This invention relates to improvements and innovations in hydraulic hoist systems for use in controllably raising and lowering loads.

The present invention is a continuation-in-part of my prior application Serial No. 796,527 filed March 2, 1959, now Patent No. 2,986,884 issued June 6, 1961. In that prior application I disclosed a hydraulic hoist control system characterized by its excellent degree of control obtainable through a wide range of speeds during both hoist raising and hoist lowering operations, and by the number of built-in safety features. Hoists built in accordance with my prior application have proved extremely satisfactory in use especially where extraordinary performance and safety are requirements.

By means of the present invention there has been provided a simplified and inexpensive hydraulic hoist control system which has good characteristics with respect to ease of control, smoothness of operation, and safety so as to be entirely adequate for many installations. By means of the present invention, it has been possible to dispense with the sequence valve, counter-balance valve, and shuttle valve which served important functions in the hydraulic control system of my prior application. While the functions of these three components are no longer performed by corresponding units in the hoist-control system of the present invention, nevertheless, to a substantial degree a special four-way control valve compensates for these units which have been dispensed with.

Accordingly, the object of the present invention, generally stated, is the provision of a relatively inexpensive hydraulic control system which is capable of excellent control both in the raising and lowering and which has adequate safety features for all but a few special installations.

More particularly, the object of the invention is the provision of such a hydraulic hoist and control system which is built around a special four-way, open center, control valve which is the only special or non-conventional component of the hoist system.

Certain other objects of the invention will, in part, be obvious, and will in part appear hereinafter and become apparent in connection with the following detailed description thereof.

For a more complete understanding of the nature and scope of the present invention, reference may now be had to the following detailed description thereof taken in connection with the accompanying drawings wherein:

FIG. 1 is a diagram of a complete hydraulic hoist and control system embodying the present invention;

FIG. 2 is a fragmentary view on an enlarged scale showing the condition of the four-way control valve of the system of FIG. 1 when it occupies the neutral position;

FIG. 3 is a view similar to FIG. 2 but showing the condition of the four-way control valve when the hydraulic system is in condition for hoist raising but not at full capacity;

FIG. 4 is a view similar to FIG. 3 but showing the condition of the valve in the maximum hoist raising condition;

FIG. 5 is a view similar to FIG. 2 but showing the condition of the four-way control valve in the condition when the brake is just ready to be released to permit hoist lowering;

FIG. 6 is a view similar to FIG. 5 showing the condition of the valve during lowering at intermediate speed or load; and

FIG. 7 is a view similar to FIG. 6 showing the condition of the four-way control valve for maximum rate of lowering.

Referring to FIG. 1 a positive displacement pump 5 of known type is shown which serves as a source of hydraulic pressure for operating the hoist. The pump 5 is driven by a uni-direction, constant speed motor 6 such, for example, as a squirrel cage type electric motor. The drive shafts of the pump 5 and the motor 6 are suitably connected by a coupling indicated at 7.

Through a control system with suitable hydraulic circuitry to be described below, the pump 5 delivers hydraulic fluid under pressure to a positive displacement hydraulic motor 10 of known type, such as for example as an axial piston, rotary hydraulic motor. The motor 10 is reversible in that it is driven in one direction during hoist raising and also driven in the reverse direction during hoist lowering. The outlet shaft 11 of the motor 10 is suitably coupled to the input connection of a gear train indicated diagrammatically at 12. The output connection of the gear train 12 is suitably connected to a drum 13 of a boat or crane which is rotatable via the cooler 27 through the return main or conduit 29.

The drum 13 is interconnected through the gear box with the center shaft 15 of a safety brake of known type indicated at 14, as is conventional.

The shaft 15 is mounted in the rotating element 16 of a free running clutch, such as Sprague clutch which is free to rotate in one direction only. In this case the brake shaft 15 is free to rotate in the hoist lifting direction.

The brake 14 has a brake drum 17 of relatively large diameter which may be clamped in braking relationship from opposite sides by means of a pair of brake shoes 18 mounted in the clamping arms 20--22 hinged at the bottom to a yoke 19.

The arms 20 are normally pulled together at the top continuously by means of a heavy compression spring 21 which is maintained under compression between a disk 22 and a flat portion 23 on the adjacent arm 20. The outer plate 22 is secured to the outer end of a rod 24, the inner end of which is provided with an eye whereby it is pivotally connected to the opposite arm 20. It will be seen that as the spring 21 is retained under compression it continuously pulls the two arms 20 together and thereby sets the brake shoes 18 on the drum 17.

It will be appreciated that the foregoing arrangement for keeping the brake 14 "set" or "on" may be varied and means other than a compression spring can be used although this is satisfactory and is highly reliable. A hydraulic cylinder unit 25 of known type may be utilized for overcoming the force of the spring 21 and separating the arms 20 sufficiently to release the brake 14. Such a hydraulic cylinder unit 25 is indicated as being interposed between the upper ends of the arms 20 which are connected by line 26 extending thereto. It will be appreciated that when fluid pressure of a predetermined value is admitted to the cylinder 25 it will operate to overcome the force of the spring 21 and release the brake. If the pressure is admitted slowly the brake 14 can be very gradually released and an important operating advantage can be taken of this characteristic of the brake 14 as will be pointed out below.

Since under prolonged heavy duty operation the hydraulic fluid or oil will undergo a considerable rise in temperature, it is desirable to provide a cooler of known type such as that indicated diagrammatically at 27. Preferably all of the oil is returned to the tank or reservoir via the cooler 27 through the return main or conduit 28. The discharge side of the cooler 27 is connected by means
of a conduit 30 with the inlet of an oil filter 31 disposed within the reservoir 8. By means of the cooler 27 and the filter 31 the hydraulic fluid is kept cool and clean.

The hydraulic control system or circuit for interconnecting the pump 5 or other source of fluid pressure with the motor 10 and brake 14 will now be described.

The principal component of the hydraulic control system is a four-way control valve 30 which is specifically adapted for this particular invention. A first conduit comprised of sections 31 and 32 connect the center or Intermediate pressure inlet port 33 of the valve 30 with the pressure discharge connection of the pump 5. In one half of the valve 30 (the lower half as viewed in FIG. 1) there are a pair of valve ports, the one adjacent to the port 33 being indicated at 34 and the one that is non-adjacent thereto being indicated at 35. Similarly, in the other side of the valve 30 (the upper half as viewed in FIG. 1) there are a second pair of valve ports, the one adjacent to the port 33 being indicated at 36 and the one non-adjacent thereto being indicated at 37. The purpose and nature of each of the ports 33-34-35-36-37 will be described below in connection with FIGS. 1-7. All of the ports are of equal width and they are separated from one another by lands of equal width.

The conduit 30 is connected to one of the two fluid connections of motor 10 by means of a conduit 40. The particular connection to which conduit 40 is connected is the one through which fluid exits during hoist raising and through which it enters during hoist lowering. Valve port 30 is connected to the second fluid connection of the motor 10 through a conduit 41, the connection being that through which fluid enters during hoist raising and through which it exits during hoist lowering. Port 35 and 37 are interconnected by a passageway 42 in the valve body which communicates with the tank return line indicated at 28.

In addition to the conduits mentioned which communicate with the valve ports 33-37 there is conduit 26 which communicates between conduit 40 and the cylinder 25 which serves to release the brake 14. Two relief valves are provided for the hydraulic circuit. Relief valve 45 is set in the brake cylinder 25 connecting between pressure conduit 31 and the tank return line 28. Relief valve 47 is set in a conduit 48 communicating between conduits 40 and 41. Leakage from the hydraulic motor 10 is conveyed to the tank return line by means of a conduit 50.

Reference is now made to FIGS. 2-7 for a description of the construction and operation of the four-way control valve 30. This valve is classified as being of the spool type in that it has a movable valve member 51 with the inner operable portion being generally in the form of a spool. The valve member 51 is longitudinally reciprocable within the valve body 52 and is maintained in fluid-tight relationship by means of O-rings 53 and 54 seated in the valve body adjacent the end openings through which the spool member 51 is slidable. One end of the valve member 51 projects a substantial distance from the valve body 52 end and this end may be used for operating the valve by any suitable means. For example, it may be operated manually either directly, or from a distance by suitable linkages. Alternatively, the valve member may be actuated electrically, hydraulically or pneumatically, in known manner.

The valve member 51 has an intermediate neutral position in which the hoist is at rest. At one side of neutral the valve member 51 can occupy a range of hoist-raising positions while at the opposite side of neutral it can occupy a range of hoist-lowering positions. The construction of the valve 30, particularly the construction of the valve or spool member 51 thereof, and the way in which the valve body 52 will now be described. Referring to FIG. 2 it will be seen that the spool member 51 has a relatively short neck portion providing a groove 55 and a relatively long neck portion providing a groove 56 which are separated by a flange section 57 provided with machined tapers 58 and 60 adjacent groove 56. At the outer end of the groove 56 on the adjacent full diameter portion there is a single taper 61. On the opposite end of the spool portion adjacent the shorter groove 55 the spool is provided with dual tapers 62 and 63 and a narrow cylindrical band 64. It will be understood that other tapers may be selected as long as the resulting operation of the valve is satisfactory. The tapers form annular orifices of variable width in cooperation with the circumferential corners of adjacent lands as will be described hereinafter.

It will be seen that the groove 56 has a length which exceeds the width of port 34 plus the lands on opposite sides thereof. Groove 55 is shorter having a length equal to the width of port 36 plus only a portion of the width of one of the adjacent lands.

In FIG. 2 the spool member 51 is in its intermediate and neutral position which is shown in FIG. 1. It will be seen that the pressure inlet port 33 communicates through an annular orifice indicated by the points or corners a-b into the longer groove 56 which is in full communication with the port 34 and also with the port 35 through the annular orifice between points e-f. The escape of fluid to tank through the orifice c-d may be prevented by building up in the conduit 40 connected with port 34. It will be seen that port 35 is cut off from communication with inlet port 33. The pressure in the inlet 33 under these conditions may, for example, be approximately 150 pounds per square inch (p.s.i.). Since the brake cylinder 25 is set to open at a substantially higher pressure (e.g. 300 p.s.i.) it will be seen that the hoist will remain at rest as the brake 14 is set, port 36 is completely shut off, and fluid can freely escape through orifice c-d to tank through return line 28.

Now assuming that it is desired to operate the hoist system so as to raise a load, the spool member is shifted to the left (downwardly as viewed in FIG. 1) from the position shown in FIG. 2 to the position in FIG. 3. As this movement occurs, it will be seen that an orifice is opened between the points e and f allowing fluid to flow from the pressure inlet port 33 into the groove 56 and hence into the port 36 which communicates with line 41. In the meantime the orifice a-b becomes restricted due to the taper 58. As this shifting movement of the spool member and orifice variation continues it will be seen that the pressure will build up in the line 41 and decrease in the port 34. When the pressure in line 41 becomes high enough it will operate the motor 10 in a hoist raising position. That is, the fluid will enter the motor 10 through the conduit 41 and will exit through the conduit 40 so as to return to the valve 30 wherein it will pass from the port 34 through orifice c-d into the port 37 and thus discharge to tank by way of return line 28. It should be noted that during this hoist raising operation the pressure in the port 36 is not controlled by the size orifice e-f but by the size of the orifice a-b. In other words, as the latter orifice becomes more restricted a greater portion of the fluid passes through orifice e-f.

In FIG. 4 the condition is shown in which the spool 51 has been moved all the way to the hoist raising condition. In this condition it will be seen that point a has moved to a place where there is no longer an orifice a-b leading from port 33 into the spool groove 56. Accordingly, all of the fluid introduced into the valve from the position of FIG. 2 (i.e. lowered as viewed in FIG. 1) and passes through the conditions shown in FIGS. 5-7. In FIG. 5 port 36 is completely shut off while orifice a-b is open into the long or wide groove 56 with orifice c-d being appreciably
restricted. Because of the restriction of orifice \( c-d \) pressure builds up in port 34 to a value (e.g. 300 p.s.i.) which is sufficient to actuate the cylinder 25 and cause the brake 14 to release. Port 36 is on the verge of opening or communicating with the tank or discharge port 37. However, as long as this communication is prevented, and the port 36 and 37 is not yet established, fluid cannot discharge from the motor 10 and the rotation of this motor is therefore limited to that which is permitted by leakage. This of course is very slow.

The taper 61 is so designed that as the spool 51 moves further in the load lowering direction to the relaxed position shown in FIG. 6 a constant pressure of say 300 p.s.i. is maintained in the port 34. However, a restricted orifice commences to open between points \( g \) and \( h \) which permits restricted flow from port 36 into the discharge port 37. Hence, the flow from port 33 of pressure fluid is no longer completely discharged from orifice \( c-d \) to tank since now some of it may pass through line 48, through the hydraulic motor 10 and out through line 41 back to the valve 36 through which it is discharged to port 37 through the orifice \( g-h \).

The taper 61 is such that during the balance of hoist lowering the portion of the fluid allowed to flow out through orifice \( c-d \) is such to always maintain a substantially constant pressure of 300 p.s.i., or whatever value is required to release the brake. However, as the spool member 51 is moved further from neutral into the range of hoist lowering, the orifice \( g-h \) is increased in width to the point where a greater portion of the hydraulic fluid discharges through port 34 so as to pass through the motor 10 and less discharges to tank through orifice \( c-d \).

During the various conditions of hoist lowering the function of the orifice \( c-d \) is to provide sufficient pressure, e.g. 300 p.s.i., in the line 40 so as to keep the brake and hold back the load in the motor 10. On the other hand, the function of the orifice \( g-h \) is to restrict the flow from the motor 10 and hold back the load and thus give the load proper control.

When the spool member 51 is shifted fully to its extreme right hand position, as shown in FIG. 7, wherein maximum hoist lowering is permitted the orifice \( c-d \) is finally closed so that all of the hydraulic fluid passes out through the port 34, flows through the hydraulic motor 10 to permit lowering, and flows back through the valve 39 and by way of the orifice \( g-h \) to tank. Even so, the orifice \( g-h \) remains restricted such that the flow through it is not excessive. In effect maximum flow-through is restricted so that it is equal to the over running torque of the hydraulic motor 10 under maximum load, plus the pressure required to release the brake. Thus, a given load drives the hydraulic motor 10 as a pump and creates a pressure on the discharge side of the hydraulic motor.

To the pressure of the load must be added the pressure on the inlet side of the hydraulic motor 10 necessary to hold the brake open.

The orifice \( g-h \) is designed to limit the maximum flow rate to give the desired maximum speed of the load and yet insure that the rate at which the hydraulic motor 10 is turning does not require more fluid than can be supplied by the pump 5. The latter condition could occur if an extra heavy load were being lowered. This would cause the motor to cavitate due to its higher speed under these circumstances. However, should this occur the pressure in port 34 will promptly drop to atmospheric or less with the result that the brake 14 will automatically set since there is no pressure maintained in the lines 40 and 26 to keep it open. Hence the load will be brought under control by the brake setting.

The function of the relief valve 45 is to prevent the hoist from lifting an extra-heavy load. That is, from raising a load which exceeds that for which the hydraulic system or hydraulic hoist is designed. If an excessive load should be applied to the hoist, the spool 51 will be put in the full hoist raising position as shown in FIG. 4.

in an attempt to raise it. However, if the load is too heavy, excessive pressure starts to build up in the relief valve 45 will open to relieve it. Otherwise, the pump 5 would continue to operate and the system would continue to build up pressure until some part failed. By reason of the pressure relief valve 45 when the pressure reaches the pre-set maximum, additional pressure is automatically discharged through the valve to the tank return line 28 and the system is thus protected.

The function of the relief valve 47 is to protect the system during hoist lowering. Thus, if a heavy load is being lowered at maximum speed and the spool member 51 is moved to the neutral position shutting off port 36, flow of fluid from the motor 10 through the line 41 would be automatically stopped. Damage might well occur under these circumstances except for the fact that the pressure relief valve 47 will open and permit the sudden surge of pressure to be dissipated or short-circuited through the line 48 back through line 40 into the port 34 which is in communication with the discharge port 35.

It will be seen that control valve 30 provides for excellent control over a wide range. During hoist-raising the valve 30 can be set so it just barely lifts the load or it may be set for maximum lifting speed control or any intermediate speed. Similarly, during hoist lowering, the valve 30 can be so operated that it just barely moves through controlled "slipping" of the brake 14, or it can be driven down at maximum speed, or at any intermediate speed. With a given load the operation is practically constant at any particular setting.

Since certain changes and modifications can be made in the embodiments of the invention as described and shown in the accompanying drawings without departing from the spirit and scope of the invention, it is intended that all matter described above or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a hydraulic hoist system adapted to drive a cable drum or the like and including, (1) a positive displacement pump having a fluid discharge connection and a fluid return inlet connection, (2) a reversible rotary hydraulic motor having two fluid connections, and (3) a brake operably coupled with said motor, said brake being free-running in the lift direction of said motor and having pressure means normally applying said brake so said motor is not free to turn in the lowering direction, and having a hydraulic cylinder unit operable whereby said pressure may be used to overcome said pressure means and release said brake, the improvement which comprises: an open-center four-way control valve comprising a valve body having a pressure inlet port, a pair of first and second ports on one side of said inlet port the first being adjacent thereto and the second being non-adjacent, a second pair of third and fourth ports on the opposite side of said inlet port, the third port being adjacent thereto the fourth port being non-adjacent, and a movable valve member operable in said valve body having an intermediate neutral position and a range of hoist-raising positions on one side of neutral and a range of hoist-lowering positions on the opposite side of neutral; first conduit means interconnecting said pressure inlet port with the discharge connection of said positive displacement pump; second conduit means interconnecting said first port with the connection of said hydraulic motor through which fluid exits during hoist raising and through which fluid enters during hoist lowering; third conduit means interconnecting said third port with the connection of said hydraulic motor through which fluid enters during hoist raising and through which fluid exits during hoist lowering; fourth conduit means interconnecting said second and fourth ports with said return inlet connection of said positive displacement pump; and, fifth conduit means interconnecting said hydraulic cylinder unit of
said brake with said second conduit means; said movable valve member in said neutral position establishing a condition of said valve wherein said pressure inlet port is in communication with both said first and second ports through said first and second orifices, and said third port is not in communication with any other port, whereby fluid entering said inlet port can discharge only through said second port; said movable valve member upon being moved from neutral into said range of hoist-raising positions establishes a second orifice between said pressure inlet port and said third port which becomes larger, while said first orifice providing communication between said inlet port and said first and second ports becomes smaller and is finally closed as said valve member moves further into said range of hoist-shifting positions but with said first and second ports being in continuous communication with each other during hoist-raising; said movable valve member upon being moved from neutral into said range of hoist-lowering positions first restricting a third orifice into said second port while said third port is not in communication with any other port thereby increasing the pressure in said first port and said second and third conduit means until said hydraulic cylinder unit is actuated to release said brake, and as said movable valve member moves still further from neutral into said range of hoist-lowering positions establishing and progressively opening a fourth orifice between said third and fourth ports and finally closing said third orifice into said second port, whereupon all of the fluid flows out through said first port, returns through said third port and discharges through said fourth port.

2. The improvement called for in claim 1 wherein: said ports in said valve body are provided by spaced circumferential grooves formed in a longitudinal spiral-receiving bore, and separated by interior lands; and said movable valve member is a spool member having, spaced full diameter portions with an intermediate full diameter flange section therebetween, and necks on opposite sides of said intermediate flange section providing spool grooves for establishment of communication between said ports, said full diameter portions having tapers formed thereon adjacent the outer ends of said spool grooves, and said flange section having a taper formed on one end thereof, said tapers providing variable orifices in cooperation with said lands.

3. The improvement called for in claim 1 wherein: said ports in said valve body are provided by spaced circumferential grooves of equal width formed in an elongated spiral-receiving bore and separated by interior lands of equal width; and said movable member is a spool member having, spaced full diameter portions with an intermediate full diameter flange section thereinbetween which at all times during operation of said hydraulic hoist system registers with at least some portion of said pressure inlet port, and a neck on each said intermediate flange section providing spool grooves for establishing operating communication between said ports, one of said spool grooves being at all times during operation in substantially full registration with said first port and having a length exceeding the width of said first port and the two lands on opposite sides thereof, and the other spool groove being at all times during operation in at least partial registration with said third port and having a length equal to the width of said third port plus a portion of the width of one land, said full diameter portions having tapers formed thereon adjacent the outer ends of said spool grooves and said flange section having a taper on the side toward said longer spool groove, said tapers providing variable width annular orifices in cooperation with said lands.

4. In a hydraulic hoist system adapted to drive a cable drum or the like and including, (1) a positive displacement pump having a fluid discharge connection and a fluid return inlet connection, (2) a reversible hydraulic motor having two fluid connections, and (3) a brake operably coupled with said motor, said brake being free-running in the lift direction, said brake pressure means normally applying said brake so said motor is not free to turn in the lowering direction, and having a hydraulic cylinder unit whereby hydraulic pressure may be used to overcome said brake pressure means and release said brake, the improvement which comprises: control valve means providing first, second, third and fourth variable control orifices each of which during some phases of operation of said hoist system from the fastest hoist raising condition through neutral to the slowest hoist lowering condition ranges from being fully closed to being fully open, movable orifice regulating and closing said third and fourth orifices are closed whereby said variable orifices, a first pressure inlet port communicating with the inlet sides of said first and second orifices, a second port communicating between the discharge side of said first orifice and the inlet side of said second orifice, a third port communicating between the discharge side of said second orifice and the inlet side of said third orifice, a fourth orifice, first conduit means interconnecting said pressure inlet port with the discharge connection of said positive displacement pump, second conduit means interconnecting said second port with the connection of said hydraulic motor through which fluid exits during hoist raising and through which fluid enters during hoist lowering, third conduit means interconnecting said third port with the connection of said hydraulic motor through which fluid enters during hoist raising and through which fluid exits during hoist lowering, fourth conduit means interconnecting the discharge sides of said third and fourth orifices with said return inlet connection of said positive displacement pump, and fifth conduit means interconnecting said hydraulic cylinder unit of said brake with said second conduit means, said control valve means having a neutral condition wherein said first and third orifices are partly open and said second and fourth orifices are closed whereby all fluid entering said pressure inlet port discharges through said first and third orifices by way of said second port while said second and fourth orifices prevent flow through said motor, said control valve means having intermediate hoist-raising conditions wherein said second orifice is partly open, said first orifice is more restricted than said second orifice and restricts the flow of fluid and regulates the hoist speed, said third orifice is wider open than in said neutral condition, and said fourth orifice is closed, in said fastest hoist raising condition of said control valve means said first and fourth orifices being closed, and said second and third orifices being wide open, said control valve means having a brake release condition wherein said first orifice is partly open, said second and fourth orifices are closed, and said third orifice is restricted sufficiently to create enough back pressure in said second and fifth conduit means to release said brake, said control valve means having intermediate hoist lowering conditions wherein said first orifice is wider open than in said brake release condition, said second orifice is closed, said third orifice is more restricted than in said brake release condition, and said fourth orifice is only slightly open and serves to throttle the flow and control the hoist speed, and in said slowest hoist lowering condition of said control valve means said first orifice being wide open, said second and third orifices being closed, and said fourth orifice being wide open but substantially more restricted than said first orifice and serving to throttle the flow of fluid and control the hoist speed.

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