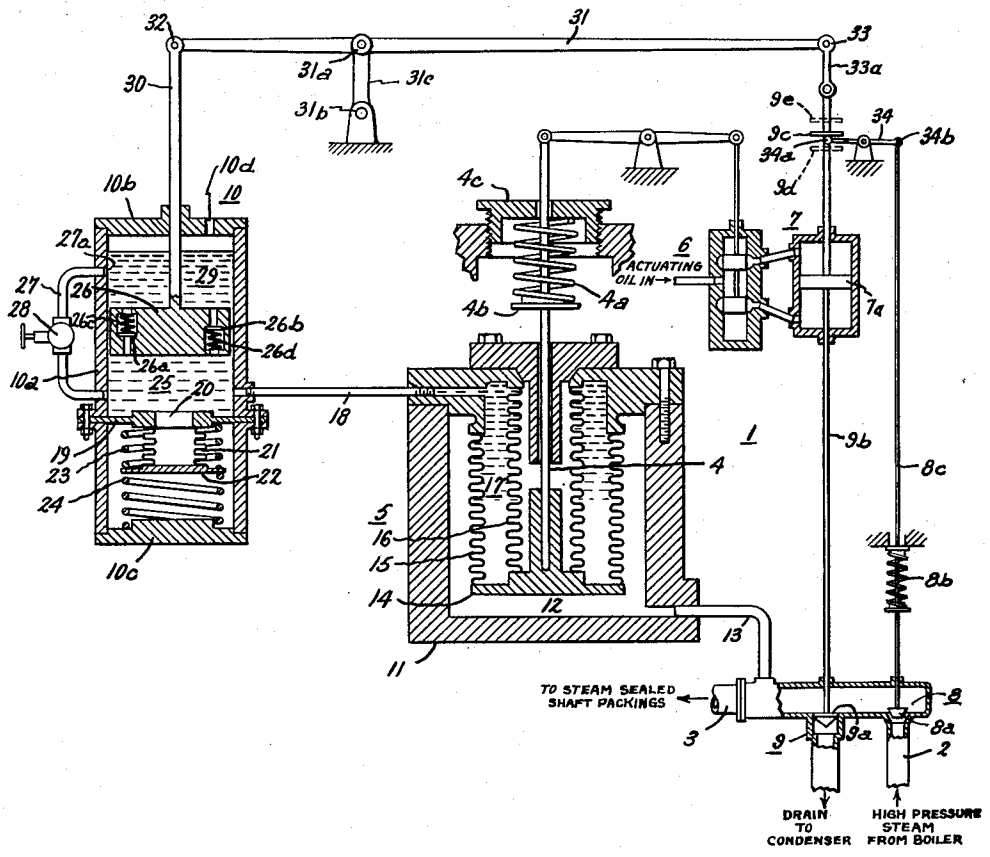
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HYDRAULIC REGULATOR WITH HYDRAULIC RESTORING AND STABILIZING DEVICE

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HYDRAULIC REGULATOR WITH HYDRAULIC RESTORING AND STABILIZING DEVICE

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This invention relates to hydraulic servo-mechanism, particularly to a hydraulic-mechanical device for overcoming inherent instability in a hydraulic regulator used to control the steam supply to the shaft packing seal of a steam turbine type of prime mover.

As will be appreciated by those skilled in the art relating to hydraulic servo-mechanisms, the tendency of a servo to become unstable and "hunt" becomes greater as the "regulation" of the mechanism approaches zero, "regulation" being the change occurring in the condition sensed as the condition being governed changes from its minimum value to its maximum value. Many expedients have been employed in the prior art to achieve stability when the regulation of the servo equals or approaches zero, or becomes negative. One such expedient is a liquid-filled dashpot, as shown for instance in the patent to Dettenborn—2,077,384, issued April 20, 1937, and Warren—2,113,416, issued April 5, 1938, both assigned to the same assignee as the present application.

A further improved hydraulic arrangement for better stability of a servo-mechanism used to control the flow of steam to the shaft packings of a steam turbine is disclosed in my U. S. Patent No. 2,635,639, issued April 21, 1953, and assigned to the same assignee. The present invention is a still further improvement of that hydraulic stabilizing arrangement.

Accordingly, the object of the present invention is to provide an improved hydraulic-mechanical stabilizing device for servo-mechanisms of the type described which gives even greater stability than the system of my copending application.

A further object is to provide hydraulic servo-mechanism of the type described for effecting stable operation with zero "regulation."

A still further object is to provide an improved hydraulic servo stabilizing device which, in the event of a sudden change in the condition being sensed, will provide instantaneously a rate of response substantially greater than that which is effected when the condition change takes place more slowly.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawing, in which the single figure represents diagrammatically hydraulic servo-mechanism having a stabilizing device incorporating the invention.

Generally, the invention is practiced by adding to the stabilizing device of my above-identified

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Patent 2,635,639, a special hydraulic restoring arrangement, eliminating the mechanical feedback system and acting directly on the hydraulic stabilizer in such a way that the speed of response of the mechanism is increased in the case of a large and fast change in the condition being controlled.

Referring now more particularly to the drawing, the hydraulic regulator indicated generally at 1 is arranged to receive high pressure steam from a boiler (not shown) through conduit 2 and supply it at a very much lower preselected pressure to the steam-sealed shaft packings (not shown) by way of conduit 3.

The pressure regulator 1 is arranged generally like the steam seal regulators previously known, having a signal output rod member 4 positioned by a condition-responsive device 5 arranged to control the pilot valve 6 of a hydraulic motor 7 so as to actuate a dual steam regulating valve, which admits steam through a valve 8, or, alternatively, dumps steam to the condenser by opening a second valve 9.

This invention particularly relates to the special hydraulic stabilizing device 10, which modifies the forces applied to the condition-responsive member 4 in order to achieve the required degree of stability.

As shown in the drawing, the condition-responsive device 5 comprises a housing 11 defining a pressure chamber 12 to which is communicated by conduit 13 the pressure of steam supplied to the shaft seals by conduit 3, as controlled by the hydraulic servo 1.

The output rod 4 is biased downwardly by a spring 4a engaging an abutment 4b carried by the rod. The upper end of spring 4a engages a threaded cap member 4c which may be screwed down farther or retracted to vary the force which spring 4a exerts on the rod 4. The lower end of rod 4 is secured to a first disk member 14, the lower surface of which is subjected to the signal pressure in chamber 12. To the outer circumference of disk 14 is sealed a flexible bellows member 15 cooperating with an inner bellows member 16 to define a first annular expansible chamber 17. The upper ends of bellows 15, 16 are sealed to the housing 11.

The annular chamber 17 is filled with a hydraulic liquid, such as a suitable petroleum oil, which liquid is communicated by way of conduit 18 with the hydraulic stabilizer 10. It will be seen that, since the space within bellows 16 communicates with the atmosphere by way of the substantial clearance space around rod 4,

the disk 14 is positioned against the bias of spring 4a by the steam pressure in chamber 12 acting on an annular area of the disk, as modified by any liquid pressure occurring in the chamber 17.

The hydraulic stablilizer 10 comprises a housing 10a which may be conveniently formed with end closure members 10b, 10c. Adjacent the mid-portion of the housing is a disk member 19 defining a large central opening 20 around which is sealed one end of a flexible bellows 21. The other end of the bellows is sealed to a "floating" disk 22, the neutral position of which is determined by two opposed coil springs 23, 24. It will be seen from the drawing that the interior of bellows 21 is in free communication, by way of the generously proportioned opening 20, with the chamber 25 above disk 19.

Slidably disposed in the upper portion of housing 10a is a piston member 26. A by-pass conduit 27 containing a needle valve 28 communicates liquid from the space 25 at the lower side of piston 26 to the chamber 29 defined above piston 26. As shown in the drawing, the normal level of oil in chamber 29 is well above the port 27a, and the surface of the liquid in chamber 29 is freely vented to the atmosphere by way of the vent 10d.

As will be apparent from the drawing, conduit 18 freely communicates hydraulic oil from annular chamber 17 to chamber 25 in the stabilizer 10, and by way of opening 20 to the interior of bellows 21, while conduit 27 communicates liquid past the needle valve 28 to the space 29 above piston 26. This chamber 29 serves as a storage reservoir for hydraulic liquid displaced from chamber 25 and also serves to keep the connecting conduits full of liquid at all times. This is why the port 27a must be below the lowest normal level of the liquid in space 29.

It is to be noted that the piston 26 is provided with a pair of oppositely acting check-valve disk members 26a, 26b, held against their seats by coil springs 26c, 26d, respectively. It will be apparent from the drawing that excessive pressure in chamber 25 will cause the check-valve disk 26a to rise against the bias of its spring permitting liquid to flow directly into chamber 29, while a sudden reduction of pressure in chamber 25 will cause check-valve 26b to open against the force of its spring 26d so as to admit liquid from chamber 29 into chamber 25. The function of these check-valves will be noted hereinafter.

As contrasted with the mechanical restoring arrangement disclosed in my Patent 2,635,639, the present arrangement includes hydraulic restoring means in the form of a feed-back lever 31 carried on a pivot 31a by means of the fulcrum 31b and link 31c. The left-hand end of lever 31 is pivoted at 32 to the upper end of piston rod 30 and the right-hand end of the lever is pivoted at 33 to the upper end of piston rod 9b by means of link 33a.

With further reference to the steam control valves 8, 9, it will be seen that the hydraulic motor piston rod 9b carries an abutment member 9c engaging the forked left-hand end portion 34a of a lever 34. The steam dump valve disk 9a is positioned directly by the double-acting hydraulic motor 7. It is to be noted that the outer diameter of the valve disk member 9a is equal to that of the valve seat with which it cooperates, so that disk 9a is capable of being displaced downwardly below the position shown in the drawing, corresponding to the dotted line position 9d of the abutment member 9c. The steam admission valve 8 has a flow control disk member 8a which is biased downwardly by a coil spring 8b into engagement with a conical seat member, as long as abutment 93 does not engage the forked end 34a of lever 34. The inlet valve stem 8c is pivoted at 34b to the right-hand end of lever 34.

With this arrangement, it will be apparent that, upon upward movement of hydraulic motor piston rod 9b, the abutment 9c merely moves away from the lever end portion 34a, and the valve disk 9a rises to open the dump port. Conversely, upon downward movement of piston rod 9b, abutment 9c engages lever end portion 34a so as to raise valve disk 8a and open the steam inlet. Such downward movement of piston rod 9b of course causes the valve disk 9a to move downwardly into its port.

The operation of this improved regulator may be outlined as follows: Assume first that the needle valve 28 is wide open. If now the steam pressure in conduit 3 should suddenly increase, the pressure responsive disk 14 will move upwardly against the downward force of spring 4a, substantially unaffected by the liquid in chamber 17, which liquid is merely displaced through conduit 18 and by way of by-pass conduit 27 to the generously proportioned reservoir space 29 above piston 26. Thus, except for a comparatively small amount of hydraulic damping effected by this flow of liquid from chamber 17 to chamber 29, the pilot valve 6 is moving in very much the same way as in the device of my prior copending application, but, since no positive "feed-back" from the hydraulic motor piston 7a to the pilot valve is present, the piston 7a would go on moving as long as the pilot valve 6 stays "off port," that is, as long as the pressure in chamber 12 is different from the value which holds the rod 4 in a position as to put the pilot valve 6 "on port." This system would be inherently unstable.

In order to make this system stable, the special action of the hydraulic stabilizer 10 is brought into action. To do this, the needle valve 28 is partly closed. If now an increase in the steam pressure occurs, the disk 14 will move upward as described previously, causing the pilot valve to move off port and piston 7a to rise, operating valves 8a or 9a, as the case may be, toward the position required by the changed steam flow which caused the steam pressure change. At the same time the upward movement of stem 9b causes the feed-back lever 31 to pivot counterclockwise about its fulcrum 31a, which motion causes the piston 26 to descend. This pushes the floating disk 22 downwardly against the bias of spring 24, increasing the fluid pressure in chamber 25, which is communicated by conduit 18 to the chamber 17. Thus disk 14 is pushed back down, restoring pilot valve 6 so as to stop the movement of hydraulic motor 7. At the same time, the increased pressure in chamber 25 effects a restricted flow of oil through conduit 27 and past needle valve 28, and this flow causes some decrease in the pressure in chamber 25. This small decrease in pressure tends to allow disk 14 to rise slightly again, and the pilot valve 6 tends to admit liquid to motor 7 for positioning the valve stem 96 upwardly.

The net effect of all these interacting factors is that the steam valves 8a and/or 9a are caused to slowly approach the position required for the new steady-state condition; and, at the time, the liquid pressure in chamber 25 has become equalized with the atmospheric pressure in chamber 29 and the pressure of the shaft sealing steam in conduit 3 has returned exactly to

the preselected steady-state value, but with an increased steam flow through the dump valve 9 and/or a decreased flow through inlet valve 8.

Since, with no positive pressure in the liquid-filled chamber 17, there is only one steam pressure in chamber 12 which will balance the force of spring 4a, with pilot 6 in the aligned or "on port" position, the net regulation of the system is zero, meaning that the steady-state pressure in conduit 3 is constant, regardless of the rate of steam flow; and this is true over the full range of operation, regardless of whether the inlet valve 8 is admitting steam to the conduit 3 or the dump valve 9 is releasing steam to the condenser.

Upon a drop of the steam pressure in conduit 3 below the preselected value, the operation of the system is the reverse of that described above. That is, the decreased pressure in chamber 12 causes disk 14 to descend, hydraulic pilot 6 causes the motor 7 to move the valve stem 8b downwardly so as to close the dump valve 9a, and/or to open the steam inlet valve 8a. Meanwhile the upward motion of piston 26 causes the floating disk 22 to rise against the bias of spring 23, producing a drop in pressure in chambers 25 and 17 which has a hydraulic restoring effect on the disk 14. The gradual bypassing of liquid through conduit 27 makes the mechanism approach slowly the new steady-state condition as described above.

An additional stabilizing effect, as fully disclosed in my prior patent, is also present in the above-described system. This effect is as follows. An increase of the steam pressure in chamber 12, causing the disk 14 to move up, tends to decrease the combined volume of chambers 17 and 25, forcing the floating disk 22 to move down against the bias of spring 24, thereby increasing the pressure in chambers 25 and 17. This tends to reduce the amount of motion transmitted to rod 4 for a given pressure change in chamber 12. This increases the "instantaneous regulation," which is the necessary transient pressure change sensed as the rate of steam flow from or to the conduit 3 changes by a certain predetermined amount within a certain short time. As will be appreciated by those skilled in the art relating to servo-mechanisms, an increase in the "instantaneous regulation" improves the stability of a control system of the type described.

It remains to note the effect of the spring-biased check valves 26a, 26b associated with the feed-back piston 26. One function of these relief valves is to prevent mechanical damage to the bellows 15, 16, 21 due to excessive pressures. It will be observed that an excessive sudden movement of piston 26 could produce a very high or a very low pressure in chamber 25. This will cause one or the other of these relief valves to open, thus interchanging liquid with the chamber 29 so as to insure that such excessive pressures will not be sufficient to cause mechanical damage to the respective bellows.

An equally important function of the check valves is that they increase the speed of response of the mechanism to sudden large changes in pressure of the steam. It will be apparent, from a consideration of the drawing, that opening of either check-valve 26a or 26b has the same effect as opening the needle-valve 28. Thus the spring-loaded relief valves in piston 26 have the same effect as if the needle valve 28 were automatically opened whenever the pressure change in chamber 25 exceeds preselected values. The advantage of having the two relief valves is that the respective springs 26c, 26b can be so selected as to have different stiffness, so that the response is different for increase in pressure in chamber 25, as compared with that occurring when there is a sudden decrease in pressure. Specifically, the spring 26c may be selected so that valve 26a requires a pressure differential of 8 pounds per square inch to open it, whereas valve 26b requires a differential of only about 3 pounds per square inch to unseat it.

It will be seen that the invention involves the interrelation of a substantial number of hydraulic-mechanical effects, which cooperate to effect a substantial improvement in the stability and response characteristics of the system. At the same time, the improved system is designed to operate with zero steady-state regulation, so that the steady-state pressure in the conduit 3 is always exactly the same regardless of the rate of steam flow. The substitution of the hydraulic feed-back effect further contributes to the stability and rate of response; and the check-valves in the feed-back piston renders the system more versatile by providing means for obtaining a somewhat different response upon a sudden large increase in steam pressure compared with that occurring upon a sudden decrease in pressure.

It will be apparent that the showing of the preferred embodiment in the drawing is intended to be diagrammatic only, and that in an actual structure the mechanical details may take many different forms. It is of course intended to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In hydraulic servo-mechanism having pilot-controlled motor means for regulating a condition with a signal output member connected to position the pilot, the combination of a condition-responsive device having means exerting a first force on the signal output member proportional to the condition being controlled, first expansible chamber means connected to exert on the signal output member a force in opposition to said first force, and hydraulic stabilizing means comprising a liquid-filled housing defining an intermediate chamber and upper and lower end chambers respectively, conduit means connecting said intermediate chamber with said first expansible chamber, said lower end chamber having an expansible wall member whereby the volume thereof may vary and opposed spring means acting on said expansible wall member to define a neutral position corresponding to a normal steady-state value of the volume thereof, said hydraulic stabilizer housing having a port establishing free communication between the intermediate chamber and said expansible lower end chamber, a reciprocable feed-back piston member in the upper portion of the stabilizer housing and separating the intermediate chamber from the upper end chamber, a bypass conduit with flow restricting means communicating between the intermediate chamber and the upper end chamber, the stabilizer housing having a vent for maintaining atmospheric pressure in the upper end chamber, and feed-back linkage means connecting the feed-back piston with the hydraulic motor whereby movement of the motor causes motion of the feed-back piston to produce a hydraulic restoring effect on the signal output member, as modified by said restricted bypass conduit and said expansible lower end chamber.

2. In hydraulic servo-mechanism having pilot-controlled motor means for regulating a condition with a signal output member connected to position the pilot, the combination of a condition-responsive device including means exerting a first force on the signal output member proportional to the condition being controlled, means defining a first expansible chamber and including a member connected to exert a force on the signal output member in opposition to said first force, and hydraulic stabilizing means including a liquid-filled housing with walls defining a second chamber having a first expansible wall member whereby the volume of the second chamber may be caused to vary, spring means acting on said expansible wall member to define a neutral position corresponding to a normal steady-state value of the volume of the second chamber, first conduit means connecting the second chamber with said first expansible chamber, a reciprocable feed-back piston member disposed to form a second movable wall of said second chamber, a bypass conduit with flow restricting means communicating between the second chamber and a third end chamber defined by the stabilizer housing at the side of said piston remote from the second chamber, the stabilizer housing having vent means for maintaining substantially ambient pressure in said third chamber, and feed-back linkage means connecting the feed-back piston with the hydraulic motor whereby movement of the motor effects movement of the piston to produce a hydraulic restoring effect on said signal output member, as modified by said restricted bypass conduit and said second expansible chamber.

3. Hydraulic servo-mechanism in accordance with claim 2 and including at least two spring-biased check-valves in the feed-back piston, one being adapted to pass liquid from the second to the third chamber in the hydraulic stabilizer when the pressure in the second chamber reaches a preselected maximum value, the other check-valve being adapted to pass liquid from the third to the second chamber when the pressure in the second chamber reaches a preselected minimum value, to effect automatic interchange of liquid between said second and third chambers for increasing the rate of response of the servo-mechanism in the event of rapid changes in the condition sensed.

4. In hydraulic servo-mechanism having pilot-controlled motor means for regulating a condition, the combination of a signal output member

connected to position the pilot, a condition-responsive device exerting a force on the signal output member proportional to the condition being controlled, means defining a first expansible chamber and including a member connected to exert a force on the signal output member in opposition to said condition-responsive force, and hydraulic stabilizing means including a liquid-filled housing with walls defining a second chamber with a first expansible wall member adapted to vary the volume of said second chamber, spring means acting on said expansible wall member to define a neutral position thereof corresponding to a normal steady-state value of the volume of the second chamber, first conduit means connecting the second chamber with the first expansible chamber, a reciprocable feed-back piston member disposed for vertical movement and forming a second upper movable wall of the second chamber, the housing defining a third chamber above said feed-back piston, bypass conduit means including a flow restricting device communicating between said second and third chambers, vent means for maintaining substantially ambient pressure on the liquid in the third chamber, feed-back linkage means connecting the feed-back piston with the hydraulic motor, whereby movement of the motor effects movement of the piston to produce a hydraulic restoring effect on said signal output member, the feed-back piston having at least two pressure relief valves, one adapted to interchange liquid between said second and third chambers when the pressure in the second chamber reaches a preselected maximum value, the other relief valve being adapted to effect interchange of liquid between the second and third chambers when the pressure in the second chamber falls to a preselected minimum value, whereby interchange of liquid between said second and third chambers is automatically effected in the event of excessive pressure changes in the second chamber.

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