April 26, 1955 R. A. BAUDRY 2,707,242

INNER-COOLED GENERATORS WITH VERTICAL COOLERS

Filed Oct. 30, 1953 2 Sheets-Sheet 1

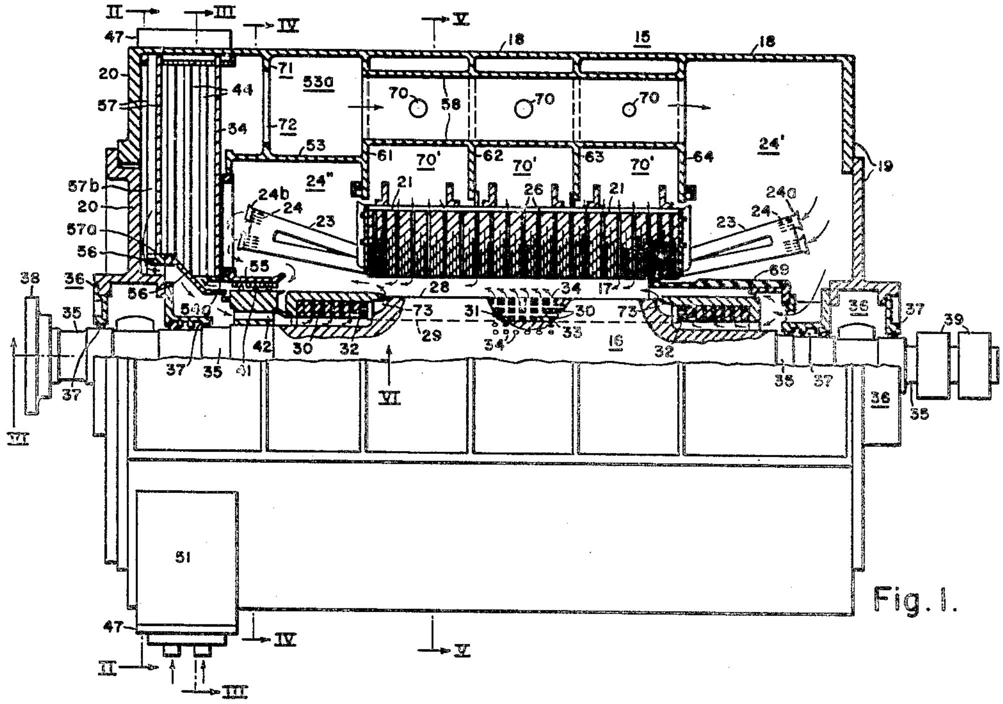

Fig. 1.

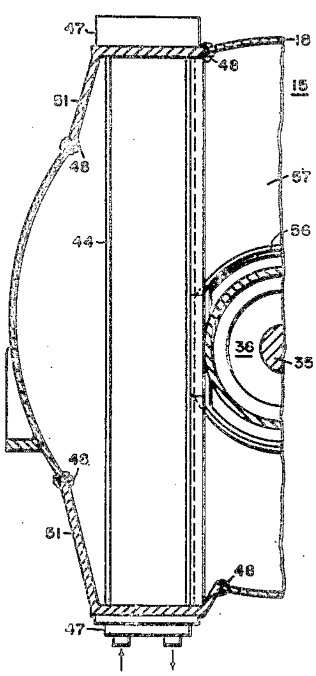

Fig. 2.

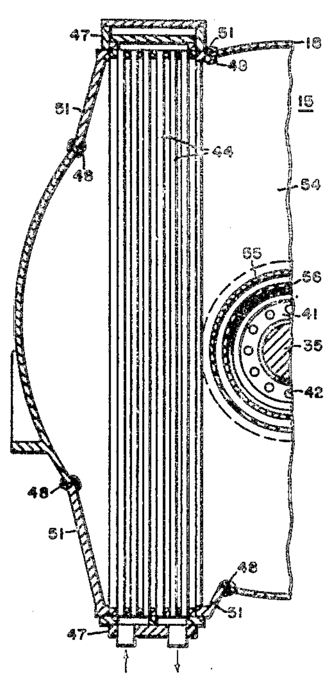

Fig. 3.

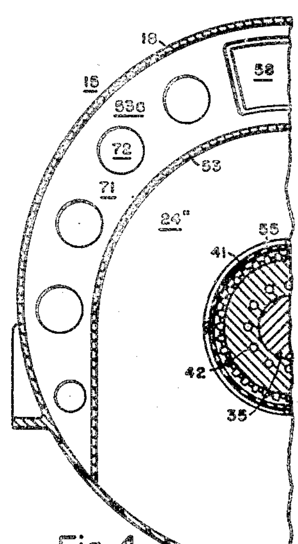

Fig. 4.

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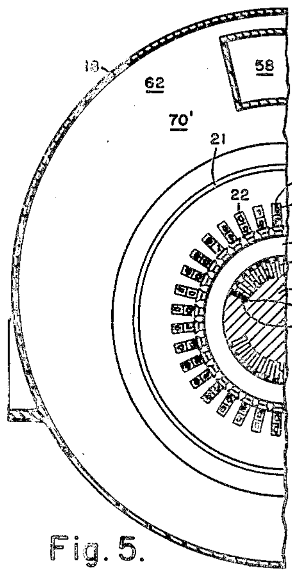

Fig. 5.

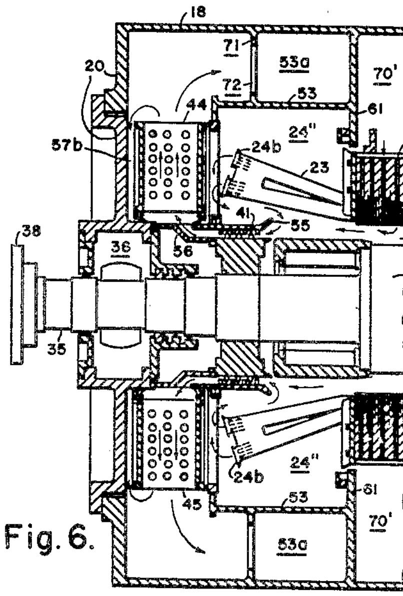

Fig. 6.

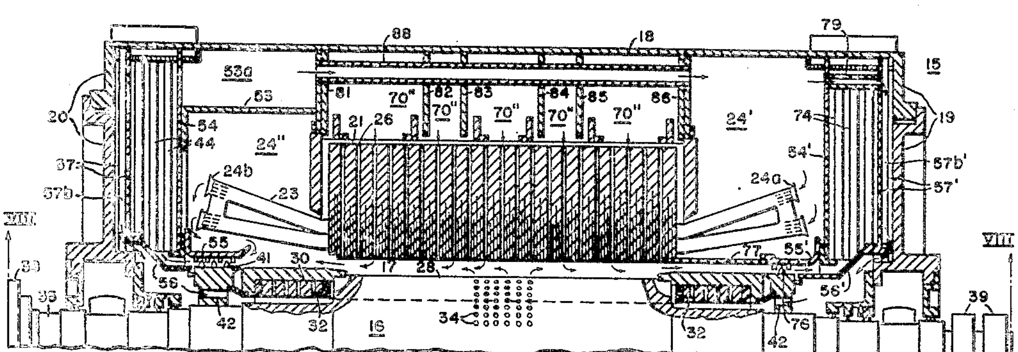

Fig. 7.

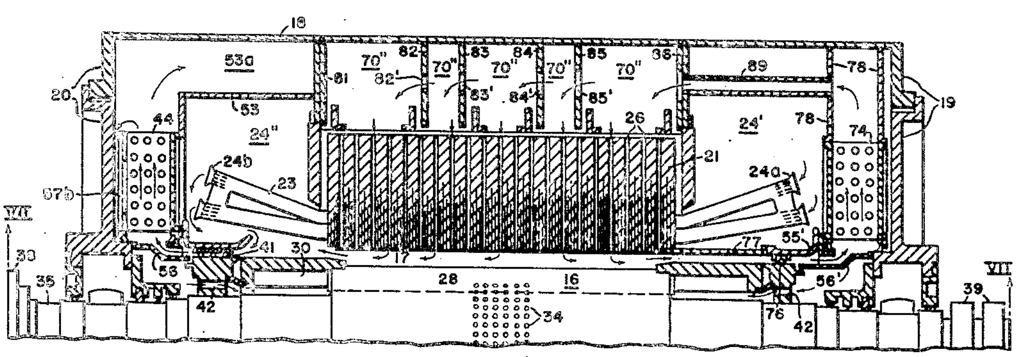

Fig. 8.

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INNER-COOLED GENERATORS WITH VERTICAL COOLERS

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Application October 30, 1953, Serial No. 389,349

19 Claims. (Cl. 310—57)

My present invention relates to improvements in inner-cooled hydrogen-cooled turbine-generators, or other similar dynamoelectric machines, in which the heat generated in the stator and rotor conductors is directly removed through cooling-ducts which are in good thermal relation to the conductors. The present invention is an improvement which is particularly useful in, and in fact was made possible or practicable by, a single-direction ventilation-system which is described and claimed in the copending application of Paul R. Heller and myself, Serial No. 394,602, filed November 27, 1953. In this single-direction ventilation-system, the air gap of the machine is sufficiently large to act as a hot-gas collecting-chamber and as an axial duct for a substantial portion of the ventilating-gas of the machine. In my present invention, this feature is combined with other improvements to provide a very compact and efficient cooling-system.

My present invention relates to a special vertical-cooler arrangement in such a single-direction ventilation-system. This vertical-cooler invention is characterized by the use of a pair of vertical coolers, disposed so as to receive the hot gas which is exhausted from the air gap by a blower at at least one end of the machine. This pair of vertical coolers is located axially between the stator winding and the frame-bracket, and said coolers are located radially between the bearing-housing and the outer frame-shell. This placement of the vertical coolers avoids the introduction of unduly heavy bulbous frame-structures, which have heretofore been used with vertical coolers, and which have required rather complicated internal baffling, and have increased the outer frame-dimensions of the machine, besides being quite impracticable for withstanding the higher gas-pressures which are even now being used for hydrogen-cooled inner-cooled generators, with still higher gas-pressures in prospect.

Vertical coolers are of necessity shorter than horizontal coolers which are disposed between the outer periphery of the stator-core and the outer frame-housing; and hence it has not often been practicable, heretofore, to use vertical coolers, notwithstanding their many practical advantages. In the single-direction ventilation-system in which my present vertical coolers are used, the reduced cooler-length, and hence the reduced cooler-volume, which are entailed by the vertical disposition of the coolers, are made possible by the use of the air gap as a hot-gas chamber exclusively, the increased gas-pressures, the increased fan-pressures, the resulting reduced quantity of cool gas which has to be moved, and the adoption of the latest designs of compact finned-tube arrangements. These features have all contributed to a reduction in the working-volume of the coolers, so that vertical cooler-arrangements are now possible.

Among the many advantages of my vertical-cooler embodiment of the single-direction ventilation-system, I would emphasize the very important advantage that no hot gas now comes into contact with the frame, this eliminating the frame-distortion problem. This is because all of the hot gas of the machine is collected in the air gap and at one end of the stator-windings, and this hot gas is evacuated, in an axial direction, by a multistage blower, and then divided into two streams, one of which flows through each of the two vertical coolers at that end of the machine. Thus, it is only the cooled gas which comes into contact with the outer cylindrical frame-housing.

In the accompanying drawing, I have shown two illustrative alternative forms of embodiment of my invention.

Figure 1 is a side-elevational view, the top half being in longitudinal section, showing a hydrogen-cooled turbine-generator embodying my invention in a form in which I use only a single pair of vertical coolers, disposed at only one end of the machine, and suitable for all except perhaps the very highest ratings of future machines which are larger than any machines thus far sold;

Figs. 2, 3, 4 and 5 are successive transverse sections on the section-planes indicated, in Fig. 1, by the lines II—II, III—III, IV—IV and V—V, respectively;

Fig. 6 is a partial horizontal sectional view, on the section-plane indicated at VI—VI in Fig. 1; and

Figs. 7 and 8 are respectively vertical and horizontal longitudinal sections of an alternative machine-design in which the vertical coolers must be used at both ends of the machine, in order to meet the required ratings.

Fig. 1 shows a turbine generator, which is illustrative of a dynamoelectric machine having a stator member **15** and a rotor member **16**, separated by an air gap **17**.

The stator member **15** includes a substantially gas-tight machine-enclosing housing, which comprises an outer cylindrical frame-shell or core-surrounding housing-portion **18**, and two brackets **19** and **20**, enclosing the respective ends of the outer frame-shell. The housing is filled with a gaseous filling, which is preferably hydrogen, at a gas-pressure which is adapted, at times, to be at least as high as 30 pounds per square inch, gauge, which may be regarded as a minimum pressure, as somewhat higher gas-pressure are contemplated. While hydrogen is preferred, it is possible to use other gases having a molecular weight lower than nitrogen, the low molecular weight being desirable in order to keep down the windage-losses resulting from the rotation of the rotor member **16** within the gas.

The stator member **15** also comprises a cylindrical stator-core **21**, having a plurality of winding-receiving stator-slots **22** (Fig. 5). The stator member also comprises an inner-cooled stator winding **23** having coil-sides lying within the winding-receiving slots **22**, and coil-ends lying beyond the respective ends of the stator-core **21**. This stator winding **23** is an inner-cooled winding, having cooling-ducts **24** which are in good thermal relation to the stator-conductors, for substantially directly cooling said stator-conductors. The stator-winding cooling-ducts **24** have inlet-openings **24*a*** at one end of the winding, and outlet-openings **24*b*** at the other end.

A recirculating stator-winding cooling-system is necessarily provided, for recirculating a stator-winding cooling-fluid in said inner-cooling stator-winding ducts **24**, said recirculating cooling-system including a means for cooling the stator-winding cooling-fluid. Although it is not necessary to use the gas which fills the machine-housing as the stator-winding cooling-fluid, I prefer to do so, in which case, the duct-inlets **24*a*** are open to an end-space **24′** within the machine, at one end of the machine, while the duct-outlets **24*b*** are open to another end-space **24″** within the machine at the other end of the machine, thus cooling the stator winding **23** with the gas which is enclosed within the machine-housing, said gas being cooled by the subsequently described coolers. The stator winding **23** is usually a polyphase winding, and in the large machine-sizes to which my present invention is particularly applicable, the stator winding **23** is provided with ground insulation **25** (Fig. 5) which is good for 10,000 volts, or higher.

The stator-core **21** is also provided with a plurality of core-ventilating stator-ducts, which may be either radially disposed ducts or spaces **26**, as shown in Figs. 1 to 8, or other suitable stator-core ventilating-ducts may be used.

The rotor member **16** has a cylindrical rotor core **28**, which has a plurality of axially extending winding-receiving slots **29**, and an inner-cooled rotor winding **30** having cooling-ducts **31** in good thermal relation to the rotor-conductors for substantially directly cooling said rotor-conductors. Preferably, or in practically every case in which my invention would be used, the rotor-winding cooling-ducts **31** have inlet-openings or means, **32**, at the respective ends of the rotor winding, and outlet-openings **33** at a plurality of intermediate discharge-points within the winding-receiving rotor-slots, these discharge-points being commonly grouped together near the center of the rotor-core, and being connected to the air gap **17** by a plurality of radially extending rotor ducts or holes **34** which discharge the rotor-cooling gas to the rotor-periphery. The rotor windings **30** are insulated for a voltage which is considerably lower than the stator windings **23**, so as to require a much thinner rotor-insulation, which is too thin to be shown on the scale to which my drawings are drawn.

The rotor core **28** is carried by a rotor shaft **35**, which is supported by a pair of bearing housings **36** near the respective frame-brackets **19** and **20**. Associated with the bearing-housings **36**, are suitable gland-seal members **37** for maintaining gas-tight joints around the respective shaft-ends. One end of the shaft is connected to a coupling **38**, whereby the machine may be connected to a turbine or other prime mover; while the other end of the shaft carries two slip rings **39** for exciting the rotor winding **30**, which serves as the field-winding for the machine.

The air gap **17** has a single gap-length of the order of from three and one half to five inches, more or less, so that the air gap is sufficiently large to act as a hot-gas collecting chamber and as an axial duct for a substantial portion of the ventilating-gas of the machine, as will be evident from the subsequent explanations.

It is necessary to provide a gas-moving means, for maintaining a circulation of the gas within the machine-enclosing housing **18—19—20**. In the form of embodiment of my invention which is shown in Figs. 1 to 6, this gas-moving means comprises a single evacuating blower **41**, carried by the rotor member at one end of the rotor core, and directed so as to evacuate hot gas from that end of the air gap **17**, and also from the stator end-space **24″** in which the stator-winding duct-outlets **24*b*** discharge. The blower **41** includes a supporting-means of such nature that it provides one or more axially extending under-blower passages **42**, extending axially underneath the blower **41**. The blower **41** is preferably a multistage blower, which is capable of developing a considerable blower-pressure for rapidly moving the hot gases in an axial direction.

It is necessary to provide a heat-exchanging means, which is disposed within the machine-housing **18—19—20**, for cooling the circulated gas. In accordance with my invention, this heat-exchanging means comprises vertically disposed coolers. In the form of my invention shown in Figs. 1 to 6, the heat-exchanging means comprises a pair of vertical coolers **44** and **45**. These coolers are located axially between the stator-winding duct-outlets **24*b*** and the housing bracket **20** at that end of the machine, as shown in Fig. 1. The blower **41** is disposed underneath, or within the axial confines of, the stator-winding end-turns which have the duct-outlets **24*b***, so that the blower **41** discharges the hot gas axially toward the portion of the housing which is occupied by the pair of coolers **44** and **45**. The two vertical coolers **44** and **45** are located radially between the bearing housing **36** and the outer frame-shell **18**, as shown in Fig. 6, so that the hot gas which is discharged axially from the blower **41** divides into two streams, one stream flowing to the right, through the vertical cooler **44**, while the other stream flows to the left, through the vertical cooler **45**, as shown in the horizontal sectional view, which is Fig. 6.

Each of the coolers **44** and **45** comprise a plurality of substantially straight, vertical, liquid-cooled, finned pipes, each end of each cooler terminating in a cooler-head **47**. The outer frame-shell **18** is provided with cooler-accommodating perforations **48**, having pressure-resistant reinforcing means **51**, which are secured to the frame-shell around each perforation **48**. The top and bottom cooler-heads **47** of each cooler **44** and **45** are hermetically but removably secured to their own reinforcing-means **51**; so that each cooler can be lifted vertically out of the machine, after disconnecting its two cooler-heads **47**. The water-connections, for circulating water or other coolant through the cooler-pipes, are preferably provided at the lower cooler-head **47**, as shown in Figs. 2 and 3.

I provide suitable hot-gas guiding-means, for guiding the hot gases to and through the blower **41** and the coolers **44** and **45**. Thus, the end-winding space **24″** into which the stator-winding duct-outlets **24*b*** discharge is confined by an outer cylindrical or arcuate partition **53**, a flat transverse plate or disc **54** which extends vertically between the two coolers **44** and **45** on the sides thereof closest to the stator end-windings, and the shroud **55** of the blower **41**. The transverse plate or disc **54** is provided with a central hole **54*a*** which is more or less hermetically joined to the outer periphery of the blower-shroud **55**.

Surrounding the inner end of the bearing, in the space between the two vertically disposed coolers **44** and **45**, there is a stationary funnel-like duct-member **56**, the inner end of which comes into near contact with the rotating end of the blower **41**, so that there is little gas-leakage at this point. This keeps the hot discharge-gases from the blower away from the inner end of the bearing, at the point where the discharged hot gases divided into two streams, flowing to the right and the left to enter the coolers **44** and **45**, respectively.

Extending vertically between the two coolers **44** and **45**, at their sides closest to the housing-bracket **20**, there is a curved transverse plate or disc **57**, which bulges or is curved, inwardly, toward the disc **54**, and away from the housing-bracket **20**. This curved transverse plate or disc **57** has a central hole **57*a*** which is substantially hermetically sealed to the large end of the funnel-like member **56**, so as to provide a separation between the hot gas which is flowing to the right and left between the two vertical coolers **44** and **45**, and cold gas which flows radially inwardly in the flat end-space **57*b*** between the curved plate **57** and the bracket **20**, and then axially inwardly through the funnel-like member **56**, into the under-blower passages **42**, to ventilate that end of the rotor-windings, as will be subsequently described.

The cold gas, which is delivered from the coolers **44** and **45**, is used for the inner-cooling of the rotor winding **30**, the inner-cooling of the stator winding **23**, and the cooling of the stator-core **21**. In the particular construction which is shown in Figs. 1 to 6, these functions are accomplished by a structure on which some of the cold gas is led into both ends of the rotor winding **30**, some to the inlets **24*a*** of the stator winding **23**, and some to the outer peripheries of the radial cooling-ducts **26** of the stator core. An essential feature of this construction is the provision of an axially extending, peripherally disposed, through duct-means, such as a duct **58** (Fig. 1), to provide an axial communication from one end of the machine to the other. In the form of embodiment shown in Fig. 1, the through-duct **58** is illustrated as being in the space between the outer periphery of the stator core **21** and the outer frame-shell **18**.

In the construction which is shown in Fig. 1, the stator member is provided, as is well known, with a plurality of axially spaced frame-rings **61** to **64**, extending inwardly from the outer cylindrical frame-shell **18** in the axial length which is occupied by the stator core **21**. The frame-ring **61** is secured to one end of the cylindrical or arcuate partition **53**, which surrounds the hot-gas discharge-end space **24″** of the stator-winding ventilation. The space **53*a*** outside of this cylindrical or arcuate partition **53** is filled with cooled gas which is delivered by the two coolers **44** and **45**. The through-duct **58** in Fig. 1 extends from this cool-gas space **53*a*** outside of the cylindrical or arcuate partition **53**, all the way through the machine, to discharge, beyond the frame-ring **64**, in the end-space **24′** which feeds said cool gas to the stator-winding duct-inlets **24*a***, and to the rotor-winding inlet-openings **32** at that end of the machine.

As shown in the horizontal sectional view, Fig. 6, the cool-gas space **53*a*** which is outside of the cylindrical or arcuate partition **53** is also in communication with the radial space **57*b*** between the curved transverse plate **57** and the housing-bracket **20**; and hence some of the cooled gas is supplied to the rotor-winding inlet-openings **32** at this end of the machine.

At the other end of the machine, the cold-gas end-space **24′** is nearly altogether, or substantially, closed off from the end of the air gap **17**, at that end of the machine, by means of a stationary cylindrical baffle-member **69**, (Fig. 1), which has a small clearance with that end of the rotor member **16**, so as to limit, or substantially stop, the escape of cool gas directly from the end-space **24′** into that end of the air gap **17**, as described in a patent of Paul R. Heller and myself, No. 2,626,365, granted January 20, 1953.

The through-duct **58** is provided with lateral openings

70 for discharging the cooled gas into the annular spaces 70′ between the successive frame-rings 61 to 64, these annular spaces 70′ being disposed between the outer periphery of the stator-core 21 and the outer cylindrical frame-shell 18. Since the radial stator-core cooling-spaces 26 are in communication with these annular frame-ring spaces 70′, the cooled gas is thus led radially inwardly, through all of these radial cooling-spaces or ducts 26 of the stator core, thereby cooling the stator core, and discharging the heated core-cooling gas into the air gap 17. A suitable resistance to the flow of this core-cooling gas is provided by a proper restriction of the size of the openings 70 in the through-duct 58, so as to properly control the division of the gas-flow, so that each part receives the quantity of gas which is required to cool the same.

The cool-gas space 53*a* which is outside of the cylindrical or arcuate partition 53 may contain a fifth frame-ring 71, which is provided with a plurality of openings 72 therethrough, as shown in Fig. 4, so that the entire space outside of this cylindrical or arcuate partition 53 is in effect a single space 53*a*, all portions of which are in communication with each other.

The operation of the form of embodiment of my invention which is shown in Figs. 1 to 6 may now be summarized. The blower 41 exhausts the hot gases from the air gap 17, and from the stator-winding outlet-end 24″ in the space inside of the cylindrical or arcuate partition 53. The blower delivers this hot gas, in two streams, so that it spreads to the right and to the left and flows laterally through the two vertical coolers 44 and 45, respectively.

The gas which is discharged from the coolers 44 and 45 is cold or cooled gas, which appears in the space 53*a* outside of the cylindrical or arcuate partition 53. A part of this gas flows into the side edges of the flat end-space 57*b* between the curved transverse plate or disc 57 and the housing-bracket 20, and it flows radially inwardly through this space. As shown in the vertical sectional view, Fig. 1, this gas then flows axially through the funnel-like duct or partition 56, so that it passes through the under-blower passages 42 and enters the rotor-winding inlet-openings 32 at that end of the machine.

The remainder of the cool air in the space 53*a* outside of the cylindrical or arcuate partition 53 leaves that space through the through-duct 58. A part of this through-duct gas is discharged through the duct-openings 70 into the peripheral annular stator-core ventilating-spaces 70′ between the successive frame-rings 61 to 64, thence flowing radially inwardly through all of the stator ventilating-spaces 26, and discharging into the air gap 17 which serves as a hot-gas collecting-chamber.

The portion of the cool gas which flows all the way through the through-duct 58 is discharged into the cool-air end-space 24′, where most of its divides between the stator-winding duct-inlets 24*a* and the rotor-winding inlet-openings 32 at that end of the machine. A very small portion of the cool gas in this end-space 24′ is admitted to that end of the air gap 17, by means of the baffle 69. In some machines, however, this baffle 69 may block substantially all gas-flow into that end of the air gap.

The inner-cooling gas, for the stator-windings 23 in Fig. 1, enters the inlets 24*a* from the end-space 24′, and it passes all the way through the stator-winding cooling-ducts 24 from that end of the machine to the other end of the machine, where it is discharged, as hot gas, through the outlets 24*b*, into the space 24″ inside of the cylindrical or arcuate partition 53, where it merges with the hot gas which is being delivered from the air gap 17. This merged hot gas is then picked up by the blower 41, and the recirculating process is continued.

The inner-cooling gas, for the rotor winding 30, in the form of my invention which is shown in Fig. 1, enters the rotor-winding inlet-openings 32 at both ends of the rotor winding 30. A small portion of this rotor-winding cooling-gas may be bypassed directly into the air gap 17, immediately after having cooled the end-winding portions of the rotor winding 30, as shown by the small openings 73 in Fig. 1. The major portion of the rotor-winding cooling gas flows axially through the rotor-winding inner-cooling ducts 31, from both ends, towards the center of the rotor core 28, at which point the heated gas is discharged to the air gap 17 through the discharge-openings 33 of the inner-cooling ducts 31 and through the radial rotor-ducts 34.

It will be observed that my use of vertically disposed coolers, as shown in Figs. 1 to 6, results in cooling the hot gases before they come into contact with the outer frame-shell 18, as distinguished from earlier systems in which the hot gases came into contact with portions of the outer frame-shell and was then drawn through the cooler before being directed into the cooling-passages of the machine. I thus provide a construction in which the expansion-and-contraction stresses in the outer frame-shell and other frame-parts are almost completely avoided. This is a very important consideration in the giant-size machines for which my invention is particularly applicable.

My placement of the vertical coolers, in a place where they do not necessitate extra lateral bulges in the frame, to accommodate the coolers, produces a frame-design which more readily adapts itself for withstanding high gaseous pressures, besides resulting in a very considerable simplification of the internal baffling which is necessary to route the gases through the cooler, and a reduction in the overall dimensions, which is important in meeting shipping-limitations in the large-size machines to which my invention is particularly applicable.

Other obvious advantages apply to vertical coolers, as distinguished from horizontal coolers, including better appearance, easier cleaning, easier removal and installation of the coolers, much better accessibility to the fans and windings through the cooler-openings, and smaller frame-ring depths which are permitted by the removal of the formerly used horizontal coolers from the frame-ring spaces 70′ between the outer periphery of the stator core and the outer frame-shell.

There are many different forms of embodiment in which my invention may be applied.

Figs. 7 and 8 show a form of embodiment of the invention, which is useful where coolers must be used at both ends of the machine, either in order to meet the required ratings, either because of cooler-limitations or ventilation-characteristics, or in order to make two different blower-pressures available, one for the inner-cooled windings 23 and 30, and the other for the stator core 21, as described and claimed in a copending application of Kilgore, Baudry and Heller, Serial No. 394,622, filed November 27, 1953.

In the machine shown in Figs. 7 and 8, the pair of vertical coolers 44, which are located at the machine-end which is bounded by the bracket 20, is duplicated by another pair of vertical coolers 74 at the machine-end which is bounded by the bracket 19. This second pair of coolers, 74, may be of the same description as the first pair, 44, except that the second coolers may sometimes be somewhat smaller. The second pair of coolers, 74, use the same kind of baffling or partition-members as the first pair of coolers, 44, as shown at 54′, 55′, 56′ and 57′, these parts corresponding to the correspondingly numbered unprimed parts at the other end of the machine.

In Figs. 7 and 8, the air-gap baffle 69 of Figs. 1 to 6 is omitted, and is replaced by a second exhaust-blower 76, which is disposed to exhaust some of the hot gases out of that end of the air gap 17. This second blower 76 develops a much lower blower-pressure than the first-described multistage blower 41. In the illustrative example in Figs. 7 and 8, this second blower 76 is shown as a single-stage blower. Otherwise, the second blower 76 is of the same description as the first blower 41, and it is provided with the same under-blower passages 42. In order to segregate the suction-side of the second blower 76 from the high-pressure cool-gas end space 24′ which services the inner-cooled windings 23 and 30, the rotor-member is provided with a cylindrical baffle 77 which is secured to the periphery of the stator core 21 at that end of the machine, and which extends close to the blower-shroud 55′ which surrounds the blower 76.

As shown in the horizontal sectional view, Fig. 8, the cool-gas discharge-sides of the second pair of vertical coolers, 74, are partitioned off from the high-pressure cool-gas end-space 24′ by transversely disposed vertical barrier-plates 78. As a consequence of the addition of these barrier-plates 78 as shown in Fig. 8, it is necessary to provide a communication-means between the high-pressure cool-gas end-space 24′ and the under-blower passages 42 at that end of the machine, by a means which is shown in the vertical sectional view, Fig. 7, this means including a plurality of ducts 79 between the plates 54′ and 57′, so that some of the high-pressure cooled gas is diverted or discharged from the end-space 24′ which services the stator-winding duct-inlets 24*a*, and this high-pressure cooled gas is delivered through the ducts 79 to the flat end-space 57*b*′ between the curved transverse plate or disc 57′ and the housing-bracket 19, being thence delivered to the large end of the funnel-like member 56′, and thence delivered to the under-blower passages 42 under the blower 76, to service that end of the inner-cooled rotor-windings 30.

In the large machine which is shown in Figs. 7 and 8, the stator-frame has six frame-rings 81 to 86, instead of the four frame-rings 61 to 64 of Figs. 1 to 6. These six frame-rings 81 to 86 are axially spaced from each other, within the axial length which is occupied by the stator core 21, the frame-rings 81 and 86 being more or less hermetically sealed with respect to the respective ends of the stator core. As in Figs. 1 to 6, these six frame-rings 81 to 86 are traversed by a through-duct 88, as shown in Fig. 7. This through-duct 88 carries the high-pressure cool gas, from the space 53*a* outside of the cylindrical or arcuate partition 53, to the end-space 24′ which surrounds the stator-winding duct-inlets 24*a*.

However, unlike the through-duct 58 of Fig. 1, the through-duct 88 of Fig. 7 is imperforate along its side-walls, so that it does not deliver any gas to the annular spaces 70″ between successive frame-rings 81 to 86. These annular spaces 70″ between successive frame-rings 81 to 86, as shown in Fig. 8, are in communication with each other, through openings 82′ to 85′ in the intermediate frame-rings 82 to 85, and the whole group of these annular spaces 70″ is placed in communication with the output-sides of the low-pressure coolers 74, by means of ducts 89 (Fig. 8), extending from the barrier-plates 78 to the frame-ring 86.

The operation of the machine which is shown in Figs. 7 and 8 will now be apparent. The hot gas, from the discharge-end space 24″ of the stator windings 23, and from the same end of the air gap 17, is compressed to a high blower-pressure by the multistage exhaust-blower 41, and is delivered through the pair of coolers 44 to the high-pressure cool-gas space 53*a* which is outside of the cylindrical or arcuate partition 53 at that end of the machine. This high-pressure cool-gas space 53*a* is in communication with the rotor-winding inlet-openings 32 at that end of the machine, through the inwardly curved portion of the transverse plate or disc 57, as shown in Figs. 7 and 8; this air passing radially inwardly between this curved plate 57 and the housing-bracket 20, to the funnel-like member 56.

The high-pressure cool-gas end-space 53*a* which is fed by the discharge-sides of the coolers 44, is placed in communication with the high-pressure cool-gas end-space 24′ at the other end of the machine, as shown by the through-duct 88 in Fig. 7. This high-pressure cool-gas end-space 24′ encloses the stator-winding duct-inlets 24*a*, so as to feed gas into these inlets. It is also in communication with the rotor-winding inlet-openings 32 at that end of the machine, through the ducts 79 and the flat end-space 57*b*′ between the curved plate 57′ and the housing-bracket 19. It will be noted that this high-pressure cool gas, for inner-cooling both the stator and rotor windings 23 and 30, is kept separate from the cool gas which ventilates the stator-core 21.

The stator-core ventilation, in Figs. 7 and 8, is obtained from the single-stage exhaust-blower 76, which draws the necessary quantity of hot gas out of that end of the air gap 17, and compresses it to a much lower blower-pressure than is obtained in the multistage blower 41. This compressed hot gas from the single-stage blower 76 is delivered through the second pair of vertical coolers, 74, and the discharge-sides of these coolers are placed in communication, by the ducts 89 in Fig. 8, with the annular spaces 70″ between the successive frame-rings 81 to 86, these annular spaces 70″ being in communication with the outer peripheries of all of the radial stator-core ventilating-spaces 26, which discharge their hot gases into the air gap, after cooling the stator core 21. In this way, the necessary low pressure-differential, which is needed to provide the relatively small amount of stator-core cooling, which is necessary, in obtained from a low-pressure blower 76, thus avoiding the expense of first compressing that quantity of gas to the same high pressure-differential which is needed for the inner-cooling of the windings, and then throttling it down to the pressure-differential which is needed by the stators-core cooling-spaces 26.

At the same time, the form of my invention which is shown in Figs. 7 and 8 retains the same vertical-cooler advantages which have been pointed out in connection with Figs. 1 to 6, while providing, also, a convenient means whereby four vertical coolers may be used, instead of just two, in order to obtain more cooler-capacity, to meet the requirements of very large future machines, or to make possible a reduction in the space-requirements of each cooler.

It is to be understood that my invention is not limited to the precise forms of embodiment which have been choosen for the illustration of the principles of the invention; as many changes can be made, in the way of adding refinements, omitting unnecessary features, changes in shape and arrangements, and the substitution of equivalents, without departing from the essential spirit of the invention.

I claim as my invention:

1. A dynamoelectric machine having a stator member and a rotor member separated by an air gap; (*a*) said stator member including: a substantially gas-tight machine-enclosing housing, comprising an outer frame-shell and two brackets closing the respective ends of the outer frame-shell; a gaseous filling for said housing; a cylindrical stator core having a plurality of winding-receiving stator-slots; an inner-cooled stator winding, having coil-sides lying within the winding-receiving stator-slots and coil-ends lying beyond the respective ends of the stator core, said stator winding having stator-winding cooling-ducts in good thermal relation to the stator-conductors for substantially directly cooling said stator-conductors; said stator core also having a plurality of core-ventilating stator-ducts; and a means for providing a through duct-means extending axially from one end of the machine to the other; (*b*) said rotor member having a cylindrical rotor core having a plurality of axially extending winding-receiving rotor-slots; and an inner-cooled rotor winding having coil-sides lying within the winding-receiving rotor-slots; said rotor winding having rotor-winding cooling-ducts in good thermal relation to the rotor-conductors for substantially directly cooling said rotor-conductors; said rotor-winding cooling-ducts having inlet-openings at the respective ends of the rotor winding and having outlet-openings at a plurality of intermediate discharge-points within the winding-receiving rotor-slots; said rotor windings being insulated for a voltage which is considerably lower than said stator windings; and said rotor core having a plurality of radially extending rotor-ducts extending between the respective outlet-openings of the rotor-winding cooling-ducts and the air gap; (*c*) a pair of bearing-housings for supporting the rotor shaft near the respective brackets of item (*a*); (*d*) said air gap being sufficiently large to act as a hot-gas collecting-chamber and as an axial duct for a substantial portion of the ventilating-gas of the machine; (*e*) a gas moving means, for maintaining a circulation of the gas within the machine-enclosing housing of item (*a*), said gas-moving means including an evacuating blower, carried by the rotor member at at least one end of the rotor core of item (*b*), and directed so as to evacuate hot gas from that end of the air gap, said evacuating blower including a supporting-means which provides an axially extending under-blower passage near the rotor-shaft, the inner end of said under-blower passage being in communication with the rotor-winding inlet-openings of item (b) at that end of the machine; (*f*) heat-exhanging means, for cooling the circulated gas, said heat-exchanging means comprising a pair of vertical coolers located axially between the stator winding of item (*a*) and the bracket of item (*a*), at the machine-end at which said evacuating blower (*e*) is located, said vertical coolers being located radially between the bearing-housing (*c*) and the outer frame-shell of item (*a*); each cooler comprising a plurality of substantially straight, vertical, liquid-cooled, finned pipes; each end of each cooler terminating in a cooler-head; said outer frame-shell of item (*a*) being provided with cooler-accommodating perforations having pressure-resistant reinforcing-means secured to said outer frame-shell around each cooler-accommodating perforation; and means for removably securing each cooler-head hermetically to its own pressure-resistant reinforcing-means; (*g*) a recirculating rotor-winding and stator-core cooling-system, comprising a gas-circulation guiding-means, including: a hot-gas guiding-means,

for guiding the heated gas of the machine into at least a portion of said gas-moving means (*e*), and for thence delivering said heated gas first through said heat-exchanging means (*f*) for cooling said gas, said hot-gas guiding-means including a means for guiding hot gas from said evacuating blower (*e*) in two streams flowing through the two vertical coolers (*f*) at that end of the machine; a first cool-gas guiding-means, for guiding a first portion of the cooled gas from the heat-exchanging means (*f*) through the inner-cooling ducts of at least the rotor winding of item (*b*), said first cool-gas guiding-means including a gas-communication means, at one end of the machine, for placing said first portion of the cooled gas in communication with that end of the through duct-means of item (*a*), and a gas-communication means, at each end of the machine, for placing its end of the through duct-means in communication with the rotor-winding inlet-openings of item (*b*) at its end of the machine; and a second cool-gas guiding-means, for guiding a second portion of the cooled gas from the heat-exchanging means (*f*) through the core-ventilating stator-ducts of item (*a*); and (*h*) a recirculating stator-winding cooling-system, comprising: a means for recirculating a stator-winding cooling-fluid in said stator-winding cooling-ducts; and a means for cooling said stator-winding cooling-fluid.

2. The invention as defined in claim 1, characterized by the gaseous filling of item (*a*) being a gas having a molecular weight lower than nitrogen, at a gas pressure which is adapted, at times, to be at least as high at 30 pounds per square inch, gauge.

3. The invention as defined in claim 1, characterized as follows: (*e''*) the gas-moving means (*e*) comprising only a single blower which is present at only one end of the rotor-core, as described in item (*e*); and (*g''*) the gas-circulation guiding-means (*g*) including a means for substantially closing the air gap at the other end of the machine.

4. The invention as defined in claim 1, characterized as follows: (*e''*) the gas-moving means (*e*) also including a second blower, carried by the rotor member at the second end of the rotor core of item (*b*), said second blower also including a supporting-means which provides an axially extending under-blower passage near the rotor-shaft, the inner end of said under-blower passage being in communication with the rotor-winding inlet-openings of item (*b*) at that end of the machine; (*f''*) the heat-exchanging means (*f*) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (*f*), except that they are disposed at the second end of the machine; and (*g''*) said hot-gas guiding-means of item (*g*) also including a means for using the second blower (*e''*) to cause at least a portion of the circulated gas to flow in two streams through said second pair of coolers (*f''*) to cool said gas.

5. The invention as defined in claim 1, characterized as follows: (*a'*) the core-ventilating stator-ducts of item (*a*) including a plurality of radially extending core-ventilating stator-ducts having their outer ends extending to the outer periphery of the stator-core; and the stator member including a means for providing an axially extending peripherally disposed core-ventilating passage in a space between the outer periphery of the stator core and said outer frame-shell of item (*a*), and means for placing said passage in communication with the outer peripheral ends of substantially all of the radially extending stator-ducts; and (*g'*) the second cool-gas guiding-means of item (*g*) including a means for feeding the cooled gas into the peripherally disposed passage of item (*a'*), and a means for returning hot gas from the inner ends of said radially extending stator-ducts of item (*a'*) to the suction side of at least a portion of said gas-moving means (*e*).

6. The invention as defined in claim 5, characterized as follows: (*e''*) the gas-moving means (*e*) comprising only a single blower which is present at only one end of the rotor-core, as described in item (*e*); and (*g''*) the gas-circulation guiding-means (*g*) including a means for substantially closing the air gap at the other end of the machine.

7. The invention as defined in claim 5, characterized as follows: (*e''*) the gas-moving means (*e*) also including a second blower, carried by the rotor member at the second end of the rotor core of item (*b*), said second blower also including a supporting-means which provides an axially extending under-blower passage near the rotor-shaft, the inner end of said under-blower passage being in communication with the rotor-winding inlet-openings of item (*b*) at that end of the machine; (*f''*) the heat-exchanging means (*f*) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (*f*), except that they are disposed at the second end of the machine; and (*g''*) said hot-gas guiding-means of item (*g*) also including a means for using the second blower (*e''*) to cause at least a portion of the circulated gas to flow in two stream through said second pair of coolers (*f''*) to cool said gas.

8. The invention as defined in claim 1, characterized as follows: (*a'*) the core-ventilating stator-ducts of item (*a*) including a plurality of radially extending core-ventilating stator-ducts extending between the outer periphery of the stator core and the air gap; and the stator member including a means for providing an axially extending peripherally disposed core-ventilating passage in a space between the outer periphery of the stator core and said outer frame-shell of item (*a*), and a means for placing said passage in communication with the outer peripheral ends of substantially all of the radially extending stator-ducts; and (*g'*) the second cool-gas guiding-means of item (*g*) including a means for feeding the cooled gas into the peripherally disposed passage of item (*a'*).

9. The invention as defined in claim 8, characterized as follows: (*e''*) the gas-moving means (*e*) comprising only a single blower which is present at only one end of the rotor-core, as described in item (*e*); and (*g''*) the gas-circulation guiding-means (*g*) including a means for substantially closing the air gap at the other end of the machine.

10. The invention as defined in claim 8, characterized as follows: (*e''*) the gas-moving means (*e*) also including a second evacuating blower, having the same description as the first-mentioned evacuating blower (*e*), except that it is disposed at the second end of the rotor core; (*f''*) the heat-exchanging means (*f*) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (*f*), except that they are disposed at the second end of the machine; and (*g''*) said hot-gas guiding-means of item (*g*) also including a means for guiding the hot gas from the second blower (*e''*) in two streams flowing through said second pair of coolers (*f''*) to cool said gas; said first cool gas guiding-means of item (*g*) drawing its cooled gas from the first pair of coolers (*f*); and said said second cool-gas guiding-means of item (*g*) drawing its cooled gas from the second pair of coolers (*f''*).

11. The invention as defined in claim 1, characterized as follows: (*aa*) the stator-winding cooling-ducts of item (*a*) having outlet-openings at a first end of the machine, and inlet-openings at the second end of the machine; (*gg*) the gas-circulation guiding-means (*g*) also including a third cool-gas guiding-means, using at least a portion of the through duct-means of item (*a*), for guiding a third portion of the cooled gas from the heat-exchanging means (*f*) through the inner-cooling ducts of the stator winding of item (*a*), said third cool-gas guiding-means including a gas-communication means, at the second end of the machine, for placing said third portion of the cooled gas in communication with the stator-winding inlet-openings of item (*aa*) at that end of the machine, and a gas-communication means for placing the stator-winding outlet-openings of item (*aa*) in communication with the suction side of the evacuating blower (*e*) at that end of the machine; and (*hh*) the recirculating stator-winding cooling-system (*h*) being a part of the gas-circulation guidin^r^-means (*g*) and (*gg*).

12. The invention as defined in claim 11, characterized as follows: (*e''*) the gas-moving means (*e*) comprising only a single blower which is present at only one end of the rotor-core, as described in item (*e*); and (*g''*) the gas-circulation guiding-means (*g*) and (*gg*) including a means for substantially closing the air gap at the other end of the machine.

13. The invention as defined in claim 11, characterized as follows: (*e''*) the gas-moving means (*e*) also including a second blower, carried by the rotor member at the second end of the rotor core of item (*b*), said second blower also including a supporting-means which provides an axially extending under-blower passage near the rotor-shaft, the inner end of said under-blower passage being in communication with the rotor-winding inlet-open-

ings of item (b) at that end of the machine; (f'') the heat-exchanging means (f) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (f), except that they are disposed at the second end of the machine; and (g'') said hot-gas guiding-means of item (g) also including a means for using the second blower (e'') to cause at least a portion of the circulated gas to flow in two streams through said second pair of coolers (f'') to cool said gas.

14. The invention as defined in claim 11, characterized as follows: (a') the core-ventilating stator-ducts of item (a) including a plurality of radially extending core-ventilating stator-ducts having their outer ends extending to the outer periphery of the stator-core; and the stator member including a means for providing an axially extending peripherally disposed core-ventilating passage in a space between the outer periphery of the stator core and said outer-frame-shell of item (a), and means for placing said passage in communication with the outer peripheral ends of substantially all of the radially extending stator-ducts; and (g') the second cool-gas guiding-means of item (g) including a means for feeding the cooled gas into the peripherally disposed passage of item (a'), and a means for returning hot gas from the inner ends of said radially extending stator-ducts of item (a') to the suction side of at least a portion of said gas-moving means (e).

15. The invention as defined in claim 14, characterized as follows: (e'') the gas-moving means (e) comprising only a single blower which is present at only one end of the rotor-core, as described in item (e); and (g'') the gas-circulation guiding-means (g) and (gg) including a means for substantially closing the air gap at the other end of the machine.

16. The invention as defined in claim 14, characterized as follows: (e'') the gas-moving means (e) also including a second blower, carried by the rotor member at the second end of the rotor core of item (b), said second blower also including a supporting-means which provides an axially extending under-blower passage near the rotor-shaft, the inner end of said under-blower passage being in communication with the rotor-winding inlet-openings of item (b) at that end of the machine; (f'') the heat-exchanging means (f) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (f), except that they are disposed at the second end of the machine; and (g'') said hot-gas guiding-means of item (g) also including a means for using the second blower (e'') to cause at least a portion of the circulated gas to flow in two streams through said second pair of coolers (f'') to cool said gas.

17. The invention as defined in claim 11, characterized as follows: (a') the core-ventilating stator-ducts of item (a) including a plurality of radially extending core-ventilating stator-ducts extending between the outer periphery of the stator core and the air gap; and the stator member including a means for providing an axially extending peripherally disposed core-ventilating passage in a space between the outer periphery of the stator core and said outer frame-shell of item (a), and a means for placing said passage in communication with the outer peripheral ends of substantially all of the radially extending stator-ducts; and (g') the second cool-gas guiding-means of item (g) including a means for feeding the cooled gas into the peripherally disposed passage of item (a').

18. The invention as defined in claim 17, characterized as follows: (e'') the gas-moving means (e) comprising only a single blower which is present at only one end of the rotor-core, as described in item (e); and (g'') the gas-circulation guiding means (g) and (gg) including a means for substantially closing the air gap at the other end of the machine.

19. The invention as defined in claim 17, characterized as follows: (e'') the gas-moving means (e) also including a second evacuating blower, having the same description as the first-mentioned evacuating blower (e), except that it is disposed at the second end of the rotor core; (f'') the heat-exchanging means (f) also including a second pair of vertical coolers, having the same description as the first-mentioned pair (f), except that they are disposed at the second end of the machine; and (g'') said hot-gas guiding-means of item (g) also including a means for guiding the hot gas from the second blower (e'') in two streams flowing through said second pair of coolers (f'') to cool said gas; said first and third cool-gas guiding-means of items (g) and (gg) drawing their cooled gas from the first pair of coolers (f); and said second cool-gas guiding-means of item (g) drawing its cooled gas from the second pair of coolers (f'').

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