

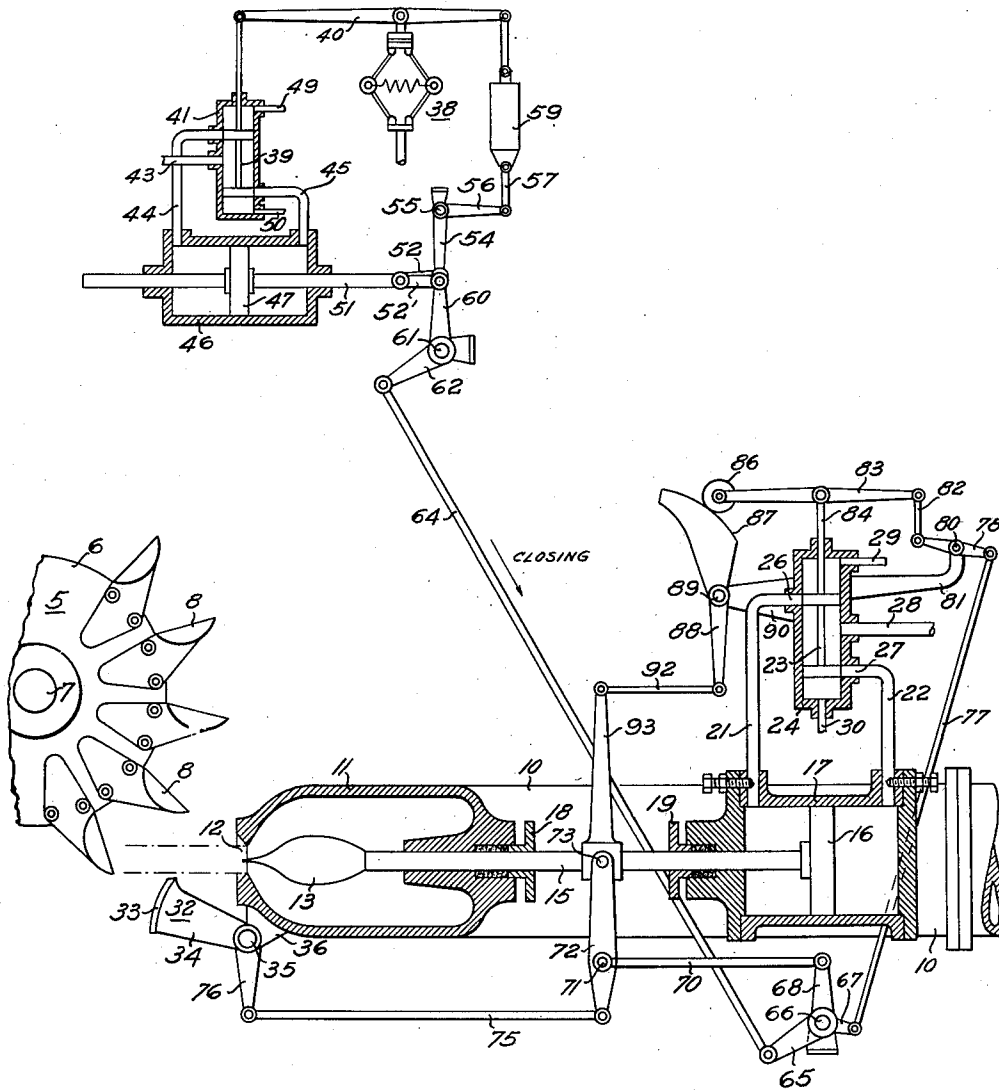
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HYDRAULIC TURBINE

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HYDRAULIC TURBINE

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The present invention relates generally to improvements in hydraulic turbines and relates more particularly to improvements in the control and operation of hydraulic turbines of the impulse type.

Considerable difficulty has heretofore been experienced in controlling the supply of operating fluid to impulse turbine runners responsive to load conditions thereon. The operating fluid is generally supplied to the runners of impulse turbines through a long pipe line and under an extremely high pressure. It is, therefore, highly impractical to utilize a quick acting valve for controlling the amount of fluid delivered to the turbine runner in accordance with variations in load upon the turbine because of the imminent danger of bursting the pipe line when rapid changes in the velocity of the flowing fluid within the pipe line are effected. Since sudden variations in the load on a turbine of this type are frequent, it is extremely dangerous to attempt sufficiently rapid closing of the valve in the supply pipe or nozzle to maintain the speed of the runner constant.

To eliminate the obvious disadvantages attendant the use of quick acting valves in the fluid supply lines of impulse turbines, it has heretofore been common practice to permit the operating fluid to issue from the nozzle at a constant rate, compensating for changes in load by deflecting more or less of the operating fluid from the buckets or blades of the runner. This deflection of a portion of the stream of operating fluid may be effected either by means of a movable nozzle which may be tilted toward or away from the buckets to change the direction of fluid flow, or by means of a separate deflector element having a hood or the like which may be moved into or out of the path of the operating fluid to deflect more or less of the fluid away from the buckets. In such installations, the fluid deflected from the buckets is wasted and performs no useful function, thereby undesirably depleting the fluid supply in the main reservoir.

To substantially reduce the large amounts of fluid wasted through the use of devices of the type hereinabove described, it has also been heretofore proposed to provide a combination of quick acting fluid deflector and relatively slow acting valve means for controlling the amount of fluid issuing from the nozzle. Such devices are likewise of two types, one type being provided with a movable nozzle for quickly deflecting the stream of operating fluid and with a needle valve for more slowly controlling the flow of fluid through the

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nozzle, and the other type being provided with a separate deflector including a hood or the like for quickly deflecting the stream or jet and with a needle valve for subsequently slowly controlling the flow of fluid through the nozzle. Many systems for synchronously controlling the operation of the jet deflecting means and the needle valve means of these prior art assemblages have heretofore been proposed. However, in the past, considerable difficulty has been encountered in providing a simple and universally applicable system for controlling the operation of the jet deflecting and needle valve means in complete synchronism and without considerable undesirable fluctuation in the speed of the wheel or runner during adjustment of the deflector and needle valve to a new position.

It is therefore an object of the present invention to provide an improved system for automatically controlling the supply of operating fluid to the runner of an impulse turbine which obviates the objectionable features of prior systems and devices.

Another object of the present invention is to provide an improved control system for synchronously operating the jet deflector and needle valve of an impulse turbine responsive to variations in load on the turbine.

Another object of my invention is to provide an improved hydraulic impulse turbine having a jet deflector and a needle for controlling flow of fluid through the nozzle with means for automatically controlling the operation of the jet deflector and needle in synchronism through the expedient of a single simple relay servomotor and standard speed governor.

Another object of the invention is to provide an improved hydraulic impulse turbine having a jet deflector and a needle for controlling flow of fluid through the nozzle with means for quickly actuating the deflector directly in response to load changes through a connection with a standard relay speed actuated governor and for simultaneously but more slowly moving the needle to effect corresponding adjustments in the position thereof, the deflector being returned to neutral position out of the path of the fluid as the needle is moved to adjusted position.

An additional object of the present invention is to provide an improved hydraulic impulse turbine comprising, a runner, a nozzle for directing a stream of fluid against the runner, a needle for controlling the flow of fluid through the nozzle, a pilot valve controlled servomotor for operating the needle, a deflector movable into and out of the

path of the fluid, a governor, means operatively connecting the governor with the deflector for moving the deflector directly in response to changes in load, means for simultaneously operating the pilot valve of the servomotor to effect adjustments in the position of the needle, and means directly responsive to the movement of the needle for moving the deflector to a position just out of the path of the fluid for each adjustment of the needle.

A further object of this invention is to provide an improved governing system for hydraulic turbines of the impulse type which is simple, durable, and inexpensive in construction and which is highly efficient and economical in operation.

Additional objects and advantages of the present invention will be apparent from the following detailed description.

A clear conception of one embodiment of the present improvement and of the mode of constructing and of utilizing apparatus built in accordance with my invention may be had by referring to the drawing accompanying and forming a part of this specification wherein the various parts are referred to by suitable reference characters.

The single figure shown in the drawing is a vertical section through a hydraulic turbine of the impulse type embodying the features of my present improvement.

Referring to the drawing, the reference numeral 5 designates the impulse wheel or runner generally. The runner 5 may be of well known construction, consisting of a disc 6 keyed to the shaft 7 and provided with a plurality of buckets or blades 8 suitably mounted at spaced intervals around the periphery thereof.

The runner 5 is driven by a jet or stream of water under pressure delivered from a suitable source of supply (not shown) by way of a pipe 10 and issuing, as indicated by dot and dash lines, from the discharge orifice 12 of a stationary nozzle 11 against the buckets 8 of the runner. An axially movable needle valve 13 for forming the operating jet and regulating the quantity of water delivered from the nozzle to the runner is provided within the nozzle 11. The amount of water delivered by the nozzle is controlled by the position of the needle as will be hereinafter more fully described.

The needle valve 13 is carried by a stem 15 secured at the end thereof to a piston 16 operating in a hydraulic cylinder 17, suitable packings 18, 19, respectively, being provided between the stem 15 and nozzle 11 and the stem 15 and cylinder 17. To actuate the piston 16, the fluid under pressure is admitted to, and discharged from, the front and rear portions of the cylinder in a well known manner by way of pipes 21, 22, respectively. Fluid flow to the cylinder 17 through the pipes 21, 22 is controlled by a pilot valve 23 working within a cylinder 24 to open and close the outlet ports 26, 27 of the cylinder 24, which ports communicate with the pipes 21, 22, respectively. Fluid under pressure is supplied to the cylinder 24 by way of pipe 28 from a suitable source (not shown), and the opposite ends of the cylinder 24 are suitably vented as by pipes 29, 30 to permit escape of fluid displaced in the cylinder 17 during movement of the piston 16.

In addition to the needle valve 13 for regulating the jet issuing from the nozzle 11, a deflector 32 is provided. As shown, the deflector 32 comprises a hood or deflector plate 33 carried by an arm or arms 34 mounted on a rockshaft 35 which,

in turn, is supported by one or more lugs 36 suitably formed on the nozzle 11 adjacent the discharge end thereof. As will hereinafter more clearly appear, the deflector 32 is swingable into the jet issuing from the nozzle 11 to deflect portions thereof from the buckets 8 of the impulse wheel until such time as the needle valve 13 may be moved to the new position of adjustment.

Movement of the needle valve 13 and deflector 32 is controlled by a governor 38, shown herein as being of the flyball type but which may be of any known construction. The governor 38 is suitably driven, through mechanical or electrical connections, in accordance with the speed of the runner 5. As herein illustrated, the governor is connected to a floating lever 40 pivotally attached at one end (left) thereof to the stem of a pilot valve 39 operating in a cylinder 41 to control the passage of fluid under pressure, supplied by a pipe 43 from a suitable source (not shown), through pipes 44, 45 leading to opposite ends of a cylinder 46 having a piston 47 provided therein. The pilot valve cylinder 41 is also vented at opposite ends, as by pipes 49, 50 to permit escape of fluid displaced in the servomotor cylinder 46 during movement of the piston 47 as will hereinafter more clearly appear.

The piston 47 carries a rod 51 extending through an end wall of the cylinder 46, suitable packing being provided between the end wall and the axially movable rod. The rod 51 is connected, as by a link 52 or the like, to a crank arm 54 carried by a rockshaft 55 which also has a crank arm 56 mounted thereon forming a bell crank. The crank arm 56 is, in turn, connected by a link 57 to a compensator device 59 which relays the motion of the piston rod 51 to the opposite end (right) of the floating lever 40 in the usual manner to return the pilot valve 39 to neutral position.

The rod 51 is further connected, by a link 52', to a crank arm 60 mounted on a rockshaft 61 which also has an arm 62 secured thereto to form a bell crank. A rod 64 connects the crank arm 62 with a crank arm 65 secured to a rockshaft 66 which has crank arms 67, 68 secured thereto to likewise form a bell crank.

The crank arm 68 carries a rod 70 which is pivotally attached at 71 to a floating power lever 72 having one end thereof pivotally mounted at 73 on the valve stem 15. The lever 72 is connected at its opposite end, by a connecting rod 75, to a crank arm 76 secured to the rockshaft 35 carrying the deflector 32. It is thus apparent that any change recorded by the governor 38 in the speed of the impulse wheel 5 is relayed, by way of pilot valve 39 and associated mechanism, to the servomotor 46, 47 and to the deflector 32 through the described mechanical connections including bell crank 60, 62, connecting rod 64, bell crank 65, 68, rod 70, lever 72, connecting rod 75, and bell crank 76, 34.

To communicate such speed changes to the needle valve 13, the crank arm 67 is connected, by way of a rod 77, to one end of a lever 78 pivotally mounted at 80 on a fixed support 81. The lever 78 is connected at its opposite end, by a link 82, to one end of a floating lever 83 which is pivoted at the opposite end thereof on a roller 86 and is connected, intermediate its ends, to the stem 84 of the pilot valve 23. Thus, as the bell crank 65, 67 rotates, responsive to changes in the speed of the wheel 5 relayed from the governor, such changes are obviously relayed by way of rod 77, lever 78, linkage 82, and lever 83 to the pilot

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valve 23 which controls the hydraulic pressure supply to servomotor cylinder 17 for actuating the piston 16 which carries the valve stem 15, thereby adjusting the needle valve 13 to a new position.

To restore the pilot valve 23 to neutral position as the needle valve 13 is moved the distance necessary to effect the demanded jet adjustment, a cam 87 carrying the roller 86 of the floating lever 83 is provided. The cam 87 is formed on one end of a lever 88 pivotally mounted at 89 on a fixed support 90, and the opposite end of the lever 88 is connected, by a link 92 or the like, to an arm 93 carried by the valve stem 15. Therefore, as the valve stem 15 of the valve 13 is moved by the piston 23, the arm 93 is carried therewith, thereby causing the lever 88, through linkage 92, to rotate the cam 87. As the cam 87 is rotated, the roller 86 is moved over the cam surface, thereby causing the floating lever 83 to likewise follow the movement thereof to restore the valve 23 to neutral position whereby further movement of the piston 16 and needle valve 13 is stopped by closing off the fluid supply to the cylinder 17.

As the needle valve 13 is moved by hydraulic pressure to its new position of adjustment, the deflector is simultaneously caused to move to a position whereby the hood 33 is stopped just outside of the jet upon completion of movement of the valve 13. This movement of the deflector is caused by rotation of the floating lever 72 around the pivot 71 as the lever is carried, by reason of its pivotal connection, with the valve stem 15, such movement being relayed to the deflector 32 through rod 75 and crank arms 76, 34.

The shape of the cam 87 and the relationship of the levers and movements are such that there is a position of the deflector 32 whereby the hood 33 thereof is just outside of the path of the jet for each position of adjustment of the needle valve 13, and there is likewise a fixed position for the bell crank 65, 68 and the pivot pin 71 for each load imposed on the governor 38 whereby the improved device will reduce the jet to the proper size and simultaneously move the deflector hood 33 to a point just outside of the path of the jet.

From the foregoing it will now be evident that in combination with a hydraulic impulse wheel 5, a nozzle 11 for directing a stream of fluid against the wheel, a needle 13 for controlling the flow of fluid through the nozzle and deflector means 32 movable toward and away from the stream, a control means has been provided for restoring the speed of the wheel to a selected value by positioning the deflector means and the needle in response to change of speed upon change to a given load on the wheel. This control means comprises the following principal elements: a control member, which may be taken as the rod 51, along with means, here shown as including a servo-motor piston 47, adapted to move the control member 51 to a position predetermined by the load on the wheel and the selected value of speed at which it is desired that the wheel shall rotate; flyballs 38, which control the position of the control member 51. A change in load on the wheel is reflected in a temporary change in the position of the flyballs and such change in position causes the control member 51 to assume a predetermined new position; actuating means for the needle 13, which is here shown as provided

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by a servo-motor including a pilot valve 23, any suitable connection, such as the linkage extending from the control member 51 to the pilot valve 23, providing means whereby the needle actuating means is caused to adjust the needle to a position which depends on the position of the member 51; and means dependent upon the position of the control member 51 and dependent upon the position of the needle 13 for positioning the deflector means 32, this means being here shown as including a link 70, a lever 72, and a link 75. While the principal elements of the control means have been identified in the particular embodiment shown in the drawing, it will be understood that this has been done by way of explanation with respect to the illustrated embodiment and not by way of limitation since those skilled in the art will understand that the invention may assume other embodiments. The operation of the invention will now be considered in detail with reference to the illustrated embodiment.

In describing the operation of the improved device, all of the parts of which are shown in the drawing as being in neutral position indicative of no load change, let us assume that there is a drop or reduction in load on the turbine. As the load on the turbine drops, the speed at which the runner 5 is driven by the jet issuing from the nozzle 11 increases; and this increase in speed of the runner is transmitted to the governor 38 in a well known manner, causing the flyballs to move outwardly by centrifugal force against the restraining action of their spring. As the governor thus responds to the increase in speed of the runner, the pilot valve 39, by reason of the connection of its stem with the left hand end of floating lever 40, is caused to be lowered within the cylinder 41, thereby opening the passage 45 and right side of the cylinder 46 to fluid pressure supplied by way of pipe 43 and opening passage 44 and left side of cylinder 46 to vent pipe 49. As the pressure within the passage 45 and right side of cylinder 46 builds up, the piston 47 and its rod 51 are moved to the left, causing the crank arms 60, 62 and rockshaft 61 to rotate in a counterclockwise direction to move the connecting rod 64 downward while simultaneously causing the crank arms 54, 56 and rockshaft 55 to rotate in a clockwise direction to restore the pilot valve 39 to neutral position through the connection of the compensator device 59 with the floating lever 40.

As the rod 64 is moved downward, it causes the crank arms 65, 67, 68 and rockshaft 66 to rotate in a counterclockwise direction. As the crank arm 68 is thus rotated, the movement thereof is in turn relayed, by rod 70, to the floating power lever 72 which is rocked to the left about its pivot 73, thereby likewise moving the rod 75 to the left to rotate the crank arm 76, rockshaft 35, and crank arm 34 of the deflector 32 in a clockwise direction, the deflector hood 33 being carried quickly into the jet by the arm 34. The movement of the deflector hood 33 into the jet, as hereinabove described, continues until a sufficient amount of water is being deflected from the buckets 8 to regulate the runner to the reduced load, whereupon the speed of the wheel will be restored to normal and the governor will stop the movement of the rod 64, thereby holding the crank arms 65, 67, 68 and the rod 70 and pivot 71 stationary.

Upon counterclockwise rotation of the crank arm 67 when the rod 64 is moved downward as described, the rod 77 is moved upward, rotating the lever 78 in a counterclockwise direction about its pivot 80 and thereby lowering the right hand end of floating lever 83 and causing the pilot valve 23, by reason of the connection of its stem 84 with the lever 83, to be lowered in its cylinder 24. As the valve 23 is lowered, the port 27, passage 22 and right side of servomotor cylinder 17 are opened to fluid pressure supplied by way of pipe 28, and the port 26, passage 21 and left side of cylinder 17 are opened to vent pipe 29. As the pressure in the passage 22 and right side of cylinder 17 builds up, the piston 16 slowly advances to the left within the cylinder, carrying the valve stem 15 and needle valve 13 therewith to gradually reduce the size of the jet issuing from the orifice 12 of the nozzle 11.

As the stem 15 of the needle valve is moved to the left, it carries the pivot pin 73 with it, thereby rotating the lever 72 counterclockwise about the pivot 71. This rotation of the lever 72 about the pivot 71 moves the deflector hood 33, through rod 75 and crank arms 76, 34, slowly in a counterclockwise direction to a point just outside of the path of the jet as shown in the drawing, whereupon movement of the needle valve 13 and deflector 32 is stopped, as will be hereinafter more fully described, with the jet reduced to correspond with the changed load requirement of the turbine.

During movement of the needle valve as hereinabove described, the stem 15 also carries the arm 93 to the left, thereby rotating the lever 88, through linkage 92, in a clockwise direction about the fixed pivot 89 and causing the cam 87 to raise the roller 86 and floating lever 83. As the lever 83 is thus raised, valve 23 is likewise lifted in cylinder 24 until it is restored to its neutral position, as shown, closing off the ports 26, 27 and passages 21, 22, thereby stopping movement of the piston 16 and needle valve 13 as well as the deflector 32. The adjustment of the jet issuing from nozzle 11 to correspond with the reduction in load on the turbine is thus completed and the various parts are retained in neutral position until again called up by the governor to effect a new adjustment for a change in load.

If there is a load increase on the turbine, the reverse sequence of operation obviously occurs, pilot valve 39 being raised to admit fluid under pressure to the left side of servomotor cylinder 46, thereby moving the piston 47 to the right until stopped by restoration of the pilot valve, through action of the compensator device 59 and floating lever 40, to neutral position. Movement of the piston 47 and rod 51 to the right rotates crank arms 60, 62 clockwise to raise the rod 64, rotating the crank arms 65, 67, 68 clockwise. As crank arm 68 rotates, rod 70, lever 72 and rod 75 are moved to the right to rotate the crank arms 76, 34 counterclockwise, thereby immediately quickly moving the deflector away from the jet. Simultaneously with the rotation of crank arm 68, crank arm 67 rotates and moves rod 77 downward, thereby raising the right hand end of floating lever 83 to lift pilot valve 23 and admit fluid under pressure to the left side of servomotor cylinder 17. As pressure builds up in the left side of cylinder 17,

the piston 16 is moved to the right, causing the needle valve 13 to open and increase the size of the jet while simultaneously rotating the deflector, through lever 72, rod 75 and crank arms 76, 34, to a position such that the hood 33 is just outside of the path of the increased jet and likewise simultaneously rotating the lever 88 and cam 87, through link 92 and arm 93, counterclockwise the roller 86 and floating lever 83, thereby restoring the valve 23 to neutral position and stopping movement of the piston 16, needle valve 13 and deflector 32.

From the foregoing detailed description, it is apparent that the present invention provides an improved system for controlling the operation and performance of hydraulic impulse turbines wherein the operation of the several parts is completely automatic and directly responsive and proportionate to changes in load placed upon the turbine with minimum waste of water during adjustments. It is to be noted that the governor responds to every change in speed of the runner and, through servomotor 46, 47 and the described mechanical connections, relays these changes directly to the jet deflector to move the deflector quickly into or away from the operating jet a distance proportionate to the changed load. As load changes are relayed from the governor to the jet deflector, the pivot 71 is moved to and held in a new position such as will insure return movement of the deflector to neutral position with the deflector hood just out of the path of the jet after complete adjustment thereof to the changed load. Simultaneously with the initial rapid movement of the deflector, movement of the needle valve through its hydraulic control mechanism is initiated as described, such movement being relayed back to the hydraulic control mechanism by way of the cam which is moved with the needle valve to stop movement of the valve when the jet has been fully adjusted to the new load imposed on the turbine. The deflector and the needle valve are therefore operated in complete synchronism through the expedient of a single standard speed responsive governor and simple relay servomotor. The improved control mechanism is simple and durable in construction and operation and has a minimum number of parts which are all readily accessible for repair, adjustment or replacement; and hydraulic turbines embodying the invention are highly efficient and economical in operation. Obviously, although one form of governor has been diagrammatically illustrated and described in conjunction with the improved system, other known types of governors may likewise be utilized therewith without departing from the invention. Similarly, the various rods, cranks, levers and links may be rearranged and reduced or increased in numbers to suit the particular requirements attendant each installation.

It should therefore be understood that it is not desired to limit the present invention to the exact details of construction and mode of operation or the particular application herein shown and described, since various modifications within the scope of the claims may occur to persons skilled in the art to which this invention applies. It is claimed and desired to secure by Letters Patent:

1. In combination with a hydraulic impulse wheel, a nozzle for directing a stream of fluid against said wheel, a needle for controlling the

flow of fluid through said nozzle, deflector means movable toward and away from said stream, and control means for restoring the speed of said wheel to a selected value by positioning said deflector means and said needle in response to change of speed upon change to a given load on said wheel, said control means comprising: a control member; a servo-motor having a pilot valve, for moving said control member; means responsive to the speed of said wheel; means whereby said speed responsive means and said servo-motor act jointly to position said pilot valve to cause said servo-motor to move said control member to and leave it in a predetermined different position in response to change from and restoration to said selected speed; a second servo-motor for moving said needle; means whereby said second servo-motor is caused to adjust said needle to a position dependent upon the position of said control member, to adjust said stream; and means dependent upon the position of said control member and dependent upon the position of said needle for positioning said deflector means.

2. In combination with a hydraulic impulse wheel, a nozzle for directing a stream of fluid against said wheel, a needle for controlling the flow of fluid through said nozzle, deflector means movable toward and away from said stream, and control means for restoring the speed of said wheel to a selected value by positioning said deflector means and said needle in response to change of speed upon change to a given load on said wheel, said control means comprising: a control member; a servo-motor having a pilot valve, for moving said control member; means responsive to the speed of said wheel; means whereby said speed responsive means and said servo-motor act jointly to position said pilot valve to cause said servo-motor to move said control member to and leave it in a predetermined different position in response to change from and restoration to said selected speed; a second servo-motor having a pilot valve, for moving said needle; means whereby said pilot valve of said second servo-motor is initially positively moved to a position dependent upon the position of said control member; means, acting on the pilot valve of said second servo-motor, responsive to the movement of said needle, to cause said second servo-motor to adjust said needle to a position dependent upon the position of said control member, to adjust said stream; and means dependent upon the position of said control member and dependent upon the position of said needle for positioning said deflector means.

3. In combination with a hydraulic impulse wheel, a nozzle for directing a stream of fluid against said wheel, a needle for controlling the flow of fluid through said nozzle, deflector means movable toward and away from said stream, and control means for restoring the speed of said wheel to a selected value by positioning said deflector means and said needle in response to change of speed upon change to a given load on said wheel, said control means comprising: a control member; a servo-motor having a pilot valve, for moving said control member; means responsive to the speed of said wheel; means whereby said speed responsive means and said servo-motor act jointly to position said pilot valve to cause

said servo-motor to move said control member to and leave it in a predetermined different position in response to change from and restoration to said selected speed; a second servo-motor having a pilot valve, for moving said needle; means whereby said pilot valve of said second servo-motor is initially positively moved to a position dependent upon the position of said control member; means, acting on the pilot valve of said second servo-motor, responsive to the movement of said needle, to cause said second servo-motor to adjust said needle to a position dependent upon the position of said control member, to adjust said stream; and means constructed and arranged initially to move said deflector means in a given direction in response to movement of said control member and then to move said deflector means in the opposite direction to a position dependent upon the position of said control member and dependent upon the position of said needle.

4. In combination with a hydraulic impulse wheel, a nozzle for directing a stream of fluid against said wheel, a needle for controlling the flow of fluid through said nozzle, deflector means movable toward and away from said stream, and control means for restoring the speed of said wheel to a selected value by positioning said deflector means and said needle in response to change of speed upon change to a given load on said wheel, said control means comprising: a control member; a servo-motor having a pilot valve, for moving said control member; means responsive to the speed of said wheel; means whereby said speed responsive means and said servo-motor act jointly to position said pilot valve to cause said servo-motor to move said control member to and leave it in a predetermined different position in response to change from and restoration to said selected speed; means positively connecting said control member with said deflector means to move said deflector means in a given direction in response to given movement of said control member; a second servo-motor having a pilot valve, for moving said needle; means whereby said pilot valve is initially moved to a position dependent upon the position of said control member; means, acting on the pilot valve of said second servo-motor, responsive to movement of said needle, to cause said second servo-motor to adjust said needle to a position dependent upon the position of said control member, to adjust said stream; and means whereby said adjustment of said needle moves said deflector means in a direction opposite from said given direction.

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