REGULATION OF HYDRAULIC TURBINES

Filed July 27, 1965 4 Sheets-Sheet 1

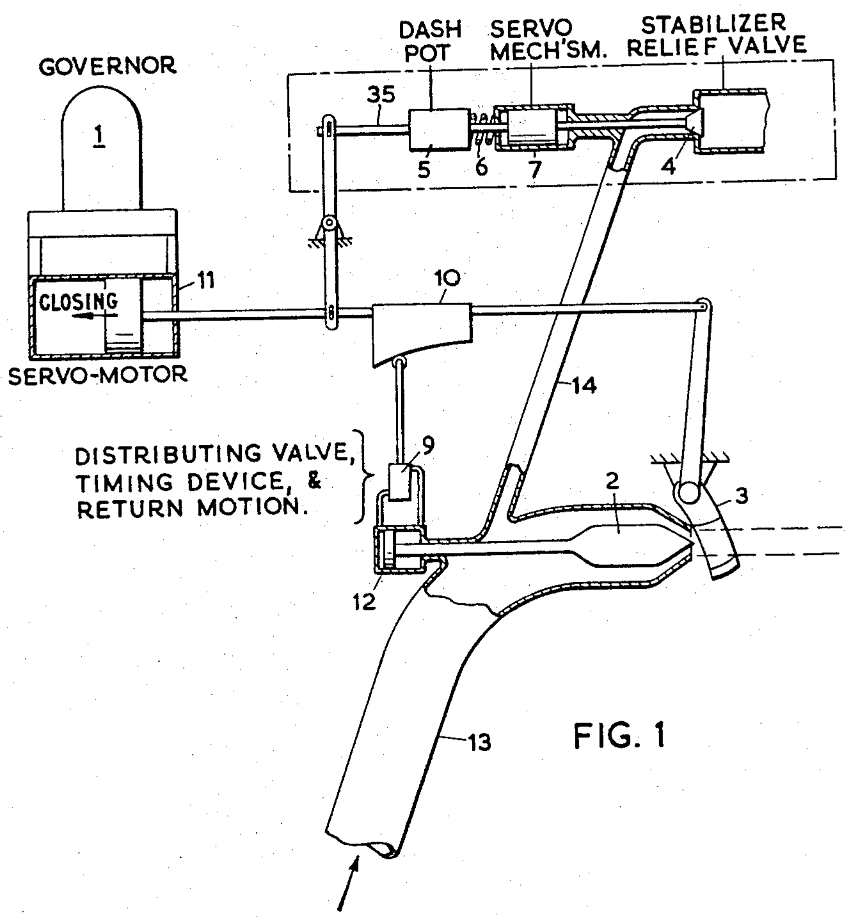

FIG. 1

REGULATION OF HYDRAULIC TURBINES

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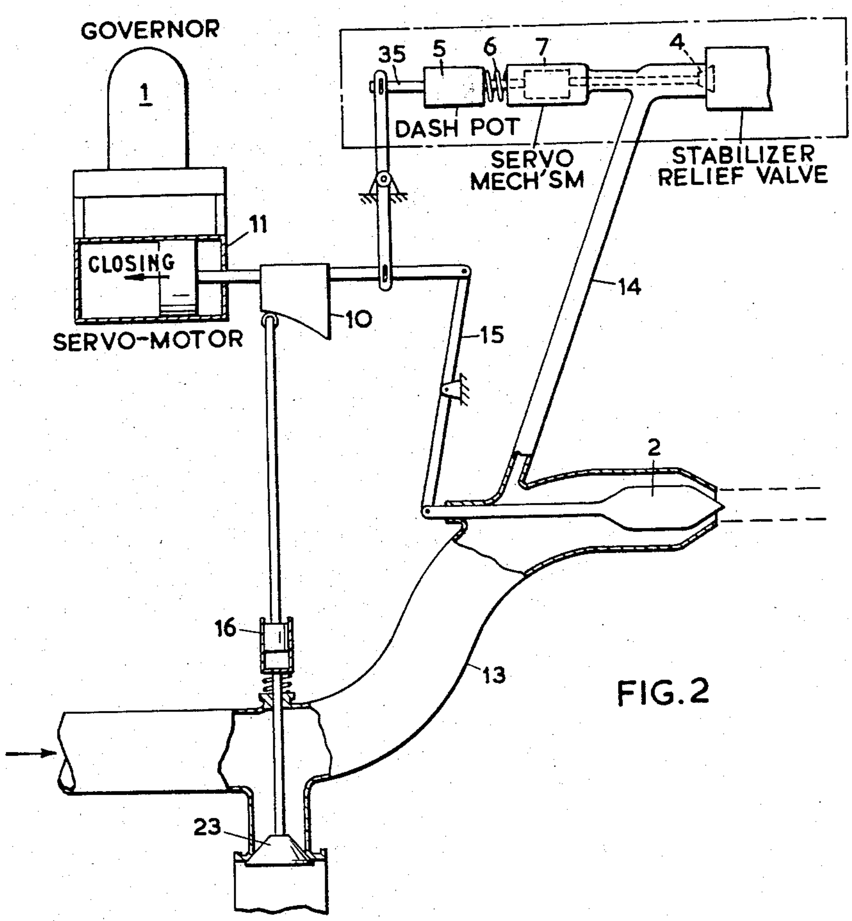

FIG. 2

Sept. 27, 1966 G. KERENSKY 3,275,008

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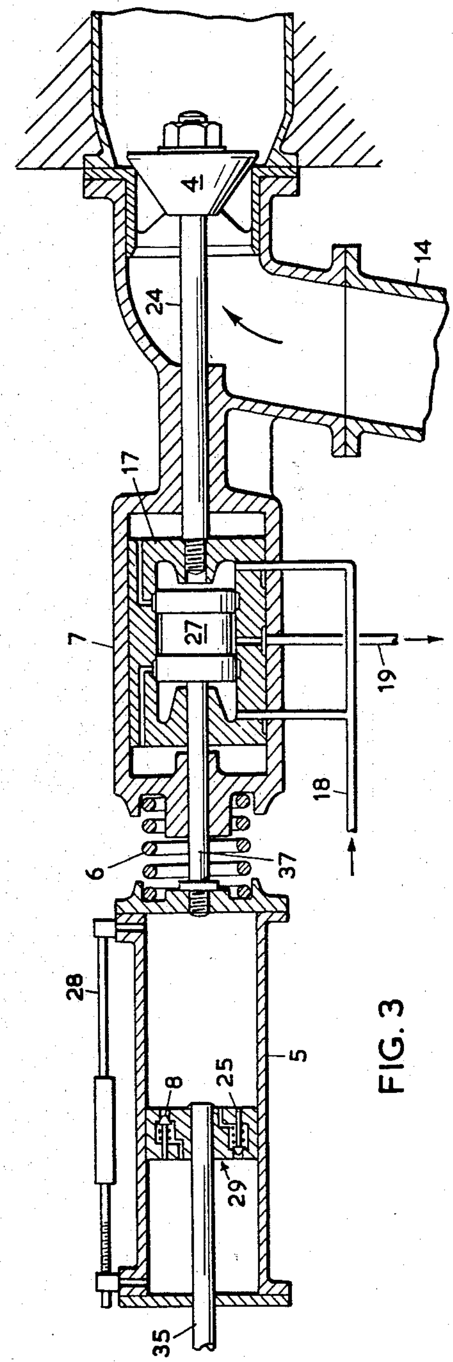

FIG. 3

REGULATION OF HYDRAULIC TURBINES

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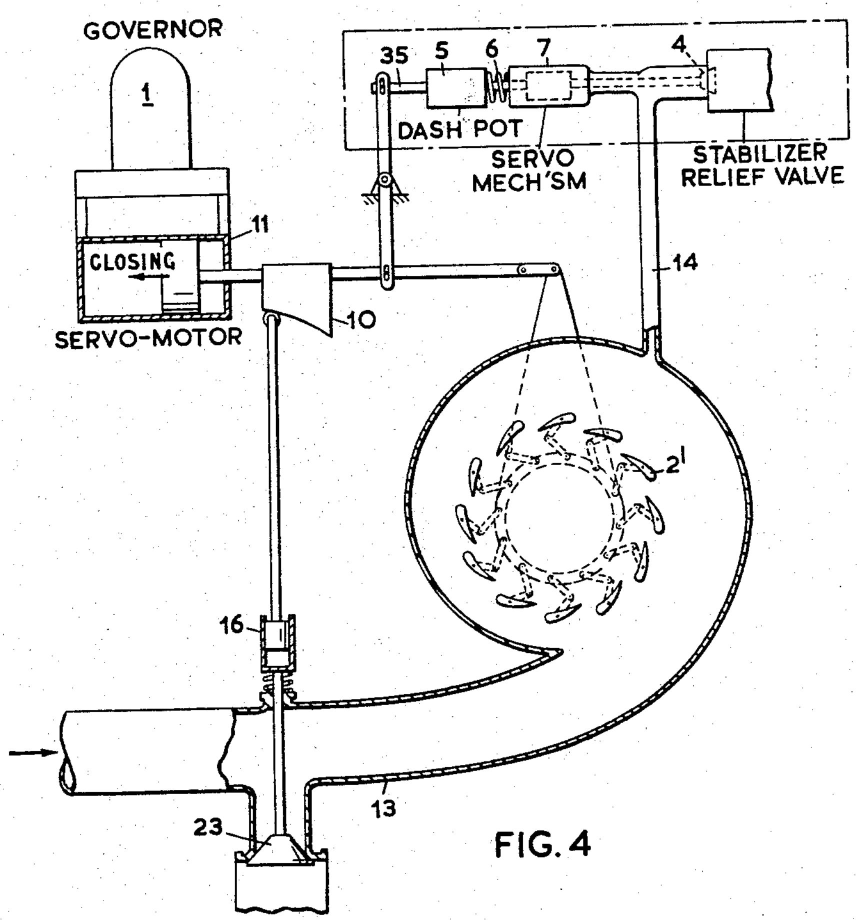

FIG. 4

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REGULATION OF HYDRAULIC TURBINES

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15 Claims. (Cl. 137—25)

This application is a continuation-in-part of my co-pending application Serial No. 397,203, filed Sept. 17, 1964, which in turn was a continuation of my application Serial No. 7,050, filed Feb. 5, 1960.

The invention relates to the regulation of hydraulic turbines operating under substantial heads and with penstocks of substantial length, for example impulse turbines and low-specific-speed reaction turbines.

A closing movement of the quantity controlling mechanism (needle of an impulse turbine, shutter mechanism of a reaction turbine) under the action of the turbine governor in response to a reduction in load or increase of rotational speed involves a pressure rise in the end of the penstock adjacent to the said quantity controlling mechanism which during the half period of oscillation in the pipe line may even force a greater energy flow past the said quantity-controlling mechanism than before the closing movement, and during this half period (which may be of several seconds) makes the governor action ineffective.

The conventional secondary regulating means (such as a relief valve of conventional characteristics at the turbine end of the penstock of an impulse or reaction turbine) cannot be made to operate effectively when the governor movement is very small or very slow for reasons which are numerous and differ in the case of each type of turbine and secondary regulating device but can be summarized by saying that a powerful device designed to deal with large and slightly uncertain flow of water either cannot be adjusted with sufficient accuracy to deal with very small changes of flow or if so adjusted becomes commercially unattractive by reason of increasing wear and reduction of efficiency. This ineffectiveness of secondary regulating means with respect to small load changes has hitherto been tolerated (i.e., the resultant speed variations have been accepted) or has been provided against by keeping the pipe lines short, the water velocities low and the inertia constant of the machinery high, but in many cases it would be advantageous to abolish the need for such tolerance with respect to speed variation or the use of the countermeasures described.

According to the present invention, in addition to the conventional quantity-controlling mechanism (e.g. needle of an impulse turbine, shutter mechanism of a reaction turbine) and to the conventional secondary regulating means (e.g. jet deflector of an impulse or relief valve of conventional characteristics at the downstream end of the penstock of an impulse or reaction turbine), if any, an auxiliary regulating means is provided which under the control of the turbine governor controls the pressure at the turbine end of the penstock upon control movements of the said turbine governor of an order of magnitude or rate substantially below the order of magnitude or rate at which the said secondary regulating means becomes effective.

Preferably the said auxiliary regulating means includes a small stabilizer relief valve branched off the turbine end of the said penstock just upstream of the said quantity controlling mechanism and arranged to be fully opened in response to said small and/or slow movements

of the said turbine governor in the sense of closing the said quantity-controlling mechanism.

For example the said auxiliary regulating means may be designed to open fully, i.e., to the limit of their capacity, upon a movement of the said turbine governor of only 2% of its stroke even if that movement is so slow as to take 5 seconds or more. This auxiliary stabilizer relief valve stands in a somewhat similar relation to the secondary regulating means as a vernier scale does to the main scale of an instrument, enabling great accuracy to be attained at one point of the scale which is momentarily in use instead of providing an improvement at all points of the scale simultaneously.

The conventional secondary regulating means as heretofore described is not sufficiently accurate to provide the desired control of the pressure at the turbine end of the penstock in response to small or slow governor movements, and such control as it does provide is therefore too coarse. The auxiliary regulating means is responsive to small and slow governor movements. The secondary regulating means therefore operates as a coarse control i.e., in response to large and fast governor movements and the auxiliary regulating means operates as a fine control. The cooperation of the coarse and fine controls provides the desired control of the pressure at the turbine end of the penstock.

Normally said stabilizer relief valve will be biased by a spring towards its closed position. However in view of its small dimensions it may, without undue loss of pressure water, be normally kept partly open and be fully opened by the said turbine governor acting on the said quantity controlling means in the sense of closing, and temporarily closed by the said turbine governor acting in the sense of opening the said quantity controlling means, so that its action is not primarily the suppression of a pressure rise in the penstock during small closing movements of the conventional quantity control mechanism of the turbine, but extends equally to the suppressing of a fall of pressure when the turbine governor makes an opening movement. In this case the auxiliary stabilizer relief valve would be centralized in the partly opened position between two springs counter-acting both a closing and an opening movement thereof.

In cases where loss of pressure water is unimportant the said stabilizer relief valve may even be spring biased towards its open position (by reversal of the aforesaid spring arrangement) and temporarily closed when the turbine governor makes an opening move of the quantity-controlling mechanism. In this case the stabilizer relief valve acts primarily by suppressing falls of pressure instead of pressure rises.

Regardless of whether the stabilizer relief valve is biased to close, to open or to maintain a half-way position its ability to compensate is not confined to its first working stroke, i.e., displacement from normal to transient condition. If a movement of the governor displaces the stabilizer relief valve from the normal position it momentarily becomes capable of following a reverse movement of the governor. Thereby during a sustained oscillation of the governor the stabilizer relief valve can suppress pressure rises and falls of pressure alternately regardless of its initial bias. This suppression of pressure changes can be total for small governor oscillations or partial for larger movements but in either case will exercise a stabilizing effect by opposing divergence and encouraging convergence of oscillations.

A preferred auxiliary regulating means according to the present invention includes a dash-pot with timing device connected between the turbine governor and the distributor valve of a servo-mechanism operating the stabilizer relief valve, and this dash-pot has an over-load device to give away upon more violent moves of the turbine regulator which would otherwise crush the stabilizer relief valve by causing it to do more than its designed stroke. The controls are then so arranged that when the governor is not moving, the stabilizer relief valve has a tendency to return to its closed position.

By this arrangement a closing move of the turbine governor (i.e. a movement of the governor in the sense of closing the quantity-controlling mechanism) will open the stabilizer relief valve and thereby effect the pressure relief desired at the turbine end of the penstock and, because this stabilizer relief valve is required only as a refinement to the action of other mechanisms, its timing and other characteristics can be totally different from those of the secondary regulating means and fully tuned to small governor movements.

In order that the invention may be clearly understood some embodiments thereof will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic arrangement according to the invention as applied to the regulation of an impulse turbine.

FIG. 2 is a similar diagrammatic arrangement which is applicable either to an impulse or a reaction turbine.

While the arrangements of FIGS. 1 and 2 are in general on conventional lines, the new components thereof are indicated in these figures within a chain-dotted frame.

FIG. 3 shows on a larger scale and in more detail an embodiment of the components diagrammatically indicated in FIGS. 1 and 2 within the chain-dotted frame, and

FIG. 4 is a diagrammatic arrangement similar to those of FIGS. 1 and 2 and which is applicable to a reaction turbine.

Referring now firstly to FIG. 1, the turbine governor **1** operates the needle **2** (quantity-controlling mechanism) controlling the flow of water to an impulse turbine, and also operates the deflector **3** (the secondary regulating means). The parts **4, 5, 6** and **7** will be described with reference to FIG. 3.

The main servo-motor **11** of the governor is shown as operating the deflector **3** directly, and operating the needle **2** through a cam-and-follower device **10** and servo valve **9**. The latter controls the supply of servo-fluid to the two sides of a servo-motor **12** for the needle **2**, and also incorporates a return spring, which maintains the cam and follower in contact. The penstock **13** is connected, upstream of the needle **2**, by a pipe **14** to a stabilizer relief valve **4** discharging to waste. The stabilizer relief valve **4** is connected, through servo-mechanism **7** and a collapsible dashpot **5** (to be described with reference to FIG. 3), to the cam **10** or to any other suitable point in the linkage operated by the main servo-motor **11**.

Referring now to FIG. 2, the turbine governor operates the needle **2**, as in FIG. 1, and also operates an ordinary relief valve **23** as the secondary regulating means (in place of the deflector **3**), this relief valve being connected to the penstock **13** and discharging to waste. The main servo-motor **11** operates the needle **2** through a linkage **15**, and operates the relief valve **23** of conventional characteristics through a cam-and-follower device **10** and dashpot **16**. The arrangement of pipe **14** and of components **4, 5, 6** and **7** is exactly the same as in FIG. 1.

In an alternative shown in FIG. 4, the arrangement is identical with that shown in FIG. 2, except only that instead of the needle **2** there is shown a conventional shutter mechanism **2'** of a reaction turbine connected to the servo-motor **11**.

In FIGS. 1, 2 and 4, the needle **2** or shutter mechanism **2'** is the quantity-controlling mechanism, and the deflector **3** or relief valve **23** of conventional characteristics are the secondary regulating means; the stabilizer relief valve **4** is the auxiliary or vernier regulating means which provides the regulation in accordance with the invention.

This auxiliary or vernier regulating means will now be described in more detail with reference to FIG. 3.

The stabilizer relief valve proper, **4**, is of the mushroom type. Its stem **24** is connected to the piston **17** of a servo-mechanism **7** which piston is hollow and contains a cylindrical valve **27** having two lands at the ends and a recessed middle portion. Hydraulic pressure fluid is supplied to the interior of piston **17** at both ends through a supply pipe **18**, and is drained off from the middle through a drain pipe **19**.

The stem **37** of the cylindrical distributor valve **27** is fixedly connected with a dash-pot **5** the piston **29** of which is connected through its stem **35** to the governor servo-motor **11**. Relief valves **8, 25** opening in opposite directions are arranged in the piston **29**, and the two ends of the dash-pot **5** are connected with one another by an adjustable timing device **28**.

A coiled compression spring **6** is interposed between the dash-pot **5** and the cylinder of the servo-mechanism **7** to provide a re-setting force to return the valve slowly to the closed position after it has been opened by governor action.

In operation, rapid changes of load and/or speed or of any other parameters to which the turbine governor **1** responds results in a rapid action by the secondary regulating device which permits effective regulation without undue pressure rise. Thus the deflector **3** (FIG. 1) partly or wholly cuts off the jet while the spear **2** adjusts itself to new flow conditions more slowly, or the ordinary relief valve **23** (FIG. 2) opens almost as fast as the needle closes suppressing the pressure rise wholly or partially.

However, when the closing movement is small or very slow these secondary regulating devices cannot be brought into play effectively as explained earlier.

Here the vernier regulation according to the present invention intervenes, as a means designed especially for matching the small movement (or the early stages of a large but slow movement) of the quantity-controlling device: any closing movement of the turbine governor **1** will through the linkage **35** move the piston **29** of the dash-pot **5**, and accordingly the dash-pot itself, to the right. The movement of the dash-pot **5** is transmitted through the rod **37** to the cylindrical valve **27** which uncovers the ducts leading hydraulic pressure fluid to the left of piston **17** and thereby opens the small stabilizer relief valve **4** connected with the piston **17** through the rod **24**. Hence a fall in pressure occurs in the pipe **14** which spreads to the part of the penstock immediately upstream of the needle **2** (or shutter mechanism) and abolishes the small pressure rise which otherwise would occur there.

Large and rapid movements of the turbine governor **1** and consequently of the dash-pot **5** bring the stabilizer relief valve quickly to the end of its stroke and the dash-pot **5** thereupon encounters solid metal-to-metal resistance to further movement with the result that pressure inside it rises and the overload safety valve **8** opens, permitting the piston **29** to continue moving without resulting in any further movement of the dash-pot **5**. When the movement of the piston **29** ceases, the safety valve **8** closes and the cylinder of dash-pot **5** creeps slowly to the left under the influence of the spring **6** controlled by the slow escape of oil from the right hand side to the left hand side of the dash-pot **5** via the timing device **28**. This movement continues until the stabilizer relief valve **4** is fully closed.

Any movement of the piston **29** towards the left at a time when the stabilizer relief valve **4** is still open results in the piston **29** and valve **4** moving together until the stabilizer relief valve is closed.

Any movement of the piston **29** towards the left at a time when the stabilizer relief valve **4** is already fully closed and therefore cannot move further in the direction results in safety valve **25** opening, to act in a similar manner to safety valve **8** as already described.

What I claim as my invention and desire to secure by Letters Patent is:

1. A device for regulating water flow through a water

turbine having a penstock for leading a flow of water to the turbine, comprising a governor, quantity control means connected to said governor to reduce the flow of water in the penstock on increase of speed sensed by said governor, first relief valve means connected to the penstock to vent water therefrom and connected to said governor to be operated thereby in the sense of opening on increase of speed, second relief valve means connected to the penstock to vent water therefrom, said second relief valve means having a stroke which is only a small part of said governor stroke and having a flow capacity which is only a small fraction of the flow capacity of said first relief valve means, and a yieldable connection between said second relief valve means and said governor to operate said second relief valve means in the sense of opening on increase of speed, and to allow said governor to over-run said second relief valve means when the latter reaches the end of its stroke.

2. A device for regulating water flow through a water turbine having a penstock for leading a flow of water to the turbine, comprising a governor, quantity control means connected to said governor to reduce the flow of water in the penstock on increase of speed sensed by said governor, first relief valve means connected to the penstock to vent water therefrom, first dash-pot means having first and second elements, said first element being connected to said first relief valve means to operate it and said second element being connected to said governor to be operated thereby in the sense of opening said first relief valve means on increase of speed, and second relief valve means connected to the penstock to vent water therefrom, said second relief valve means having a stroke which is only a small part of said governor stroke and having a flow capacity which is only a small fraction of the flow capacity of said first relief valve means, servo-motor means connected to said second relief valve means, second dash-pot means comprising a third element and a fourth element, said third element being connected to said governor means to be operated thereby and said fourth element being connected to said servo-motor means to operate it, resilient means to load said fourth element, and said second dash-pot means comprising also means to allow collapsing of the two elements thereof under the influence of said resilient means only at a rate substantially slower than the rate at which the two elements of said first relief valve means collapse, and said second dash-pot means also comprising safety valve means whereby said third element may over-run said fourth element when the latter reaches the end of its stroke.

3. A device as claimed in claim **2**, wherein said resilient means loads said fourth element in the sense of closing said second relief valve means.

4. A device as claimed in claim **2**, wherein said resilient means loads said fourth element in the sense of opening said second relief valve means.

5. A device as claimed in claim **2**, wherein said resilient means biases said fourth element to a partly-open position of said second relief valve means.

6. In a water turbine having a penstock for leading a flow of water to the turbine, a governor, quantity control means connected to the governor to reduce the flow of water in the penstock on increase of speed sensed by said governor, first relief valve means connected to the penstock to vent the water therefrom and connected to said governor to be operated thereby in the sense of opening on increase of speed, and second relief valve means connected to the penstock to vent water therefrom and so connected to the governor that a partial motion of the governor will cause a full stroke of said second relief valve, said latter connection comprising a dash-pot means between said second relief valve means and said governor to operate said relief valve means in the sense of opening on increase of speed, and to allow said governor to over-run said second relief valve means when the latter reaches the end of its stroke.

7. In a water turbine having a penstock for leading a flow of water to the turbine, comprising a governor, quantity control means connected to said governor to reduce the flow of water in the penstock on increase of speed sensed by said governor, first relief valve means connected to the penstock to vent water therefrom, first dash-pot means having first and second elements, said first element being connected to said first relief valve means to operate it and said second element being connected to said governor to be operated thereby in the sense of opening said first relief valve means on increase of speed, and second relief valve means connected to the penstock to vent water therefrom, said second relief valve means having a stroke which is only a small part of said governor stroke and having a flow capacity which is only a small fraction of the flow capacity of said first relief valve means, servo-motor means connected to said second relief valve means, second dash-pot means comprising a third element and a fourth element, said third element being connected to said governor means to be operated thereby and said fourth element being connected to said servo-motor means to operate it, resilient means to load said fourth element, and said second dash-pot means comprising also means to allow collapsing of the two elements thereof under the influence of said resilient means only at a rate substantially slower than the rate at which the two elements of said first relief valve means collapse, and said second dash-pot means also comprising safety valve means whereby said third element may over-run said fourth element when the latter reaches the end of its stroke.

8. A speed control for a hydraulic turbine comprising a governor responsive to the speed thereof, means for regulating the quantity of fluid flowing to the turbine in response to changes in the speed thereof, and means for controlling the pressure of said fluid, said latter means comprising a coarse control for controlling the pressure in response to changes in the speed of the turbine, and a fine control for controlling the pressure in response to changes in speed over a small portion of the total movement of the governor.

9. A speed control for a hydraulic turbine comprising a governor for regulating the quantity of fluid flowing through a penstock to the turbine in response to the speed thereof and means for controlling the pressure of said fluid, said latter means comprising a first valve operated by the governor to discharge fluid from the penstock in response to a first change of speed of the turbine, and a second valve operated by the governor to discharge fluid, at a smaller rate than said first valve discharges, from the penstock in response to a second change of speed of the turbine which is substantially less than said first change of speed.

10. A device for regulating water flow through a water turbine having a penstock for leading a flow of water to the turbine, comprising a governor, quantity control means connected to said governor to be moved in the sense to reduce the flow of water in the penstock on increase of speed by said governor, secondary regulating means connected to said governor to be operated thereby in the sense to reduce the speed on increase of speed sensed by said governor, stabilizer relief means connected to the penstock to vent water therefrom, said stabilizer relief valve means having a stroke which is only a small part of the governor stroke and having a flow capacity which is only a small fraction of the flow capacity of said penstock, and a yieldable connection between said stabilizer relief valve means and said governor to operate said stabilizer relief valve means in the sense of opening on increase of speed, whereby to stabilize small fluctuations in said speed, and to allow said governor to over-run said stabilizer relief valve means when the latter reaches the end of its stroke.

11. A device for regulating water flow through a water turbine having a penstock for leading a flow of water to the turbine, comprising a governor, quantity control means connected to said governor to be moved in the sense to reduce the flow of water in the penstock on increase of speed sensed by said governor, secondary regulating means connected to said governor to be operated thereby in the sense to reduce the speed on increase of speed sensed by said governor, stabilizer relief valve means connected to the penstock to vent water therefrom, said stabilizer relief valve means having a stroke which is only a small part of the governor stroke and having a flow capacity which is only a small fraction of the flow capacity of said penstock, servo-motor means connected to said stabilizer relief valve means, dash-pot means comprising a first component and a second component, said first component being connected to said governor means to be operated thereby and said second component being connected to said servo-motor means to operate it, resilient means to load said second component, and said dash-pot means comprising also means to allow collapsing of the two components thereof under the influence of said resilient means only at a slow rate, and said dash-pot means also comprising safety valve means whereby said first component may over-run said second component when the latter reaches the end of its stroke.

12. A device as claimed in claim **11**, wherein said resilient means loads said second component in the sense of closing said stabilizer relief valve means.

13. A device as claimed in claim **11**, wherein said resilient means loads said second component in the sense of opening said stabilizer relief valve means.

14. A device as claimed in claim **11**, wherein said resilient means loads said second component to a partly-open position of said stabilizer relief valve means.

15. In a water turbine having a penstock for leading a flow of water to the turbine, a governor, quantity control means connected to the governor to be moved in the sense to reduce the flow of water in the penstock on increase of speed sensed by said governor, and stabilizer relief valve means connected to the penstock to vent water therefrom and so connected to the governor that a partial motion of the governor will cause a full stroke of said stabilizer relief valve means, said latter connection comprising a dash-pot means between said stabilizer relief valve means and said governor to operate said stabilizer relief valve means in the sense of opening on increase of speed, and to allow said governor to over-run said stabilizer relief valve means when the latter reaches the end of its stroke.

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