(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 785 560 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
23.07.1997 Bulletin 1997/30

(51) Int. Cl.[6]: **H01F 27/32**

(21) Application number: **97100473.4**

(22) Date of filing: **14.01.1997**

(84) Designated Contracting States:
CH DE FR GB LI SE

(30) Priority: **19.01.1996 JP 7110/96**

(71) Applicant: **HITACHI, LTD.**
Chiyoda-ku, Tokyo 100 (JP)

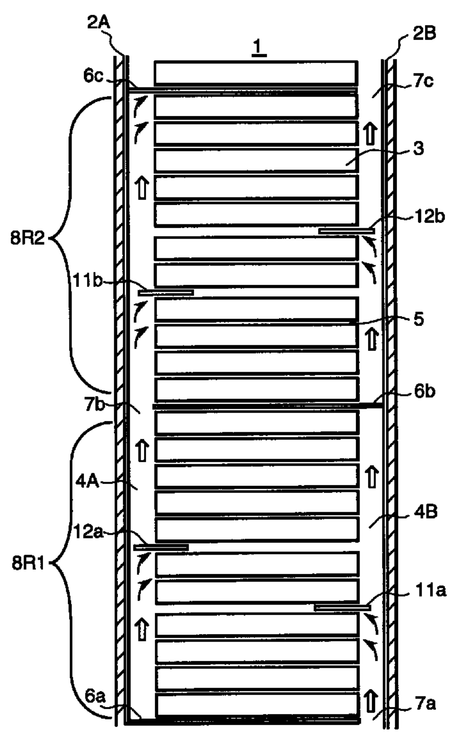
(72) Inventors:
- **Oono, Yasunori**
  Mito-shi, Ibaraki 310 (JP)
- **Sakamoto, Takeshi**
  Naka-gun, Ibaraki 319-11 (JP)
- **Seino, Kazuyuki**
  Hitachi-shi, Ibaraki 316 (JP)
- **Fujita, Hiroyuki**
  Hitachioota-shi, Ibaraki 313 (JP)
- **Hiraishi, Kiyoto**
  Hitachi-shi, Ibaraki 317 (JP)

(74) Representative: **Strehl Schübel-Hopf Groening & Partner**
Maximilianstrasse 54
80538 München (DE)

(54) **Transformer winding structure**

(57) In a baffle region where plural disc like windings are arranged, a branching baffle is extended over toward an inside vertical duct and increases an amount of insulating and cooling fluid which flows a horizontal duct. In the baffle region, a return flow baffle is extended over toward an outside vertical duct and the insulating and cooling fluid flows horizontal ducts at a back portion of the branching baffle. The return flow baffle can flow the insulating and cooling fluid in the horizontal ducts where the flow easily stagnates at a vicinity of the branching baffle. The flow rate of the insulating and cooling fluid in the horizontal duct can be uniformed and the temperature rise can be uniformed. In all horizontal ducts, the flow rate for necessary the cooling can be secured.

FIG. 1



EP 0 785 560 A1

Description

Background of the Invention:

The present invention relates to a transformer windings structure and, in particular to a transformer windings structure suitable for use in a forced circulation cooling type SF_6 gas insulating transformer comprised of disc like windings or helical like windings.

As to the transformer windings structure installed in city, from an aspect of the disaster prevention, there is strong demand for non-flammability and also there is a strong demand for obtaining a large capacity and a compact size.

In the transformer windings structure using a non-flammable insulating and cooling fluid, there is a SF_6 gas insulating transformer wherein SF_6 gas is employed as the non-flammable insulating and cooling fluid. Since the cooling function properties such as density, specific heat and thermal conductivity etc. of SF_6 gas are smaller than those of the liquid insulating and cooling fluid, the cooling performance in SF_6 gas is low and further the insulating withstanding force in SF_6 gas is small.

As a result, a volumetric flow rate of SF_6 gas as the insulating and cooling fluid is made large, and further as an insulating distance in the transformer windings structure, in other words a duct size for flowing the insulating and cooling fluid is made large.

As a transformer windings structure, in case of the disc like windings wound a strand in a disc like form surrounding an iron core or the helical like windings wound in a helical like form surrounding an iron core, an inside and an outside vertical ducts are provided by arranging vertical spacers along to an inner and an outer insulating cylinders at an inside and an outside of a radial direction of the winding.

Further, horizontal ducts are formed by inserting horizontal spacers between each of number stages of the winding at an axial direction of the disc like winding. Plural baffles are inserted at the axial direction of the winding and form plural baffle regions.

Plural opening portions or plural inflow and outflow ports of the baffles are provided alternatively at the inside and the outside of the radial direction of the winding. In accordance with the axial direction flow of the insulating and cooling fluid the flow direction at the radial direction in the winding changes alternatively every the baffle region each.

With the above stated a transformer windings structure, when the volumetric flow rate of the cooling fluid is large and a cross-sectional area of the horizontal duct where the large amount insulating and cooling fluid flows.

Since the large amount cooling fluid flows to the horizontal duct disposed at an upper portion (a downstream side) of the baffle region, it has a tendency to flow small cooling fluid to the horizontal duct disposed at a lower portion (an upstream side).

As a result, it causes a large difference in a temperature rise distribution in the winding, it is a tendency to heighten a maximum temperature rise in the winding in comparison with a mean temperature rise in the winding.

As stated in above, to improve the gas flow in the windings, there are following methods as the prior arts. In a transformer windings structure, a radial direction width of the vertical ducts along to an inner and an outer insulating cylinders are made large (Japanese patent laid-open publication No. 168,707/1992).

In a transformer windings structure, a vertical duct (a gas duct) penetrated through at an axial direction at a vicinity of a central portion of the radial direction of the winding in addition to another vertical duct is provided (Japanese patent laid-open publication No. 43,937/1977).

In a transformer windings structure, radial direction sizes or positions are differed every stages of the winding each (for example, Japanese patent laid-open publication No. 40,820/1978, Japanese patent laid-open publication No. 34,025/1979, etc.)

However, in the above stated prior art a transformer windings structure, the large amount gas flows in the vertical duct disposed along to the insulating cylinders having the small flow resistance.

But since the gas flow rare which flows to the vertical duct disposed at the vicinity of the central portion of the radial direction of the winding or the horizontal duct is relativity small, an effect in the temperature rise reduction is inevitably small.

Further, in case where the radial direction width of the vertical duct is made large or the above stated vertical duct or the above stated gas duct is provided, the radial direction size in the winding increases and as a whole the transformer volume is made large.

Further, in case where the radial direction position of the vertical duct or the gas duct differs every stages of the winding each, many number of branch and confluence causes in the flow of the cooling fluid. Therefore, the pressure loss in the cooling fluid increases and the flow rate of the cooling fluid is lessened or a provision of a large head blower is required.

In particularly, as the transformer installed in city, since a compact size transformer is strongly required, it is necessary to form a compact size a transformer windings structure.

Summary of the invention:

An object of the present invention is to provide a transformer windings structure wherein a flow rate distribution of the insulating and cooling fluid for flowing in horizontal ducts can be uniformed.

Another object of the present invention is to provide a transformer windings structure wherein the local overheat in the unit disc like winding or the unit helical like winding can be prevented.

A further object of the present invention is to provide a transformer windings structure wherein the temperature rise distribution can be uniformed and the temperature rise can be reduced.

A furthermore object of the present invention is to provide a transformer windings structure wherein a whole a transformer windings structure can be formed with a compact size.

According to the present invention, a transformer windings structure comprises an inner insulation cylinder, an outer insulation cylinder, an inside vertical duct, an outside vertical duct, plural horizontal ducts, plural inside vertical spacers for forming the inside vertical duct and provided on an inner wall portion of the inner insulation cylinder at a vertical direction, plural outside vertical spacers for forming the outside vertical duct and provided on an inner wall portion the outer insulation cylinder at a vertical direction, plural horizontal spacers for forming the plural horizontal ducts and provided on between the inner insulation cylinder and the outer insulation cylinder, plural windings laminated in an axial direction with a predetermined space by the inside vertical duct spacers and the outside vertical duct spacers and provided on between the inner insulation cylinder and the outer insulation cylinder, the inside vertical duct formed on between the windings and the inner insulation cylinder by inserting the plural inside vertical duct spacers, the outside vertical duct formed between the plural windings and the outer insulation cylinder by inserting the plural outside vertical duct spacers.

The transformer winding structure comprises further plural baffles provided on between the plural windings at an axial direction of a whole windings, plural inflow and outflow ports alternatively opened at the outside vertical duct at a radial direction or at the inside vertical duct at a radial direction and formed at opened spaces which are formed on between tip ends of the plural baffles and the inner wall portion of the outside vertical duct and the inner wall portion of the inside vertical duct, and plural baffle regions formed on between two adjacent baffles, the insulating and cooling fluid flows in zigzags into the plural baffle regions toward an axial direction.

The transformer windings structure further comprises a constructive structure (a branching baffle) for flowing the insulating and cooling fluid into the horizontal duct and the outside vertical duct or the inside vertical duct, at least one part of the constructive structure is extended over toward into the inner wall portion of the outside vertical duct or the inner wall portion of the inside vertical duct, and at a position nearer to an outlet side of the baffle region than an installation position of the constructive structure.

The transformer windings structure comprises further another constructive structure (a return flow baffle, a flow control projection) for flowing the insulating and cooling fluid into the horizontal duct and the outside vertical duct or the inside vertical duct, at least one part of the another constructive structure is extended over into the inner wall portion of the inside vertical duct or the inner wall portion of the outside vertical duct.

In particular, it is effective that each of the branching baffles and the return flow baffles is formed by a plate like device and the return flow baffle is arranged at the position near the outlet by separating from the branching baffle with two stages or three stages of the unit disc winding.

Further, in at least one part of the horizontal duct which is disposed at a substantial 1/4-3/4 range from the inlet in the baffle region, the insulating and cooling fluid is directed to flow toward the reversal direction against the adjacent horizontal duct. In other words, the insulating and cooling fluid is directed to flow from the outlet side vertical duct toward the inlet side vertical duct.

In the other greater part of the horizontal ducts, the insulating and cooling fluid is directed to flow from the inlet side vertical duct toward the outlet side vertical duct.

As a result, for example, in place of the vertical duct, the transformer windings structure can employ a flow control projection for venting a part of the flow in the vertical duct toward the horizontal duct.

As shown in the prior art a transformer windings structure, in case where the transformer windings structure have no branching baffle and no return flow baffle, in the horizontal duct surrounding from the first number stage unit disc winding to the third number stage unit disc winding (it differs from the width of the horizontal duct) starting from the downstream side of the baffle, the flow of the insulating and cooling fluid stagnates.

At the downstream side of the flow stagnation portion, the insulating and cooling fluid flows more than the flow rate for necessary to perform the cooling effect. Accordingly, the local overheat in the unit disc winding generates at the flow stagnation portion and the periphery portion of the flow stagnation portion.

On the other hand, with the transformer windings structure construction according to the present invention stated in above, at the vicinity of the branching baffle a part of the insulating and cooling flowing fluid along to the vertical duct is forced to flow into the horizontal duct where the flow stagnates.

Accordingly, the flow rate for necessary to perform the cooling effect the horizontal ducts which are positioned near to the inlet from the branching baffle can be secured.

Further, by the provision of the branching baffle the part of the flow of the insulating and cooling fluid is checked and at the downstream side of the branching baffle the flow rate flowing more than necessary amount for perform the cooling effect can be lessened.

Accordingly, the flow rate distribution of the insulating and cooling fluid of each of the horizontal ducts are positioned at the downstream side from the branching baffle is wholly uniformed.

Further, the return flow baffle works to compulsively flow the insulating and cooling fluid flowing the outlet side vertical duct to the inlet side vertical duct.

Accordingly, the stagnation of the flow in two or three horizontal ducts which are positioned at a back portion (the downstream side) of the branching baffle can be avoided, such a stagnation of the flow causes in case of a single use or an independent use of the branching baffle.

In all horizontal ducts the flow rate of the insulating and cooling fluid can be comparatively uniformed, in comparison with no provisions of the branching baffle and the return flow baffle, the temperature rise of each of the unit disc windings can be uniformed.

As a result, the reliability improvement and the extension of the service life of the insulation material can be attained. Further, since the insulating and cooling fluid flows is forced to flow comparatively to uniformly to each of the horizontal ducts, the flow rate of the insulating and cooling fluid can be effectively utilized for the performance of the winding cooling.

Since the flow control projection disposed at the outlet side vertical duct works to compulsively flow the insulating and cooling fluid flowing the outlet side vertical duct to the inlet side vertical duct, using the above flow control projection in place of the return flow baffle, the similar effects shown in case of the provision of the above stated branching baffle and the above stated return flow baffle can be obtained.

In case where many unit disc windings are included in one baffle region, the flow rate of the insulating and cooling fluid lowers in the horizontal ducts which are positioned at a rear portion (the downstream side) of the return flow baffle, the temperature rise of the unit disc winding at the vicinity of the above stated horizontal ducts may enlarge.

In the above stated case, by the provision of plural pairs of a pair of the branching baffle and the return flow baffle in one baffle region, the more insulating and cooling fluid is introduced to the horizontal duct where the flow rate is insufficient.

Therefore, the scattering of the flow rate of each of the horizontal ducts in case of the use of one pair of the branching baffle and the return flow baffle can be further reduced.

Brief Description of Drawing:

Fig. 1 is a partially cross-sectional schematic view showing a winding portion of a first embodiment of a transformer windings structure according to the present invention;

Fig. 2 is a partially squint view showing the first embodiment of the transformer windings structure according to the present invention;

Fig. 3 is an explanatory graph showing the flow velocity in a horizontal duct of one embodiment of the transformer windings structure according to the present invention by comparing with that of the prior art;

Fig. 4 is a temperature rise characteristic graph showing one example of a test result of the first embodiment of the transformer windings structure according to the present invention;

Fig. 5 is a partially cross-sectional schematic view showing a winding portion of a second embodiment of a transformer windings structure according to the present invention;

Fig. 6 is a temperature rise characteristic graph showing one example of a test result of the second embodiment of the transformer windings structure according to the present invention;

Fig. 7 is a partially cross-sectional schematic view showing a winding portion of a third embodiment of a transformer windings structure according to the present invention;

Fig. 8 is a squint view showing a structure of a flow control projection employed in the third embodiment of the transformer windings structure according to the present invention;

Fig. 9 is a partially cross-sectional schematic view showing a winding portion of a fourth embodiment of a transformer windings structure according to the present invention; and

Fig. 10 is a schematic view of is a schematically basic structure view of an SF_6 insulting transformer having a transformer windings structure according to the present invention.

Description of the Invention:

Hereinafter, one embodiment of a transformer windings structure according to the present invention will be explained in detail in accordance with an illustrated embodiment.

Fig. 1 is a partially cross-sectional schematic view showing a winding portion of a first embodiment of a transformer windings structure according to the present invention, and Fig. 2 is a squint view of the winding portion shown in Fig. 1 of the transformer windings structure.

In Fig. 1, the first embodiment of the transformer windings structure according to the present invention comprise a winding 1, an inner insulating cylinder 2A, and an outer insulating cylinder 2B. The transformer windings structure comprise plural of unit disc like windings 3 and each of the unit disc like winding 3 is wound between the inner insulating cylinder 2A and the outer insulating cylinder 2B.

Each of the inner insulating cylinder 2A and the outer insulating cylinder 2B forms as a partitioning wall with the unit disc winding 3.

The transformer windings structure comprise further plural baffles 6a, 6b and 6c. The plural baffles 6a, 6b and 6c are arranged at an axial direction of the winding 1. A first stage baffle region 8R1 is formed between the baffles 6a and 6b, and a second stage baffle region 8R2 is formed between the baffles 6b and 6c and this second stage baffle region 8R2 is positioned at the downstream of the first stage baffle region 8R1.

The plural baffles 6a, 6b and 6c have alternatively inflow port and outflow ports 7a, 7b and 7c at the radial direction. The insulating and cooling fluid enters into the baffle region 8R1 through the inflow port and outflow port 7a and further enters into the baffle region 8R2 through the inflow port and outflow port 7b.

In some baffle region, at both sides of an inside and an outside of the winding 1, the transformer windings structure comprise an inside vertical duct 4A and an outside vertical duct 4B. A width at a radial direction of the inside vertical duct 4A is 22 mm, and a width at a radial direction of the outside vertical duct 4B is 25 mm.

In the baffle region 8R1, a branching baffle (one structural construction) 11a is provided between a fourth number stage unit disc winding 3 and a fifth number stage unit disc winding 3 at an upper portion (a downstream side) of the baffle 6a. A part of this branching baffle 11a extends over toward into the outside vertical duct 4A.

The branching baffle 11a has a thickness of 2 mm and a width of 40 mm. A space between an inner wall of the outer insulating cylinder 2B and a projected right end of the branching baffle 11a is 6 mm.

Further, a return flow baffle 12a (another structural construction) is provided between a sixth number stage unit disc winding 3 and a seventh number stage unit disc winding 3 at the upper portion (the downstream side). A part of this return flow baffle 12a extends over toward into the outside vertical duct 4B.

The return flow baffle 12a has a thickness of 1.5 mm and a width of 40 mm. A space between an inner wall of the inner insulating cylinder 2A and a projected left end of the return flow baffle 12a is 8 mm.

Further, in the baffle region 8R2, a branching baffle 11a is provided between the fourth number stage unit disc winding 3 and the fifth number stage unit disc winding 3 at the upper portion (the downstream side) of the baffle 6b. A part of this branching baffle 11b extends over toward into the inside vertical duct 4A.

A return flow baffle 12b is provided between the sixth number stage unit disc winding 3 and the seventh number stage unit disc winding 3 at the upper portion (the downstream side) of the baffle 6b. A part of this return flow baffle 12b extends over toward into the outside vertical duct 4B.

Each of the dimensions of the baffles 6b and 6c and the dimension of the branching baffle 11b and further each of a space between the inner insulating cylinder 2A and the branching baffle 11a and a space between the outer insulating cylinder 2B and the return flow baffle 12b in the second stage baffle region 8R2 is set similar to those of the first stage baffle region 8R1.

A manner for fixing the return flow baffle 12b will be explained referring to Fig. 2. In Fig. 2, plural vertical spacer 9a are adjacently arranged to the inner insulating cylinder 2A with an equal interval at a circumferential direction. Plural outside vertical spacer 9b are adjacently arranged to the outer insulating cylinder 2B with an equal interval at the circumferential direction.

Plural horizontal spacer 10 are mounted between the inside vertical spacer 9a and the outside vertical spacer 9b. A space in a height direction of the horizontal spacer 10 and the unit disc winding 3 is maintained at constant.

In Fig. 2, the return flow baffle 12b is mounted to the outside vertical spacer 9b. Further, since the return flow baffle 12b is sandwiched between two horizontal spacers 10, the return flow baffle 12b is surely fixed according to the weight of the winding 1.

A manner for fixing the branching flow baffle 11a or 11b is similarly to that of the above stated return flow baffle 12a or 12b.

With the above stated a transformer windings structure construction, the insulating and cooling fluid enters into the first stage baffle region 8R1 from the inflow and outflow port 7a and ascends in the outside vertical duct 4B.

At an installation portion of the branching baffle 11a, the insulating and cooling fluid branches to the straight flow for flowing in the outside vertical duct 4B leaving alone and to the bending flows for flowing the horizontal ducts 5 which are formed between the baffle 6a and the branching baffle 11a.

The branching baffle 11a works to limit an amount of the cooling fluid for flowing the outside vertical duct 4B within the insulating and cooling fluid which is flown from the inflow and outflow port 7a of the first stage baffle region 8R1 and to the bending flow of the insulating and cooling fluid into the horizontal ducts 5.

The return flow baffle 12a works to limit an amount of the cooling fluid for flowing the inside vertical duct 4A within the insulating and cooling fluid which is flown in the first stage baffle region 8R1 and to flow the insulating and cooling fluid into the horizontal ducts 5.

The insulating and cooling fluid passing through the horizontal ducts 5 ascends the inside vertical duct 4A. At the installation portion of the return flow baffle 12a, the insulating and cooling fluid branches to the straight flow for flowing in the outside vertical duct 4B leaving alone and to the bending flow for flowing the horizontal ducts 5.

In the horizontal ducts 5, the insulating and cooling fluid flows toward the outside vertical duct 4B or at the reversal direction oppositely to the flow of the insulating and cooling fluid of the adjacent horizontal ducts 5.

At the branching baffle 11a, the insulating and cooling fluid flown the outside vertical duct 4B leaving alone flows into the horizontal duct 5 and reaches to the inflow and outflow port 7b of the second stage baffle region 8R2.

In this second stage baffle region 8R2, by the provisions of the branching baffle 11b and the return flow baffle 12b the insulating and cooling fluid repeats to branch and to conflate similar to those of the first stage baffle region 8R1 and reaches finally to the inflow and outflow port 7c.

Fig. 3 is a graph showing the flow velocity at the central portion of each of the horizontal ducts 5 of the second stage baffle region 8R2 of the above first embodiment of the transformer windings structure according to the present invention.

In a right side in Fig. 3, the flow velocity of the above first embodiment of the transformer windings structure according to the present invention is shown with a solid line arrow mark and a flow velocity of the prior art in which the transformer windings structure has no branching baffle and no return flow baffle is shown with a dotted line arrow mark.

As a reference value of the flow velocity, in Fig. 3 in case of the flow flowing from a left side toward a right side, the above reference value of the flow velocity indicates plus. In a left side in Fig. 3, a left end number is a stage number of the unit disc winding 3.

As clearly understood from Fig. 3, in the prior art a transformer windings structure the flow velocity at an upper portion and a down portion of a third number stage unit disc winding is about 0.1 m/sec and substantially stagnates. Since the heat removal from the unit disc winding is insufficient in the prior art a transformer windings structure, the local overheat occurs in the unit disc winding.

Comparing with the prior art a transformer windings structure, in the above stated first embodiment of the transformer windings structure according to the present invention, even it attentions to in any unit disc winding, the mean flow velocity of an upper and a lower horizontal ducts is more than 1 m/sec and this flow velocity is substantially sufficient to perform the winding cooling.

Further, in the horizontal duct where the large amount cooling fluid flows more than a necessary amount, however according to the above stated first embodiment of the transformer windings structure the flow velocity in the above stated horizontal duct 5 can be reduced some degree.

As a result, the flow velocity distribution in each of the horizontal ducts 5 can be uniformed and the scattering of the temperature rise of the unit disc winding can be remarkably reduced.

The above facts obtained by the above stated first embodiment of the transformer windings structure will be expressed by the experimental data which were obtained using a test apparatus.

The test apparatus was constituted of a vessel for receiving the winding shown in Fig. 1, a cooler, a blower, various kinds of measuring instruments, and pipes. The insulating and cooling fluid (SF_6 gas) circulated in the test apparatus.

In the winding, a heater and a thermocouple were buried into a copper (Cu) wire having a width of 28 mm and a height of 14.5 mm and by winding an insulating film a dummy conductor including the winding were prepared. One unit disc winding 3 was prepared by arranging plural obtained dummy conductors.

The unit disc winding 3 was formed by overlapping an unit disc winding having a total eleven stages per one baffle region comprised of a pair of the baffles 6a and 6b through the horizontal spacer 10 at the height direction.

The cooling characteristic test was carried out with respect to a case of the insertions of the branching baffle and the return flow baffle and a case of no insertions of the branching baffle and the return flow baffle.

A test manner was that the heater buried in the dummy conductor was heat-generated by flowing a predetermined current and SF_6 gas being the cooling fluid was circulated by the blower and then the temperature of the dummy conductor was measured.

Fig. 4 is the temperature rise characteristic graph showing one example of the test result. In the test, the cooling fluid pressure was 0.6 MPa, the heat generation density of the winding was 316 kW/m^3. The dimension of the winding was a flow passage length at the horizontal direction of 147 mm, a horizontal duct height of 4.5 mm, an inside vertical duct width of 22 mm, and an outside vertical duct width of 25 mm.

A horizontal axis in Fig. 4 shows the mean temperature rise of each of the dummy conductors starting from the inlet gas temperature of the baffle region and it illustrates the case of the second stage baffle region 8R2 in Fig. 1. A vertical axis shows a number of the unit disc winding at the height direction starting from the baffle 6b of the unit disc winding.

In Fig. 4, a result according to this first embodiment of the transformer windings structure of the present invention is shown with ○ mark where the branching baffle and the return flow baffle are provided on the transformer windings structure.

Further, a result according to the prior art is shown with △ mark where the branching baffle and the return flow baffle are not provided on the transformer windings structure.

As clearly understood from Fig. 4, in comparison with the case of no provisions of the branching baffle and the return flow baffle, in the case of the provisions of the branching baffle and the return flow baffle as shown in the first embodiment of the transformer windings structure, the maximum temperature rise of the unit disc winding can be reduced with about 50 %.

Fig. 5 is a partially cross-sectional schematic view showing a winging portion of a second embodiment of a transformer windings structure according to the present invention.

Similarly to the first embodiment in Fig. 1, the transformer windings structure in the second embodiment comprise a winding 1, an inner insulating cylinder 2A, an outer insulating cylinder 2B, an inside vertical duct 4A, an outside vertical duct 4B, horizontal ducts 5, a branching baffle 11a, a branching baffle 11b, a return flow baffle 12a, and a return flow baffle 12b, etc..

In this second embodiment of the transformer windings structure, a width of the inside vertical duct 4A is 42 mm and a width of the outside vertical duct 4B is 45 mm. The different elements in this second embodiment compared with the first embodiment are the above both vertical duct widths which have about two times widths those of the first embodiment.

As to the second stage baffle region 8R2, in case of no provisions of the branching baffle and the return flow baffle on the transformer windings structure, the insulating and cooling fluid flow substantially stagnates and the flow velocity at the upper and the lower horizontal baffles surrounding the nearest unit disc winding 3 becomes 0.1 m/sec.

Accordingly, in this second embodiment of the transformer windings structure according to the present invention, the branching baffle 11b is installed on between the third number stage unit winding 3 and the fourth number stage unit disc winding 3 starting from the baffle 6b.

Further, the insulating and cooling fluid flows smoothly in the horizontal ducts 5 formed between the branching baffle 11b and the baffle 6b. A space between a projected left end of the branching baffle 11b and an inner wall of the inner insulating cylinder 2A is 6 mm.

The return flow baffle 12b is installed on between the fifth number stage unit winding 3 and the sixth number stage unit disc winding 3 starting from the baffle 6b. A space between a projected right end of the return flow baffle 12 and an inner wall of the outer insulating cylinder 2B is 8 mm.

In the outside horizontal duct 5 positioned at the upper side of the fourth number stage unit winding 3 and the fifth number stage unit disc winding 3 starting from the baffle 6b, the insulating and cooling fluid flows from the outside vertical duct 4B toward the inside vertical duct 4A.

However, in the other greater part of the horizontal ducts 5, the insulating and cooling fluid flows from the inside vertical duct 4A toward the outside vertical duct 4B.

In this second embodiment of the transformer windings structure according to the present invention, even it attentions to which unit disc winding 3, the mean flow velocity in the upper and down horizontal ducts 5 is more than 1 m/sec and this flow velocity is sufficient to perform the winding cooling.

The effects of this second embodiment of the transformer windings structure according to the present invention will be explained according to a test data. A test apparatus and a test method in this second embodiment are similarly to those of shown in the first embodiment in Fig. 1.

Fig. 6 is the temperature rise characteristic graph showing another example of a test result. In the test, cooling fluid pressure was 0.6 MPa, the heat generation density of the winding was 316 kW/m^3. The dimension of the winding was a flow passage length at the horizontal direction of 147 mm, a horizontal duct height of 4.5 mm, an inside vertical duct width is 42 mm and an outside vertical duct width of 45 mm.

A horizontal axis in Fig. 6 shows the mean temperature rise of each of the dummy conductors unit is windings starting from the inlet gas temperature of the baffle region. A vertical axis shows a number of the unit disc winding at the height direction starting from the baffle 6b.

In Fig. 6, a result of this second embodiment the transformer windings structure according to the present invention is shown with ○ mark where the branching baffle and the return flow baffle are provided on the transformer windings structure.

Further, a result according to the prior art is shown with △ mark where the branching baffle and the return flow baffle are not provided on the transformer windings structure.

As clearly understood from Fig. 6, in comparison with the case of no provisions of the branching baffle and the return flow baffle, in the case of the provisions of the branching baffle and the return flow baffle as shown in the second embodiment, the maximum temperature rise of the unit disc winding can be reduced with about 65 %.

Fig. 7 is a partially cross-sectional view showing a winding portion of a third embodiment of a transformer windings structure according to the present invention.

Similarly to the first embodiment shown in Fig. 1, the transformer windings structure of the third embodiment comprise a winding 1, an insulating cylinder 2A, an outer insulating cylinder 2B, an inside vertical duct 4A, an outside vertical duct 4B, horizontal ducts 5, a branching baffle 11a, and a branching baffle 11b, etc..

However, in this third embodiment, in place of the return flow baffle 12a, a flow control projection 13a is provided on the inner insulating cylinder 2A. Further, in place of the return flow baffle 12b, a flow control projection 13b is provided on the outer insulating cylinder 2B.

As to the first stage baffle region 8R1, the flow control projection 13a is arranged to oppose against the seventh stage unit disc winding 3 starting form the baffle 6a and to contact to the inner insulating cylinder 2A. As to the second stage baffle region 8R2, the flow control projection 13b is arranged to oppose against the seventh stage unit disc winding 3 starting form the baffle 6b and to contact to the outer insulating cylinder 2B.

Fig. 8 is a squint view showing a structure of the flow control projection 13a of the third embodiment shown in Fig. 7. A cross-sectional shape of the flow control projection 13a taken from along to the flow in the inside vertical duct 4A has a triangular shape.

An angle between the base of the triangular shape of the flow control projection 13a which contacts to the inner insulating cylinder 2A and a lower side (an inflow side) is 45° and also an angle between the base of the triangular shape and an upper side (an outflow side) is 45° . A height of the triangular shape is 12 mm.

The flow control projection 13a operates to force the flow of a part of the insulating and cooling fluid, which flows the upper portion of the inside vertical duct 4A, from the baffle 6a to the horizontal duct 5 which is disposed at the upper side of between the fifth number stage unit disc winding 3 and the sixth number stage unit disc winding 3.

As a result, the part of the insulating and cooling fluid is forced to flow from the inside vertical duct 4A to the outside vertical duct 4B.

Accordingly, similar to the first embodiment shown in Fig. 1, the flow velocity in the upper and the lower horizontal ducts 5 of every unit disc winding 3 according to this third embodiment can be obtained more than 1 m/sec.

Further, according to this third embodiment of the transformer windings structure, the maximum temperature rise in the unit disc winding 3 is reduced about 50 % in comparison with no provisions of the branching baffles 11a and 11b and the flow control projections 13a and 13b.

In the transformer windings structure of each of the above stated embodiments shown in Fig. 1, Fig. 5 and Fig. 7, the unit disc winding having the eleven stages is included in one baffle region.

However, in case of the unit disc winding having more many stages than the eleven stages, it can provide plural pairs of the branching baffle and the return flow baffle or the flow control projection.

Accordingly, in the horizontal duct mounted on a range of about 1/4-3/4 starting from the inlet of the baffle region, plural flows of the insulating and cooling fluid directed from the outlet side vertical duct to the inlet side vertical duct can be generated, thereby the flow of the insulating and cooling fluid can be uniformed.

As a result, according to the above stated embodiment, the similar effects shown in the above stated former three embodiments can be obtained.

Fig. 9 is a partially cross-sectional schematic view showing a winding portion of a fourth embodiment of the transformer windings structure according to the present invention.

In Fig. 9, the transformer windings structure of the fourth embodiment according to the present invention comprises a first branching baffle 11a1, a first return flow baffle 11b1, a second branching baffle 11a2, a second return flow baffle 11b2.

Namely, the transformer winding structure comprises two pairs of baffles, which a pair of the first branching baffle 11a1 and the first return flow baffle 11b1 and a pair of the second branching baffle 11a2 and the second return flow baffle 11b2.

In this transformer windings structure of the fourth embodiment according to the present invention, a baffle region 8R1 is formed between an upstream side baffle 6a and a downstream side baffle 6b.

The two pairs comprised of the branching baffle 11a1 and the return flow baffle 12a1 and the branching baffle 11a2 and the return flow baffle 12a2 are arranged in the baffle region 8R1 and further arranged between the upstream side baffle 6a and the downstream side baffle 6b.

Fig. 10 is a schematic view of is a schematically basic structure view of an SF_6 gas insulting transformer having a transformer windings structure according to the present invention.

In Fig. 10, an SF_6 gas insulting transformer comprises mainly a tank 101, an iron 102, tap windings 103, high pressure outside windings 104, middle pressure windings 105, high pressure inside windings 106, low pressure windings 107, a cooler 108 and a blower 109. The iron core 102 comprises a leg member and a yoke member.

In the above stated SF_6 gas insulting transformer, a winding portion is constituted by the high pressure outside windings 104, the middle pressure windings 105, the high pressure inside windings 106, and the low pressure windings 107. The windings are wound at a surrounding portion of the leg member of the iron 102.

With the above stated winding portion of the above stated SF_6 gas insulting transformer, one of the various transformer windings structure according to the present invention can employ.

In the above stated embodiments, as the unit winding the disc like winding is exemplified, however a helical like winding can be employed.

According to the present invention, in a transformer windings structure, at an axial direction of an unit disc like winding or an unit helical like winding which is formed by an inner and an outer insulation cylinders around an iron core leg as partitioning walls, plural baffles provided on between the plural windings at an axial direction of a whole windings, plural inflow and outflow ports alternatively opened at the outside vertical duct at a radial direction or at the inside vertical duct at a radial direction and formed at opened spaces which are formed on between tip ends of the plural baffles and the inner wall portion of the outside vertical duct and the inner wall portion of the inside vertical duct, and plural baffle regions formed on between two adjacent baffles, the insulating and cooling fluid flows in zigzags into the plural baffle regions toward an axial direction.

The transformer windings structure further comprises a constructive structure (a branching baffle) for flowing the insulating and cooling fluid into the horizontal duct and the outside vertical duct or the inside vertical duct, at least one part of the constructive structure is extended over toward into the inner wall portion of the outside vertical duct or the inner wall portion of the inside vertical duct.

The transformer windings structure further comprises further at a position nearer to an outlet side of the baffle region than an installation position of the constructive structure, another constructive structure (a return flow baffle, a flow control projection) for flowing the insulating and cooling fluid into the horizontal duct and the outside vertical duct or the inside vertical duct, at least one part of the another constructive structure is extended over into the inner wall portion of the inside vertical duct or the inner wall portion of the outside vertical duct.

Accordingly, with the transformer windings structure construction according to the present invention stated in above, at the vicinity of the constructive structure (the branching baffle) a part of the insulating and cooling flowing fluid along to the vertical duct is forced to flow into the horizontal duct where the flow stagnates.

Accordingly, the flow rate for necessary to perform the cooling effect the horizontal ducts which are positioned near to the inlet from the constructive structure (the branching baffle) can be secured.

Further, by the provision of the constructive structure (the branching baffle) the part of the flow of the insulating and cooling fluid is checked and at the downstream side of the constructive structure (the branching baffle) the flow rate flowing more than necessary amount for perform the cooling effect can be lessened.

Accordingly, the flow rate distribution of the insulating and cooling fluid of each of the horizontal ducts are positioned at the downstream side from the constructive structure (the branching baffle) is wholly uniformed.

Further, the another constructive structure (the return flow baffle or the flow control projection) works to compulsively flow the insulating and cooling fluid flowing the outlet side vertical duct to the inlet side vertical duct.

Accordingly, the stagnation of the flow in two or three horizontal ducts which are positioned at a back portion (the downstream side) of the constructive structure (the branching baffle) can be avoided, such a stagnation of the flow causes in case of a single use or an independent use of the constructive structure (the branching baffle).

In all horizontal ducts the flow rate of the insulating and cooling fluid can be comparatively uniformed, in comparison with no provisions of the constructive structure (the branching baffle) and the another constructive structure (the return flow baffle or the flow control projection), the temperature rise of each of the unit disc windings can be uniformed.

Accordingly, the flow rate of the insulating and cooling fluid flown in the horizontal duct can be uniformed, and the local overheat in the horizontal duct can be prevented and further the temperature rise distribution can be uniformed.

Therefore, a whole windings structure can be formed with a compact size, and temperature rise in the windings can be reduced.

Claims

1. A transformer winding structure comprising:

   a plurality of axially laminated windings (1) disposed between an inner and an outer insulation cylinder (2A, 2B),
   axially extending inner spacers (9a) forming an inner axial duct (4A) between said windings and said inner cylinder (2A),
   axially extending outer spacers (9b) forming an outer axial duct (4B) between said windings and said outer cylinder (2B),
   radially extending spacers (10) forming a plurality of radial ducts (5) between said inner and outer cylinders (2A, 2B),
   a plurality of axially acting baffles (6a, 6b, 6c) provided between said windings (1) and having end portions spaced alternatively from said inner and outer cylinders (2A, 2B) for causing an insulating and cooling fluid to flow in zigzag fashion through said winding structure in a generally axial direction,

   characterised by structural means (11a, 11b; 11a1, 11a2; 12a, 12b; 12a1, 12a2; 13a, 13b) extending at least partly into said inner or outer vertical ducts (4A, 4B) for diverting said insulating and cooling fluid from said axial ducts (4A, 4B) into and through said radial ducts (5).

2. The structure of claim 1, wherein a baffle region (8R1, 8R2) is defined between every two adjacent baffles (6a, 6b; 6b, 6c), each baffle region including a first structural means (11a, 11b; 11a1, 11a2) spaced from one said two baffles by 1/4 to 1/3 of the axial length of the baffle region, and a second structural means (12a, 12b; 12a1, 12a2; 13a, 13b) disposed closer to the other baffle.

3. The structure of claim 1 or 2, wherein each said structural means (11a, 11b; 11a1, 11a2; 12a, 12b; 12a1, 12a2; 13a, 13b) is formed by a plate-like member.

4. The structure of claim 3, wherein said plate-like member is fixed by sandwiching by a radially extending spacer (10).

5. The structure of any preceding claim, wherein said insulating and cooling fluid is SF_6.

6. An insulating transformer comprising a high pressure winding section (104, 106), a middle pressure winding section (105) and a low pressure winding section (107), wherein at least one of said winding sections has the structure defined in any preceding claim.

FIG. 1

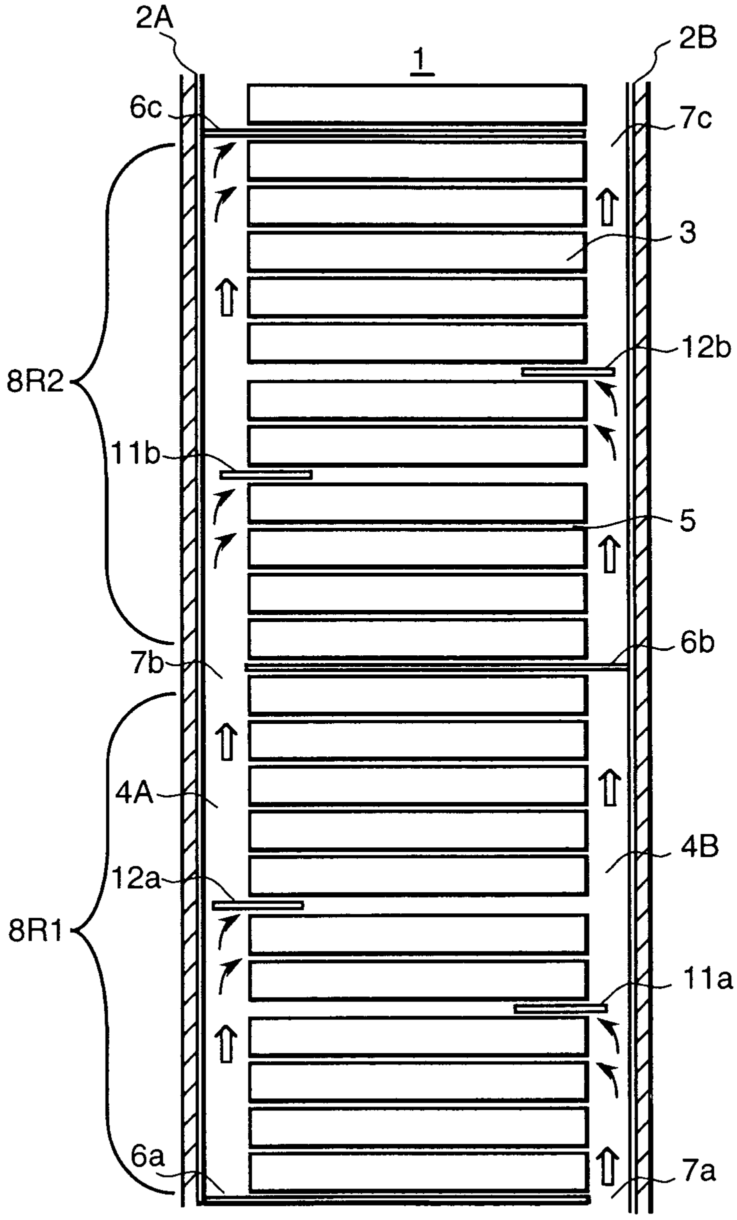


FIG. 2

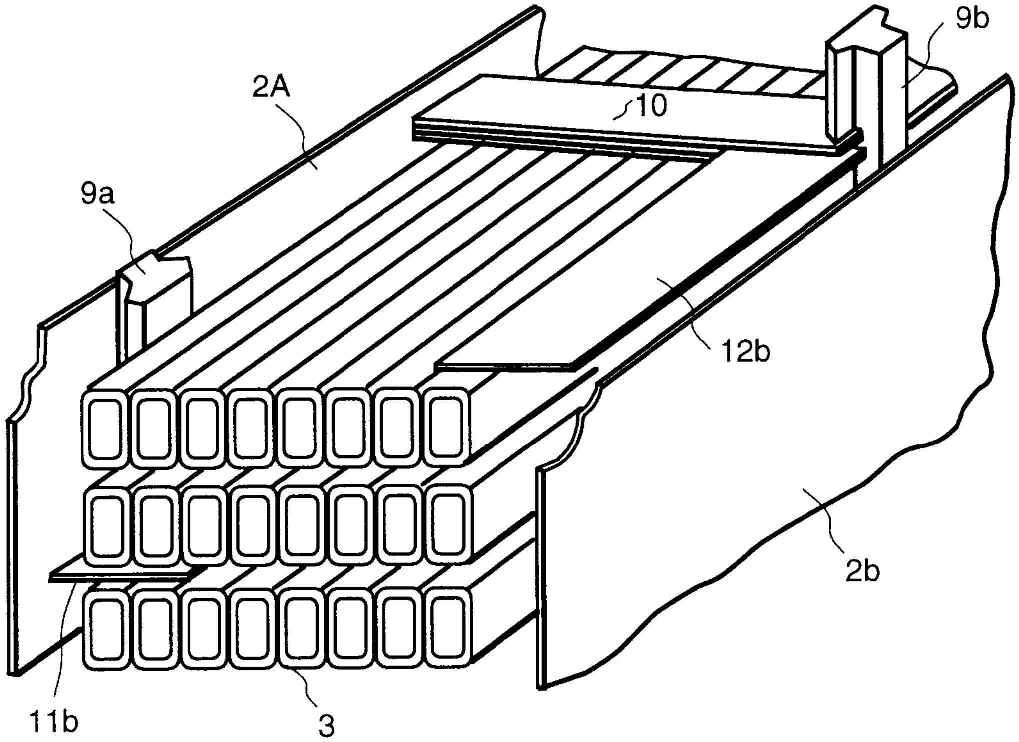

9b
2A
10
9a
12b
2b
11b
3

FIG. 4

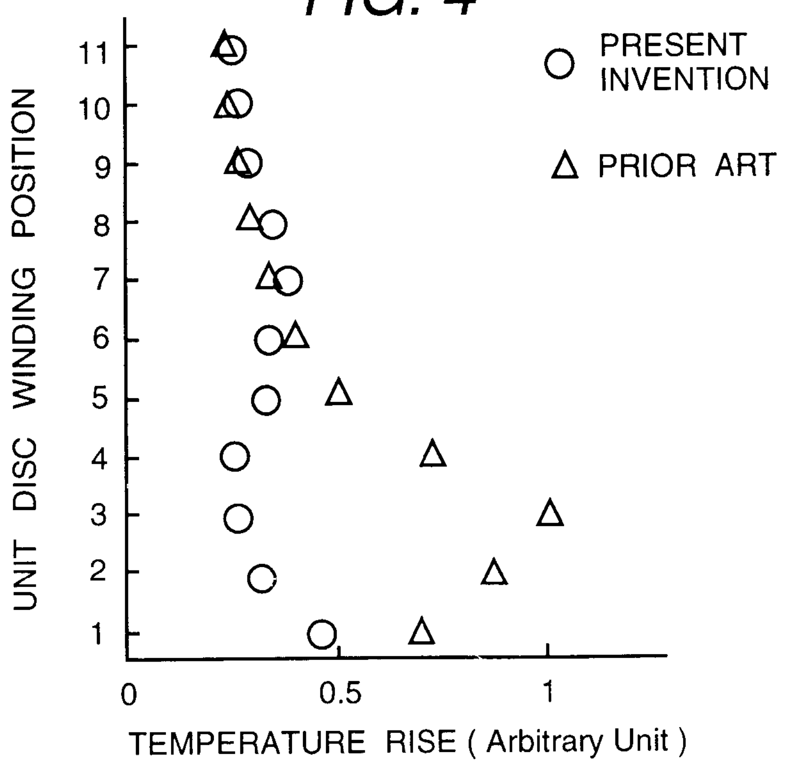

PRESENT INVENTION
PRIOR ART
UNIT DISC WINDING POSITION
11
10
9
8
7
6
5
4
3
2
1
0
0.5
1
TEMPERATURE RISE (Arbitrary Unit)

FIG. 3

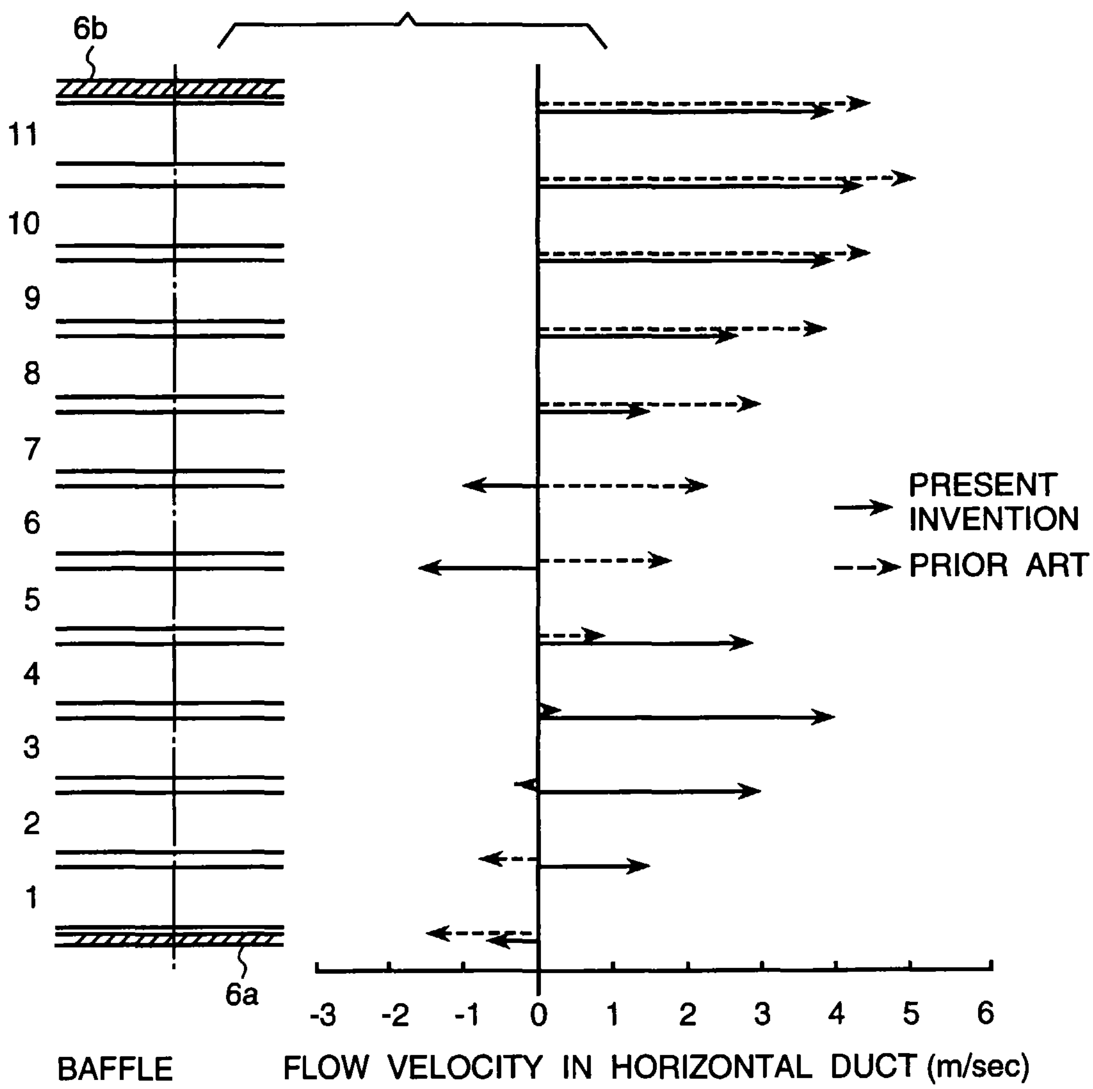

6b
11
10
9
8
7
6
5
4
3
2
1
6a
PRESENT INVENTION
PRIOR ART
-3 -2 -1 0 1 2 3 4 5 6
BAFFLE
FLOW VELOCITY IN HORIZONTAL DUCT (m/sec)

FIG. 5

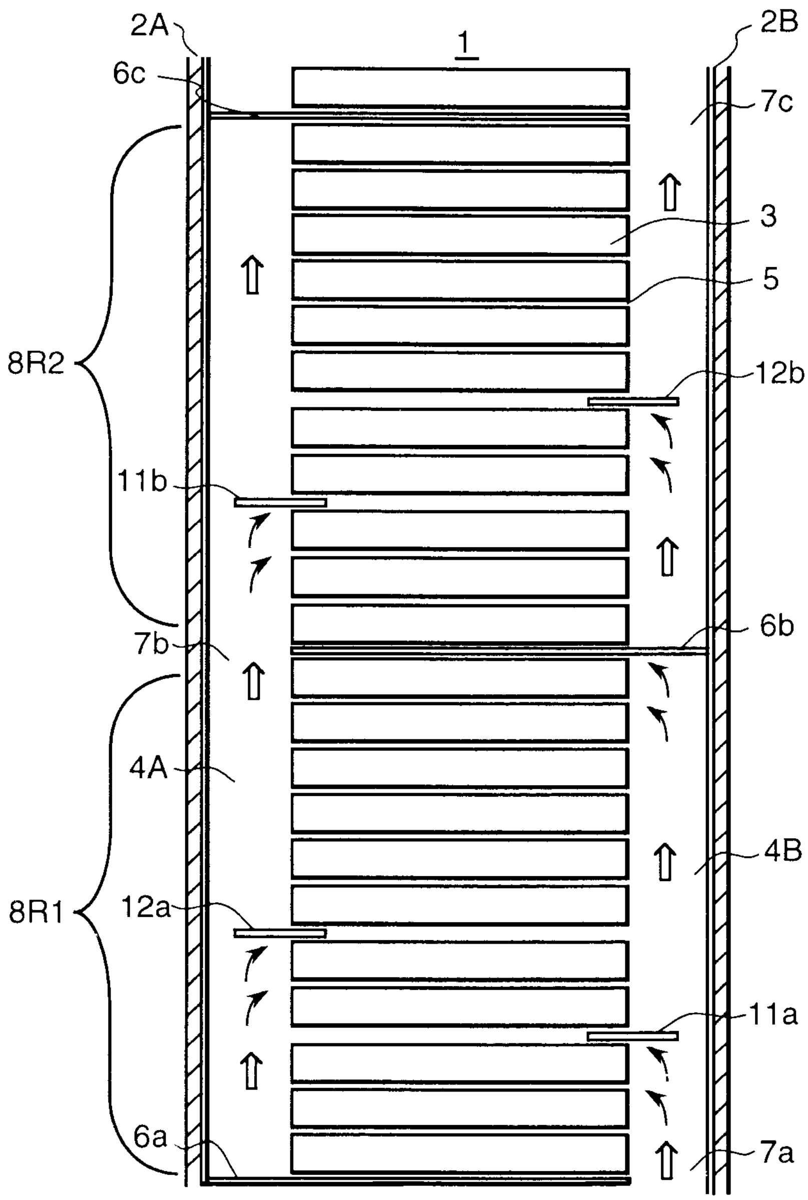


FIG. 6

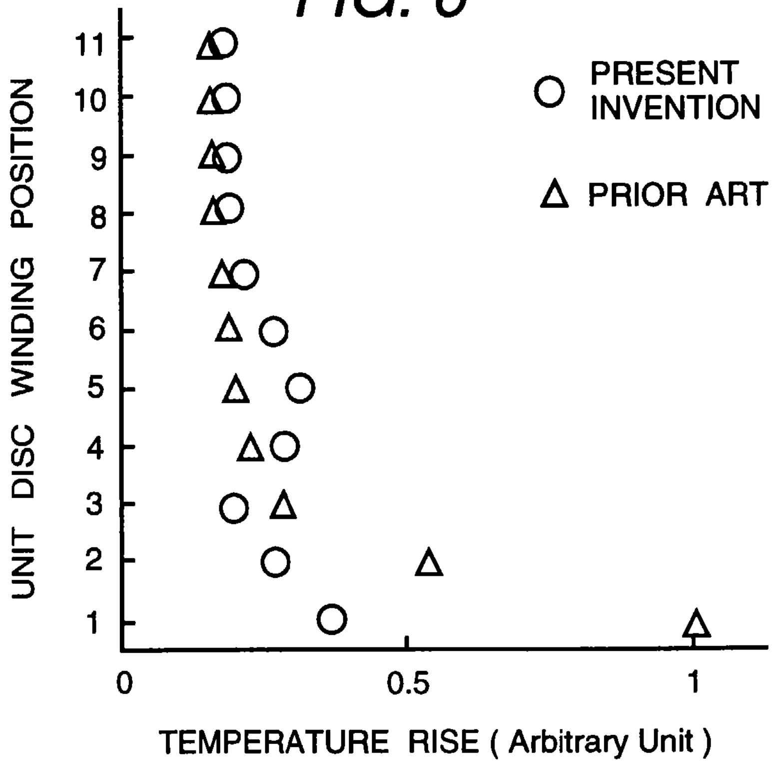

UNIT DISC WINDING POSITION
11
10
9
8
7
6
5
4
3
2
1
0
0.5
1
TEMPERATURE RISE (Arbitrary Unit)
PRESENT INVENTION
PRIOR ART

FIG. 8

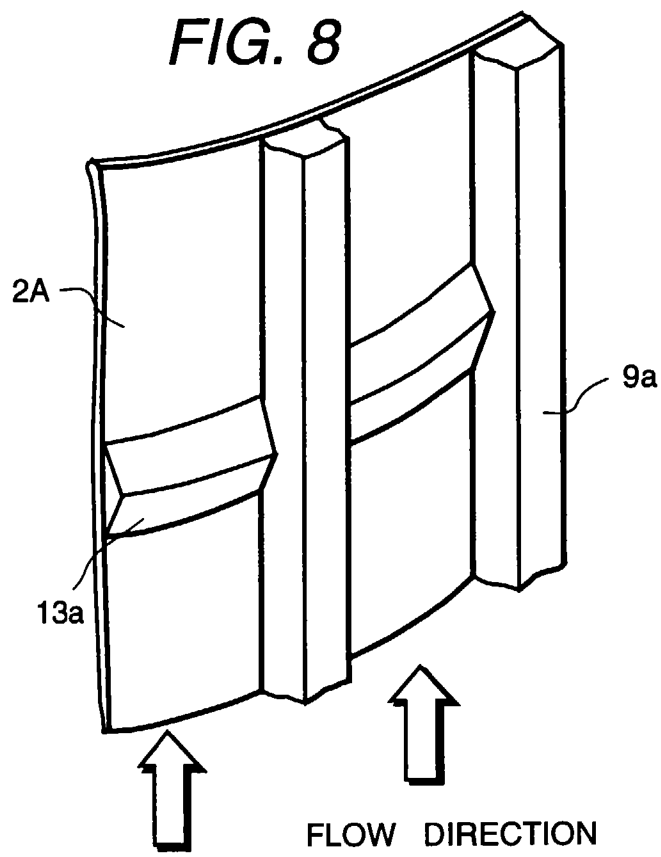

2A
9a
13a
FLOW DIRECTION

FIG. 7

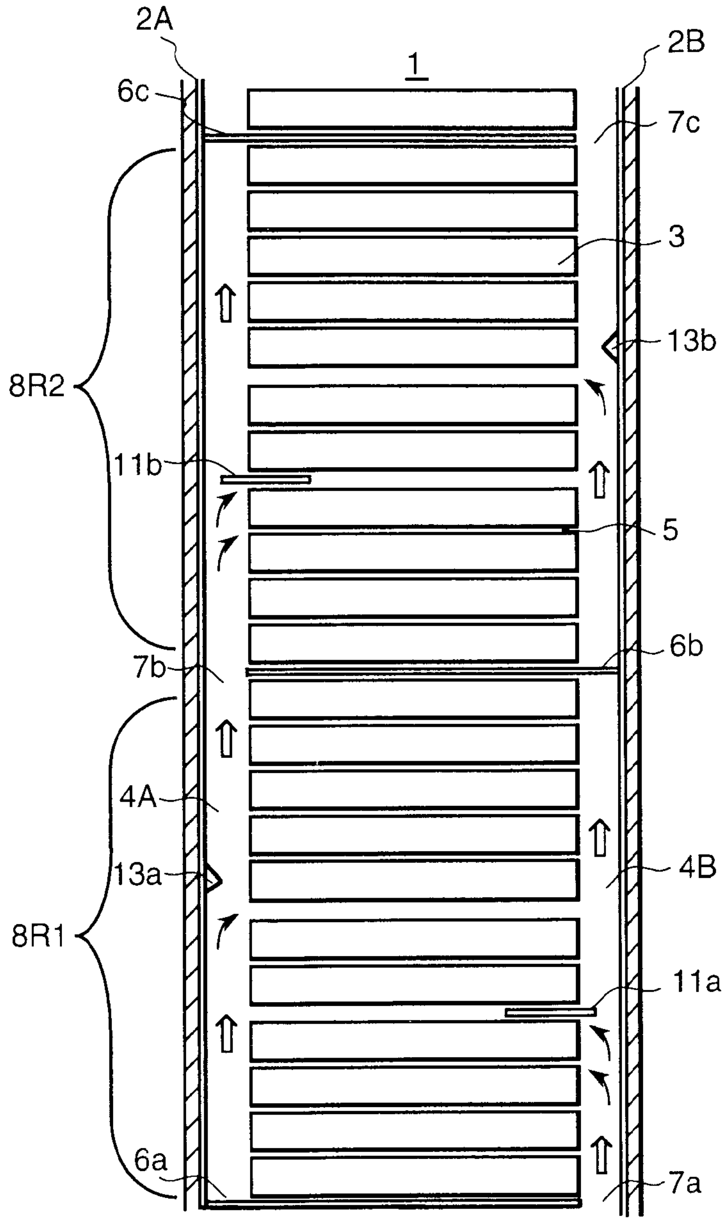


FIG. 9

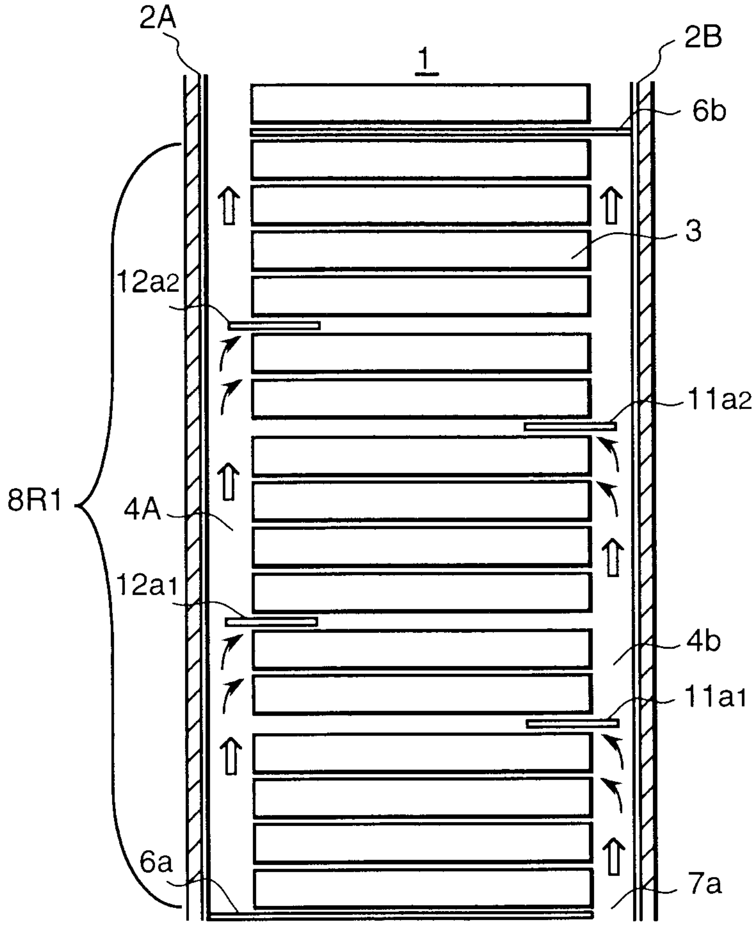
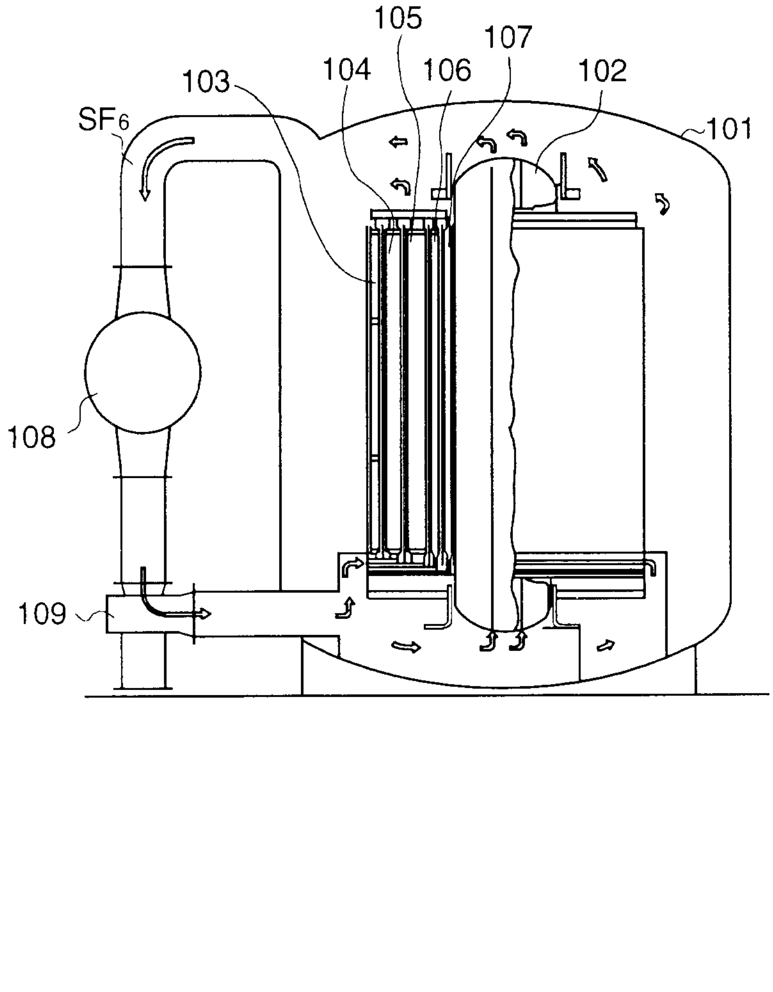


FIG.10



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 0473

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 3 902 146 A (MURALIDHARAN RAMACHANDRAN) 26 August 1975 * column 4, line 14 - line 23 *	1	H01F27/32
A	US 4 207 550 A (DAIKOKU TAKAHIRO ET AL) 10 June 1980 * figures 1-13 *	1	
A	US 5 296 829 A (KOTHMANN RICHARD E ET AL) 22 March 1994		
A	IEEE TRANSACTIONS ON POWER APPARATUS AND SYSTEMS, vol. 101, no. 2, 1982, NEW YORK US, pages 2229-2235, XP002029942 T.SATO ET AL.: "Cooling effect by gas density of SF6 gas insulated transformer"		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 April 1997	Vanhulle, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)