United States Patent

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[54] **HYDRAULIC SERVO VALVE WITH PRESSURE FEEDBACK**
12 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **137/625.63**
[51] **Int. Cl.** **F16k 11/07**
[50] **Field of Search** 137/625.63, 625.64, 625.66

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ABSTRACT: A servovalve including a hollow valve spool containing a multipiece plunger-piston stack defining separate first stage and feedback pressure areas for the spool. The plunger-piston stack extends the entire length of the bore in which the spool is contained to provide a central load reaction path therefor.

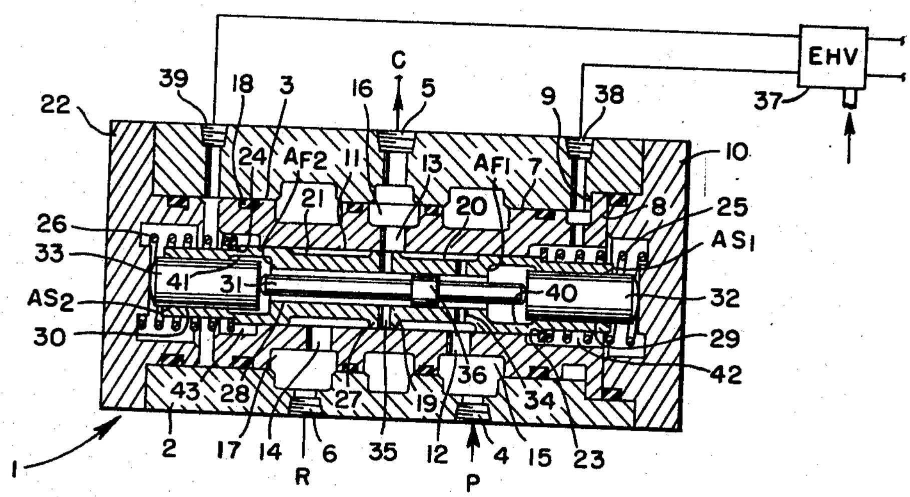
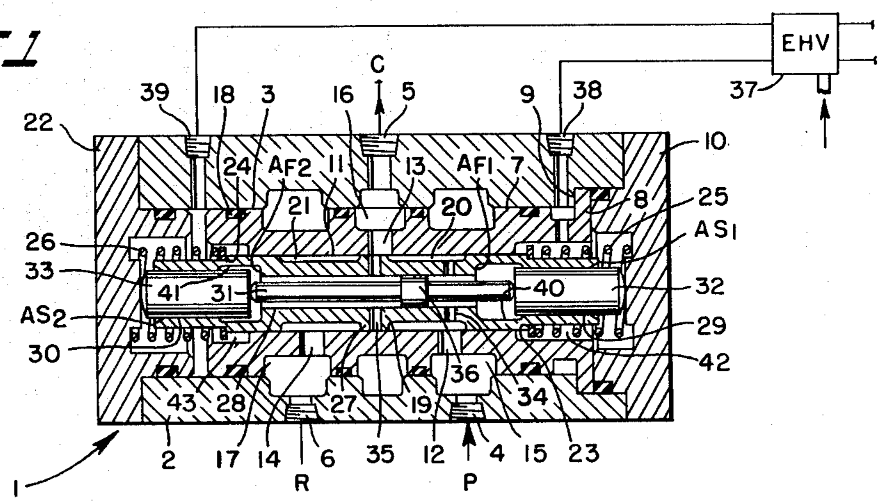


FIG. 1



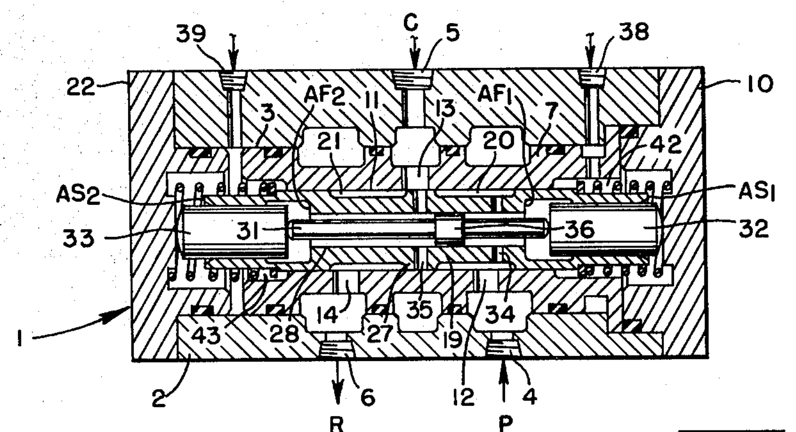


FIG. 2

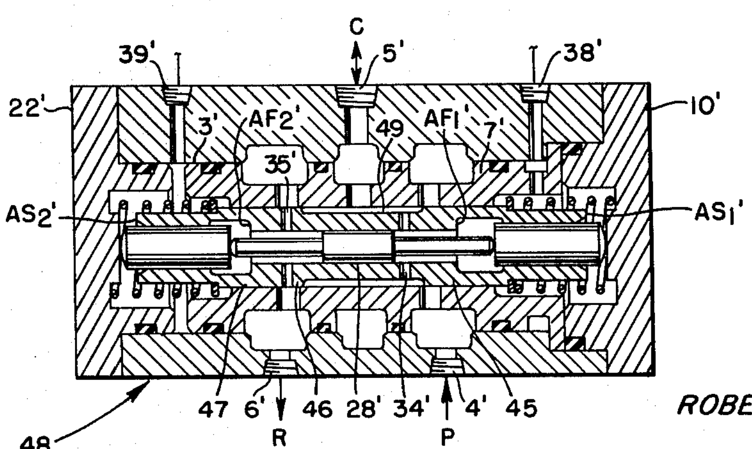


FIG. 3

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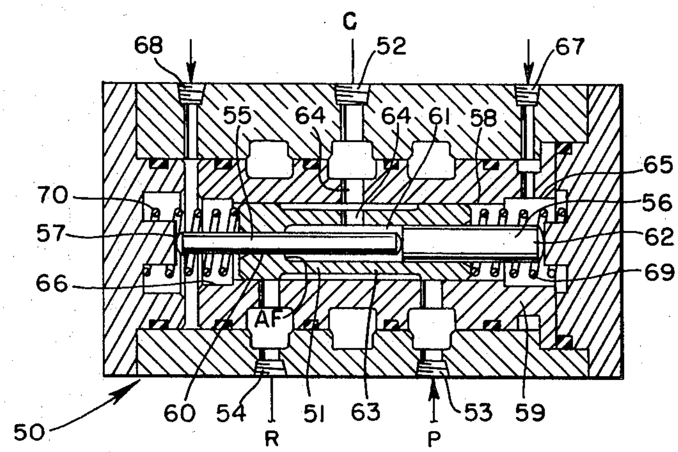

FIG. 4

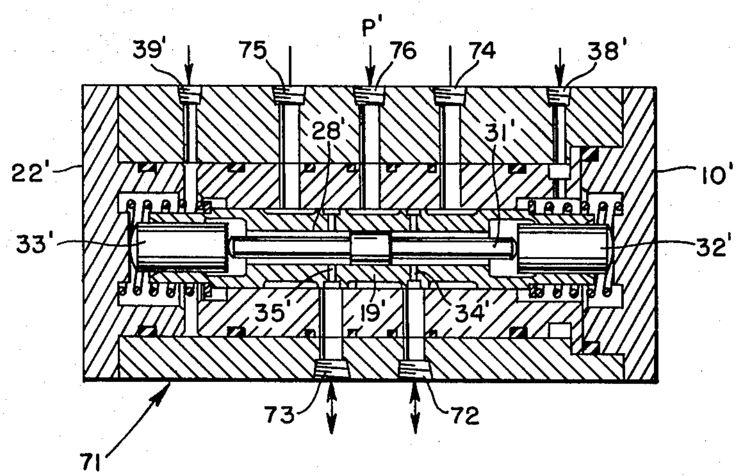

FIG. 5

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HYDRAULIC SERVO VALVE WITH PRESSURE FEEDBACK

BACKGROUND OF THE INVENTION

This invention relates to a certain improvements in hydraulic servovalves with pressure feedback for use as force transducers or pressure regulators to control load accelerations and actuator forces such as may be found in aircraft and missile control systems, antiskid braking systems, and industrial automatic machines.

To achieve normal feedback operation of a servovalve, the valve spool is frequently provided with reduced end portions which extend into inserts in the bore for the spool to define separate feedback and first stage spool pressure areas at each end. This arrangement requires close concentricity between the diameters of the valve spool, bore, and inserts, as well as lap fits between each of the parts to preclude leakage from one pressure area to another, which substantially increases manufacturing cost.

Such close concentricity requirements can be eliminated by providing separate headed pistons at the ends of the valve spool instead of reducing the end portions of the valve spool, but this may result in undesirable piston cocking and friction because of the pressure loads which are supported on the head of the pistons rather than on center. The piston heads are necessary to retain the pistons against movement because the differential pressure across the pistons may reverse. The inserts of the first-mentioned servovalve must also be retained for the same reasons.

Previous known servovalves further require that the sum of the feedback and first stage areas substantially equal the total area of the valve spool. Since the first stage area is normally about twice the feedback area, the first stage flow requirements must be quite large for large spool diameters, which affects the cost of the system and places some restrictions on the size and weight of the servovalve.

SUMMARY OF THE INVENTION

To reduce the cost of manufacture, the servovalve of the present invention has no concentricities and few lap fits. Moreover, the servovalve has a relatively few number of parts with a minimum number of seals, thus further reducing the cost of manufacture, which is a principal object of this invention.

Another object is to provide a servovalve with a central load reaction path which eliminates side loads and friction.

A further object is to provide a servovalve in which the total feedback and first stage pressure areas may be substantially less than the area of the valve spool, whereby the first stage flow requirements may be minimized.

These and other objects of the present invention may be achieved by providing a servovalve with a multipiece piston and/or plunger stack extending axially through the valve spool which defines with the valve spool separate first stage and feedback pressure areas. The piston and plunger stack extends from one end of the spool bore to the other to provide a central load reaction path for unequal pressure forces. A slight lateral clearance in the piston-plunger stack prevents side loading of the spool, and internal plunger porting reduces the number of spool seals required.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1 is a longitudinal section through a preferred form of three-way servovalve constructed in accordance with this invention showing the valve spool in the normal open position for supplying fluid pressure to the cylinder passage;

FIG. 2 is a longitudinal section like FIG. 1, but the valve spool has been moved to a position communicating the cylinder passage with return;

FIGS. 3 and 4 are longitudinal sections through modified forms of three-way servovalves in accordance with this invention; and

FIG. 5 is a longitudinal section of a preferred form of four-way servovalve in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. 1 and 2 there is illustrated a typical three-way pressure control valve 1 in accordance with this invention, including a housing 2 having a bore 3 therein intersected by axially spaced-apart passages 4, 5 and 6, the passage 4 being a fluid pressure supply passage adapted to be connected to a fluid pressure source P; the passage 6 being a return passage adapted to be connected to a reservoir R; and the passage 5 being a cylinder passage adapted to be connected to a pressure operated cylinder C or other pressure operated device. Contained within the housing bore 3 is a valve sleeve 7 having a flange 8 at one end clamped between a shoulder 9 of the housing and an end cap 10 for retaining the sleeve 7 in place. The sleeve 7 has a longitudinal bore 11 therein which communicates with the passages 4, 5 and 6 in the housing 2 through radial passages 12, 13 and 14 and annular grooves 15, 16 and 17 in the sleeve 7. Suitable O-ring seals 18 between the housing 2 and sleeve 7 isolate the grooves 15, 16 and 17 from each other. Axially slidably received in the sleeve bore 11 is a valve spool 19 having a pair of axially space-apart annular grooves 20 and 21 therein for selectively communicating the cylinder passage 5 with the supply passage 4 and return passage 6 upon movement of the valve spool in opposite directions.

The ends of the bore 3 are closed by end caps 10 and 22 which may be bolted or otherwise secured to the housing. Interposed between the end caps 10 and 22 and annular shoulders 23 and 24 on the valve spool 19 are compression springs 25 and 26 which desirably normally bias the valve spool 19 to the open position shown in FIG. 1 in which the supply passage 4 is in communication with the cylinder passage 5 via the annular groove 20 and fluid communication between the cylinder passage 5 and return passage 6 is blocked by the cylinder land 27 between annular grooves 20 and 21. Alternatively, the valve pressure characteristics could be reversed by spring biasing the valve spool in the opposite direction if desired.

The valve spool 19 is shorter than the overall length of the bore 3 between the end caps 10 and 22 to permit limited axial movement therein, and has a longitudinal opening or bore 28 therethrough which is counterbored at 29 and 30 adjacent opposite ends contained within the longitudinal bore 28 is a plunger 31, the ends of which engage pistons 32 and 33 which extend from the end caps 10 and 22 into the counterbores 29 and 30 thus to provide a substantially continuous, axially fixed piston-plunger stack or support over the full length of the bore 3 which acts as a central load reaction path for the valve spool when unequal pressure forces are supplied thereto.

Spaced apart radial passages 34 and 35 in the valve spool 19 supply feedback pressure from the supply passage 4 and cylinder passage 5 to the annular areas A_{F1} and A_{F2}, respectively, at the ends of the bore 28 which areas are desirably but not necessarily equal. The annular areas A_{F1} and A_{F2} are separated by a land 36 on the plunger 31 located intermediate the radial passages 34 and 35. However, since the pressure in the bore 28 on opposite sides of the plunger land 36 is substantially balanced when the valve spool is in the normal open position of FIG. 1 and the leakage area is small even when the pressures are unbalanced, the plunger land 36 may have a free fit in the bore 28.

The pistons **32** and **33**, on the other hand, should have a close sliding or lap fit in the counterbores **29** and **30** to isolate the fluid pressure in the bore **28** from the fluid pressure in the enlarged ends of the bore **11** which are supplied from an electrohydraulic valve **37** through suitable flow passages **38** and **39**. The extent of lap fit between the pistons **32** and **33** and counterbores **29** and **30** may be kept to a minimum by relieving the counterbores at **40** and **41** adjacent the ends of the bore **28**.

Fluid pressure supplied to the ends of the bore **11** acts on the end areas A_{s1} and A_{s2} of the valve spool **19** surrounding the pistons **32** and **33**. These areas may be equal or unequal but are preferably approximately twice as great as the feedback areas $A_{F1}$and A_{F2}. However, the feedback areas A_{F1} and A_{F2} plus their associated first stage areas A_{s1} and A_{s2} need not be equal to the total cross-sectional area of the valve spool as in conventional designs, whereby even for large spool diameters, the first stage areas A_{s1} and A_{s2} may be quite small to minimize the first stage flow requirements.

Assuming that the areas A_{F1} and A_{F2} are equal and the areas A_{s1} and A_{s2} are also equal, at zero input signal to the electrohydraulic valve **37**, the forces acting on opposite ends of the valve spool are equal and the valve spool is maintained in the open position shown in FIG. **1** by the compression springs **25** and **26**, permitting unrestricted flow of pressurized fluid between the supply passage **4** and cylinder passage **5**. When electrical inputs are applied to the electrohydraulic valve **37** causing a greater fluid pressure in the end **43** than in the end **42**, the valve spool **19** moves to the right to the FIG. **2** position closing communication between the supply passage **4** and cylinder passage **5** and opening communication between the cylinder passage **5** and return passage **6**, whereby the pressure in the cylinder passage **5** falls off. The supply passage **4** pressure and cylinder passage **5** pressure are still fed back to the respective feedback areas A_{F1} and A_{F2} through the radial passages **34** and **35**. Any such reversal of fluid pressure load is supported through the center of the spool by the three-piece piston and plunger stack. The piston-plunger stack also eliminates side loads and friction, and of course no concentricity between the various piston and plunger parts is required because of the loose connections therebetween.

Metering of the flow between the cylinder port **5** and supply and return passages **4** and **6** during movement of the valve spool **7** in opposite directions is accomplished by opposite sides of the cylinder land **27** of the FIGS. **1** and **2** embodiment. Alternatively, the cylinder land may be eliminated altogether and such metering accomplished by the pressure and return lands **45** and **46** on the valve spool **47** or the servovalve **48** at opposite ends of the annular groove **49** as shown in FIG. **3**. This permits direct porting of the supply passage **4'** and return passage **6'** to the appropriate feedback areas A_{F1}' and A_{F2}' through the radial passages **34'** and **35'** and longitudinal bore **28'** in the valve spool **47**. One advantage of such a construction is that the cylinder or supply pressure acting on the feedback area A_{F1}' urges the plunger toward return, tending also to communicate the radial passage **34'** with the return passage **6'** via annular groove **49** and thus tending to equalize the feedback pressures at the return level. Otherwise, the details of construction and operation of the servovalve **48** are substantially the same as the servovalve **1** previously described, and the same reference numerals followed by a prime symbol are used to designate like parts.

In FIG. **4** there is shown a modified form of three-way servovalve **50** in which the valve spool **51** is in an intermediate position blocking fluid communication between the cylinder passage **52** and both the pressure supply passage **53** and return passage **54**. In place of the three-piece piston and plunger stack of FIGS. **1—3**, there is provided two pistons **55** and **56**. The piston extends from the end wall **57** of the bore **58** in the sleeve **59** and has a close sliding fit in a bore **60** in the valve spool **51** from which it extends into a counterbore **61**. The piston **56** has a close sliding fit in the counterbore **61** and extends from the inner end of the plunger **55** to the other end wall **62** of the bore **58**. Feedback pressure from the cylinder passage **52** is supplied to the interior of the valve spool **51** through an annular groove **63** and radial opening **64** in the valve spool, where it acts on the feedback area A_F at the inner end of the counterbore **61**. Fluid pressure is supplied to the ends **65** and **66** of the bore **58** from an electrohydraulic valve through passages **67** and **68**, and springs **69** and **70** engage the ends of the valve spool **51**, as before. When the pressure force acting on the left end of the valve spool **51** is greater than the total feedback and right end pressure forces, the valve spool will move to the right thus to establish open communication between the pressure feed passage **53** and cylinder passage **52**, whereas when the total feedback and right end pressure forces are greater than that action on the left end, the valve spool will move toward the left to establish communication between the cylinder passage **52** and return passage **54**.

A typical four-way pressure control valve **71** in accordance with this invention is shown in FIG. **5**, which is generally similar to the three-way valve **1** of FIGS. **1** and **2**, except that two cylinder passages **72** and **73** and two return passages **74** and **75** are provided instead of one. The cylinder passages **72** and **73** may be alternately connected to the pressure supply passage **76** and one or the other of the return passages **74** and **75** upon movement of the valve spool **19'** in one direction or the other from the intermediate neutral position of FIG. **5**. When the valve spool **19'** is moved to an operating position, the pressures in the cylinder passages **72** and **73** are fed back against each other through the radial passages **35'** and **34'** in the valve spool which communicates with the bore **28'**. Otherwise, the details of construction and operation of the servovalve **71** of FIG. **5** are substantially identical to the servovalve **1** of FIG. **1** and **2**, and accordingly no further discussion is thought to be necessary. The same reference numerals followed by a prime symbol are used to designate like parts.

From the foregoing, it can now be seen that the various forms of servovalves disclosed herein are of a relatively simple and inexpensive construction which require no concentricities and have very few lap fits. In each instance, the servovalves are provided with a central support extending the full length of the bore in which the spools are disposed which acts as a central load path for supporting the valve spools against lateral pressure loads as well as reversal pressure loads. The central support is desirably of a multipiece construction so that the different diameters required for establishing feedback and first stage pressure areas need not be concentric as aforesaid, but it will be apparent that a single-piece construction may be provided if desired, especially if pressure feedback is eliminated.

I claim:

1. A pressure control valve comprising a housing containing a bore intersected by pressure feed, cylinder, and return passages, a valve spool axially movable within said bore for selectively establishing fluid communication between said cylinder passage and said pressure feed and return passages, a longitudinal opening through said valve spool, and axially fixed support means extending through said longitudinal opening from one end of said bore to the other for providing a central load reaction path for said valve spool.

2. The pressure control valve of claim **1** wherein there are two of said return passages and two of said cylinder passages intersecting said bore, said valve spool being movable to establish fluid communication between said pressure feed passage and one of said cylinder passages and between the other cylinder passage and one of said return passages, and vice versa.

3. The pressure control valve of claim **1** further comprising spring means engaging the end of said valve spool for urging said valve spool to a position establishing fluid communication between said cylinder passage and pressure feed passage or return passage.

4. The pressure control valve of claim **1** wherein said longitudinal opening in said valve spool has a counterbore in one end, and said support means comprises two separate pistons, one of said pistons having close sliding engagement with the wall of said longitudinal opening and extending from the end of said bore adjacent said longitudinal opening into said counterbore, and the other of said pistons having close sliding engagement with the wall of said counterbore and extending from the inner end of said one piston to the other end of said bore, said pistons providing a substantially continuous, axially fixed support for said axially movable valve spool over the full length of said bore, the inner end of said counterbore providing a feedback area in communication with said cylinder passage.

5. The pressure control valve of claim 4 further comprising valve means for providing variations in the fluid pressure at the ends of said bore for varying the fluid pressure force action on the end areas of said valve spool exposed to fluid pressure in the ends of said bore.

6. A pressure control valve comprising a housing containing a bore intersected by pressure feed, cylinder, and return passages, a valve spool axially movable within said bore for selectively establishing fluid communication between said cylinder passage and said pressure feed and return passages, a longitudinal opening through said valve spool, and support means extending through said longitudinal opening from one end of said bore to the other for providing a central load reaction path for said valve spool, said longitudinal opening in said valve spool having a counterbore in both ends, and said support means comprising a plunger contained in said longitudinal opening with the ends of said plunger extending into said counterbores, a first piston separate from said plunger having a close sliding fit in one of said counterbores and extending from one end of said bore into engagement with said plunger, and a second piston separate from said plunger having a close sliding fit in the other of said counterbores and extending from the other end of said bore into engagement with said plunger, the inner ends of said counterbores providing feedback areas, and passage means in said valve spool providing fluid communication between said cylinder passage and one of said feedback areas.

7. The pressure control valve of claim 6 wherein said passage means in said valve spool provide communication between said cylinder passage and both of said feedback areas when said valve spool is in a position communicating said cylinder passage with said pressure feed passage.

8. The pressure control valve of claim 7 further comprising a land on said plunger separating said pressure feed areas, said land having a free fit in said longitudinal opening.

9. The pressure control valve of claim 6 wherein said passage means in said valve spool provide communication between said cylinder passage and one of said feedback areas and between said pressure feed passage and the other of said feedback areas.

10. The pressure control valve of claim 6 further comprising means for varying the fluid pressure in the ends of said bore for varying the fluid pressure force acting on the end areas of said valve spool exposed to fluid pressure in the ends of said bore.

11. A pressure control valve comprising a housing containing a bore intersected by pressure feed, cylinder and return passages, a valve spool axially movable within said bore for selectively establishing fluid communication between said cylinder passage and said pressure feed and return passages, a longitudinal opening through said valve spool, and support means extending through said longitudinal opening from one end of said bore to the other for providing a central load reaction path for said valve spool, there being two of said return passages and two of said cylinder passages intersecting said bore, said valve spool being movable to establish fluid communication between said pressure feed passage and one of said cylinder passages and between the other cylinder passage and one of said return passages, and vice versa, said longitudinal opening in said valve spool having a counterbore in both ends, and said support means comprising a plunger contained in said longitudinal opening with the ends of said plunger extending into said counterbore, a first piston having a close sliding fit in one of said counterbores and extending from one end of said bore into engagement with said plunger, and a second piston having a close sliding fit in the other of said counterbores and extending from the other end of said bore into engagement with said plunger, the inner ends of said counterbores providing feedback areas, and passage means in said valve spool providing communication between the cylinder passages and said feedback areas.

12. A pressure control valve comprising a housing containing a bore intersected by pressure feed, cylinder, and return passages, a valve spool axially movable within said bore for selectively establishing fluid communication between said cylinder passage and said pressure feed and return passages, a longitudinal opening through said valve spool, and support means extending through said longitudinal opening from one end of said bore to the other for providing a central load reaction path for said valve spool, said longitudinal opening in said valve spool having a counterbore in both ends, and said support means comprising a plunger contained in said longitudinal opening with the ends of said plunger extending into said counterbores, a first piston having a close sliding fit in one of said counterbores and extending the entire distance between one end of said bore and the adjacent end of said plunger, and a second piston having a close sliding fit in the other of said counterbores and extending the entire distance between the other end of said bore and the other adjacent end of said plunger, said piston and plungers providing a substantially continuous, axially fixed support for said axially movable valve spool over the full length of said bore, the inner ends of said counterbores providing feedback areas, and passage means in said valve spool providing fluid communication between said cylinder passage and at least one of said feedback areas.