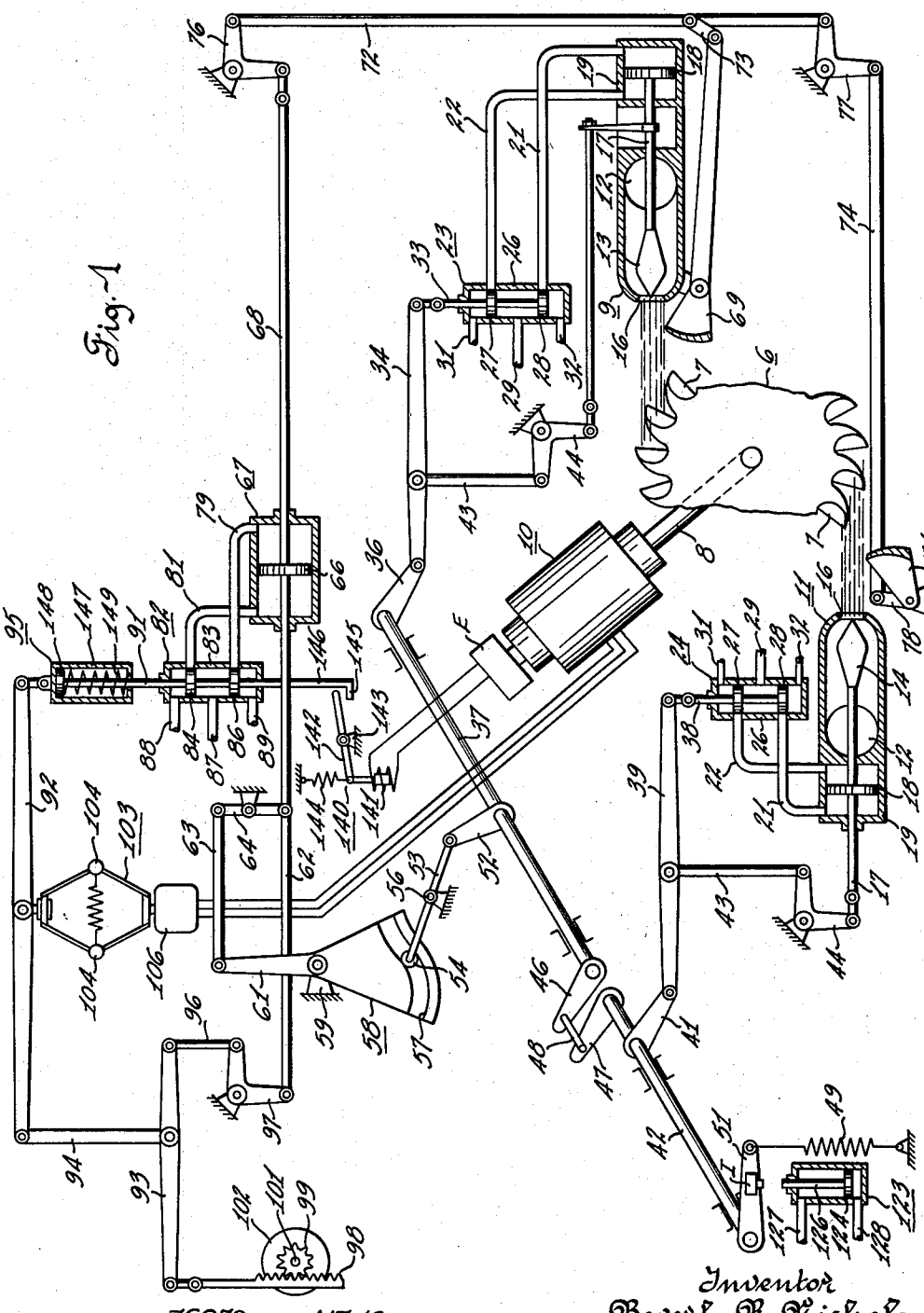
Aug. 4, 1964 B. R. NICHOLS 3,143,656

CONTROL SYSTEM FOR HYDRAULIC TURBINE

Filed Jan. 24, 1961 2 Sheets-Sheet 1

Fig. 1



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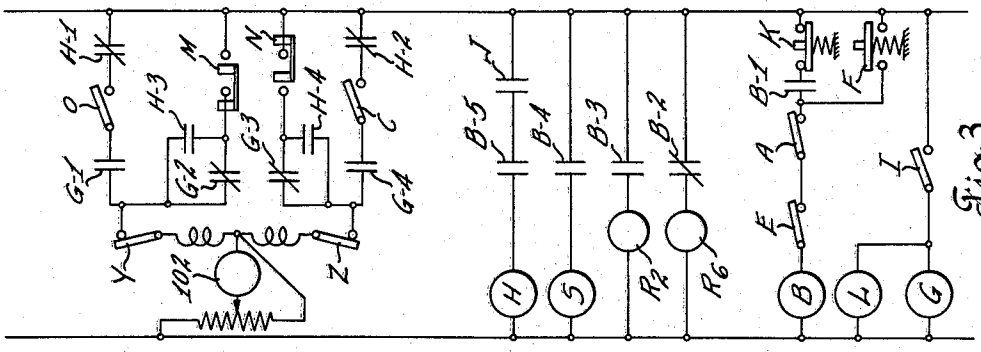


Fig. 3

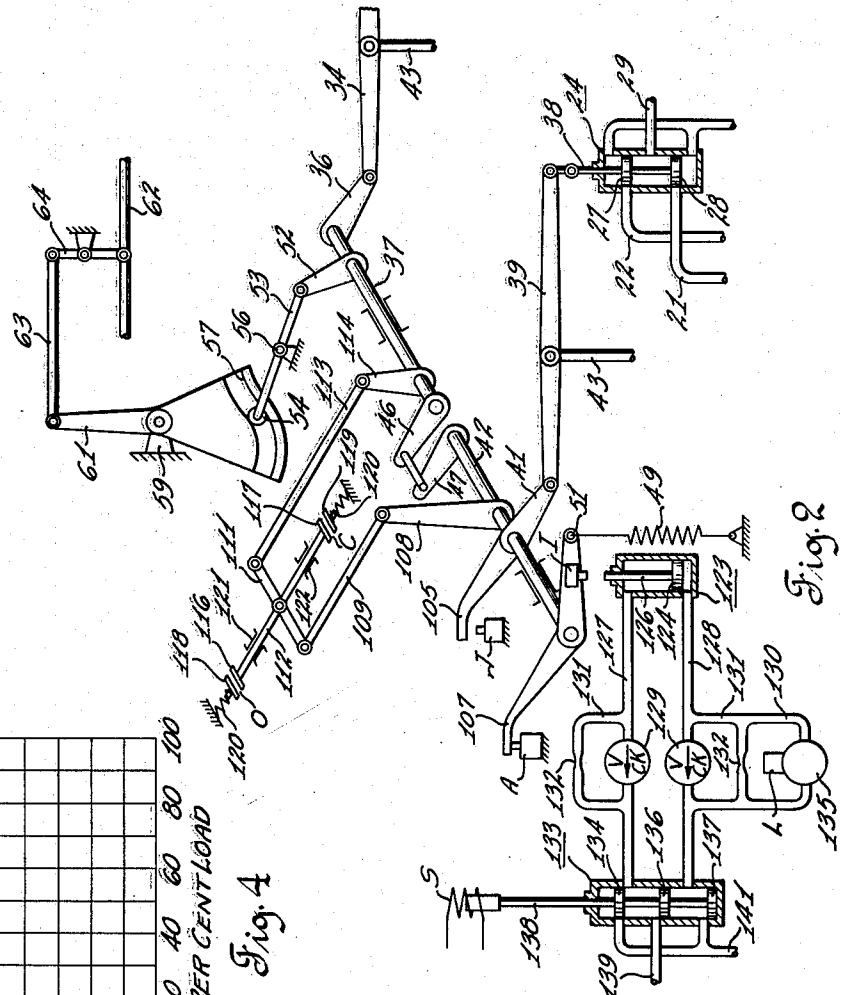


Fig. 2

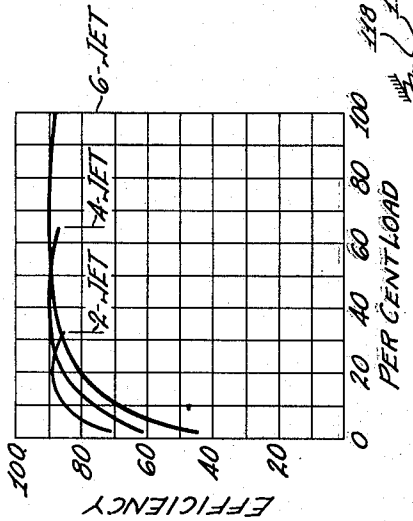


Fig. 4

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3,143,656

CONTROL SYSTEM FOR HYDRAULIC TURBINE

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Filed Jan. 24, 1961, Ser. No. 84,724
11 Claims. (Cl. 290—40)

This invention pertains to a hydraulic turbine and more particularly to a control system for a multijet impulse type hydraulic turbine wherein water at high pressure is discharged through a plurality of nozzles to act on a rotary bucket wheel.

In large hydraulic turbine installations the most efficient manner of operating the machine is to run the machine at or near full rated load. In certain instances, however, the full output of the turbine is not required and to conserve water it is therefore desirable to run the turbine at part load. Multijet impulse turbines may be operated at relatively high part load efficiency by closing a sufficient number of needles to maintain the required load with the remaining needles operating at relatively large nozzle openings.

A particular example of the efficiency of a multijet impulse turbine operating at part load is exhibited by a six jet turbine. FIG. 4 of the application drawings is a graph showing the typical power-efficiency characteristics of a six jet impulse turbine. Referring to FIG. 4, the efficiency of a six jet impulse turbine with all jets open is relatively constant from full load to approximately forty percent of full load. The efficiency rapidly decreases below about forty percent of full load. The efficiency of this turbine operating below forty percent load may be improved considerably by closing a portion of the needles. Particularly if the turbine is operating at less than twenty-five percent of full load the efficiency of the turbine can be improved considerably by closing four needles and operating with two needles set at a greater needle opening than is required to carry the same load when the load is divided between the six needles.

It should be understood that although the invention will be described in relation to a six jet turbine, the invention is applicable to a turbine handling any number of jets.

It is, therefore, a general object of this invention to provide a control system for a multijet impulse type turbine wherein a portion of the turbine jets or nozzles may be closed allowing the remainder of the turbine nozzles to supply the part load requirements of the turbine.

Another object of the subject invention is to provide a control system for a multijet impulse type turbine wherein a portion of the nozzles will close and the remaining nozzles will open so that the remaining nozzles are carrying approximately the same part load that would be carried by all of the nozzles.

An additional object of the subject invention is to provide a control system of the hereinbefore described type designed to complete this transfer of operation from all nozzle operation to part nozzle operation with a minimum change in power output.

Another object of the subject invention is to provide a control system of the hereinbefore described type wherein the remainder of the nozzles, after they have been opened to the point where they are carrying the part load of the turbine, remain under the control of the control mechanism which controls the turbine when it is operating under all of the nozzles.

A further object of the invention is to provide a control system of the hereinbefore described type wherein the remainder of the nozzles are under control of the turbine shutdown mechanism during the change over period when a portion of the nozzles are closing and the remainder of the nozzles are opening.

A more specific object of the invention is to provide a control system of the hereinbefore described type wherein there is a feed back system between the portion of the nozzles which are closing and the remainder of the nozzles which are opening.

These and other objects of the invention will become more fully apparent as the description of a particular embodiment of the invention is read in conjunction with the accompanying drawings wherein like reference characters in the various views designate the same or similar objects.

In the drawings:

FIG. 1 is a diagrammatic representation of a portion of the mechanism of one embodiment of the invention;

FIG. 2 is a diagrammatic representation showing an additional portion of the mechanism of said one embodiment of the invention;

FIG. 3 is a diagrammatic showing of one embodiment of the electric circuitry of the invention; and

FIG. 4 is a graph showing the typical power efficiency characteristics of a six jet impulse type turbine.

Referring to FIG. 1, there is disclosed an impulse type turbine wheel generally designated **6** having a series of buckets **7** formed on the periphery of the wheel. The turbine wheel is mounted on a shaft **8** which is connected to a conventional electric generator **10** so that rotation of the turbine wheel **6** causes the generator to rotate and provide electricity to a load. Although only two nozzles **9** and **11** have been shown, it should be understood that additional nozzles may be provided. Each nozzle is provided with an intake opening **12** which is in fluid communication with the pen stock (not shown) of the turbine to deliver water to the nozzles. Needle valves **13** and **14** are longitudinally disposed within the nozzles **9** and **11** respectively in close proximity to an orifice **16** provided in the end of each nozzle adjacent the turbine wheel buckets **7**. In this manner the water entering through the intake **12** is allowed to pass through the nozzle and out through the orifice **16** to impinge on the turbine wheel buckets **7**. The configuration of the needle valves **13** and **14** is complementary to the configuration of the nozzle orifices **16** so that the needle valves may be moved into the nozzle orifices to regulate the amount of or shut off the flow of water to the turbine wheel.

Each needle valve may be controlled by a servomotor and in this respect may be provided with an elongated stem **17** extending rearwardly from the nozzle orifice **16** and is rigidly connected to a piston **18** of servomotor **19**. Each servomotor is provided with fluid supply conduits **21** and **22** which alternately deliver and return fluid to and from the servomotor depending on whether the needle is opening or closing respectively. The fluid supply lines are in turn connected to a servomotor control valve. The control valve **23** controls the needle valve **13** and the control valve **24** controls the needle valve **14**.

Each servomotor control valve is comprised of a cylinder **26** having two axially spaced connected pistons **27** and **28** slidably disposed within the cylinder. As shown, the needle valves **13** and **14** are in a stationary position and the pistons **27** and **28** of each control valve are so disposed within the control valve cylinders as to block the flow of fluid through the fluid conduits **21** and **22**. Each control valve cylinder **26** is provided with a pressure fluid intake conduit **29** which is connected to a source of pressurized fluid (not shown). Each control valve cylinder is also provided with a pair of discharge conduits **31** and **32** which are in fluid communication with a fluid reservoir (not shown).

The pistons **27** and **28** of control valve **23** are connected together by a rod **33** which extends through a fluid sealed opening in the control valve cylinder and is pivotally con-

nected to one end of a floating lever 34. The other end of the floating lever 34 is pivotally connected to a lever 36 which is supported on and for rotation with a first or two needle control shaft 37. The pistons 27 and 28 of control valve 24 are connected together by a rod 38 which extends through a fluid sealed opening in the control valve cylinder and is pivotally connected to one end of another floating lever 39. The other end of the floating lever 39 is connected to a lever 41 supported on and for rotation with a second or four needle control shaft 42. As was previously pointed out, the invention is being described in relation to a six jet turbine and a division of two and four needles. Only one needle for each shaft is being described as the control mechanism for all needles is the same. It should be understood that any number of needles may be provided on each of the shafts 37 and 42 without departing from the spirit of the invention.

Each of the floating links 34 and 39 may be provided with a follow up link 43 pivotally connected intermediate the ends thereof. Each of the follow up links 43 may be connected to a bell crank 44 which in turn may be connected to the rods 17 of the needle valves 13 and 14 in the manner clearly shown in the drawings.

Although the two and four needle control shafts 37 and 42 are not rigidly connected together, it is necessary that there be a predetermined relationship between the movements of these two shafts. This relationship may be accomplished in many ways and in the preferred embodiment, for illustration purposes only, the two needle control shaft 37 is shown with a lever 46 rigidly connected to one end thereof. The four needle control shaft 42 also has a lever 47 rigidly connected to the end of the four needle control shaft which is adjacent to the said one end of the two needle control shaft to which the lever 46 is connected. Rigidly connected to the lever 46 is a pin 48 providing an abutment surface for engagement with the lever 47. In the illustrated arrangement of the levers 46 and 47 and pin 48, the four needle control shaft 42 may be moved in a counterclockwise direction without causing a corresponding movement of the two needle control shaft 37. However, movement of the two needle control shaft 37 in a counterclockwise direction causes the pin 48 to contact the lever 47 and rotate the four needle control shaft 42 in the same direction. Furthermore, the four needle control shaft 42 is biased in a clockwise direction by a spring 49 which is connected to a lever 51 which is connected to the control shaft 42. The spring thereby causes the shaft 42 to follow the clockwise rotation of the shaft 37.

With further reference to FIG. 1, the two needle control shaft 37 is provided with a cam follower lever 52 rigidly connected to control shaft 37 for rotation therewith. The free end of lever 52 is pivotally connected to a link 53. The other end of link 53 has a cam follower roller 54 attached thereto. The link 53 is pivotally connected to a fulcrum 56 intermediate its ends. The cam follower roller 54 rides in a cam surface 57 provided in a cam 58. The cam 58 is pivotally connected to a support 59 and is provided with an elongated lever 61 rigidly connected to the cam for rotation therewith about the support 59. The cam lever 61 has its free end connected to an elongated piston rod 62 through connecting links 63 and 64.

The elongated piston rod 62 is connected to a piston 66 reciprocably contained within a servomotor cylinder 67. The piston 66 has an additional piston rod 68 connected thereto and extending in an opposite direction from the elongated piston rod 62. The piston rod 68 is connected to jet deflectors 69 and 71 through a mechanical linkage including links 72, 73 and 74 and bell cranks 76, 77 and 78. The jet deflectors 69 and 71 are pivotally supported adjacent the orifices 16 of the nozzles 9 and 11 respectively.

The servomotor cylinder 67 has two supply conduits 79 and 81 connecting the servomotor 67 in fluid communication with a servomotor control valve 82. The servomotor control valve 82 comprises a cylinder 83 and two connected axially spaced pistons 84 and 86 slidably disposed therein. In the stationary position of the needle valves as shown in FIG. 1, the servomotor control valve pistons are positioned to block the flow of fluid through the fluid conduits 79 and 81. Control valve 82 is provided with a pressure fluid intake conduit 87 which is in fluid communication with a source of pressurized fluid (not shown). The control valve 82 is also provided with two return conduits 88 and 89 which are connected to a fluid reservoir (not shown).

The pistons 84 and 86 have a piston rod 91 connected thereto which extends through a fluid sealed opening in the end of the cylinder 83 and is connected to one end of a floating lever 92 through a lost motion connection generally designated 95. The lost motion connection and its function will be described later. The other end of the floating lever 92 is pivotally connected intermediate the ends of another floating lever 93 through a link 94. One end of the floating lever 93 is pivotally connected to one arm of a bell crank 97 by a link 96 and the other arm of the bell crank 97 is connected to the elongated piston rod 62. The other end of the floating lever 93 is pivotally connected to a gear rack 98 which meshes with a spur gear 99 fast on the shaft 101 of a speed level motor 102.

A conventional speed level governor generally designated 103 having flyballs 104 is pivotally connected to the floating lever 92 intermediate the ends thereof. The governor is driven by a motor 106 which is electrically connected to the turbine driven generator 10. In the conventional operation of the governor, the flyballs 104 will move outward as the load decreases and the speed of the generator increases and conversely the flyballs 104 will move together as the load increases and the speed of the generator decreases. These movements of the flyballs cause the floating lever 92 to move downward and upward respectively due to its connection with the governor.

The operation of the system as so far shown and described in FIG. 1 is as follows. With the system needle valves 13 and 14 in the position as shown, if there is a decrease in the load supplied by the turbine generator, the flyballs 104 of the governor will move outward due to an increase in the speed of the generator. As the governor flyballs move outward, the floating lever 92 is pulled downward pivoting about the connection between the end of the floating lever 92 and the link 94. This downward movement causes the servomotor control valve piston 84 to move downward providing a fluid connection between the left hand side of the servomotor 67 and the return passage 88 through the supply conduit 81. The piston 86 of the control valve 82 is also moved downward providing a fluid connection between the pressure inlet conduit 87 and the fluid conduit 79. This connection allows pressurized fluid to flow into the righthand portion of the servomotor 67 moving the piston 66 to the left. Because of the connection between the piston rod 68 and the jet deflectors 69 and 71, movement of the piston rod 68 to the left causes the jet deflectors to move toward the stream of water flowing through the nozzle orifices 16. As the piston 66 moves to the left the elongated piston rod 62 also moves to the left causing the cam 58 to pivot in a clockwise direction about the fulcrum 59. The cam follower roller 54 moves upward because of the configuration of the cam surface 57 causing the lever 52 to move in a counterclockwise direction. This causes the two control shafts 37 and 42 to move in a counterclockwise direction causing the floating levers 34 and 39 to pivot about their respective connections to links 43 and move the control valve pistons 27 and 28 downward. Downward movement of the pistons 27 connects the fluid conduits 22 with the return passages 31 and downward movement of the pistons 28 connects the fluid conduits 21 with the pressure inlet conduits 29. This movement of the control valves 23 and 24 causes pres-

surized fluid to move to the rear of servomotors 19 causing the needle valves 13 and 14 to move in a closing direction. The connections between the floating levers 34 and 39 and the needle valve stems 17 is a follow up or feed back connection. As the needles are moved in a closing direction, the crank arms 44 cause the links 43 to move upward causing the floating levers 34 and 39 to pivot about their connections with the levers 36 and 41. This upward movement of the floating levers causes the pistons 27 and 28 to move back to their original positions to block off the fluid conduits 21 and 22.

As the elongated rod 62 moves to the left, the bell crank 97 is rotated in a clockwise direction. This causes the floating lever 93 to move downward pivoting about its connection to gear rack 98. As floating lever 93 moves downward, link 94 causes floating lever 92 to pivot about its connection to the governor and thereby move the control valve pistons 84 and 86 back to the closed position. This process of closing and stopping of the needle valves continues until the turbine speed matches the load requirements of the generator.

Referring to FIG. 2, the four needle control shaft 42 has two levers 105 and 107 attached thereto having the free ends thereof terminating adjacent to switches J and A respectively. The function of each switch will be described in the complete description of the operation of the invention.

Also attached to the four needle control shaft 42 is a lever 108 having its free end pivotally connected to a link 109. The link 109 is also connected to one end of a lever 111 which lever is pivotally connected intermediate its ends to a rod 112. The other end of the lever 111 is pivotally connected to a link 113 which is also pivotally connected to a lever 114 fast on the two needle control shaft 37. On either end of the rod 112 is provided an electric switch contact 116 and 117. The contact 116 is positioned in close proximity to a contact 118 and the contact 117 is positioned in close proximity to an additional contact 119. Each contact 118 and 119 is supported to allow longitudinal movement of the rod 112 beyond initial engagement with the contacts 118 and 119. As herein shown, the contacts 118 and 119 are supported by springs 120. The contacts 116 and 118 operate as electric switch O and the contacts 117 and 119 operate as electric switch C. In the particular embodiment shown, the rod 112 is provided with guides 121 and 122 to restrict movement of the rod in a longitudinal direction.

A needle closing servomotor 123 is positioned in close proximity to the lever 51 which is connected to the four needle control shaft 42. The lever 51 has a switch I positioned thereon. The servomotor 123 has a piston 124 reciprocable therein which has a piston rod 126 extending through the servomotor cylinder and positioned for selective engagement with the lever 51 and the switch I. Attached to the cylinder of servomotor 123 are two fluid conduits 127 and 128. The conduits 127 and 128 each are provided with a conventional check valve 129 which allows fluid to pass through the valve in the direction indicated by the arrows, however, blocks the flow of fluid in the opposite direction. Each fluid conduit has a branch passage 131 bypassing and being in parallel relation with the respective check valves 129. Each branch passage has a fluid restrictor 132 provided therein. The branch passage 132 for the passage 128 has an additional bypass passage 130 in parallel relation with the check valve and restrictor valve. This branch passage 130 is provided with an open and closed valve 135 which may be actuated by a conventional solenoid L. The fluid conduits 127 and 128 have their other ends connected to a servomotor control valve generally designated 133. The control valve 133 has three axially spaced and interconnected pistons 134, 136 and 137 slidably contained within the cylinder. Each of the pistons is connected to a rod 138 which forms a part of a conventional solenoid generally designated S. Also connected to the servomotor control valve 133 is a fluid pressure intake conduit 139 and two discharge conduits 141.

Operation

Assume the turbine is developing between fifty and one hundred percent of full load divided between six needles and the load requirements are reduced to twenty percent of full load. As shown on the graph of FIG. 4, unit efficiency will be increased appreciably by closing four needles and opening two needles sufficiently to carry the twenty percent load on the two needles. The turbine output may be reduced to approximately thirty percent of full load by the usual governor controls. That is, as the load is removed from the generator, it tends to speed up causing the flyballs 104 to move outward moving the floating lever 92 downward causing the needles 13 and 14 to move in a closing direction, as explained previously. If the turbine is connected to a large electrical system, the speed of the turbine will be maintained at system speed and the output torque of the turbine must then be changed by adjustment of the speed level motor 102 by manual speed level motor switches M and N. It should be noted here that in the circuit diagram of FIG. 3, the switches with the diagonal line are normally closed and those without the diagonal line are normally open.

Needle operated limit switch A will close when contacted by lever 107 when the position of the needles is less than fifty percent setting up circuit B through closed contact E. It is believed obvious that the switch A can be provided with additional travel after initial contact such as being spring loaded much in the same manner as the switches C and O so that it will have sufficient stroke to allow the four needle control shaft 42 to completely close after initial contact between the switch and lever 107. The contact E is activated by conventional governor shutdown mechanism generally designated 140 and is closed at all times except when a substantial portion of the load is suddenly removed from the turbine. This mechanism will be described later. With the closing of the needle operated limit switch A the electric circuit is now in condition to transfer the system from six needle operation to two needle operation. This condition of the electrical circuit is shown in FIG. 3. The switch A is incorporated in the system as a safety measure so that the system cannot be transferred from six needle operation to two needle operation until the load has dropped to fifty percent or less depending on system requirements.

Operation of the needle transfer mechanism may be initiated in any manner and is shown herein as being initiated by closing momentary switch F. By closing this switch, a circuit will be completed through relay B. The circuit through relay B will be maintained through a normally open holding contact B–1 which closes when relay B is energized. When relay B is energized, switches B–3, B–4 and B–5 will close. When the relay B is energized contact B–2, which is normally closed, will open and the red light R_6 indicating six needle operation will deenergize. Contact B–3 when closed will cause red light R_2 to glow indicating two needles are in operation.

When contact B–4 closes as a result of energizing relay B, solenoid S will be energized causing the piston rod 138 (FIG. 2) to move upward connecting the fluid conduit 128 with the pressure intake conduit 139. The solenoid L is so arranged that the valve 135 is open when the solenoid L is deenergized. With this arrangement fluid can flow unrestricted through the passage 130 into the servomotor and move the piston 124 upward at a relatively fast rate. Upward movement of the piston rod 126 will cause it to engage lever 51 and close the switch I. Closing of switch I completes the circuit for relay G and solenoid L. When energized, solenoid L closes the valve 135 causing the fluid to pass through the restrictor 132 thereby slowing down the movement of the piston rod 126. The four needle control shaft 42 is rotated in a counterclockwise or needle closing direction by the piston rod 126. The lever

47 connected to four needle control shaft 42 normally engaged with the pin 48 will move away from the pin as the shaft rotates in a counterclockwise direction. The rate of closure of the four needle control shaft 42 after the valve 135 is closed is determined by the restrictor valves 132 in the fluid circuit between the servomotor control valve 133 and the servomotor 123. The restrictor valves are preadjusted to cause the four needle shaft to close at a predetermined rate somewhat less than the opening rate of the two needle shaft to prevent excessive changes in turbine output during the transition period. The significance of this relationship will become apparent as the description of the operation of the invention progresses.

When relay G is energized by closing the switch I, the switches G–1 and G–4 close and switches G–2 and G–3 open. This transfers control of the speed lever motor from manual switches M and N to automatic contacts C and O so that the two needle control shaft 37 will open under control of the closing movement of the four needle control shaft 42. As the four needle control shaft 42 is closed by the servomotor 123, the lever 108 rotates to the left causing the contact 116 to engage contact 118 closing the switch O. When switch O closes, referring to FIG. 3, the speed level motor 102 is energized through the circuit including the switches Y, G–1, O and H–1. This causes the speed level motor 102 (FIG. 1) to move in an opening direction (as indicated on the drawing) causing the floating lever 93 to move downward which causes the floating lever 92 to fulcrum about its connection to the governor causing the servomotor control valve 82 pistons 84 and 86 to move upward providing a fluid path between the pressure inlet conduit 87 and conduit 81 to the servomotor 67. As previously explained, movement of the rod 62 to the right causes the two needle control shaft to move in an opening direction. It is recognized that this opening movement of control shaft 37 will cause deflectors 69 and 71 to move away from the jet stream contrary to the closing movement of needle 14. However, this is not detrimental to the operation of the system as the deflectors only enter the jet stream when the system dangerously overspeeds.

The speed level motor 102 is adjusted so that it causes the two needle control shaft 37 to revolve at a speed greater than the speed of the restricted closing movement of four needle control shaft 42. This is necessary so that the two needles will open approximately two units for every one unit of closure of the four needles. That is, it is necessary that the two needles provide as much water force on the turbine buckets 7 as the six needles did when the transfer switch F was closed. As the two needle shaft 37 rotates in a needle opening direction, the lever 114 moves in a clockwise direction tending to open the switch O. The lever 114 is shorter in length than the length of lever 108 and therefore with the two needle control shaft 37 revolving faster than the four needle control shaft 42, the rod 113 moves to the right substantially at the same rate as the rod 109 moves to the left. However, since rod 109 must be moved to the left before the rod 113 is moved to the right, the switch O will be moving in a closed direction as long as the servomotor 123 is causing the four needle control shaft 42 to move in a closing direction. If the two needle control shaft 37 should move in an opening direction sufficiently fast to open the switch O, the speed level motor will be stopped because of a break in the circuit through the switches Y, G–1, O and H–1. However, the four needle control shaft continues to move in a closing direction and will therefore cause the switch O to again close causing the speed level motor to again move the two needle control shaft in an opening direction. In actual practice, the switch O will alternately open and close causing the needles controlled by the two needle control shaft to open in steps. Because of this relationship between the closing movement of the four needles and the opening movement of the two needles, the output of the turbine will remain substantially constant during the change over period.

This operation of closing and opening switch O continues until the four needle control shaft 42 has completely moved to a needle closed position. When the four needle control shaft has moved to the position where the needles controlled by this shaft are completely closed, the lever 105 contacts a switch J. Closing of switch J (FIG. 3) causes the relay H to be energized. When the relay H is energized switches H–1 and H–2 open and switches H–3 and H–4 close. Opening of switches H–1 and H–2 takes the operation of the speed level motor away from the control of the switches C and O and returns control of the speed level motor to the manual switches M and N. With the opening of switches H–1 and H–2, the two needle control shaft is now under control of the governor mechanism in the manner previously described.

When it is desired to return the system to six needle operation, the momentary push button switch K is opened. This causes the relay B and indirectly the relay H because of opening switch J to deenergize returning all of the B and H switches to their normal condition. When relay B is deenergized, switch B–4 opens deenergizing the solenoid S. When the solenoid S is deenergized, the piston rod 138 moves downward connecting the conduit 128 to return passage 141 and the pressure conduit 139 with the upper portion of the servomotor 123 allowing spring 49 to move the lever 51 in a clockwise direction following the predetermined restricted lowering movement of piston rod 126 and causing the four needle shaft 42 to move in a clockwise direction. As the four needle control shaft moves in the clockwise direction, the rod 109 moves to the right closing the switch C. This causes the speed level motor to be energized through the circuit including the switches Z, G–4, C and H–2 resulting in a closing movement of the speed level motor. The two needle control shaft 37 is thereby moved in a closing direction. This operation is the same as the opening operation of the two needle shaft by the speed level motor except in a reverse direction. The two needle control shaft 37 continues to move in a counterclockwise direction while the four needle control shaft is moving in a clockwise direction until the pin 48 connected to the lever 46 contacts the lever 47. At this point, the two needle control shaft stops further clockwise rotation of the four needle control shaft. However, the piston rod 126 continues to move away from the lever 51 since the solenoid valve S has allowed the control valve 133 to port fluid to the upper side of the piston 124. As the piston rod 126 moves away from lever 51, the switch I is opened. When switch I is opened, relay G is deenergized returning all of the G switches to their normal positions. At this point all six needles are again carrying the turbine load and are under control of the governor mechanism as previously explained.

The normally closed switch E operated by governor shutdown mechanism 140 and connected to the B relay circuit, is closed when the generator is carrying a load. If during the transfer from six needle to two needle operation the load should be removed from the generator, it would tend to speed up. This could cause considerable damage to the generator unless the turbine were immediately shut down. In order to provide for this emergency the switch E is opened when the load is removed from the generator causing the relay B and indirectly the relay G to deenergize returning the system to the complete control of the governor and remaining automatic control thereof from the speed level motor. When there is a sudden and substantial removal of load due to overspeed of the generator, switch E, which may be a conventional mercury switch, is opened. This causes a solenoid 141 to deenergize causing a lever 142 to pivot in a clockwise direction about its connection to a fulcrum 143 due to the urging of spring 144. Clockwise rotation of lever 142 causes it to intercept a flange 145 on an extension 146 of the servomotor control valve 82 forcing the pistons

84 and 86 downward. Downward movement of these pistons causes the servomotor 67 to move in a needle closing direction and will cause the turbine to slow down. The lost motion connection 95 is provided between the control valve 82 and the floating lever 92 so that movement of the control valve 82 by the governor shutdown mechanism will not interfere with the governor setting. The lost motion connection comprises a hollow cylinder 147 into which the rod 91 extends. A flange 148 on the upper end of rod 91 is generally in contact with the upper inner end of the cylinder 147 because of the biasing effect of a spring 149. However, when the lever 142 forces the pistons 84 and 86 downward, the spring 149 is compressed and the setting of the governor is not upset.

When switch E is opened, relay B is deenergized, the speed level motor is returned to control of manual switches M and N and needle controls are restored to normal operation under control of the governor.

Although only 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.

Having now particularly described and ascertained the nature of my said invention and the manner in which it is to be performed, I declare that what I claim is:

1. In a control system for a hydraulic turbine the combination comprising: governing means; a plurality of fluid flow devices capable of movement through a plurality of positions between open and closed positions; a plurality of actuating mechanisms connected to said devices, at least one of said mechanisms being connected to said governing means whereby predetermined movements of said governing means cause said one of said mechanisms to move one of said devices through said positions; motion transmitting means connected between said one of said actuating mechanisms and the remainder of said actuating mechanisms to maintain the same operative relationship between all actuating mechanisms; and an auxiliary actuating mechanism selectively engageable with said remainder of said mechanisms and capable of overriding said motion transmitting means to move said remainder of said mechanisms in a device closing direction.

2. In a control system for a hydraulic turbine the combination comprising: governing means; a plurality of fluid flow devices capable of movement through a plurality of positions between open and closed positions; a plurality of actuating mechanisms connected to said devices, at least one of said mechanisms being connected to said governing means whereby movement of said governing means causes said one of said mechanisms to move one of said devices through said positions; motion transmitting means connected between said one of said actuating mechanisms and the remainder of said actuating mechanisms to maintain the same operative relationship between all mechanisms; a first auxiliary actuating mechanism selectively engageable with said remainder of said mechanisms and capable of overriding said motion transmitting means to move said remainder of said mechanisms in a device closing direction; and a second auxiliary actuating mechanism selectively engageable with said one of said mechanisms and capable of overriding said governing means to move said one of said mechanisms in a device opening direction when said first auxiliary actuating mechanism is moving said remainder of said mechanisms in a device closing direction.

3. The combination set forth in claim 2 and further comprising: motion regulating means to cause said second auxiliary actuating mechanism to move in a device opening direction at a faster rate than said first auxiliary actuating mechanism moves in a device closing direction.

4. In a control system for a hydraulic turbine connected in driving relation to an electric generator the combination comprising: a plurality of fluid flow devices capable of movement through a plurality of positions between open and closed positions; governing means connected to said generator and movably responsive to changes in the rotative speed of said generator; a plurality of actuating mechanisms individually connected to said devices for moving said devices through said positions, at least one of said mechanisms connected to said governing means and responsive to predetermined movement of said governing means to move one of said devices through said positions; motion transmitting means connected between said one of said mechanisms and the remainder of said mechanisms to maintain the same operative relationship between all mechanisms; a first auxiliary actuating mechanism selectively engageable with said remainder of said mechanisms and capable of overriding said motion transmitting means to move said remainder of said mechanisms in a device closing direction; a second auxiliary actuating mechanism selectively engageable with said one of said mechanisms and capable of overriding said governing means to move said one of said mechanisms in a device opening direction when said first auxiliary actuating mechanism is moving said remainder of said mechanisms in a device closing direction; and load sensing means connected to said generator and to said second auxiliary actuating mechanism to cause said second auxiliary actuating mechanism to become inoperative when the rotative speed of said generator exceeds a predetermined amount whereby said governing means will cause said one of said mechanisms to move in a device closing direction.

5. In a control system for a hydraulic turbine connected in driving relation to an electric generator the combination comprising: a plurality of fluid flow devices connected to said turbine for supplying motive fluid thereto, said devices being capable of movement through a plurality of positions between open and closed positions; governing means connected to said generator and movably responsive to changes in the rotative speed of said generator; a first control means connected to one of said devices and said governing means, said first control means being responsive to predetermined movements of said governing means to cause said one of said devices to move through said positions; a second control means connected to each of the remainder of said devices, said second control means being movable to cause said remainder of said devices to move through said positions; motion transmitting means connecting said second control means in driven relation to said first control means to maintain the same operative relationship therebetween, said motion transmitting means including means permitting closing movement of said second control means by means other than said first control means without interfering with the movements of said first control means; a first auxiliary actuating mechanism selectively engageable with said second control means and operative to move said second control means in a device closing direction; and a second auxiliary actuating mechanism selectively engageable with said first control means and operative to move said first control means in a device opening direction while said second control means is moving in a device closing direction.

6. In a control system for a hydraulic turbine connected in driving relation to an electric generator the combination comprising: a plurality of fluid flow devices connected to said turbine for supplying motive fluid thereto, said devices being capable of movement through a plurality of positions between open and closed positions; governing means connected to said generator and movably responsive to changes in the rotative speed of said generator; a first control means connected to one of said devices and said governing means, said first control means being responsive to predetermined movements of said governing means to cause said one of said devices to move through said positions; a second control means connected to each of the remainder of said devices, said second control means being movable to cause said remainder of said devices to move through said positions; motion transmit-

ting means connecting said second control means in driven relation to said first control means to maintain the same operative relationship therebetween, said motion transmitting means including means permitting closing movement of said second control means by means other than said first control means without interfering with the opening and closing movements of said first control means; a first auxiliary actuating mechanism selectively engageable with said second control means and operative to move said second control means in a device closing direction; a second auxiliary actuating mechanism selectively engageable with said first control means and operative to move said first control means in a device opening direction while said second control means is moving in a device closing direction; and motion regulating means connected to said first and second control means causing said first control means to move in a device opening direction at a faster rate than the device closing rate of movement of said second control means.

7. In a control system for a hydraulic turbine connected in driving relation to an electric generator the combination comprising: governing means connected to said generator and movably responsive to changes in the rotative speed of said generator; a plurality of fluid flow devices capable of movement through a plurality of positions between open and closed positions; a plurality of power devices individually connected to said fluid flow devices for actuation thereof; a first control means; an actuating mechanism connected to said governing means and said first control means and responsive to movements of said governing means to move said first control means; first linkage means connecting at least one of said power devices to said first control means, said one of said power devices moving one of said fluid flow devices through said positions as a result of predetermined movements of said governing means; a second control means; second linkage means connecting the remainder of said power devices to said second control means; motion transmitting means interconnecting said first and second control means comprising, abutment means on each of said control means engageable for coextensive movement of said first and second control means when said first control means is moving in a closing direction, and biasing means connected to said second control means and biasing said second control means in an opening direction and into engagement with said first control means, said first control means abutment means limiting the biasing effect on said second control means; a first auxiliary actuating mechanism selectively engageable with said second control means, said first auxiliary actuating mechanism being capable of over-riding said biasing means to move said second control means in a closing direction; a second auxiliary actuating mechanism selectively engageable with said first control means for moving said first control means in an opening direction; and switch means for activating said second auxiliary actuating mechanism, said switch means being connected to said first and second control means whereby closing movement of said second control means closes said switch and opening movement of said first control means opens said switch.

8. The combination set forth in claim 7 and further comprising: safety switch means connected to said generator and responsive to a predetermined speed of said generator to deactivate said second auxiliary mechanism.

9. In a control system for a hydraulic turbine connected in driving relation to an electric generator the combination comprising: governing means connected to said generator and movably responsive to changes in the rotative speed of said generator; a plurality of fluid flow devices capable of movement through a plurality of positions between open and closed positions; a plurality of power devices individually connected to said fluid flow devices for actuation thereof; a first control means; an actuating mechanism connected to said governing means and said first control means and responsive to movements of said governing means to move said first control means; first linkage means connecting at least one of said power devices to said first control means, said one of said power devices moving one of said fluid flow devices through said positions as a result of predetermined movements of said governing means; a second control means; second linkage means connecting the remainder of said power devices to said second control means; motion transmitting means interconnecting said first and second control means comprising, abutment means on each of said control means engageable for coextensive movement of said first and second control means when said first control means is moving in a closing direction, and biasing means connected to said second control means and biasing said second control means in an opening direction and into engagement with said first control means, said first control means abutment means limiting the biasing effect on said second control means; a first auxiliary actuating mechanism selectively engageable with said second control means, said first auxiliary actuating mechanism being capable of over-riding said biasing means to move said second control means in a closing direction; a second auxiliary actuating mechanism selectively engageable with said first control means for moving said first control means in an opening and closing direction; and first switch means for activating said second auxiliary mechanism, said switch means being connected to said first and second control means and having first and second closed positions to cause said second auxiliary mechanism to move in a device opening and a device closing direction respectively, said first closed position being effected by closing movement of said second control means and being broken by opening movement of said first control means, and said second closed position being effected by opening movement of said second control means and being broken by closing movement of said first control means.

10. The combination set forth in claim 9 and further comprising: second switch means electrically connected to said first switch means and being activated when said second control means has moved to a device closed direction to open said first switch means.

11. In a control system for a hydraulic turbine the combination comprising: a plurality of fluid flow devices capable of movement between open and closed positions for causing rotation of said turbine; first means connected to at least one of said devices for regulation thereof; second means connected to the remainder of said devices for regulation thereof; means connecting said first and second regulating means to maintain the same operative relationship between all of said devices; governing means connected to said first regulating means for controlling operation thereof; and auxiliary means capable of overriding said connecting means to move said second regulating means in a device closing direction.

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