially outward between convolutions of said outer layer, the radially extending portions of said second series of heat conducting members being interspersed with the radially extending por-

tions of said first series of heat conducting members and the radially extending portions of both said series projecting into the ambient atmosphere and having a substantial area exposed thereto.

4. An electrical transformer comprising a toroidal magnetic core and heat generating windings thereon arranged as inner and outer layers of current-carrying convolutions having layers of insulation between the layers of convolutions, and means for conducting heat to the ambient atmosphere comprising a series of heat conducting members each having a first metal portion extending along the core locally and confronting at least one of said layers of convolutions, said first metal portions being integrally connected and extending half-way around the axis of the toroidal core, said members each having another metal portion extending integrally from said first portion and disposed radially outward so as to extend between adjacent convolutions of at least one of said layers into the ambient atmosphere.

5. An electrical transformer in accordance with claim 3 further including a pair of rings of equal diameter coaxial with the axis of the toroidal core, said rings being separated axially and being joined to the outermost portions of both said series of heat conducting members for uniting said heat conducting members and defining a rolling surface for the transformer and constituting mechanical protective means therefor.

6. An electrical transformer in accordance with claim 2, further including electrical terminals connected to said winding, wherein said interconnecting means includes portions at the axial extremities of said cooling fins in planes between which said core and said winding and said terminals are disposed for providing protection against mechanical damage.

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