Oct. 31, 1950 C. J. FECHHEIMER 2,527,878

COOLING SYSTEM FOR DYNAMOELECTRIC MACHINES

Filed Sept. 11, 1948 4 Sheets-Sheet 1

Fig. 1

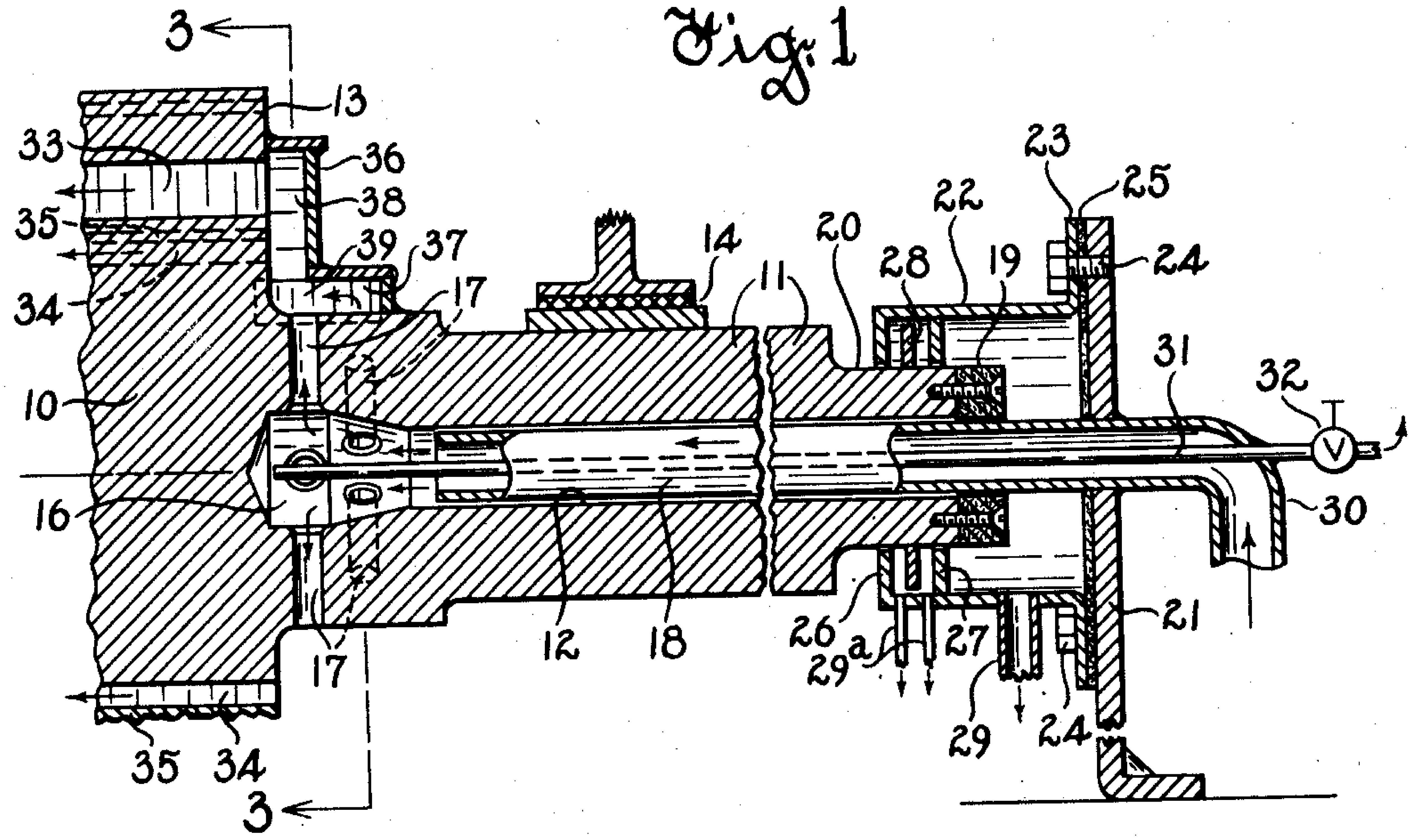
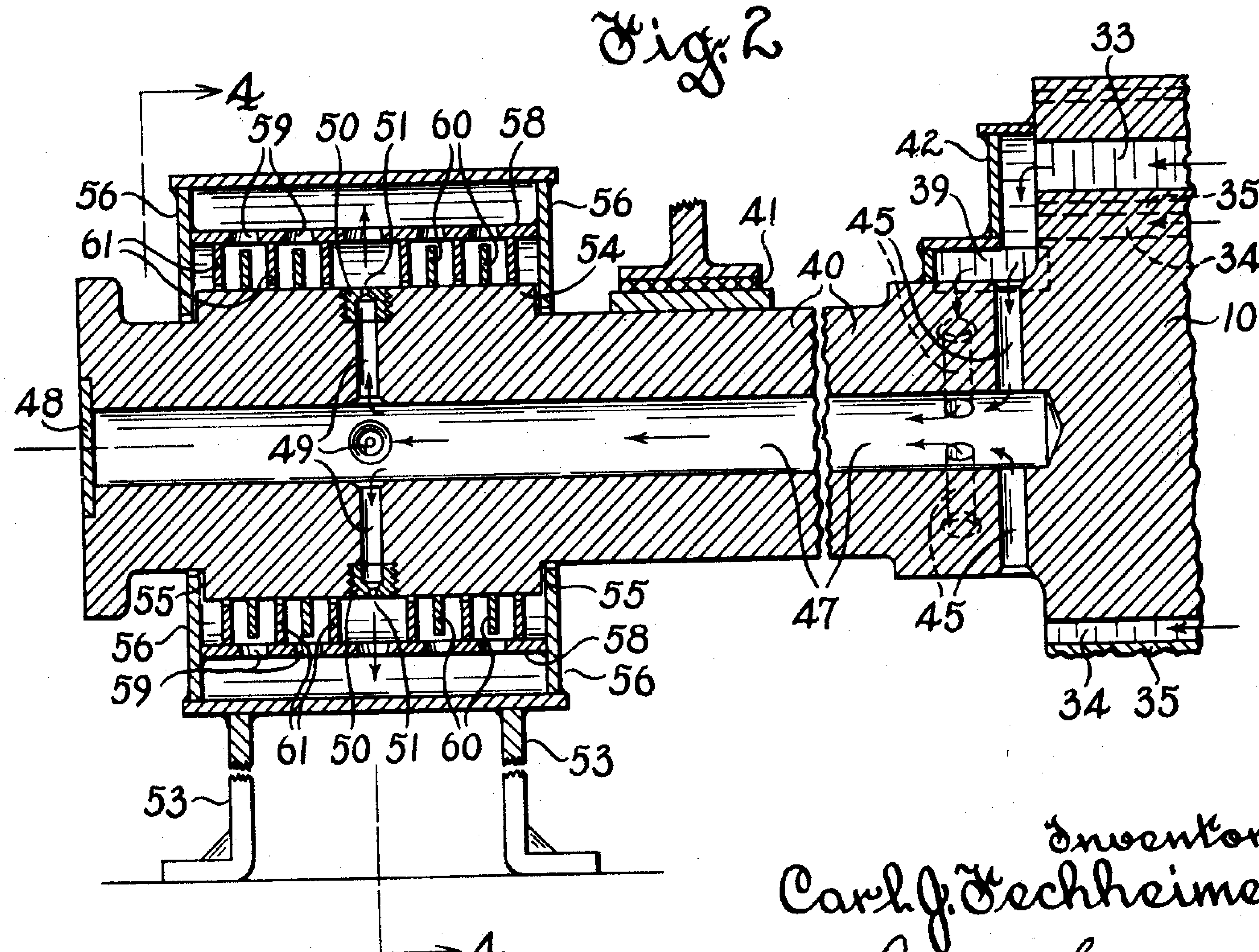


Fig. 2



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Oct. 31, 1950 | **C. J. FECHHEIMER** | **2,527,878**

COOLING SYSTEM FOR DYNAMOELECTRIC MACHINES

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Fig. 3

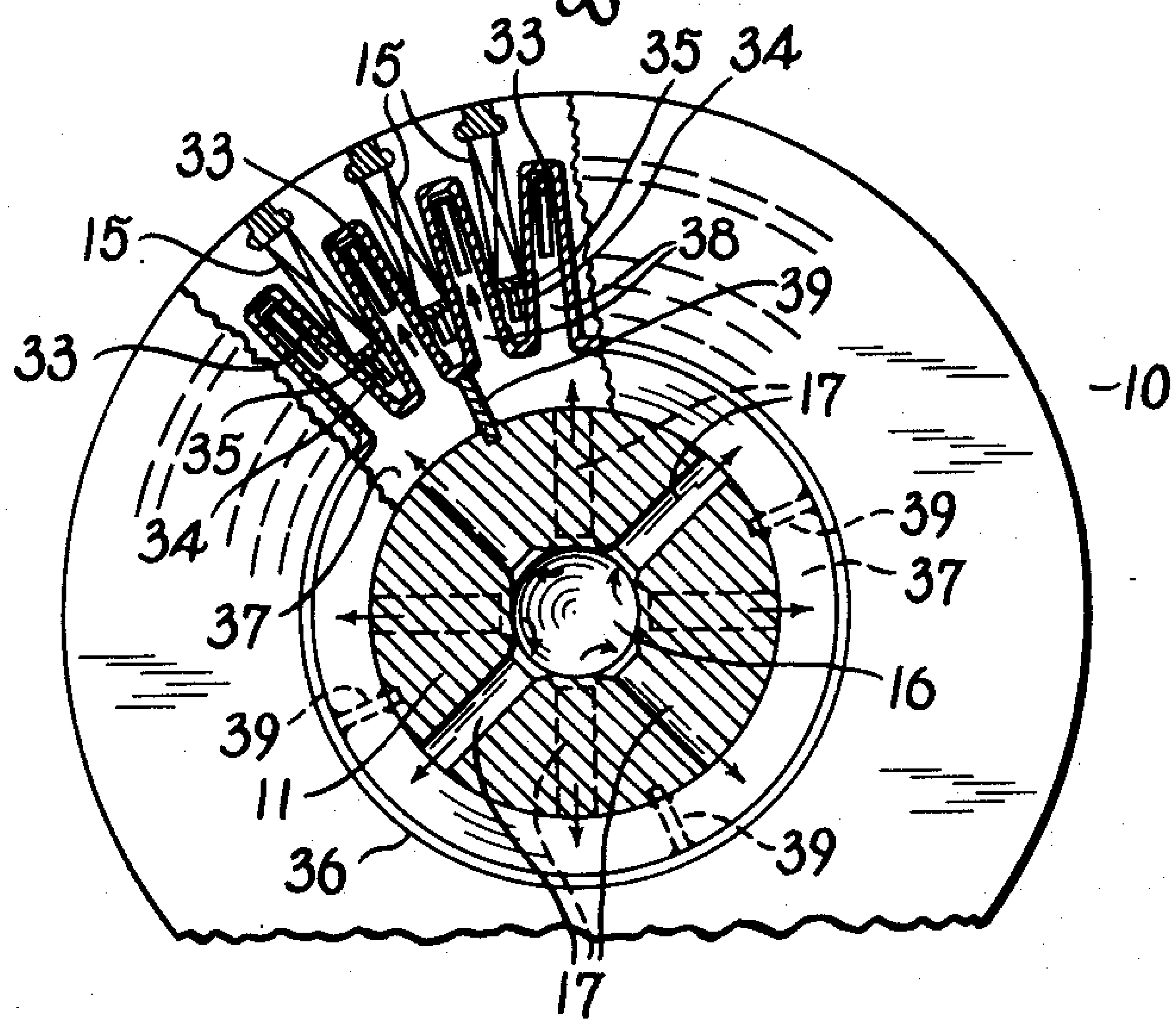
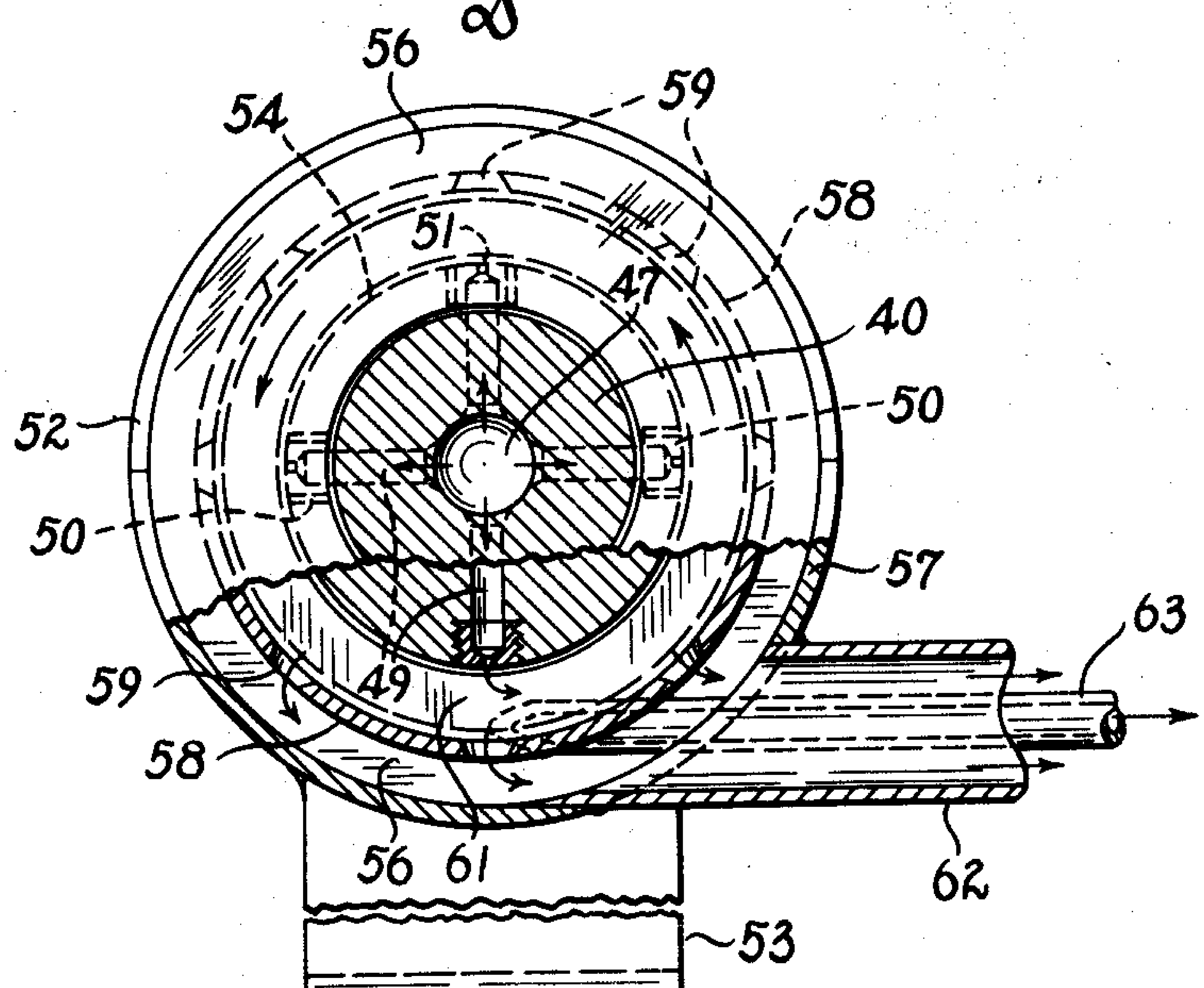


Fig. 4



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COOLING SYSTEM FOR DYNAMOELECTRIC MACHINES

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Fig. 5

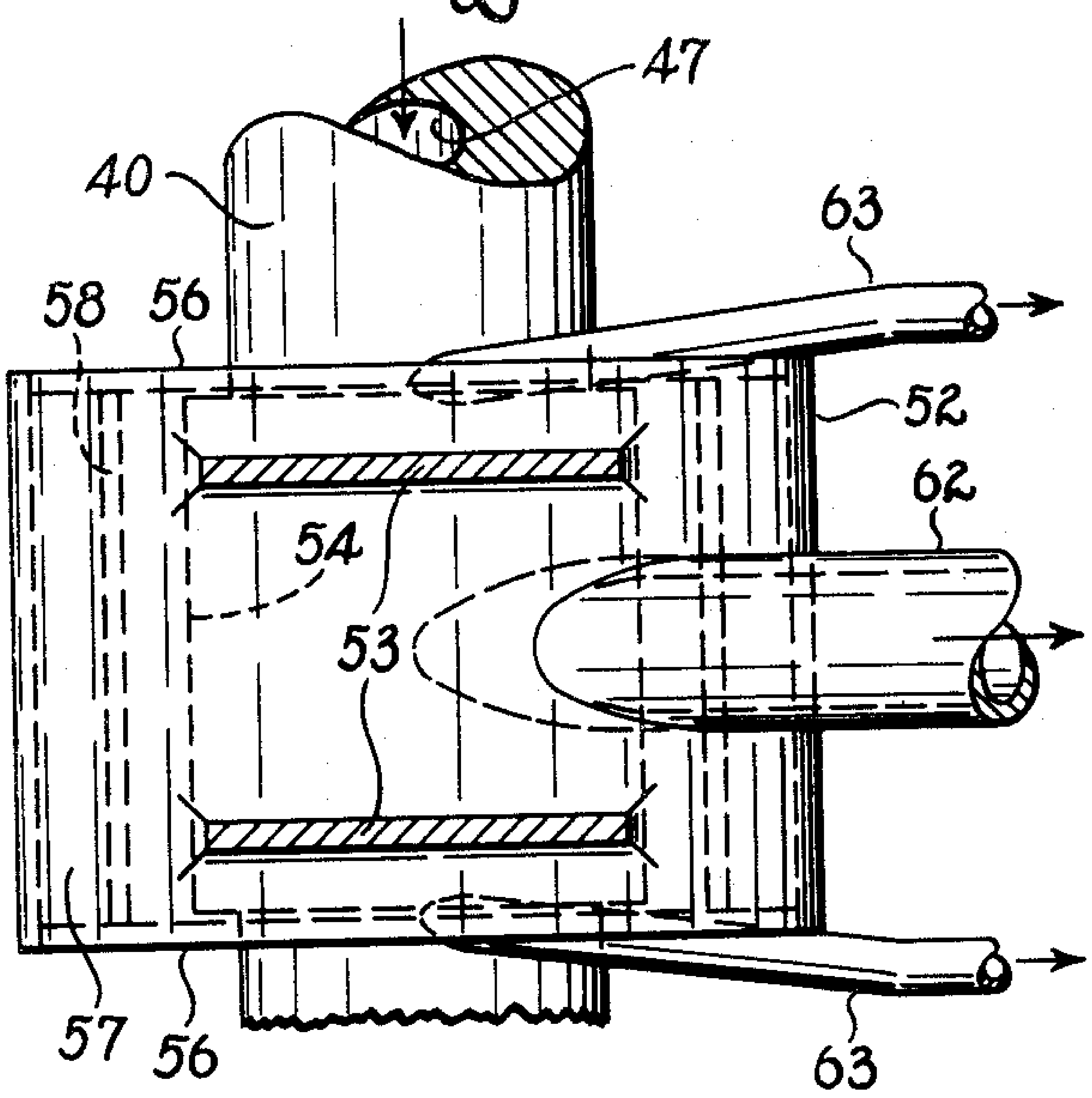


Fig. 6

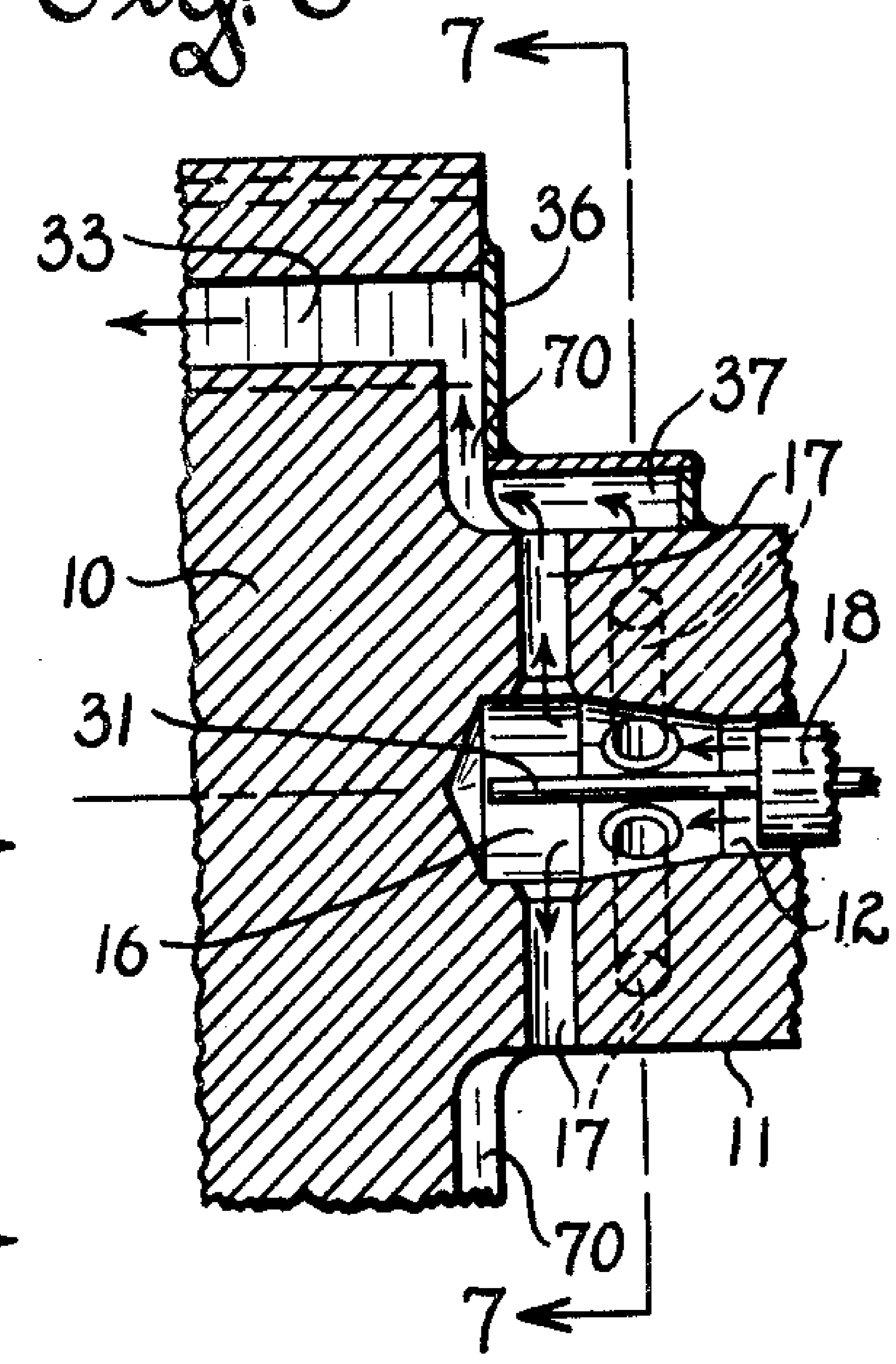
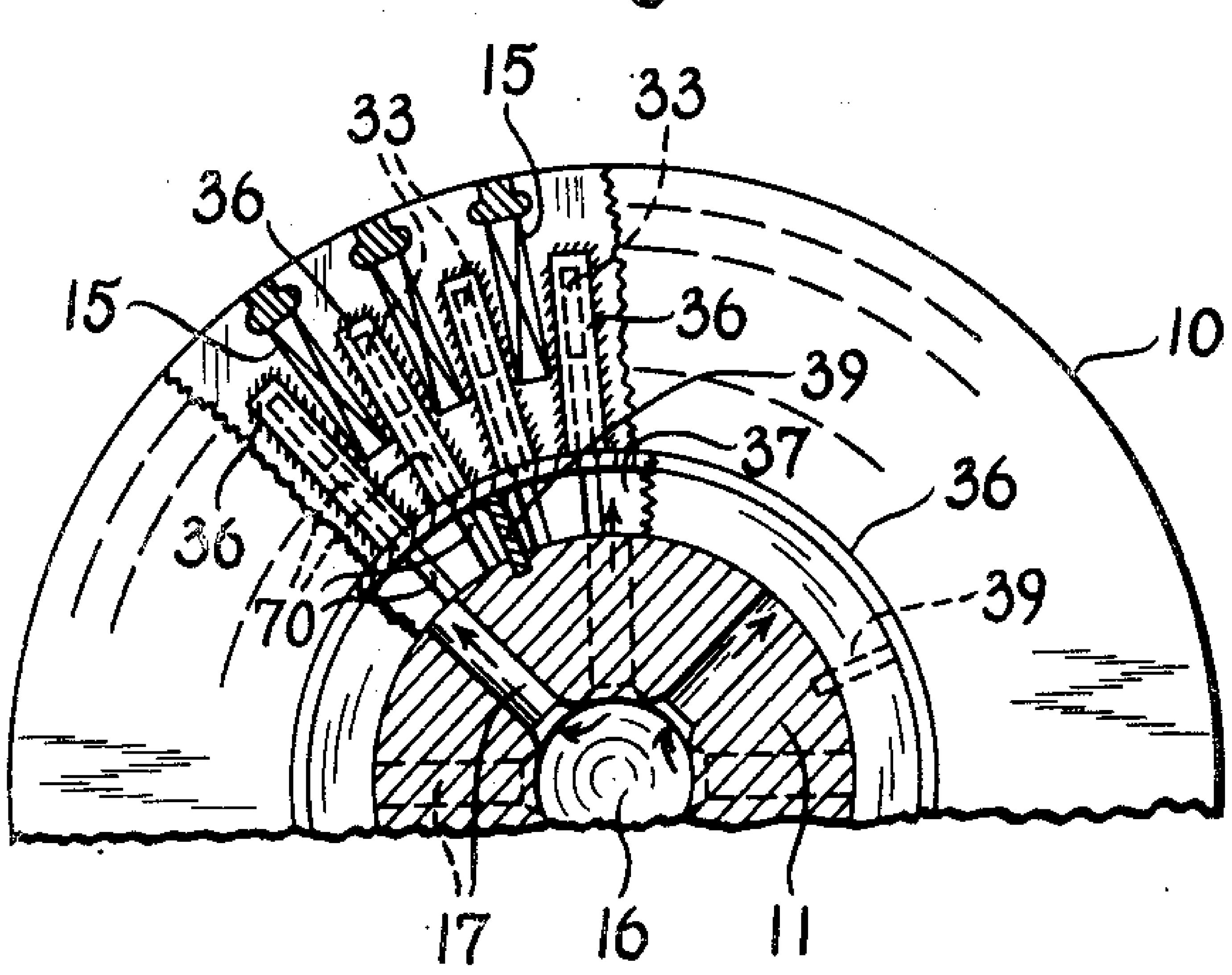


Fig. 7



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COOLING SYSTEM FOR DYNAMOELECTRIC MACHINES

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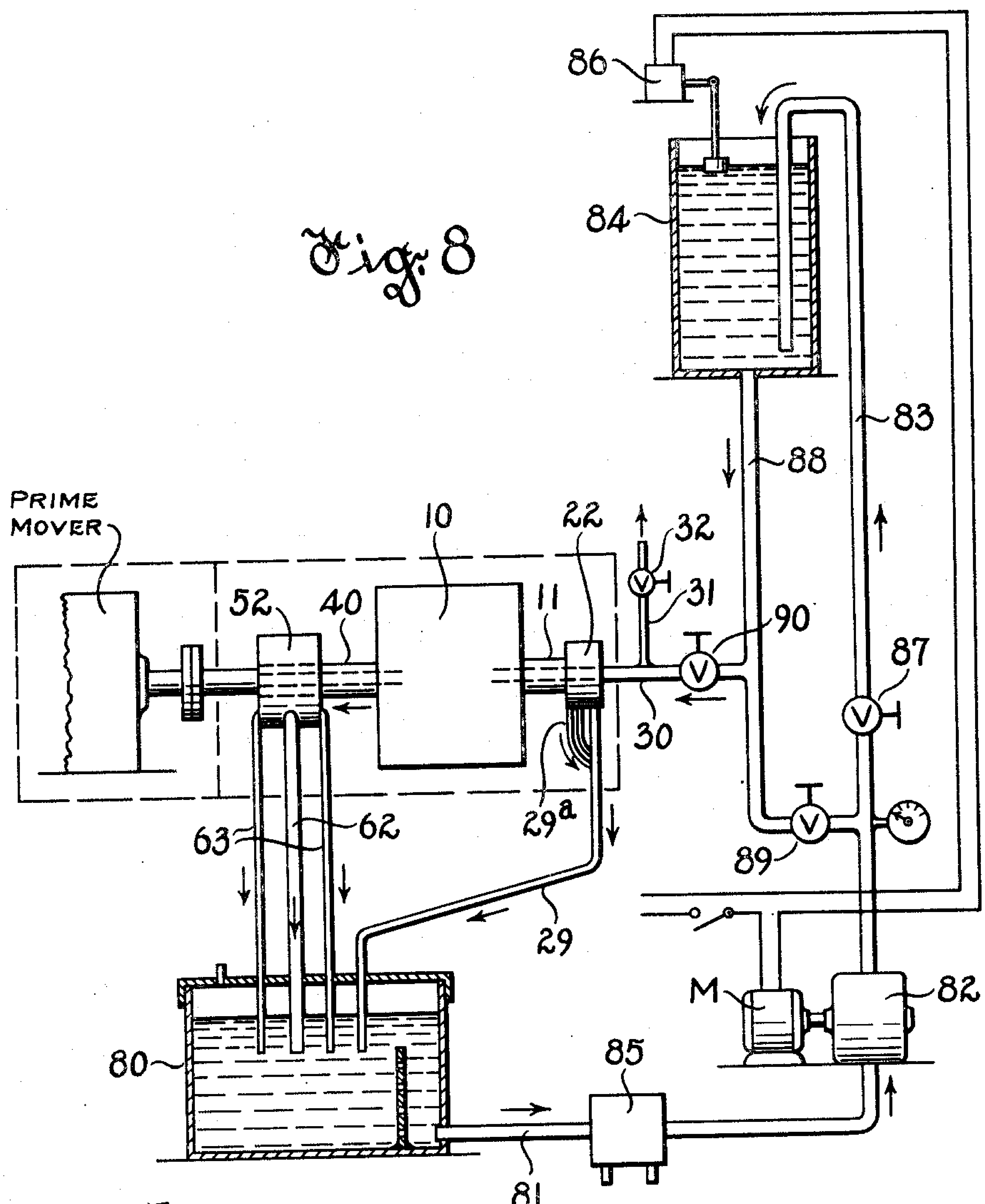
Fig. 8



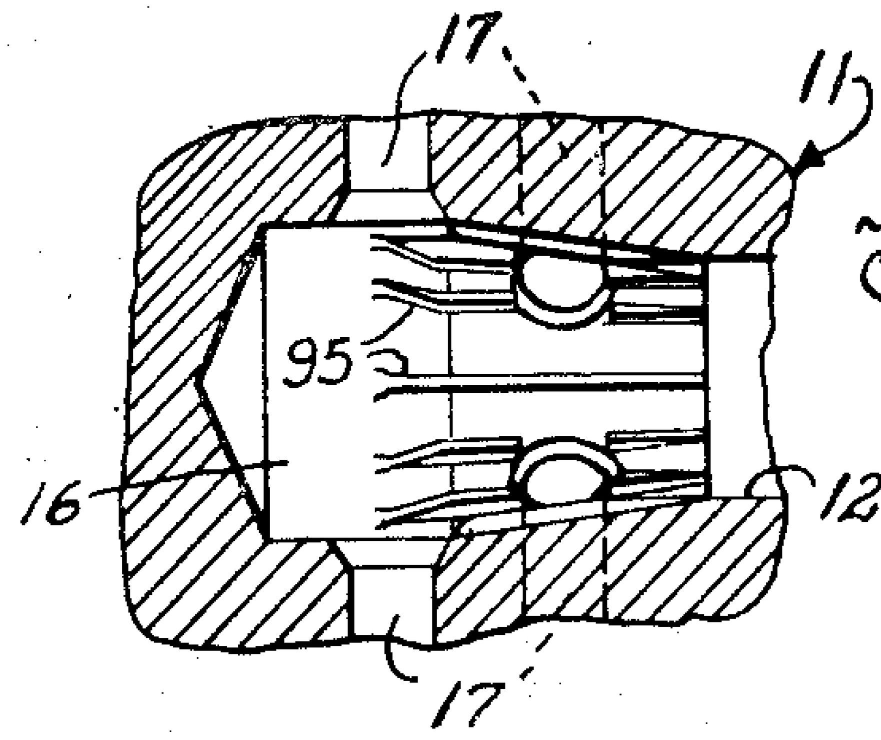


Fig. 9

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Patented Oct. 31, 1950 2,527,878

UNITED STATES PATENT OFFICE

2,527,878

COOLING SYSTEM FOR DYNAMOELECTRIC MACHINES

Carl J. Fechheimer, Milwaukee, Wis.

Application September 11, 1948, Serial No. 48,862

15 Claims. (Cl. 171—252)

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The invention relates to improvements in liquid cooled dynamoelectric machines, particularly machines operating at high speed such as turbo generators. The invention is in certain aspects an improvement of the inventions disclosed in my prior Patents 2,285,960 of June 9, 1942, and 2,381,122 of August 7, 1945.

The present application relates particularly to improved means for controlling the flow of cooling liquid through the rotor of a dynamoelectric machine, and particularly to means for preventing circumferential flow of liquid due to tangential inertia forces, and including means for regulating the circulation of the liquid flow between an outside storage tank for the cooling liquid and the cooling liquid ducts in the machine.

The invention provides means for preventing leakage of cooling liquid at the entrance to and discharge from the rotor, without requiring rubbing seals at these locations.

The invention further provides priming means for the liquid circulating system effective to initiate the flow of liquid through the machine upon starting.

Means are also provided for regulating the flow of cooling liquid from an elevated storage tank through the rotor to a collecting sump.

An object of the present invention is to provide means for automatically initiating the flow of cooling liquid through the machine upon starting thereof.

Another object is to provide means for regulating the flow of cooling liquid through the machine.

Another object is to provide the rotating part of the machine with self contained means to compensate for the tangential inertia forces which normally would inhibit a regulable flow of cooling liquid through the rotor of the machine.

Another object is to obviate the necessity of troublesome stuffing boxes or rubbing seals, for confining the liquid within a predetermined path through the machine.

Another object is to provide a simple, efficient and self regulating system of cooling liquid circulation for the rotor of high speed dynamoelectric machines.

Another object is to provide means which eliminate the possibility of gas or vapor traps within the cooling ducts.

Another object is to provide means for recirculating and cooling of the cooling medium.

Another object is to provide in the rotating part of a machine cooling ducts which are easily manufactured.

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Other objects and advantages will hereinafter appear.

An embodiment of the invention is illustrated in the accompanying drawing, in which Fig. 1 is a longitudinal section of the entering end for the cooling liquid of a high speed dynamoelectric machine's rotor.

Fig. 2 is a view similar to Fig. 1, of the exit end for the liquid from the rotor.

Fig. 3 is a transverse section along the line 3—3 of Fig. 1.

Fig. 4 is a transverse section along the line 4—4 of Fig. 2.

Fig. 5 is a bottom view of Fig. 4.

Fig. 6 is a modification of the structure shown in Fig. 1.

Fig. 7 is a section along the line 7—7 of Fig. 6.

Fig. 8 is a diagrammatic showing of a liquid circulating system for the rotor, and

Fig. 9 is a view of a fragment of Fig. 6 but on an enlarged scale.

Referring now to Figs. 1 and 3, the same illustrate the end of the rotor **10**, at which the cooling liquid is admitted thereto. The rotor **10** is provided with an integral shaft extension **11**, which has a central bore **12** extending from the outer end of the shaft to a point approximately coplanar with the transverse right hand end plane **13** of the rotor **10**. The shaft is supported in a bearing **14** of suitable construction. The rotor **10** is provided with radial slots **15**, in which the conductors of an energizing winding are imbedded in the usual manner.

At its inner end the diameter of the bore **12** has a preferably tapered enlargement to form a pocket **16**, which connects with a number of outwardly extending smaller bores **17**, which terminate on the outer periphery of the shaft **11**, near the part where it merges into the main cylindrical body of the rotor **10**. A stationary conduit **18** of slightly smaller external diameter than the bore **12** has its inner end spaced axially from the pocket **16**. The outer end of the shaft **11** has an end section **20** of reduced diameter to the end surface of which is fastened a ring shaped packing **19** which surrounds the tube **18** with a very small clearance. The tube **18** is supportingly attached by welding or other means to a stationary bracket **21**.

Fastened to the support **21** is a catch-basin **22**, consisting of a cylindrical drum, provided at one end with a circular flange **23**, through which it is bolted to the support **21** by means of screws **24**. A gasket ring **25** is interposed between the flange **23** and the bracket **21**. At the other end the catch-basin is provided with an inwardly extending radial flange 26 and a similar flange 27 is attached to the inside of the drum at some distance from the flange 26, so that the two flanges and the inner wall of the catch-basin form a circular internal groove, said groove being divided by a concentric circular disc 28 attached to the shaft end section 20, so as to clear the inner wall of the catch basin and to divide the aforementioned groove into two sections. The lower part of the catch-basin 22 is provided with a drain pipe 29 to conduct away liquid which may leak past the ring 19. The small amount of liquid that may escape past the flange 27 is drained off through one or more pipes 29*a*, the rotating disc 28 accentuating this drainage.

At its outer end the conduit 18 is provided with an L-bend 30. A small conduit 31 is fixedly mounted concentric with the conduit 18. The conduit 31 extends into the enlargement 16, while its outer end passes through the bend 30, and is connected to a suitable trap, an eudiometer, or other device from which the entrapped air may escape, or be collected. A valve 32 is indicated in Fig. 1, which may or may not be required. A gauge or U-tube (not shown) containing mercury may also be connected to conduit 31, so as to indicate the pressure in pocket 16. Conduit 31 may be supported by small lugs (not shown) from the interior of the conduit 18. The cylindrical inner surface of the bore 12 may be rifled for purposes which will be explained hereinafter.

The rotor 10 is provided with axial ducts 33 (Figs. 1, 2 and 3), which preferably are arranged in the teeth intermediate of the winding slots 15 and additional ducts 34 may be provided below the bottoms of the winding slots 15 and sealed against the latter by wedges or plates 35, which may be placed into said slots and welded to the rotor before the windings are inserted into the slots 15. Liquid connections between the bores 17 and the cooling ducts 33 is afforded by a casing or enclosure 36, which provides a generally toroidal coaxial space 37 around the shaft 11, said casing also providing a plurality of radial ducts 38, which extend from the toroidal space outwardly between the slots 15 to the ducts 33 and 34 to form hydraulic connections between the ducts 33 and 34 and the toroidal space 37. The enclosure 36 is welded or otherwise attached in a liquid tight manner to the shaft and to the rotor respectively. As shown in Fig. 3, the toroidal space 37 is circumferentially divided by partitions 39, which preferably extend from the shaft 11 to the circumferential wall of the enclosure 36, so as to divide the toroidal space into a number of compartments to more effectively direct the flow of liquid from the bores 17 to the radial ducts 38. The partitions 39 may be curved or may be set at an angle from the position shown in the drawing. They may extend between the two side walls or may be spaced therefrom. These radial partitions prevent or impede circumferential flow of the liquid with respect to the rotor in the space 37, which flow would arise from the tangential inertia forces known as "Coriolis" forces, and which would seriously impede radial flow of the liquid.

The outlet end of the rotor is shown in Figs. 2, 4 and 5. The rotor 10 is provided with a shaft extension 40 which is journalled in a bearing of suitable type 41. The rotor ducts 33 and 34 communicate with the toroidal interior of a casing 42, which in all respects is constructed similar to the casing 36 aforedescribed.

Like partition plates 39 in the outlet casing prevent the tangential flow of the liquid in the manner just described for the inlet casing, it being understood that the tangential force is in the opposite direction. The shaft adjacent to the outlet end of the rotor 10 is provided with ducts 45 corresponding to the ducts 17 at the inlet end of the rotor. The ducts 45 terminate in an axial bore 47, the outer end of which may be closed by a disc shaped plug 48. The shaft 40 is provided with a plurality of substantially radial ducts 49. The outer end of the ducts 49 are provided with screw plugs 50, which in turn are provided with orifices 51. The plugs 50 are preferably made of a material which resists erosion due to the high velocity of the cooling liquid passing therethrough.

Surrounding the shaft 40 about the ducts 49 is a stationary collecting chamber 52, which is mounted concentric with the shaft 40 on suitable supports 53. The diameter of the shaft 40 inside of the collecting chamber 52 is preferably somewhat enlarged as at 54 to provide axial clearances 55 between the inner circular side walls 56 of the collecting chamber 52 and the shaft. The enlargement of the shaft diameter also compensates for the weakening of the shaft due to the holes 49 and the bores for the plugs 50. Concentric with the outer circumferential wall 57 of the collecting chamber 52 is a cylindrical inner partition 58, which partition is provided with perforations 59. The perforations may be chamfered to facilitate the flow of liquid therethrough. The partition 58 is welded to the side walls 56 of the collecting chamber 52. The enlarged diameter of the shaft 54 has attached thereto a number of radial rings 60 of such outer diameter that they afford a small clearance from the partition 58. Attached to the partition 58 are inwardly extending rings 61 arranged intermediate of the rings 60. An outlet pipe 62 (Figs. 4 and 5) is attached to the outer collecting chamber 52 near its bottom and preferably tangential thereto, being so directed that the discharged liquid will tend to enter it. Each of the side walls 56 of the collecting chamber may be further provided with a drain pipe 63, also preferably tangential thereto.

In the modification Figs. 6 and 7, the radial ducts 38 of Figs. 1 and 3 are replaced by ducts 70 cut out of the end of the rotor 10. In all other respects the arrangement is the same as aforedescribed. It is of course understood that the same modification is applicable to the other end of the rotor shown in Fig. 2.

The entrance ends of the radial bores 17, 45 and 49, are preferably tapered or rounded so as to reduce the resistance to the flow of the entering liquid.

Instead of constructing the casings 36 and 42 to provide a toroidal space 37 which, as shown, is subdivided into a plurality of circumferential compartments, the casing may be modified to provide a plurality of sectional compartments, each interposed between one or more bores 17 or 45, and one or a plurality of radial duct 38.

It may be advisable to coat the interior surfaces of the partition 58 and other parts of the liquid passages, especially the surfaces against which the cooling liquid impinges with a high velocity, with a ceramic enamel or other erosion resistant coating.

While the invention has been described as applied to a rotor which is a solid forging, it may also be used with a rotor built up from discs or plates. In that event the axial ducts will be lined with tubes of suitable cross section to prevent leakage of liquid between adjacent plates, as fully described in my Patent 2,381,122 aforementioned.

Referring now to Fig. 8, the same illustrates a liquid circulating system which may be employed to supply cooling liquid to the machine. The cooling liquid is stored in a sump 80 from which it is conveyed through a pipe 81 to a pump 82. The pump forces the liquid through a pipe 83 into an elevated tank 84. A heat exchanger 85 for cooling the liquid may be interposed in the pipe 81 or alternatively (not shown) in the pipe 83. The pump may be driven by a motor M which is connected to a suitable power supply through a float switch 86, responsive to the liquid level in the tank 84. Instead of using a float switch, an overflow pipe may be provided in the tank 84 to carry surplus liquid back to the sump 80. A valve 87 in the pipe 83 may be employed to regulate the supply of liquid to the tank 84. A pipe 88 connects the bottom of the tank 84 with the pipe 30 through a valve 90. If the pump 82 is above the level of the liquid in the sump 80, the pipe 88 is provided (as shown) with a branch connection which includes a valve 89 to afford when said valve is open, a direct connection between the bottom of the tank 84 and the outlet of the pump 82.

The operation of the hydraulic system for the rotor is as follows: The sump 80 is first filled with cooling liquid and the tank 84 is partially filled. If the pump 82 is above the sump 80, the valve 89 is opened, so as to prime the pump. It may be advantageous to provide a check valve (not shown) in the pipe 81 between the pump 82 and the sump 80. After priming, valve 89 is closed and the motor M is started, and valve 87 is opened. This fills the tank 84. Thereafter valve 90 is opened, while the rotor 10 is simultaneously rotated slowly until all of its ducts and its hollow shafts are filled with liquid. A pressure gauge (not shown) which may be connected to the conduit 31, will initially indicate a fluctuating pressure, but ultimately the pressure becomes constant when all of the passages are filled with liquid.

When the rotor is stationary or is rotated slowly, the head acting on the liquid in the machine is substantially the height of liquid in the tank 84, and most of the liquid passing through the machine is discharged into the sump 80, through the pipe 62, while a small amount is discharged through the pipes 29 and 63. The liquid from the sump 80 is returned to the tank 84. Thereafter the rotor is accelerated to its normal speed by its prime mover. The rate of flow of liquid increases rapidly with increasing speed of the rotor owing to the action of the radial outlet ducts 49. As the rotor speed increases, the throttle valve 87 is opened so as to keep the tank 84 nearly filled.

It is not absolutely necessary to start the flow of liquid through the rotor by initially turning it over slowly, but when starting the flow of liquid while the rotor revolves, there is a lapse of time after full speed is attained until full liquid flow is established. The rate of flow at full speed of the rotor is determined mainly by the centrifugal head generated in the outlet ducts 49 and the cross sectional area of the orifices 51. As the inlet head is small, the head in the bore 47 may be below atmospheric pressure, and it might drop until it becomes the controlling factor in the rate of flow of liquid. To overcome this, the pressure drop between the entrance pipe 18 and the bore 47 may be reduced by rounding or beveling the entrances of the various passages such as 17 and 45, by shortening the conduit 18, and/or by rifling the bore 12, the rifling 95 being such as to cause the liquid to rotate at approximately the angular velocity of the rotor. If the rate of flow of liquid is limited by its entrance pressure, it may obviously be increased by raising the level of the liquid in the tank 84.

In order to avoid vapor lock which would impede the flow of cooling liquid it is important that the liquid temperature at any point of the cooling system does not exceed the boiling point thereof at the pressure prevailing at said point, or conversely that for the temperature prevailing at any point of the cooling system, the pressure does not fall below the boiling pressure for said temperature.

The collecting chamber 52 and the catch basin 22 are preferably split and the two halves bolted together in a suitable manner for easy assembly.

Modifications of the structure shown which are within the scope of the present invention will readily suggest themselves to those skilled in the art. It will furthermore be apparent that the invention is applicable to rotating machine elements other than dynamoelectric machines, through which a liquid is passed.

What I claim as new and desire to secure by Letters Patent is:

1. The combination with a dynamoelectric machine rotor body provided with a plurality of longitudinal ducts for passing a cooling liquid therethrough, and an axial hollow shaft extension at each end of said body, of means to afford a liquid passage between the interior of said shaft extensions and through said ducts, said last mentioned means comprising, at each end of said body, a plurality of compartments arranged around the axis of the respective shaft extension, each compartment being interposed between the respective shaft interior and the respective ends of a selected individual group of said rotor ducts for affording a separate liquid passage between the respective group of ducts and the interior of the respective shaft extension.

2. The combination with a dynamoelectric machine rotor body provided with a plurality of longitudinal ducts for passing a cooling liquid therethrough, an axial hollow shaft extension at each end of said body, a coaxial hollow ring for each end of said body and arranged to afford a chamber adjacent to the respective end and with connecting ducts between the respective chamber and the interior of the respective shaft extension to afford at each end of the rotor a liquid connection between the respective shaft interior and the corresponding cooling ducts, of a plurality of partitions in each chamber for dividing said chamber into a plurality of hydraulically parallel compartments, each compartment coacting with a selected individual group of said rotor ducts for affording a separate liquid passage between the respective coacting group of ducts and the interior of the respective shaft extension.

3. The combination with a dynamoelectric machine rotor provided with a plurality of longitudinal cooling ducts for the passage of a cooling liquid therethrough, shaft extensions from the ends of said rotor, each shaft extension having a concentric bore for the admission of cooling liquid at one and discharge thereof at the other end of said rotor respectively, and a separate casing arranged at each end of the rotor, each providing a toroidal liquid tight chamber for affording a liq-

uid path between the respective bore and the respective ends of said ducts, of a plurality of partitions in each chamber for dividing it into a plurality of compartments, each compartment cooperating with a selected individual group of said longitudinal cooling ducts for affording a separate liquid passage between the respective coacting group of ducts and the respective bore.

4. The combination with a dynamoelectric machine rotor provided with a plurality of longitudinal cooling ducts, said rotor having at each end a shaft extension provided with a concentric bore, one being a liquid admission bore and the other a liquid discharge bore, and having further a separate casing arranged at each end of said rotor, each of said casings providing a toroidal liquid tight chamber and affording a liquid connection between the respective bore and the respective ends of said ducts, and a discharge orifice connected to said discharge bore and arranged to convert the static head of said liquid resulting from rotation of said rotor into a velocity head, of a plurality of partitions in each chamber for dividing it into a plurality of compartments, each compartment cooperating with a selected individual group of said cooling ducts for affording a separate liquid passage between the respective coacting group of ducts and the respective bore.

5. The combination with a dynamoelectric machine rotor provided with a plurality of longitudinal cooling ducts, said rotor having at each end a shaft extension provided with a concentric bore, one being a liquid admission bore and the other a liquid discharge bore, and having further a separate casing arranged at each end of said rotor, each of said casings providing a toroidal liquid tight chamber and affording a liquid connection between the respective bore and the respective ends of said ducts, and a discharge orifice connected to said discharge bore and arranged to convert the static head of said liquid resulting from rotation of said rotor into a velocity head, of a plurality of partitions in each chamber for dividing it into a plurality of compartments, each compartment cooperating with a selected individual group of said cooling ducts for affording a separate liquid passage between the respective coacting group of ducts and the respective bore, and a stationary housing affording a collecting chamber concentric with the shaft extension having said discharge bore and arranged to receive the liquid discharged by said discharge orifice.

6. The combination with a dynamoelectric machine as defined in claim 5 of a stationary sump connected to said collecting chamber and arranged to receive liquid therefrom, an elevated storage tank connected to said sump, means to force liquid from said sump into said tank, and a connection between said tank and said admission bore for admitting cooling liquid from the former to the latter.

7. The combination defined in claim 6, and including a heat exchanger interposed between said collecting chamber and said admission bore and adapted to withdraw heat energy from the liquid passing therebetween.

8. The combination as defined in claim 5, and including within said chamber, at either side of said discharge orifice, a separate circular disc concentric with, and fixedly attached to the periphery of the respective shaft extension, and cooperating stationary discs located within said chamber adjacent to and parallel with said first named discs.

9. The combination as defined in claim 5 and including a stationary liquid catch basin surrounding the outer end of the shaft extension having said inlet bore, a circular disc concentric with and attached to said shaft extension, a cooperating stationary disc located within said basin and concentric with said shaft extension, and a conduit for discharging liquid from said basin.

10. The combination with a rotating machine element provided with means for passing a liquid therethrough and including a shaft having an axial liquid discharge bore, a discharge orifice in said shaft in communication with said discharge bore and arranged to convert the static head of a liquid in said bore into a velocity head, of an inner hollow cylinder having a perforate wall surrounding said shaft and extending axially in both directions from said orifice, an outer solid walled stationary hollow cylinder axially coextensive with said inner cylinder and provided with solid end walls arranged to afford a clearance for said shaft, said outer cylinder being adapted to intercept liquid passing through said inner cylinder, at least one circular disc fixed to said shaft on either side of the plane of rotation of said orifice, cooperating circular discs axially alternating with said first named discs and fixed to the inside of said inner cylinder, and a liquid discharge conduit connected to the interspace between said cylinders.

11. The combination with a rotating machine element provided with means for passing a liquid therethrough and including a shaft having an axial liquid discharge bore, a discharge orifice in said shaft in communication with said discharge bore and arranged to convert the static head of a liquid in said bore into a velocity head, of an inner hollow cylinder having a perforate wall surrounding said shaft and extending axially in both directions from said orifice, an outer solid walled stationary hollow cylinder axially coextensive with said inner cylinder and provided with solid end walls arranged to afford a clearance for said shaft, said outer cylinder being adapted to intercept liquid passing through said inner cylinder, at least one circular disc fixed to said shaft on either side of the plane of rotation of said orifice, cooperating circular discs axially alternating with said first named discs and fixed to the inside of said inner cylinder, a liquid discharge conduit connected to the interspace between said cylinders, and a liquid discharge outlet connected to the interspace between said shaft and said first cylinder.

12. In a dynamoelectric machine, a rotor having a plurality of ducts longitudinally therethrough, shaft portions extending from the rotor ends and severally provided with a co-axial bore and with generally radial bores coacting for admission of cooling liquid to and for discharge of the liquid from the rotor ducts, and casings fixed on the rotor and the several shaft extensions, the casing having partitions forming compartments severally connecting the radial shaft bores with groups of rotor ducts and in liquid-tight relation.

13. In a dynamoelectric machine, a rotor having a plurality of ducts longitudinally therethrough, shaft portions extending from the rotor ends and severally provided with a co-axial bore and with radial bores coacting for admission of cooling liquid to and for discharge of the liquid from the rotor ducts, casings fixed on the rotor and the shaft extensions for severally connecting the radial shaft bores with groups of rotor ducts

and in liquid-tight relation, and collecting chambers related with the ends of the shaft portions for receiving liquid discharged from the shaft portion bores and for discharging liquid therefrom.

14. A rotating machine element comprising a body having a plurality of ducts therethrough, shaft portions extending from the ends of the body, each shaft portion having an axial passage and each shaft portion having passages extending radially from the axial passage, and casings severally fixed on the body ends and the shaft portions and extending about the shaft portions, the casings having partitions providing a plurality of compartments severally connecting one radial passage with a group of ducts for the flow of cooling liquid therethrough.

15. The combination with a rotating machine element having a plurality of ducts longitudinally therethrough and including shaft portions extending therefrom, each shaft portion having a coaxial bore and each shaft portion having generally radial bores coacting for admission of cooling liquid to and for discharge of the liquid from the ducts, a portion of the wall of the shaft axial bore serving for admission of liquid to the machine element being rifled for bringing liquid flowing therethrough to substantially the speed of rotation of the machine element, and casings fixed on the machine element and about portions of the several shaft extensions and having partitions therein forming compartments connecting the radial shaft bores with the ducts and in liquid tight relation.

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