This invention relates to improvements in mechanisms for controlling the flow of water and more particularly to means for balancing hydraulic forces having undesired actions on the control gates or valves or hydraulic turbines and tending to make actuation of the gates more difficult and uncertain.

In the usual impulse turbine, the jet of water is directed toward the buckets of the turbine wheel by a fixed nozzle of the converging jet type and the volume of the water passing through the nozzle is controlled by a needle or valve having a streamlined enlarged free end or tip movable into and out of the nozzle opening. The needle is operated by a servomotor, usually of the fluid pressure actuated type, which is controlled by a speed governor. When the needle is in the position at which it closes the nozzle, the needle is subject to forces tending to keep the needle closed against any opening movement of the operating servomotor. Such force is determined by the effective cross sectional area of the needle (the area of the nozzle opening minus the area of the needle stem) times the pressure in the nozzle pipe. As the needle is withdrawn from the nozzle to the open position, the needle tip is drawn backward into the nozzle opening into a region where a static pressure acts on the tip in the needle opening direction. Further, the flow of water about the needle stem must be turned along the streamlined surface of the needle tip and the reaction of the force required for turning the water along the surface of the needle tip also tends to cause opening of the needle. The above two forces add the action of the servomotor in opening the needle but in the wide open needle position act to oppose any closing movement of the servomotor and tend to retain the needle in its wide open position. It will therefore be seen that forces acting on the needle oppose the action of the servomotor both in opening the needle from its closed position and in closing the needle from its wide open position.

The forces opposing movement of the needle in both the closing and opening direction can be computed on a theoretical basis or can be determined from measurement and test on a completed nozzle. If the forces are computed before manufacture of the nozzle and needle, the present invention teaches how to so design and proportion the parts that the closing and opening forces are approximately balanced. When the forces are balanced, the needle operating servomotor can be kept to the minimum size required mainly to move the mass of the needle and to overcome friction without also providing sufficient power to overcome adverse hydraulic forces opposing movement of the needle.

In the usual reaction type turbine, the quantity of water delivered to the turbine runner or wheel from the spiral casing is controlled by a plurality of vanes on vertical axes linked to a ring on the cover plate of the turbine. The position of the ring is changed or shifted by a fluid pressure operated servomotor controlled by a speed responsive governor. As in the usual impulse type turbine, the hydraulic forces act on the vanes of a reaction turbine to oppose the action of the servomotor at various positions of adjustment, and frequent reversals of force are required from the servomotor for operating the gate vanes.

It is therefore an object of the present invention to provide improved means for balancing hydraulic forces acting on the water supply control gate or valve of hydraulic turbines to oppose either the closing or opening operation of the usual controlling servomotor.

Another object of the invention is to provide means for avoiding or minimizing the reversals of force in the operation of a servomotor actuating the needle valve or other devices controlling the supply of water to a hydraulic turbine.

Another object of the invention is to provide a cylinder having a piston movable therein responsive only to hydraulic forces opposing the closing and opening of the water flow control gate or valve of a hydraulic turbine and acting on such gate or valve in such direction as to tend to balance such forces.

Another object of the invention is to provide a cylinder connected with the penstock and with a point of varying pressure in the nozzle on an impulse hydraulic turbine and a piston connected with the nozzle needle or valve which is subject to forces opposing the closing and opening of the needle to thereby balance such forces and to reduce the total forces required from a servomotor for operating the needle.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawing, in which:

The figure of the drawing is a somewhat diagrammatic view showing an impulse hydraulic turbine with its nozzle and needle operable by a hydraulic servomotor controlled by a pivot valve actuated by a speed governor and having a cylinder and a piston formed as a portion of the nozzle and needle structure and subject to hydraulic forces acting on the needle to thereby
balance such forces as oppose the action of the needle operating servomotor.

Referring more particularly to the drawing by characters of reference, the reference numeral 11 designates a foundation provided with a water discharge passage 12 and having mounted thereon a casing 13 enclosing a wheel 14 from the periphery of which buckets 15 extend into a jet of water. A water pressure supply conduit or penstock 17 ends in a converging nozzle 18 extending adjacent the buckets 15 and the volume of water discharged through the nozzle is controlled by a needle which may be considered as formed with the stem portion 21 and an enlarged or bulbous tip portion 22 for the purpose of seating in the nozzle 18 and forming a gate for closing off the nozzle discharge opening. The stem 21 of the needle extends through the walls of the supply penstock 17 and is shown as having a piston portion 23 formed thereon for movement in a cylinder 24, shown as formed integral with the supply pipe 17. It will be understood that the piston 23 and cylinder 24 may be made as separate parts with the piston merely attached to the stem and that the cylinder may be mounted on the supply pipe or adjacent thereto.

The needle 21, 22 is movable to control the effective open area of the nozzle 18, by a fluid pressure operated servomotor comprising a cylinder 26 and a piston 27 movable therein. The servomotor cylinder 26 is shown as mounted on the balancing cylinder 24 by a spacer 28 but may be separately mounted and the servomotor piston 27 is shown as directly connected with a needle stem 21, but may be otherwise connected therewith. Movement of the servomotor piston 27 is under the control of a pilot valve 30 receiving fluid pressure from a suitable source by way of a pipe 31 and discharging fluid pressure from the servomotor cylinder 26 by way of a pipe 32. Pipes 33 and 34 connect the pilot valve 30 with the servomotor 27 at the opposite ends thereof. Pilot valve 30 is connected with a lever 35 which is adjustable by means of the usual synchronizing screw 37 and which is connected by a link 38 with a floating lever 39 of a speed governor. The speed governor comprises a fluid pressure operated servomotor generally indicated at 41 which is controlled by a fl yball head 42 driven by a motor 43 which is energized from an electric line 44 connected with a generator (not shown) driven by the turbine. Movement of the servomotor piston 27 is transmitted by a bell crank 45 to a rod 47 connected with a lost motion or time delay device 48 which is in turn connected with the end of the floating lever 38. Speed variations of the turbine 14, 16 and of its governor affect the speed of the motor 43 to control the flyball head 42, the servomotor 41 and the floating lever 38, as is disclosed in U. S. Patent 2,106,684 to Ring, Nichols and Pfau dated January 25, 1938. The other portions of the governing system and their actions and functions are likewise well known and are not therefore further described.

The needle tip 22 is provided with ports 51 leading to a passage 52 extending centrally through the needle stem 21 to ports 53 in the stem and on the right hand side of the balance piston 23. The balance cylinder 24 is connected by a port 54, at the left hand end and opposite from the cylinder portion into which the needle ports 53 discharge, with the penstock 17. It will be seen that the effective area of the piston 23 is greater on one side thereof than on the other; that is, the piston 23 is a differential piston. The effective areas of the balance piston 23 are critical points of the structure in that for maximum balance, the diameter of the piston should be equal to the diameter of the discharge opening of the nozzle and the larger area of the piston should be of sufficient size to counteract the forces tending to open the needle. The location and size of the pressure points in the structure. The ports 51 must be located, for maximum balance, on the portion of the needle tip 22 just forward; that is, toward the tip of the needle, of the annular portion of the needle tip surface seating in the nozzle when the needle is closed and in such position that variations in the pressure areas through which the needle moves correspond to variations in the hydraulic forces acting on the needle tip. The size of the needle ports 51 depends on the desired and designed rate of flow through the needle. Because of the high pressure and long penstocks usual with impulse turbine installations, the desired rate of movement of the needle is slow and the ports are therefore quite small.

In operation, when the needle 21, 22, ports 51 are open to atmospheric pressure within the turbine casing 13 and such pressure acts through the ports 51, the needle passage 52, ports 53 and in the right hand end of the cylinder 24 on the larger face of the balance piston 23. The full penstock pressure in pipe 17 will, however, act through the port 54 in the left hand end of the cylinder 24 on the smaller face of the balance piston 23. If such smaller piston face is equal in diameter to the diameter of the nozzle opening, the pressure acting on the needle tip portion inside of the nozzle which tends to keep the needle in closed position is exactly balanced by the pressure on the balance piston and the operating servomotor 26, 27 need not be designed to provide a force to overcome the pressure on the needle tip in the closed position, but only to overcome friction. When the needle is to be moved to open the nozzle, the operating servomotor 26, 27 draws the needle backward and the ports 51 immediately enter a region of static pressure just within the nozzle, which acts on the needle tip. Such pressure is transmitted through the ports 51, passage 52 and ports 53 and acts on the larger face of the balance piston 23. The static pressure also acts on the needle, tending to open the needle. Such pressure on the needle tip and the reaction due to the turning of the water along the surface of the tip, which also tends to open the needle, is balanced by the pressure acting on the larger face of the balance piston 23. The forces tending to force the needle into the full open position are therefore balanced and the opening servomotor 26, 27 need be designed only to overcome the inertia and frictional resistance of the needle to opening movement.

While the improved device has been specifically illustrated and described as utilized in conjunction with a hydraulic turbine of the impulse type, it may also be employed for balancing other flow control mechanisms against variations in pressure.

From the above description it will be seen that the present invention provides means for balancing the afore described port and controlling valve of a hydraulic turbine and for which the operating servomotor must now be designed in addition to the power required for overcoming the inertia and frictional resistance in
the valve movement. The operating servomotor can therefore be greatly reduced in size and the entire flow control has greatly increased sensitivity. It will further be seen that the structure is available for all pressures and volumes of water encountered and that varying inlet pressure is of no consequence in operation of the valve because of the fact that the operation of the balance cylinder and its piston is directly hydraulically responsive to the various pressure differences. Although the hydraulic connections have been shown in the simplest way possible, it will be understood that the arrangement of the passages from the different pressure points may be modified, within the scope of the claims, from the specific arrangement disclosed herein.

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 device for balancing the forces acting on a gate controlling the flow of water under pressure in a conduit and having a tendency to move in a closing direction, said conduit having points of substantially constant and variable pressure, a cylinder connected with said points of substantially constant and variable pressure, and a piston movable in said cylinder and connected with said gate for balancing the varying forces acting thereon, one side of said piston being subjected to the constant pressure to oppose movement of said gate in a closing direction and the other side of said piston being subjected to the variable pressure to assist the tendency of said gate to move in said closing direction.

2. In a device for balancing the forces acting on a gate controlling the flow of water under pressure in a conduit, said gate being constructed to have a tendency to move in a closing direction, a cylinder having one end thereof connected with a point of substantially constant pressure in said conduit and having the other end thereof connected with a point of variable pressure in said conduit, and a differential piston movable in said cylinder and connected with said gate for balancing the varying forces acting thereon, the smaller side of said piston being subjected to the constant pressure to oppose the tendency of said valve to move in said closing direction and the larger side of said piston being subjected to the variable pressure to assist the tendency of said valve to move in said closing direction.

3. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, and a piston within a cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit to assist the tendency toward movement of said needle.

4. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, and a piston within a cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit to assist the tendency toward movement of said needle.

5. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, and a piston within a cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit to assist the tendency toward movement of said needle.

6. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, and a piston within a cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit to assist the tendency toward movement of said needle.

7. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, and a piston within a cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit to assist the tendency toward movement of said needle.
needle to assist the tendency toward movement thereof, one aperture of the needle passage being outside of the seat in said needle when said needle is in seated position.

8. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a passing passage extending therethrough, said needle having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, a cylinder connected by a passage with said conduit, and a piston within said cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit acting through the passage connecting said conduit with said cylinder to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit acting through the passage extending therethrough, said needle having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, a cylinder connected by a passage with said conduit, and a piston within said cylinder and connected with said needle for balancing the forces acting thereon, the area of the needle passage being dependent upon the designed speed of movement of said needle.

9. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in said nozzle for controlling the discharge of water therefrom and having a passing passage extending therethrough, said needle having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, a cylinder connected by a passage with said conduit, and a piston within said cylinder and connected with said needle for balancing the forces acting thereon, one side of said piston being subjected to the full pressure in said conduit acting through the passage connecting said conduit with said cylinder to oppose the tendency toward movement of said needle and the other side of said piston being subjected to a pressure varying from atmospheric pressure to the full pressure in said conduit acting through the passage extending therethrough, said needle having a tendency to move in one direction, a servomotor for moving said needle to and from the seat in said nozzle, a cylinder connected by a passage with said conduit, and a piston within said cylinder and connected with said needle for balancing the forces acting thereon, the area of the needle passage being dependent upon the designed speed of movement of said needle.

10. In a device controlling the discharge of water as a jet, a conduit for conveying the water under pressure, a nozzle connected with said conduit, a needle extending through and seating in