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[54] **PRESSURE COMPENSATING VALVE MECHANISM FOR HYDRAULIC CONTROL VALVES**

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[52] **U.S. Cl.** **137/115;** 137/506; 137/596.12; 137/625.48; 251/285
[51] **Int. Cl.** **F15b 13/02**
[58] **Field of Search** 137/102, 115, 116.3, 488, 137/512.2, 512.3, 513.5, 596.12, 596.13, 625.48, 506; 251/285

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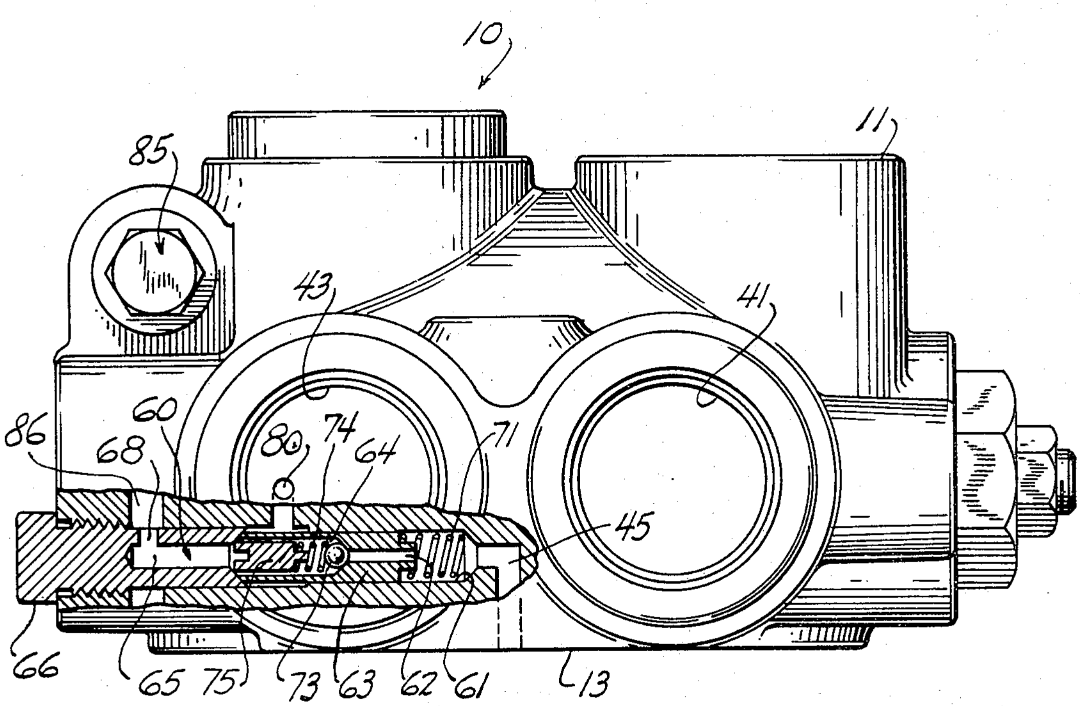
[57] **ABSTRACT**

A pressure compensating valve mechanism having a differential pressure actuated spool type valve plunger and featuring means to assure exceptionally fast response thereof to variations in pressure differential while at the same time effecting such damping of plunger movements during normal modulation thereof as is essential to plunger stability.

6 Claims, 4 Drawing Figures



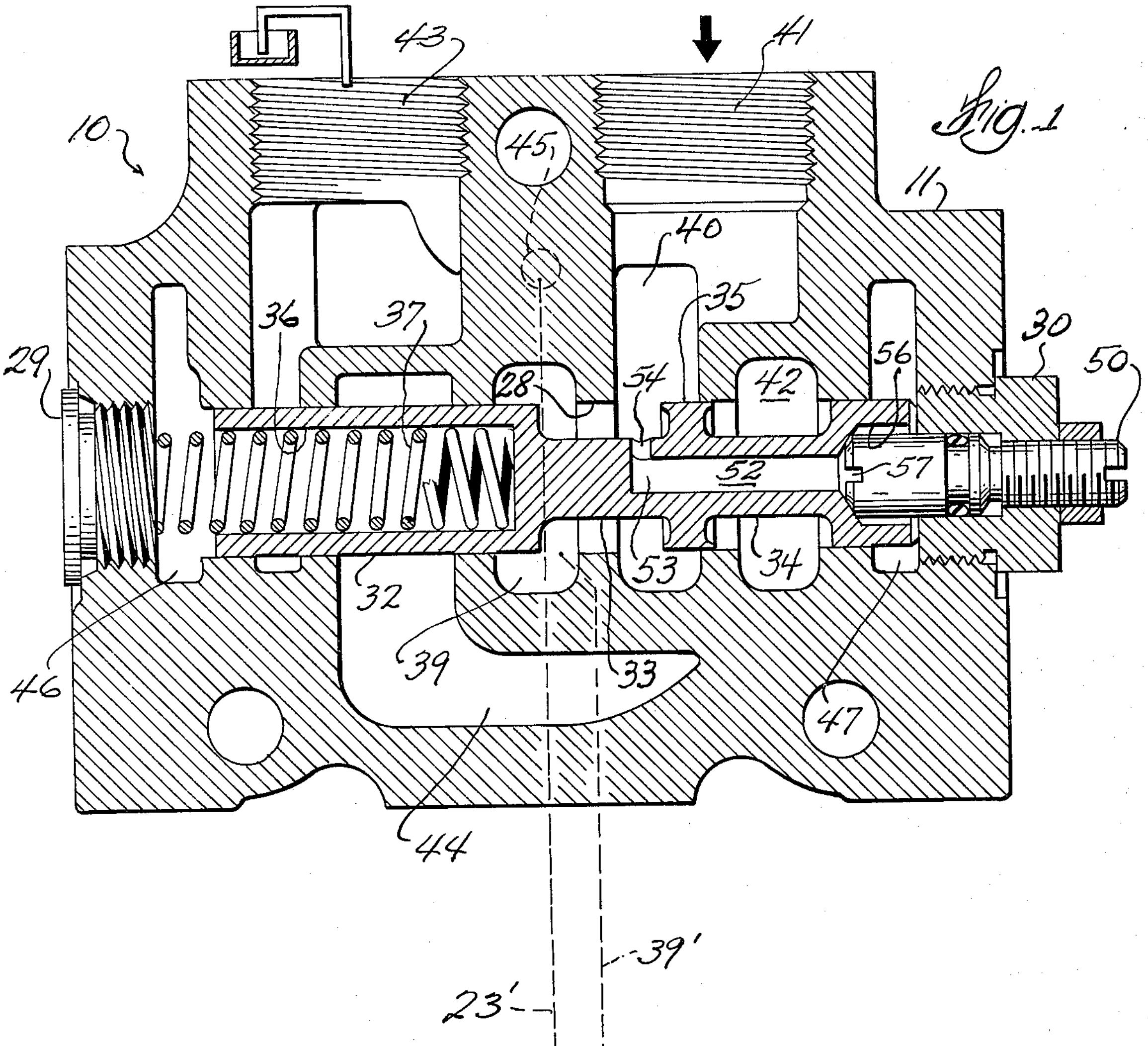

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Fig. 1

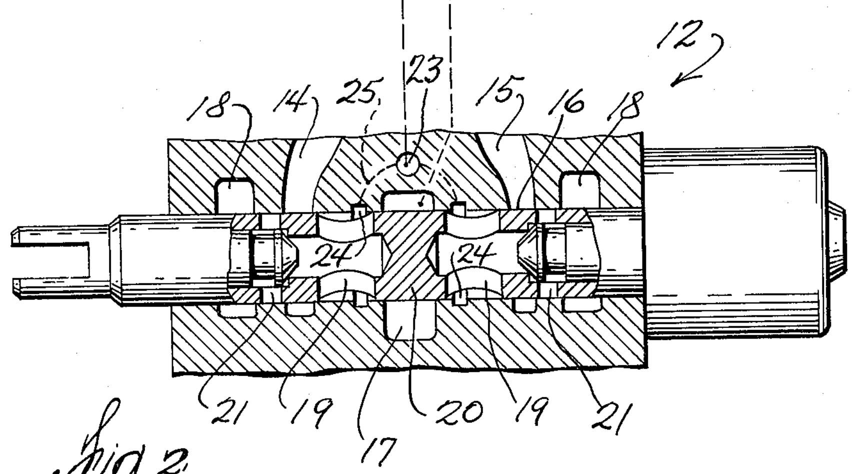
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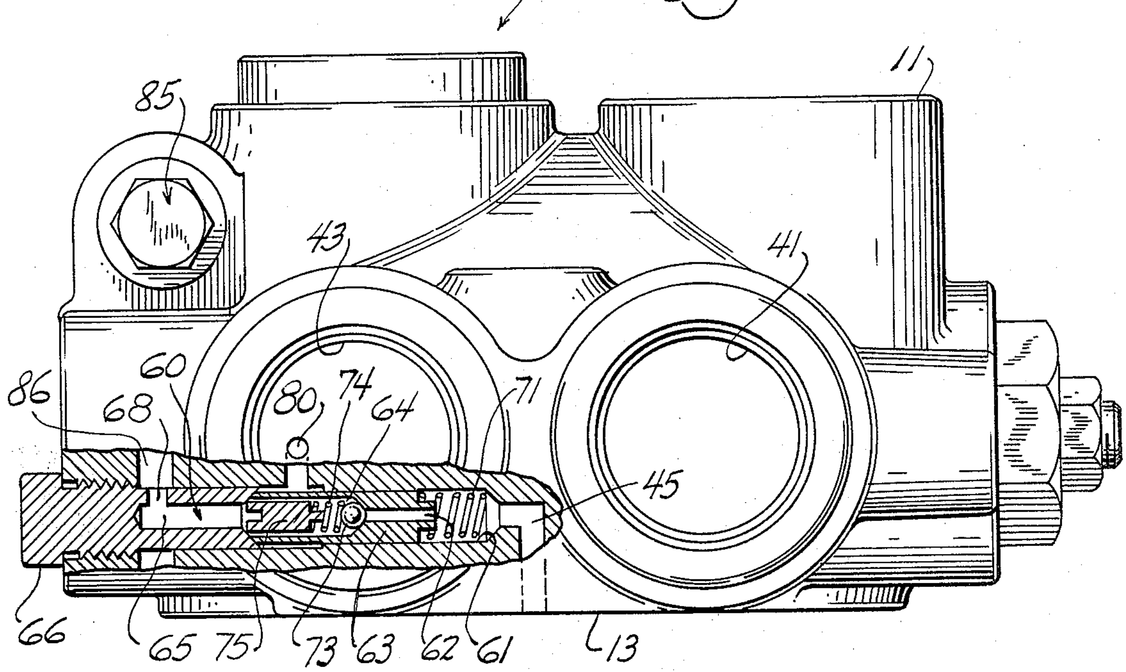
Fig. 2

Fig. 3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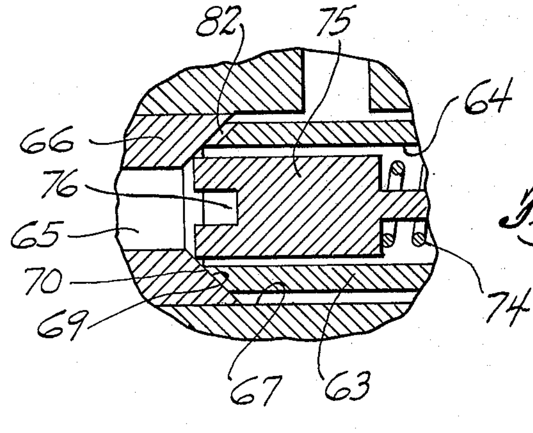
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Fig. 4

PRESSURE COMPENSATING VALVE MECHANISM FOR HYDRAULIC CONTROL VALVES

This invention relates to control valve mechanism mechanisms governing the operation of hydraulic cylinders and other fluid motors, and it has more particular reference to pressure compensating valve mechanisms such as are used in conjunction with control valve mechanisms to enable them to maintain the motors governed thereby in operation at precisely controlled preselected speeds.

A conventional pressure compensated control valve of the type to which this invention pertains is disclosed in Tennis U.S. Pat. No. 3,718,159 which issued Feb. 27, 1973. The control valve of that patent is provided with a plurality of control sections assembled in a bank, and its pressure compensating valve mechanism is embodied in an inlet section at one end of the bank.

The pressure compensating mechanism comprises a spool type valve plunger which operates in a bore closed at its ends to define inlet and feedback chambers into which the ends of the plunger extend. Source fluid, feed, and bypass ports open to the bore at axially spaced locations, and the plunger is movable back and forth in the bore to regulate communication of the source fluid port with the feed and bypass ports in accordance with variations in the pressure differential of said chambers.

The pressure of source fluid manifested in the inlet chamber tends to move the plunger in one direction toward an unloading position at which all source fluid entering the mechanism flows to the bypass port. The compensating plunger occupies this unloading position whenever the motor control spools of all the valve sections are in neutral positions.

The pressure of signal fluid in the feedback chamber tends to move the plunger in the opposite direction, toward a feed position at which it closes off the bypass port from the source fluid port and communicates the latter with the feed port. In this way, pressure fluid in the source fluid port is compelled to flow to a feeder passage which connects with the feed port, and which extends through all of the valve sections in the bank.

Such motion of the plunger to its feed position occurs as a consequence of actuation of one of the control spools to a working position communicating one of its service passages with the feeder passage. At that time, the pressure of fluid in the selected service passage is manifested in the feedback chamber, through a control or signal port, to cause the compensating plunger to move in the bypass closing direction a distance determined by the extent of displacement of the control spool out of its neutral position.

As is well known, the compensating plunger will maintain a substantially uniform pressure drop across the orifice defined by the motor control spool in any working position thereof at which it meters flow of source fluid to the motor governed thereby. By so doing, of course, the pressure compensating plunger will function to maintain the fluid motor in operation at a substantially constant speed corresponding to the metering position of the control spool. Any source fluid in excess of that needed for motor operation at the desired speed is directed to the bypass port by the compensating plunger.

In order to achieve precise control over the speed of the governed motor under any given operating condition, the movement of the compensating plunger must be damped sufficiently to prevent undesirable back and forth fluctuation thereof in consequence of pressure pulsations such as normally occur in the system during operation of hydraulic equipment driven by the governed motor. Stability of the plunger under such conditions is thus a requisite to any efficient compensating valve mechanism.

The desired plunger stability is achieved by the incorporation of substantially small diameter orifices in the fluid control passages through which the inlet and feedback chambers are communicated with the source fluid and signal ports. The best damping effect on compensating plunger movement is achieved when these orifices are quite small in cross sectional area. With such small orifices, however, the plunger was incapable of fast response to any new modulating position demanded by readjustment of the motor control spool. Nor could the plunger move quickly to its bypass position at times when conditions demanded such response thereof.

Stated in another way, for good plunger damping and stability, the control passages connecting with the inlet and feedback chambers should be severely restricted; while for fast response of the plunger to variations in pressure differential across its ends, these same control passages should be relatively unrestricted.

As a result of these conflicting requirements, it has been customary in the past to size the orifices in the control passages in such a way as to effect a compromise between fast response of the compensating plunger and stability thereof.

The present invention has as its principle objective the provision of a compensating valve mechanism which is constructed in a way that assures the desired stability of its compensating plunger under any given operating conditions, and which also assures exceptionally fast response of the plunger to changes in pressure differential across its ends.

More specifically, it is the purpose of this invention to provide a pressure compensating mechanism of the character described wherein substantially unrestricted control passages lead respectively to its inlet and feedback chambers, and wherein pressure actuatable means not only compels substantially restricted discharge of fluid out of the feedback chamber to assure the desired damping of the compensating plunger during normal modulating movement thereof but also assures substantially unrestricted discharge of fluid from the feedback chamber at times when faster response of the compensating plunger to changing pressure conditions becomes necessary.

With these observations and objectives in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings, which exemplify the invention, it being understood that changes may be made in the specific apparatus disclosed herein without departing from the essentials of the invention set forth in the appended claims.

The accompanying drawings illustrate one complete example of an embodiment of the invention constructed according to the best mode so far devised for the practical application of the principles thereof, and in which:

FIG. 1 is a sectional view of a pressure compensating valve mechanism of this invention;

FIG. 2 is a fragmentary sectional view of a conventional control valve for a hydraulic motor, shown connected with the compensating mechanism of FIG. 1 for purposes of illustration;

FIG. 3 is a top view of the valve mechanism seen in FIG. 1, with portions broken away and shown in section in order to illustrate internal construction; and

FIG. 4 is an enlargement of a portion of the mechanism seen in FIG. 3.

Referring now to the accompanying drawings, the numeral **10** generally designates a pressure compensating valve mechanism of this invention. The valve mechanism is housed in a body **11** that is here shown by way of example as comprising the inlet section of a stacked control valve.

The control valve comprises at least one control section **12** such as seen in FIG. **2**, which is adapted to be secured to the inlet section **11** with a flat surface thereof in mating engagement with a flat surface **13** on the underside of the inlet section.

In general, the inlet and control sections **11** and **12** are comparable to those disclosed in Tennis U.S. Pat. No. 3,718,159, to which reference may be had for a complete description of said components.

The control section **12** is of the type adapted to govern a reversible fluid motor, such as a double-acting hydraulic cylinder (not shown). It has a pair of service passages **14** and **15** for connection with the opposite ends of the cylinder, and a valve spool **16** which is actuatable from a neutral position shown to working positions at opposite sides of neutral to communicate a selected one of the service passages with a feeder passage **17**, and to communicate the nonselected service passage with a return passage **18**.

Source fluid in the feeder passage **17** flows to the selected service passage through substantially large inner ports **19** in the wall of hollow portions of the spool, located adjacent to but at opposite sides of a solid center portion **20** thereof, and through outer ports **21** in the wall of the hollow portions of the spool. The ports **21** also serve to connect the service passages with the return passages **18** in a manner deemed obvious from a consideration of FIG. **2**.

As fully described in the aforesaid Tennis patent, actuation of the control spool **16** to either working position results in subjection of a signal passage **23** in section **12** to "load" pressure at the selected service passage. For that purpose, the "load" pressure is detected at enlargements **24** of the bore containing valve spool **16**, through a connecting groove **25** in the face of the control section **12**. The enlargements **24**, of course, are communicated with the selected service passages **14** or **15** through the adjacent hollow interior portions of the valve spool.

Referring now to the inlet section **11** in which the pressure compensating valve mechanism **10** is housed, it will be seen that the body of said section is provided with a bore **28**, the opposite ends of which are closed by plugs **29** and **30**. An elongated spool-type pressure compensating plunger **32** is slidable axially back and forth in the bore between limits which can be defined by the engagement of its ends with the plugs **29** and **30**.

A pair of axially spaced circumferential grooves **33** and **34** in the plunger define between them a land **35**. One end portion of the plunger has a deep well **36** to accommodate a substantially strong coil spring **37**. This spring is confined between the bottom of the well and the adjacent plug **29**, and it urges the plunger toward its right hand limit of motion, in what can be considered the "feed" direction.

As in the aforesaid Tennis patent, the compensating valve mechanism **10** comprises a number of ports that open to its bore **28** at axially spaced locations. Reading from left to right in FIG. **1**, there is provided a feed port **39** which opens through the surface **13** at the underside of the body **11** at a location to register with the feeder passage **17** in a control section **12** secured to the body **11**; an inlet port **40** for source fluid which opens to one side of the body as at **41**; and a bypass port **42** which can be communicated with an outlet or tank port **43** for fluid to be returned to a reservoir. Communication between the bypass port **42** and the tank port **43** is provided by passage means in the interior of the body **11**, including a passageway **44**.

For convenience of illustration, a duct **39'** is shown connecting feed port **39** with feeder passage **17**. Similarly, the signal passage **23** in control section **12** is shown connected by a duct **23'** with a portion **45** of said signal passage in the body of the inlet section **11**. It is to be understood, however, that the signal passage portion **45** opens through surface **13** at the underside of the inlet section, in register with passage **23** in the control section **12**.

The opposite end portions of the plunger **32** cooperate with the plugged end portions of the bore **28** to define a pair of plunger actuating chambers **46** and **47**. The chamber **46** is at the left hand end of the plunger and can be considered as a feedback chamber which is communicated with the signal passage portion **45** to receive pressurized signal fluid therefrom. The other chamber **47** can be considered as an inlet chamber which is connected with the inlet port **40** to receive source fluid therefrom. Pressure fluid flowing into either chamber tends to move the plunger toward the other chamber.

The valve plunger **32** is movable axially back and forth between a bypass position and a full feed position such as seen in FIG. **1** and which, if desired, can be defined by the engagement of its right hand end with adjustable stop **50** screw threaded into the plug **30**. In that full feed position of the plunger, the groove **33** therein establishes full flow communication between the feed and inlet ports **39** and **40**, respectively; while the land **35** between the plunger grooves **33** and **34** closes off communication between the inlet and bypass ports **40** and **42**, respectively.

Source fluid in port **40** is led into the inlet chamber **47** through a control passage **52** comprising a coaxial blind bore **53** in the right hand end portion of the compensating plunger, a radial port **54** in the plunger opening outwardly from the inner end of the blind bore to the plunger groove **33**, and a counterbore **56** to which the outer end of bore **53** opens. As will be understood by those skilled in the art, the plunger port **54** will be in communication with the inlet port **40** at all times.

Contrary to past pressure compensating valve constructions wherein the control passage **52** was severely restricted, as by a small diameter radial port at its inner end, the control passage here shown provides a substantially unrestricted flow path from the inlet port **40** to the inlet chamber **47**, for substantially free transfer of pressure fluid therebetween. In other words, the radial port **54** at the inner end of the bore **53** is here provided by a hole substantially larger in diameter than was the practice heretofore.

The adjustable stop **50** projects into the counterbore **56** for engagement with the bottom thereof, and its exterior is suitably spaced from the wall of the counterbore. A cross slot **57** in the inner end of the stop assures communication between the bore **53** and the counterbore **56** at times when the plunger **32** is in its limit of motion defined by said adjustable stop.

The compensating plunger **32** is shown in the operating position it will occupy whenever the control spool **16** in valve section **12** is in a full operating position at one side or the other of its neutral (hold) position seen in FIG. **2**.

The compensating plunger is held in this full feed position by the force of its spring **37** augmented by a fluid pressure force imposed thereon by signal fluid at a pressure substantially corresponding to that which is present in the service passage then in communication with the feeder passage **17**.

In said working position of the main spool, signal passage **23** is communicated with the feedback chamber **46** of the pressure compensating valve mechanism through control passage portion **45** in the inlet section, and a branch of the latter generally designated **60** formed in the body **11** of the compensating valve mechanism. The branch **60** extends outwardly from its junction with passage portion **45** to the feedback chamber **46**, in spaced relation to the plunger **32** but parallel to the latter and to the underside **13** of the body.

The branch passage **60**, of course, comprises a terminal portion of the signal passage. Referring to FIGS. **3** and **4**, it will be seen that the branch passage **60** is provided by a bore **61** in body **11**, an axial passage **62** in the body of a hollow check valve **63** located in said bore, a counterbore **64** in the check valve to which passage **62** opens, and a bore **65** in a plug **66** threaded into the body at a location alongside the plug **29**. The plug **66** closes the mouth of a counterbore **67** to which the bore **61** opens, and it has a radial port **68** therein to communicate the branch **60** of the signal passage with the feedback chamber **46**.

The inner end of the plug **66** is formed with a coaxial conically surfaced seat **69** for engagement by a conically surfaced head **70** on the adjacent end of the check valve **63**. The check valve is yieldingly held in a closed position of engagement with seat **69** by a spring **71** confined in the bore **61** inwardly of the check valve.

Communication between the axial passage **62** in the check valve and its counterbore **64** is controlled by a ball check **73**, which is engageable with an outwardly facing seat at the bottom of said counterbore. A spring **74** confined between the ball check **73** and a spring seat member **75** yieldingly holds the ball check seated. The spring seat member is confined in the counterbored interior of the check valve **63** with its outwardly facing end in engagement with the valve seat **69** on the inner end of the plug **66**.

It should be observed that the exterior of the spring seat member **75** is spaced from the wall of the counterbore **64** in which it is received, and that said space cooperates with a cross slot **76** in the outer end of the spring seat member to provide communication between the axial passage **62** and the bore **65** in plug **66**.

From this it will be seen that the signal passage branch **60** in the inlet section **11** comprises the passage portion **45**, the adjacent portion of bore **61**, axial passage **62** in check valve **63**, counterbore **64** in said check valve, the space between the wall of said counterbore and the exterior of the spring seat member **75**, the bore **65** in plug **66**, and port **68** which communicates with the feedback chamber.

According to this invention, signal passage branch **60** is designed to provide a path controlled by ball check **73** along which signal fluid can flow substantially unrestrictedly to the feedback chamber **46**. This is to say that none of the passage portions defining the signal passage branch **60** offers any appreciable restriction to the flow of signal fluid to the feedback chamber **46**.

The check valve **63** in which the ball check **73** is located, governs communication between the feedback chamber **46** and a venting passage **80**, here shown communicating with tank port **43**. This venting passage opens to the space in counterbore **67** surrounding the outer portion of check valve **63**. Hence, when check valve **63** is moved off of its seat, it communicates the feedback chamber with the venting passage **80**.

According to this invention, venting passage **80** is also of a size to permit fluid from the feedback chamber **46** to flow substantially freely to the tank **43** whenever check valve **63** is caused to open in response to force exerted on its seat engaging end by pressure fluid in feedback chamber **46**.

The spring **71** which yeildingly holds the check valve **63** seated is strong enough to withstand pressure pulsations which are manifested in the feedback chamber **46** during normal modulating operation of the compensating plunger. The motions of the plunger in response to such pulsations are damped through the provision of substantially restricted passage means by which the feedback chamber **46** is communicated with the tank port **43** or any other low pressure passage in the body of the inlet section **11**.

By way of example, such restricted venting passage means can be provided either by a small orifice in the plunger communicating the well **36** therein with the tank port **43**; or by bore clearance around the exterior of the plunger at its left hand extremity.

While these venting expedients are satisfactory, this invention provides a restricted venting passage comprising a narrow shallow notch **82** in the conically surfaced head **70** of the check valve **63**, as seen in FIG. **4**. When check valve **63** is seated, the notch **82** is effective to afford such restricted communication between the feedback chamber **46** and the tank port as is necessary for the desired damping of compensating plunger motions occurring as a consequence of signal pressure pulsations in a first range of pressures manifested in the feedback chamber.

Any such normal pressure pulsations manifested in the feedback chamber **46** are incapable of overcoming the spring force holding check valve **63** seated. The closing force exerted on the larger check valve **63** is not overcome until there is mainfested in the feedback chamber a pressure greater than any in the aforesaid normal range of pressure and capable of exerting an opening force on the check valve **63** sufficient to overcome the closing force exerted thereon by spring **71** augmented by any closing force which fluid in the signal duct exerts upon the end of the check valve remote from the feedback chamber. At that time, check valve **63** opens to allow substantially unrestricted communication of the feedback chamber with the tank port.

This last condition can arise at times, for example, when the valve spool 16 in control section 12 is returned to its neutral position from a working position such as described; or as a consequence of adjustment of said spool to a new working position. In either event, the compensating plunger will respond in an exceptionally prompt manner by movement to a full bypass position if the main spool 16 is returned to neutral; or to whatever new modulating position is demanded by the readjusted working position of the main spool.

The inlet section 11 is also provided with a relief valve mechanism 85 like that disclosed in the aforesaid Tennis patent. The relief valve functions as a pilot valve for the compensating plunger 32. For that reason, it is connected with the feedback chamber 46 through a passage 86, so as to be opened in consequence of excessively high system pressure manifested in the feedback chamber. When the relief valve opens, of course, it communicates the feedback chamber with the tank port 43; and it is set to open whenever pressure in the feedback chamber 46 rises to a value considerably in excess of that at which check valve 63 opens.

Promptly upon opening of the relief valve 85, the pressure of inlet fluid in chamber 47 becomes effective to actuate the compensating plunger 32 to its full open position at which all source fluid entering the inlet 41 flows to the bypass port 42. In this respect, it should be observed that the full feed position of the plunger can be so determined by the adjusting screw 50 as to assure that bypass of source fluid will begin substantially immediately upon opening of the relief valve, after only a very slight leftward movement of the plunger out of its full feed position seen in FIG. 1.

This is to say, that in said full feed position of the plunger, its land 35 can be positioned with but a small edge portion of its right hand extremity engaged in that zone of bore 28 lying between the inlet port 40 and the bypass port 42. Consequently, such rapid bypass response of the plunger to opening of the relief valve is effected with an action comparable to that of a poppet valve.

From the foregoing description, together with the accompanying drawings, it will be readily apparent to those skilled in the art that this invention makes possible for the first time the features of exceptionally fast response of the plunger of a pressure compensating valve mechanism to variations in pressure differential across its ends, without sacrificing such damping of the plunger during normal modulating operation thereof as will assure the desired plunger stability.

The invention is defined by the following claims:

1. In a valve mechanism having pressure fluid inlet, feed and bypass ports, and wherein flow of signal fluid into a feedback chamber causes force to be imposed on a pressure compensating valve plunger to move the same in a feed direction and thereby effect diversion of inlet fluid to the feed port, and wherein flow of inlet fluid into an inlet chamber causes force to be imposed on the plunger to move the same in a bypass direction and thereby effect diversion of inlet fluid to the bypass port, movement of the plunger in the bypass direction tending to increase the pressure in the feedback chamber and the speed of such plunger movement being dependent upon the rate at which fluid can be expelled thereby from the feedback chamber, the improvement which comprises:

A. means providing separate substantially unrestricted ducts through which inlet and signal fluid can flow rapidly to the inlet and feedback chambers, respectively;

B. a one way valve arranged to open under signal fluid pressure to allow signal fluid to flow to the feedback chamber;

C. means defining a restricted first venting passage which connects with the feedback chamber and is at all times effective to damp pulsations of moderate pressure therein such as occur during normal modulating operation of the plunger;

D. means defining a substantially unrestricted second venting passage connecting with the feedback chamber to provide for rapid flow of fluid therefrom;

E. a fluid pressure actuatable valve member governing fluid flow through said second venting passage, said valve member being movable to a passage open position under force which pressure fluid in the feedback chamber imposes thereon;

F. and means to yieldingly hold said valve member in its passage closing position against opening forces which said moderate pressure pulsations impose thereon while allowing the valve member to be opened in consequence of higher pressures in the feedback chamber resulting from movement of the plunger in the bypass direction, said last named means comprising a surface on the valve member upon which signal fluid exerts passage closing force.

2. The valve mechanism of claim 1, wherein said last named means further comprises a spring which augments the closing force exerted upon said valve member by pressure of signal fluid.

3. The valve mechanism of claim 1, further characterized by:

A. said valve member being located in the signal duct and engaging an annular seat therein coaxial with the signal duct;

B. and said valve member having an axial passage therethrough comprising part of the signal duct.

4. The valve mechanism of claim 3, wherein said one way valve is located in said axial passage in the valve member and is cooperable with an annular seat on the latter, coaxial with said axial passage.

5. The valve mechanism of claim 4, further characterized by:

A. a spring seat member confined in said axial passage between the one way valve and said first designated annular seat;

B. and a spring reacting between said seat member and the one way valve.

6. The valve mechanism of claim 5, wherein another part of said signal duct is provided by a space around the exterior of the spring seat member.

* * * * *