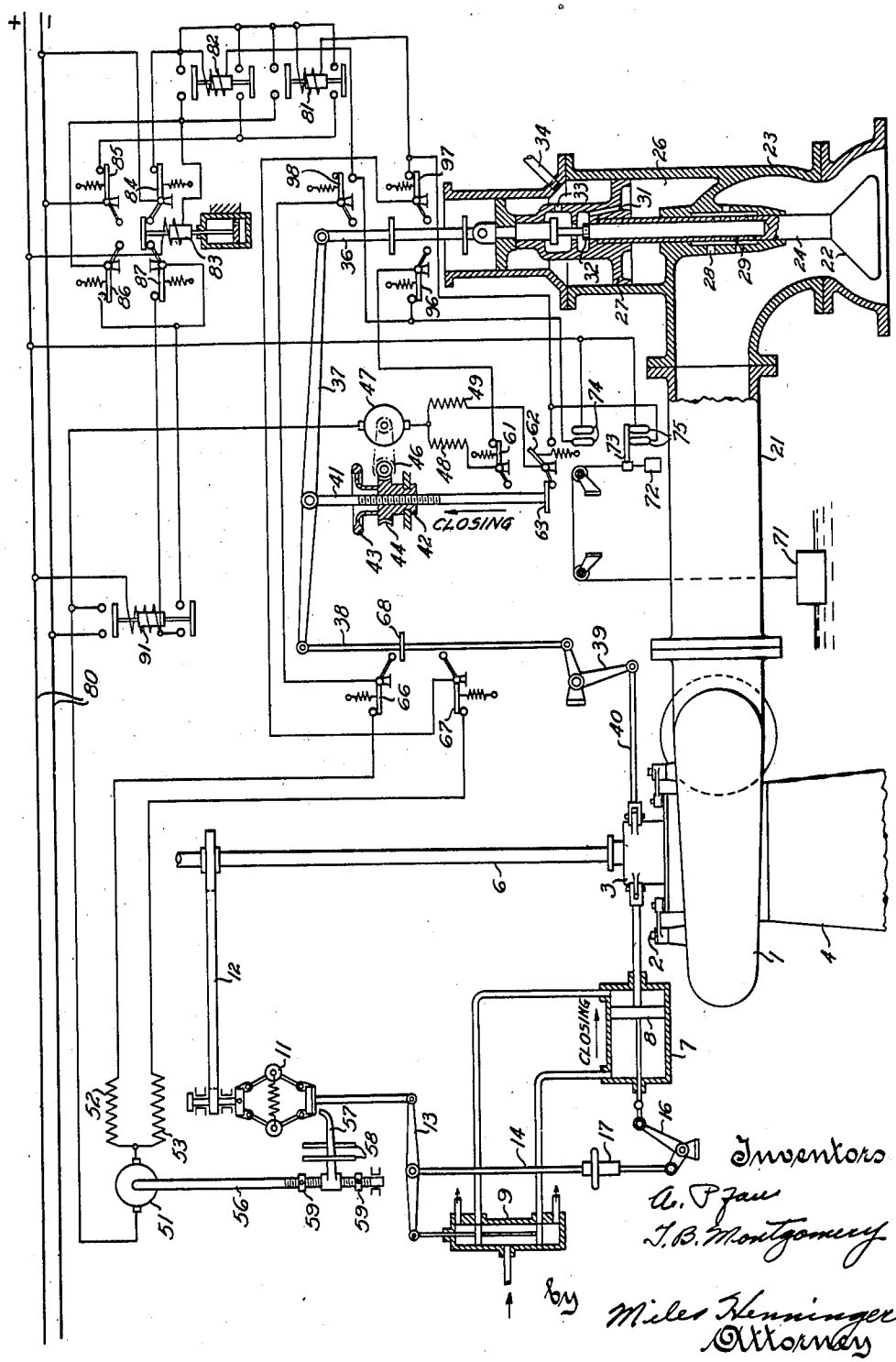
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HYDRAULIC TURBINE CONTROL SYSTEM

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Inventors
A. Pfau
J. B. Montgomery
by Miles Kenninger
Attorney

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HYDRAULIC TURBINE CONTROL SYSTEM

Arnold Pfau, Milwaukee, and Terryl B. Montgomery, Wauwatosa, Wis., assignors to Allis-Chalmers Manufacturing Company, Milwaukee, Wis., a corporation of Delaware

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This invention relates to improvements in control systems for hydraulic turbines and particularly to a turbine installation from which substantially the entire quantity of water flowing to the installation must be discharged at all times.

When a hydraulic turbine is used in a location where it is impossible to provide forebay or water storage space or when all of the water available for operating the turbine must be continuously available for use downstream from the turbine regardless of fluctuating loads on the turbine, it is necessary that means be provided which will bypass water around the turbine when the load on the turbine is not sufficient to require the full flow of the available water therethrough. The valve of such bypass must act synchronously with the turbine gate, that is, the area of the bypass opening must be varied simultaneously with gate opening variations so that the total water passage area remains substantially constant. When the turbine is to be operated up to its full capacity at which the gate vanes are fully opened, such full opening must of course correspond to the area required for passage of the available or desired quantity of water. And the total water bypass area must also at all times be sufficient to pass the desired quantity of water.

If there is only a small forebay water storage space, any downstream demand for water exceeding the flow into the intake of the turbine will result in emptying the storage space and drawing air into the turbine intake and bypass. Such entrance of air always has disturbing or destructive effects in a hydraulic turbine installation and prevents the orderly delivery of power from the turbine. When the water is delivered to the turbine by way of a long pipe line or penstock, the entry of the air into the penstock may prove disastrous. It is therefore necessary to provide a control which will limit the total area of discharge opening to that area required to pass only the amount of water available without draining any portion of the turbine water passages and without permitting entry of air thereinto.

It is therefore an object of the present invention to provide a control system for hydraulic turbines in which the total flow of water through the turbine and through the bypass around the turbine is automatically maintained substantially constant.

Another object of the invention is to provide a control system for hydraulic turbines in which the turbine gate opening is responsive to loads imposed on the turbine while the valve of the bypass around the turbine is controlled responsive to the level of the water in the forebay.

Another object of the invention is to provide a control system for hydraulic turbines in which the operation of the normal load and speed responsive control means for the gate of the turbine is limited or controlled by means responsive only to the level of the water in the forebay.

Another object of the invention is to provide a control system for hydraulic turbines in which the load limiting means and the bypass control means are operated by increments only and are so interlocked as to prevent overrunning of either the turbine gate or bypass valve operating means.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawing, which represents a diagrammatic illustration of the present improved system at high forebay level when the turbine is running at substantially no load with the turbine gate nearly closed and with the bypass valve nearly fully open.

Referring more particularly to the drawing by characters of reference, the reference numeral 1 designates a spiral casing extending about and directing the flow of water to a hydraulic turbine wheel of the usual construction under the control of a gate made up of the usual gate vanes of which the stems 2 are connected with a shifting ring 3. Water passing through the turbine is discharged into a draft tube 4 and the power produced by the turbine is delivered by way of a shaft 6 to a suitable load. The opening area of the gate vanes is adjusted by movement of the shifting ring 3 by means responsive to the speed of the turbine and including a fluid pressure operated servomotor 7, 8 to which pressure is admitted and from which pressure is discharged under the action of a pilot valve 9. The pilot valve 9 is actuated by a flyball head 11 of the usual construction, driven from the shaft 6 as by a belt 12, and acting on one end of a floating lever 13 having the other end connected with the stem of the valve. The floating lever 13 is movably fulcrumed on a rod 14 connected by way of a bell-crank 16 to the piston 8 of the servomotor and the rod is adjustable in length by manual movement of a sleeve and wheel 17, thus providing means for starting and manually controlling the turbine gates.

When the gate shuts off the flow of water through the turbine, the water in the spiral casing 1 flows through a bypass including a con-

necting pipe 21 and through a relief valve 22, discharging the water into the discharge pit from the turbine. The valve 22 is enclosed in an elbow-like casing 23 with the valve stem 24 guided in and passing through one wall of the elbow to a cylindrical chamber formed by an extension 26 from the casing. The valve stem 24 is joined to a piston 27 movable in a cylinder 26 for closing the valve upon the admission of fluid pressure below the piston. The valve stem is hollow and forms a passage for fluid pressure taken from the valve casing by way of apertures 28 and 29 and delivered below the piston 27 by way of a passageway 31 when a control valve 32 is raised from its seat. Water is discharged from below the piston 27 by way of the piston passage 31, a port 33 above the valve 32 and a drain pipe 34. The gate and the control valve are connected by a leverage including a rod 36 with one end of a floating lever 37 having the other end connected by way of a rod 38, a bellcrank 39 and a link 40 with the shifting ring 3. The floating lever 37 is fulcrumed on a rod 41 which screw-threadedly engages a nut 42 engaging or formed as a part of a hand wheel portion 43 and a worm wheel portion 44. The hand wheel 43 provides means by which the bypass may be initially manually opened or may be adjusted to meet conditions occurring during operation of the unit.

Rotation of the nut 42 raises and lowers the rod 41 and causes movement of the control valve 32 to control the opening and closing of the relief valve 22. Rotation of the nut may be by means of the hand wheel 43 or by means of the worm wheel 44 upon movement of the worm 46 into engagement therewith. The worm 46 is driven through suitable connections with a reversible electric motor 47 having two fields indicated at 48 and 49. The armature of the motor 47 is connected with the armature of a reversible motor 51 also having two fields indicated at 52 and 53. The motor 51 drives a screw-threaded spindle 56 having movable thereon a nut with a finger 57, rotation of the nut being prevented by guides 58 and travel of the nut being limited by stops 59. The finger 57 extends into the path of movement of the flyball 11 and limits or reduces the movement of such flyball in one direction only, that is, when the load imposed on the tubine exceeds the limit allowable due to the level of the water in the forebay. The fields 48 and 49 of the motor 47 are controlled in part by limit switches 61 and 62, respectively, which are normally spring held in closed position and are movable into open position by a flange 63 on the threaded rod 41 which acts as the fulcrum for the floating lever 37. And fields 52 and 53 of the motor 51 are controlled in part by limit switches 66 and 67, respectively, which are normally spring held in closed position and are movable into open position by a flange 68 on the rod 38 connecting one end of the floating lever 37 with the gate operating shifting ring 3.

The draining of the penstock and the turbine water passages which would permit dangerous entry of air is prevented if a sufficiently high water level is retained in the forebay. Such water level is controlled by a float 71 counterbalanced by a weight 72 and carrying a contact finger 73 by which electric circuits are closed either by way of a pair of contacts 74 or a pair of contacts 75.

Motors 47 and 51 are energized from a so-called house-power line 80 supplied from an independent source and supplying energy to the motors intermittently under the control of a so-called notching circuit which intermittently closes and interrupts the motor supply circuits. The notching circuit includes relays 81 and 82 which are energized upon bridging of the contacts 75 or 74, respectively. The actuation of relays 81 and 82 being precisely the same, only the circuits resulting from the energization of relay 81 will be described. The coil of relay 81 is energized when control contacts 75 are bridged and the energized circuit includes a switch 84. The relay 81 closes its lower contacts which complete a circuit placing the switch 85 in parallel with a switch 84 and the upper contacts of relay 81 close simultaneously and complete the circuit through contacts of switch 84 to the coil of a time delay relay 83 and also complete a circuit to the coil of relay 91 through contacts of switches 86, 87 and the upper contacts of relay 81, and the switch 84. Relay 91 then lifts and by its upper contacts connects both the motors 47 and 51 to one conductor of line 80. A power impulse is then given to the motors if their respective limit switches 61, 62 and 66, 67 are closed and if the proper one of a plurality of interlocking switches 96, 97, 98 are in the proper positions and if the proper float switch contacts 74 or 75 are closed. Relay 91 when energized, by its lower contacts, bypasses the contacts of switch 87, which prevents the deenergization of its coil upon subsequent opening of switch 87. During the time the motors are operating, relay 83 is rising to the top of its stroke where it opens switches 85, 86 interrupting the circuit to both relays 81 and 91 which interrupt the flow of power to the motors 47 and 51, and also interrupt the circuits to the relay 83. The relay 83 drops at a delayed rate until it closes the switches 84 and 87, whereupon relays 81 and 91 are again energized to reclose the circuits by which another impulse is sent to the motors 47 and 51. Such impulse or intermittent supplies of energy are continued until either the rod 38 or rod 41 moves sufficiently to cause engagement of the flanges thereon with the limit switches adjacent either of the rods and thus opens such switches.

The plurality of interlocking switches 96, 97, 98 are mounted on the casing of the bypass for operation by the rod of the bypass to limit the independent movement of both the motors 47 and 51 by interlocking the circuits of such motors. Without such interlocks it would be possible for either motor to overrun to the detriment of the gate or bypass operation by the other motor. Switches 96, 97 and 98 enter into one or more of the circuits driving the motors 47 and 51 and thus control the operation of such motors in both directions of operation.

The operation of the electrical portions of the control system will be best understood if the conditions and positions of the several elements are traced through a number of conditions which the system is required to meet. The circuits will therefore be traced through the sequence of operations when (*a*) the forebay is filled to a high level with the bypass open to discharge all of the water possible and with the turbine gates closed and to be opened following backing off of the load limit device, (*b*) the forebay is at low level with the bypass closed and the gate is to be closed and (*c*) the forebay level is rising to the high level with both the bypass and the gates closed and to be opened.

Under condition (*a*), the bypass 22 is fully

open, the turbine gate is closed, the fulcrum 41 is lowered to open switch 62 and the high forebay level has raised the float 71 to the position at which the contact finger 73 bridges the contacts 75. The so-called notching circuit then is completed to cause intermittent energization of motor 51 for backing off the load limit to permit the turbine to take on load. A circuit is completed to the coil of relay 81 and closes its lower and its upper contacts simultaneously. Closure of the lower contact of the relay 81 places switches 84 and 85 in parallel and closure of the upper contact of the relay 81 closes the circuit to the coil of the relay 83 through the switch 84 and also closes the circuit of the relay 91 through the switches 86 and 87. The relay 91 then closes the circuit to the armature of the motor 51 and its winding 53 through the switches 67, 97 and the contacts 75. An impulse is thus given to motor 51 to back off the load limit and allow the gate to open. As the gate opens, the floating lever 37 is mechanically shifted by the gate opening so that bypass 22 is closed to the degree required to cause the water to flow through the turbine to supply load as it comes on the turbine. Since switch 62 is held open by flange 63, winding 49 of the motor 47 will not be energized. As the turbine takes on load and the turbine gate opens, the bypass valve will be moved toward closed position through the action of mechanical linkage.

The rising of relay 83 allows switches 84 and 87 to open without effect on the above circuit. At the top of its stroke the relay 83 opens the switches 85 and 86 which interrupt the circuit to the relays 81 and 91. Such interruption of the relay circuits continues until the relay 83 has dropped back to the position shown. As long as the contacts 75 are bridged, the relay 81 is kept intermittently energized and causes repetitious opening and closing of the above circuits until the gate is fully opened after the load limit is fully backed off. The flange 68 on the rod 38 then opens the switch 67 to interrupt the circuit to the motor 51. It will be understood that each opening impulse to the gate produces a closing impulse on the bypass because of the mechanical relay action by way of link 40, bellcrank 39 and rod 38. Complete closing of the bypass can occur only when the load on the turbine is sufficient to require all of the water flowing into the forebay. When the turbine is at low load only, the gate will be positioned to pass only a portion of the water while the remaining water must flow through the bypass. The mechanical connection between the gate and the bypass alone adjusts the position of the bypass so long as the forebay level remains between the predetermined high and low level points.

When condition (*b*) is present in which the forebay level has dropped while the bypass valve 22 is closed, and it is desired to close the turbine gate to prevent the entrance of air into the turbine passages, the float 71 drops to the position at which the finger 73 bridges the contacts 74. The bypass valve 22 being closed by mechanical action as above stated, the flanges on the bypass rod 36 have opened the switches 96 and 97 and have closed the switch 98. Opening of the gate and closure of the bypass valve has moved the rod 38 to the position where the flange 68 has allowed switch 66 to close. The circuit is then completed to the coil of the relay 82 over the switch 84. The relay 82 closes and completes the circuit to the relay 91 and the other circuits described above as a part of the notching circuit. Circuits are then completed through the contacts 74, switches 98 and 66, the winding 52 and the armature of the motor 51 to raise the load limit finger into engagement with the flyballs 11 which raises the pilot valve 9 to admit fluid pressure for closing the turbine gates. While the bypass valve is closed, switch 96 is held open by a flange on rod 36 so that, at such time, winding 48 will not be energized and operation of motor 47 will not result. However, as soon as the turbine gate begins to close, the bypass will begin to open slightly by mechanical action and thereby open switch 98 and permit switch 96 to close. Winding 48 of motor 47 is energized by way of the switch 61 to lift the fulcrum 41 and to close the bypass 22 against the mechanical opening of the bypass as the gates are closed. Lifting of the fulcrum and closing of the bypass interrupts the circuit to the motor 51 intermittently and mechanical opening of the bypass restarts the motor 51 so that the gate is closed by increments. Each closing movement of the gate causing opening movement of the bypass, is superposed on the closing movement of the bypass due to raising of the fulcrum and the bypass therefore also closes by increments until the gate is fully closed. The circuits of motors 47 and 51 are then interrupted by switches 96 and 98 respectively.

When condition (*c*) prevails the forebay level is rising so that the bypass or the gate should be opened. No action takes place until the float 71 has risen sufficiently to cause bridging of the contacts 75 by the finger 73. The relay 81 is then energized and the above described notching circuit including the relay 91 are energized. Circuits are therefore completed to the bypass motor 47 and its winding 49 over the switch 62 and the contacts 75. The fulcrum rod 41 then moves down intermittently and causes movement of the bypass 22 downwardly until the flange 63 on the fulcrum rod opens the switch 62. As soon as the flange on the bypass rod allows switch 97 to close, circuits are also completed by the relay 91 to the armature of the motor 51 and its winding 53 over the switches 67, 97 and the contacts 75 to move the load limit finger away from the flyballs to allow the turbine gate to be opened either manually or under the control of the flyball head 11. When the fulcrum 41 has been lowered to fully open the bypass, the flange 63 opens the switch 62 and the circuit to the winding 49 of the motor 47 is interrupted. Load coming on the turbine opens the gates and the flange 68 on rod 38 opens the switch 67 to interrupt the circuit to the winding 53 of the motor 51. The action of opening the gates causes mechanical closing of the bypass as required by the load to be supplied by the turbine.

It will be seen from the above, that the gate of the turbine is responsive to the load on the turbine under the control of the flyball head excepting that the load limit blocks movement of the flyballs when the forebay level is low. Indirectly, therefore, the gates of the turbine are responsive to low level in the forebay as well as responsive to turbine load. The bypass is responsive to high and low levels in the forebay but between such high and low levels the bypass is regulated only by mechanical relaying action from the turbine gates. Both the turbine gates and the bypass can, of course, be manually actuated if desired.

Although but one embodiment of the present invention has been illustrated and described, it will be apparent to those skilled in the art that

various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electrically operated means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electrically operated means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the movement of said gate, and circuits for energizing both of said electrically operated means, said circuits being so arranged that at low forebay level said gate opening limit means moves in the direction of decreased load setting and the fulcrum of said leverage moves into the position to cause closing of said bypass while at high forebay level said limit means and the fulcrum of said leverage move in the direction of increased load setting and into position to cause opening of said bypass respectively, said circuits including a plurality of pairs of contacts bridged responsive respectively to high and low levels of water in the forebay for controlling completion of said circuits.

2. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electrically operated means movable for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electrically operated means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the movement of said gate, and circuits for energizing both of said electrically operated means, said circuits being so arranged that at low forebay level said gate opening limit means moves in the direction of decreased load setting and the fulcrum of said leverage moves into the position to cause closing of said bypass while at high forebay level said limit means and the fulcrum of said leverage move in the direction of increased load setting of said load limit means and into the position to cause opening of said bypass, respectively, said circuits including, a plurality of pairs of contacts bridged responsive respectively to high and low levels of water in the forebay for controlling completion of said circuits, and switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass.

3. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electrically operated means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electrically operated means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the movement of said gate, and circuits for energizing both of said electrically operated means, said circuits being so arranged that at low forebay level said gate opening limit means moves in the direction of decreased load setting and the fulcrum of said leverage moves into the position to cause closing of said bypass while at high forebay level said limit means and the fulcrum of said leverage move in the direction of increased load setting of said load limit means and into the position to cause opening of said bypass, respectively, said circuits including, a plurality of pairs of contacts bridged responsive respectively to high and low levels of water in the forebay for controlling completion of said circuits, switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass, and switches actuated by the stem of said bypass valve for interlocking the circuits of said electrically operated means to prevent simultaneous closing and opening of said gate and said bypass.

4. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectivley closing and opening said gate, reversible electrically operated means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, reversible electrically operated means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the movement of said gate, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for intermittently energizing both of said electrically operated means in either direction of operation, said circuits including a plurality of pairs of contacts for severally controlling completion of said circuits upon the several bridging of said pairs of contacts responsive to high and low levels of water in the forebay, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position.

5. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electric motor driven means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for energizing both of said motors and including a plurality of pairs of contacts bridged responsive to high and low water levels in the forebay for controlling completion of said circuits, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position.

6. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electric motor driven means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for energizing both of said motors, said circuits including a plurality of pairs of contacts bridged responsive to the water level in the forebay for controlling completion of said circuits, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position, and switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass.

7. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, electric motor driven means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for energizing both of said motors, said circuits including a plurality of pairs of contacts bridged responsive to high and low levels of water level in the forebay for controlling completion of said circuits, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position, switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass, and switches interlocking the circuits of said motors and actuated by the stem of said bypass valve to secure synchronous opening and closing of said gate and said bypass respectively.

8. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, reversible electric motor driven means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, reversible electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for intermittently energizing both of said motors in either direction of operation and including a plurality of pairs of contacts for severally controlling completion of said circuits upon the several bridging of said pairs of contacts responsive to high and low levels of water in the forebay, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position.

9. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, reversible electric motor driven means for limiting gate

opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, reversible electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for intermittently energizing both of said motors in either direction of operation, said circuits including a plurality of pairs of contacts for severally controlling completion of said circuits upon the several bridging of said pairs of contacts responsive to high and low levels of water in the forebay, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position, and switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass.

10. In a control system for hydraulic turbines supplied with water from a forebay under control of a gate, means responsive to increase and decrease in the speed of the turbine for respectively closing and opening said gate, reversible electric motor driven means for limiting gate opening movement of said speed responsive means, a valved bypass for conducting water from the forebay and around the turbine, a leverage mechanically interconnecting said gate and the valve of said bypass and pivoted on an adjustable fulcrum, said leverage opening said bypass upon closing of said gate and vice versa responsive to changes in load on the turbine, reversible electric motor driven means for moving the fulcrum setting of said leverage for controlling operation of the valve of said bypass regardless of the action of said gate on said leverage, the fulcrum being lowered at high water levels tending to move the bypass valve to open position when said gate is closed and being raised at low water levels tending to move the bypass valve to closed position, and circuits for intermittently energizing both of said motors in either direction of operation, said circuits including a plurality of pairs of contacts for severally controlling completion of said circuits upon the several bridging of said pairs of contacts responsive to high and low levels of water in the forebay, bridging of said pairs of contacts at high level completing the circuit for backing off said load limit means and bridging of said pairs of contacts at low level completing the circuit for moving said load limit means into load limit position, switch means operated by said leverage for stopping both of said electrically operated means when said means severally reach predetermined settings in the direction of opening and closing said gate and of opening and closing said bypass and switches interlocking the circuits of said motors and actuated by the stem of said bypass valve to secure synchronous opening and closing of said gate and said bypass respectively.

ARNOLD PFAU.
TERRYL B. MONTGOMERY.