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GOVERNING SYSTEM

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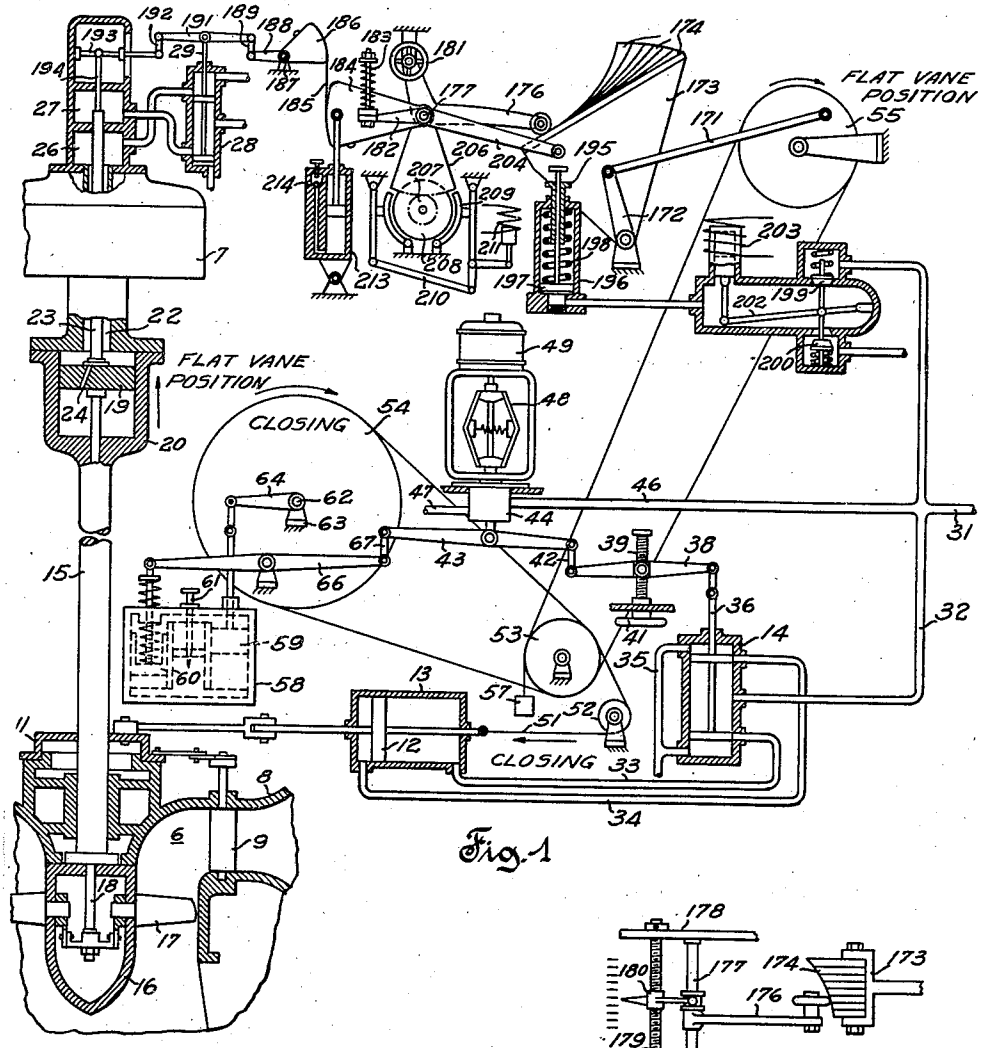


Fig. 1

Fig. 2

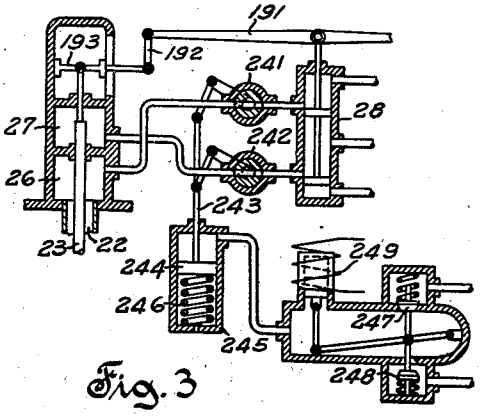


Fig. 3

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GOVERNING SYSTEM

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15 Claims. (Cl. 253—143)

This invention relates generally to improvements in governing systems for fluid pressure operated prime movers and more particularly to systems for governing hydraulic turbines of the adjustable runner vane type.

Governing systems for hydraulic turbines of the adjustable runner vane type must provide accurate and quick response to both normal and abnormal operation of the turbine and must also provide for normal maintenance of predetermined relations between the gate controlling the flow of pressure and the positioning of the runner vanes with provision for variation of such relations when desired.

In governing hydraulic turbines of the adjustable runner vane type, a fixed relation must be maintained between the degree of gate opening and the setting of the runner vanes which determine the area of the water passages between the runner vanes. The runner vane adjusting means must therefore be accurately and rapidly responsive to changes in the position of the gate without any appreciable lag or any tendency to over-run the vane setting required by the then existing gate position. During starting of the turbine, the then normally relatively flat position of the runner vanes is, however, not desirable because when the vanes are in such flat position, it is possible to obtain only a very low torque at a high speed, whereas the starting requirements are a very high torque at a low speed which can be secured only by a relatively steep tilt of the runner vanes. The runner vane adjusting means must therefore be provided with means by which its normal operation can be neutralized and by which the requirement for steep tilting of the vanes during the starting operations of the governing system may be met. Under some conditions of operation of the governing system or of the hydraulic turbine itself, it may be necessary to operate the turbine as a fixed runner machine or to conserve the fluid pressure used as the source of power for operating the governing system. The first above condition is met by providing means for locking the runner vane adjusting means in a fixed position responsive to manual operation or automatically responsive to predetermined conditions, and the second above condition is met by manual or fluid responsive means for interrupting the flow of fluid pressure to the servomotor for positioning the runner vanes.

It is therefore an object of the present invention to provide a governing system for prime movers in which both normal and abnormal conditions of operation of the prime mover are effective to vary the control of the prime mover by the governing system.

Another object of the invention is to provide a prime mover governing system which includes means for adjustment of the normal starting conditions and for maintaining normal operating speed and load capacity of the prime mover.

Another object of the present invention is to provide a governing system for hydraulic turbines of the adjustable runner vane type in which a predetermined relation is maintained between the gate position and runner vane position during normal operation and in which such relation may be varied or interrupted responsive to conditions other than the normal operation of the turbine.

Another object of the invention is to provide a prime mover governing system with manually operable means eliminating the action of automatic portions of the system when operation of the prime mover is required regardless of the action of such automatic means.

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

Fig. 1 diagrammatically illustrates a hydraulic turbine driven electric generating unit having applied thereto an automatic speed and load governing system embodying the various elements and subcombinations of the present invention;

Fig. 2 is a top view diagrammatically illustrating the structure by which a cam follower is moved to contact with any one of a plurality of cams controlling the relation between the runner vane setting of an adjustable vane turbne and the gate opening thereof; and

Fig. 3 is a diagrammatic illustration of automatically controllable means for preventing flow of fluid pressure to the servomotor for adjusting the vanes of an adjustable runner vane turbine, when conservation of such pressure is required for the operation of other portions of the governing system.

The various elements constituting the present control or governing system are not shown in their relative positions, their true size nor in their relative proportions, but are shown entirely diagrammatically to facilitate the explanation of the construction and operation of the system.

Referring to the drawing by characters of reference, the governing system is shown as applied to a prime mover such as a hydraulic turbine generally indicated at 6 and shown as being of

the adjustable vane propeller type driving a conventional electric current generator 7. The turbine 6 has the usual casing 8 forming a peripheral water inlet in which are mounted a plurality of movable vanes 9 forming a gate controlling the flow of fluid into the turbine. The term "gate" is intended to include any means used for the purpose of controlling the flow of fluid pressure to any prime mover to which the governing system of the present invention is applicable. The gate or guide vanes 9 are connected by conventional linkage to a shifting ring 11 mounted on the turbine casing for movement into different positions to control the position of the gate vanes and hence to control flow of water into the turbine. The shifting ring 11 is connected with and actuated by a piston 12 movable within a cylinder 13, the piston 12 and cylinder 13 forming a fluid pressure operated servomotor controlled by an automatically operated pilot valve generally designated 14 in the governing system of the present invention. The shifting ring 11, servomotor 12, 13 and pilot valve 14 and their connections comprise means for operating the gate 9.

The turbine 6 is connected with the generator 7 by a hollow shaft 15 which, at its end within the turbine casing 8, is provided with a hub 16 in which are journaled a plurality of propeller vanes 17 extending substantially radially from the hub. The several propeller or runner vanes 17 are interconnected internally of the hub 16 by any one of several known means, to an operating rod 18 which extends upwardly through the shaft 15 to connect with a piston 19 movable within a cylinder 20 which is either inserted in or formed as a portion of the shaft 15. It will be understood that the relative positions of the runner vanes govern the area of the fluid flow passages or openings between the vanes and that adjustment of the runner vanes to increase or decrease such area depends on the direction of movement of the vanes. The runner vane operating servomotor 19, 20, is double acting and is operated by fluid pressure admissible above the piston 19 through a passageway 22 formed in the shaft 15 and by fluid pressure admissible below the piston 19 through a tube 23 extending through the passage 22 in the shaft 15 and communicating with the underside of the piston 19 by way of passage 24 through such piston. The tube 23 is fixedly mounted on the piston 19 and accordingly moves with such piston. Fluid pressure is transmitted either through the passageway 22 or the tube 23 by way of a so-called distributing head having two chambers 26 and 27 connected with the passageway 22 and with the tube 23 respectively. Flow of fluid pressure to the distributing head chambers from a suitable source (not shown) is controlled by a pilot valve generally designated 28, the stem 29 of the pilot valve 28 being shiftable automatically to maintain a predetermined relation between the positions of the gate vanes 9 and the runner vanes 17. The servomotor 19, 20, distributing head 26, 27, and pilot valve 28 and their interconnections comprise means for adjusting the runner vanes 17.

Fluid pressure is applied from a suitable source (not shown) to the automatic pilot valve 14 by way of a pipe 31 and a pipe 32 and, under control of the pilot valve, is supplied to the gate operating servomotor 12, 13 through pipes 33 and 34. Pressure is discharged from the servomotor 12, 13 by way of the pilot valve 14 into a pipe 35 leading back to the source of fluid pressure. The stem 36 of the automatic pilot valve 14 is connected with one end of a lever 38 having as its fulcrum a fixedly mounted screw 39 operable locally by means of the hand wheel 41 or remotely by suitable means. The other end of the lever 38 is connected by way of the link 42 with a floating lever 43 of which the fulcrum is formed by the piston of a fluid pressure operated servomotor 44 supplied with pressure through the pipe 46 and discharging through the pipe 47. The supply of fluid through the pipe 46 to the servomotor 44 is controlled by a valve (not shown) which is operated by a flyball structure 48 driven by a motor 49 responsive to the speed of the generator 7. The detailed structure of the servomotor 44, the servomotor control valve, the flyball structure 48 and the motor 49 can be seen in Patent No. 2,106,684, issued January 25, 1938, to J. J. Ring, B. R. Nichols and A. Pfau, and such structure is accordingly not shown herein in detail, and will be described only sufficiently to allow comprehension of its functional cooperation with other portions of the present control system. Variations in load on and hence speed of the generator 7 which produce variations in speed of the motor 49 and flyball structure 48, causes movements of the servomotor 44 and the leverage 43, 42 and 32 to actuate the gate pilot valve 14 which moves to admit pressure for operating the gate servomotor 12, 13 and hence to shift the gate 9 in either direction dependent on the sense of the speed change.

Every movement of the gate servomotor piston 12 must be relayed by way of the flyball operated floating lever 43 to the gate pilot valve 14 to restore such valve to neutral position after each movement thereof to thereby prevent movement of the gate 9 beyond a desired position. Such relay comprises a cable 51 attached at one end to the gate servomotor piston 12 and passing respectively over pulleys 52, 53, 54 and 55 with the free end of the cable attached to a weight 57 to keep the cable taut. The cable 51 permits location of the servomotor 12, 13 wherever desired and at a distance from the remainder of the governing system.

To secure stable operation of the turbine and to allow only a predetermined speed difference or so-called speed droop between no load and full load gate vane opening to thereby meet requirements from maintenance of the desired speed and hence of constant frequency of the generator, pulley 54 is connected through a dashpot and linkage with the flyball floating lever 43. The dashpot comprises a casing 58 divided into two chambers by a partition and by pistons 59 and 60 and provided with a valve 61 for controlling the rate of flow of fluid under pressure from one dashpot chamber to the other. Pulley 54 is fixedly mounted on a shaft 62 supported on a fixed bracket 63 and the pulley shaft has fixed thereon an arm 64 connected with the piston 59. The dashpot piston 60 is connected by a lever 66 and a link 67 with one end of the flyball operated floating lever 43. It will be understood that all movements of the gate vane servomotor 12, 13 are relayed to the floating lever 43 through the dashpot 58 and linkage 64, 66, 67 thus providing means for returning the gate pilot valve 14 to the neutral or mid-position after each movement thereof and that such returning actions are subject to the damping action of the dashpot.

Hydraulic turbines in which the runner vanes are adjustable can operate at their maximum effi-

ciency only if a predetermined relation is maintained between the runner vane setting and the gate vane opening and such relation must be variable for different heads under which the turbine is to operate. The runner vanes are operated or adjusted by the servomotor 19, 20 responsive to fluid pressure controlled by the pilot valve 28. Operation of the gate servomotor 12, 13 causes movement of the relay cable 51 which rotates pulley 55 mounted on a fixed portion of the governor base. The rotation of the pulley acts through a rod 171 on an arm 172 keyed on a shaft on which is secured a holder 173 for a plurality of cams 174 having different cam surfaces formed to give the proper runner vane setting-gate opening relation for different heads. A follower 176 rides on the surface of one of the cams 174 and transmits the cam movement to a shaft 177. The shaft 177 is mounted on a fixed portion of the governor base in the supports 178 (see Fig. 2) for a screw 179 engaging a nut 180 connected with the cam follower 176. The cam follower is splined or otherwise fastened to the shaft 177 in such manner that rotation of the screw 179 by means of hand wheel 181 moves the cam follower from the surface of one cam to the surface of any other cam as may be desired.

Movement of the shaft 177 is transmitted to a lever 182 mounted on the shaft and connected through a compression spring connection 183 with a sector shaped arm 184 rotatable on the shaft and grooved in one end to provide a seat for a cable 185 which is used to allow placing of the governing system at a distance from the prime mover itself. The cable 185 extends from the sector arm 184 to a similar sector shaped arm 186 mounted on a pivot 187 which is on or closely adjacent pilot valve 28 which is itself mounted on or adjacent the prime mover-generating unit. An arm 188 is connected with sector arm 186 and is connected by way of a link 189 with a floating lever 191 to which is connected the stem 29 of the pilot valve 28. The other end of the floating lever 191 is connected by way of a link 192 with a cross head 193 guided in vertical movement by the walls of the oil distributing head 26, 27 and connected to a rod 194 mounted on the tube 23 and therefore movable with such tube. The cams 174, cam follower 176, cable sectors 184 and 186 and their interconnections comprise means for varying the action of the gate operating means on the runner vane adjusting means.

When an adjustable vane propeller turbine is shut down, the gates are closed and the runner vanes are turned to flat position. In such flat position of the runner vanes, the runner vanes can, however, produce only a very small torque and it is desirable to set the runner vanes initially in steep position and to return the runner vanes to the control of the proper cam only after the turbine has commenced rotating. A power cylinder 196 is mounted adjacent the cams 174 and is provided with a piston 197 under the compression of a spring 198. Fluid pressure may be admitted to the cylinder 196 from the pipe 31 through valve 199 and may discharge from the cylinder through valve 200. The two valves 199 and 200 are under spring pressure and are interconnected to be operated by the same lever 202 actuated by a solenoid 203 which may be energized either automatically responsive to an operating condition of the turbine or under manual control during starting of the turbine or when the turbine is to be started. Upon opening of the valve 199 fluid pressure lifts the piston 197 and the piston rod rises into contact with a lever 204 which is keyed to the shaft 177 and is capable of rotating the shaft to lift the follower 176 off cams 174 and to cause movement of the linkage necessary to operate the pilot 28 in a direction to admit pressure to the upper side of the runner servomotor 19, 20 for moving the runner vanes into steep position. It will be understood that servomotor 196, 197 and its control neutralize the effect of movement of cams 174 on the adjustment of the runner vanes by lifting cam follower 176 from the cams. Upward movement of piston 197 is limited by a stop 195 threaded into cylinder 196 and having the rod of piston 197 passing therethrough. After the turbine has commenced rotating, solenoid 203 is deenergized and valves 199 and 200 are closed and opened respectively to allow discharge of pressure from the cylinder 196. The spring 198 then returns the piston 197 to the end of the cylinder and the entire cam follower mechanism connected with lever 204 returns to the initial position thus bringing cam follower 176 again to the surface of the cams 174 which then take over the control of the pilot valve 28 in a predetermined relation to the movement of the gate operating means.

If some emergency requires that the oil pressure necessary for operating the entire governing system be conserved, it is essential that the runner vane movement be temporarily interrupted. Mechanical locking means are therefore provided for preventing operation of the valve 28 so long as the oil pressure is below a predetermined value. A gear sector 206 is keyed on the shaft 177 and engages a gear 207 mounted on or formed as portion of a brake drum 208. A plurality of brake shoes 209 are pivoted for movement into and out of contact with the drum 208 and are interconnected by a linkage 210 which is connected with the core of solenoid 211. Energization of the solenoid 211 is preferably controlled responsive to oil pressure so as to energize the solenoid when the oil pressure drops below a predetermined value. The brake shoes 209 are then drawn against the brake drum 208 and the valve 28 is held in fixed position until the oil pressure rises and again causes deenergization of the solenoid 211.

A dashpot 213 with an adjustable valve 214 is mounted adjacent the sector arm 184 and is connected therewith to obtain smooth and regular movement of the linkage required for movement of the valve 28. The rate of movement of the dashpot is controlled by adjustment of the valve 214 for controlling the by-passing of fluid around the piston of the dashpot. The dashpot regulates the speed of movement of the runner vane control means which vary the action of the gate operating means and the spring 183 allows overtravel of the runner control means in the direction of adjustment of the vanes to steep position.

When the fluid pressure operating the governing system falls below a predetermined value, it is desirable to conserve the remaining pressure for operation of the gate servomotor 12, 13 and to prevent dissipation of the pressure by operation of the runner servomotor 19, 20. Flow of the pressure to the runner servomotor is therefore interrupted under conditions of low fluid pressure by hydraulically operated valves 241 and 242 inserted in the piping between the pressure distributing head 26, 27 and the pilot valve 28. Valves 241 and 242 are shown as being of the rotary plug type connected by a common oper-

ating rod 243 with a piston 244 movable in a power cylinder 245 under the action of the fluid pressure and against the action of the spring 246. Pressure flow to the cylinder 245 and discharge from the cylinder is controlled by valves 247 and 248, respectively, which are under spring pressure and are operated by a solenoid 249 controllable by any suitable fluid pressure responsive means capable of closing the circuit to the solenoid when the governor operating fluid pressure drops below a predetermined value and of opening the circuit when the pressure again rises. The mechanical locking means previously described may be operated with or independently of the above hydraulic locking means and may be responsive to the same or to different conditions.

The sequence of operations of the governing system will now be briefly described from the normal shut down position shown in Fig. 1 of the drawing through the starting operation. Starting of the system involves only rotation of the synchronizing screw 39 to raise the gate pilot valve 14 and energization of the solenoid 203 to cause the piston 197 to raise the runner pilot valve 28. Gate 9 is then opened and raising of the runner pilot valve 28 admits pressure on top of the runner servomotor piston 19 to place the runner vanes 17 in steep position for starting. Adjustment of the synchronizing screw 39 is continued until flyballs 48 are extended to approximately synchronous speed of the unit. Solenoid 203 is then deenergized and cam follower 176 comes to rest on a predetermined cam surface 174 to allow the runner pilot valve 28 to discharge sufficient pressure to bring the runner vanes 17 to the position determined by the contour of the cam 174 then under the cam follower 176. The unit is now in full operation under the control of the flyballs and will deliver power up to the maximum limit set and at only such speed variations as are permitted by adjustment of the speed droop dashpot modifying the connections for restoring the gate pilot valve 14 to its mid-position.

It will be understood that the present invention provides normal operating means including a pilot valve 14 and the servomotor 12, 13 for operating the gate 9. Such gate operating means is controlled by speed responsive means including motor 49, flyballs 48, servomotor 44 and leverage 43, 42 and 38. The gate pilot valve 14 and the servomotor 12, 13 are returned to mid-position by the cable 51 acting through pulley 54 on the dashpot 58, 59, 60 and 61 and through leverage 66, 67 on the leverage 43, 42 and 38. The runner vane control mechanism includes normal operating means which are required for steep tilting of the runner vanes during starting and which comprises valves 199 and 200, power cylinder 196, 197 and lever 204 acting on the mechanism for maintaining a predetermined relation between gate position and runner vane position during normal operation of the unit. Such normal operation runner vane control mechanism includes a plurality of cams 174 and a cam follower 176 acting through an over-travel spring 183, under the modifying action of a dashpot 213, on the runner pilot valve 28 connected to the leverage 188 to 194, inclusive, for actuating the valve 28 and for restoring such valve to mid-position after each movement of the runner servomotor piston 19.

The system also includes means responsive to abnormal conditions and affecting the operation of the runner vane servomotor 19, 20 and includes solenoid operated valves 247 and 248 controlling power cylinder 244, 245 which operates shutoff valves 241 and 242. The position of the runner vanes 17 is fixed on the occurrence of abnormal conditions by the brake 208 to 211 inclusive and by valves 247 and 248 acting on the power cylinder 244, 245 to actuate the valves 241 and 242 which lock the runner vane mechanism mechanically and hydraulically, respectively.

This application is a division of application Serial No. 317,800, filed February 8, 1940.

Although but one embodiment of the present invention has been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

As is claimed and desired to secure by Letters Patent:

1. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of the said gate operating means, means for varying the action of said gate operating means on the movement of said runner vane adjusting means, and means for regulating the speed of movement of said gate action varying means.

2. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, means for varying the action of said gate operating means on the movement of said runner vane adjusting means, and a dashpot for regulating the speed of movement of said gate action varying means.

3. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a cam movable into varying positions responsive to the movement of said gate operating means, a cam follower movable in contact with said cam for controlling the action of said runner vane adjusting means, and means for regulating the speed of movement of said cam follower.

4. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of the said gate operating means, means for varying the action of said gate operating means on the movement of said runner vane adjusting means, and means for taking up the difference in movement between said gate action varying means and said runner vane adjusting means.

5. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, means for varying the action of said gate operating means on the movement of said runner vane adjusting means,

and a spring connection for permitting overtravel of said gate action varying means in one direction.

6. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of the said gate operating means, and means independent of said gate operating means for neutralizing the effect thereof on said runner vane adjusting means.

7. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a servomotor for neutralizing the effect of said gate operating means on said runner vane adjusting means, and means responsive to an operating condition of said prime mover for controlling the operation of said servomotor.

8. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a pressure operated servomotor for neutralizing the effect of said gate operating means on said runner vane adjusting means, and valves for controlling the supply of fluid pressure to said servomotor responsive to an operating condition of the prime mover.

9. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a servomotor for neutralizing the effect of said gate operating means on said runner vane adjusting means, means responsive to an operating condition of the prime mover for controlling the operation of said servomotor, and a stop for limiting the action of said servomotor in neutralizing the effect of said gate operating means on said runner vane adjusting means.

10. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of the said gate operating means, and means for mechanically locking said runner vane adjusting means in position responsive to an operating condition of the prime mover.

11. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a brake drum connected with said runner vane adjusting means for movement thereby, and brake bands movable into contact with said drum for mechanically locking said runner vane adjusting means in position responsive to an operating condition of the prime mover.

12. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, a brake drum connected with said runner vane adjusting means for rotation thereby, brake bands movable into contact with said drum for mechanically locking said runner vane adjusting means in position, and means responsive to an operating condition of the prime mover to bring said brake bands into contact with said brake drum.

13. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of the said gate operating means, and means for hydraulically locking said runner vane adjusting means in position responsive to an operating condition of the prime mover.

14. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, fluid pressure operated means for adjusting the runner vanes responsive to the movement of said gate operating means, and shut-off valves controlling the flow of fluid pressure to said runner vane adjusting means for hydraulically locking the same in position.

15. In a governing system for a prime mover having a gate controlling the flow of fluid thereto and having a runner with adjustable vanes, means for operating the gate responsive to the speed of the prime mover, means for adjusting the runner vanes responsive to the movement of said gate operating means, shut-off valves controlling the flow of fluid pressure to said runner vane adjusting means for hydraulically locking the same in position, and means responsive to an operating condition of the prime mover to operate said shut-off valves.

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