INNER-COOLED GENERATORS WITH SINGLE-DIRECTION VENTILATION

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Our invention relates to inner-cooled hydrogen-cooled turbine-generators, or other dynamoelectric machines, in which the heat generated in the stator and rotor windings is directly withdrawn from the winding conductors, through inner-cooling ducts which are disposed in good thermal relationship with the winding-coolers.

Hitherto, such inner-cooled machines have been designed with the same kind of stator-core cooling which has been used for several decades in turbine generators, that is, since long before the introduction of inner-cooling. The conventional method of cooling the stator-cores of machines having such large length-to-diameter ratios as are prevalent in turbine-generators, has been to provide the stator-core with a large number of radial ventilating-spaces, which are disposed between small bunches of stator-core laminations, and these radial ventilating-spaces have been surrounded with a plurality of peripheral annular ventilating-spaces, which have been alternately intake-zones and outlet-zones. The cooling-gas, which was at first air, but which has been hydrogen since about 1890, was introduced into the radial ventilating-passages, which forced the gas first radially inwardly into the air gap, then radially outwardly in the next group of core-passage spaces, then across the adjacent outlet-space surrounding the stator-core, then to the next adjacent inlet-space surrounding the stator-core, and radially inwardly through those stator-core passages to the air gap, and so on. This used the air gap, so far as the stator-core ventilation was concerned, only as a means for transferring the heat from one group of radial inlet-passages to the next adjacent group of radial outlet-passages of the stator-core. The air gap also cooled the hot gas, which was discharged from the rotor-member into the air gap, with the stator-core cooling-gas, thus considerably increasing the hottest-point temperature of the stator core.

Our experience with inner-cooled turbine-generators has convinced us that the above-described old or conventional stator-core cooling-method is not at all desirable in these machines. The inner-cooling ducts of the stator and rotor windings successfully dissipate all of the copper losses or conductor-heat, into the coolant which flows through these inner-cooling ducts. Consequently, the heat which is to be removed from the stator and rotor cores is only the relatively small amount of heat which is produced by hysteresis and eddy currents within these structures. The rotor-core heat is adequately withdrawn by the coolant which inner-cools the rotor-windings. This leaves, therefore, only the stator-core heat-losses, due to hysteresis and eddy currents, which can be withdrawn by relatively small quantities of coolant.

Considerations such as the foregoing have led us to believe, and tests have verified our predictions, that the total amount of gas, which is required for generators of the inner-cooled type, is substantially smaller than for the conventional type of generator and cooling. In one case, the total volume of cooling-gas which is required by a generator having inner-cooling was less than one half of that which was required by a generator of the same rating, but without inner-cooling.

According to our present invention, it is possible, therefore, to make the air gap of our inner-cooled generator sufficiently large to serve as a hot-gas collecting-chamber and as an axial duct for a substantial portion of the ventilating-gas of the machine. In one form of embodiment, all of the gas which is used for cooling the stator-core passes radially inwardly through the radial core-ventilating passages, and discharges, as hot gas, into the air gap; and substantially all of the rotor-cooling gas, for cooling both the innercooled rotor-windings and the rotor-core, also discharges into the air gap, which thus acts as a hot-gas collecting-chamber. The gas is then drawn from one end of the air gap by a special multistage axial blower, and is thence blown through the coolers; and from the coolers, the cooled gas is led into the inner-cooling ducts of the stator and rotor windings, and into the core-cooling passages of the stator core. This arrangement results in the simplest and most efficient utilization of the machine-space, it provides a more efficient blower-system which is capable of producing higher compression-ratios and of supplying lower-temperature gas to the windings, and it permits a frame-construction which is more suited to operation with the higher gas-pressures which are now preferred in inner-cooled turbine-generators.

Several different illustrative forms of embodiment of our invention are shown in the accompanying drawings.

Figure 1 is a side-elevational view, the top half being in longitudinal section, showing a hydrogen-cooled turbine-generator embodying our invention in a form in which we use only a single air 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 views of the sectional views of the machine shown in Fig. 1, and including the various parts of the machine not shown in Fig. 1, which illustrates an embodiment of our invention in which the cooling-gas is recirculated and discharged from the machine at one end, and at the same time is discharged from the machine at the other end, through the machine at the same time, and is then discharged into the machine at the other end.

A recirculating stator-winding cooling-system is necessary.
sarily 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-moving means as the stator-winding cooling-fluid, we prefer to do so, in which case, the duct-inlets 24r are open to an end-space 24' within the machine, at one end of the machine, while the duct-outlets 24b are open to another end-space 34' 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 as previously described in the heat exchanging means comprises a pair of vertical coolers 44 and 45. These coolers are located axially between the stator-winding duct-outlets 24b and the housing-bracket 20 at that end of the machine, as shown in Fig. 1. The cooler 44 is the machine-housing all the air in the machine housing confines, of the stator-winding end-turns which have the duct-outlets 24b, so that the blower 41 discharges the hot gas axially toward the portion of the housing which is occupied by that 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. 5, so that the hot gas which it heated coolers. The stator winding 23 is usually a multiaxis winding, and in the large machine-sizes to which our present invention is particularly applicable, the stator winding 23 is provided with ground insulation 25 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 36, as shown in Figs. 1 to 10, or axially disposed ducts or holes as shown in Figs. 11 to 14.

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 cooling the rotor-conductors. Preferably, or in practically every case in which it our invention would be used, the rotor winding-ducts 30 have inlet-openings or means, 32, at the respective ends of the rotor-ducts, the entry openings being a plurality of intermediate discharge-points within the winding-receiving rotor-slots, these discharge-points being commonly grouped together throughout the entire length of the core. It is commonly the case that the rotor winding-ducts 30, so as to require a much thinner rotor-insulation, which is too thin to be shown on the scale to which our 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 face-frames 19 and 20. Associated with the bearing-housings 36, are suitable gland-seal members 57 for maintaining the 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 extends through the bearing-frame into the bearing-housing 36, which serves as the engine-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 this gap is suitably 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.

The air gap 17 between the inner and outer peripheries of the stator core 20 and 21 and the outer frame-shell 18 is illustrated as being in the space between the outer periphery of the stator core 20 and the outer frame-shell 18.

The outer frame-shell 18 is provided with cooler-accommodating perforations 35, having pressure-resistant reinforcing means 51, which are secured to the frame-shell around each perforation 50. The top and bottom cooler-heads 47 of each cooler 44 and 45 are hermetically but removable secured to their own reinforcing-means 51, so that each cooler can be lifted vertically out of the machine, after the two cooling-water-connections, for circulating water or other coolant through the cooler-pipes, are preferably provided at the lower cooler-head, as shown in Figs. 2 and 3.

We prefer to provide 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 24b discharge is confined by an outer approximate partition 52, 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 housing 18, so that the hot gases, as provided with a central hole 54c 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 discharge-gases are being discharged into the two streams, flowing to the right and left to enter the coolers 44 and 45, respectively.

Extending vertically between the two coolers 44 and 45, at their sides closest to the blower, 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 57c 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 57b 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, extending axially under the 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 this two cooling units 23 and 44 is 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 in which some of the cold gas is led into both ends of the stator winding which are connected to the inlets 24c 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 a plurality of air-piping-ducts 24d, as shown in 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 24b is illustrated as being in the space between the outer periphery of the stator core 20 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 direction through the core 21. The central 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 stator member is provided with a radial ring 65, through which the cold-gas intake 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 53a outside of the cylindrical or arcuate partition 53 and is in communication with the radial space 57b 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 that end of the machine.

At the other end of the machine, the cold-gas end-space 24β 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 stationery cylindrical baffle-member 69 (Fig. 1), which is driven by the rotor-frame 32, as shown in Fig. 2, at the upper end member 16, so as to limit, or substantially stop, the escape of hot gas directly from the end-space 24β into that end of the air gap 17, as described in our Patent No. 2,625,365, granted January 20, 1953.

The through-duct 58 is provided with lateral openings 70 for discharging the cooled gas into the annular spaces 70a between the successive frame-rings 61 to 64, these annular spaces 70a being disposed between the outer periphery of the stator-core 21 and the outer cylindrical frame-shell 18. Since the radial stator-core cooling-space 25β is in communication with these annular frame-rings 70a, the cooled gas is thus delivered 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 flow of this gas and thus to receive the quantity of gas which is required to cool the same.

The cool-gas space 53a which is outside of the cylindrical or arcuate partition 53 may be cooled by the cooler-frame 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 communication with the coolers 44 and 45, all portions of which are in communication with each other.

The operation of the form of embodiment of our 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 24β 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 vertical coolers 44 and 45, respectively.

This gas which is discharged from the coolers 44 and 45 is cold or cooled gas, which appears in the space 53a outside of the cylindrical or arcuate partition 53. A part of this gas flows into the sides of the flat end-space 57b 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 25β and enters the cooling-end-winding-openings 32 at that end of the machine.

The remainder of the cool air in the space 53a outside of the cylindrical or arcuate partition 53 leaves that space through the through-duct 58. A part of this through-duct 58 is provided with the peripheral annular stator-core ventilating-spaces 70β 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 cooler-air end-space 24α, where most of it divides between the stator-winding-duct-inlets and the rotor-winding-duct-inlets 32 at that end of the machine. A very small portion of the cool gas in this end-space 24α is admitted through the air gap 17, by means of the baffles 69. In some machines, however, this hot-gas 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 inner-cooler 44a from the end-space 24α, and it passes all the way through the through-ducts 24 from that end of the machine to the other end of the machine, where it is discharged, as hot gas, through the outlet 24β into the space 24β inside of the cylindrical or arcuate partition 53, where it merges with the reduced volume of 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 our 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 the 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 line 59 in Fig. 1, through the small 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 end of the rotor member openings 33 of the inner-cooling ducts 31 and through the radial rotor-ducts 34.

It is noted that our invention, as embodied in Figs. 1 to 6, uses a large air gap 17, to receive the bulk of the coolant from the stator-core cooling-vents 24 and from the rotor-winding-discharge-ducts 34, discharging this hot gas axially to a high-pressure, multistage axial blower 41 which is located at one end of the rotor member. The high-pressure gas is then blown through suitable coolers, and the cooled high-pressure gas is then distributed to the various inner-coolings for cooling the inner-cooled stator-windings 30, the inner-cooled stator-windings 23, and the stator-core 21. This arrangement greatly simplifies the amount of baffling which is necessary to properly distribute the coolant. It results in the simplest and most efficient use of the machine-space. It provides a more efficient blower-system, which is capable of recirculating the coolant at higher blower-pressures and blower-velocities, as a result of the use of a single multistage blower, as distinguished from two smaller blowers, one at each end of the rotor member, thus involving only one velocity-head loss, and more blowers spaced at such a sum of the pressures which would be obtained from two separate blowers.

The use of a single multistage axial blower or compressor 41 is made possible by the reduced volume of gas which needs to be handled in our invention, this reduced volume being made possible by the use of denser gas (or higher gas-pressures), and the use of higher gas-velocities, resulting in a greater blower-efficiency, which results from handling a reduced volume of gas at higher velocities.

Our use of an exhaust-blower 41, for drawing the hot gas out of the ventilating parts of the machine, and mixing said hot gas directly through a cooler or coolers before recirculating the same through the ventilating passages of the machine, has in addition another advantage, because a high-pressure fan produces an appreciable temperature-rise, as a result of compression, if the gas has a density approaching that of air. In the factory-testing of the machine, it is desirable to operate the machine in air, for routine electrical and discharge tests, balancing the machine. Our use of an exhausting blower, as distinguished from a blower which blows the gas from the cooler into the ventilating passages of the machine, thus has the advantage of avoiding blowing the hot gas out of the machine during these preliminary air-tests at the factory, air which has been heated, by the compressing action of the multistage blower, to a temperature which is too high for the machine-windings. Subsequently, when the air is evacuated or blown out from the machine, and
replaced with hydrogen, our evacuating high-pressure blower avoids the introduction of even the small temperature changes that would occur in conventional systems. The high-temperature blower, which did not use the high-temperature blower as a collecting chamber for the hot gas, avoids the temperature changes that are possible in the conventional system.

By avoiding mixing or coning out some of the hot gas with other gases, which could not be heated, our system is improved. The result is a high-temperature blower with a higher efficiency. Furthermore, the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core. As in Fig. 1 to 6, these six frame-rings 81 to 86 are traversed by a through-duct 88 shown in Fig. 7. This through-duct 88 carries the high-pressure cool gas, from the space 53a to the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core. In Fig. 1 to 6, these six frame-rings 81 to 86 are traversed by a through-duct 88 shown in Fig. 7. This through-duct 88 carries the high-pressure cool gas, from the space 53a to the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core.

However, unlike the through-duct 85 of Fig. 1, the through-duct 88 of Fig. 7 is imperforated along its sidewalls, so that it does not deliver any gas to the annular spaces 79 between frame-rings 81 to 86, as shown in Fig. 8, in accordance with the requirement that the stator core 21 is not cooled by the high-pressure cool gas passing through the through-duct 88. The high-pressure cool gas is used to cool the stator core 21, which is sealed from the through-duct 88.

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 24a of the stator windings 23, and from the space 53a of the annular spaces 79, is compressed to a high-pressure by the multi-stage exhaust blower 41, and is delivered through the pair of coolers 44 to the high-pressure cool gas space 53b which is in communication with the cylindrical or arcuate space 53 at that end of the machine. This high-pressure cool gas is used in the cooling of the stator core 21, whereas the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core. As in Fig. 1 to 6, these six frame-rings 81 to 86 are traversed by a through-duct 88 shown in Fig. 7. This through-duct 88 carries the high-pressure cool gas, from the space 53a of the cylindrical or arcuate space 53 at that end of the machine. This high-pressure cool gas is used in the cooling of the stator core 21, whereas the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core. As in Fig. 1 to 6, these six frame-rings 81 to 86 are traversed by a through-duct 88 shown in Fig. 7. This through-duct 88 carries the high-pressure cool gas, from the space 53a of the cylindrical or arcuate space 53 at that end of the machine. This high-pressure cool gas is used in the cooling of the stator core 21, whereas the stator core 21, the frame-rings 81 to 86 being more or less hermetically sealed with respect to the respective ends of the stator core.
of the pressure-differential which is created by the blower 91 alone, as will subsequently appear. Of these blowers 91 and 91', in Figs. 9, 10, and 10, the blower 91 is an exhaust-blower, for evacuating gas out of that end of the air gap and also from the chamber 24. The gas from the stator-winding duct-outlets 24b, as was the case with the multi-stage blowers in Figs. 1 to 8. This blower 91 is provided with the previously described under-blower passages 42, and it delivers its hot gas to a single pair of vertical coolers 44 and 45, with the same baffles or partition-arrangements which has already been described for the end of the machine which is bounded by the frame-bracket 20 in Figs. 1 to 8.

The stator member in Figs. 9 and 10 has four frame-rings 92 to 95, corresponding to the six frame-rings 81 to 84 of Figs. 7 and 8. Each of these frame-rings is perforated in accordance with internal and external pressure-differential which is created by the blower 91 alone, as will subsequently appear. Of these blowers 91 and 91', in Figs. 9, 10, and 10, the blower 91 is an exhaust-blower, for evacuating gas out of that end of the air gap and also from the chamber 24. The gas from the stator-winding duct-outlets 24b, as was the case with the multi-stage blowers in Figs. 1 to 8. This blower 91 is provided with the previously described under-blower passages 42, and it delivers its hot gas to a single pair of vertical coolers 44 and 45, with the same baffles or partition-arrangements which has already been described for the end of the machine which is bounded by the frame-bracket 20 in Figs. 1 to 8.

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gas may flow uninterruptedly all the way through the entire axial length of each of these axial core-passages 120; but if the machine is very long, it may be desirable, as shown in Figs. 12 and 14, to subdivide these axial core-passages 120, in two or more places, as shown in the radial ventilating spaces 121 and 122, which are provided at spaced intermediate points in the stator core 21. These radial vent-spaces are closed at their inner, or air-end, ends, as shown at 123; and they are open at their outer peripheries, the radial space 121 being in communication with a peripheral annular space 121', which is just underneath the space between the two frame-rings 113 and 114, while the radial core-ventilating space 122 is in communication with a peripheral annular space 122' which is just underneath the space between the two frame-rings 115 and 116. The purposes of these spaces will soon be apparent.

Referring back, now, to the cool-gas spaces 118 and 118', as shown in Figs. 11 and 14, it will be noted that the inner frame-shell 103 is provided with certain openings which are disposed on the same horizontal level as the rotor member 16. At the extreme end of the inner frame-shell 103, close to the housing-bridge 20, and between this bridge and the discharge-passages 24, there is an opening for the blowers 41, the inner frame-shell 103 is provided with an opening or openings 124, which discharges some of the cool gas radially inwardly into the flat end-space 124' close to the bridge 24, hence flowing axially inwardly through the underblower passages 42 to the rotor-winding inlet-openings 32 at that end of the machine. At the other end of the machine, the inner frame-shell 103 is provided with one or more openings 125 (Fig. 14), which discharge cool gas into the cool-gas end-space 126, at the end of the machine which is bounded by the housing-bridge 19. This end-space 126 is in free communication with the stator-winding duct-inlets 24a, the rotor-winding inlet-openings 32 at that end of the machine, and the stator-core axial-passages 120 at that end of the machine. As in Fig. 12, the cool-gas (a) is discharged at this end, by the air-gap baffle 69, so that little or no air is admitted to that end of the air gap 17, from the cool-gas end-space 126.

In addition to the above-described openings 124 and 125 which discharge cool gas from the spaces 118 and 118', the inner frame-shell 103 is provided with three other openings 127, 128 and 129, at about the same horizontal level as the rotor member 16, as shown in Fig. 14. The opening 127, in the inner shell 103, communicates with the previously described peripheral annular space 121', which feeds cool gas radially inwardly into the radial core-ventilating space 121 of the stator core, and from this point the cool gas flows, in two opposite directions, into the two adjacent portions of the axial core-passages 120, the discharge 128, in the inner shell 103, is in communication with the other previously described peripheral annular space 122', but it is shut off from communication with the annular space between the two frame-rings 115 and 116 by means of a short radially disposed duct 128', which extends from the opening 128 into communication with a closed end of an axially disposed duct 130, which extends through the frame-rings 115, 113, 111 and 112, terminating before it reaches the frame-ring 111.

This terminal end of the axial duct 130 is also closed, and is in communication with a short radial duct 129', which is in communication with the opening 129 in the inner frame-shell 103, this opening discharging into the hot-gas space 24' which is in communication with the intake side of the blower 41.

In summarizing the operation of the apparatus shown in Figs. 11 to 14, it will not be noted that the cool gas in the cool-gas spaces 118 and 118' is discharged in three different paths, at the horizontally disposed openings 127, 128 and 129, the opening 127 discharging into the hot-gas end-space 126 at the right-hand end of the machine, and from this space, three streams of cool gas are delivered, respectively, to the stator-winding-discharge ducts 24, the rotor-winding inlet-openings 32 at that end of the machine, and the stator-core axial-openings 120 at that end of the machine. The inner-cooling-stator-winding ducts 24 discharge into the hot-gas space 24' at the left-hand end of the machine. The rotor-winding inner-cooling ducts discharge through the centrally disposed discharge-openings 34 and thence into the air gap 17, which is in turn in communication with the hot-gas space 24, in two places, as shown in Figs. 12 and 14. The stator-core axial-openings 120 receive cool gas at two points, as described, and discharge their heated gas into the hot-gas space 24' at the left-hand end of the machine.
least some of the cooled gas in communication with that end of the through duct-means of item (e) 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 end of the machine.

2. The invention as defined in claim 1, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

3. The invention as defined in claim 1, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

4. The invention as defined in claim 1, characterized as follows: (2) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

5. The invention as defined in claim 1, characterized as follows: (e') the blower (e) being present at only one end of the rotor core; and (g) the gas-circulation guiding-means (g) further including a means for substantially closing or opening the other end of the machine.

6. The invention as defined in claim 5, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

7. The invention as defined in claim 5, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.  

8. The invention as defined in claim 1, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; and (b) 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.

9. The invention as defined in claim 8, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

10. The invention as defined in claim 8, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

11. The invention as defined in claim 1, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

12. The invention as defined in claim 11, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; and (b) 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.

13. The invention as defined in claim 11, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

14. The invention as defined in claim 1, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

15. The invention as defined in claim 14, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.

16. The invention as defined in claim 14, characterized as follows: (a) the stator winding being an inner-cooled winding having rotor-winding cooling-ducts in good thermal relation to the stator-ducts for substantially directly cooling said stator-ducts; (b) 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.
ing between the outer periphery of the stator core and the air gap; (c') the housing (c) also 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 the core-surrounding hous-

Portion of item (c), said passage being in communication with the outer peripheral ends of substantially all of the radially extending core-ventilating stator-ducks (a'); and (g') the gas-circulation guiding-means (g) being a means which also causes a plurality of streams of stator-core ventilating-gas to flow radially inwardly through all of the radially extending stator-ducks of item (a), said gas-circulation guiding-means also including: a means for guiding some of the cooled gas from said heat-exchanging means (f) to said axially extending core-ventilating passage of item (c').

15. The invention as defined in claim 14, characterized as follows: (aa) the stator winding being an inner-cooled winding having stator-winding cooling-ducks in good thermal relation to the stator-conductors for substantially directly cooling said stator-conductors; and (hh) a recirculating stator-winding cooling-system comprising: a means for recirculating a stator-winding cooling-fluid in said stator-winding cooling-ducks; and a means for cooling said stator-winding cooling-fluid.

16. The invention as defined in claim 14, characterized as follows: (aa) the stator winding being an inner-cooled winding having stator-winding cooling-ducks in good thermal relation to the stator-conductors for substantially directly cooling said stator-conductors, said stator-winding cooling-ducks having outlet-openings at one end of the machine and inlet-openings at the other end of the machine; and (gg) the gas-circulation guiding-means (g) being a means which also causes a plurality of streams of stator-winding ventilating-gas to flow through the stator-winding cooling-ducks of item (aa), said gas-circulation guiding-means also including: a means for guiding some of the cooled gas from the heat-exchanging means (f) to the inlet-openings of item (aa); and a means for returning hot gas from the outlet-openings of item (aa) to the suction side of the blower (e).

17. The invention as defined in claim 1, characterized as follows: (a') the stator member having a plurality of radially extending core-ventilating stator-ducks extending between the outer periphery of the stator core and the air gap; (c') the housing (c) also 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 the core-surrounding hous-

Portion of item (c), said passage being in communication with the outer peripheral ends of substantially all of the radially extending core-ventilating stator-ducks (a'); (e') the blower (e) being present at only one end of the rotor-core; (g') the gas-circulation guiding-means (g) being a means which also causes a plurality of streams of stator-core ventilating-gas to flow radially inwardly through all of the radially extending stator-ducks of item (a), said gas-circulation guiding-means also including: a means for substantially closing the air gap at said other end of the machine; and a means for guiding some of the cooled gas from said heat-exchanging means (f) to said axially extending core-ventilating passage of item (c').

18. The invention as defined in claim 17, characterized as follows: (aa) the stator winding being an inner-cooled winding having stator-winding cooling-ducks in good thermal relation to the stator-conductors for substantially directly cooling said stator-conductors; and (h) a recirculating stator-winding cooling-system comprising: a means for recirculating a stator-winding cooling-fluid in said stator-winding cooling-ducks; and a means for cooling said stator-winding cooling-fluid.

19. The invention as defined in claim 17, characterized as follows: (aa) the stator winding being an inner-cooled winding having stator-winding cooling-ducks in good thermal relation to the stator-conductors for substantially directly cooling said stator-conductors, said stator-winding cooling-ducks having outlet-openings at the blower-end of the machine and inlet-openings at the other end of the machine; and (gg) the gas-circulation guiding-means (g) being a means which also causes a plurality of streams of stator-winding ventilating-gas to flow through the stator-winding cooling-ducks of item (aa), said gas-circulation guiding-means also including: a means for guiding some of the cooled gas to the inlet-openings of item (aa) at the said other end of the machine; and a means for returning hot gas from the outlet-openings of item (aa) to the suction side of the blower (e).

References Cited in the file of this patent

UNITED STATES PATENTS
2,185,728 Fecheheimer Jan. 2, 1940
2,573,670 Moses Oct. 30, 1951
2,663,808 Rosenberg Dec. 22, 1953

FOREIGN PATENTS
518,207 Great Britain Feb. 20, 1940