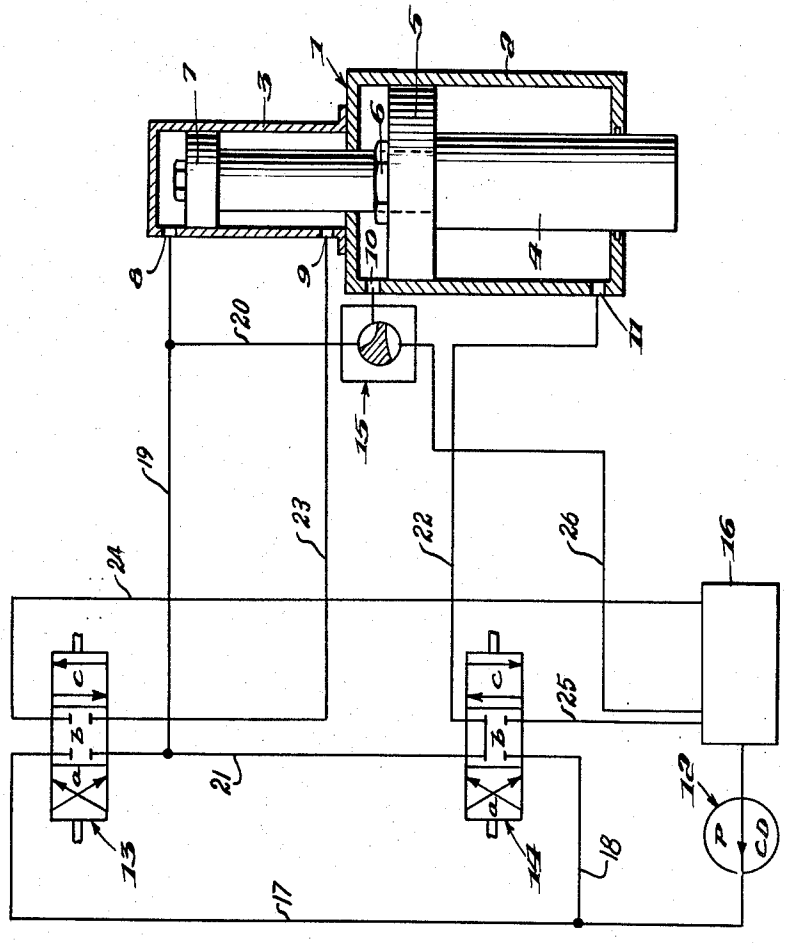
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HYDRAULIC SYSTEM

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HYDRAULIC SYSTEM

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This invention relates to a hydraulic system including a hydraulic power cylinder and more particularly, to a system for operating the piston of a hydraulic cylinder at changeable speeds for extending and retracting movement.

Hydraulic power cylinders have found many useful applications in modern equipment. They are particularly useful for applying a large force to move an object over a relatively short distance. The force exerted by a hydraulic cylinder is directly proportional to the pressure of the fluid supplied to the cylinder and the cross sectional area of the piston. To produce a large force, high pressure fluid must be supplied to the cylinder or the cylinder must have a large cross sectional area, or both. It is sometimes less expensive to make a cylinder of large cross-sectional area than it is to provide a high pressure hydraulic fluid system. Accordingly, the use of large cylinders is preferred. If a large force is required in both directions, a double acting cylinder may be used. The cross sectional areas of opposite sides of the piston should be approximately the same to provide the necessary force in either direction.

A double acting hydraulic cylinder is satisfactory when the operating conditions are such that a large force is required in both directions. Often, however, a double acting hydraulic cylinder is used in an operating cycle in which large forces are required in both directions but at some portion of the cycle the piston is moving under light load or no load conditions. Its speed of travel, under these conditions, is limited by the volume of fluid that can be supplied to the piston by the hydraulic pump and the piston moves as slowly under no load as it does under full load.

An inherent disadvantage of a hydraulic cylinder is that the displacement of the cylinder must be large to create a large force, but the speed of movement of the cylinder decreases as the size of the cylinder increases. If a hydraulic cylinder is arranged to move, for example, a heavily loaded container in both forward and return travel, but at certain periods in the cycle the container is unloaded and must be moved rapidly, it has been necessary heretofore to provide an independent means for accomplishing the rapid movement because a cylinder which would meet the speed requirements may not be able to exert sufficient force to move the container under load.

Accordingly, it is an object of this invention to provide a hydraulic system in which the speed of the piston and the force exerted by the piston of a hydraulic cylinder are variable.

It is a further object of this invention to provide a hydraulic system which has the economies of a constant flow rate hydraulic pump, but which drives the piston of a double acting hydraulic cylinder at several selected speeds.

It is another object of this invention to provide a hydraulic system for operating a hydraulic cylinder under full load and at high speed which is efficient and requires only a minimum of hydraulic fluid pumping equipment.

In accordance with a preferred embodiment of the invention, tandem, double acting hydraulic cylinders are provided. One of the cylinders has a cross sectional area which is considerably smaller than that of the other. The pistons of both cylinders are mounted on a common piston rod and spaced from each other along its length so that each piston moves in its respective cylinder. A constant flow pump supplies hydraulic fluid to ports on opposite sides of the small and large pistons. Valves are arranged in the system to direct the flow of hydraulic fluid to one or more of the ports to impart multiple speeds and forces to the piston rod of the tandem hydraulic cylinder.

This preferred embodiment of the invention is illustrated in the accompanying drawing, which is a schematic view of the hydraulic system of this invention.

The hydraulic system of this invention includes a tandem, double acting hydraulic cylinder. The tandem cylinder **1** includes a large cylinder portion **2** and a small cylinder portion **3** arranged in axial alignment end to end. A piston rod **4** extends through the large and small portions of the cylinder and a large piston **5** is secured to the piston rod **4** by a retaining ring **6**. The diameter of the large piston **5** is considerably greater than that of the piston rod **4** to form an annular space on opposite sides of the larger piston **5** so that it is double acting. The piston rod **4** extends into the small cylinder portion **3** of the tandem cylinder and a small piston **7** is secured to the end of the piston rod. The small piston **7** has a cross sectional area which is considerably less than that of the large piston **5**, but its diameter is greater than that of the piston rod **4** in the small cylinder portion **3**, so that an annular space is provided between the piston rod and the wall of the small cylinder **3**. Ports through the cylinder wall are provided on both sides of each piston. Ports **8** and **9** communicate with opposite sides of the small piston **7**, and ports **10** and **11** communicate with opposite sides of the large piston **5**.

Hydraulic fluid is supplied to the tandem cylinder **1** by a pump **12**. The pump **12** may be a high pressure or a low pressure pump, or it may consist of several pumps, depending on the power requirements of the cylinder, and delivering a constant volume of hydraulic fluid, but by means of bypass valves, or other means, the excess fluid which is not required in the system is recirculated through the pump. Since the pump **12** operates at a constant speed and delivers a constant volume of fluid, the drive motor for the pump does not require adjustment during operation of the hydraulic cylinder **1**.

Two valves, a first valve **13** and a second valve **14** are arranged in parallel branch conduits **17** and **18** to control the flow of fluid from the pump **12**. The first and second valves **13** and **14**, respectively are conventional distributing valves of the type which have three positions for controlling the flow of fluid through the valve. The position of the valve spools may be changed by electrical, hydraulic or mechanical means. The distributing valves **13** and **14** are provided with three positions for accomplishing cross flow in position *a*, no flow in position *b*, a through flow in position *c*. A rotary or other type of adjustable auxiliary valve **15** is also provided to control the flow of fluid through the port **10** in the large cylinder **2**. Each of the valves **13**, **14** and **15** is adjustable independently of the other.

The small cylinder **3** of the tandem cylinder **1** requires a smaller volume of fluid than the larger cylinder **2** to move the piston rod **4** a certain distance. With a constant flow rate of hydraulic fluid, the small piston **7** would move faster than the large piston **5**. The force exerted by the fluid on the piston is proportional to the cross sectional area of the piston and the large piston **5** would exert a considerably large force on the piston rod **4** than would the small piston **7** if hydraulic fluid at the same pressure were supplied through the ports **8** and **10**. By the arrangement of the valves in accordance with this invention, however, the limitations of a constant flow

rate hydraulic system can be minimized to provide a variety of speeds and forces of the piston rod 4.

Forward extending movement of the piston 4 can be accomplished at three different speeds and forces by adjusting the position of the valves 13, 14 and 15. With the first valve 13 in position *c*, the second valve 14 and the auxiliary valve 15 in the positions shown in the drawing, hydraulic fluid is supplied from a conduit 19 to the small piston 7 through the port 8, and from a conduit 20 through the port 10 to one side of the large piston 5 and from conduits 21 and 22 through port 11 to the opposite side of the piston 5. The exposed area of the large piston 5 on the side of the port 10 is larger than that of the piston 5 on the side of the port 11 and the resultant force on the piston 5 is in the direction of the extending movement of the piston rod 4. In addition to the force on the piston 5 there is a force on the small piston 7 due to the fluid supplied through the port 8. The resultant force on both pistons causes the piston rod 4 to move outwardly. As the piston rod 4 moves, fluid is forced out of the port 9, through a conduit 23 through the valve 13, and through a conduit 24 to a reservoir tank 16, and as the pressure in the cylinder 2 increases, the fluid flows out of the port 11, through the conduits 22 and 21 and into the ports 8 and 10 through the conduits 19 and 20. The volume of fluid flowing out of the cylinder 2 supplements the fluid flowing from the pump 12 to provide an increased volume of flow to the high pressure sides of the pistons 5 and 7. With this arrangement, the piston rod 4 travels at a more rapid rate than if the additional fluid from port 11 were not recirculated to the high pressure side of the small piston 7.

The maximum force for forward movement of the piston rod 4 is accomplished by adjusting the first valve 13 to position *c* and second valve 14 to position *c*. The auxiliary valve 15 remains in the position shown in the drawing. With the valves in these positions, hydraulic fluid flows through the conduits 19 and 20 to the ports 8 and 10 and fluid exhausted through the port 11 flows through the conduits 22 and 25 to the tank 16. Since there is no appreciable back pressure on the fluid in the lower part of the cylinder 2, the resultant force on the cylinder is greater than that which results when the distributing valve 14 is in the position *b*. Since the volume of fluid supplied to the pressure side of the piston 5 is reduced, however, the speed of movement of the piston rod 4 is accordingly reduced.

To accomplish the maximum speed of forward movement of the piston rod 4, while exerting the least amount of force, valves 13 and 14 are adjusted to positions *c* and the auxiliary valve 15 is rotated so that the port 10 communicates with the tank 16 through the conduit 26. With the valves in these positions, the pump 12 supplies hydraulic fluid to the small piston 7 through the conduit 19 to the port 8 and upon movement of the piston rod 4, fluid is exhausted through the port 9 via the conduits 23 and 24 to the tank 16 and through the port 11 via the conduits 22 and 25 to the tank 16. The port 10 also communicates with the tank 16, and movement of the piston 5 creates a suction which draws the fluid up from the tank 16 and into the port 10. Since the fluid from the port 11 supplies fluid for the port 10, none of the hydraulic fluid from the pump 12 is diverted to fill the cylinder 2. Only a small force is produced, however, since only the small piston 7 is active. Since the pump 12 is supplying fluid exclusively to the port 8, the speed of movement of the piston rod 4 is faster than that obtained with the other two arrangements of valves.

To effect return travel of the piston rod 4, the first distributing valve 13 is adjusted to position *a*. The second valve 14 and the auxiliary 15 are in the positions shown in the drawing. Hydraulic fluid is thus supplied through the conduit 23 to the port 9 of the small cylinder 3. Since the displacement volume of the cylinder 3 is small, the piston 7 moves rapidly. Fluid exhausted through the ports 8 and 10 by the movement of the piston rod 4, is recirculated to the port 11 of the larger cylinder 2 through the conduits 19, 21 and 22. In this manner the full capacity of the pump supplies fluid to the working cylinder 3 and none of the fluid is diverted to fill the non-working cylinder 2. Recirculation of the hydraulic fluid provides a greater speed of travel of the piston rod 4 than would be obtained if the constant volume pump were required to supply fluid to the non-working cylinder 2 also.

If a greater amount of force is required on the piston rod 4 during the return stroke, distributing valve 13 is adjusted to position *a* and valve 14 is also adjusted to position *a*. The auxiliary valve 15 is in the position shown in the drawing. This valve arrangement supplies pressure fluid directly to ports 9 and 11 through the conduits 23 and 22, respectively, for the return stroke of the piston 4. The fluid expelled through the ports 8 and 10 by the movement of the pistons 5 and 7 is conveyed directly to the tank 16. Since both pistons 5 and 7 are exposed to fluid under pressure, the piston rod 4 exerts a greater force than that achieved by actuation of only the smaller cylinder 3. The greater force is obtained, however, at the expense of speed of return movement, since the pump 12 supplies pressure fluid to the large cylinder 2 as well as the small cylinder 3.

In operation, the fluid pump 12 supplies hydraulic fluid under pressure to the distributing valves 13 and 14. For slow speed high force forward travel, valve 13 is adjusted to position *c*, valve 14 is in position *c* and valve 15 is in the position shown in the drawing. Intermediate speed, medium force is obtained by moving valve 13 to position *c*, valve 14 to position *b* and rotary valve 15 to the position shown in the drawing. Maximum speed, minimum force is obtained by moving valve 13 to position *c*, valve 14 to position *c*, and moving the rotary valve 15 approximately 45° counterclockwise from the position shown in the drawing.

For return travel at high speed, but with a minimum of force, valve 13 is adjusted to position *a*, valve 14 is moved to position *b* and the rotary valve 15 is in the position shown in the drawing. For return travel with a maximum force, but at a slower speed, valve 13 is moved to position *a* and valve 14 is moved to position *a* and the rotary valve 15 is in the position shown in the drawing.

It is possible with the hydraulic system of this invention to obtain three combinations of speed and force in forward travel with a double acting hydraulic cylinder, and two combinations in return travel. The important advantages of the system are that it is efficient and simple to operate. A constant flow pump, such as that used in the hydraulic system of this invention has a minimum of controls and after it is started, no adjustments to the pump are necessary to operate the system. Due to the efficient utilization of the fluid in the system, the size of the pump is at a minimum, thus reducing the cost of the system.

While this invention has been illustrated and described in one embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

I claim:

1. A hydraulic system comprising a fluid pump, an expansible hydraulic cylinder, tandem double-acting pistons mounted in the cylinder, means connecting the pistons in the cylinder, said pistons and said cylinder defining working chambers on one side of the pistons for forward extending movement of the connecting means and working chambers for return travel of the connecting means on the opposite side of the pistons, ports in the cylinder wall communicating with each of the working chambers, a reservoir, conduit means for supplying fluid from the reservoir to the pump, first valve means, second valve means, conduit means for supplying fluid from the pump to the first and second valve means, conduit means for discharging fluid from the

valve means independently to the reservoir, conduit means communicating between said first and second valve means and said extending working chambers, and conduit means communicating independently between one of said return working chambers and said first valve means, and between the other of said return working chambers and said second valve means, said second valve means including means for selectively providing communication between said other return working chamber and said extending working chambers, whereby a plurality of forces and rates of travel of the connecting means in the cylinder are provided.

2. A hydraulic system comprising a fluid pump, an expansible hydraulic cylinder, tandem double-acting pistons mounted in the cylinder, one of said pistons having a greater diameter than the other, means connecting the pistons in the cylinder, said pistons and said cylinder defining working chambers on one side of the pistons for forward extending movement of the connecting means and working chambers for return travel of the connecting means on the opposite side of the pistons, ports in the cylinder wall communicating with each of the working chambers, a reservoir, conduit means for supplying fluid from the reservoir to the pump, first valve means, second valve means, conduit means for supplying fluid from the pump to the first and second valve means, conduit means for discharging fluid from the valve means independently to the reservoir, conduit means for communicating between said first and second valve means and said extending working chambers, and conduit means communicating independently between one of said return working chambers and said first valve means, and between the other of said return working chambers and said second valve means, said second valve means including means for selectively providing communication between said other return working chamber and said extending working chambers, and auxiliary valve means for selectively shutting off fluid communication with said first and second valve means and bypassing fluid from one of the extending working chambers to the reservoir, whereby a plurality of forces and rates of travel of the connecting means in the cylinder are provided.

3. A hydraulic system comprising a fluid pump, an expansible hydraulic cylinder, tandem double-acting pistons mounted in the cylinder, one of said pistons having a greater diameter than the other, means connecting the pistons in the cylinder, said pistons and said cylinder defining working chambers on one side of the pistons for forward extending movement of the connecting means and working chambers for return travel of the connecting means on the opposite side of the pistons, ports in the cylinder wall communicating with each of the working chambers, a reservoir, conduit means for supplying fluid from the reservoir to the pump, first and second distributing valves, conduit means for supplying fluid from the pump to the first and second distributing valves, conduit means for discharging fluid from the first and second valves independently to the reservoir, conduit means communicating between said first and second valves and extending working chambers, and conduit means communicating between one of said return working chambers and said first valve, and between the other of said return working chambers and said second valve, said valves each having a valve spool movable to a first, a second, and a third position, said first position of the valves connecting said pump and said extending working chambers through said conduit means and said return working chambers and said reservoir through said conduit means, said second position of said first valve interrupting fluid flow between the pump and the expansible cylinder, said second position of said second valve providing communication between said other return working chamber and said extending working chambers, said third position of the valves providing communication between the pump and the return working chambers and providing communication between the extending working chambers and the reservoir, whereby a plurality of forces and rates of travel of the connecting means in the cylinder are provided.

4. A hydraulic system comprising a fluid pump, an expansible hydraulic cylinder, tandem double-acting pistons moutned in the cylinder, one of said pistons having a greater diameter than the other, means connecting the pistons in the cylinder, said pistons and said cylinder defining working chambers on one side of the pistons for forward extending movement of the connecting means and working chambers for return travel of the connecting means on the opposite side of the pistons, ports in the cylinder wall communicating with each of the working chambers, a reservoir, conduit means for supplying fluid from the reservoir to the pump, first and second distributing valves, first conduit means for suuplying fluid from the pump to the first and second distributing valves, second conduit means for discharging fluid from the first and second valves independently to the reservoir, third conduit means communicating between said first and second valves and the extending working chambers, and fourth conduit means communicating independently between one of said return working chambers and said first valve, and between the other of said return working chambers and said second valve, said valves each having a valve spool movable to a first, a second, and a third position, said position of the valves connecting said pump and said extending working chambers through said third conduit means and said return working chambers and said reservoir through said second conduit means, said second position of said first valve interrupting fluid flow between the pump and the expansible cylinder, said second position of said second valve providing communication between said larger return working chamber and said extending working chambers, said third position of the valves providing communication between the pump and the return working chambers and providing communication between the extending working chambers and the reservoir, and auxiliary valve means for providing communication between the extending working cylinder of the larger diameter cylinder and either the smaller extending working cylinder or the reservoir, selectively.

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