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PRIME MOVER CONTROL SYSTEM

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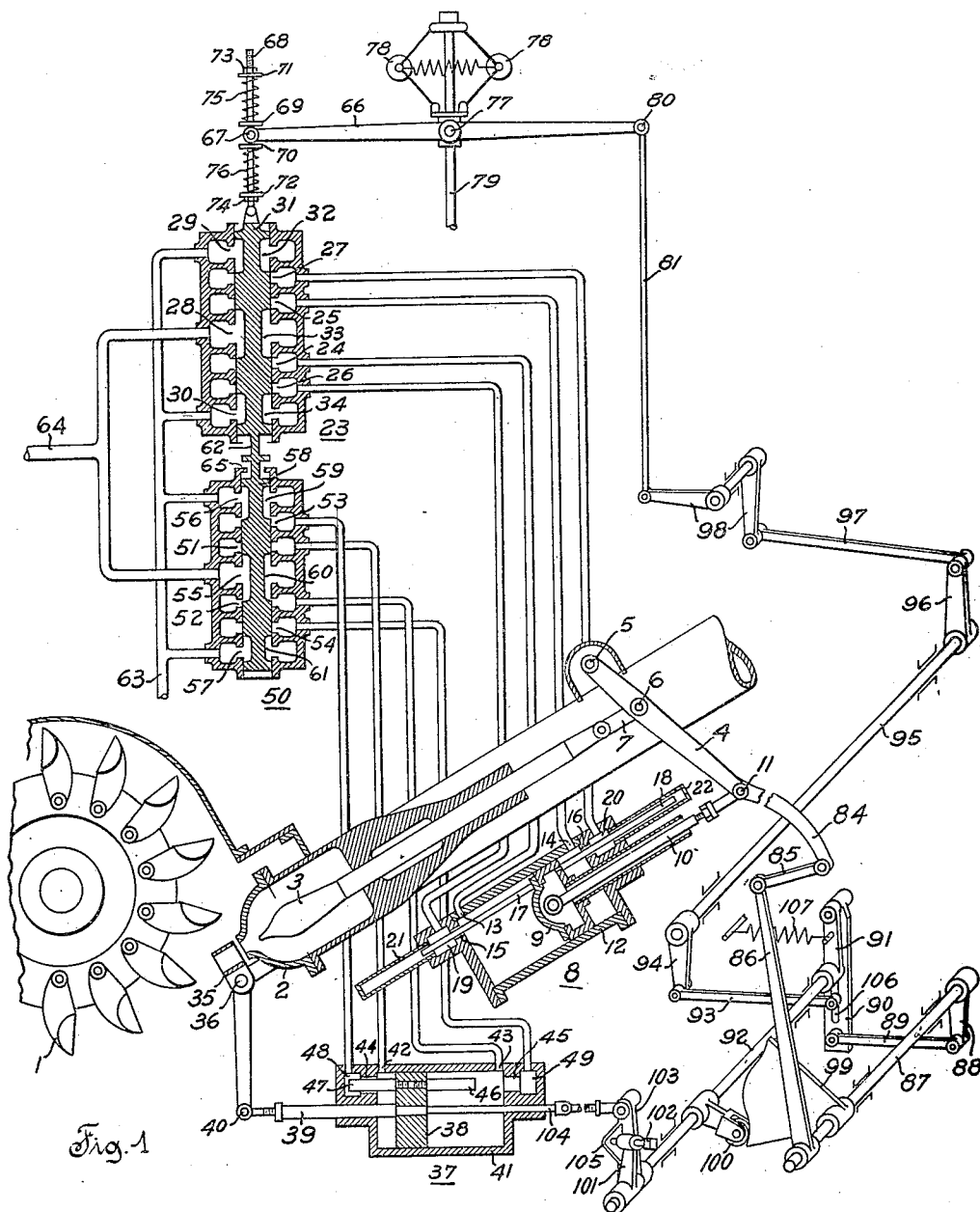


Fig. 1

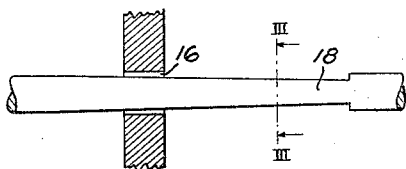


Fig. 2



Fig. 3

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PRIME MOVER CONTROL SYSTEM

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This invention relates in general to control systems for prime movers. It is particularly adapted for the control of water wheels and specifically impulse water wheels.

5 One of the objects of the invention is the provision of means whereby the power generated by the prime mover may be varied quickly, and, more particularly, without causing excessive pressure changes in the conduit
10 supplying operating fluid to the prime mover.

A more specific object is the provision of means whereby the quantity of operating fluid delivered to the prime mover may be varied at a rate dependent upon the quantity
15 of fluid being delivered at a given time, and more specifically, also dependent upon whether the amount delivered is being increased or decreased.

Another object is the provision of means
20 whereby for slow changes of load on the prime mover, or changes of load not greater than a predetermined amount, the regulation of the power generated by the prime mover may be accomplished by changing the delivered quantity of operating fluid only, while
25 for sudden changes of load larger than a predetermined amount the operating fluid is at once diverted from the prime mover to a predetermined extent. It is a further object to
30 provide means whereby the quantity of fluid flowing in the delivering conduit is so regulated with respect to the quantity diverted that when the load becomes stable at any predetermined value, no fluid will be diverted
35 from the prime mover.

Still another object is to provide a system of control in which the means for varying the quantity of fluid flowing in the delivering conduit and the means for diverting the fluid
40 are operated by separate servo-motors, and, more specifically, in which the servo-motors are controlled by a single governor.

A further object is the provision of means
45 for compensating or restoring the governing means responsive to the motions of the means for varying the quantity of fluid and the means for diverting the fluid, and, more specifically, the provision of means whereby the compensating or restoring effect produced by
50 the motion of the diverting means comes into

action at a time dependent upon the position of the quantity-varying means. A still further object is the provision of means whereby the compensating or restoring effect of the quantity-varying means and the diverting
55 means may be caused to be different, and further, may be adjusted. Other objects will appear as the description of the invention proceeds.

The novel features of the invention will appear from this specification and the accompanying drawing forming a part thereof showing one embodiment of the invention, and all these novel features are intended to
60 be pointed out in the claims.

In the drawing Fig. 1 is a partially diagrammatic showing, certain parts being shown in vertical section, of one embodiment of the invention as it may be applied in connection with the control of an impulse water
70 wheel; Fig. 2 is an enlarged detail, and Fig. 3 is a section taken on the line III—III of Fig. 2.

Referring to the drawing the prime mover here shown is an impulse water wheel 1
75 against which a stream of water may be directed by means of a nozzle 2. The size of the stream issuing from the nozzle 2 is here shown as controllable by means of a needle 3
80 which may be moved to different positions by means of a lever 4 swingable about a stationary pivot 5. The lever 4 is here shown as having pivotally connected thereto at 6 a link 7 which is in turn pivoted to the needle 3. The lever 4 is operable by means of a
85 servo-motor 8 provided with a piston 9 having connected thereto the piston rod 10 in turn suitably pivoted at 11 to the lever 4. The piston 9 is disposed in a cylinder 12 provided with inlet ports 13, 14 at its respective
90 ends. Outlet ports 15, 16 are also provided at the respective ends of cylinder 12 and the piston 9 carries rods 17 and 18 of varying cross-section which are adapted to pass
95 through the outlet ports 15, 16 respectively, noting that inlet ports 13 and 14 are not controlled by rods. The outlet ports 15, 16 are here shown connected respectively to outlet chambers 19, 20. These chambers are ex- 100

tended so as to receive the rods 17 and 18, as by means of tubes 21 and 22 respectively.

The servo-motor 8 is here shown as controllable by means of a regulating valve 23.

5 This valve has ports 24, 25 connected, as by means of the indicated pipes, to the inlet ports 13 and 14 respectively of the cylinder 12. The regulating valve 23 is also provided with ports 26, 27 connected by the indicated pipes
10 to the outlet chambers 19 and 20 respectively. The regulating valve 23 is provided with an inlet port 28 through which fluid under pressure may be admitted for operating the servo-motor 8. The regulating valve is also provided
15 with a pair of outlet ports 29, 30 adapted to receive pressure fluid discharged from the servo-motor 8, as will more fully appear. The regulating valve is here shown as of the type having a valve piston 31 provided
20 with annular recesses 32, 33 and 34. These annular recesses are so disposed and proportioned that when the valve piston 31 is in the neutral position shown in the drawing no fluid will be admitted from the inlet port
25 28 to either the port 24 or the port 25 and consequently the piston 9 of the servo-motor 8 will be held stationary. The ports 26 and 27 will also be closed.

Here shown as associated with the nozzle
30 2 is a deflecting means 35, here shown as in the form of a tubular hood, which is suitably pivoted at 36 so that it may be swung into the stream issuing from the nozzle 2. The deflecting means 35 is adapted to be
35 swung by means of a servo-motor 37 provided with a piston 38 to which is connected a piston rod 39 suitably pivotally connected at 40 to an arm associated with the hood 35. The piston 38 is disposed in a cylinder 41 here
40 shown as provided with inlet ports 42, 43 at each end thereof. The cylinder 41 is also provided with outlet ports 44, 45 at each end thereof through which rods 47 and 46 are adapted to respectively pass. The outlet
45 ports 44, 45 are connected respectively to outlet chambers 48, 49.

The servo-motor 37 is controllable by means of a regulating valve 50 which is provided with ports 51, 52 connected, as by means of
50 the indicated pipes, to the inlet ports 42, 43 respectively. The regulating valve 50 is also provided with ports 53, 54 connected by the indicated pipes to the outlet chambers 48, 49 respectively. The regulating valve 50 is
55 also provided with an inlet port 55 through which fluid under pressure may be admitted for the purpose of operating the servo-motor 37. The regulating valve is also provided with outlet ports 56, 57 through which pressure
60 fluid discharged from the servo-motor 37 may flow as will more fully appear. The regulating valve 50 is here shown as of the same type as the regulating valve 23, being provided with a valve piston 58 having annular
65 recesses 59, 60 and 61.

The valve piston 58 is here shown as rigidly connected with the valve piston 31 by any suitable connection 62. It will be noted that the relation of the valve pistons 31 and 58 is such that when, as shown on the drawing, the valve piston 31 is in its neutral position as hereinbefore described, the valve piston 58 is below its neutral position, for a purpose which will appear hereinafter.

All of the outlet ports 29, 30, 56 and 57 of the two regulating valves 23, 50 are connected in any suitable manner to the common discharge pipe 63. The two inlet ports 28, 55 of the regulating valves are connected to the common inlet pipe 64. This inlet pipe is connectible to a source of fluid under pressure (not shown).

The stroke of the valve pistons 31 and 58 may be limited in any suitable manner as by means of a collar 65 which is disposed between a pair of shoulders on the valve stem or connection 62.

The position of the regulating valve pistons is here shown as controllable by means of a floating lever 66 with one end of which a rod 68 is associated by means of the pivoted swivel connection 67. The rod 68 is provided with a pair of loose collars 69, 70 which are adapted to abut against the swivel connection 67, and with another pair of loose collars 71, 72 which may be positioned by means of nuts 73, 74 threaded on rod 68. Between the collars 71, 69 is disposed a spring 75, and another spring 76 is disposed between the collars 70, 72. The rod 68 is suitably pivotally connected to the valve piston 31. The connection hereinbefore described permits the floating lever 66 to move the valve pistons of the regulating valves and when they reach their limit of motion if there is any further movement of floating lever 66, either the spring 75 or spring 76 will be compressed.

The floating lever 66 is provided with a floating pivot 77 the position of which is controlled by means of the flyballs 78 which may be driven by a shaft 79 so as to respond to the speed of the prime mover 1. The driving connection between shaft 79 and the prime mover has not been shown.

The other end of the floating lever 66 is provided with a pivot 80 with which a rod 81 is associated and which is connected by linkage, which will now be described, to both the lever 4, and consequently the servo-motor 8, and to the servo-motor piston 38.

The lever 4 is provided with an extension 84 which has pivoted thereto a link 85 in turn pivoted to a lever 86. The lever 86 is rigidly associated with a shaft 87. The shaft 87 is mounted in stationary bearings as diagrammatically indicated on the drawing. The shaft 87 has rigidly associated therewith a crank 88 to which is pivotally connected a link 89 in turn pivoted to a floating lever 90.

The floating lever 90 is pivoted at its other end to a crank 91. The crank 91 is rigidly associated with a shaft 92 carried in stationary bearings as diagrammatically indicated on the drawing. Pivottally connected to the floating lever 90 is a link 93 in turn pivoted to a crank 94. The pivotal connection between the link 93 and the floating lever 90 is here shown as adjustable, the pivot being adjustable in a slot 106 in the lever 90. This is for the purpose of varying the amount of swing of the crank 94 for any given amount of movement of the aforesaid pivot associated with the lever 90. The crank 94 is rigidly associated with a shaft 95 carried in stationary bearings as diagrammatically indicated. The shaft 95 also carries a crank 96 here shown as having pivoted thereto a link 97 in turn pivoted to one arm of a bell crank lever 98 the other arm of which is pivottally connected to the rod 81.

The shaft 87 is here shown as carrying a cam 99 which is adapted to engage a follower 100, provided with a roller, the follower 100 being associated with a crank rigidly associated with the shaft 92. The shaft 92 also carries fixed thereto an arm 101 here shown as provided with a screw 102 serving as an adjustable abutment as will appear. Loosely swingable about the shaft 92 is a lever 103 which has suitably pivoted thereto a rod which, as here shown, is in turn pivottally connected to an auxiliary piston rod 104. The lever 103 is provided with a lug 105 which in the position of the parts shown on the drawing is in engagement with the end of the screw 102. The screw 102 is biased toward engagement with the lug 105 by reason of a spring 107 which is here shown as connected to the crank 109 so as to tend to rotate the latter in a counter-clockwise direction as viewed in the drawing.

The operation of the control system is as follows. Let it be assumed that a portion of the load is removed from the wheel 1 so that there will be a slight increase of speed. This will cause the floating pivot 77 to be slightly lifted thereby lifting the valve pistons 31 and 58. It is assumed that the increase in speed is only sufficient to lift the valve pistons enough so that piston 58 would not have reached its neutral position. The lifting of the valve piston 31 places the inlet port 28 in communication with the port 25 thereby admitting fluid under pressure through port 14 to the servo-motor cylinder. At the same time the discharge port 30 is placed in communication with the port 26. The admission of fluid under pressure to port 14 causes the servo-motor piston 9 to move the needle 3, through the linkage hereinbefore described, toward the closed position. As the piston 9 moves it displaces the fluid ahead of it through the outlet port 15, the fluid then flowing to outlet chamber 19 through the connected pipe

through ports 26 and 30 to the discharge pipe 63. The speed of the piston 9, and consequently of the needle 3, is determined by the rate at which fluid may flow through the outlet port 15. This is in turn determined by the effective cross section of the port 15, in turn determined by the cross section of the rod 17 at the port 15. The closing movement of the needle 3 of course decreases the size of the stream from the nozzle 2 and therefore the power generated by the wheel 1. This at once tends to lower the speed of the wheel but at the same time the motion of the needle causes the lever 86 to turn counter-clockwise thereby causing the crank 88 to pull the link 89 towards the right as viewed in the drawing. The floating lever 90 is thereby swung about its pivot on crank 91 thereby pulling the link 93 toward the right which motion as can be readily seen moves the rod 81 upwardly, thereby causing the end 67 of the floating lever to be moved downwardly to thereby restore the valve piston 31 to its neutral position in which communication between ports 25 and 28 is cut off so that no further flow of fluid to port 14 takes place. The described motions all take place simultaneously thereby adjusting the position of the needle 3 so that the size of the stream from the nozzle is reduced to take care of the fraction of load removed from the wheel.

It is to be noted that during the entire operation as hereinabove described the valve piston 58 has been in such position that the inlet port 55 is in communication with the port 52 whereby fluid under pressure is admitted through port 43 to the cylinder of servo-motor 37 thereby maintaining the piston 38 in the position shown on the drawing in which position the hood 35 is held coaxial with the stream issuing from nozzle 2, that is, in its fully withdrawn or non-deflecting position. It will therefore be seen that for changes of load which are not greater than a predetermined amount or for slow changes of load, the regulation of the power generated by the prime mover is accomplished by changing the amount of water issuing from nozzle 2.

Let it be assumed that the parts are again in the position shown on the drawing but that instead of the previously assumed small reduction of load a greater fraction of the load is removed from the wheel 1 such that the speed rises suddenly or sufficiently to lift the floating pivot 77 enough to carry the valve piston 58 above its neutral position, then the inlet port 55 will be placed in communication with the port 51 thereby admitting fluid under pressure to the port 42 to thereby cause the piston 38 to move towards the right as viewed in the drawing. Since with the parts in the position shown in the drawing the stream from the nozzle 2 is its full size, the aforesaid motion of piston 38

will cause the hood 35 to at once cut into the stream a predetermined amount thereby deflecting a portion of that stream away from the wheel 1. Furthermore, since under the assumed conditions the lug 105 is in contact with the screw 102, the motion to the right of the piston 38 will cause the crank 101 to be turned in a clockwise direction thereby also turning the crank 91 in the same direction. This motion of crank 91 will cause the floating lever 90 to be turned about its pivotal connection with the link 89, and the link 93 will consequently be pulled toward the right thereby, as will be obvious, causing the rod 81 to be moved upwardly and restoring the valve piston 58 to its neutral position. This cuts off communication between the inlet port 55 and the port 51 thereby stopping further motion of the piston 38 and maintaining the hood 35 in its deflecting position.

While the hereinabove described deflection of the stream is being accomplished the needle 3 is also being moved toward the closed position since the valve piston 31 has also been lifted and the operation of the needle is accomplished as already hereinbefore described in connection with a slight load change. The motion of the needle also acts on the restoring connections to aid in moving rod 81 upwardly so that the restoring action of the needle and of the deflector are taking place simultaneously and accumulatively.

It is to be further noted that while the hereinabove described deflection of the stream takes place, the follower 100 leaves the surface of cam 99 since the action of the deflector is faster than that of the needle. The deflection of the stream and its reduction in size of course reduce the power generated by the wheel 1, thereby tending to reduce the speed of the wheel. The reduction in speed coacts with the described restoring action of both the needle and deflector on the regulating valve pistons 31 and 58. After deflecting motion of the deflector has been stopped by restoration of the valve piston 58 to its neutral position, the valve piston 31 is still above its neutral position and therefore closing motion of the needle continues since ports 25 and 28 are still in communication. Before the valve piston 31 reaches its neutral position, the valve piston 58 is brought to a position just below its neutral and ports 52 and 55 are therefore placed in communication, as are also ports 53 and 56. Fluid under pressure is therefore admitted to port 43, the piston 38 being then moved toward the left and displacing the fluid ahead of it and expelling it from outlet port 44 to discharge port 56. The deflector 35 therefore withdraws from the stream, and if the closing motion of the needle has not yet taken up the lost motion between the cam 99 and follower 100, the spring 107 will cause the

screw 102 to follow the lug 105 so that the resultant counter-clockwise motion of crank 91 causes the link 93 to move to the left and therefore, as will be clear, pull the rod 81 downwardly. This action, as will be apparent, lifts the valve pistons 31 and 58 to a predetermined extent and therefore retards the withdrawal of the deflector from the stream and at the same time maintains continuation of the needle closing movement.

As soon as the cam 99 and follower 100 come into engagement, further movement of the deflector away from the stream is uncontrolled by the restoring connection because the lug 105 leaves the screw 102 and the latter is prevented from following the lug because the follower 100 butts against the cam 99. The deflector therefore rapidly moves to its fully withdrawn position as shown in the drawing.

It will be evident that the hereinbefore described actions are taking place simultaneously rather than step-by-step as the description thereof necessitates. The final result is that the needle is adjusted to a new position where the size of the stream is reduced to correspond with the reduced load, and the deflector has returned to its fully withdrawn position.

Let it be now assumed that a still further reduction in load occurs and that it is of sufficient degree to produce a speed rise enough to again cause lifting of valve piston 58 above its neutral position. The piston 38 is again caused to move to the right, but at the beginning of this motion lug 105 is not in contact with screw 102, it being remembered that due to the new position of the needle, the cam 99 has turned the shaft 92 clockwise. As a consequence the deflector moves rapidly, without producing any restoring action on valve piston 58, until the lug 105 strikes the screw 102. At that time the deflector 35 is just at the edge of the reduced stream and begins to cut into it, because the cam 99 is so designed that for any position of the needle the deflector 35 will be just at the edge of the stream when lug 105 strikes screw 102. Further motion of piston 38 then transmits restoring action to the valve pistons 31 and 58. The needle is of course meanwhile being also moved toward closed position, and the remaining operations are as already hereinbefore described, the stream size being finally reduced to the proper amount to correspond to the reduced load, and the deflector being returned to its fully withdrawn position.

Shock to the deflector and associated parts at the limits of movement is prevented by the action of the rods 47 and 46. It will be noted that the rod 46 is of such length that the piston 38 may travel a predetermined distance before the rod 46 enters port 45 and therefore the fluid ahead of the piston is freely displaced through port 45 until rod 46

enters said port. The displacement of fluid is then restricted, dependent upon the cross section of rod 46, and the motion of the piston is thus cushioned. The same clearly holds true with respect to motion of the piston 38 toward the left, the motion being cushioned when rod 47 enters port 44. 70

Within its limits of motion except for the purpose above stated, the motion of the deflector and its servo-motor may be as rapid as desired since the deflection of the stream has no deleterious effects on the pressure in the conduit feeding the nozzle 2. The motion of the needle is however preferably so controlled that the speed of the needle for any given position it may be in is such that there will be no undue pressure rise or drop, depending upon whether the needle is decreasing or increasing the stream size. It is of course evident that while the rod 17 controls the speed of closing movement of the needle, the rod 18 controls the speed of opening movement thereof. Moreover for any given position of the needle the closing speed thereof is controlled by the cross section of the rod 17 at the port 15. If therefore it is desired that that speed should vary from position to position of the needle, the rod 17 may be made of varying cross section as shown in Fig. 2. The rod 17 may be of originally round section and may have portions filed away as shown in Fig. 3. The same applies to rod 18 with regard to the opening speeds. 80

The connection between the end 80 of the floating lever, and the restoring linkage has been shown as a simple rod 81, but it will be apparent that a dash pot compensating device of any usual or desired form, such for example as shown in the patent to Englessen 1,126,433, January 26, 1915, may be interposed in the said connection. Such compensating means has not been shown, as forming no part per se of the present invention. 85

It will be clear that the single servo-motor 8 may be operatively related to any desired number of needles whether the nozzles which such needles control are related to the same or different prime movers, and that the servo-motor 37 may be operatively related in like manner, deflectors in number the same as the number of needles. 90

It should be understood that it is not desired to limit the invention to the exact details of description shown and described, for obvious modifications may occur to persons skilled in the art. 95

It is claimed and desired to secure by Letters Patent:

1. In combination, a turbine having an impulse runner, a nozzle for directing a stream against said runner, governor means for varying the size of said stream, a stream deflector normally in non-deflecting position, means responsive to the actuation of said governor means in excess of a predetermined amount for rapidly operating said stream deflector, and means operative after a predetermined movement of said stream deflector operating means to regulate the speed of operation of said stream deflector operating means in accordance with the position of said stream deflector. 100

2. In combination, a turbine having an impulse runner, a nozzle for directing operating fluid against said runner, a needle for said nozzle, a pilot valve controlled servo-motor for operating said needle, a deflector for deflecting said operating fluid away from said runner, a pilot valve controlled servo-motor for operating said deflector, means for so rigidly connecting said valves together that their neutral positions are displaced whereby said second servo-motor is operative to bias said deflector to its extreme non-deflecting position when the pilot valve of said first mentioned servo-motor is in its neutral position, and governor means for simultaneously operating the pilot valves of said servo-motors. 105

3. In combination, a turbine having an impulse runner, a nozzle for directing a stream against said runner, means responsive to the speed of said turbine for varying the size of said stream, means operative to change the direction of said stream, said last mentioned means having a normal position, means for rapidly operating said last mentioned means when said turbine accelerates at a rate in excess of a predetermined value, means operative upon a predetermined movement of said direction changing means for reducing the speed of operation of said direction changing means, and means for restoring said direction changing means to said normal position before the speed of said impulse wheel returns to normal. 110

4. In combination with a nozzle for directing a stream against an impulse wheel, a deflector for deflecting said stream, said deflector being normally in non-deflecting position, means for varying the size of said stream, means dependent upon the size of the stream for controlling the rate of movement of said size varying means, means for operating said deflector in response to a predetermined condition, means for restoring said deflector to its non-deflecting position in response to predetermined motion of said size varying means, and means whereby said restoring means does not become effective until after said size varying means has reduced said stream a predetermined amount. 115

5. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream said means being normally in the same non-deflecting position irrespective of the size of said stream, a needle for said nozzle, a servo-motor for operating said needle, a servo-motor for operating said deflecting means, valve means for controlling 120

said servo-motors respectively, a common operating means for said valve means, and means whereby said valve means causes said servo-motor for said deflecting means to
 5 move said deflecting means to its said normal position while said valve means is in neutral position with respect to control of said needle-servo-motor.

6. In combination with a nozzle for directing a stream against an impulse wheel, means for reflecting said stream, a needle for said
 10 nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common
 15 operating means for said regulating valves, a restoring relay connection between said needle-servo-motor and said common operating means, and a lost motion connection between said servo-motor for said deflecting
 20 means and said relay connection.

7. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for said
 25 nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said regulating valves, a restoring relay connection between
 30 said needle-servo-motor and said common operating means, a lost motion connection between said servo-motor for said deflecting means and said relay connection, and means whereby operation of said needle to alter the size of said stream changes the amount of lost
 35 motion in said last named connection.

8. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for said
 40 nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said regulating valves, a restoring relay connection between
 45 said needle-servo-motor and said common operating means, a lost motion connection between said servo-motor for said deflecting means and said relay connection, and means whereby operation of said needle to decrease the size of said stream increases the amount
 50 of lost motion in said last named connection.

9. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for said
 55 nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, means for operating said regulating valves whereby when said regulating valve for said needle-servo-motor is brought to neutral position
 60 said regulating valve for said deflecting-means-servo-motor is in a position to cause said deflecting means to move to its withdrawn position, a restoring relay connection between said needle-servo-motor and said op-
 65 erating means, and a lost motion connection

between said servo-motor for said deflecting means and said relay connection.

10. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for
 70 said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, means for operating said regulating valves whereby when said regulating valve for said
 75 needle-servo-motor is brought to neutral position said regulating valve for said deflecting-means-servo-motor is in a position to cause said deflecting means to move to its
 80 withdrawn position, a restoring relay connection between said needle-servo-motor and said operating means, a lost motion connection between said servo-motor for said deflecting means and said relay connection, and
 85 means whereby operation of said needle to alter the size of said stream changes the amount of lost motion in said last named connection.

11. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for
 90 said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said
 95 regulating valves, a restoring relay connection between said needle-servo-motor and said common operating means, a lost motion connection between said servo-motor for said
 100 deflecting means and said relay connection, and means for causing said needle-servo-motor to move said needle at a rate dependent upon the position of said needle.

12. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle
 105 for said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said
 110 regulating valves, a restoring relay connection between said needle-servo-motor and said common operating means, a lost motion connection between said servo-motor for said
 115 deflecting means and said relay connection, and means for causing said needle-servo-motor to move said needle at a rate dependent upon the position and direction of motion of said needle.

13. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle
 120 for said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said
 125 regulating valves, means responsive to the speed of said wheel for actuating said common operating means, a restoring relay connection between said needle-servo-motor and
 130

said common operating means, and a lost motion connection between said servo-motor for said deflecting means and said relay connection.

5 14. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, 10 a regulating valve for each of said servo-motors, means for operating said regulating valves whereby when said regulating valve for said needle-servo-motor is brought to neutral position said regulating valve for said deflecting-means-servo-motor is in a position to cause said deflecting means to move 15 to its withdrawn position, means responsive to the speed of said wheel for actuating the regulating valve operating means, a restoring relay connection between said needle-servo-motor and said operating means, and 20 a lost motion connection between said servo-motor for said deflecting means and said relay connection.

25 15. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle for said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means. 30 a regulating valve for each of said servo-motors, a common operating means for said regulating valves, a shaft carrying a crank, a floating lever having one end pivotally connected to said crank, means for operatively 35 connecting the other end of said floating lever with said common operating means and said needle-servo-motor respectively, means whereby a predetermined movement of said needle-servo-motor turns said shaft 40 a predetermined amount, and a lost motion connection between said deflecting-means-servo-motor and said shaft.

16. In combination with a nozzle for directing a stream against an impulse wheel, 45 means for deflecting said stream, a needle for said nozzle, a servo-motor for said needle, a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said 50 regulating valves, a shaft carrying a crank, a floating lever having one end pivotally connected to said crank, means for operatively connecting the other end of said floating lever with said common operating 55 means and said needle-servo-motor respectively, a cam operatively connected to said needle-servo-motor, a follower carried by said shaft whereby said cam may turn said shaft, and a lost motion connection between 60 said deflecting-means-servo-motor and said shaft.

17. In combination with a nozzle for directing a stream against an impulse wheel, means for deflecting said stream, a needle 65 for said nozzle, a servo-motor for said needle,

a servo-motor for said deflecting means, a regulating valve for each of said servo-motors, a common operating means for said regulating valves, a restoring relay connection between said needle-servo-motor and 70 said common operating means, and means whereby the motion of said deflecting-means-servo-motor may be relayed through a portion of said restoring connection independently of said needle-servo-motor. 75

18. In combination, a hydraulic turbine having an impulse runner, a nozzle for directing a stream of water against said runner, a needle for controlling the flow of said water, a servo-motor for operating said needle, 80 a hood operable to deflect the water away from said runner, a second servo-motor for operating said hood, means responsive to a sudden reduction of load on said runner for causing said first servo-motor to actuate said needle slowly to reduce the flow 85 of water to said runner and for causing said second servo-motor to actuate said hood rapidly to deflect the water from said runner, means for slowing down the movement of 90 said hood after a predetermined movement thereof, relay means for stopping said second servo-motor and causing said first servo-motor to continue to actuate said needle, and means including mechanical linkage for 95 restoring said hood toward its initial position initially at a slow rate and finally at a faster rate.

In testimony whereof, the signature of the inventor is affixed hereto. 100

WILLIAM M. WHITE.

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