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[56]

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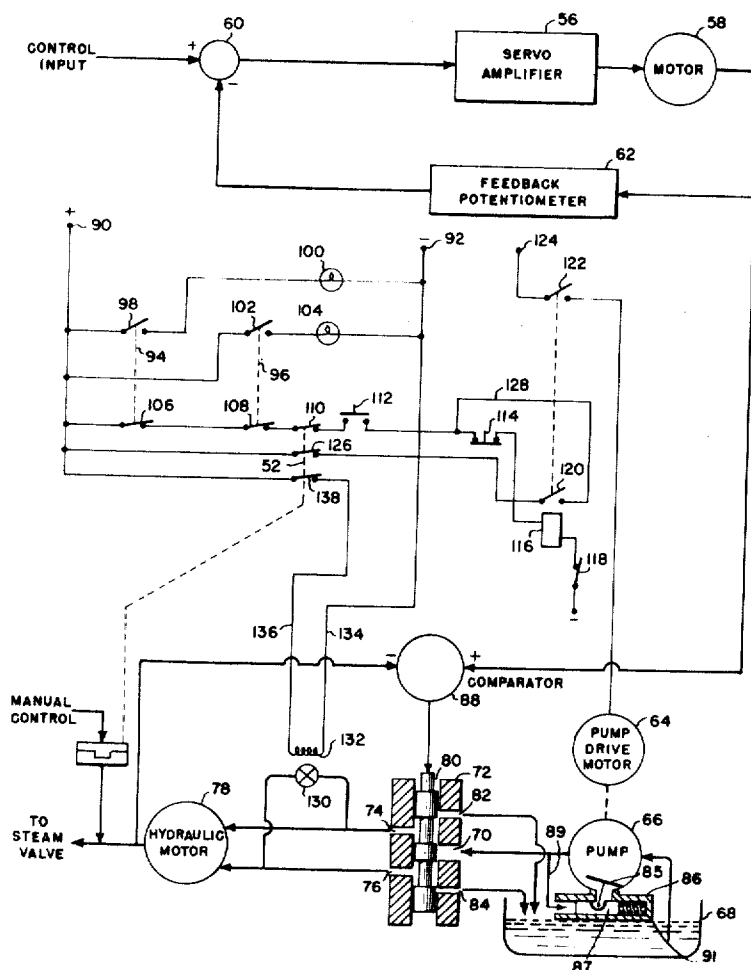
[54] **HYDRAULIC ACTUATOR**
7 Claims, 5 Drawing Figs.

[52] **U.S. Cl.**..... **60/52 CD,**
60/DIG. 2, 91/1

[51] **Int. Cl.**..... **F15b 15/18**

[50] **Field of Search**..... 60/52 CD,
52 US, 20, 102, DIG. 2; 91/1, 380

ABSTRACT: A servomechanism for use in controlling steam valves of turbines comprises a remote electrical servo arranged to drive a local hydraulic servo, which actuates the valves. Provision is made for manual actuation of the valves, with an interlock which prevents the hydraulic servo from being reactuated when the error signal is off zero by a predetermined amount. The interlock automatically bypasses driving oil at the ports of the hydraulic servomotor when manual control is effected.



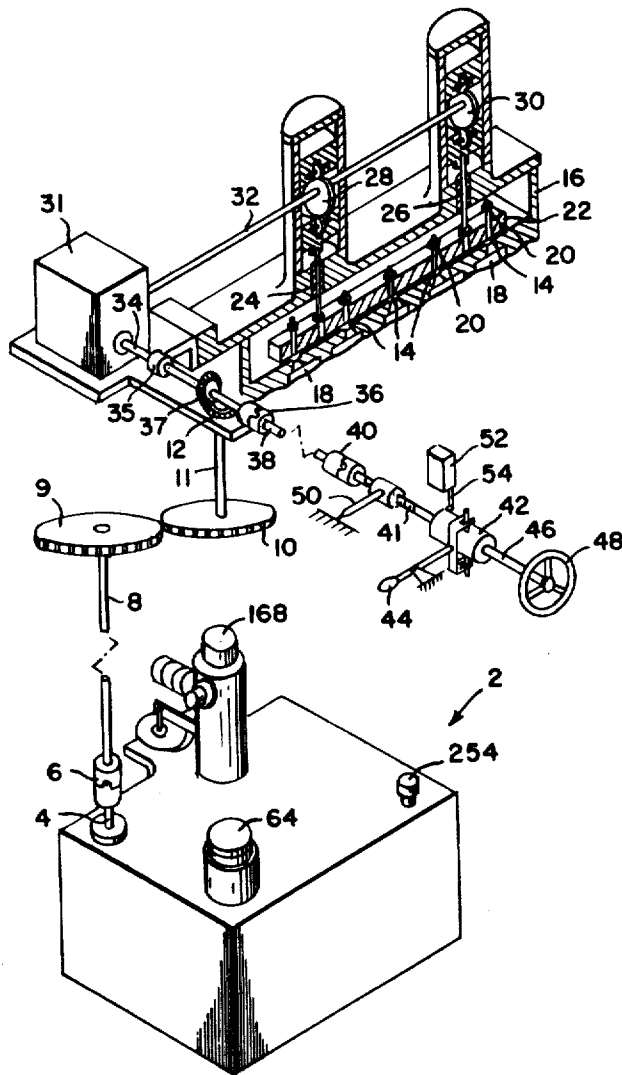


FIG. 1.

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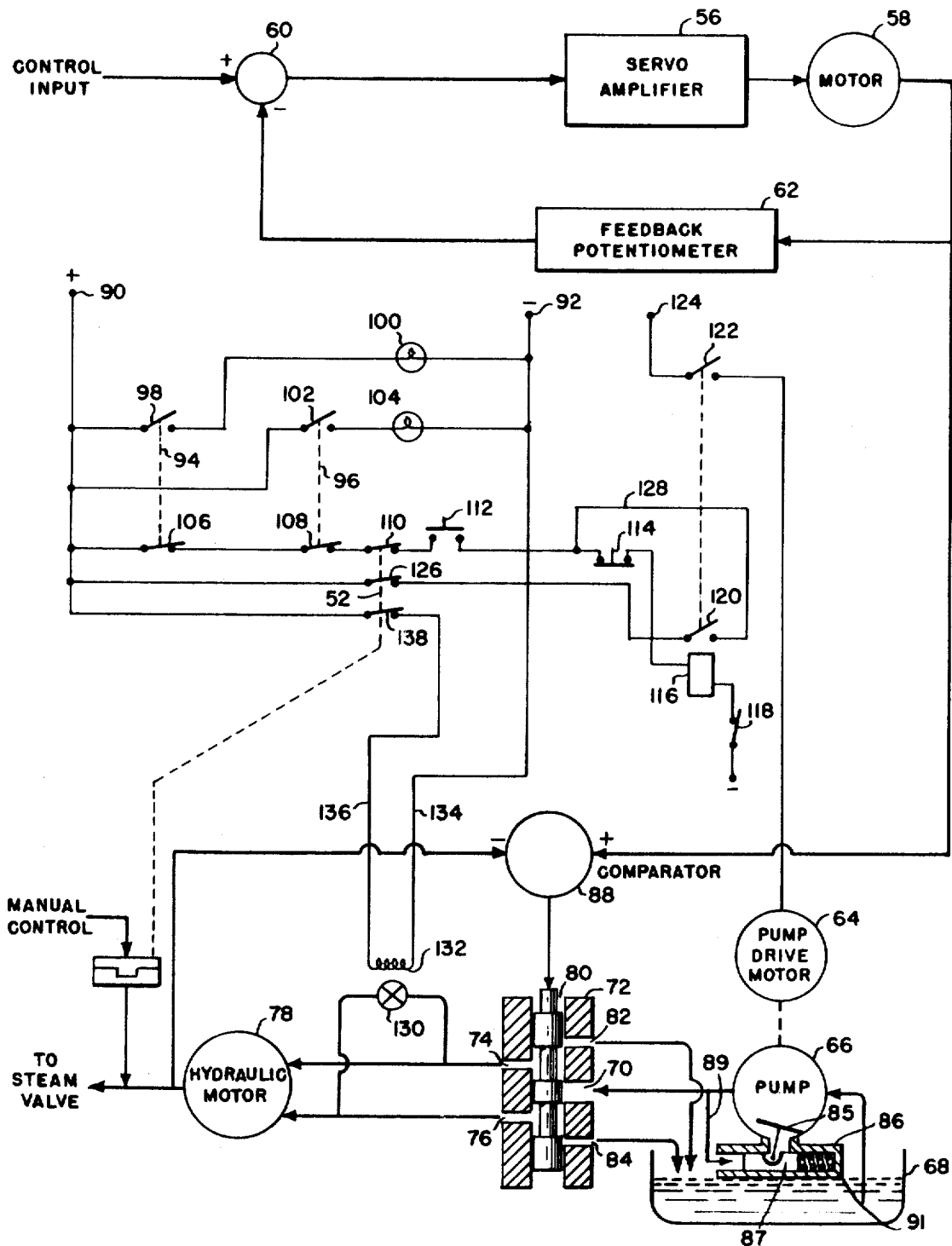


FIG. 2.

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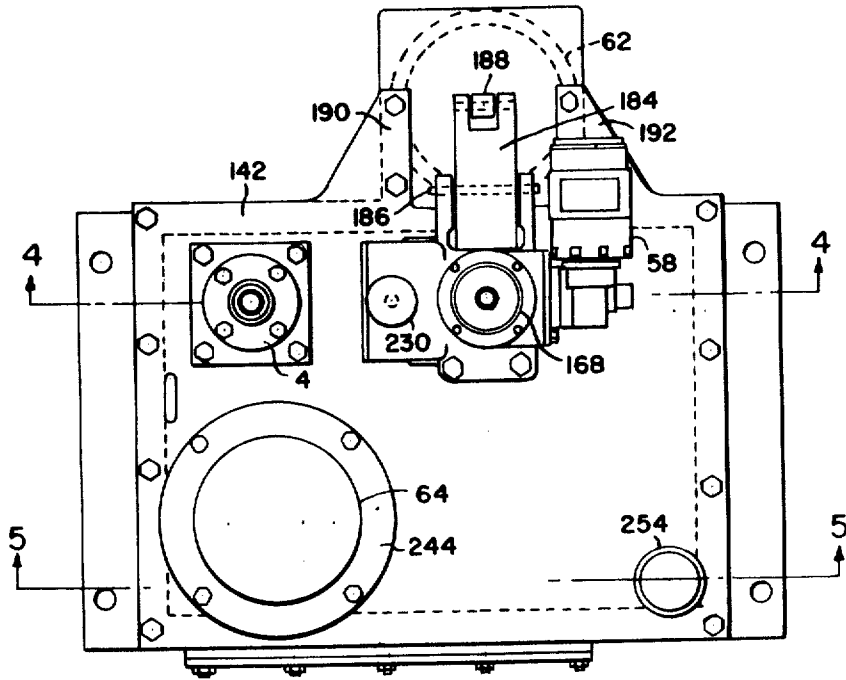


FIG. 3.

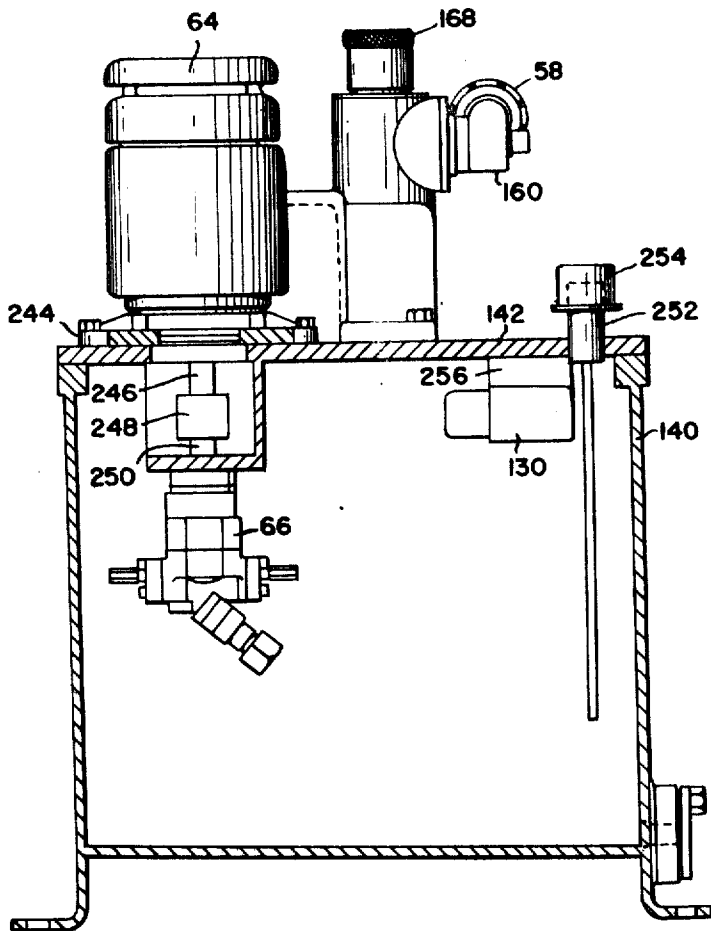


FIG. 5.

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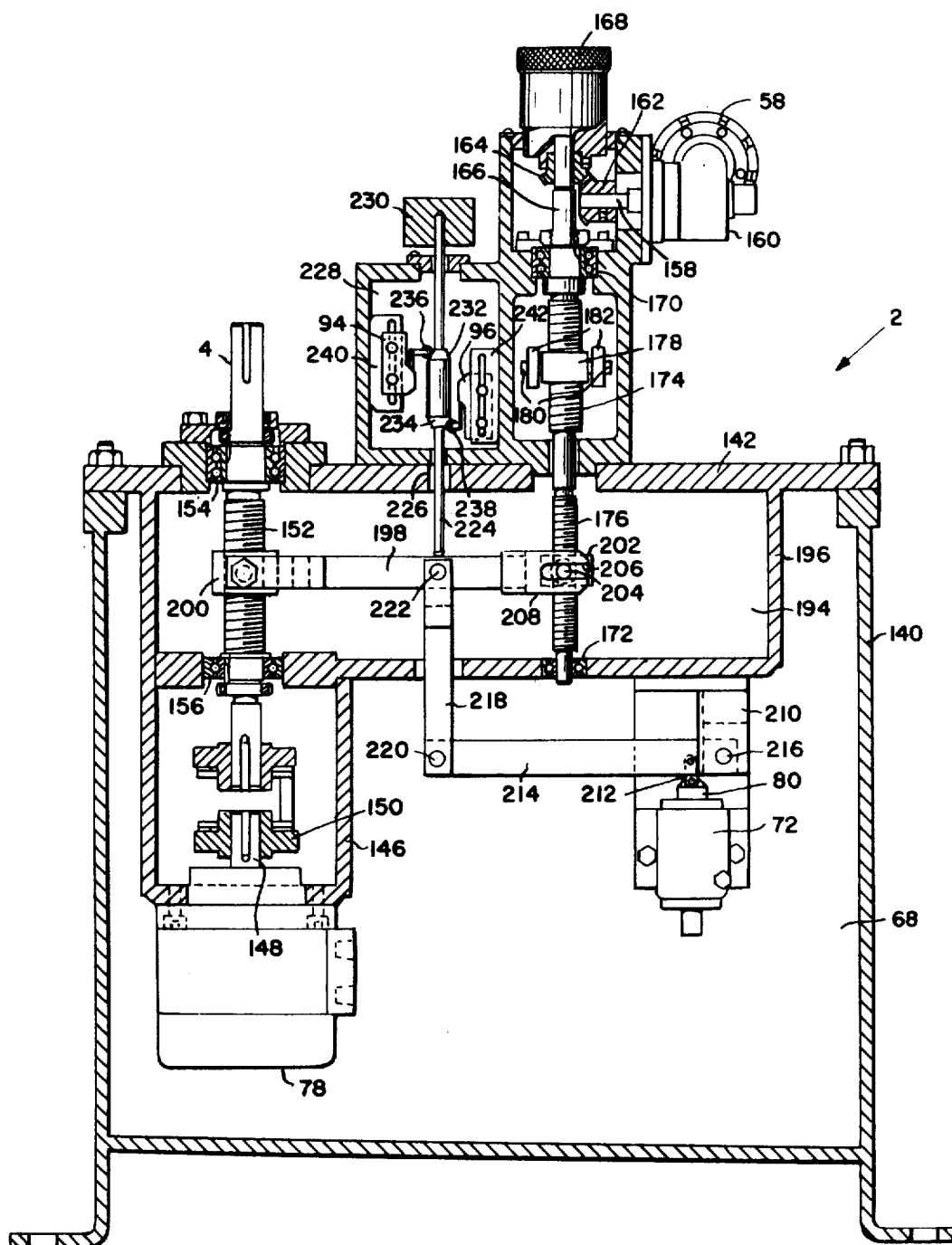


FIG. 4.

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HYDRAULIC ACTUATOR

BACKGROUND OF THE INVENTION

This invention relates to a servomechanism for operating, for example, the valves of a steam turbine, and more particularly to a control system permitting alternatively local and remote control of the valves.

The control system may be used, for example, to permit speed control of a turbine-powered ship both from the bridge and from the engine room.

In a control system, where manual control is desired as an alternative to remote control involving a feedback servomechanism or a "followup" system, a difficulty arises when, following manual operation, the feedback servomechanism is reactuated while the control input does not correspond to the position of the output shaft. The result is an undesirable surging or "bumping" of the output shaft from the position established by manual control to another position established by the control input at the moment at which transfer is effected from manual to servo operation.

Ordinarily, manual control of a valve normally driven by a hydraulic motor would require a disconnection of the valve from the hydraulic motor shaft, since a hydraulic motor cannot be back-driven because of the incompressibility of the liquid which drives it.

In ordinary hydraulic servomechanisms, driving energy is consumed continually at a high level, whether or not a control movement is taking place. In the case of valve control, where operation is intermittent, a great deal more energy is consumed than is necessary.

Another difficulty involved in the remote control of valves is the fact that changes of the control input signal are often effected at a high rate. It is necessary, however, to limit the rate at which steam valves are operated in order to prevent damage to the turbine or boiler, which could be caused by surges associated with rapid opening or closing of valves.

SUMMARY OF THE INVENTION

In accordance with this invention, the difficulties involved in the return from manual to automatic operation are avoided by the provision of an interlock, which senses a deviation of the output shaft of the hydraulic motor from correspondence with the position of the input to the hydraulic servomechanism. This deviation corresponds to an error signal which is greater or less than zero by a predetermined amount, and might be caused, for example, by movement of the shaft of the hydraulic motor by manual operation without a corresponding movement of the control input to the hydraulic servomechanism. The interlock prevents electrical power from being delivered to the motor which drives the hydraulic motor driving pump until the position of the shaft of the hydraulic motor and the control input to the hydraulic servomechanism are brought into correspondence.

In addition, a clutch, which is engaged when manual control is desired, to permit manual rotation of the output shaft of the hydraulic motor and of the shaft controlling the valve, operates a switch which opens the circuit to a solenoid-operated bypass valve connected between ports of the hydraulic motor. When manual control is taking place, this bypass valve is opened, permitting driving liquid to flow freely from one port of the hydraulic motor to the other. Engagement of the clutch also effects opening of the circuit to the pump drive motor.

The pump which delivers driving oil to the hydraulic motor is of the variable delivery type. The pump unloads so that no oil is delivered to the system when the hydraulic motor is not in operation. This prevents the pump from overheating, and reduces the power required by the pump drive motor when the hydraulic motor is not in operation.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of the housing of the hydraulic servomechanism, showing its connection to a steam valve, and showing the manual control;

FIG. 2 is a schematic diagram of the entire servomechanism;

FIG. 3 is a top plan view of the housing of the hydraulic servomechanism;

FIG. 4 is a vertical section taken on the surface 4-4 indicated in FIG. 3; and

FIG. 5 is a vertical section taken on the surface indicated at 5-5 in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the hydraulic servomechanism is indicated generally at 2. An output shaft 4 is connected through coupling 6, shaft 8, gears 9 and 10 and shaft 11 to a miter gear 12.

A bank of valve members 14 is provided within steam chest 16 to regulate the admission of steam to chests indicated at 18, and which are associated respectively with groups of turbine nozzles. Each of the valve members 14 has a threaded stem, on which is locked a nut 20 adapted to be engaged by a lifting bar 22. Bar 22 is arranged to be lifted and lowered by a pair of rods 24 and 26, which are respectively reciprocated by cams 28 and 30. Cams 28 and 30 are driven by shaft 32, which is connected through a self locking worm gear in box 31 to shaft 34, which is the input worm shaft. Shaft 34 is connected to miter gear 12 through coupling 35 and miter gear 37 so that shaft 34 is in driving relationship with shaft 4, the output shaft of servomechanism 2.

Nuts 20 are positioned at various heights with respect to the valve stems in order to open valves 14 sequentially as bar 22 is lifted.

Also connected to drive shaft 32 through the worm gearbox 31 is a shaft 38, which is connected through couplings 36 and 35 to the worm gear input shaft 34. Shaft 38 is connected through coupling 40, shaft 41, slip clutch 42 and shaft 46 to a handwheel 48. Clutch 42 is engageable by movement of lever 44 to connect shaft 41 to a shaft 46, which is rotatable by a handwheel 48. Shaft 41 is provided with a position indicator 50, which is moved in a direction parallel to the shaft by threads. An electrical switch 52 is operable by lever 54, which is arranged to be moved when the clutch is engaged.

FIG. 2 shows an electrical servosystem comprising a servoamplifier 56, which is arranged to drive a reversible DC servomotor 58. The input to the servoamplifier is derived through an error detector 60 from a control input and the output of a conventional feedback potentiometer 62. Typically, the feedback network comprises a pair of potentiometers arranged in a bridge network. The control input is delivered to the shaft of one potentiometer, while the shaft of the other potentiometer is driven by the motor. When the shafts are in corresponding positions, the output of the bridge, which is delivered to the input of the servoamplifier, is zero.

Provision is made for limiting the speed at which the shaft of motor 58 tracks the control input, in order to prevent a rapid variation of the control input from causing a rapid change in the position of the valve. The limiting can be effected by adjusting the shunt field current in motor 58.

An electric motor 64 is arranged to drive a pump 66, which draws oil from a reservoir 68, and delivers it to an inlet port 70 of a relay valve 72. Outlet ports are provided at 74 and 76, and are arranged to communicate with ports of a reversible hydraulic motor 78. A controllable spindle is provided at 80, and it is shown in its neutral position, in which port 70 is closed off.

If the spindle is moved upwardly, oil is delivered from port 70 to port 76, and the hydraulic motor 78 is driven in a first direction. Oil leaving the hydraulic motor is delivered to port 74 of the relay valve, and is delivered through exhaust port 82 to the reservoir. When spindle 80 is moved downwardly, the

relay valve delivers oil from port 70 to port 74, from which it is conducted in the opposite direction through the hydraulic motor to drive it in the opposite direction. The oil leaving the motor passes through port 76, and through port 84 to the reservoir.

Pump 66 is preferably a positive displacement pump of the multiple piston Lucas-type which may have its flow varied by the tilting of a cam plate 85 by means of a compensator 86. Compensator 86 comprises a slidable piston 87 which controls the cam plate angle. Piston 87 is connected, through connection 89, to be positioned in dependence on the pump outlet pressure. It is urged by spring 91 in a direction tending to increase the pump outlet, and is urged by the pressure in connection 89 in a direction tending to decrease the pump output. The effect is to deliver a constant pressure regardless of downstream conditions. If spindle 80 is in the neutral position cutting off port 70, the compensator will cause the displacement of the pump to go to zero.

The position of spindle 80 is controlled by a comparator 88, which is in the form of a mechanical linkage, which will be described. The linkage positions a pivot in response to the difference between a pair of inputs. One of the inputs corresponds to the position of the shaft of motor 58, and the other corresponds to the position of the shaft of hydraulic motor 78. At this point, it should be noted that the only functions of the electrical servosystem are to provide for remote control and to insure that the control input to the comparator 88 varies slowly.

Reference should now be made to the wiring diagram in FIG. 2 which shows terminals 90 and 92, to which are supplied positive and negative DC voltages respectively. Limit switches are indicated at 94 and 96, each being a double-pole, single-throw switch having one set of normally closed contacts and one set of normally open contacts. These switches are limit switches, and, as will be seen from the description which follows, they are arranged to be operated when the spindle 80 is off its neutral position by a predetermined extent. Both switches are shown in the positions in which they would be when spindle 80 is in its neutral position.

Normally open contacts 98 of switch 94 are arranged to energize an indicator lamp 100 when they close. Normally open contacts 102 of switch 96 are arranged to energize a second indicator lamp 104. The positive terminal 90 is connected through normally closed contacts 106, and normally closed contacts 108, to normally closed contacts 110 of the three-pole, single-throw switch 52 (previously described), which is controlled by engagement of the clutch to effect manual operation. From contacts 110, connection is made through a normally open pushbutton switch 112 and normally closed pushbutton switch 114 to the coil of relay 116. The other end of the coil is connected through switch 118 to the negative supply.

Relay 116 has a first set of normally open contacts 120, which act as holding contacts, and a second set of normally open contacts 122, which, when closed, conduct current from power terminal 124 to energize motor 64.

Normally closed contacts 126 of switch 52 connect the positive supply to holding contacts 120 of relay 116. The other side of contacts 120 is connected to the junction between pushbutton switches 112 and 114 by line 128.

A solenoid-operated valve 130, having an actuating coil 132 is arranged to permit flow of driving liquid between ports of hydraulic motor 78. Valve 130 is open when coil 132 is unenergized. One end of coil 132 is connected to the negative supply terminal 92 through line 134. The other end of coil 132 is connected through line 136 and through normally closed contacts 138 of switch 52 to the positive supply terminal 90. Whenever switch 52 is energized, i.e., at all times except during manual operation, valve 130 is closed.

The various elements which are illustrated diagrammatically in FIG. 2 are shown in detail in FIGS. 3, 4 and 5. The elements in FIGS. 3, 4 and 5 which correspond to elements in FIG. 2 have corresponding reference numerals.

Referring particularly to FIG. 4, the hydraulic servomechanism 2 comprises a housing 140, which is closed by a cover 142 to enclose an oil reservoir 68.

Hydraulic motor 78 is mounted on bracket 146, which is suspended from the cover. Its output shaft 148 is coupled to shaft 4 by coupling 150. Shaft 4 operates the steam valve, as shown in FIG. 1.

It is provided with a threaded portion 152, and is supported by ball bearings 154 and 156. Electric servomotor 58 drives shaft 158 through a gearbox 160. On shaft 158, there is mounted a miter gear 162, which meshes with miter gear 164 on shaft 166. At the upper end of shaft 166 there is mounted a handwheel 168. Shaft 166 is supported by ball bearings 170 and 172, and is provided with threaded sections 174 and 176.

A threaded travelling block 178 is connected by pins 180 to the forked end 182 of a lever 184 (FIG. 3). Lever 184 is pivoted on a horizontal pin 186, and operates a plunger 188 of potentiometer 62, which is mounted on brackets 190 and 192, which extend to the rear from cover 142. Potentiometer 62 is part of the feedback circuit of the electrical servomechanism.

Referring back to FIG. 4, threaded portion 176 of shaft 166 is located parallel to and opposite threaded portion 152 of shaft 4 within a space 194, which is partially enclosed by bracket 196. An arm 198 is pivoted at one end to a threaded travelling block 200, which rides on threaded section 152 of shaft 4. A travelling block 202 is threaded on threaded section 176, and is provided with pins 204, which ride in slots 206 provided in a fork 208, which is fixed to the right-hand end of arm 198.

Extending downwardly from bracket 196, a bracket 210 mounts relay valve 72, the spindle 80 of which is provided with a link 212. A spring (not shown) urges spindle 80 upwardly. An arm 214 is pivoted on bracket 210 at 216, and is connected to link 212 at a point near pivot 216. Arm 214 is linked to arm 198 by member 218, which is pivoted at 220 and 222.

It will be observed at this point that there is only one position of pivot 222 for which spindle 80 rests in its neutral position. The position of pivot 222 depends on the relative positions of shafts 166 and 4.

A rod 224 extends through an opening 226 in the cover into space 228, its lower end resting on arm 198 just above pivot 222. A weight 230 is provided at the upper end of the rod, and within the space 228, the rod is machined to provide cam surfaces 232 and 234, which operate limit switches 94 and 96 through their rollers 236 and 238. Switches 94 and 96 are microswitches and are mounted in slotted brackets 240 and 242, so that their positions in relation to cam surfaces 232 and 234 can be adjusted. Desirably, these switches are positioned to be operated when shaft 4 is more than one-fourth turn out of correspondence with shaft 166.

Referring to FIG. 5, electric pump drive motor 64 is shown mounted on cover 142 by bracket 244. Its shaft 246 is coupled through coupling 248 to the drive shaft 250 of pump 66, which receives oil from the interior of housing 140, and delivers it to relay valve 72 under pressure. The various interconnections between the pump, the relay valve and the hydraulic motor are not shown except diagrammatically in FIG. 2, but it will be understood that they consist of conventional tubing suitable for conducting oil under pressure. An air vent is provided at 252, and is covered by cap 254. The solenoid valve 130 is mounted by bracket 256, which is attached to the cover.

The overall operation of the servomechanism will be understood from reference to FIGS. 2 and 4.

The control input will ordinarily be a handwheel located on the bridge of a ship. The electrical servomechanism positions the shaft of electric servomotor 58 in accordance with the position of the handwheel. Motor 58 is located in the engine room, and the position of its shaft determines the position of the shaft of the hydraulic motor through the action of the hydraulic servomechanism.

Referring to FIG. 4, it will be seen that the position of the shaft of motor 58 determines the position of travelling block

202 on threaded section 176 of shaft 166. If motor 58 rotates shaft 166 in a direction to raise block 202, pivot 222 is moved upwardly, and the consequent movement of arm 214 permits spindle 80 to move upwardly under the action of its spring to permit driving liquid from pump 66 to flow through the hydraulic motor. The oil connections are arranged so that shaft 4 of the hydraulic motor rotates in a direction such that travelling block 200 is moved downwardly. The downward movement of block 200 returns pivot 222 to its original position, whereupon spindle 80 is returned to its neutral condition, and no further flow takes place through the hydraulic motor. If motor 58 rotates shaft 166 in the opposite direction, travelling block 202 is moved downwardly. This causes driving liquid to be directed in the opposite direction through the hydraulic motor to cause shaft 4 to rotate in a direction such that block 200 is moved upwardly to restore pivot 222 and spindle 80 to their neutral positions. Shaft 4 is thus made to follow the shaft of motor 58, and consequently follows the movement of the handwheel on the bridge of the ship.

In normal operation, the movement of pivot 222 is only very slight, and not enough to actuate either of switches 94 and 96.

When the valve is to be operated by the control system, pump drive motor 64 will be operating continuously. However, the operator will ordinarily desire to change the setting of the valve only intermittently. As a result, pump 66 is almost continuously pumping into a closed port 70. When port 70 is closed, no flow takes place at the outlet of the pump, and compensator 86 senses this absence of flow, and reduces the output of the pump as necessary. The result is that pump drive motor 64 operates at a small percentage of its normal full rated power requirement except when a change is being effected in a setting of the valve. An additional advantage is that, during the idling condition, a relatively small amount of power is delivered to the oil in the form of heat, and no oil cooler is required.

The shunt field current limits the speed of response of the shaft of motor 58, and this prevents the valve from being opened or closed too rapidly.

When manual operation of the valve is desired, lever 44 (FIG. 1) is operated to engage clutch 42. When the clutch is engaged, lever 54 opens switch 52. Referring now to FIG. 2, contacts 110, 126 and 138 will be open. Opening of contacts 126 removes holding current from relay 116 (relay 116 having previously been latched by momentary operation of pushbutton 112). Contacts 122 open and remove power from the pump drive motor 64.

The opening of contacts 110 prevents restarting of the pump drive motor 64 by operation of pushbutton 112 until clutch 42 is disengaged.

Opening of contacts 138 removes current from coil 132 to open solenoid-operated valve 130. Manual control can now be effected, and hydraulic motor 78 can be back-driven by operation of the manual handwheel 48 (FIG. 1) while the valve is being adjusted manually.

From FIG. 4, it will be apparent that the back driving of the hydraulic motor through shaft 4 will cause a movement of travelling block 200 without a corresponding correcting movement of block 202. Therefore, the result of manual operation can be the movement of spindle 80 of the relay valve to a position such that the return of pump 66 to operation would result in a violent movement of shaft 4 from a position corresponding to the position in which the shaft of motor 58 was before manual operation was begun. This is where switches 94 and 96 come into play.

If, at the resumption of automatic operation, shafts 4 and 166 are not in corresponding position, that is, if their positions differ by more than one-fourth turn, one or the other of switches 94 and 96 will be operated by the cam on rod 224. If pivot 222 is too low, switch 96 is operated, and indicator lamp 104 is energized through contacts 102. If the pivot is too high, lamp 100 is energized through contacts 98. These lamps provide an indication of the direction in which correction must take place before automatic operation is resumed. One of con-

tacts 106 and 108 will be opened, and the opening of either removes power from pushbutton 112, so that its actuation has no effect.

The return of shafts 4 and 166 to correspondence can be accomplished by varying the control input until both of lamps 100 and 104 are extinguished, or by operating the manual control until both lamps are extinguished. In addition, handwheel 168 (FIG. 4) can be operated with the same effect.

When both of contacts 106 and 108 are closed, as indicated by the fact that neither of lamps 100 and 104 is on, and the contacts of switch 52 are closed by disengagement of clutch 42, actuation of pushbutton 112 momentarily will cause relay 116 to become latched through its holding contacts 120, and the pump drive motor 64 will resume operation. Since it is necessary for spindle 80 of the relay valve to be in its neutral position at this time, no surging of the valve or "bumping" will take place.

Switch 114, which will normally be located on the bridge, permits the removal of holding current from relay 116, and therefore permits the operator on the bridge to stop the operation of pump drive motor 64 whenever he desires. Switch 118 may be located in the engine room for the same purpose.

In an installation aboard a steam turbine powered ship, two separate systems of the type disclosed can be provided, one controlling the flow of steam to the "ahead" nozzles, and the other controlling the flow of steam to the "astern" nozzles for reverse operation of the turbine.

I claim:

1. A servomechanism for imparting motion to an element comprising a reversible motor having mechanical output means adapted to impart motion to said element, a source of power for operating said motor, means producing a feedback signal varying with the position of said mechanical output means, means comprising said feedback signal with a command signal and producing an error signal when said feedback signal differs from said command signal, means responsive to said error signal for delivering power from said source to operate said motor in a direction to reduce said error signal, and means responsive to said error signal for preventing the delivery of power to operate said motor when the magnitude of said error signal exceeds a predetermined limit.

2. A servomechanism according to claim 1 including additional means adapted to impart motion to said element, a clutch connecting said additional means to said mechanical output means, means for engaging and disengaging said clutch, and means responsive to the condition of said clutch for preventing the delivery of power to operate said motor when said clutch is engaged.

3. A servomechanism according to claim 1 in which said reversible motor is a hydraulic motor, said source of power is a pump, and said means responsive to said error signal is a relay valve connected to deliver driving liquid from said pump through said hydraulic motor in a first direction when said command signal exceeds said error signal and in a second direction when said error signal exceeds said command signal and including an electric motor connected to drive said pump wherein said means responsive to said error signal for preventing the delivery of power to operate said motor comprises at least one switch connected to deliver electric power to said electric motor and means for opening said switch when said error signal exceeds said predetermined limit.

4. A servomechanism according to claim 1 in which said reversible motor is a hydraulic motor, said source of power is a pump, and said means responsive to said error signal is a relay valve connected to deliver driving liquid from said pump through said hydraulic motor in a first direction when said command signal exceeds said error signal and in a second direction when said error signal exceeds said command signal and including an electric motor connected to drive said pump, additional means adapted to impart motion to said element, a clutch connecting said additional means to said mechanical output means, means for engaging and disengaging said clutch, and means responsive to the condition of said clutch

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for preventing the delivery of power to operate said motor when said clutch is engaged wherein said means responsive to the condition of said clutch comprises at least one switch connected to deliver electric power to said electric motor and means for opening said switch when said clutch is engaged.

5. A servomechanism according to claim 1 in which said reversible motor is a hydraulic motor, said source of power is a pump, and said means responsive to said error signal is a relay valve connected to deliver driving liquid from said pump through said hydraulic motor in a first direction when said command signal exceeds said error signal and in a second direction when said error signal exceeds said command signal and including an electric motor connected to drive said pump, additional means adapted to impart motion to said element, a clutch connecting said additional means to said mechanical output means, means for engaging and disengaging said clutch, and means responsive to the condition of said clutch for preventing the delivery of power to operate said motor when said clutch is engaged wherein said means responsive to the condition of said clutch comprises at least one switch connected to deliver electric power to said electric motor and means for opening said switch when said clutch is engaged, and wherein said means responsive to said error signal for preventing the delivery of power to operate said motor comprises at least one additional switch connected in series with

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said switch and means for opening said additional switch when said error signal exceeds said predetermined limit.

6. A servomechanism according to claim 1 in which said reversible motor is a hydraulic motor, said source of power is a pump, and said means responsive to said error signal is a relay valve connected to deliver driving liquid from said pump through said hydraulic motor in a first direction when said command signal exceeds said error signal and in a second direction when said error signal exceeds said command signal and including an electric motor connected to drive said pump and means responsive to the condition of said relay valve for reducing the flow of liquid from the outlet of said pump when said error signal is zero.

7. A servomechanism comprising a reversible motor having an output shaft, an input shaft, a lever, means positioning a first point on said lever in accordance with the position of said output shaft, means positioning a second point on said lever in accordance with the position of said input shaft, means positioned by a third point on said lever for controlling said reversible motor to operate in a direction to maintain said third point in a first predetermined range of positions, and means positioned by said third point on said lever for preventing operation of said motor when said third point is moved out of a second predetermined range of positions.

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