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3,236,497

HYDRAULIC PUMPS AND PUMP-TURBINES

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4 Sheets-Sheet 1

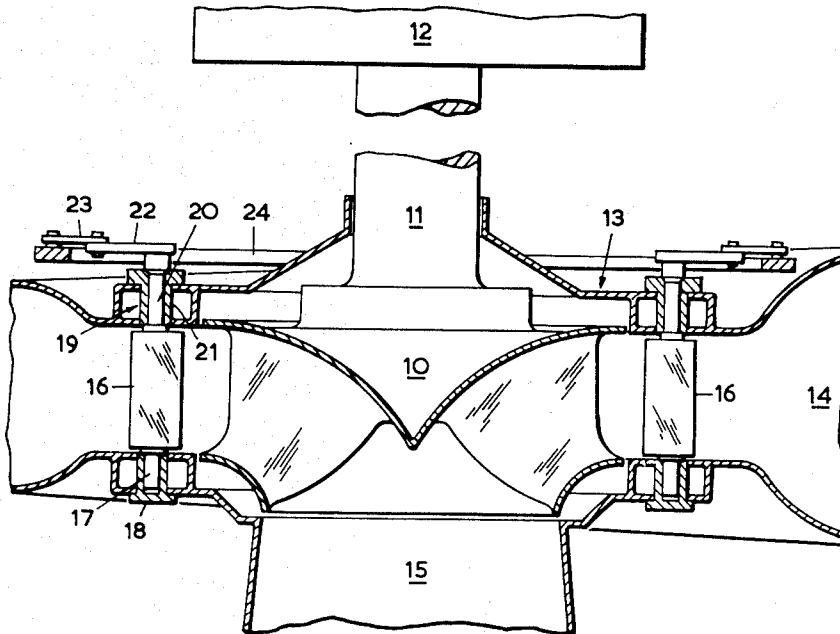


FIG.1

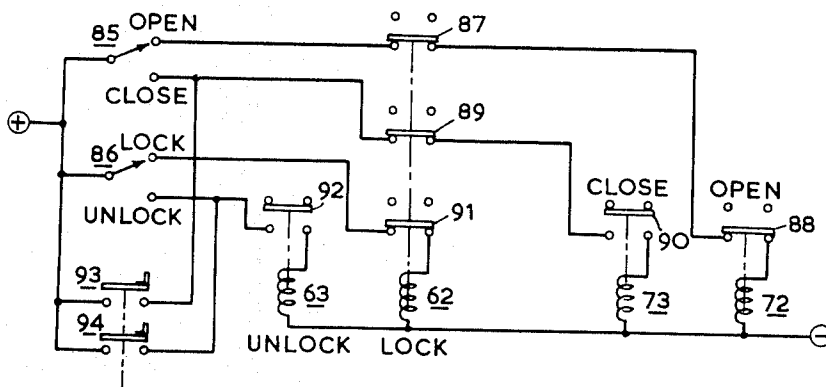


FIG.7

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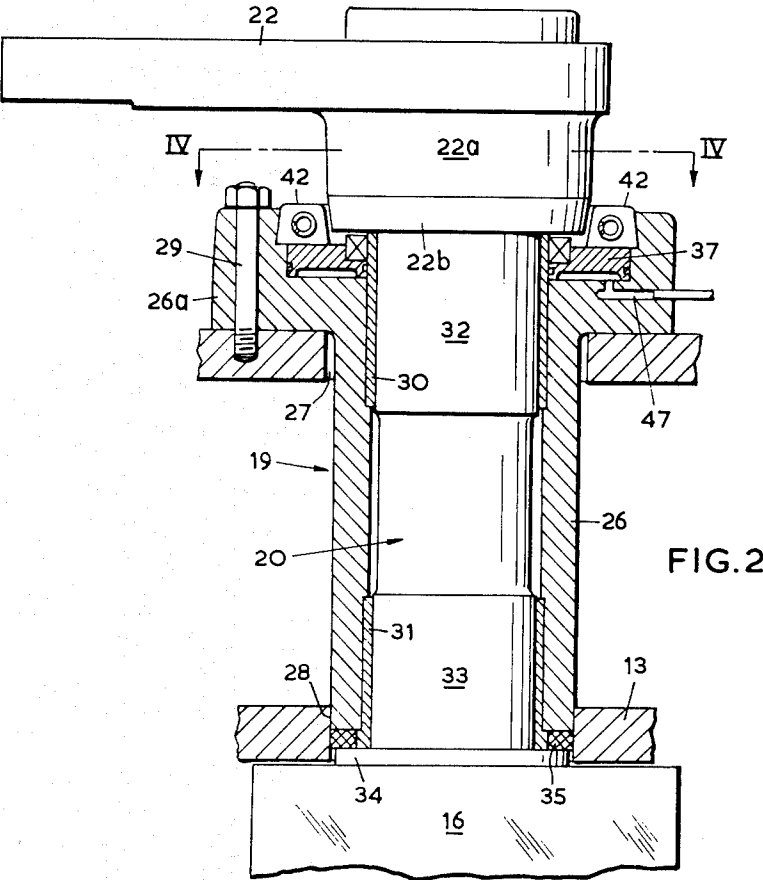


FIG. 2

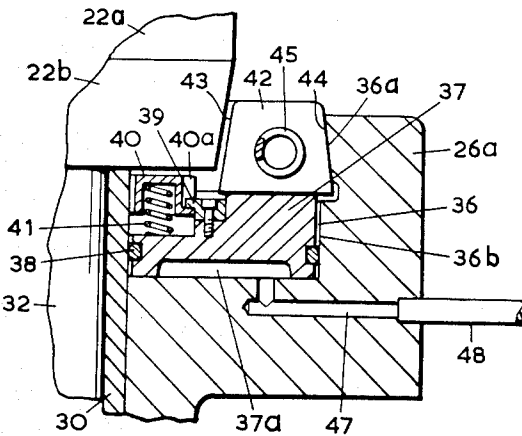


FIG. 3

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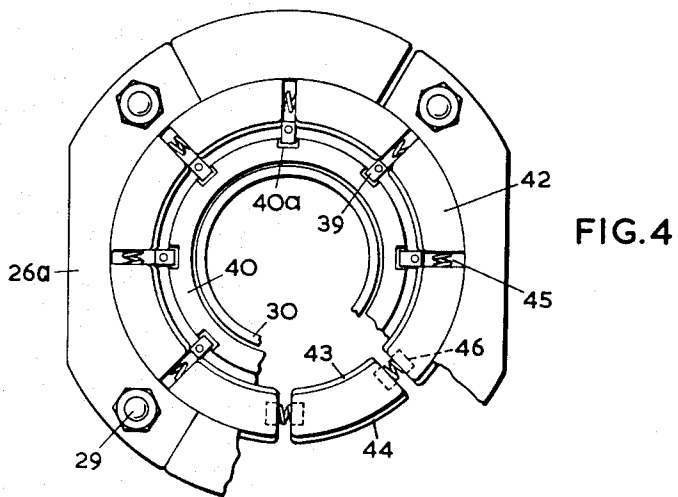
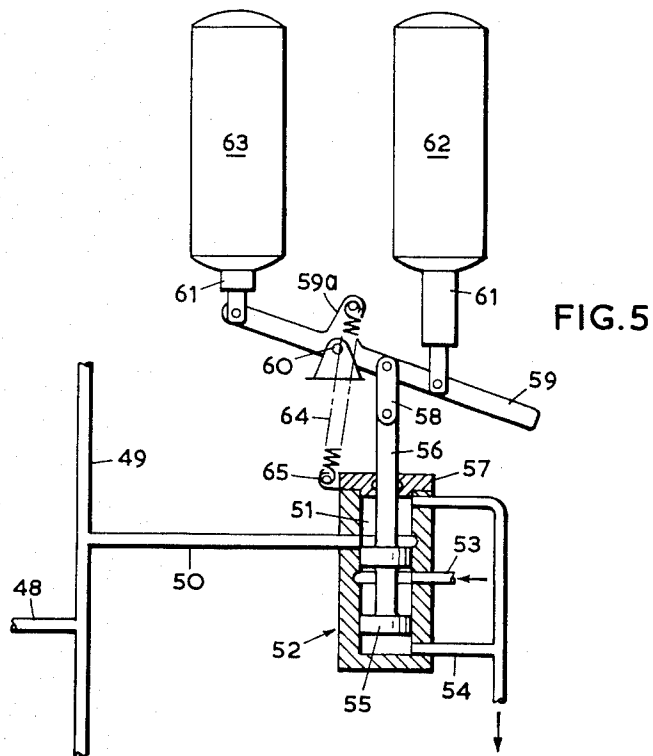
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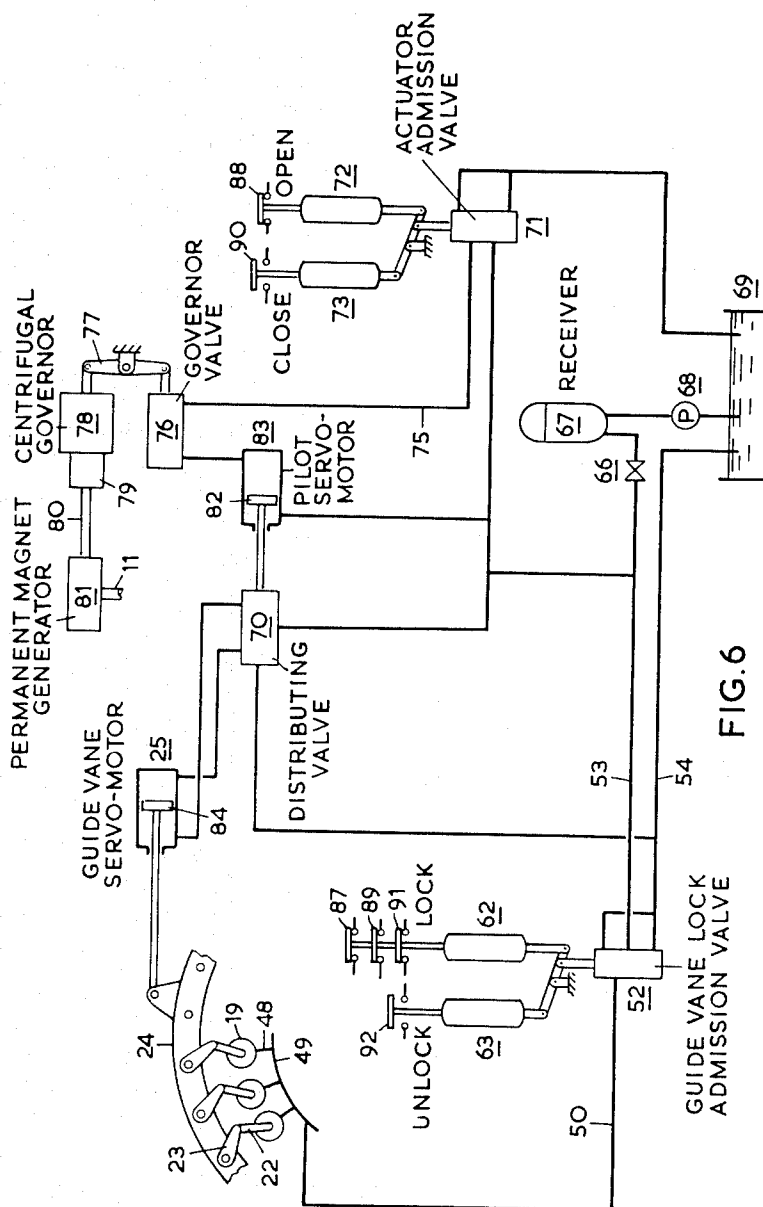


FIG. 6

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HYDRAULIC PUMPS AND PUMP-TURBINES

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3 Claims. (Cl. 253—24)

This invention relates to hydraulic pumps and pump-turbines.

According to the invention, a hydraulic pump-turbine including a rotary runner-impeller (hereinafter called the "rotor") has a plurality of rotatably-adjustable guide vanes adjacent the rotor for varying the speed of rotation of the rotor when the pump-turbine is operating as a turbine, guide-vane control means for adjusting the guide vanes and locking means for locking the guide vanes against rotational movement when the pump-turbine is operating as a pump.

According to a preferred feature of the invention, the pump-turbine includes electric control means for causing the guide-vane control means to be operated, an electric power supply for the said control means, and means for allowing the said control means to be connected to the power supply when the guide vanes are unlocked and for causing the said control means to be disconnected from the power supply when the guide vanes are locked.

According to another preferred feature of the invention, each guide vane has an extension co-axial with the axis of rotation of the vane member, and the locking means include a locking member for frictionally locking each said axial extension.

According to a further preferred feature of the invention, each locking member comprises a segmental ring co-axial with the said extension of the corresponding guide vane and having a surface for engaging a surface thereof and another surface for engaging a fixed surface, at least one of the said surfaces of the ring and the surface for engagement therewith being part-conical.

According to yet another preferred feature of the invention, the locking means include fluid-pressure operated means for moving the locking member into engagement with the said extension of the corresponding vane means and spring means for urging the locking member out of said engagement on reduction of the said fluid pressure below a predetermined value.

The invention also includes locking means for a hydraulic pump or pump-turbine according to the invention.

A hydraulic pump-turbine forming part of a pump-turbine-generator set, in one preferred form according to the invention, will now be described by way of example and with reference to the accompanying drawings, of which:

FIG. 1 is a diagrammatic sectional elevation of a pump-turbine (hereinafter called "the machine") forming part of the set;

FIG. 2 is a sectional elevation showing part of the machine shown in FIG. 1 in an enlarged view;

FIG. 3 is a sectional elevation showing part of the machine shown in FIG. 2 in a further enlarged view;

FIG. 4 is a partly cut-away plan view taken on the line IV—IV of FIG. 2;

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FIG. 5 is a diagrammatic part sectional elevation showing control gear for guide vane locking means of the machine;

FIG. 6 is a diagram showing part of a hydraulic control system for operating guide vanes and guide vane locking means of the machine; and

FIG. 7 is a circuit diagram showing part of an electric circuit associated with the hydraulic control system shown in FIG. 6.

With reference firstly to FIG. 1, the machine includes a runner-impeller 10 (which will hereinafter be called the "rotor") mounted on the lower end of a vertical main shaft 11 which also carries an electric motor-generator indicated diagrammatically at 12. The rotor 10 operates in a casing generally indicated at 13, which includes an annular upper chamber 14 and an axially-disposed draught tube 15. The machine may operate either as a pump or as a turbine: when operating as a pump, the motor-generator 12 acts as a motor and drives the pump, the rotor acting as impeller, the draught tube 15 serving as water inlet to the machine and the chamber 14 as outlet; similarly, when the machine is operating as a turbine, the draught tube becomes the outlet, the rotor acts as a runner and the motor generator acts as a generator.

Arranged in a ring concentrically with the rotor 10 and between the rotor and the chamber 14 are a number of vertically-mounted adjustable guide vanes 16. Each guide vane 16 carries a lower bearing journal 17 which is free to pivot in a lower bearing 18 in the machine casing 13, and also a co-axial upper bearing assembly generally indicated at 19. The bearing assembly 19 includes a shaft 20 which is fixed rigidly to the vanes 16 and is free to pivot in an upper bearing 21 in the casing.

With reference now to FIG. 6 also, rigidly attached to the upper end of each shaft 20 is an operating lever 22 to which is pivoted one end of a link 23; the other end of each link 23 is pivoted to a guide-vane actuating ring 24 (a portion only of which is shown in FIG. 6), which is connected for operation by a servo-motor shown diagrammatically at 25, in such a way that the motor 25 may rotate the ring 24 through an angle sufficient to turn the guide vanes 16 (each about the common axis of its bearings 17 and 21), so as to vary the inlet angle at which water enters the blades (shown only in FIG. 1) of the rotor 10, through the action of the links 23 and levers 22. For clarity, in FIG. 1 only two guide vanes 16 and their associated levers 22 and links 23 are shown, three bearing assemblies 19 and their associated links and levers being indicated diagrammatically in FIG. 6.

FIGS. 2 to 4 show in greater detail the upper bearing assembly 19 of one guide vane 16: it should be noted that in FIG. 4 the shaft 20 and lever 22 are omitted. The bearing assembly comprises a cylindrical hollow bearing housing 26, which is located in two co-axial holes 27, 28 in the machine casing 13, and which has an enlarged concentric head portion 26a secured to the casing 13 by studs 29. In the bore of the housing 26 are upper and lower bearing sleeves 30, 31, which engage journals 32, 33 respectively formed on the shaft 20. At the lower end of the shaft 20 is a co-axial shoulder 34 which has a greater diameter than the shaft. There is just sufficient clearance between the shoulder 34 and the lower end of the lower bearing sleeve 31 to allow free rotation of the former. Packing 35 is inserted between the shoulder 34 and housing 26.

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The operating lever 22 has an end bush 22a with a co-axial part-conical surface 22b at its lower end, the shaft 20 being secured in the bush 22a. In the enlarged head portion 26a of the housing 26 there is formed a co-axial annular recess 36. The upper part 36a of the annular surface of the recess 36 is tapered inwardly towards the top. The lower portion of the recess 36 has parallel sides 36b and accommodates an annular piston 37, which surrounds the bearing sleeve 30 concentrically and which is free to move axially in the recess 36. Toroidal oil-resisting rubber sealing rings 38 are provided between the piston 37 and both the sleeve 30 and the sides 36b of recess. The piston 37 has an annular recess 37a on its bottom side; and to its top side there are secured a number of inwardly-projecting lips 39.

An annular thrust ring 40 is mounted on the top side of the piston 37 through a number of evenly-spaced compression springs 41, the flat top side of the ring 40 being adjacent the bottom of the bush 22a. Recesses 40a are formed in the outer circumference of the ring 40 to accommodate the lips 39, which act against the action of the springs 41 to restrain the upward movement of the ring 40.

A segmented locking ring 42 is formed with the surfaces of its sides 43, 55 tapered so as to correspond respectively with the tapers on the bush 22a and on the surface 36a of the recess 36. Compression springs 45 engage circular holes 46 in the ends of the segments of the ring 42, so tending continuously to force the segments outwards.

An oil duct 47 is formed in the head portion 26a of the bearing housing between the recess 36, where the duct 47 communicates with the recess 37a in the piston 37, and an oil inlet pipe 48.

With reference now to FIGS. 5 to 7 also the oil inlets 48 of all the bearing assemblies 19 are connected to a ring pipe (only part of which is shown) which in turn is connected through a duct 50 to the upper portion of the valve chamber 51 of a guide-vane lock admission valve 52. The valve chamber 51 also has in its central portion an oil inlet 53 and an oil exhaust 54 which communicates with both the top and bottom of the chamber 51. A double-acting piston 55, free to move axially in the chamber 51, is formed with a piston rod 56 which passes out of the valve through the top cover 57 of the valve. The upper end of the piston rod 56 is pivoted through a link 58 to an operating lever 59 which in turn is pivoted about a fixed axis 60; to the lever 59 are pivoted the plungers 61 of a single-acting "lock" solenoid 62 and a single-acting "unlock" solenoid 63. The lever 59 has a lug 59a to which is attached one end of a tension spring 64, the other end of which is attached to a fixed point 65. When the "unlock" solenoid 63 is energized, as will be described below, its plunger 61 is drawn upwards and the piston 55 moves downwardly to the position shown in FIG. 5, in which the ring pipe 49 is connected through the upper part of the valve chamber 51 with the exhaust 54. When the "lock" solenoid 62 is energized, the piston is drawn upwards so that the ring pipe 49 is now connected through the central portion of the valve chamber 51 with the oil inlet 53. The toggle action of the spring 64 urges the piston 55 into one or other of these two positions.

The oil inlet 53 is connected through the main stop valve 66 of the set with an oil receiver 67, oil in which is maintained under pressure and at a constant level by a pump 68 which draws oil from a sump 69. The exhaust 54 of valve 52 also discharges into the sump 69. Also supplied with oil from receiver 67 through stop valve 66 are a guide vane servomotor distributor valve 70 and an actuator admission valve 71. The latter is generally similar to the guide-vane lock admission valve 52 and is similarly actuated by a single-acting "open" solenoid 72 and a single-acting "close" solenoid 73, a spring (not shown) acting in the same way as the spring

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64 to keep the valve stable in one or other of two positions. The valve 71 connects receiver 67 in one of these positions (the "open" position) through line 75 with a governor valve 76. The valve 76 is controlled through a lever mechanism (indicated at 77) by a centrifugal governor 78 driven by a motor 79, which in turn is energized through electrical connections 80 by a permanent-magnet generator 81 mounted on the main shaft 11 of the machine. The governor valve 76 supplies oil, the amount depending on the position in which the valve 76 is set by the governor 78, to one side of the differential piston 82 of a pilot servomotor 83: the other side of the piston 82, which has the smaller surface area, is supplied with oil from the receiver 67 through the stop valve 66.

The piston 82 of the pilot servomotor 83 is connected to operate the guide-vane servomotor distributing valve 70, which supplies oil to one or other side of the operating piston 84 of the guide-vane servomotor 25 so as to open or close the guide-vanes as described above.

With reference to FIG. 7, the coils of the solenoids 62, 63, 72 and 74 are connected across a D.C. electric supply, to the positive terminal of which there are connected the poles of two manually-operated two-way switches, a guide-vane control switch 85 and a guide-vane lock control switch 86. The switch 85 is connected, when in the position for opening the guide-vanes, through limit switches 87, 88 operated by the plungers of the "lock" solenoid 62 and the "open" solenoid 72 respectively, with the positive side of the coil of solenoid 72. In its other position, for closing the guide-vanes, the switch 85 is connected through limit switches 89, 90, operated by the plungers of the solenoids 62 and 73 respectively, with the positive side of the coil of the "close" solenoid 73. The switch 86 is connected in one position, for locking the guide-vanes, to the positive side of the coil of solenoid 62 through another limit switch 91 operated by the latter; and in its other position, for unlocking the guide-vanes, switch 86 is connected to the positive side of the coil of the "unlock" solenoid 63, through a limit switch 92 operated by the solenoid 63. Each limit switch is arranged so as to be opened when the plunger of the associated solenoid, when the coil thereof is energized, reaches the end of its travel. FIG. 7 shows the limit switches in positions corresponding to the positions of the solenoids shown in FIG. 6.

Pairs of contacts 93 and 94 of the shut-down relay for the set are connected between the positive terminal of the D.C. supply and the positive side of the limit switches 89 and 92 respectively.

In operation, when the machine is acting as a turbine it is desirable to be able to adjust the guide vanes 16 so as to vary the mass flow of water through the machine. During turbine operation, therefore, the vanes are free to move in the bearings 18 and 21 under control of the guide-van servomotor 25, the piston 37 being held by its own weight and by the action of the springs 41 against the floor of the recess 36, while the locking ring 42 lies on top of the piston 37 and out of contact with the bush 22a, in the position shown in FIGS. 2 to 4. In this position, the piston 55 of the guide vane lock admission valve 52 is in its lower position, the plunger of the "unlock" solenoid 63 being maintained by the action of spring 64 in its upper position and that of the "lock" solenoid 62 in its lower position (all as seen in FIG. 5).

The limit switch 92 is therefore open and the limit switches 87, 89 and 91 are all closed. One or other of the limit switches 88 and 90 is also closed, the other being open. If it is the limit switch 90 that is open, as shown in FIG. 7, movement of the guide-vane control switch 85 to its "open" position now completes the D.C. circuit through the coil of solenoid 72, which opens the admission valve 71, so admitting oil to the governor valve 76, and at the same time drawing the plunger of solenoid 73 downwards: this closes the limit switch 90. When the

plunger of solenoid 72 reaches the top of its stroke, where it is held by the spring 74, it opens the limit switch 88. If the control switch 85 is now moved to its "close" position, the "close" solenoid 73 is energized and the same procedure works in reverse, the valve 71 closing off the oil supply from the valve 76.

When oil is admitted as described above to the valve 76, the latter allows oil to pass to the pilot servomotor 83, whereupon differential oil pressure between the two sides of the piston 82 causes the latter to move the distributing valve 70 so as to admit oil to one side of the piston 84 of the guide vane servomotor 25. The latter then operates the ring 24 to open the guide vanes. When the governor valve 76 is closed, oil pressure on the left (as seen in FIG. 6) of the piston 82 of the pilot servomotor 83 moves the piston 82 to the right and the valve 70 admits oil to the other side of the piston 84, which acts to close the guide vanes.

When the valve 71 is open, the governor 78, responsive to the speed of rotation of the machine through the action of the permanent-magnet generator 81 driving the governor motor 79, controls the governor valve 76 so as to govern the admission of oil to the servomotor 83 in such a way that, if the speed of the machine exceeds a predetermined amount, the valve 76 closes. Thereupon, oil on the left (as seen in FIG. 7) of piston 82 in servomotor 76 moves this piston to the right so that the guide vanes are closed.

When the machine is operating as a pump, continuous adjustment of the guide vanes is normally not necessary, and it has been found beneficial to provide locking means such as that described, for locking the guide vanes once they have been set to suit the prevalent pumping head and power input of the machine, in order to eliminate vibration due to the forces applied by water flowing past them. The guide vanes are locked by moving the lock control switch 86 to its "lock" position. The coil of the "lock" solenoid 62 is thus energized, drawing the solenoid plunger and piston 55 upwards (as seen in the drawings) as described above, so that the valve 52 admits oil from the inlet 53 to the ring pipe 49. At the same time limit switch 92 is closed and limit switches 87, 89 and 91 opened. Since the limit switches 87 and 89 are open, the guide vanes can now not be opened or closed by operation of the control switch 85.

There is now oil under pressure in the ring pipe 49, in the inlet ducts 48 and in the recess 37a on the underside of each piston 37. This pressure is sufficient to raise the piston 37. The piston forces the locking ring 42 upwards, the segments of the latter being urged together, against the action of springs 45, by the part-conical surface 36a, until the locking ring is wedged between the housing 26 and the bush 22a. At the same time the bush 22a, with shaft 20, is given an upward thrust by the action of ring 42 which forces the shoulder 34 against the bearing sleeve 31—the ring 40 is at the same time raised against the bottom of the bush 22a. The friction between the bush 22a, ring 42 and housing 26, together with that between the shoulder 34 and bearing sleeves 31, is enough to lock the guide vanes against vibration.

To unlock the guide vanes, the switch 86 is moved to its "unlock" position, the coil of solenoid 63 is energized, the valve 52 returns to the position shown in FIG. 5 so that oil is released from the underside of the piston 37, through the ring pipe 49 and valve 52 to the sump 69. Each piston 37 is then forced downwards by the springs 40, whereupon the segments of the locking ring 42 are forced outwardly by the compressed springs 45 and downwardly by the surface 36a, so disengaging the ring 42 from the bush 22a.

If emergency closing of the guide vanes is required when the vanes are locked, the shut-down relay closes the contacts 93 and 94, thus energizing the "unlock" solenoid 63—and thereby unlocking the guide vanes—and

then energizing the "close" solenoid 73 so as to close the guide vanes.

The adjustment and locking of the guide vanes can be arranged for automatic operation. For example the coils of solenoids 62 and 63 can be connected in the control circuit of the machine so that the guide vanes become locked automatically when pumping is taking place and when the machine reaches a predetermined speed, and unlocked as soon as the speed falls below that speed preparatory to stopping.

Locking means similar to the guide-vane locking means shown in FIGS. 3 and 4 can be used in other parts of the water system associated with a water turbine or pump: for example, a butterfly valve may be provided with such device to prevent vibration. In such applications the locking means is not necessarily mounted on a vertical axis but may be on a horizontal axis or indeed at any convenient angle.

The locking ring 42 need not have both its locking surfaces made part-conical in form as described: for example the surfaces 22b and 43 may be conical and the surfaces 36a and 44 cylindrical.

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

1. A rotary hydraulic machine comprising a machine casing, a rotor mounted for rotation in said casing, a plurality of guide vanes disposed in said casing around the rotor, fluid-pressure operated guide vane locking means arranged adjacent the guide vanes, electrically-operated two-position guide vane lock operating means operatively connected to said guide vane locking means and arranged so as in a first said position to cause the guide vane locking means to lock the guide vanes against movement relative to said casing and in a second position to cause the guide vane locking means to unlock the guide vanes, fluid-pressure operated guide vane actuating means for opening and closing the guide vanes, electrically-operated first valve means for operating said guide vane actuating means, first duct means connected between said first valve means and said guide vane actuating means, an electric control circuit for said first valve means, and electric switch means operated by said guide vane lock operating means and arranged in said electric control circuit so as to break said control circuit whereby to render said first valve means inoperative when the guide vane lock operating means is in said first position.

2. A rotary hydraulic machine according to claim 1 and comprising governor means responsive to the speed of rotation of said rotor, second valve means connected to said governor means for operation thereby, second pressure fluid duct means connected between said second valve means and said guide vane actuating means, third pressure fluid duct means connected between said first valve means and said second valve means, and means in said first valve means for allowing passage of pressure fluid through said third duct means to said second valve means when said first valve means is in a first position and for preventing said passage while allowing passage of pressure fluid through said first duct means when said first valve means is in a second position.

3. A rotary hydraulic machine according to claim 1 and comprising governor means responsive to the speed of rotation of said rotor, second valve means connected to said governor means for operation thereby, second pressure fluid duct means connected between said second valve means and said guide vane actuating means, third pressure fluid duct means connected between said first valve means and said second valve means, and means in said first valve means for allowing passage of pressure fluid through said third duct means to said second valve means when said first valve means is in a first position for operating said guide vane actuating means to open said guide vanes and for preventing said passage while allowing passage of pressure fluid through said first duct means when said first valve means is in a second position for

operating said guide vane actuating means to close said
guide vanes.

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