Feb. 26, 1957 G. CAMILLI ET AL 2,783,441

TRANSFORMER

Filed July 25, 1952 2 Sheets-Sheet 1

Fig.1.

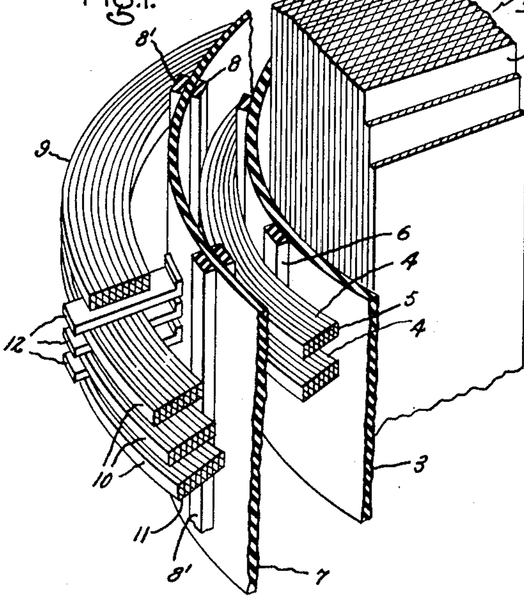


Fig.2.

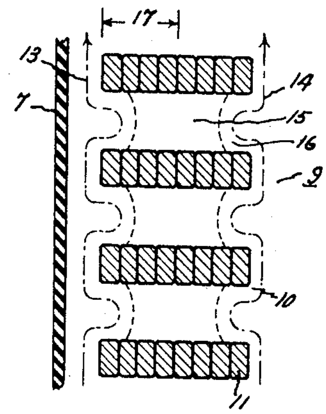


Fig.6.

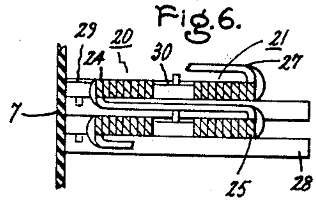


Fig.7.

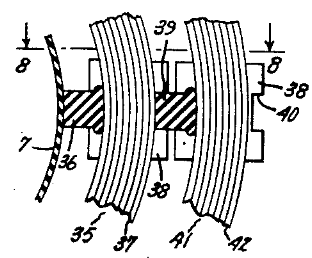


Fig.9.

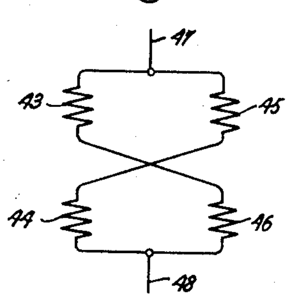
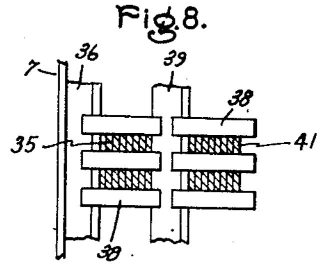


Fig.8.



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TRANSFORMER

Filed July 25, 1952 2 Sheets-Sheet 2

Fig. 3.

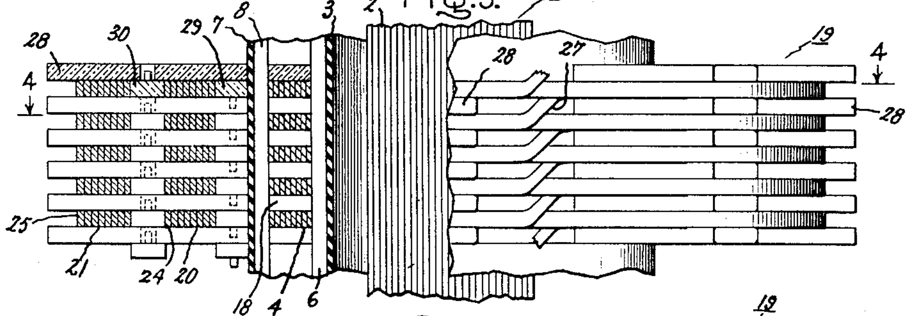
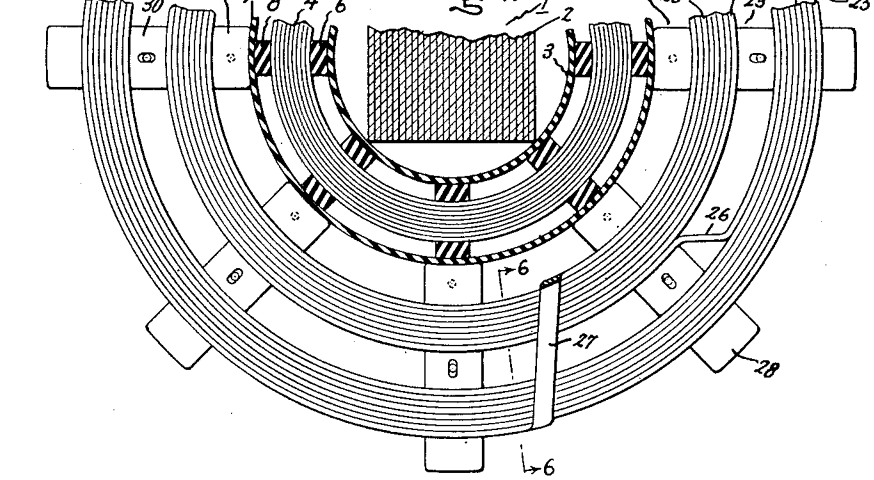


Fig. 4.



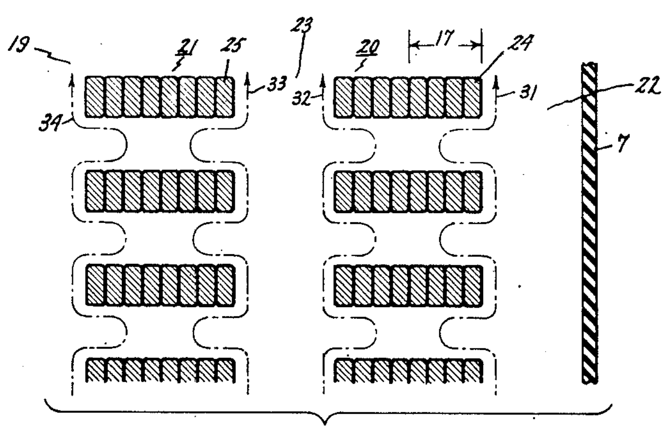


Fig. 5.

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TRANSFORMER

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Application July 25, 1952, Serial No. 300,944

1 Claim. (Cl. 336—180)

This invention relates to transformers and more particularly to coils for transformers of the dry type.

In the conventional dry-type transformer construction, a laminated core is provided with two or more vertically arranged leg portions. In a single phase transformer, the windings are conventionally arranged on one or two of the legs while in a three-phase transformer, windings are arranged on each of the legs. Considering only one core leg, it has been the practice to mount a sleeve or cylinder of insulating material on the leg with the low voltage winding being wound thereon. This assembly is in turn surrounded by another cylinder of insulating material on which is wound the high voltage winding. The high voltage winding has conventionally been formed of a plurality of axially spaced apart horizontally arranged disk-shaped annular coils spaced from the outer insulating cylinder by axially extending spacing members. This arrangement permits cooling air to be circulated through the space between the inner periphery of the disk coils and the outer cylinder and, of course, over the outer periphery of the coils.

The efficiency of convective heat transfer from such horizontal disk coils to the air surrounding the coils depends upon the thickness of the stagnant boundary layer of air clinging to the surface of the coils. This boundary layer of air acts as thermal insulation and determines the local surface temperature rises over the local ambient temperature. These slow moving boundary layers of air tend to become quite thick, reducing the convective heat transfer coefficient, particularly when the ventilating path through the coils is long and arduous. It has been found that from a thermal standpoint, the conventional horizontal disk coils were very inefficient and it is therefore desirable to provide a disk type coil arrangement which will produce a reduction in the temperature rises over the surrounding ambient.

It is therefore an object of this invention to provide an improved transformer construction having disk-type coils wherein the thermal efficiency is increased.

Further objects and advantages of this invention will become apparent by reference to the following description and the accompanying drawing, and the features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

This invention in its broadest aspects provides a disk-shaped annular transformer coil having a plurality of sections, these sections being radially spaced apart thereby defining annular ducts for ventilating the coil. The splitting of disk coils into several radially spaced apart sections reduces the effective total length of air flow path up through the coils thereby increasing the amount of air flow for a given heat dissipation giving lower air temperatures surrounding the coil. Furthermore, the stagnant air film thickness clinging to the coil surfaces is greatly reduced with the net result that the local heat transfer coefficient is increased and the temperature rise of the coil over local air is substantially reduced.

In the drawing, Fig. 1 is a fragmentary broken away view showing a dry type transformer of conventional construction;

Fig. 2 is a fragmentary cross-sectional view showing the arrangement of the high voltage coils of the transformer of Fig. 1 and the path of the air flow through the coils;

Fig. 3 is a fragmentary side elevational view, partly in section, illustrating a transformer provided with the improved split high voltage coils of this invention;

Fig. 4 is a vertical view, partly in section, taken along the line 4—4 of Fig. 3;

Fig. 5 is a fragmentary cross-sectional view showing the improved split coil construction of Figs. 3 and 4 and the air flow therethrough;

Fig. 6 is a fragmentary cross-sectional view taken along the line 6—6 of Fig. 4.

Fig. 7 is a fragmentary cross-sectional view illustrating a modified form of this invention;

Fig. 8 is a fragmentary cross-sectional view taken along the line 8—8 of Fig. 7; and

Fig. 9 is a circuit diagram schematically illustrating one connection for the improved split coils of this invention.

Referring now to Fig. 1, there is shown a portion of a vertically arranged leg **1** of a transformer core formed of a plurality of relatively thin laminations of magnetic material **2**. The leg **1** is surrounded by a cylinder **3** formed of insulating material which in turn is embraced by a plurality of axially spaced apart disk-type low voltage coils **4**. The low voltage coils **4**, which are each formed from a radially wound continuous conductor **5**, are wound on axial spacers **6** formed of insulating material and outer cylinder **7**, also formed of insulating material, is supported thereon by means of axial spacers **8**. High voltage winding **9** is wound over the outer cylinder **7** and comprises a plurality of horizontal spaced apart disk type coils **10** wound on axial spacing members **8'** formed of suitable insulating material. Here again, each of the coils **10** is formed from a continuous radially wound conductor **11** with each coil being electrically connected to the adjacent coils to form the complete high voltage winding **9**. Spacing members **12** maintain the proper axial spacings between the disk coils **10**.

Referring now to Fig. 2, there is shown a fragmentary cross-sectional view of the high voltage winding **9** of Fig. 1. It will be seen that the ventilating air flows between the coils **10** and the cylinder **7**, as shown by the arrows **13** and over the outer periphery of the coils as shown by the arrows **14**. It will also be seen that the circulating air **13** and **14** only partially enters the spaces between the coils **10** thereby resulting in an area of stagnant air **15** between the coils and a slow moving boundary layer **16** adjacent the edges of the coils. It has been found that the thickness of the boundary layer varies approximately as the ¼ power of the distance from the edge of the coil to the center, as shown by the dimension **17**.

Referring now to Figs. 3, 4 and 5, in which like elements are indicated by like reference numerals, it is seen that the laminated core **1** is again surrounded by inner insulating cylinder **3** which in turn is surrounded by low voltage winding coils **4**. Coils **4** are wound on axial spacing members **6** and are spaced apart by spacer members **18**. Outer cylinder **7** is again mounted on low voltage coils **4** by means of axial spacing members **8**. In order to improve the thermal efficiency, however, the high voltage coils **19** are each divided into an inner section **20** and an outer section **21**, the inner section **20** being radially spaced from the cylinder **7** thus defining an annular ventilating duct **22** and the outer section **21** being radially spaced from the inner section **20** thus defining another annular ventilating duct **23**. Here, each inner coil section **20** is formed of a continuous radially coiled conductor **24** and each outer coil section **21** is similarly formed of a continuous radially coiled conductor **25**. A crossover **26** connects the outer end of conductor **24** of coil section **20** to the inner end of conductor **25** of coil section **21**, while another crossover **27** connects the outer end of conductor **25** of coil section **21** to the inner end of the inner section of the adjacent coil. It is thus seen that the outer and inner sections of each coil are serially connected while each complete coil is in turn serially connected to form the high voltage winding of the transformer.

In order to provide for the necessary radial and axial spacing of the coil sections **20** and **21**, a plurality of radially extending spacing members **28** are arranged between the coils 19 with radial spacers **29** and **30** being suitably secured thereto to provide the requisite radial spacing. The spacing members **28, 29** and **30** are all formed of insulating material and are more fully described in copending application, Serial No. 300,904, filed July 25, 1952, now Patent No. 2,756,397, of Curtis M. Cederstrom, Lloyd S. Blair and John C. Russ assigned to the assignee of the present application.

Referring now to Fig. 5, it is seen that the effective total length of air flow path up through the coils is decreased with air flowing through the inner duct **22** as shown by the arrow **31**, through the outer duct **23** as shown by the arrows **32** and **33**, and over the outer periphery of the coils as shown by the arrow **34**. It is readily seen that the width of the stagnant air area between each coil section is much smaller than that found in the prior art arrangement of Fig. 2 and that by splitting the disk coils into two parts, the distance **17** from the edge of each coil to the center line thereof is cut in half and thus the heat transfer coefficient is increased by 2¼ or 19%. It has been found that in large dry type power transformers, the width of the gap **23** should be between ½ inch and ¾ inch. It is now readily seen that the construction of Figs. 3, 4 and 5 increases the amount of air flow for a given heat dissipation thus giving a lower air temperature surrounding the coil sections and also reducing the stagnant air film thickness clinging to the coil section surfaces, thereby increasing the heat transfer coefficient and reducing the coil temperature rise over the local ambient air temperature.

Referring now to Figs. 7 and 8 in which like parts are again illustrated by like reference numbers, there is shown a modified form of this improved transformer coil construction. It will be readily seen that the adjacent disk coils **19** of the construction of Figs. 3, 4 and 5 must be connected together by means of conductor **27** which must cross the total radial build of each disk coil. This necessitates hand taping which may be both slow and delicate. To obviate the necessity for this operation, the arrangement of Figs. 7 and 8 may be used. Here, a plurality of inner disk coils **35** are first wound on the outer cylinder **7**, being spaced therefrom by means of axial spacing members **36** formed of suitable insulating material. Each disk coil **35** is formed of a continuous radially wound conductor **37** and each disk coil **35** is connected to its adjacent inner disk coil. The inner disk coils **35** are axially spaced apart by means of suitable spacers **38** also formed of insulating material. After all of the inner disk coils **35** are wound, outer longitudinal spacing members **39** are positioned in slots **40** in the spacing members **38** and outer disk coils **41** are wound thereon again being separated by spacers **38**. The disk coils **41** are similarly formed of a continuously radially wound conductor **42** with all of the outer disk coils **41** being electrically connected to form a continuous winding. The inner disk coils **35** thus form an inner winding section and the outer disk coils **41** form a separate outer winding section, these two sections then being electrically connected in parallel to form the complete winding.

In order to insure that the current is evenly divided between coils of the inner and outer sections of the windings of Figs. 7 and 8, the electrical connection of Fig. 9 may be employed wherein inner coils **43** and **44** are cross connected to outer coils **45** and **46**, the resultant serially connected coils **43** and **46**, and **44** and **45** being connected in parallel across lines **47** and **48**. This arrangement will insure that the current divides equally between the two winding sections.

While the improved disk coil of this invention has been shown as comprising two sections, it will be readily apparent that it may comprise more radially spaced apart sections than the two shown. It will also be readily understood that while air has been referred to as a ventilating medium, this construction may actually be used in any gaseous insulated transformer. It will now be readily seen that this invention provides an improved transformer coil construction characterized by its improved thermal efficiency and lower temperature rise.

While we have shown and described specific embodiments of this invention, further modifications and improvements will occur to those skilled in the art. We desire it to be understood, therefore, that this invention is not limited to the form shown and we intend in the appended claim to cover all modifications which do not depart from the spirit and scope of this invention.

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

In a transformer, a cylindrical mounting member, a plurality of disc-shaped annular coils coaxially arranged on said mounting member, axially extending spacers between said mounting member and said coils to provide a first annular ventilating duct, radially extending spacers between said coils to provide ventilating ducts between said coils, each of said coils being comprised of an inner close spirally wound section of a plurality of turns and an outer close spirally wound section of a plurality of turns, and spacing means between each of said inner and outer sections to provide a second annular ventilating duct, the inner sections of substantially one-half of adjacent said coils being serially connected, the outer sections of said one-half of said coils being serially connected, the inner sections of the other half of adjacent said coils being serially connected, the outer sections of said other half of said coils being serially connected, said serially connected inner sections of said one-half of said coils being connected in series with said serially connected outer coils of said other half, said serially connected inner sections of said other half being connected in series with said serially connected outer coils of said one-half, said serially connected inner and outer sections being parallel connected.

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