July 6, 1937. G. A. JESSOP ET AL 2,085,909

HYDRAULIC MACHINE

Filed Dec. 4, 1936 8 Sheets-Sheet 1

Fig. 1

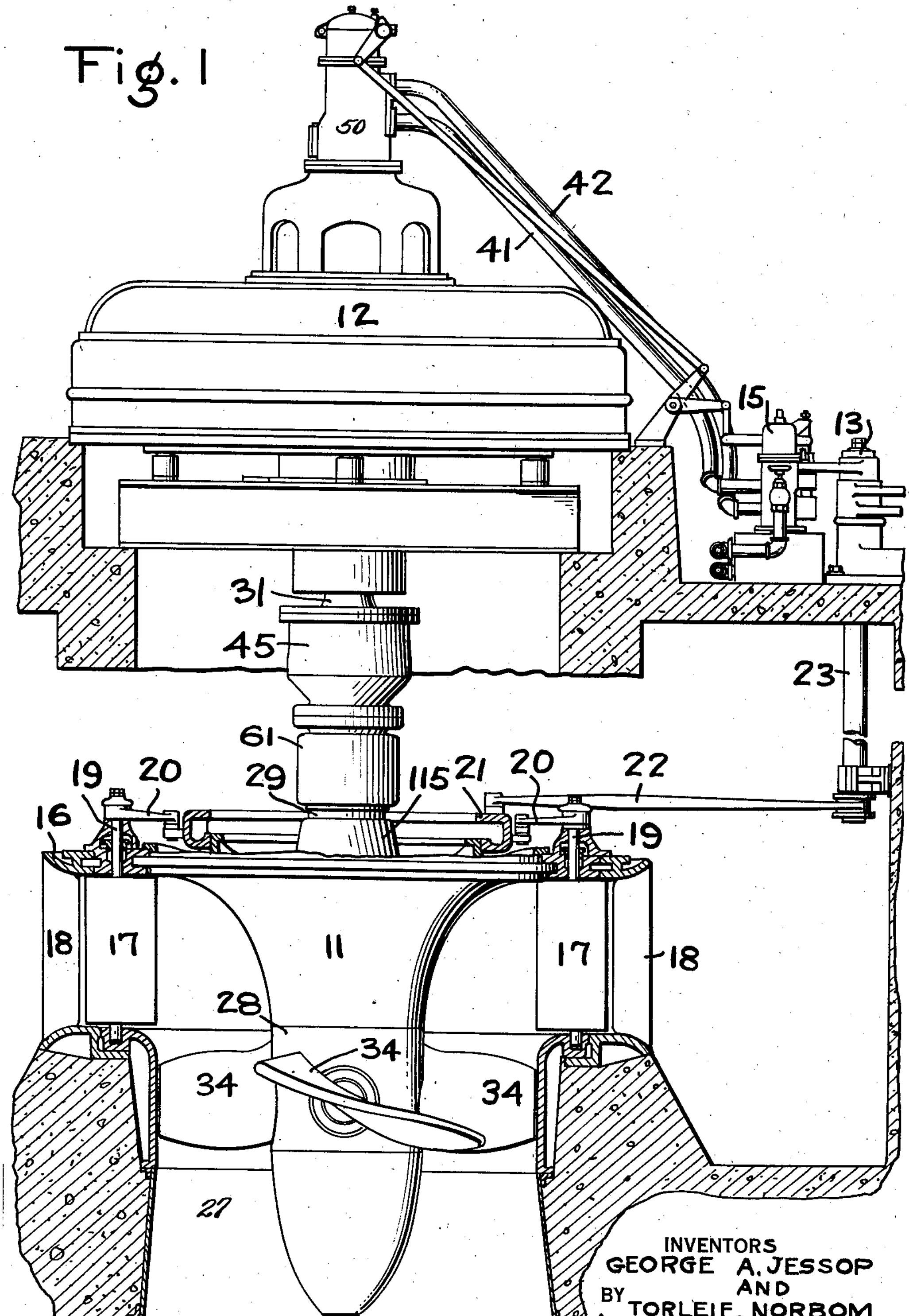

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Fig. 2

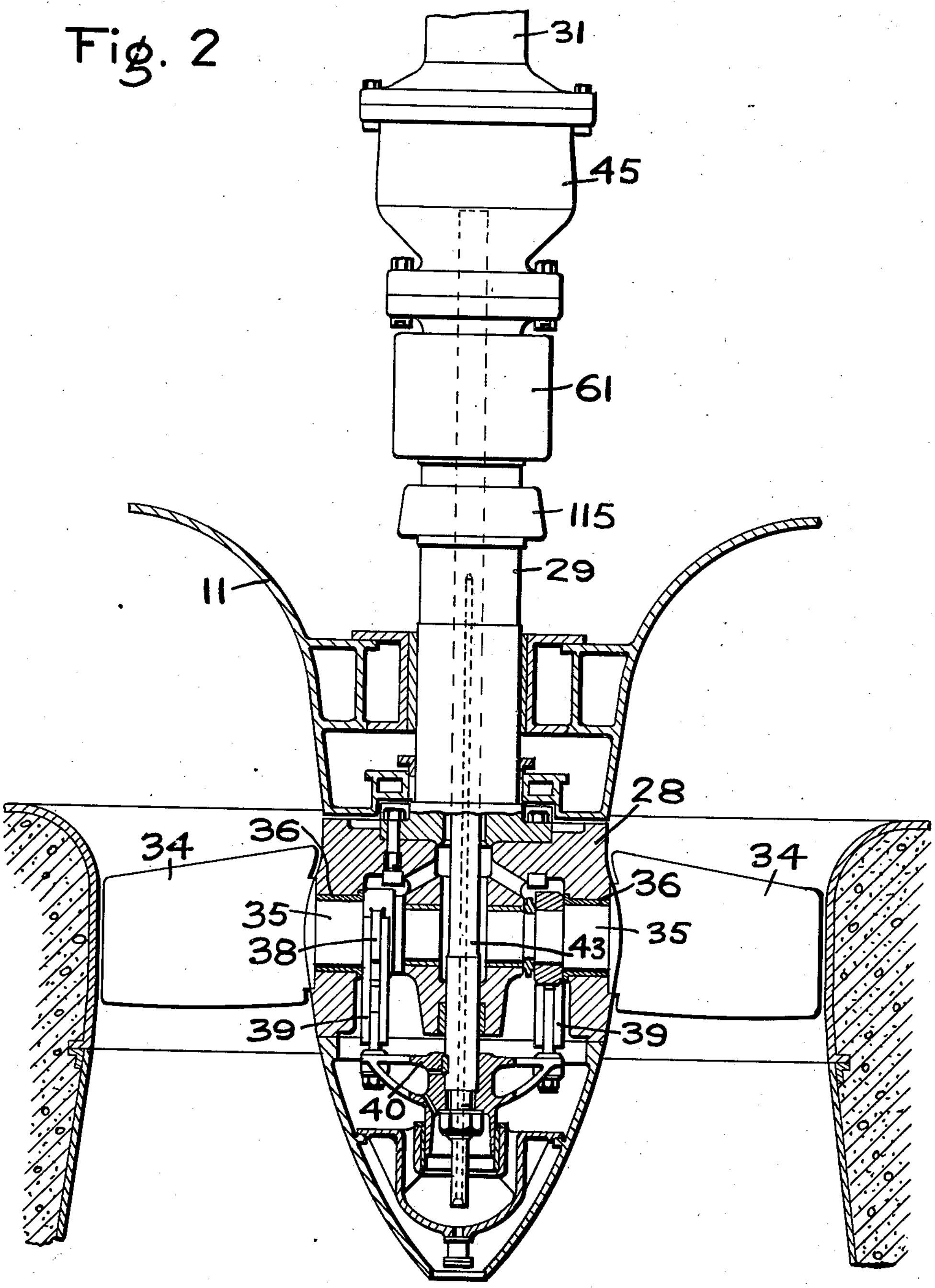

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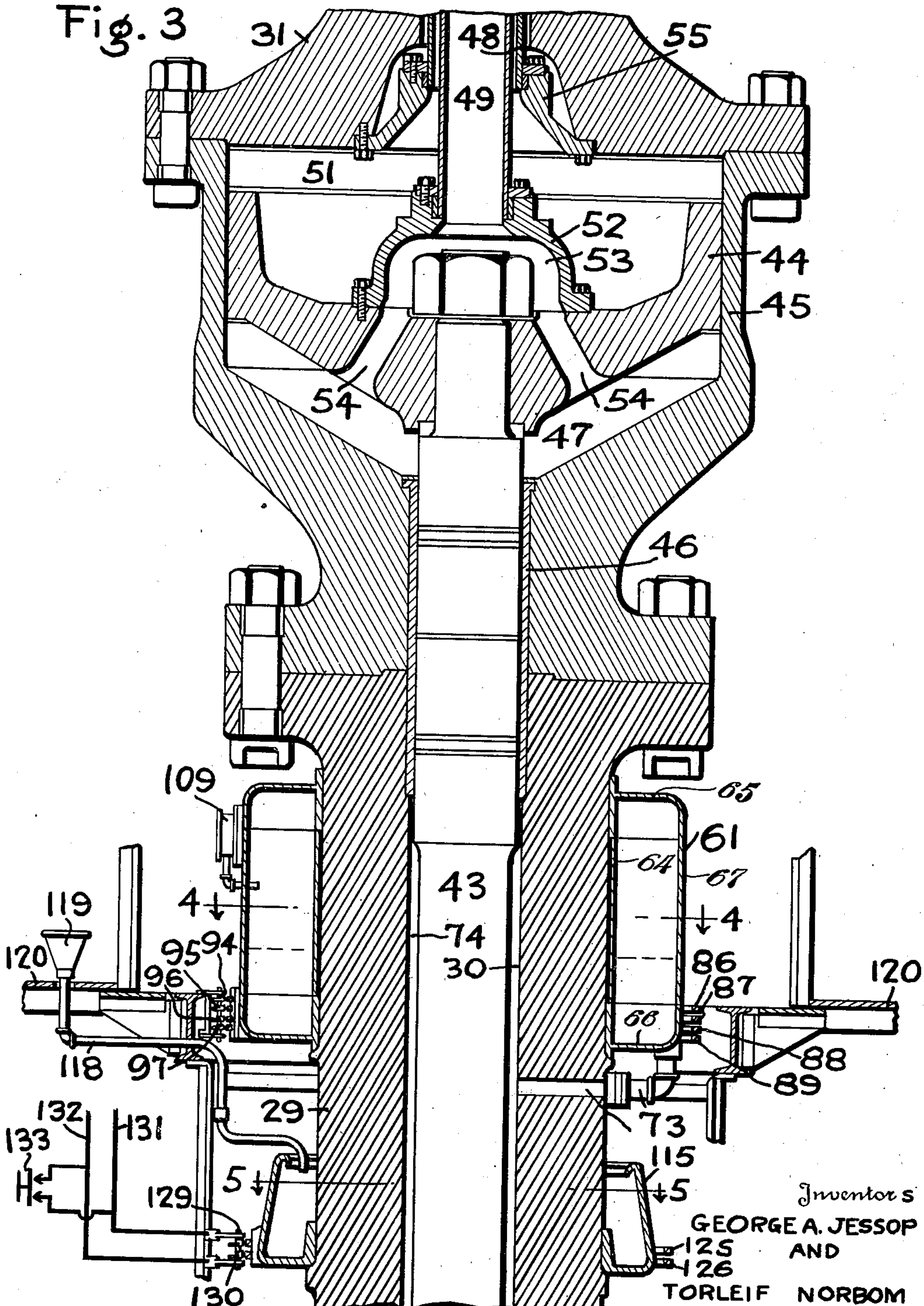
Fig. 3



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HYDRAULIC MACHINE

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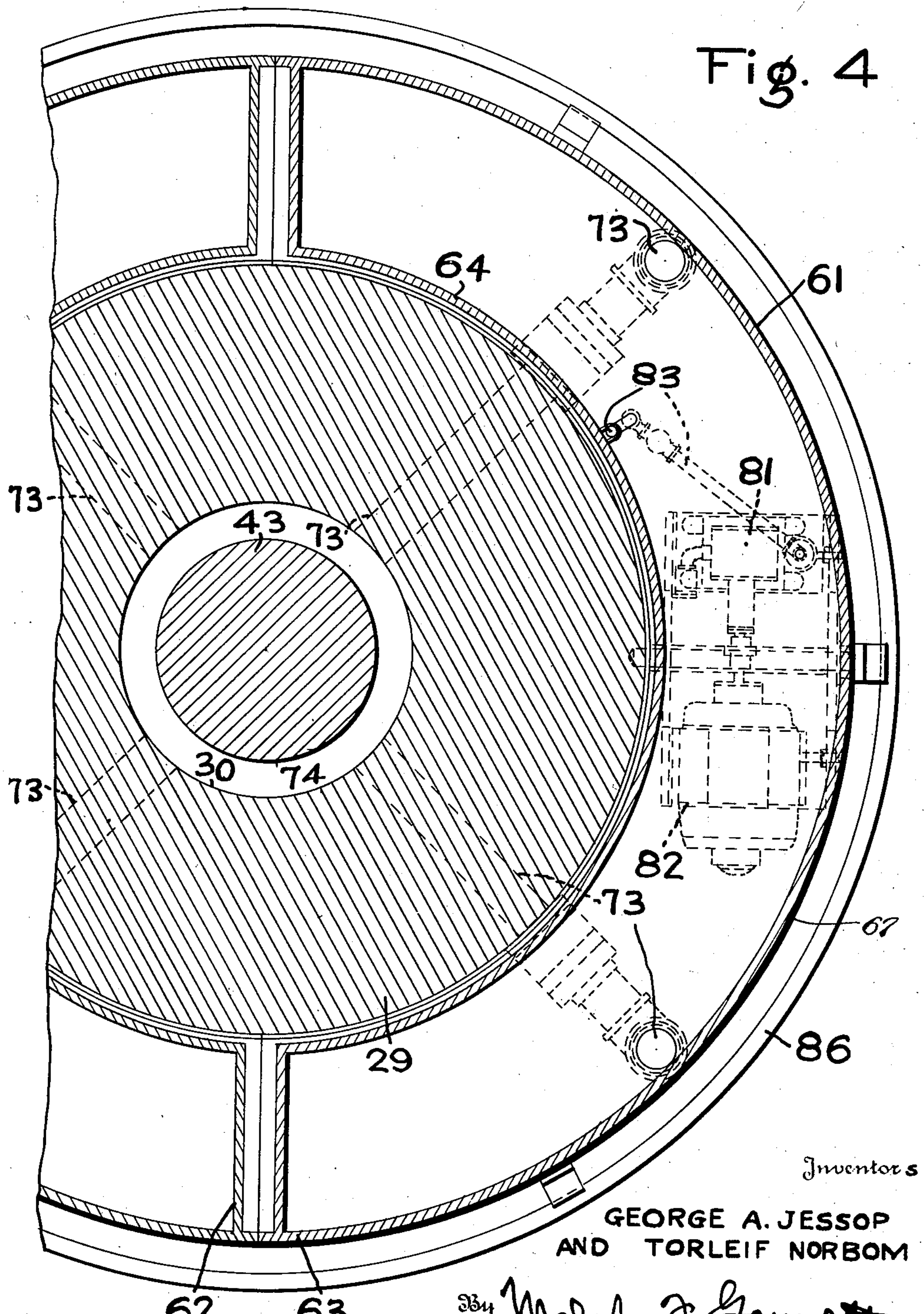

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HYDRAULIC MACHINE

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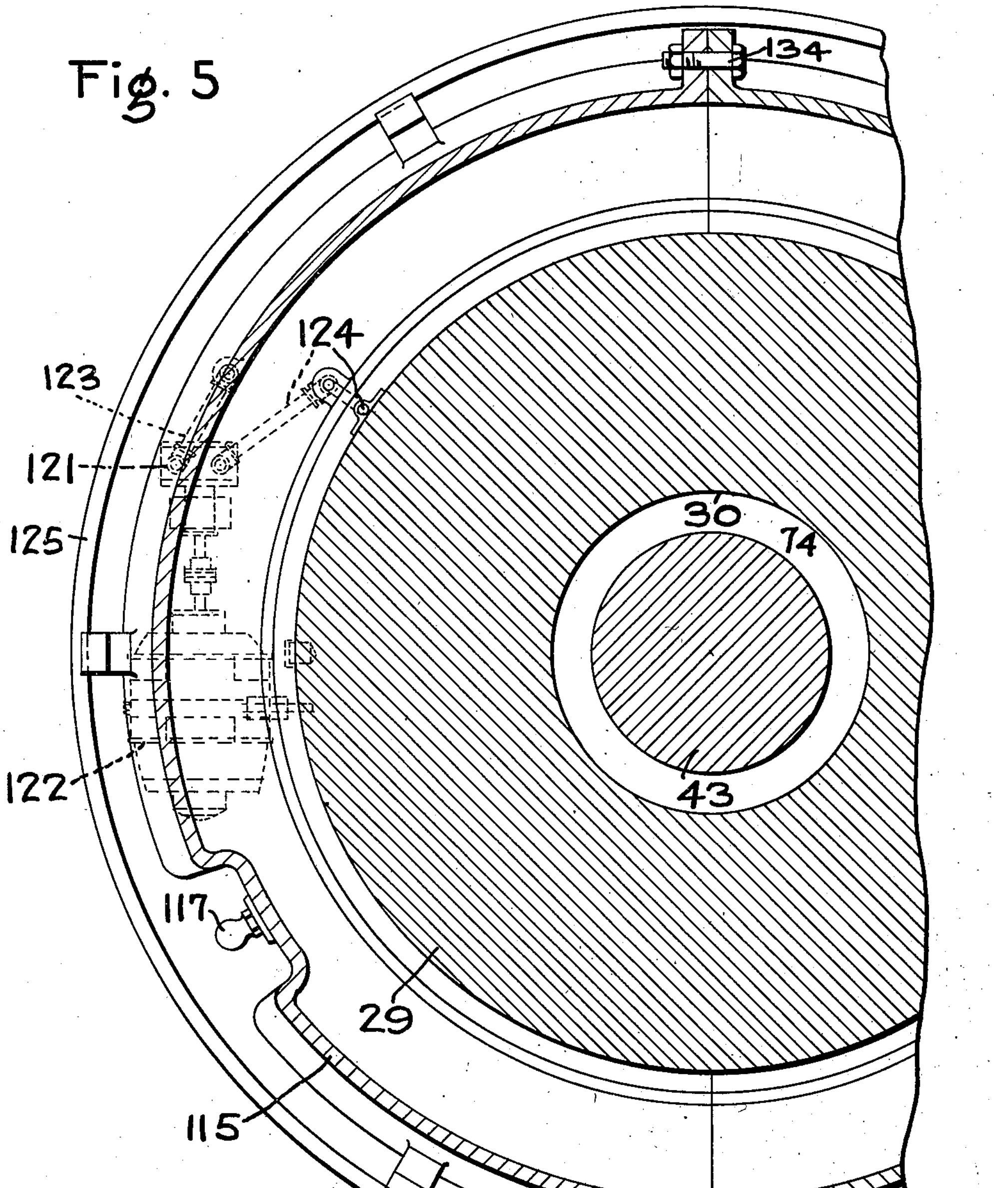
Fig. 5



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HYDRAULIC MACHINE

Filed Dec. 4, 1936 8 Sheets-Sheet 6

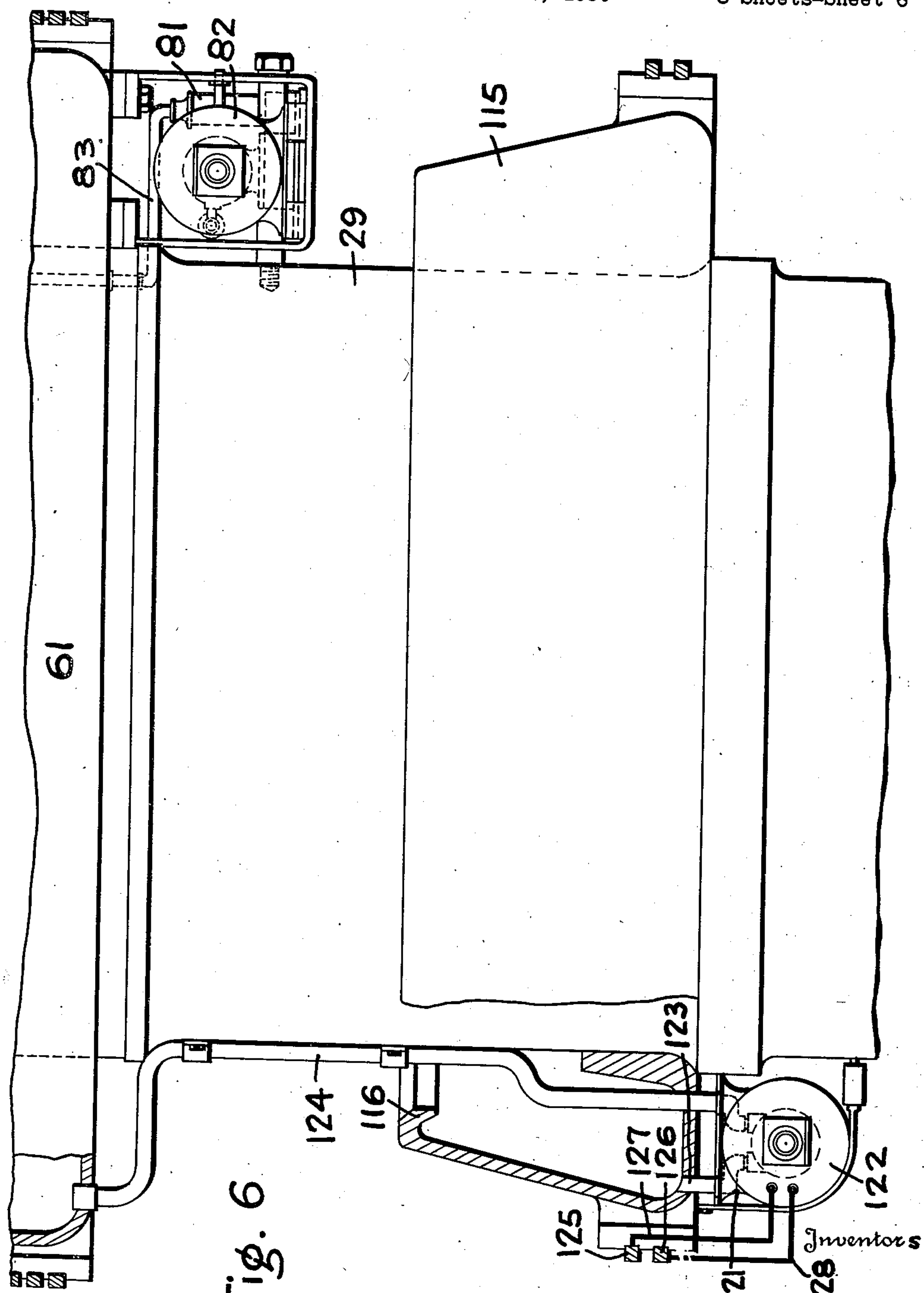

Fig. 6

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HYDRAULIC MACHINE

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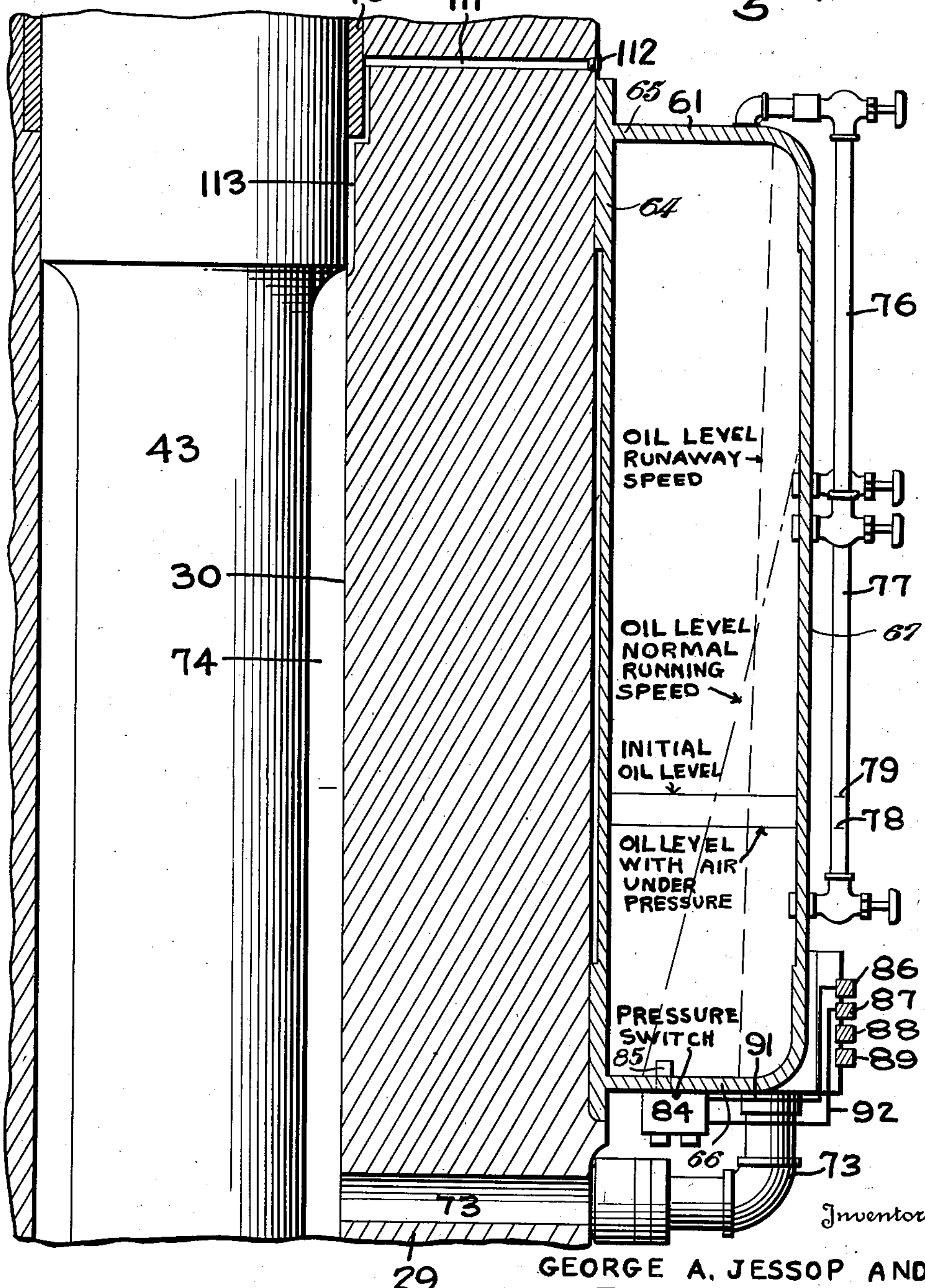
Fig. 7



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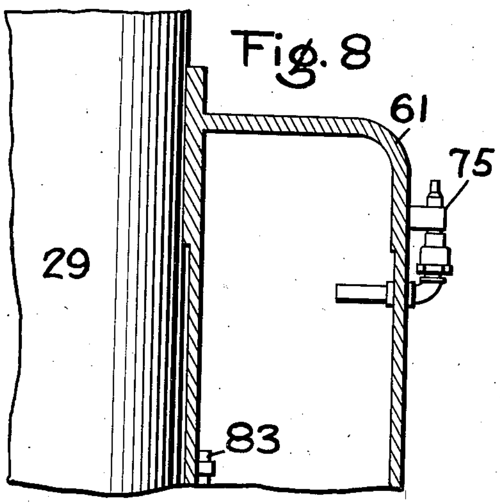


Fig. 8

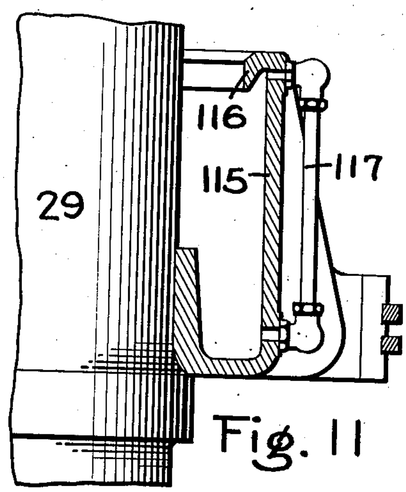


Fig. 11

Fig. 9

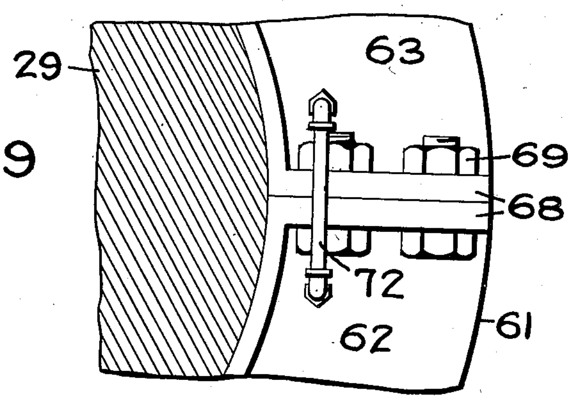


Fig. 10

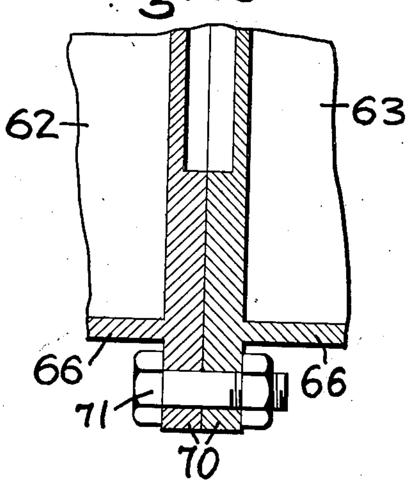
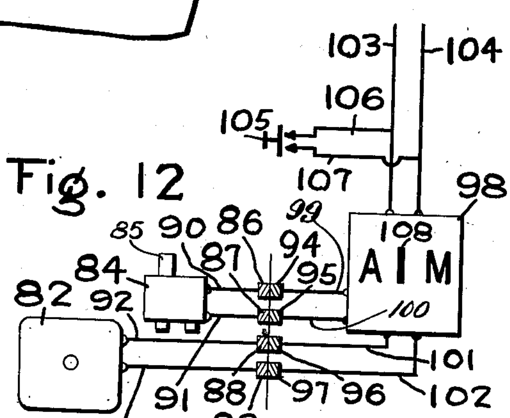


Fig. 12



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Patented July 6, 1937

2,085,909

UNITED STATES PATENT OFFICE

2,085,909

HYDRAULIC MACHINE

George A. Jessop and Torleif Norbom, York, Pa., assignors to S. Morgan Smith Company, York, Pa., a corporation of Pennsylvania

Application December 4, 1936, Serial No. 114,169

3 Claims. (Cl. 253—148)

This invention relates to hydraulic machines, such as hydraulic turbines, pumps and the like, and more particularly to the type of hydraulic machines having runners with movable or adjustable blades. The hubs of the runners of the above type of hydraulic machines are filled with oil for lubricating the blade operating mechanism within the runner hub, and the present invention relates more particularly to specific mechanical details for supplying oil under pressure to the hub of the runner from a suitable reservoir carried by the shaft of the hydraulic machine.

An object of the invention is to provide improved means for maintaining a predetermined pressure of lubricating oil in the runner hub of adjustable blade hydraulic machines.

Another object of the invention is to provide an improved means for maintaining the lubricating oil in the runner hub of an adjustable blade hydraulic turbine at a predetermined pressure by means of air under pressure.

Another object of the invention is to provide an improved lubricating system for adjustable blade hydraulic turbines in which the lubricating oil is automatically maintained at a predetermined pressure at all times.

With the foregoing and other object and advantages in view, the invention consists in the preferred construction and arrangement of the several parts which will be hereinafter fully described and claimed.

In the accompanying drawings:—

Figure 1 is a view partly in section of an adjustable blade hydraulic turbine embodying the present invention;

Fig. 2 is an enlarged view partly in section of the turbine runner and its shaft, parts being omitted;

Fig. 3 is an enlarged vertical section of the upper portion of the runner shaft shown in Fig. 2;

Fig. 4 is a horizontal section taken on the line 4—4 of Fig. 3;

Fig. 5 is a horizontal section taken on the line 5—5 of Fig. 3;

Fig. 6 is an enlarged elevation partly in section of a portion of the structure shown in Fig. 3, illustrating the connection between the two oil receptacles;

Fig. 7 is an enlarged vertical section of a portion of the upper oil receptacle, showing the fluid gauges;

Fig. 8 is another enlarged fragmentary vertical section of the upper oil receptacle showing the pressure relief valve;

Fig. 9 is a horizontal view showing the fluid connection at the top between the two halves of the upper oil receptacle;

Fig. 10 is a detail vertical section showing the manner of fastening the two halves of the upper oil receptacle together;

Fig. 11 is an enlarged vertical section of a portion of the lower oil receptacle showing the oil level gauge; and

Fig. 12 is a diagram of the air pump motor electrical circuit.

While the invention is susceptible of various modifications and alternative constructions, it is here shown and will be described hereinafter in a preferred embodiment, but it is not intended that the invention is to be limited thereby to the specific embodiment shown, but it is intended to cover all modifications and alternative constructions falling within the spirit and scope of the invention as defined by the appended claims.

In an application for Letters Patent for Hydraulic machine filed by us in the United States Patent Office on the 22nd day of August, 1935, Serial No. 37,349, now Patent No. 2,070,601 dated February 16, 1937, we showed a lubricating system for adjustable blade runners in which the pressure of the lubricating oil in the hub of the runner was adapted to be maintained at a predetermined pressure by compressed air contained in an air tight tank mounted on the runner shaft and operatively connected with the lubricating system. No means were provided for supplying air under pressure to the air tight tank of the above named earlier invention while the turbine was in operation. In order to check the pressure of the air and replenish or reduce the same, it was necessary to shut-down the machine.

The present invention differs from the above named earlier invention in that means are provided for automatically maintaining the pressure of the air at a predetermined amount at all times, so that it is not necessary to shut-down the machine as is the case with our prior invention.

Hydraulic turbines of the type herein shown and described are usually connected to an electric generator for the purpose of operating the same, the complete generating unit comprising, a hydraulic turbine, an electrical generator, and a governor mechanism. The governor is adapted to automatically control the operation of the turbine, so that the turbine will operate at a substantially uniform speed, irrespective of the variations of the load. The runner of the turbine has adjustable blades, the angular positions of which are adapted to be varied according to the load, so that the turbine will operate at its highest efficiency at all times.

In mechanisms of the above type, the controlling fluid is generally oil, means being provided for controlling the oil in such a manner that when the governor operates to adjust the angles of the wicket gates of the turbine, the runner blades will be caused to rotate in a similar direction so as to effect a corresponding adjustment in the angles or positions thereof. In this way the parts of the turbine will be simultaneously adjusted so that all of the parts will at all times retain their correct relationship with each other and the turbine will operate with maximum efficiency and smoothness and with minimum vibration.

Referring to the drawings and especially to Fig. 1, the complete unit may comprise a hydraulic turbine 11, an electrical generator 12, and a governor mechanism 13. As will be hereinafter more fully described, the runner blades of the turbine 11 are adapted to be adjusted by suitable mechanism under the control of a control device 15 associated with the governor 13. The control device 15 is adapted to function in the manner shown and described in McCormack Patent No. 1,937,772, granted December 5, 1933 for Hydraulic turbine.

The turbine 11 comprises a casing 16 which forms a peripheral water inlet in which are mounted an annular series of wicket gates 17 and guide vanes 18.

Projecting from the upper ends of the wicket gates 17 are stems or shafts 19 which are rotatably mounted in the upper portion of the casing 16.

The wicket gates 17 are adapted to be simultaneously rotated into different angular positions to control the flow of water into the turbine in the usual manner, and for this purpose the upper ends of the stems 19 are usually provided with gate operating arms 20 which are fixed to said stems and connected by links to a gate adjusting ring 21. The gate adjusting ring 21 is connected by link means 22 to a shaft 23 of the governor mechanism 13.

The lower portion of the turbine casing 16 forms an axially directed chamber 27 in which the runner 28 operates.

The hub of the runner 28 is fixed to the lower end of a shaft 29. The upper end of shaft 29 is connected to the shaft 31 of the generator 12 as shown in Figs. 1, 2 and 3. Shaft 29 has a bore 30 formed longitudinally therein for a purpose to be hereinafter described.

A suitable number of blades 34 are rotatably supported in the hub of the runner 28 and project radially therefrom.

The inner end of each blade 34 is formed with a trunnion 35 which is journalled in bearings 36 supported in the hub.

Means are provided for simultaneously rotating all of the blades 34 and for maintaining them in equal angular relationship, such means comprising preferably an arm 38 rigidly fixed on the trunnion 35 of each blade and links 39 which connect the arms on the different blades to a cross head 40 fixed to the lower end of an operating rod 43 which extends upwardly through the bore 30 of the runner shaft 29.

As shown in Fig. 3, the upper end of the operating rod 43 is fixed to the piston 44 of a servo motor 45 which is mounted in the runner shaft 29 adjacent to the point where the runner shaft is joined to the generator shaft 31.

The servo motor piston 44 may be contained in a cylinder, the upper portion of which is closed by the lower portion of the generator shaft 31, as shown in Fig. 3.

The upper portion of the operating rod 43 passes through a bushing 46 mounted in the runner shaft 29, and this bushing besides forming a bearing for the operating rod 43, provides means for closing the chamber 47 on the lower side of piston 44.

The servo motor piston 44 is double acting, and in order to supply oil to both sides thereof for the purpose of operating the same in both directions, two tubes or pipes 48 and 49 are employed. The pipes 48 and 49 are mounted within the hollow generator shaft 31 and rotate therewith, said pipes extending from the servo motor upwardly through the shaft 31 to a head 50 which is mounted on top of the generator 12, as shown in Fig. 1.

The lower end of pipe 49 is fixed to a cap 52 carried by the piston 44, and chamber 53 formed within the cap, is connected to piston chamber 47 by means of passages or ports 54 formed in the piston 44, so that oil supplied through pipe 49 will flow into chamber 47.

The lower end of pipe 48 terminates above the cap 52, so as to be in communication with chamber 51 of the servo motor. The lower end of pipe 48 may be secured to the lower end of the generator shaft 31 by means of a member 55 having a peripheral flange which is bolted or otherwise secured to the adjacent portion of the generator shaft 31. The member 55 provides means for closing the lower end of the hollow generator shaft 31 and thereby cut off communication from the chamber 51 to the space within said shaft exteriorly of the pipes 48 and 49.

Pipes 48 and 49 are connected to the control valve device 15 of the governor mechanism 13 through pipes 41 and 42, respectively. As fully explained in Patent 1,937,772 above referred to, through the action of the governor in accordance with variations in load, oil will be supplied to the chambers on the opposite sides of the servo motor piston 44 to operate the same and thereby effect rotation of the runner blades.

The mechanism within the hub of the runner 28 requires thorough lubrication. Therefore, it has been customary to fill the hub of the runner with some suitable heavy lubricating oil, since the comparatively light oil used in the governor mechanism for operating the servo motor 45 does not possess sufficient lubricating properties for satisfactorily lubricating the blade operating mechanism within the runner hub.

With two kinds of oil thus used in the turbine, several problems have been confronted in actual practice. One of these problems has been the provision of suitable means for preventing the two oils from becoming mixed together to such an extent as to prove ruinous to the proper functions of either, i. e., to provide means whereby the light oil supplied to the servo motor 45 is prevented from flowing down through the hollow turbine shaft 29 and mixing with the heavy lubricating oil in the hub of the runner 28. Another problem has been to provide suitable seals around the joints where the trunnions 35 of the adjustable blades 34 enter the hub of the turbine, so as to prevent leakage of the lubricating oil in the hub outwardly through these joints and the entrance of water, sand and other impurities inwardly through these joints.

It is almost impossible to provide a seal which will entirely prevent leakage of the governor oil from the bottom of the servo motor 45 into the hollow runner shaft 29 leading downwardly to the runner hub. It is much better to have any oil leakage which occurs here to be in the direction such that the light governor oil passes to the heavy lubricating oil, rather than have the heavy oil mix with the light oil. This is because of the delicacy of the governor 13 which would have its functions interfered with if any substantial quantity of the heavy oil should become mixed with the light governor oil. On the other hand, the blade operating mechanism within the hub of the runner is much more rugged and it can withstand some mixture of light oil with the heavy lubricating oil within the hub. The light oil in any event usually passes to the heavy oil at a slow rate and becomes mixed therewith at an elevation slightly below the bottom of the servo motor 45, so that some time is required for the light governor oil to mix with the heavy lubricating oil to such an extent as to deteriorate the quality of the oil in the hub and substantially reduce its viscosity.

As shown in Fig. 3, rod 43 fits snugly in bushing 46 and the latter functions to close the upper end of the hollow runner shaft 29 and thus prevent oil in chamber 47 from entering the hollow runner shaft 29 in appreciable quantities.

Surrounding the runner shaft 29 is a closed chamber 61 adapted to contain lubricating oil under a predetermined pressure for the hub of the runner 28. Therefore, in order to reduce the loss of pressure from chamber 61 to a minimum, said chamber is preferably constructed of two semi-circular sections 62 and 63. The sections 62 and 63 are each a complete tank enclosed on all sides, and each section comprises an inner wall 64 which fits around the runner shaft 29, a top wall 65, a bottom wall 66, and an outer wall 67. The walls 64, 65, 66 and 67 are preferably formed from sheet metal, such as plate steel, and all of said walls are connected together, so as to provide a unitary homogeneous structure which is entirely fluid tight.

For the purpose of connecting the two sections 62 and 63 together, the top walls 65 thereof are formed with upwardly extending flanges 68 which are secured together by bolts 69, and the bottom walls 66 thereof are formed with downwardly extending flanges 70 which are bolted together, as indicated at 71, Fig. 10.

The two sections 62 and 63 of the chamber 61, are in communication with each other at the top, by means of a pipe 72, as shown in Fig. 9. This connection is necessary so that the pressure of the fluid in both sections will be the same at all times.

The heavy lubricating oil for the hub of the runner 28 is supplied to the interior of the hub from the chamber 61, through a plurality of pipes and passages 73, which extend from the bottom of the two sections 62 and 63 downwardly and inwardly through the shaft 29 to the space 74 between the operating rod 43 and the wall of the bore 30, as shown in Figs. 3, 4 and 7. Any number of connections 73 can be utilized between chamber 61 and the space 74. In the present instance four of such connections are shown, two from each of the sections 62 and 63.

As shown in Fig. 8, near the top of the chamber 61 there is a relief valve 75 of any approved construction for relieving the pressure within said chamber should the pressure at any time exceed a predetermined amount.

As shown in Fig. 7, the outer wall of the chamber 61 is provided with suitable gauges 76 and 77 for indicating the height of the oil within said chamber. In the instant case two oil gauges are employed, due to the fact that the height of the chamber 61 is such as to prohibit the use of a single gauge having a long sight glass, since a long sight glass would quickly break on account of the vibration of the runner shaft 29 when the turbine is in operation. It has been found desirable to employ two standard gauges and superpose such gauges in the manner shown in Fig. 7. These sight gauges are so disposed as to indicate the level of the oil from a point at the top of chamber 61 to a point a slight distance above the bottom of the chamber. A predetermined amount of lubricating oil should be contained in the chamber 61 at all times, and when the level of the oil in said chamber, as indicated by the lower gauge 77, is less than the amount required, as indicated by the mark 78 on said gauge, additional lubricating oil is adapted to be supplied to the chamber 61 in the manner to be hereinafter more fully described.

For the purpose of supplying air under pressure to chamber 61, an air compressing unit is mounted underneath the chamber 61, as shown in Figs. 4 and 6. This air compressing unit consists of an air pump 81 and an electric motor 82 for operating the pump 81. The outlet of the air pump 81 is connected to the interior of the tank section 63 by a pipe 83. The portion of the pipe 83 within the tank section 63 is disposed adjacent to the inner wall 64 and extends upwardly a suitable distance, as indicated in Fig. 8.

According to the present invention, air under pressure is adapted to be automatically supplied to chamber 61, and, therefore, in order to replenish the supply of air when the pressure of the air within the chamber 61 decreases a predetermined amount, a pressure switch device 84 for controlling pump motor 82, is employed. This pressure switch device may be of any approved construction, since devices of this type are readily purchasable in the open market from many manufacturers. The pressure switch device 84 is preferably mounted at a convenient point on the bottom of the chamber 61, with the pressure port 85 of said device inserted in an opening formed in the bottom of the chamber 61 and extending upwardly into said chamber, as shown in Fig. 7.

Surrounding the lower portion of the chamber 61 are four collector rings 86, 87, 88 and 89.

As shown in Fig. 12, collector rings 86 and 87 are connected to terminals of the pressure switch device 84 by conductors 90 and 91, respectively. Collector rings 88 and 89 are connected to terminals of the air pump motor 82 by conductors 92 and 93, respectively.

As shown in Figs. 3 and 12, electric current is supplied to the collector rings 86, 87, 88 and 89 by brushes 94, 95, 96 and 97, respectively. These brushes are electrically connected to a magnetic starter device 98, as diagrammatically shown in Fig. 12, by conductors 99, 100, 101 and 102, respectively.

The magnetic starter device 98 may be of any approved design of the type adapted to be controlled manually or to function automatically to control the supply of electric current to the air pump motor 82.

The magnetic starter device 98 is diagrammatically shown in Fig. 12. The letter "A" on the device 98 indicates the automatic portion of said device by which actuation of the pressure switch device 84 automatically closes the electric circuit from electric supply conductors 103 and 104 to conductors 92 and 93 respectively. The letter "M" on the device 98 indicates the portion of said device by which the operation of the electric motor 82 may be manually controlled from a push button switch 105, which is electrically connected to the supply conductors 103 and 104, by conductors 106 and 107, respectively.

The heavy vertical mark, indicated at 108 on the magnetic starter device 98, designates the neutral position of said device. Normally the magnetic starter device 98 will be in neutral position so that the motor 82 will not operate the pump 81 to supply air under pressure to the chamber 61.

During operation of the turbine, when the pressure of the fluid in chamber 61 decreases an amount sufficient to cause the pressure switch device 84 to operate, the magnetic starter device 98 will be automatically actuated so as to close the electric circuit to motor 82. On the other hand, when it is desired to introduce a supply of air under pressure into the chamber 61 at any time, the push button switch 105 can be manually operated to close the electric circuit to motor 82.

The pressure of the fluid in the chamber 61 is indicated by a suitable pressure gauge device 109 which is mounted on the outer wall 67 of said chamber, as shown in Fig. 3.

As shown in Fig. 7, runner shaft 29 has a passage 111 formed therein at a joint a slight distance above chamber 61. This passage extends from bushing 46 outwardly to the exterior of shaft 29, and the outer end of said passage is normally closed by means of a plug 112.

The upper portion of rod 43 is enlarged to snugly fit in the bushing 46 and in order to connect the space 74 between the main portion of rod 43 and the wall of the bore 30 in the shaft 29, a groove or slot 113 is formed in shaft 29, as shown in Fig. 7.

The purpose of passage 111 and groove 113 will be hereinafter more fully described.

Surrounding the runner shaft 29 and located a suitable distance beneath the chamber 61, is a pan 115 for containing a suitable supply of heavy lubricating oil.

The outer wall of pan 115 tapers inwardly from the bottom of said pan upwardly to the top of the pan as shown in Fig. 6.

The upper edge of the pan 115 is bent inwardly, as indicated at 116, Fig. 6, to provide a downwardly extending lip. The inner edge of the lip 116 surrounds the runner shaft 29 and is spaced a suitable distance therefrom. The construction is such that the top of the oil pan 115 is open, and the lip 116 prevents escape of oil from the pan when the turbine is in operation and the oil in the pan is thrown upwardly around the outer wall of the pan by centrifugal forces.

The oil pan 115 carries a sight glass 117 by which the level of oil within the pan will be indicated (see Fig. 11).

When the supply of oil in the pan 115 is low, additional oil can be introduced into the pan through a pipe 118. The inner end of pipe 118 terminates in the open top of the pan 115 and the outer or upper end of said pipe is formed with a funnel 119. The funnel 119 is located at a convenient point in the stationary turbine structure above a floor 120, as shown in Fig. 3.

In order that oil can be delivered to chamber 61 from the oil pan 115, an electrically operated pump unit is utilized. Said pump unit comprises an oil pump 121 adapted to be driven by an electric motor 122 (see Figs. 5 and 6).

The inlet of the pump 121 is connected to the bottom of the oil pan 115 by a pipe 123 and the outlet of said pump is connected to chamber 61 by a pipe 124. Pipe 124 is fixed to the exterior of the runner shaft 29, as shown best in Fig. 6.

For the purpose of supplying electric current to motor 122, a pair of collector rings 125 and 126 are mounted on the lower portion of the oil pan 115, and these collector rings are connected to the terminals of the motor 122, by conductors 127 and 128, respectively.

As shown in Fig. 3, electric current is supplied to the collector rings 125 and 126 by brushes 129 and 130, respectively, said brushes in turn being connected to a suitable source of electric current by conductors 131 and 132, respectively.

The operation of the oil pump motor 122 is adapted to be manually controlled by a push button switch 133 electrically connected to the conductors 131 and 132, as shown in Fig. 3.

As shown in Fig. 5, the oil pan 115 may be constructed of two semi-circular halves so that said pan can be mounted on the runner shaft 29, and the halves of the pan 115 are fastened together by bolts 134.

In installations where the head is relatively high the pressure of the water on the runner blades is for the most part of the operating range higher than the oil pressure in the hub of the runner. Since the presence of water in the runner hub is undesirable, and since it is practically impossible to keep the packings of the runner blade trunnions absolutely tight, it is necessary, in order to prevent water leakage, to keep the pressure of the oil within the runner hub higher than the maximum pressure of the water outside of the hub. To do this it is necessary to maintain the pressure of the lubricating oil within the runner hub sufficiently high, so that the natural oil level is higher than the elevation of the servo motor. However, since this is not possible to do, by the present invention, it is proposed to increase the pressure of the lubricating oil within the runner hub and maintain the oil under increased pressure by means of air under pressure supplied to the oil chamber 61 by the electrically driven air pump 81.

With compressed air in the chamber 61 the pressure of the oil within the hub of the runner can be such that the lubricating oil will have a natural level equal to the elevation of the part of the turbine oil head which supplies the oil to the chamber 47 on the underside of the servo motor piston 44, and still not have a tendency for the heavy hub oil to leak into the light governor oil with which the servo motor is operated.

Assuming that the runner hub is filled with lubricating oil and that the turbine has been installed in position in its setting, before the turbine is initially placed into operation it is necessary to fill the chamber 61 with a predetermined amount of lubricating oil and also a predetermined amount of air under pressure.

Therefore, at the first filling of the chamber 61 heavy lubricating oil is supplied to said chamber from the oil pan 115 through the operation of the oil pump 121 until the level of the oil in chamber 61 rises to the point indicated at 79 on the oil level gauge 77 (see Fig. 7). Before the oil pump 121 is operated in the above manner the plug 112 is removed so that a vent is provided by passages 111 and 113.

When the oil thus being supplied to chamber 61 reaches the level indicated at 79 (Fig. 7) on the oil gauge 77, the push button switch 133 which controls the operation of oil pump motor 122 is released, so that no further oil is supplied to chamber 61.

The push button switch 105 is next operated to close the electric circuit by which air pump motor 82 is operated, so that air under pressure is supplied to chamber 61.

The introduction of air under pressure into chamber 61 forces oil from chamber 61 through the pipes and passages 73 into the space 74 between the operating shaft 43 and the bore 30 of the runner shaft 29.

The oil thus supplied to the space 74 will flow upwardly through the groove 113 to passage 111. When the oil flows outwardly through the open end of passage 111 the plug 112 is replaced.

The level of the oil in chamber 61 will now be at the point indicated at 78 on the oil gauge 77.

The air pump 81 is continued in operation so as to supply air under pressure to the chamber 61 until the pressure in said chamber has reached the desired amount, as indicated by pressure gauge 109.

In actual practice it has been found necessary to supply the chamber 61 with varying amounts of air under pressure, such amounts depending upon the sizes of the turbines as well as the elevation of the tailwater. For instance, with a turbine of a given size, the pressure of the air in chamber 61 necessary to maintain the pressure of the lubricating oil at the desired amount is approximately 15 pounds when the tailwater elevation is approximately 50 feet, while with a tailwater elevation of approximately 25 feet, only approximately 3 pounds of air under pressure is required in chamber 61.

After the chamber 61 has thus been initially supplied with the desired amount of air under pressure, the push button switch 105 is released and the magnetic starter device 98 is set for automatic control.

During the operation of the turbine the pressure of the fluid in chamber 61 is maintained automatically by the pressure switch device 84 which will function in the manner hereinabove described to effect operation of the air pump 81.

Since the chamber 61 is composed of two sections 62 and 63, and since said sections are connected at the top by pipe 72, the pressure of the fluid in both sections of the chamber 61 will at all times be the same. Also, since the bottoms of the two sections 62 and 63 are connected with the space 74 through the several pipes and passages 73, oil will flow in uniform quantities from the two sections into the space 74.

The pressure in chamber 61 can be the equivalent to the pressure which would be obtained if the free level of the hub oil extended up to the part of the oil head of the turbine which feeds the bottom chamber 47 of the servo motor 45, or to any elevation desired between the servo motor and some point in the oil head. The pressure of the governor oil in chamber 47 of the servo motor 45 is always at least substantially the equivalent to the static head of oil between the oil head and the bottom of the servo motor cylinder. If the pressure in the chamber 61, therefore, has not exceeded the limit as described above, there will never be any tendency for leakage of the heavy lubricating oil into the light governor oil. In the event that, through the process of governing, high pressure is introduced below the servo motor piston 44, then, of course, there will be a tendency for the light oil to leak into the heavy oil.

The vertical operating rod 43 moves up and down to operate the runner blades. When the rod 43 moves down oil must be displaced out of the hub of the runner 28 up through the space 74 and into chamber 61. This will, of course, raise the pressure in chamber 61. When the rod 43 is raised, oil must be supplied to the hub of the runner 28 from chamber 61, thus reducing the pressure in the chamber 61. Chamber 61, therefore, should be large enough and should contain sufficient compressed air, so that the variation in pressure at the extreme oil levels will be small, and so that in any event the oil pressure maintained is sufficient to prevent leakage of water into the hub of the runner around the joints between the trunnions of the runner blades and the hub.

During the operation of the turbine the oil in chamber 61 is thrown outwardly of said chamber by centrifugal force and the oil assumes the position indicated by broken line 136 (Fig. 7). However, even though the oil is forced to such position in the chamber 61, such oil will be in communication with the space 74, due to the fact that pipes 73 are connected to the bottom of the chamber 61 at a point adjacent to the outer wall of said chamber.

As is well known in the art, hydraulic turbines are adapted to operate at a normal running speed which is substantially uniform. However, the parts of the turbine are designed to withstand stresses and strains which may result should the runner attain what is known as "runaway speed," the latter being usually many R. P. M. faster than the normal running speed of the turbine.

Broken line 137 indicates the position of the oil around the outer wall of the chamber 61, should the turbine operate at a runaway speed. It will also be noted that in this case the oil will flow from chamber 61 through the pipes and passages 73 to the space 74 within the runner shaft 29.

Having thus described our invention, what we claim is:

1. In a hydraulic machine, a runner having a hollow hub, a plurality of blades rotatably mounted in said hub, mechanism within the hub for rotating said blades, a hollow shaft connected to the hub, said hub and said shaft containing oil for lubricating the blade operating mechanism within the hub, a fluid tight oil chamber surrounding the runner shaft and rotatable therewith and adapted to contain lubricating oil for supplying the hub and shaft through a passage connecting the interior of said chamber with said shaft, an air pump carried by said shaft, an electric motor for operating said pump, means connecting the air pump with the interior of said chamber whereby air under pressure is delivered to said chamber, means for supplying electric current for operating said pump motor, and a pressure switch device operable by variations in pressure within said tank for controlling the operation of said pump motor.

2. In a hydraulic machine, a runner having a hollow hub, a plurality of blades rotatably

mounted in said hub, mechanism within the hub for rotating said blades, a hollow shaft connected to the hub, said hub and said shaft containing oil for lubricating the blade operating mechanism within the hub, a fluid tight chamber surrounding the runner shaft and adapted to contain lubricating oil and air under pressure, an oil passage connecting said chamber with said shaft, an air pump and means for operating the same carried by said shaft for supplying air under pressure to said chamber, an oil reservoir also mounted on said shaft, means for supplying fresh oil to said reservoir, means connecting said reservoir with said chamber, an oil pump operatively connected to said reservoir, and means for operating said pump whereby oil from said reservoir will be delivered to said chamber.

3. In a hydraulic machine, a runner having a hollow hub; a plurality of blades rotatably mounted in said hub, mechanism within the hub for rotating the blades, a hollow shaft connected to the hub, said hub and said shaft containing oil for lubricating the blade operating mechanism, a fluid tight chamber surrounding the runner shaft and adapted to contain lubricating oil and air under pressure, an oil passage connecting said chamber with said shaft, an air pump carried by shaft, means for automatically and manually operating said air pump to supply said chamber with air under pressure, an oil reservoir also mounted on said shaft, means connecting said reservoir with said chamber, and means for pumping oil from said reservoir into said chamber.

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