April 28, 1964 R. S. SPROULE 3,130,955

RUNNER BLADE SERVO SYSTEM FOR TURBINES

Filed May 9, 1961 4 Sheets-Sheet 1

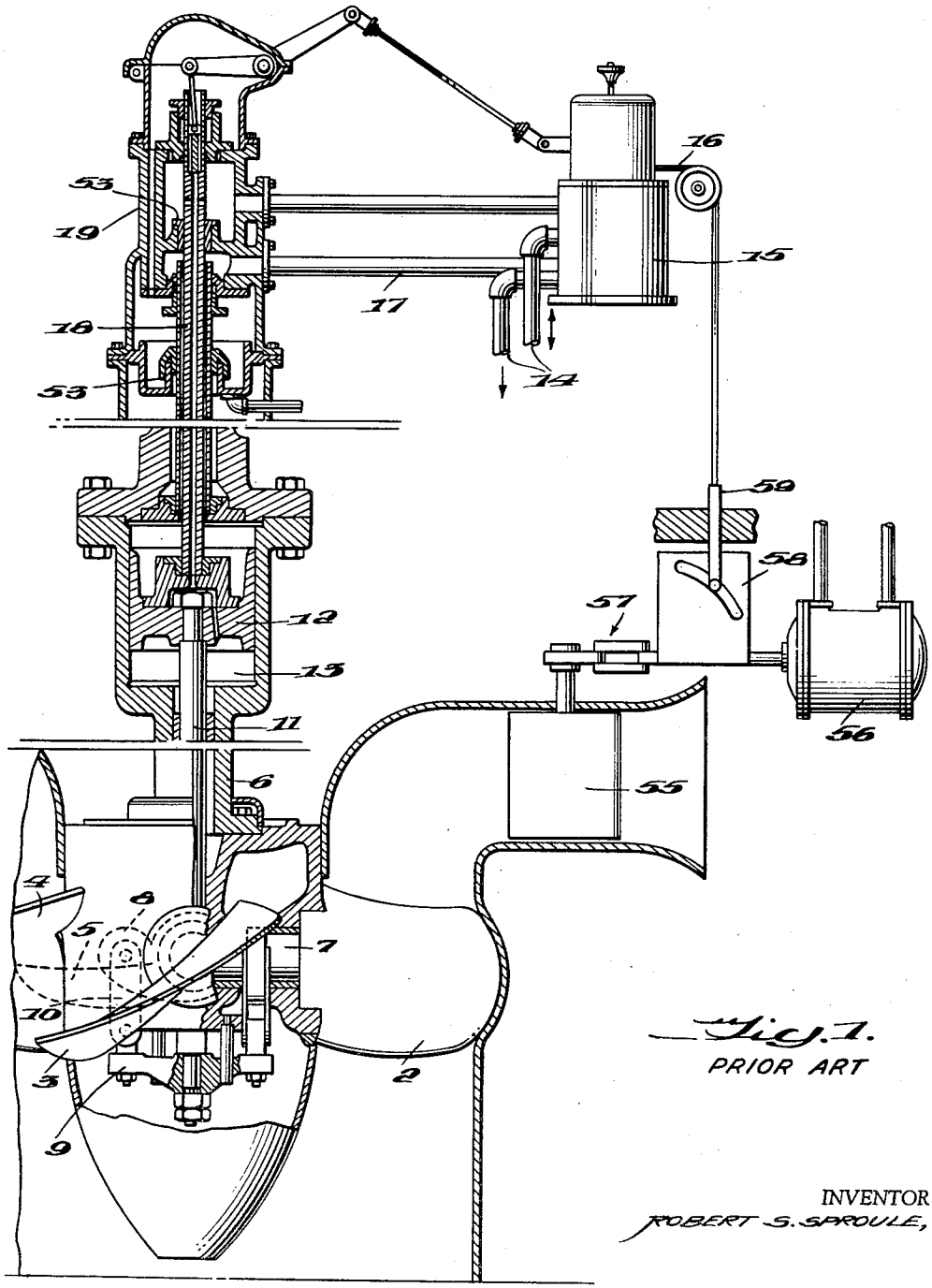


Fig. 1.
PRIOR ART

INVENTOR
ROBERT S. SPROULE,

BY Larson and Taylor

ATTORNEYS

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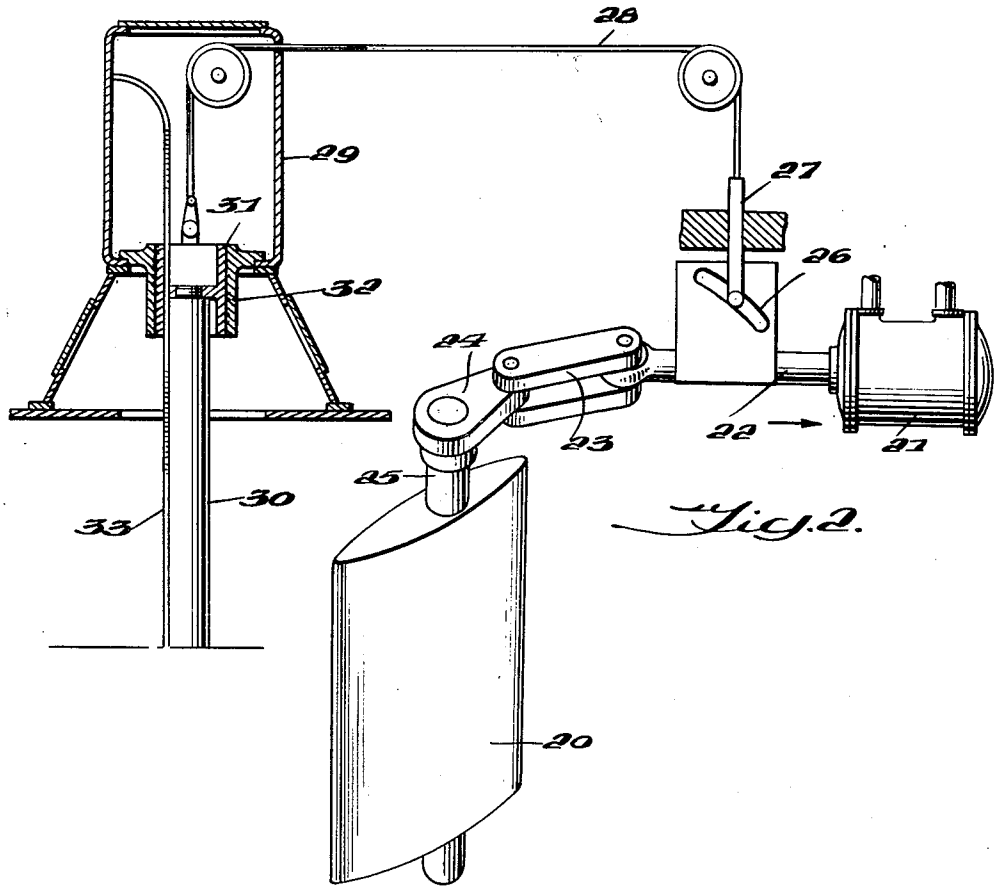


Fig. 2.

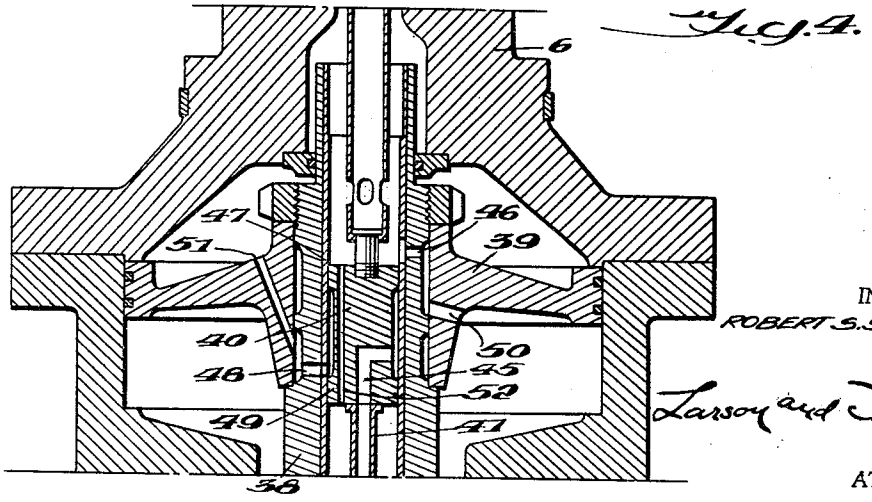


Fig. 4.

INVENTOR
ROBERT S. SPROULE,

Larson and Taylor

ATTORNEYS

April 28, 1964 R. S. SPROULE 3,130,955

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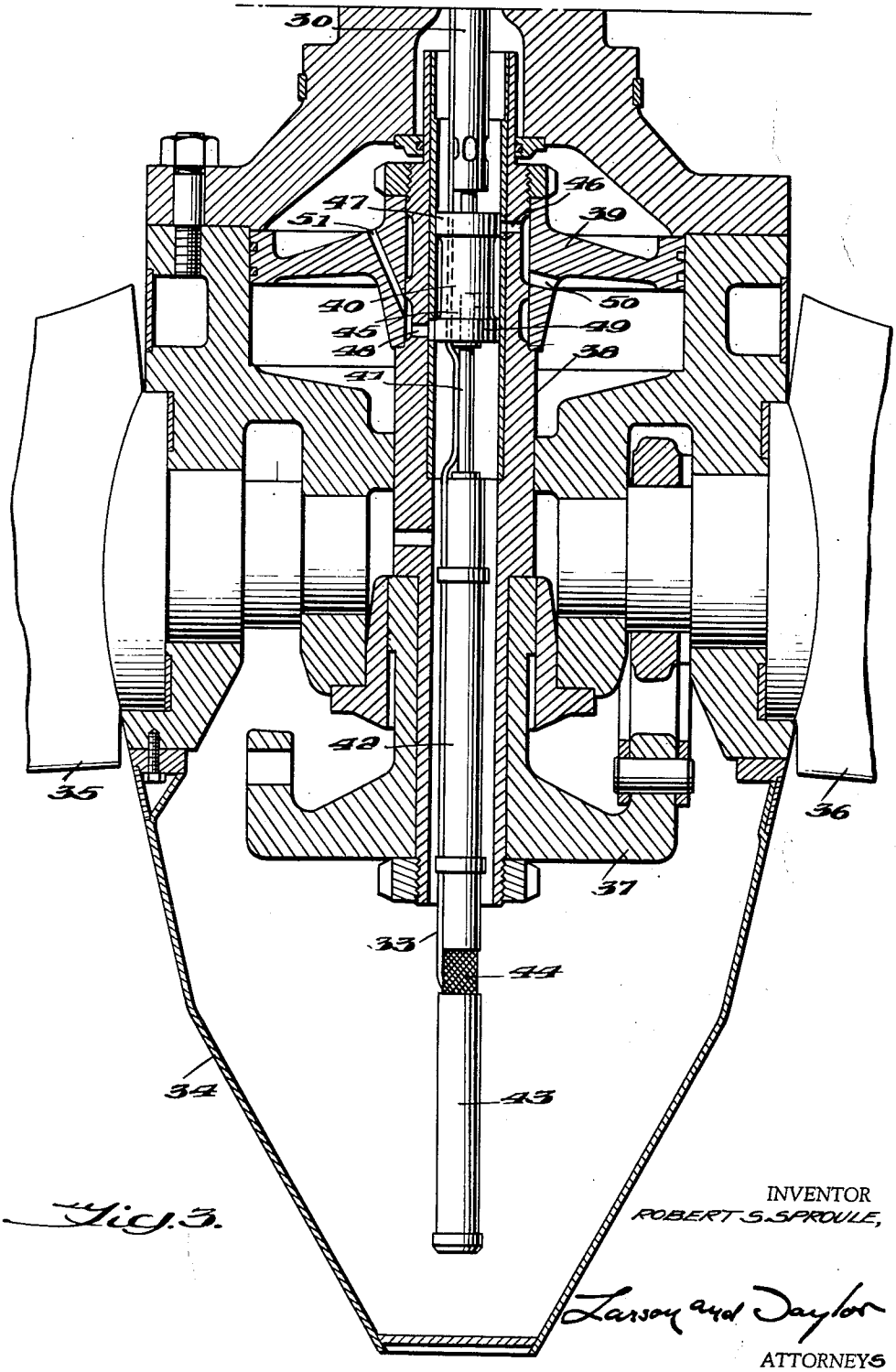


Fig. 3.

INVENTOR
ROBERT S. SPROULE,

Larson and Taylor

ATTORNEYS

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Fig. 5.

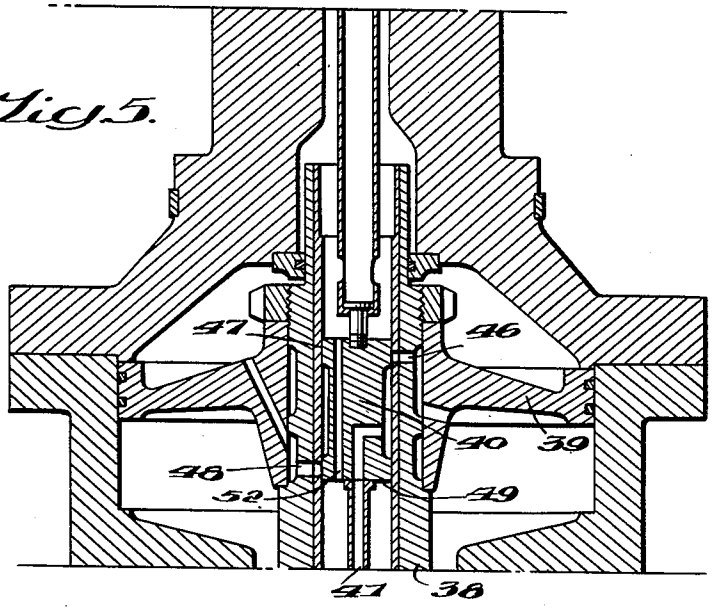
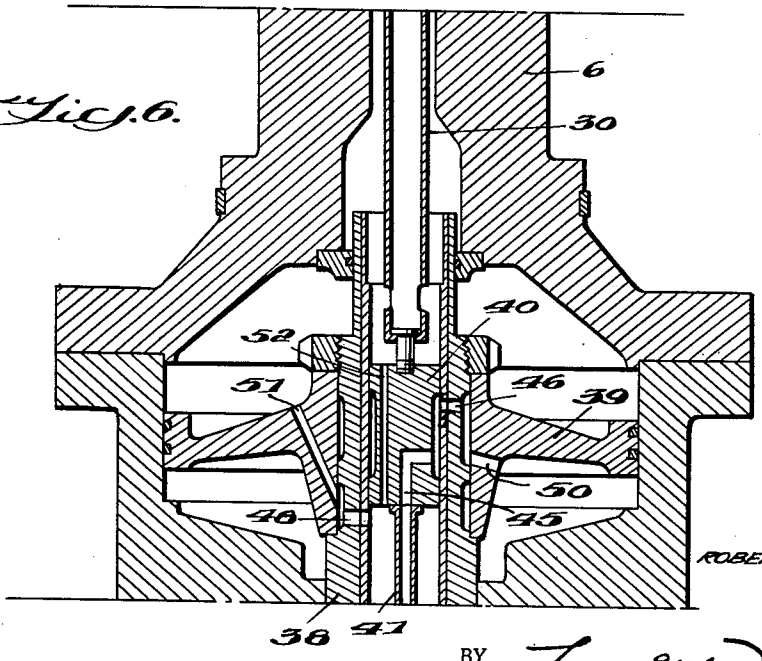


Fig. 6.



INVENTOR
ROBERT S. SPROULE

BY Lawson and Taylor

ATTORNEYS

United States Patent Office 3,130,955 Patented Apr. 28, 1964

3,130,955

RUNNER BLADE SERVO SYSTEM FOR TURBINES

Robert S. Sproule, Montreal, Quebec, Canada, assignor to Dominion Engineering Works Limited, Montreal, Quebec, Canada

Filed May 9, 1961, Ser. No. 108,814
3 Claims. (Cl. 253—31)

This invention relates to hydraulic turbines and pumps and more particularly to a runner blade servo system for Kaplan type turbines.

Hydraulic turbines are provided with adjustable wicket gate assemblies which are adapted to admit a varying supply of water to the runner assembly depending upon the power required of the turbine. In the Kaplan type turbine the runner blades are also adjustable in that it has been found that the turbine will run more smoothly and more efficiently with a particular runner blade angular position for each wicket gate setting. Heretofore the runner blade setting has been achieved by a servo motor which receives control signals from the wicket gate setting and which by means of a hydraulic system positions a piston and rod assembly.

According to such prior art devices the piston and rod assembly which regulates the position of the runner blades is disposed within the rotating shaft supporting the runner. The piping connected to the hydraulic positioning system is usually connected to the rotating shaft.

It can be appreciated that such prior art assemblies have many inherent disadvantages due to the piping connected to the runner shaft. It is necessary to provide rotary seal junctions in the hydraulic piping system and there is sometimes the risk of spilling oil on the generator. The piping system is unsightly and costly to install and maintain.

According to the present invention all of the foregoing disadvantages are eliminated by providing a rotating assembly which includes a casing structure serving as an oil reservoir and housing the other components of the hydraulic runner-blade positioning system. Thus, it becomes necessary to provide only an electrical connection for energizing the pump motor and a relatively simple mechanical connection for shifting the position of the control valve in response to movements of the wicket gates. Thus, all of the external piping which was essential with prior art systems is eliminated. The problems in connection with rotary seals for the hydraulic system are overcome and there is no danger of oil being spilt upon the generator.

An object of the present invention is to provide a runner blade servo system for Kaplan turbines without external piping.

Another object of the present invention is to mount the control system for positioning the runner blades within the casing of the rotating assembly.

Still another object of the present invention is to eliminate the piping and rotary seals necessary in the runner blade control systems of prior art Kaplan turbines.

Other objects and many of the attendant advantages of the present invention will become more fully apparent upon consideration of the following detailed specification in connection with the accompanying drawings, wherein:

FIG. 1 is an elevational view partly in section showing the conventional type of runner blade control system,

FIG. 2 is an elevational view partly in section of a portion of the runner blade control system according to the present invention,

FIG. 3 is a sectional view of another portion of the runner blade control system according to the present invention,

FIG. 4 is a sectional view showing the control valve in position to shift the blade actuating piston downwards,

FIG. 5 is a sectional view showing the control valve and piston in equilibrium and,

FIG. 6 is a sectional view showing the control valve in position to shift the blade actuating piston upwards.

Referring now more specifically to the drawings wherein there is shown in FIG. 1 at **1** a runner hub in which are rotatably journalled runner blades **2**, **3**, **4**, and **5**. Rigidly connected with the runner hub **1** is a shaft **6** which drives the rotor of a generator (not shown). The runner blades are driven by water fed thereto through a casing (not shown) surrounding the runner blades. A plurality of wicket gates are mounted within this casing and the angular position of these wicket gates is set in accordance with the power demand on the turbine. It has been found that the turbine runs more smoothly and efficiently when the runner blades are set at a specific angular position for each angular position setting of the wicket gates. Thus, means must be provided for setting the angular position of the runner blades in accordance with the angular position setting of the wicket gates.

According to prior art systems for regulating the position of the runner blades there is provided a shank rigidly mounted on the inner end of each of the runner blades such as, for example, the shank **7** on the inner end of blade **2**. Each of these shanks is rotatably journalled in the runner blade hub **1** and each is provided with a crank arm such as the crank arm **8** mounted on the shank of runner blade **3**. A pivotally mounted link interconnects each of the crank arms with a crosshead member **9** such as, for example, the link **10** interconnecting the crank arm **8** with the crosshead **9**. It can be seen that by virtue of this construction vertical movement of the crosshead **9** will produce simultaneous angular shifting of the runner blades **2**, **3**, **4**, and **5**.

The crosshead **9** is connected with a piston rod **11** which has the upper end thereof fixed to a piston **12** slidable within cylinder **13**. The position of the piston **12** is determined by a hydraulic system including a motor and pump and air/oil accumulator tank (not shown) connected with supply pipes **14** to a blade control valve **15**. The details of the blade control valve and the hydraulic system will not be described in detail herein since they are of conventional construction and form no part of the present invention. One of the wicket gates is shown at **55** and the angular position of the gate is set by a hydraulic piston and rod assembly **56** through linkage **57**. The hydraulic piston and rod assembly **56** also positions cam **58** which actuates the control valve **15** through cam follower **59** and control cable **16**. Movement of the piston of the hydraulic assembly **56** to set the angular position of wicket **55** also repositions the cam **58**, thus actuating control valve **15** to transmit oil through piping **17** and conduit **18** to hydraulic cylinder **13**. The piston **12** is driven in either direction to shift the angular setting of the runner blades in accordance with the position of the wicket gates.

The housing **19** for the connections with pipe **17** and the upper end portions of the conduits **18** is usually disposed above the generator (not shown) and it can be seen that there is danger of oil leaking onto the generator parts. Furthermore, due to the fact that the conduits **18** must be interconnected with the rotating shaft **6** there must be provided rotary seals such as indicated at **53** and as these seals become worn the danger of leakage in the oil system is increased. The system shown in FIG. 1 is difficult to install and maintain.

According to the present invention the rotating assembly includes as part thereof the complete servo actuating system which positions the runner blades in response to an external signal so that the rotary seals and hydraulic

piping associated with the FIG. 1 embodiment are eliminated.

In FIG. 2 there is shown a wicket gate 20 which is one of a set of gates (not shown). These wicket gates are pivotally mounted within a scroll casing (not shown) for admitting water to the runner blades. The angular position of the wicket gates is determined by the power demand on the turbine and is set by a hydraulic system including a cylinder 21 and piston rod 22 which is connected with a piston disposed within the cylinder 21. Hydraulic fluid supply to either end of the cylinder by a motor and pump and air/oil accumulator tank (not shown) drives the piston rod 22 and the link 23 pivotally connected with the outer end of a crank arm 24 rigidly mounted on shaft 25. Thus it can be seen that the angular position of the wicket gate 20 may be readily shifted by the system described.

The runner blades are angularly positioned in accordance with the wicket gate position by a control system including a cam 26 mounted on piston rod 22 and a cam follower 27 having control cable 28 connected therewith. The control cable passes over a pair of pulleys and extends into a housing 29 wherein the end thereof is connected with the upper end of control rod 30. The upper end of the control rod 30 is connected with a sleeve 31 which is reciprocable in, but does not rotate in, guide 32. An electric cable 33 is adapted to move vertically with the control rod 30 and passes between sleeve 31 and control rod 30.

Referring now to FIG. 3 the hub section of the casing structure is shown at 34 and this casing is adapted to rotatably journal a plurality of runner blades such as are shown at 35 and 36. These blades are journalled in the same manner as the blades described in the prior art FIG. 1 embodiment and are connected with a crosshead 37 by means of linkage which, for convenience of illustration, is not shown in detail but which is identical to the linkage shown and described in FIG. 1. The crosshead is connected to a hollow shaft 38 which has a piston 39 rigidly fixed to the upper end thereof. It can be seen that movement of the piston 39 and shaft 38 will produce angular movement of the runner blades.

The lower end of control rod 30, the upper end portion of which is shown in FIG. 2, has mounted thereon a valve body 40 which is spool shaped, hydraulic pressure pipe 41, pump 42, and electric motor 43. It can be seen that the electric cable 33 extends the entire length of the control rod to provide the electrical energy for driving the motor 43. The motor 43 drives the hydraulic pump 42 which has an inlet as shown at 44 so as to pump hydraulic fluid through the pump and conduit 41 through duct 45 within the valve spool 40. There are provided ports 46 and 48 in the shaft 38 which, in the position of the valve shown in FIG. 3 are covered by lands 47 and 49 respectively. Ducts 50 and 51 are provided in the piston 39.

The operation of the presently disclosed system will now be described. The casing structure of the rotating assembly serves as a reservoir containing oil whose free surface may be at any desired level within the hollow shaft. Filling of the casing may take place through the hollow shaft. As the wicket gates shown in FIG. 2 move to an open position the piston rod 22 moves in the direction shown by the arrow. This movement of the cam 26 will cause the control rod 30 to be lowered. The positions of the valve parts are shown in FIG. 4. The lowering of the valve spool 40 causes the land 49 to uncover port 48 so that hydraulic pressure pipe 41 is connected through duct 45, port 48 and duct 51 with the space above the upper surface of piston 39. Similarly the land 47 has uncovered ports 46 which are connected via duct 50 with the space below the surface of the piston 39. In this position of the valve spool 40 hydraulic fluid will be pumped to the space above the upper surface of the piston 39 to force the piston downwardly and force hydraulic fluid through duct 50, port 46 and return duct 52 in the valve spool 40. The piston 39, shaft 38 and crosshead 37 will move downwardly until the lands 47 and 49 cover ports 46 and 48, respectively. The movement of the crosshead 37 will cause the runner blades to open and assume an angle corresponding with the changed angle of the wicket gates.

In FIG. 5 the piston 39 is shown in a position of equilibrium with the land 49 covering port 48 and the land 47 covering port 46. In this position there is no connecting passageway open to either side of the piston 39, the piston cannot be shifted in position and will retain the runner blades in the adjusted position.

In FIG. 6 the parts are shown in the position in which the control rod 30 has, in response to movement of the wicket gates, moved the valve spool 40 upwardly so that the hydraulic pressure pipe 41 is connected through duct 45 with ports 46 and duct 50 in piston 39 allowing hydraulic fluid to be pumped to the space below the lower surface of piston 39 and thereby forcing piston 39 upwards. At the same time hydraulic fluid in the space above piston 39 will return to the pump through duct 51 and ports 48. It can be seen that in this position of valve spool 40 the piston 39 will move upwardly until the shaft 38 reaches a position wherein the ports 46 and 48 are again covered by the lands 47 and 49 on the valve spool 40.

It can be seen that the present invention provides a means for angularly adjusting the runner blades in accordance with the angular positioning of the wicket gates. The mechanism for effecting the control is disposed entirely within the casing. The hydraulic system disclosed provides an accurate control, is simple to install and maintain and overcomes all of the aforementioned disadvantages of prior art control systems. The piston moves in the same direction as the valve spool so that the piston will always move the same amount as the valve spool has moved. By virtue of the simplicity of construction and in providing a minimum of movable parts a maximum degree of reliability is assured.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. For example, the specific positioning of the piston, pump and motor may be readily varied to suit any particular operational requirement. The pump is shown as being electrically driven but, if desired, a suitable gear driven pump could be provided. Thus, the invention is limited only by the scope of the appended claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a Kaplan type turbine including adjustable wicket gates and wicket gate operating mechanism for changing the settings of the wicket gates to control the flow of water to the runner blades of the turbine, a rotating assembly including a rotatable shaft, a casing rigidly secured to said shaft, a passageway extending along the longitudinal axis of the shaft communicating with the casing, runner blades journalled in said casing for rotation about axes radial to the casing, a piston operatively connected to the blades for changing and controlling the pitch setting of the blades, a valve for controlling the operation of said piston, the longitudinal axis of said valve lying on the longitudinal axis of the casing and shaft, a control rod extending through said passageway for controlling the position of said valve, the casing comprising an oil reservoir, an electric motor in said casing, control means for said electric motor extending through said passageway, a pump driven by said motor, the inlet of said pump communicating with the reservoir, the outlet of the pump communicating with the valve whereby said pump may be driven to move said piston and alter the runner blade setting when changes in the wicket gate setting move the control rod to reposition said valve.

2. In a Kaplan type turbine according to claim 1 wherein said valve comprises a spool type valve and the outlet of said pump communicates with the central portion of said spool.

3. In a turbine of the class described having adjustable wicket gates and adjustable runner blades, a casing for mounting said runner blades, said casing being rotatable on a vertical axis, means disposed within said casing for adjusting the angular position of said runner blades, said means comprising a pump, drive means for said pump, a control valve, a servo motor operatively connected with said runner blades, fluid passageways connecting said pump, valve and servo motor, means connected to said control valve for positioning said valve in response to movement of said wicket gates whereby said servo motor drives said runner blades to a predetermined angular position, and a hollow shaft extending vertically upwardly from said casing, said pump, said drive means for said pump and said control valve having a common longitudinal axis extending co-extensively with the longitudinal axis of said hollow shaft.

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