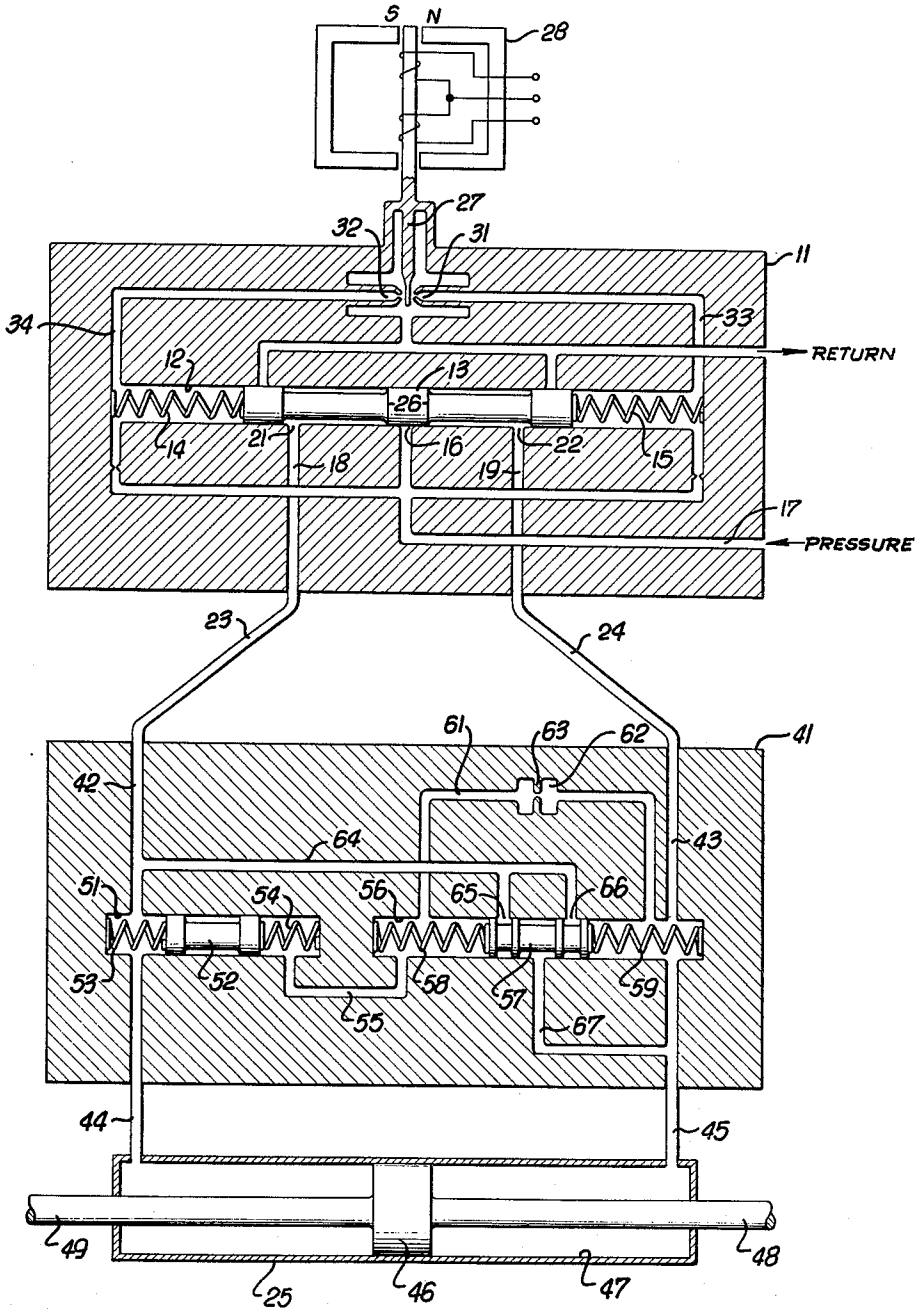
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DYNAMICALLY VARIABLE ORIFICE FOR LOAD DAMPING

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DYNAMICALLY VARIABLE ORIFICE FOR LOAD DAMPING

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This invention relates generally to hydraulic servo systems and more particularly to a hydraulic valve which can be utilized with such systems to dynamically damp oscillations. More specifically a dynamically variable orifice is inserted in the system between the hydraulic valve and the load to bypass power and hydraulic fluid which may cause the load to go into oscillation at its resonant frequency.

The use of servomechanisms for controlling hydraulic actuators which are in turn further used for controlling various apparatus is well known in the art. In some instances such hydraulic actuators are utilized in controlling loads which are extremely heavy and have a large inertia. Under certain conditions such loads have a resonant frequency which is within or very near the band pass of the hydraulic actuating system. Means must therefore be taken to damp oscillations that may occur as the result of application of hydraulic power from the control valve of the system to the load, particularly in those areas wherein the frequency of application of the power is near or approaches the resonant frequency of the load.

Various control valves have been used in the prior art to accomplish this purpose. For example, such valves as those illustrated in Patent No. 3,042,005, issued July 3, 1962, to Samuel A. Gray and entitled Dynamic Pressure Feedback Servo Valve, and Patent No. 3,064,627, issued November 20, 1962, to John W. Blanton and entitled Derivative Load Pressure Feedback. Although valves of the type disclosed in these two patents have proven exceedingly successful for the purposes intended, it has been found that the long-term reliability of such damping systems has not in all instances proven successful, particularly where the fluid within the hydraulic system becomes contaminated. It has also been found that since these systems are incorporated with the main servo control valve which applies power to the load, a greater or added expense in encountered in manufacturing, calibrating, and testing the equpiment prior to its utilization.

Accordingly, it is an object of the present invention to provide a valve which can be utilized to dynamically damp a load which valve is rugged and inexpensive to manufacture.

It is another object of the present invention to provide a valve for dynamically damping a load which may be utilized separate and apart from the remainder of the servo control system, including the remainder of the hydraulic valve and controlling mechanisms.

It is another object of the present invention to provide a hydraulic control valve which can be utilized to dynamically damp a load which is relatively simple to calibrate and to maintain.

It is another object of the present invention to provide a hydraulic valve system for dynamically damping a load which system is highly reliable as compared to prior art systems, even under those operating conditions where high levels of contamination are encountered.

Additional objects and advantages of the present invention will become apparent from a consideration of the following description taken in conjunction with the accompanying drawing, which is presented by way of example only and is not intended as a limitation upon the scope

of the present invention as defined in the appended claims and in which:

The single figure illustrates schematically a hydraulic control valve system for dynamically damping a load in accordance with the present invention.

A hydraulic valve dynamic damping system in accordance with the present invention includes means for applying hydraulic pressure from a control valve to a load and means communicating with said first named means for sensing changes in the power applied to said load. Communicating with said sensing means is a differentiating means which preferably is in the form of a restricted bypass orifice. Also communicating with said means for applying power to a load is a bypass orifice which includes means for maintaining said orifice in a closed and sealed condition during static or quiescent conditions of said system. Said means for maintaining said orifice closed communicates with said differentiating means whereby pressures differentiated by said bypass orifice are communicated to said means for maintaining said orifice closed. Said means for maintaining said orifice closed is responsive to differential pressures sensed by said bypass orifice thereby to open said orifice by an amount proportional to sudden changes in the power applied to said load, thereby to bypass a portion of said power and fluid flow away from said load.

Referring now to the drawing there is illustrated a body **11** having a cylinder **12** provided therein with a spool valve **13** positioned within the cylinder **12**. A pair of springs **14** and **15** are affixed to the spool valve **13** to normally position it in a substantially central position within the cylinder **12** as is well known in the prior art. The cylinder **12** communicates by way of a port **16** with a passageway **17** which in turn communicates with a source of fluid under pressure (not shown) as is well known in the art. A pair of outlet passageways **18** and **19** also communicate through ports **21** and **22** respectivley with cylinder **12** for applying power through conduits **23** and **24** respectively to a load **25** as will be more fully explained below.

The positioning of the spool valve **13** controls the application of power to the load through the conduits **23** and **24**. In the centered position as illustrated in the drawing, the spool valve **13** has a central enlarged portion **26** which maintains the port **16** in a closed condition, thereby preventing the application of power to the load **25**. The spool valve **13** is responsive to control signals applied thereto to move in either direction along the cylinder **12** thereby permitting the fluid under pressure to flow through either the conduit **23** or **24**. The control signals to which the spool valve **13** is responsive are obtained by actuating a flapper valve **27** by any means desired, such as a torque motor **28**, thereby to restrict the fluid flow from nozzle **31** or **32**, thus increasing the pressure appearing in one or the other of passageways **33** or **34** which communicate with the passageway **17** to which the source of fluid under pressure is connected, and which also communicate with the end portions of the spool valve **13**.

Thus if the pressure increases in passageway **34** the spool valve **13** is moved toward the right as viewed in FIG. 1, thus causing the fluid under pressure to flow through passageway **17**, port **16**, out of the cylinder **12**, through port **21** and into passageway **18** and through conduit **23**. If pressure increases in the passageway **33** the operation of the system applying the power to the load is exactly the reverse, thus causing fluid to flow through the conduit **24** to the load **25**.

Since the operation and structure of a valve control system as above described is well known in the prior art and is described in each of the two patents above referred to, further detailed description of the structure and the

operation thereof will not be given. It should furthermore be expressly understood that any hydraulic control system which is effective to apply power to a desired load may be utilized in conjunction with the dynamic damping system in accordance with the present invention. The above description therefore is given by way of example as one control valve which may be utilized.

The damping control system in accordance with the present invention is also illustrated in FIG. 1 and includes a body 41 having passageways 42 and 43 which communicate respectively with conduits 44 and 45 for applying hydraulic power to a load actuating device 25. The load actuating device 25 includes a piston 46 housed within a cylinder 47 and having actuating rods 48 and 49 interconnected with the piston 46. The piston 46 moves longitudinally within the cylinder 47 in response to hydraulic fluid pressure applied to one surface or the other thereof thus actuating the load mechanism attached to either of the rods 48, 49, as is well known in the prior art.

A bore 51 is provided within the body 41 and in communication with the passageway 42. Positioned within the bore 51 is a spool valve 52 which is positioned under static or quiescent conditions by springs 53 and 54 which are connected between the ends of the spool valves 52 and the respective ends of the bore 51. A passageway 55 communicates between the bore 51 and an additional bore 56. Housed within the additional bore 56 is a second spool valve 57 which is also maintained in its static or quiescent position by springs 58 and 59 which are interconnected between the ends of the spool valve and the respective ends of the bore 56. The bore 56 also communicates with the passageway 43 communicating between the outlet 24 of the control valve and the load actuating device 25.

Shunted around the spool valve 57 and communicating with the bore 56 at longitudinally spaced portions thereof is a passageway 61. It should be noted that the passageway 61 communicates with the bore 56 on opposite sides of the spool valve 57. Inserted within the passageway 61 is an orifice 62 having a restricted passageway 63 therein. The function of the restricted passageway 63 will be described more fully hereinafter. Also communicating with the bore 56 is a passageway 64 extending from the passageway 42 carrying the hydraulic fluid and power from the control valve to the load actuating device. The passageway 64 terminates at bore 56 in a pair of ports 65 and 66. Also communicating with the bore 56 is a passageway 67 which in turn communicates with the passageway 42, also interconnected between the control valve and the load actuating device.

In a quiescent or steady state condition, that is when the power being applied to the piston 46 is not changing, the spool valve 57 is positioned by the springs 58 and 59 in such a manner that the ports 65 and 66 are maintained in a closed condition. This positioning of the spool valve 57 occurs because the bore 56 on each side thereof is exposed to the fluid pressure present in the passageway 43 through the bypass passageway 61. Since the steady state pressure on each side of the spool valve 57 is equal, the springs 58 and 59 exert the only force upon the ends of the spool valve 57. These springs are selected to exert substantially equal forces thereby to center spool valve 57 when no pressure difference is present across it.

Under such steady state conditions the piston 46 and the connecting rods 48 and 49 represent an exceedingly "stiff" hydraulic actuating system thereby retarding or resisting attempted movements of the load to which the actuating system is connected.

The spool valve 52 is positioned by springs 53 and 54, which are selected to exert equal force, and in addition thereto by any pressure differential that may exist between the passageways 42 and 43 under steady state conditions. The pressure difference between passageways 42 and 43 is applied across spool valve 52 in the following manner. The left end (as viewed in the drawing) of the spool valve 52 is directly exposed to the fluid pressure in passageway 42 as illustrated. The right end thereof is exposed to the fluid pressure in passageway 43 through bypass passageway 61, bore 56 (left side), and passageway 55. Therefore, spool valve 52 assumes a position dependent upon the pressure difference between passageways 42 and 43 and under steady state conditions is stationary. Spool valve 57 is not affected by such a pressure differential since it is exposed only to the pressure in passageway 43 which interconnection of passageway 61 is applied to each side thereof as above described.

It will now be assumed that a command signal is applied to the leads controlling the torque motor 28 in such a manner that pressure is built up in passageway 34 and decreases in passageway 33 thus causing spool valve 26 to move to the right as illustrated in FIG. 1. A sudden pressure increase is applied from the passageway 17 through the port 16 out of the cylinder 12 through the port 21, the passageway 18, the conduit 23 and into the passageway 42 and ultimately to the load actuating device 25. The pressure in passageway 43 suddenly decreases. This sudden change in pressure is sensed by the spool valve 52 which now suddenly moves toward the right as viewed in the drawing. This sudden move toward the right causes the hydraulic fluid contained within the bore 51 to compress and exert a pressure which is transmitted through passageway 55 to the left side of the bore 56. The increase in pressure tends to equalize on each side of the spool valve 57 through the bypass passageway 61. However, as a result of the restricted orifice 63 positioned within the orifice 62 located within the passageway 61, a sudden buildup of pressure is experienced within the bore 56 on the left side of the spool valve 57 as viewed in the drawing. In essence, the restricted orifice 63 within the passageway 61 differentiates the sudden application of pressure which occurred through movement of the spool valve 52.

As a result thereof a pressure differential appears across the spool valve 57, the pressure being increased on the left side thereof within the bore 56. This increase in pressure causes the spool valve 57 to move slightly to the right. This slight movement toward the right opens the port 66 which communicates with the bore 56. The opening of the port 66 by the spool valve 57 permits hydraulic fluid to flow from pasageway 42 through passageway 64, through the port 66, into the bore 56, and out of the port 67 into the pasageway 43. This movement of the spool valve 57 bypasses both power and fluid flow from the load actuating mechanism 25. Thus the total of the sudden increase of power is not experienced by the piston 46.

It should, however, be readily apparent that the spool valve 57 is quickly centered after the change in pressure difference between passageways 42 and 43 is detected by the restricted orifice 63 and once again is in a steady state condition. Under the steady state condition, the total power is applied across the load actuating device 25.

It can thus be seen that the spool valve 57 assumes a momentary position which is proportional to the rate of change of pressure between passageways 42 and 43, that is the first differential thereof, and when the rate of change drops to zero, again is centered, thus causing the bypass of power and fluid to cease. Therefore, the load affixed to the load actuating device is not subjected to sudden and intense changes of power application which may cause it to oscillate at its resonant frequency. Obviously the foregoing description is simplified for purposes of clarity of description and ease of understanding. It should be readily apparent that several changes in power applied may occur during any given time increment; however, the above operation will follow with respect to any rate of change whether it be increasing in passageway 42 or 43.

For example, it is now assumed that the command signal applied to the windings of the torque motor is such that the pressure builds up in the passageway 33 of the

control valve, thus causing the spool valve **26** to move to the left. A sudden increase in pressure is then experienced in the passageway **43** and a sudden decrease in pressure in the passageway **42**. Under these circumstances the spool valve **52** suddenly moves toward the left, thus in turn causing a flow of fluid from the right toward the left through the passageway **61** and through the restricted orifice **63**. The differential pressure appears across the spool valve **57** thus causing it to move toward the left as viewed in the drawing. Under these conditions the port **65** is slightly opened, thus causing the flow of fluid through the pasasgeway **67**, into the bore **56**, through the port **65**, the passageway **64** and into the passageway **42**, thus again bypassing a part of the power and the flow of hydraulic fluid away from the load actuating mechanism **25**.

It should, from the foregoing, become apparent that the damping system of the present invention is, in essence, a dynamically variable orifice for bypassing sudden power and fluid flow changes away from the load, the opening or cross section of the orifice being directly and dynamically variable proportional to the rate of change of power application to the load actuating device.

There has thus been disclosed a hydraulic valve system for dynamically damping a load through the utilization of a dynamically variable orifice which system is utilizable with any hydraulic valve system for applying power to a load and which is separate and distinct therefrom. The system in accordance with the present invention is therefore much less expensive to manufacture than are prior art systems, is rugged, and is easily maintained.

What is claimed is:

1. A dynamically variable orifice for damping fluid pressure changes applied from a valve to a load device, said orifice comprising: first and second passageways communicating between a valve and a load device for applying fluid pressure from said valve to said load device; first means movable in response to any difference in fluid pressure between said first and second passageways; second means movable only in response to changes in fluid pressure between said first and second passageways; a bypass passageway communicating with said first and second passageways for diverting fluid pressure from said load device, said bypass passageway being closed by said second means during steady state application of pressure to said load device; and differentiating means communicating with said first and second means for moving said second means only in response to changes in fluid pressure between said first and second passageways thereby to open said bypass passageway by an amount proportional to the rate of change of said fluid pressure and divert a portion of said fluid pressure from said load device.

2. A dynamically variable orifice as defined in claim 1 in which said first means is a movable valve communicating directly with said first passageway and through said differentiating means with said second passageway.

3. A dynamically variable orifice as defined in claim 2 in which said second means is a movable valve communicating directly with said second passageway.

4. A dynamically variable orifice as defined in claim 3 in which said second means is a spool valve and said differentiating means is an equalizing passageway communicating with each end of said spool valve and having a restricted orifice therein.

5. A dynamically variable orifice for damping fluid pressure changes applied from a valve to a load device, said orifice comprising: a housing; first and second passageways through said housing communicating between a valve and a load device for applying fluid pressure from said valve to said load device; said housing defining a first bore therein communicating with said first passageway; a first spool valve movably disposed within said bore; said housing defining a second bore therein communicating with second passageway; a second spool valve movably disposed within said second bore; a communicating passageway between said first and second bores; a bypass passageway communicating with said first and second passageways for diverting fluid pressure from said load device, said bypass passageway being closed by said second spool valve during steady state application of pressure to said load device; and differentiating means communicating with said second passageway and said first bore for moving said second spool valve only in response to changes in fluid pressure between said first and second passageways thereby to open said bypass passageway by an amount proportional to the rate of change of said fluid pressure and divert a portion of said fluid pressure from said load device.

6. A dynamically variable orifice as defined in claim 5 in which said differentiating means is a passageway communicating with each end of said second bore on each side of said second spool valve and having a restricted orifice therein.

7. A dynamically variable orifice as defined in claim 6 in which said second spool valve is spring loaded at each end thereof thereby to be disposed substantially centrally of said second bore in the absence of changes in pressure between said first and second passageways thereby to maintain said bypass passageway closed.

8. A dynamically variable orifice as defined in claim 7 in which said first spool valve is spring loaded at each end thereof and assumes a position within said first bore during steady state fluid pressure conditions within said first and second passageways which is proportional to the difference in fluid pressure between said first and second passageways and the spring constants of said springs.

9. A dynamically variable orifice for damping fluid pressure changes applied from a valve to a load device, said orifice comprising: a housing; first and second passageways through said housing communicating between a valve and a load device for applying fluid pressure from said valve to said load device; a first spool valve movably disposed within said housing and having one end thereof communicating with said first passageway; a second spool valve movably disposed within said housing and having one end thereof communicating with said second passageway; a third passageway communicating with the opposite ends of said spool valves; a bypass passageway communicating with said first and second passageways for diverting fluid pressure from said load device, said bypass passageway being closed by said second spool valve during steady state application of pressure to said load device; and an equalizing passageway communicating with each end of said second spool valve and having a restricted orifice therein whereby pressure changes between said first and second passageways are detected by said first spool valve and differentiated by said restricted orifice to cause said second spool valve to open said bypass passageway by an amount proportional thereto for diverting fluid pressure from said load device.

No references cited.