United States Patent

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[54] **CONCENTRIC SPOOL VALVE**
12 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **137/553,** 91/51, 91/461, 137/85, 137/625.62, 137/625.69, 137/596

[51] **Int. Cl.** **F16k 37/00,** F16k 11/07

[50] **Field of Search** ..... 137/82-—86, 596, 596.17, 625.62, 625.64, 625.69, 637.2, 553; 91/1, 51, 363, 365, 461

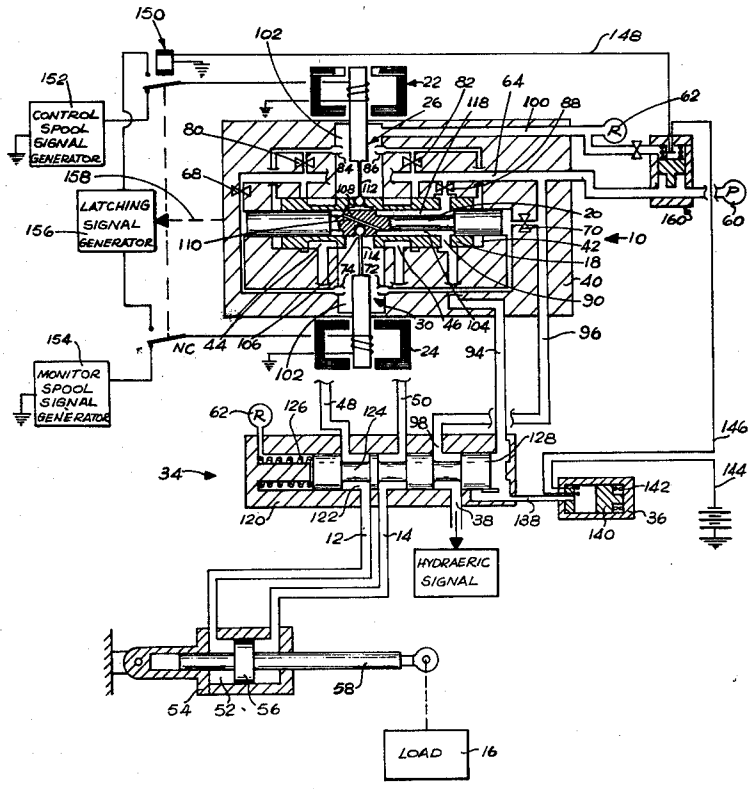
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ABSTRACT: A device which compares the position of concentric spools which normally move in unison. Any disagreement in the relative position of the spool positions above a predetermined amount uncovers a flow port which results in a hydraeric signal being generated to indicate the disagreement.



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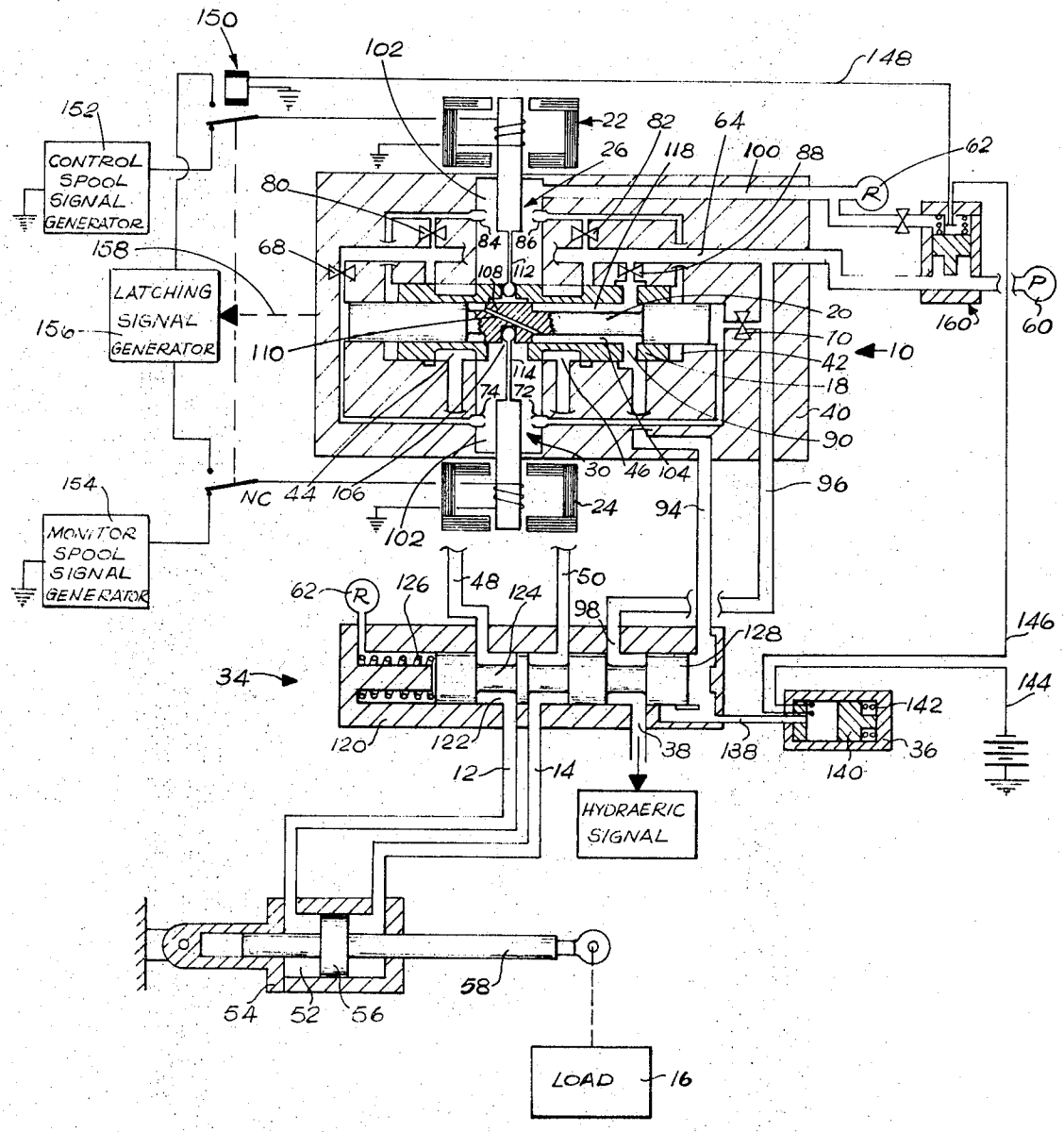


Fig. 1

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Fig 2

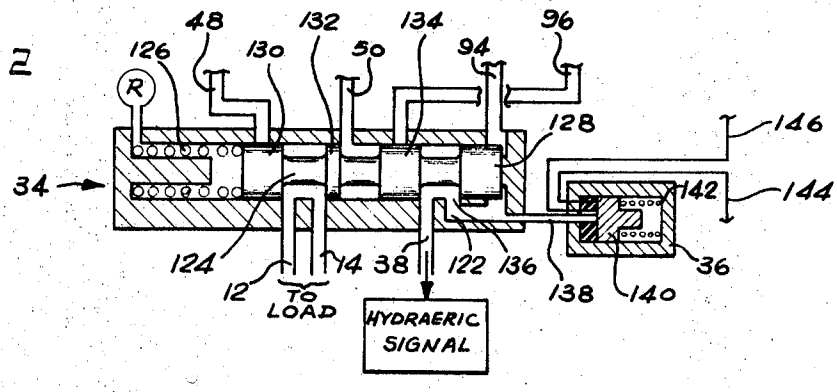


Fig 3

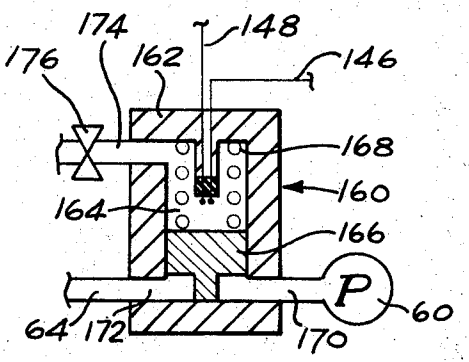
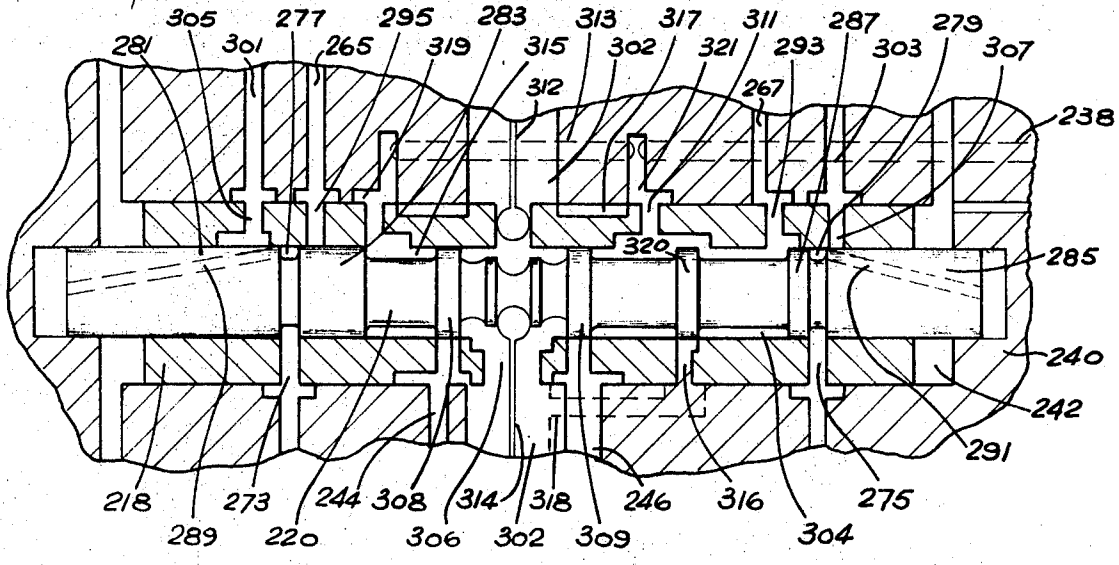


Fig 5



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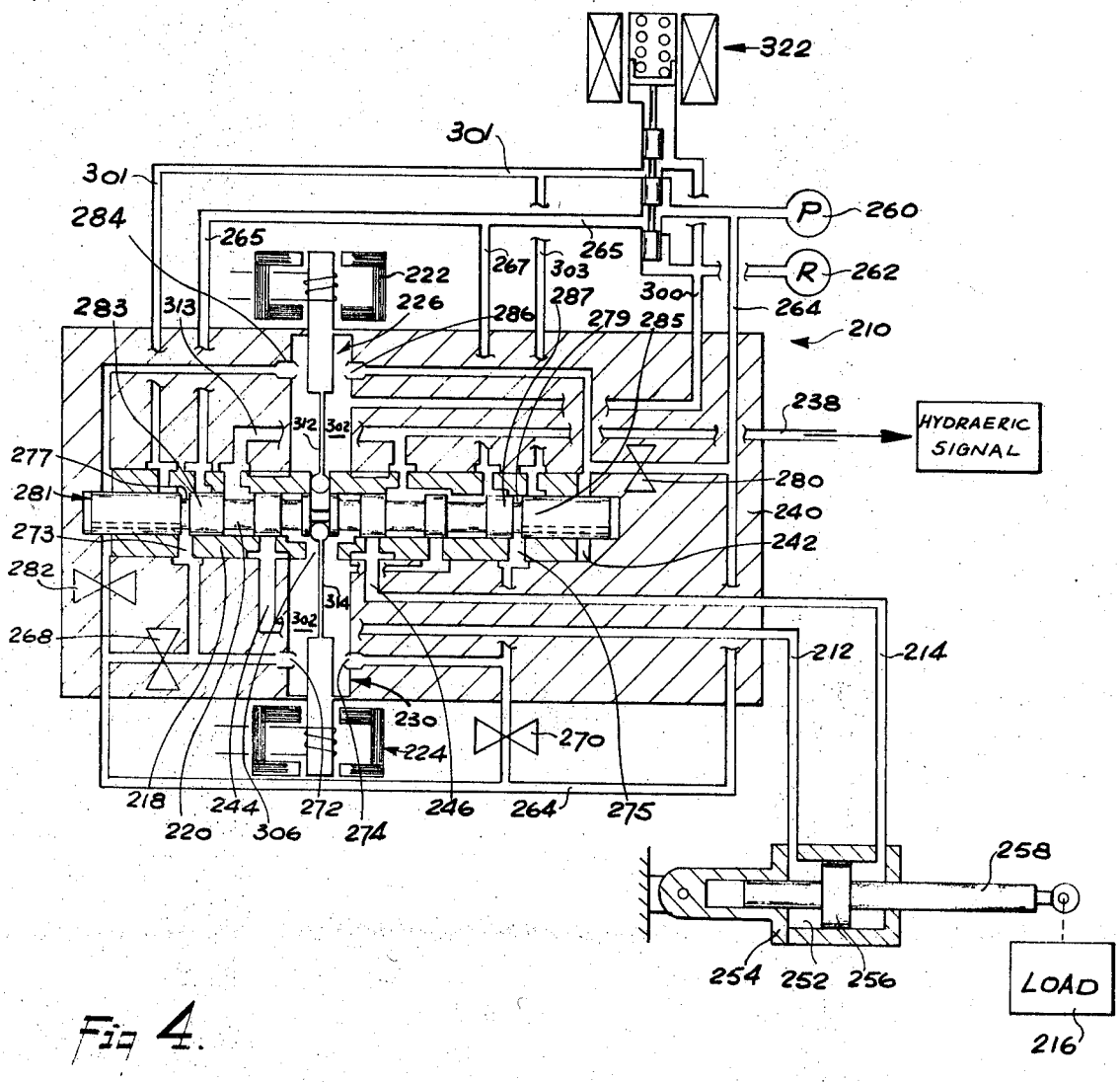


Fig 4.

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CONCENTRIC SPOOL VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The fields of art to which the invention pertains include the fields of fluid handling, valve and valve actuation.

2. Description of the Prior Art

The term "hydraeric" as used throughout the specification and claims is intended to be generic to fluid under pressure and includes both hydraulics and pneumatics. As is well known in the prior art, redundant control systems typically include a plurality of control channels interconnected from an input signal source to an output load which is controlled by the system. The control channels are operative in such a manner that in the event of a failure of one or more of the channels, such failure is detected and a shutoff portion of the system is activated in order to deactivate the failed channel. A hydraeric signal is generated which may be utilized to effect a transfer from the failed portion of the system to a duplicate, operable portion of the system, thus enabling the overall control system to continue to operate irrespective of the failed component. Alternatively, in the event of the failure of a sufficient number of control channels, the hydraeric signal can effect a transfer to a manual mode of operation.

Such redundant control systems are particularly important in controlling the multiple control surfaces on aircraft, and particularly with respect to the present generation aircraft of the supersonic or subsonic type embodying control surfaces which experience heavy loads and require the utilization of power to effect proper control. Since power assist is necessary with respect to such aircraft, it is also necessary to detect failures which may occur at any point throughout the control system and to quickly eliminate such failures thereby to preclude damage to the aircraft. As exemplary of present redundant systems, see U.S. Pat. No. 3,257,911 to K.D. Garnjost et al. In such failure-detection systems, spool positions must be converted to hydraeric pressure, pressure converted to force, force compared to corresponding force from other valves, the disparity converted to a valve motion, the valve to a hydraeric pressure, the pressure to a force and the force again to a motion. Each of these conversions requires a time delay and the complexity of construction of such a system makes it relatively expensive to manufacture and maintain.

SUMMARY OF THE INVENTION

The present invention provides a hydraeric servovalve construction that eliminates many of the foregoing conversions. Valves are provided which detect their own failure, generate a hydraeric signal to inform logic elements of the failure and can render themselves ineffective for further control. The time passing between failure sensing and correction is greatly reduced.

Specifically, the devices described herein are useful in a hydraeric control system wherein hydraeric fluid is applied from a source thereof to a load through ports controlled by a control valve spool. The mechanism of this invention for effecting a desired system change upon failure involves the provision of a bore within the control valve spool and a monitor spool concentrically disposed in the bore. Independent means are provided for positioning the monitor spool and for moving the monitor and control spools in substantial unity. When an error is above a predetermined value, the spools will move in relation to each other to effect a hydraeric signal of the failure.

In particular embodiments, the monitor and control spools are controlled by hydraeric pressure differentials across each spool, each differential being controlled by separate torque motors and associated flapper valves. Hydraeric pressure is provided in the control valve spool bore and a system return is in communication with such bore. The relative movement of the monitor spool and control valve spool effects venting of the pressure to the return to cause a system change. To enable such internal spool venting, a land is formed on the monitor

spool within the control valve spool bore and a bore is defined through the land whereby hydraeric pressure on both sides thereof are equalized. Upon relative movement of the monitor and control valve spools, the piston bore effects venting to the return of the control valve spool bore. In one embodiment, a hydraeric path to the control valve spool is in communication with a separate shutoff valve for the system and effects the application of opposite electrical signals to the torque motors to thereby latch the system in an overtravel position. In another embodiment, initial relative displacement of the monitor and control valve spools causes venting through the monitor spool land bore to effect the application of opposite hydraeric pressure differentials to the monitor and control valve spools to thereby latch the system in an overtravel position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a valve constructed in accordance with an embodiment of this invention;

FIG. 2 is a schematic diagram illustrating a portion of the structure of FIG. 1 in a shutoff position;

FIG. 3 is a schematic diagram illustrating a portion of the structure of FIG. 1 utilized to effect a delay in electrical activation at startup;

FIG. 4 is a schematic diagram of a valve constructed in accordance with another embodiment of this invention; and

FIG. 5 is a schematic diagram illustrating a portion of the structure of FIG. 4 in larger view.

DETAILED DESCRIPTION

Referring to FIG. 1, there is illustrated schematically a concentric spool comparator servovalve 10 for controlling the flow of hydraeric fluid through output control passageways 12 and 14 to thereby control a load 16. The servovalve 10 can be briefly described as a two-stage servovalve, the second stage including two spools 18 and 20 concentrically disposed, one in the other. An input signal is independently applied to separate torque motors 22 and 24, controlling the movement of the concentric spools 18 and 20, respectively, via first stage valves such as flapper valves 26 and 30, respectively. During normal operation, the input signals are identical and the spools 18 and 20 are in identical positions, i.e., they do not move relative to each other. When an error is above a predetermined value, the spools 18 and 20 move in relation to each other. This relative displacement of the concentric spools 18 and 20 causes a drop in hydraeric pressure to a shutoff valve 34 to (a) actuate a pressure switch 36 to thereby cause appropriate opposite electrical hard-over signals to be applied to the torque motors 22 and 24 for locking the mechanism; (b) vent a hydraeric signal port 38 to inform logic elements of the failure; and (c) shutoff flow to the control passageways 12 and 14 while simultaneously connecting them together.

Referring to the drawing in more detail, the concentric spools include an outer control valve spool 18 and an inner monitor spool 20. A housing is provided defining a bore 42 therewithin in which the control valve spool 18 is slideably disposed. The housing 40 defines a pari of passageways 44 and 46 which are connected by means of passageways 48 and 50 through the shutoff valve 34 to the output passageways 12 and 14. The output passageways 12 and 14 are in communication with the chamber 52 of an actuator cylinder 54 on opposite sides of an actuator piston 56 therein to effect movement of the actuator rod 58 to position the load 16, as is well known in the prior art.

A source 60 of hydraeric fluid is provided in communication with a network of passageways defined by the housing 40 to conduct the hydraeric fluid to the ends of the concentric spools 18 and 20 to thereby provide means for establishing differential pressures across the spools and a system return 62 is provided therefor. As shown, hydraeric fluid from the source 60 is conducted through a passageway 64 and branches thereof, through fixed restrictions 68 and 70 to opposite sides of the inner, monitor control spool 20. The hydraeric fluid is

also conducted to the oppositely disposed nozzles 72 and 74 of the monitor spool flapper valve 30. Branch passageways are provided from the passageway 64 to feed hydraeric fluid through restrictions 80 and 82 to the opposite sides of the control valve spool 18 and to the oppositely disposed nozzles 84 and 86 of the flapper valve 26 which is utilized to control the movement of the control valve spool 18. Hydraeric fluid from the source 60 is also fed through a branch passageway and restriction 88, via openings 90 in the control valve spool through a passageway 94 to the shutoff valve 34 for purposes hereinafter described. Another passageway 96 feeds hydraeric fluid from the passageway 64 through a port 98 in the shutoff valve to the hydraeric signal port 38.

The system return 62 is connected via a return passageway 100 to a common return chamber 102 utilized for both flapper valves 26 and 30.

The outer, control valve spool 18 is formed with a bore 104 longitudinally therethrough through which the inner, monitor valve 20 extends. The control valve spool 18 is provided centrally with a port 106 which during normal operation is blocked by a central land 108 on the monitor spool 20. The central land 108 defines a passageway 110 therethrough for establishing open communication between opposite sides thereof, and this passageway 110 vents return to the bore 104 irrespective of the translation direction of the spools 18 and 20.

A feedback element 112 is connected between the flapper of the control spool torque motor 22 and the central region of the control valve spool 18, to provide feedback effect, as is well known to the prior art (see U.S. Pat. No. 2,947,286). A feedback element 114 extends through the control valve spool central port 106 into a central portion of the monitor spool 20 to provide position feedback to the monitor spool torque motor 24.

With respect to control operation, hydraeric fluid is fed from the source 60 through the passageway 64 and branches and restrictions previously described to the nozzles and the ends of the control and monitor spools 18 and 20. Since the reaction areas of these second stage spools are different, the restriction pairs 68, 70 and 80, 82 are sized so that the first stage flow gains are appropriately proportional to achieve identical movement of the spools 18 and 20 responsive to differential pressure signals generated by the nozzle-flapper first stages upon receipt of identical signals by the respective torque motors 22 and 24.

The fluid-metering function is accomplished only by the control valve spool 18, that is, it is only through movement of the control valve spool 18 within the bore 42 that fluid flow through passageways 44 and 46 is metered. Movement of the control valve spool 18 to the left, with respect to the drawing, exposes the left side passageway 44 to hydraeric fluid from the source 60 by means of a branch passageway connecting to the passageway 64 as shown. At the same time, the right side passageway 46 is directly exposed to the system return 62 by opening into communication with the return chamber 102 associated with the flapper valves 26 and 30. Accordingly, upon leftward movement of the control valve spool 18 with respect to the housing 40, hydraeric fluid from the source 60 is fed through the passageway 48, through the shutoff valve 34 to the actuator passageway 12, and from there to the left side of the actuator piston 56. The right side of the actuator piston 56 is exposed to the system return through the right side actuator passageway 14, through the shutoff valve 34, and via the passageway 50 to the passageway 46. Rightward movement of the control spool 18, with respect to the housing 40, operates in a symmetrical manner to direct hydraeric fluid from the source 60 to the right side of the actuator piston 56 and to connect to the left side thereof to the system return. During such operation, the monitor spool 20 substantially follows each movement of the control valve spool 18.

With respect to failure detection operation, it will be seen that relative movement between the control and monitor spools 18 and 20 results in exposure of one side or the other of the monitor spool central land 108 to the system return by communication thereof with the system return chamber 102, and this venting to return is effected to the other side of the land 108 by means of the passageway 110 therethrough. Accordingly, the annular space 118 on the right side of the monitor spool land 108 is vented to return regardless of the direction of the relative movement between the control and monitor spools 18 and 20. This results in venting to return of the shutoff valve 34 through the passageway 94.

The shutoff valve 34 includes a housing portion 120 which defines a central bore 122 lengthwise therein in which a spool 124 is positioned for selectively covering and uncovering various ports defined by the housing thereby to shut off operation of the actuator valve 54. A spring 126 is positioned between the left side of the shutoff valve bore 122 and the end of the spool 124. The spring 126 is compressed by extreme leftward movement of the spool 124 therein. The spool 124 is maintained in the extreme leftward position during normal operation of the servovalve 10 by means of hydraeric fluid form the source 60 being applied to a right side land 128 of the spool via the passageway 94 thereto and the venting to system return 62 of the opposite side of a left side 129.

Upon relative movement between the control and monitor spools 18 and 20, the annular space 118 is vented as described above to thereby vent the shutoff valve passageway 94, so that there is a pressure drop in the chamber 131 on the right side of the land 128 of the shutoff valve spool 124. This venting allows the force of the spring 126 to move the shutoff valve spool 124 to the right as viewed in FIG. 1.

Referring to FIG. 2, the shutoff valve 34 is shown following translation of the spool 124 as above described. It will be seen that the output passageways 12 and 14 are connected together thereby equalizing pressure in each side of piston 56. Lands 130 and 132 on the shutoff valve spool 124 close off communication between the load passageways 12 and 14 and their respective feeding passageways 48 and 50. Furthermore, another land 134 on the shutoff valve spool 124, is moved into position to block flow of hydraeric fluid from the pressure passageway 96. Simultaneously, movement of the right side land 128 opens communication, via a port 136, between the now-vented-to-return passageway 94 and the hydraeric signal port 38. Such venting effects a sudden change in hydraeric signal to inform logic elements of the detected failure, as well known to the prior art.

Simultaneously with the foregoing shutoff valve movements, the venting to return of the passageway 94 effects the closing of the pressure switch 36 via a passageway 138 between the pressure switch 36 and the chamber 131. Referring additionally to FIG. 1, the pressure switch 36 is there shown in an open position wherein hydraeric fluid fed from the passageway 64 via the passageway 94 is applied against a piston 140 within the pressure switch 36 to force the piston 140 against the return force of a spring 142 therein so as to prevent the piston 140 from effecting electrical contact between electrical leads 144 and 146. As illustrated in FIG. 2, upon venting to return through the passageway 138, spring 142 translates the piston 140 toward the left and into contact with the electrical leads 144 and 146 thereby electrically connecting them together.

Any other pressure switch means known to the art can be utilized, the effect being to cause electrical current to be supplied from a source thereof, shown as a battery 145 via the electrical leads 144 and 146, interconnected by piston 140, and electrical lead 148 connected to a double pole solenoid switch 150 to energize the same. Prior to activation of the solenoid switch 150, the two torque motors 22 and 24 received identical electrical signals for operation thereof from a control spool signal generator 152 and a monitor spool signal generator 154. However, upon activation of the solenoid switch 150, both torque motors 22 and 24 are caused to receive latching signals from a latching signal generator 156. The latching signal generator 156 receives feedback signals, as indicated by the arrow 158, from the servovalve 10 relating

the offcenter position of each of the second stage spools 18 and 20 and generates opposite polarity electrical and hard-over signals to the torque motors 22 and 24 to thereby cause the monitor and control spools to assume opposite extreme positions to thereby latch the spools in an overtravel position. Any of a variety of means known to the art can be utilized to relate the offcenter directions of the second stage spools; for example, nozzle pressure detectors can be utilized.

Since the pressure switch 36 will effect latching signals, as above, in the absence of hydraeric pressure, means must be provided during initial pressurization of the system to disconnect the pressure switch 36 so as to allow pressure equilibrium to be obtained without latching. Any of a variety of delay devices known to the art may be utilized. Referring to FIG. 3, a delay device 160 is shown in an open position, prior to initial pressurization. The delay device includes a housing 162, which defines a bore 164 therein, and a piston 166 slideably disposed in the bore 164 abutting a return spring 168. Upon pressurization, hydraeric fluid from the source 60 is fed into the passageway 64 via inlet and outlet ports 170 and 172, respectively, through the delay device housing 162. An exhaust line 174 is connected to the return 62 (FIG. 1) through a restriction 176. Upon pressurization, the delay piston 166 is caused by the hydraeric pressure to move against the return spring 158 to effect contact between electrical leads 146 and 148 disposed within the housing. However, the exhaust restriction 176 is sized so as to delay translation of the delay piston 166 for a period of time sufficient to allow the remainder of the system to obtain pressure equilibrium.

Referring now to FIG. 4, there is illustrated schematically a concentric spool comparator servovalve 210 constructed in accordance with another embodiment of this invention and utilized for controlling the flow of hydraeric fluid through output passageways 212 and 214 to thereby control a load 216. This servovalve 210 is similar to the servovalve 10 described above with respect to FIGS. 1—3 in that it can be described as a two-stage servovalve with the second stage including spools 218 and 220 concentrically disposed, one in the other. Here too, an input signal is independently applied to separate torque motors 222 and 224 which control the movement of the concentric spool 218 and 220 via first stage flapper valves 226 and 230. During normal operation, the input signals are identical and the second stage spools 218 and 220 are in identical positions. When an error is above a predetermined value, the spools 218 and 220 will move in relation to each other. This relative displacement of the concentric spools 218 and 220 will automatically cause a pressure differential to be applied across the inner monitor spool 220 in such direction as to continue the overtravel of the spools to thereby effect a hydraulic latch, locking the inner spool 220 into its overtravel position. Displacement of the inner spool 220 into its overtravel position will shut off the supply pressure and vent the output passageways 212 and 214 to the system return. A hydraeric signal passageway 238 will also be vented to inform logic elements of the failure.

Referring to FIG. 5 and to FIG. 4 in more detail, a housing 240 is provided defining a bore therein in which the control spool 218 is slideably disposed. The housing 240 defines a pair of passageways 244 and 246 which are connected by means of the aforenoted output passageways 212 and 214, respectively, to the chamber 252 of an actuator cylinder 254 on opposite sides of a piston 256 carried on an actuator rod 258. Movement of the actuator rod 258 to position the load 216 is effected and controlled by selectively pressurizing one of the output passageways 212 and 214 while exposing the other of the passageways to the return.

A source 260 of hydraeric fluid is provided in communication with a network of passageways defined by the housing 240 to conduct the hydraeric fluid to the ends of the concentric spools 218 and 220 to thereby establish differential pressures across the spools, and a system return 262 is provided therefor.

Briefly, the passageways are disposed so that first stage flow of hydraeric fluid from flapper valve 226 goes directly to the ends of the control spool 218. The first stage flow for the monitor spool 220 must go through the control valve spool 218 and this is accomplished by directing the fluid flow through a port in the control valve spool into an annulus in the monitor spool 220 and through passageways in lands disposed on the ends of the monitor spool 220 as will hereinafter be described.

The control valve spool 218 is formed with a bore 304 longitudinally therethrough and the monitor valve 220 is slideably disposed within this bore 304. As shown, hydraeric fluid form from the source 260 is conducted through a passageway 264 and branches thereof, through restrictions 280 and 282 to opposite sides of the outer, or control valve spool 218. The hydraeric fluid is also conducted to the oppositely disposed nozzles 284 and 286 of the flapper valve 226 which is utilized to control the movement of the control valve spool 218. Branch passageways are provided from the passageway 264 to feed hydraeric fluid through restrictions 258 and 270 to the oppositely disposed nozzles 272 and 274 of the monitor spool flapper valve 230. This hydraeric fluid is also conducted through ports 273 and 275 in the control spool 218 into annular spaces 277 and 279 defined between pairs of lands 281, 283 and 285, 287 respectively disposed on opposite ends of the monitor spool 220. From there, the hydraeric fluid flows through passageways 289 and 291, defined by the end lands 281 and 285, respectively, to the ends of the monitor spool 220. Sealed cavities are formed at the ends of the monitor spool except for communication through the passageways 289 and 291.

Hydraeric fluid flows from the source 260 through a branch 265 and subbranches 267 and 269 to oppositely disposed ports 293 and 295, respectively, through the control spool 218. With respect to the left hand side, in the drawing, of the control spool 218, the port 295 thereat is utilized only for purposes of failure detection, as will hereinafter be described. With respect to the right hand side of the control spool 218, the port 293 thereat is utilized (a) for latching upon failure (b) to supply hydraeric fluid to the hydraeric signal passageway 238, and (c) to supply hydraeric fluid for the metering function of the control spool 218.

The system return 262 is connected via a return passageway 300 to a common return chamber 302 utilized for both flapper valves 226 and 230. A system return 262 is also connected via a return passageway 301 and branch 303 to ports 305 and 307, respectively, through opposite end portions of the control valve spool 218. The return ports 305 and 307 are closed during normal operation by the monitor spool end lands 281 and 285, respectively, but one or the other of the ports 305 and 307 are exposed into communication with the relevent land passageway 289 and 291 when the spools 218 and 220 are in relative displacement, so as to facilitate latching into an overtravel position, as hereinafter described. The control valve spool 218 is provided centrally with a port 306 whereby its bore 304 can communicate with the flapper return chamber 302; however, during normal operation the port 306 is blocked by monitor spool land 308 and 309 on opposite sides thereof.

A feedback element 312 is connected between the flapper of the control valve spool torque motor 322 and the central region of the control spool 218 and a feedback element 314 extends through the control valve spool central bore 306 into a central portion of the monitor spool 220 to provide position feedback to the monitor spool torque motor 224.

With respect to control operation, hydraeric fluid is fed from the source 260 through the passageway 265 and branch 267 into the control valve spool bore 304 via the right side port 293 therethrough. From there, the hydraeric fluid feeds via a port 311 in the control valve spool to the hydraeric signal passageway 238 and to a bridging passageway 313 (both shown in shadow in FIG. 2). Reduced diameter portions 315 and 317 are formed in the outer surface of the control valve

spool 218 for communication with the passageways 244 and 246. The bridging passageway 313 enables the provision of hydraeric fluid supply ports 319 and 321 adjacent the reduced diameter portions 315 and 317 communicates with a hydraeric supply port 319 or 321 the thereby supply hydraeric fluid to the passageway 244 or 246. Simultaneously therewith, the other reduced diameter position is exposed to the system return 262 by opening into communication with the return chamber 302. Accordingly, upon leftward movement of the control valve spool 218 with respect to the housing 240, hydraeric fluid from the source 260 is fed through the passageway 265, through the branch passageway 267, through the control valve spool port 293 into the control valve spool bore 304, out of the bore 304 through the control valve spool port 311, through the bridging passageway 313, into the supply port 319, into the left side reduced diameter portion 315, and from there into the left side passageway 244. The right side reduced diameter portion 317 is simultaneously exposed to the return chamber 302, thereby exposing the right side passageway 246 to return. Rightward movement of the control spool 218, with respect to the housing, operates in a symmetrical manner to direct hydraeric fluid from the source 260 to the right side passageway 246 and to connect the left side passageway 244 to the system return.

With respect to movement in unison of the control spool 218 and the monitor spool 220, hydraeric fluid is fed from the source 260 through the passageway 264 and restrictions 280 and 282 to the ends of the control valve spool 218, and hydraeric fluid is also fed from the passageway 264 through the restrictions 268 and 270 through ports 273 and 275 in the control valve spool 218 leading to the annular spaces 277 and 279, respectively, as described above and, from there, through the passageways 289 and 291, respectively, to the ends of the monitor spool 220. Since the reaction areas of the second stage spools 218 and 220 are different, the restriction pairs 268, 270 and 280, 282 are sized so that the first stage flow gains are appropriately proportional. Identical movement of the spools 218 and 220 is thereby effected upon receipt of identical signals by the respective torque motors 222 and 224.

With respect to failure detection and latching operation, it will be seen that relative movement between the control and monitor spools 218 and 220 results in exposure of one or the other of the passageways 289 and 291 to a system return passageway 301 or 303 to expose that end of the monitor spool to return 262. The other passageway is simultaneously exposed to hydraeric fluid from the passageway 265 or branch 267 to thereby conduct hydraeric fluid from the source 260 to the opposite end of the monitor spool 220. The result is that a large differential pressure is effected across the monitor spool 220 to further move the monitor spool 220 within the control spool bore 304 in the same direction as the initial error detecting relative movement. In other words, if the error or failure caused relative movement of the monitor spool 220 to the left of the control valve spool 218, the passageway 289 on the left side of the monitor spool communicates with the return line 301 to expose that end of the monitor spool to the system return 262 and the passageway 291 at the other end of the monitor spool exposes that end of the monitor spool to hydraeric fluid from the passageway 267. The resultant differential effects further leftward movement of the monitor spool 220 within the control valve spool bore 304 until the left end of the monitor spool 220 contacts the inner left surface of the control spool 218. Rightward movement of the monitor spool 220 relative to the control valve spool 218 operates in a symmetrical manner to further move the monitor spool 220 within the control spool 218 to abut that end of the monitor spool against the right side of the control spool 218. In either case, the spools are effectively latched into an overtravel position.

Relative movement of the spools also effect a venting of the passageways 244 and 246 and of the hydraeric signal passageway 238. Venting of the hydraeric signal passageway 238 is accomplished by means of a vent port 316 into the bore 304, which vent port 316 is in communication with the return chamber 302 via a passageway 318 (shown in shadow in FIG. 5). A land 320 on the monitor spool 220 covers the vent port 316, but upon relative movement of the spools, the vent port 316 exposes the control spool bore 304 to return and via the control valve spool bore 311, vents the hydraeric signal passageway 238 to return to thereby signal failure to logic units in the system.

By the same means, the bridging passageway 313 is vented. Accordingly, if the monitor spool 220 has moved to the right relative to the control valve spool 218, the monitor spool lands 308 and 309 move to expose the left side passageway 244 to the system return 262 via the bridging passageway 313 and simultaneously the right side passageway 246 is exposed directly to the system return chamber 302. Leftward movement of the monitor spool 220 relative to the control valve spool 218 operates in a symmetrical manner to vent the right side passageway 246 to the bridging passageway 313 and the left side passageway 244 directly to the return chamber 302. In either case, both actuator passageways 244 and 246 are vented to the system return.

The servovalve 210 can be unlocked from a failed position by means of a four-way solenoid valve such as depicted at 322. Such four-way solenoid valves are well known to the art and in this embodiment serve to reverse the pressure and return system ports to unlatch the valve and force the monitor and control spools to an operative position.

I claim:

1. In a hydraeric control system for applying hydraeric fluid from a source thereof to a load through ports controlled by a control valve spool, and including a mechanism for effecting a desired system change upon failure, the improvement wherein a bore is defined by said control valve spool and said mechanism comprises:

a monitor spool slideably disposed in said bore;

independent means for positioning said monitor spool;

means for moving monitor spool and control spool in substantial unity; and

means for detecting relative movement between said control spool and said monitor spool.

2. The improvement of claim 1 including means for applying a hydraeric pressure differential across said control valve spool and means for applying a hydraeric pressure differential across said monitor spool in proportion to said control valve spool hydraeric differential.

3. The improvement of claim 1 including a hydraeric path through said control valve spool, said monitor spool and control valve spool being formed so that said relative movement causes a change in hydraeric pressure in said path to thereby effect a change in said system.

4. The improvement of claim 1 including a hydraeric path through said control valve spool and a system return, said monitor spool and control valve spool being formed so that said relative movement vents said path to said return to thereby effect a change in said system.

5. The improvement of claim 1 including a hydraeric path into said control valve spool bore and a system return in communication with said control valve spool bore, said monitor spool and control valve spool being formed so that said relative movement effects the venting of said hydraeric path to said return to thereby effect a change in said system.

6. The improvement of claim 5 including a shutoff valve for said system in communication with said hydraeric path and operative upon venting of said hydraeric path to shut off said load from said hydraeric fluid source.

7. The improvement of claim 5 including means responsive to a hydraeric pressure drop for signaling failure of said system, said pressure responsive means being in operative communication with said hydraeric path.

8. The improvement of claim 2 including a hydraeric path and a system return path to each end of said monitor spool, said monitor spool and control valve spool being formed so that upon said relative movement communication is effected

between that end of said monitor spool in the direction of its relative movement and said system return path and between the other end of said monitor spool and said hydraeric path to thereby latch said system in an overtravel position.

9. The improvement of claim 2 including first and second means responsive to electrical signals for controlling the hydraeric pressure differentials to said monitor spool and control valve spool, respectively, wherein substantially identical linear movements of said monitor and control spools are normally effected by identical electrical signals to said first and second means.

10. The improvement of claim 9 including means responsive to said relative movement to effect the application of opposite electrical signals to said first and second means to thereby latch said system in an overtravel position.

11. The improvement of claim 2 including a land on said monitor spool within said control spool bore and a bore defined through said land in communication with said control valve spool bore whereby hydraeric pressure on both sides of said land are equalized, said monitor spool and control valve spool being formed so that said land bore effects a change in hydraeric pressure within said control valve spool bore upon said relative movement of said monitor and control spools.

12. A redundant control system comprising a plurality of control channels, each control channel including a control member and a monitor member, means for effecting substantially identical movements of said control and monitor members and means responsive to a differential in said movements to disable that channel independently of the others of said plurality of control channels.