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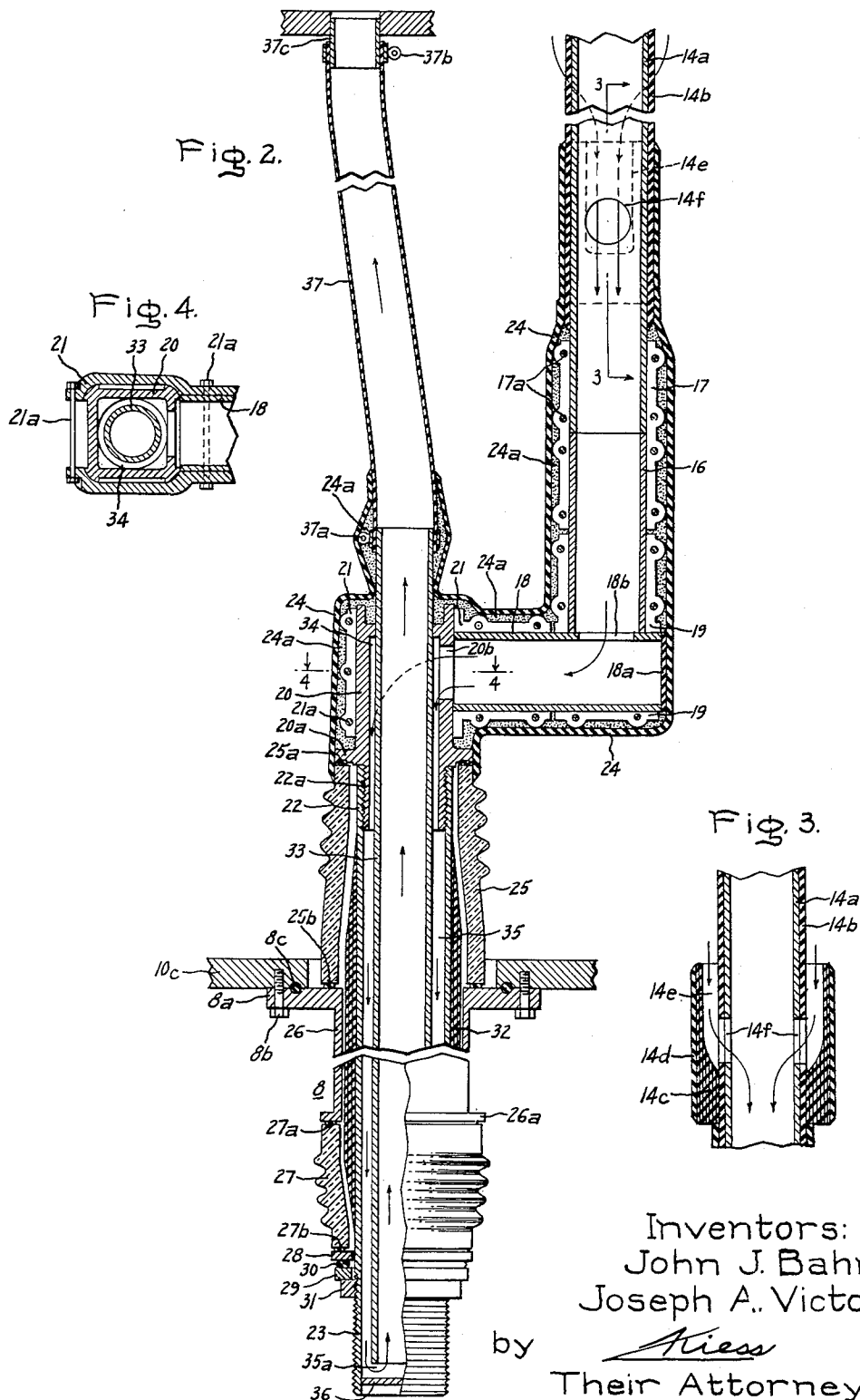
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GAS-COOLED HIGH VOLTAGE BUSHING FOR LARGE GENERATOR

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1

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GAS-COOLED HIGH VOLTAGE BUSHING FOR LARGE GENERATOR

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This relates to very large capacity electric generators, particularly to generators having a sealed casing containing a coolant gas such as hydrogen, although not necessarily limited thereto. The invention resides in an improved high voltage bushing construction for passing the electrical conductors through the wall of the sealed casing.

As the capacity of extremely large electric generators has increased, the physical size of the insulated bushings required to carry the load current through the casing of the machine has likewise increased. Heretofore it has been common practice to rely on convection currents in the fluid surrounding the bushing to dissipate the heat generated in the structure by passage of the heavy current therethrough. This has resulted in bushings of such large size that further increases have become impractical. Accordingly, a purpose of the present invention is to provide an improved "forced ventilation" gas-cooled bushing arrangement for large capacity electric generators of the type described.

A further object is to provide an improved ventilated high voltage bushing in which the cooling passages therein are arranged to become a part of the gas-cooling circuit of the generator proper.

Another object is to provide improved gas-cooled bushing structure requiring mechanical components of generally conventional construction, so the parts for the bushing assembly are readily obtainable and only a minimum number of parts need be fabricated specially.

Other objects and advantages will become apparent from the following description, taken in connection with the accompanying drawings in which Fig. 1 is a longitudinal view of a large generator, partly in section, showing the relation of the improved bushing structure to the casing of the generator and the gas coolant circuit therein, Fig. 2 is an enlarged sectional view of the bushing structure per se, Fig. 3 is a detail view of coolant gas inlet arrangement of the bushing, and Fig. 4 is a detail view, taken on the section 4—4 in Fig. 2, to make more clear another portion of the coolant gas circuit.

Generally stated, the invention is practiced by providing coolant passages throughout the length of the bushing and the electrical conductor associated immediately therewith, and arranging suitable ports and conduits communicating with selected portions of the generator coolant flow path at such pressures that the differential therebetween causes an adequate flow of cooling fluid through the bushing structure.

Referring now more particularly to Fig. 1, the invention is shown as applied to a very large generator having an output on the order of 200,000 kw., the sealed casing of which is indicated generally at 1. The generator rotor 2 has a shaft portion 2a adapted to be coupled to a prime mover such as a steam turbine (not shown). The laminated stator structure 3 is suitably supported in the generator frame members 1a. Mounted on the right-hand end of the rotor is a suitable cooling fan, indicated diagrammatically as an axial flow single stage blower 4.

2

As will be appreciated by those skilled in the art, the generator frame and associated baffle members are arranged to direct coolant gas from the fan 4 to the air gap between rotor 2 and stator 3, through radial passages provided in the stator structure, and through a water-cooled heat exchanger 5. This gaseous coolant flow path is indicated by the flow arrows in Fig. 1. The details need not be noted here, except that to maintain circulation of the cooling gas through the ventilation passages, there will be created a pressure differential between chambers 6 and 7 of perhaps 8" of water, representing the friction drop in pressure experienced by the coolant fluid between these two points in the circuit.

It is to be noted that, in accordance with usual practice, these pressures refer to operation with air as the cooling gas. When a gas of smaller density such as hydrogen is employed, the pressures will be proportionately lower, according to the density of the gas.

The high voltage bushings to which the invention particularly relates are illustrated generally in Fig. 1 at 8, 9. Actually, there may be several pairs of these bushings disposed circumferentially around the casing, the precise number being a function of the electrical circuit employed. Ordinarily there will be six bushings for a three-phase generator. Since the high voltage bushings are all of generally similar construction, only the details of the one identified 8 are described herein.

It will be apparent that the bushings 8, 9 are supported on a box structure 10 secured to the outer wall of the generator casing 1. It is to be particularly observed that the generator casing is provided with a generous opening at 11 through which cooling fluid from the chamber 6 is communicated to the interior of box 10 by way of an opening 12 between the box and generator casing. The box structure 10 includes an axially extending portion 10a which serves to form a portion of the coolant path to the ports 10b, through which coolant is admitted to the annular chamber identified 13. With this arrangement it will be apparent that coolant discharged from the fan 4 is caused to circulate directly over the outside surfaces of the bushings 8, 9.

It will also be observed in Fig. 1 that bushing assembly 8 is connected to a conductor 14 having a terminal 15 secured to the armature conductor bars 15a. Conductor 14 is supported from the adjacent wall of the generator casing by means of a suitable insulating bushing 16. The details of this are not material, since any conventional insulator may be used.

It will be observed that the bushings 8, 9 are provided with bolting flanges 8a, 9a secured by suitable threaded fastenings 8b to a cover plate member 10c. The internal end portions of the bushing assemblies project through openings in the cover plate 10c and are disposed in the box 10 in a manner which will be obvious from Fig. 1.

The details of the bushing 8 will be seen in more particularity by reference to Figs. 2-4.

In Fig. 2, it will be seen that the electrical conductors are hollow tubular members of conductive material, ordinarily copper. The conductor identified generally at 14 in Fig. 1 has an inner conductive copper tubular member 14a (Fig. 2) insulated by a wound layer of tape or equivalent insulation 14b. The conductor 14a is coupled to a similar short section of conductive tubing identified 16 by a conventional coupling clamp member 17, made in two parts and secured together by suitable fastenings 17a. Those familiar with the art will appreciate that this is a purely conventional type of coupling device commonly used to connect bus bars or equivalent high capacity conductors of electricity. The short tube 16 is in turn coupled to another short tube 18 by a coupling clamp member 19. Tube 18 is connected to a special fitting 20 by an-

3

other clamping device 21, which is of the same type as that shown at 19.

As will be seen more particularly as the description proceeds, the special fitting 20 performs a number of functions. It serves as the primary conductive path from the conductor tube 18 to another conductive tube 22, which may be threaded onto the reduced end portion of fitting 20 as indicated by the threaded joint 22a. To improve the electrical bond at this point, this joint may be brazed. The conductor tube 22 terminates at the external side of the bushing assembly in a threaded terminal portion 23, which is adapted to receive a suitable threaded coupling device for connecting the bushing conductor to the external circuit (not shown).

Those skilled in the art will appreciate that it is important, from an electrical standpoint, that there be no magnetic material between the bushing structures 8, 9. To this end, the cover plate member 10c is fabricated of aluminum or equivalent non-magnetic material.

Because the voltage potential of the electrical conductors will be on the order of 20,000 volts to ground in normal operation, it is of course of the utmost importance that proper electrical insulation be provided for the conductive members 14a, 16, 18, 20, 22. Actually, this insulation must be adequate to withstand approximately 40,000 volts applied as a "high potential test" during assembly. The insulation for the conductor 14a comprises a wound layer of suitable insulating tape identified 14b, which may, for instance, be of well-known mica or glass composition. It will be seen that this tape covering joins a similar layer of tape identified 24 which extends over the conductors 16, 18, 20, all the way to the upper end of the porcelain insulator 25. In order to facilitate winding of this tape layer, and provide a smooth external contour, the comparatively irregular coupling members 17, 19, 21, are covered with a plastic insulating material identified 24a, which may, for instance, be an asbestos and varnish composition.

The porcelain insulator 25 is of conventional construction and abuts the radial flange 20a of fitting 20 with a compressible gasket 25a therebetween. The lower end of insulator 25 abuts flange 8a of the support cylinder member 26, with a similar gasket 25b therebetween. The gaskets 25a, 25b, are of course for the purpose of providing a fluid seal and permitting differential thermal expansion between the ceramic insulator 25 and the related metal parts, without imposing excessive stresses on the insulator.

The support cylinder member 26 is also of aluminum, in order to obtain non-magnetic properties, and is secured to the cover plate member 10c by threaded fastenings 8b. A suitable gasket 8c provides a fluid seal. The lower end flange 26a of support cylinder 26 abuts a second conventional porcelain insulator 27, with a gasket 27a therebetween. The lower end of insulator 27 is engaged by a washer member 28, with a similar gasket 27b therebetween. Another washer member 29 is spaced from the washer 28 with a compressible gasket 30 therebetween. A clamping nut 31 is threaded on the extreme end portion 23 of the conductor 22 so as to compress the washers 28, 29 together and against the end of insulator 27, in a manner which will be obvious from Fig. 2.

The conductor 22 is insulated from the aluminum support cylinder member 26 by a laminated insulator identified 32. This may be made of a paper and phenolic laminated insulating material such as those known to the trade as "Textolite" or "Herkolite." This insulating tube is of such length, extending well into the porcelain insulators 25, 27, as to provide a dielectric path of sufficient length between the conductor 22 and metal support cylinder 26 as to prevent current leakage therebetween.

By reference to Fig. 1, it will be seen that the upper end portion of the conductor 14 is disposed in the high pressure coolant chamber 6. High pressure coolant is admitted to the hollow conductor 14a by an inlet fitting

4

shown in detail in Fig. 3. This comprises a gas inlet box identified 14c, conveniently formed of a laminated phenolic impregnated plastic insulating material, such as "Textolite," made in two or more segments and secured in place by a winding of insulating tape 14d. It will be seen in Fig. 3 that the members 14c define a plurality of gas inlet passages 14e communicating with suitable ports 14f in the conductor 14a and insulating tape 14b. There may of course be three or more of these passages instead of the two shown in Fig. 3.

It will also be observed that the gas inlet openings 14e face generally "up-stream" with respect to the coolant flow in the chamber 6. Thus there may be some impact pressure tending to induce flow of coolant into the box structure 14c. It will be apparent from the flow arrows in Fig. 2 how the coolant entering through the box structure 14c passes through the conductor 14a, through a suitable port 18b in the conductor 18, thence through a port 20b in the fitting 20.

In order to provide high velocity gas flow relative to the conductor 22, and to provide a convenient exit for the coolant, the special cooling tube member 33 is disposed coaxially within the conductive tube 22. It will be seen in Fig. 2 that the upper end of cooling tube 33 fits snugly into an opening in the fitting 20 and projects a substantial distance therefrom. The remainder of tube 33 defines longitudinal coolant passages with the walls of the fitting member 20 and the surrounding conductive tube 22. This coaxial relation may be seen more clearly in the sectional view of Fig. 4, which will make it clear how the cooling tube 33 defines an axial passage 34 with the fitting 20, and how the clamp fitting 21 is secured by the threaded fastenings 21a to hold the conductor 18 to fitting 20.

It will be apparent from Fig. 2 that coolant from the hollow conductor 18 enters port 20b and passes by way of the passage 34 to the annular space 35 defined between cooling tube 33 and conductor tube 22. The lower end of cooling tube 33 defines a substantial axial clearance space 35a with an end closure disk 36 secured by any suitable means in the open end of the threaded conductor portion 23. The cooling tube 33 forms the discharge passage for spent coolant. To this end, the extreme upper end of tube 33 is connected to a hose 37 of flexible synthetic rubber or other suitable insulating material secured by a suitable hose clamp 37a and by clamp 37b to a nipple 37c in a manner which will be obvious from the drawing. It will also be seen that the insulating tape 24a extends over the hose clamp, with a filling of insulating plastic material 24a. By comparison with Fig. 1, it will be seen that the coolant discharge hose 37 extends axially and discharges into the annular chamber 7. As noted previously, chamber 7 is at a pressure differential on the order of 8" of water below the pressure in the coolant supply chamber 6. This pressure differential is of course what produces the flow of coolant indicated by the flow arrows in Fig. 2.

It will be seen that the invention provides a reasonably simple mechanical structure with effective electrical insulation between the high voltage conductors and the grounded metal parts, and ready means for securing adequate flow of coolant, both over the outside surfaces of a portion of the bushing assembly and in heat transfer relation with the inner surfaces of the conductive members throughout the length of the bushing assembly. The various ports and coolant passages must of course be suitably proportioned, taking into consideration the magnitude of the pressure drop available for causing the coolant flow, in order that the quantity of coolant flowing and the velocities over the metal conductor surfaces will be sufficiently high to effect the heat transfer required to maintain the conductors at safe operating temperatures. It will be seen that the annular passages 34, 35 may readily be proportioned so as to obtain the necessary coolant velocity therein. It is also important to note that the

5

lowest temperature coolant is brought into heat exchange relation with the innermost end portions of the conductor 14a, which are likely to be hottest because connected directly to the terminal fitting 15 and the end portions of armature bars 15a which are somewhat difficult to cool. Thus, a substantial amount of heat will be transmitted by conduction to the upper end portions of conductor tube 14a.

While only one embodiment of the invention has been described particularly herein, it will be obvious to those skilled in the art that many minor alterations and substitutions of mechanical equivalents might be made without departing from the spirit of the invention. The precise type and arrangement of the coupling clamp members 17, 19, 21, etc., may take other forms, as may the coolant inlet fitting 14c. The coolant discharge tube 33 may be either of a suitable metal or of a plastic insulating material. The precise mechanical means used to seal and secure the porcelain insulators 25, 27 may of course take many forms.

It is of course intended to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

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

1. In a ventilated high voltage bushing assembly for a gas-cooled generator having means for circulating a coolant gas, the combination of a first conductive tube member disposed in a portion of the generator casing constituting a high pressure portion of the coolant flow path and connected electrically to the generator conductors, a second conductive tube disposed substantially at right angles to the first tube and having a port in the side wall thereof communicating with the interior of said first tube, a cylindrical fitting member having a circumferential flange portion adjacent one end and adjacent the other end thereof a port in the side wall communicating with the interior of said second tube, conductive clamp means securing said first tube to said second tube and the second tube to said fitting, the end of said cylindrical fitting member remote from the port being secured to a third conductive tube having an exterior threaded end portion adapted to be connected to an external electrical circuit and having an end closure member, a first cylindrical ceramic insulator disposed around the adjacent end portions of said cylindrical fitting and third conductive tube and spaced radially therefrom, one end of said ceramic insulator abutting said circumferential flange of the cylindrical fitting member with a compressible ring member therebetween, a cylindrical support member disposed around said third conductive tube and spaced radially therefrom and having a first radially extending end flange adapted to be secured to a wall portion of the generator casing, said first end flange abutting the adjacent end of said first ceramic insulator with a compressible ring member therebetween, a second cylindrical ceramic insulator disposed around the exterior end portion of the third conductive tube and spaced radially therefrom with one end portion abutting the adjacent end of the cylindrical support member with a compressible ring member therebetween, a pair of washer members disposed on the threaded end portion of the third conductive tube with a compressible ring member between the washers and another compressible ring between the end of the second ceramic insulator and the adjacent washer, an insulating sleeve member disposed on the third conductive tube in the annular space defined by said third tube with the support cylinder member and said first and second ceramic insulators respectively, a coolant inlet member of insulating material secured to the portion of the first conductive tube in the high pressure coolant chamber and defining gas inlet passages communicating with at least one inlet port in the first conductive tube, a coolant discharge tube having one end portion disposed in said cylindrical fitting member and defining therewith longitudinal coolant pas-

6

sages communicating with the aforesaid side-wall port in the fitting, the coolant discharge tube also defining with the third conductive tube an annular passage communicating with said longitudinal passages in the fitting, the other end of said coolant discharge tube being spaced axially from the end closure member of the threaded end portion of the third conductive tube whereby coolant from the annular passage around the tube is communicated to the interior thereof, a coolant discharge hose member secured to the end portion of the coolant discharge tube projecting from said cylindrical fitting member, said hose having the other end thereof connected to discharge into a chamber in the generator casing forming a portion of the coolant circuit at a substantially lower pressure than that of said coolant inlet chamber, and a layer of insulating material covering said first and second conductive tubes and said cylindrical fitting and the projecting end portion of the coolant discharge tube, whereby the pressure differential maintained by the coolant circulating fan between said coolant inlet chamber and said lower pressure coolant chamber in the generator casing causes flow of cooling gas through the tubular first and second conductors, through the annular passage defined by the coolant discharge tube with the cylindrical fitting member and third conductive tube respectively and out through the coolant discharge tube and hose.

2. In a ventilated high voltage bushing assembly for a generator having means for circulating a coolant fluid, the combination of a first conductive tube member disposed in a first chamber of the generator casing constituting a first portion of the coolant flow path and connected electrically to the generator stator conductors, a cylindrical fitting member having a circumferential flange portion and adjacent one end a port in the side wall thereof, a second conductive tube member communicating between said port and the first tube, means securing the first tube to the second tube and the second tube to said fitting member, the other end of the fitting member being secured to a third conductive tube member having an exterior end portion adapted to be connected to an external electrical circuit and having an end closure member, a first ceramic insulating bushing disposed around the abutting portions of the cylindrical fitting member and third conductive tube and spaced radially therefrom, one end of said first ceramic bushing abutting said circumferential flange of the cylindrical fitting, a cylindrical support member disposed around the third conductive tube and spaced radially therefrom and having a radially extending flange adapted to be secured to a wall portion of the generator casing, a second ceramic insulating bushing disposed around the exterior end portion of the third conductive tube and spaced radially therefrom, the ends of the cylindrical support member being in abutting relation with the adjacent ends of the first and second insulating bushings respectively, clamping means associated with the exterior end of the third conductive tube and adapted to clamp the insulating bushings into sealing relation with the respective end portions of the support cylinder member, an insulating sleeve member disposed around the third conductive tube in the annular space defined by the third tube with the support cylinder member and with the first and second insulating bushings respectively, means defining a coolant port secured to a portion of the first conductive tube disposed in said first coolant chamber, a first coolant tube having one end portion disposed in the cylindrical fitting member and defining therewith at least one longitudinal coolant passage communicating with the side-wall port in the fitting, said first coolant tube also defining with the third conductive tube an annular passage communicating with the longitudinal passage in the fitting, the other end of the first coolant tube being spaced axially from the end closure member of the third conductive tube whereby the annular passage around the coolant tube communicates with the interior thereof, a second coolant conduit member secured to the end portion of the first

7

coolant tube projecting from said cylindrical fitting member, the other end of said second coolant conduit being connected to communicate with a second portion of the coolant path at a substantially different pressure than that of said first portion, and a layer of insulating material covering the first and second conductive tube members and the cylindrical fitting, whereby the pressure differential maintained by the coolant circulating means between said first and second coolant path portions causes a flow of cooling fluid in the first and second tubular conductors, the longitudinal passage defined by the fitting member, the annular passage defined between the coolant discharge tube and the third conductive tube, and the coolant discharge conduit.

3. In a ventilated high voltage bushing assembly for a generator having means for circulating a coolant fluid, the combination of a plurality of conductive tube members assembled together in series to define a coolant inlet passage, an interior end portion of said tube assembly being disposed in a high-pressure chamber of the coolant flow path and having a coolant inlet port, said tube assembly having at the opposite end thereof an exterior end portion with a closure member and adapted to be connected to an external electrical circuit, a cylindrical support member surrounding said exterior tube end portion for securing the bushing assembly to the generator casing, first and second insulating cylinder means disposed between the respective end portions of said support member and engaging axially spaced portions of the conduc-

8

tive tube assembly, a third insulating cylinder member disposed coaxially between said exterior tube end portion and the support cylinder member, and a coolant discharge tube disposed coaxially within said exterior tube end portion, one extreme end portion of said coolant discharge tube being spaced axially from said closure member of the exterior tube end portion, and coolant discharge conduit means communicating with the other end of the coolant discharge tube and connected to discharge coolant into a portion of the generator coolant flow path at a substantially lower pressure than that in said high pressure chamber, whereby the pressure differential created by the coolant circulating means effects flow of coolant into one end portion of said conductive tube assembly, through the annular passage defined between the exterior tube end portion and said coolant discharge tube, and out through the coolant discharge tube and discharge conduit.

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