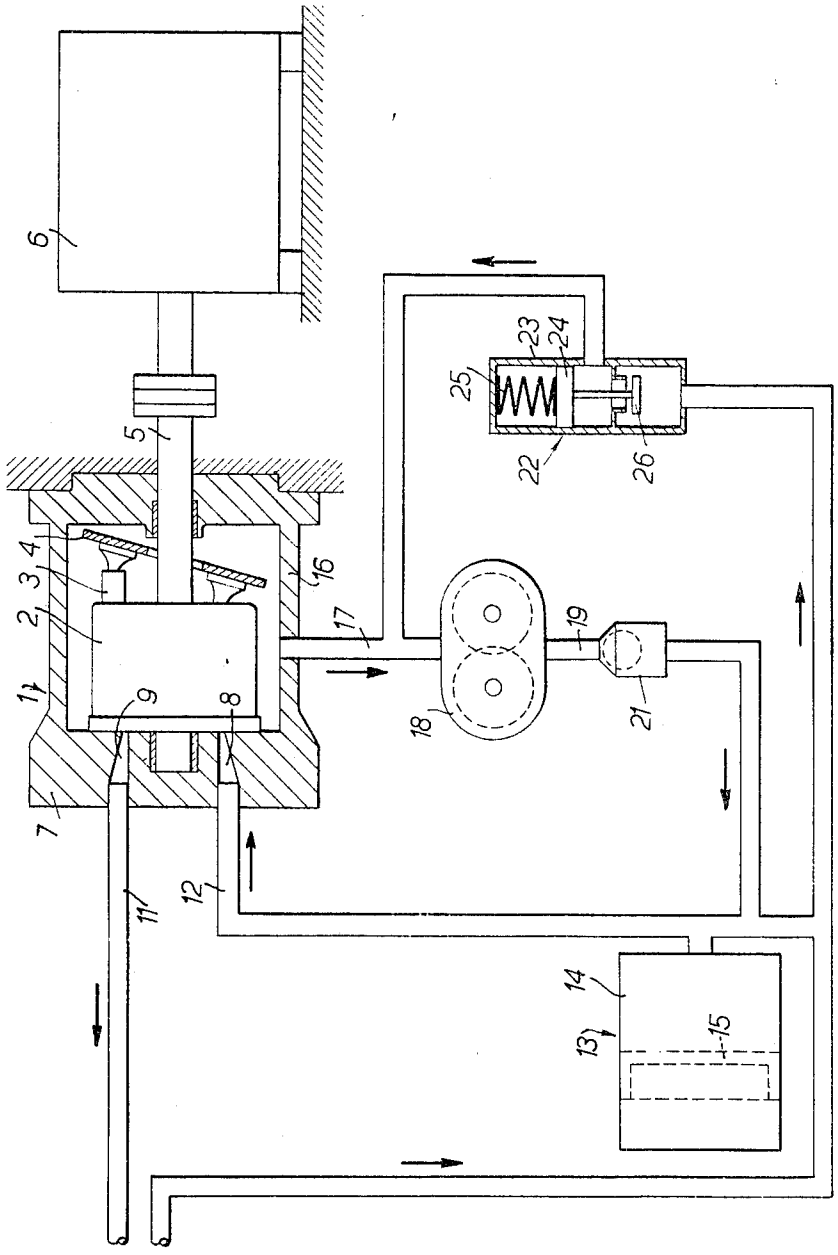
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HYDROSTATIC POWER TRANSMISSION

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HYDROSTATIC POWER TRANSMISSION

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This invention relates to a hydrostatic power transmission comprising a positive displacement hydraulic pump in hydraulic connection with a positive displacement hydraulic motor. The term "positive displacement" means that the pump or motor includes a variable volume device which in the case of the pump is adapted to pressurise hydraulic liquid by reduction in volume or in the case of the motor is adapted to increase in volume under the action of pressure liquid applied to it. A positive displacement pump or motor may include one or more variable volume devices. Where the pump or the motor is continuously rotatable the variation of volume per revolution may be fixed or variable. The pump or the motor may be a partly rotatable unit, or a linearly movable unit such as a piston and cylinder unit.

In accordance with the present invention a hydrostatic power transmission includes a low pressure hydraulic accumulator connected to the transmission pump inlet, a low pressure boost pump arranged to pump liquid to the pump inlet, collecting means to collect leakage from the pump and to feed such leakage to the inlet of the boost pump, and a by-pass valve connected between the collecting means and the accumulator arranged to maintain a substantially constant pressure in said collector means.

The by-pass valve may comprise a cylinder, a piston within the cylinder spring-loaded to one end thereof, vent means to connect the other end of the cylinder to atmosphere, a valve member carried by the piston and co-operating with a seat located at the said one end of the cylinder whereby the pressure in the collecting means will act on the piston against the loading of the spring so that excessive pressure in the collecting means will seat the valve to close the by-pass and thus to raise the effective pumping range of the boost pump to a maximum.

The transmission pump may be an axial piston unit and the collecting means may be a casing around the cylinder block of the axial piston pump.

Each piston of the axial piston pump may include a slipper which is urged against a cam surface by virtue of the liquid pressure exerted in the associated cylinder, rotation of the cam surface and/or of the cylinder block thereby reciprocating the pistons within their cylinders.

One of the advantages of the invention is that the boost pump need be capable only of pumping at low rate, the accumulator serving to accommodate variations in the total liquid volume in the transmission. Variation in the total liquid volume may occur if the transmission motor is such that the quantity of liquid which it contains varies during operation, for example if the motor is a simple piston and cylinder unit. Volume variation in the transmission may also result from temperature variations or pressure variations in the transmission.

One embodiment of the invention will be described with reference to the accompanying diagrammatic drawing. In this drawing the transmission pump 1 includes a rotary cylinder barrel 2 having cylinders from which plungers 3 project to engage an inclined swash plate 4. The cylinder barrel 2 is rotated by means of a drive shaft 5, power being supplied by any convenient prime mover 6. The cylinder barrel 2 presses against a valve plate 7 for co-operation with the inlet and delivery ports 8 and 9. From these ports, pipes 11 and 12 extend to a hydraulic motor.

This motor may take any known form and may for example comprise a simple double-acting piston and cylinder or alternatively, may comprise a multi-cylinder rotary motor.

Connected to the pipe 12 is a low pressure accumulator 13 comprising a cylinder 14 having a floating piston 15. One end of the cylinder 14 is connected to pipe 12 and liquid enters that end of the cylinder to press against the piston 15. On the opposite side of the piston 15 a quantity of inert gas is trapped to form a spring medium to pressurise the liquid contained in the cylinder 14. Any other known form of accumulator may be used.

The pump 1 includes a casing 16 surrounding the cylinder barrel and swash plate, this casing having a rotary seal operative on the drive shaft 5. The pipe 17 extends from casing 16 to a low pressure gear pump 18 also driven by the prime mover 6. The delivery 19 of the gear pump 18 is connected to the pipe 12 through the medium of a non-return valve 21. A by-pass valve 22 interconnects pipes 12 and 17. The by-pass valve includes a cylinder 23 having a piston 24 loaded by spring 25. The piston 24 controls the seating of a valve member 26. Piston 24 is exposed to pressure from the pipe 17, i.e., from pump casing 16, such pressure reacting against the loading of spring 25 to close valve 26 onto its seating if the pressure in pipe 17 reaches more than a predetermined value. The space behind piston 24 which encloses the spring 25 is vented to atmosphere. The valve 26 has been shown out of proportion so that its function will be appreciated. In fact valve 26 is very small in comparison with piston 24 so that the pressure of liquid in the accumulator has substantially no influence on the movement of piston 24.

During operation of the transmission the prime mover 6 will rotate the drive shaft 5 and the cylinder barrel 2. Such rotation moves the piston 3 around the swash plate 4 causing reciprocation of each piston in its cylinder. Low pressure from the accumulator 13 acts on the pistons 3 which are connected to the inlet port 8. The timing of the inlet port 8 having regard to the swash plate 4 is such that pistons 3 in connection with the port 8 must move outwardly if they are to remain in contact with the swash plate 4. The pump 18 will draw liquid through pipe 17 from the casing 16 and deliver it at a low pressure to pipe 12 and the accumulator 13. Thus the casing 16 is maintained at a lower pressure than the inlet port 8 whereby a pressure differential is applied to each piston 3 in connection with the port 8 urging it outwardly into contact with the swash plate 4. The valve 22 responds to pressure within the pump casing 16 in such a way that if the pressure in the casing becomes too high valve member 26 is seated to prevent the by-pass flow so that the pump 18 is fully effective to pump liquid from the casing. Alternatively if the pressure in the casing becomes too low, valve member 26 will open to permit by-pass flow around the pump 18 so that the effective pumping capacity of the pump 18 is reduced and liquid is removed from the casing at a lower rate. The selected pressure from the casing 18 is thus held by the by-pass valve at a small value above atmospheric which depends on the loading of the spring 25. This pressure is selected to ensure that a substantial quantity of liquid remains in the casing to effect lubrication.

The motor fed by the pipes 11 and 12 may be a simple double-acting ram whose total volume may vary in accordance with the position of the ram. In this case the capacity of the accumulator 13 should be arranged to be greater than the maximum possible volumetric variation of the ram. To prevent leakage from the system it is preferred that any seal or seals forming a part of the ram or motor and serving to isolate pressure liquid from the atmosphere should be provided with a trap or traps to collect leakage liquid and to feed it to the inlet of the gear pump 18.

When the motor fed by the pipes **11** and **12** is a rotary multi-piston motor the motor should be mounted in a casing for the collection of leakage from the pistons, such casing being connected to the pipe **17**.

The displacement of the pump **1** may be adjusted by adjustment of the swash angle of the swash plate **4** for adjustment of the speed of operation of the motor. If it is desired to be able to reverse the motor a reversing valve may be provided in the lines **11** and **12** so that the accumulator **13**, the pump **18** and the valve **22** always remain in connection with the return pipe **12** leading into the pump. Reversal of the motor may also be effected by reverse of the inclination of the swash plate **4** in the pump and in this case the flows in the pipes **11** and **12** become reversed. The accumulator **13**, the delivery from the pump **18** and the connection of the valve **22** may then be connected through the medium of a shuttle valve to the pipes **11** and **12**, the shuttle valve being so arranged that it will select the pipe **11** or **12** at low pressure for connection to the accumulator **13**. Alternatively the pump **1** may comprise a fixed delivery pump having a relief valve to by-pass delivery to the inlet when the delivery pressure exceeds a predetermined value. If necessary to reverse or halt the motor whilst the pump is in operation a valve can be provided between the pump and the motor for feeding the pump delivery in one direction or the other to the motor, or alternatively to short circuit the pump when no motor movement is required. Where the transmission pump is a variable delivery pump, for example of the swash plate kind, the delivery of the pump as determined by the angle of the swash plate may be controlled by a suitable servo motor. Alternatively, direct manual control may be employed.

In the described embodiment the pipe **17** which draws liquid from the pump casing extends from the lowermost part of this casing. It is within the scope of this invention for the pipe to extend from a position in the casing of intermediate height to ensure that some liquid will always remain in the casing for lubrication purposes. Alternatively means may be provided in the casing responsive to the level of oil in the casing to throttle the flow of liquid into the pump **18** if the level falls below a predetermined height.

I claim as my invention:

1. A hydrostatic power transmission including a low pressure hydraulic accumulator connected to the transmission pump inlet, a low pressure boost pump arranged to pump liquid to the pump inlet, collecting means to collect leakage from the pump and to feed such leakage to the inlet of the boost pump, and a by-pass valve connected between the collecting means and the accumulator to maintain a substantially constant pressure in said collecting means, said by-pass valve comprising a cylinder,

a piston within the cylinder spring-loaded to one end of the cylinder, vent means to connect the other end of the cylinder to atmosphere, and a valve member carried by the piston and cooperating with a seat located at the said one end of the cylinder, whereby the pressure in the collecting means acts on the piston against the loading of the spring and when excessive, seats the valve to close the by-pass and thus raise the effective pumping rate of the boost pump.

2. In combination, a hydraulic power transmission having a hydraulic pump in hydraulic connection with a hydraulic motor, a low pressure hydraulic accumulator connected to the transmission pump inlet, means for collecting leakage from the transmission pump, a low pressure boost pump operative to feed the collected leakage to the transmission pump inlet, a conduit interconnecting the leakage collecting means and the accumulator so as to by-pass the boost pump, and a valve in the conduit operative to maintain a substantially constant pressure in the leakage collecting means by closing the conduit when the leakage pressure becomes excessive, and thus raising the effective pumping rate of the boost pump.

3. A hydrostatic power transmission as claimed in claim **2** wherein the transmission pump is an axial piston pump and the collecting means is a casing around the cylinder block of the axial piston pump.

4. A hydrostatic power transmission as claimed in claim **1** wherein the transmission pump is an axial piston pump and the collecting means is a casing around the cylinder block of the axial piston pump.

5. A hydrostatic power transmission as claimed in claim **3** including a slipper for each piston and a cam surface against which the slipper is urged by virtue of the liquid pressure exerted in the associated cylinder, relative rotation between the cam surface and the cylinder block thereby reciprocating the pistons in their cylinders.

6. A hydrostatic power transmission as claimed in claim **4** including a slipper for each piston and a cam surface against which the slipper is urged by virtue of the liquid pressure exerted in the associated cylinder relative rotation between the cam surface and the cylinder block thereby reciprocating the pistons in their cylinders.

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