

[54] **CLOSED LOOP-OPEN LOOP CIRCUIT
FOR HYDRO-STATIC TRANSMISSIONS**

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91/452**

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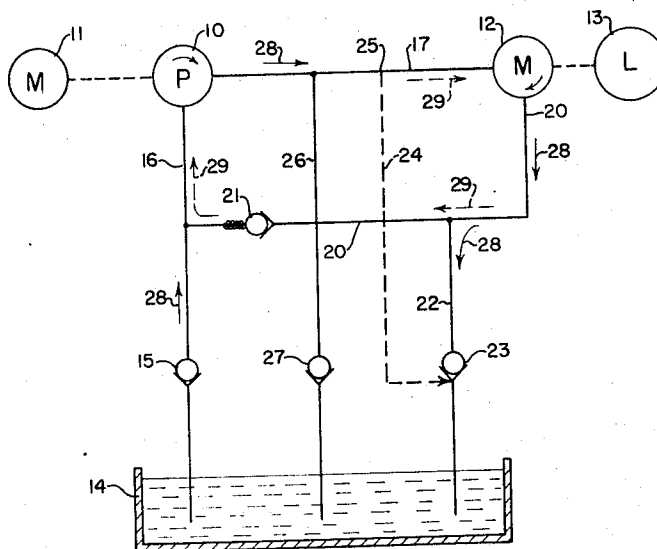
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[57] **ABSTRACT**

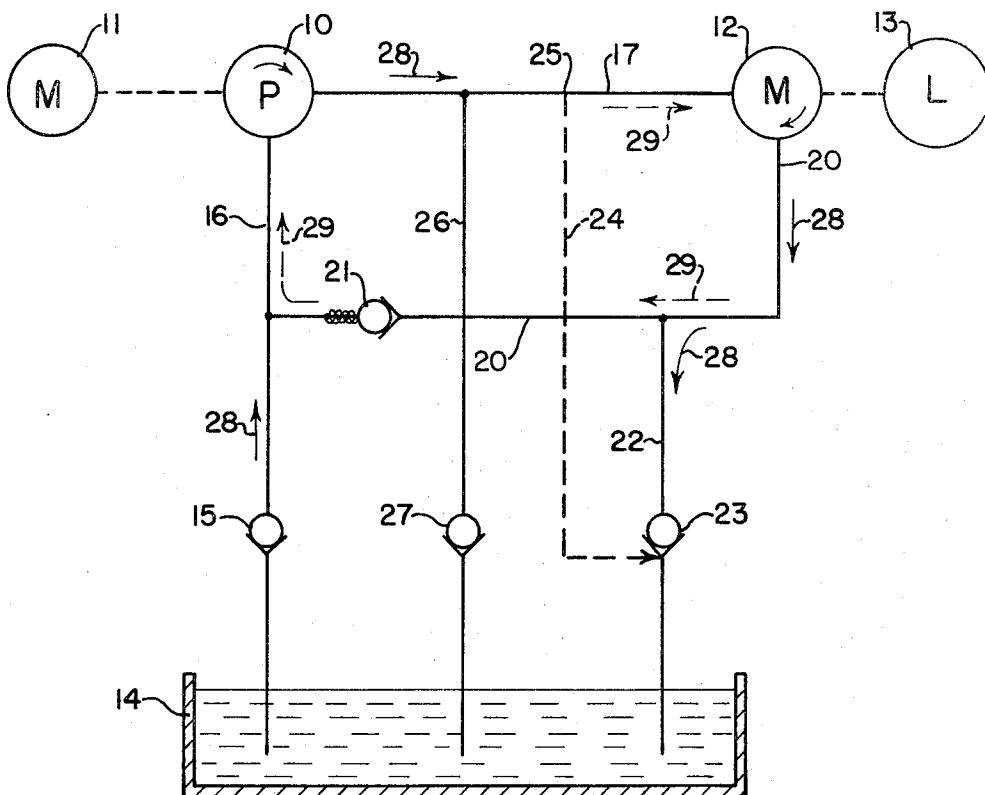
A hydro-static transmission circuit including a positive displacement hydraulic pump and motor in combination which operates in open loop fashion when the circuit is operating in its normal or pump driving state. When it is desired to slow down the motor and it becomes overrunning, a pilot operated check valve closes blocking the normal discharge of the motor to the reservoir and creating a closed loop system to absorb energy from the system.

9 Claims, 1 Drawing Figure



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CLOSED LOOP-OPEN LOOP CIRCUIT FOR HYDRO-STATIC TRANSMISSIONS

The present invention pertains to hydro-static transmissions and more particularly to such transmissions which employ positive displacement pumps and motors and may have an over-running load.

A hydro-static transmission consists, in general, of a positive displacement hydraulic pump, a positive displacement hydraulic motor, and conduits connecting the pump output to the motor. In a closed loop system the motor output is connected by a conduit to the pump input so that the hydraulic fluid is forced in a continuous loop from the pump through the motor and back to the pump. Such closed loop systems are advantageous when the motor is used to drive a load which may become overrunning for example when the pump output is reduced with the hope of slowing down the motor. In the event the motor becomes overrunning and acts as a pump, the pump effectively becomes a motor and serves, together with its driving means, as a braking or retarding force on the motor and its overriding load. In other words, it absorbs work from the system.

Due to the fact that considerable heat is generated in the hydraulic circuit, such closed loop systems normally require heat exchangers to cool the hydraulic fluid. Such systems also require precharge pumps to initially fill the system with hydraulic fluid. Both of these requirements increase the complexity of the system as well as its cost.

In an open circuit system, the pump draws its fluid from an open reservoir, and the motor discharges to the same or another open reservoir. The surface of the reservoir acts as an effective heat exchanger. Likewise, the need for precharging pumps is eliminated in an open loop system. However, such systems cannot normally be used when an overrunning load may be encountered since when the motor becomes a pump there is no closed loop return conduit from the motor to the pump blocking the discharge and hence no work can be absorbed in such a system. The motor runs free or coasts to the extent that suction at its inlet will permit.

In accordance with the present invention a hydro-static transmission arrangement of the general type described is provided which includes a check valve in the output circuit of the motor which is actuated by pressure conditions in the input circuit. Under normal operating circumstances the check valve is maintained in an open condition, connecting the motor output to an open reservoir or sump and permitting the system to operate as an open loop system. In the event an over-running condition occurs where the inlet pressure drops to a predetermined value, the check valve closes thereby connecting the output of the motor to the pump input and converting the system into a closed loop system.

It is the primary object of the present invention to provide an improved hydro-static transmission system which possesses the advantages of an open loop system while maintaining the ability to operate as a closed loop system in the event an overrunning load is encountered.

It is also an object of the invention to provide an improved hydro-static transmission system which is capable of operating as a closed loop system when an over-running load is encountered but which eliminates the necessity of expensive heat exchange equipment.

A further object of the invention is the provision of a hydro-static transmission system which operates as an open loop system under normal conditions but which immediately and automatically converts to a closed loop operation when an overrunning load is encountered.

For a more complete understanding of the invention and of the objects and advantages thereof reference should be had to the following detailed description and the accompanying drawing wherein there is shown a preferred embodiment of the invention.

The sole FIGURE of the drawing is a schematic flow diagram showing of a hydro-static transmission circuit embodying the teachings of the present invention.

In the embodiment illustrated, there is provided a positive displacement pump 10 which is driven by a suitable prime mover 11 which may, for example, be an electric motor. The pump 10 is intended to supply hydraulic fluid under pressure to a positive displacement hydraulic motor 12 which, in turn, drives a load 13. The present invention provides a novel conduit and valve arrangement for interconnecting the pump 10 and motor 12 which operates as an open loop hydraulic circuit when the pump is driving the motor 12, hydraulic fluid being drawn from a reservoir or sump 14 to the pump 10 and then to the motor 12 after which it is returned to the sump 14. The novel valving and conduit arrangement operates as a closed loop system in the event the motor 12 becomes overrunning, the motor 12 now acting as a pump and supplying pressure at the inlet of the pump 10 so that the pump and its driving means 11 absorb energy from the system and serve as a brake on the operation of the hydraulic motor 12.

As illustrated in the drawing, the inlet of the pump 10 is connected to the sump 14 by a conduit 16 and check valve 15, the check valve 15 permitting the flow of fluid from the sump 14 to the inlet of the pump 10. The outlet of the pump 10 is connected by a conduit 17 to the inlet of the hydraulic motor 12. The outlet of the motor 12 is connected to a conduit 20 which, in turn, is connected to the pump inlet conduit 16 through a spring loaded check valve 21 and to the sump by a conduit 22 which includes a pilot operated check valve 23. The pilot operated check valve 23 is controlled, through a pilot line indicated by dotted line 24, by the pressure in the pump outlet conduit 17. The valve 23 is of the type well known to those skilled in the art which is opened or closed dependent on the pressure or signal actuation through pilot line 24. The pressure indication over line 24 is normally hydraulic, but it could also be an electrical signal. In essence, valve 23 is opened whenever the pressure over line 24 exceeds a predetermined minimum amount and closed whenever this pressure drops below a predetermined minimum amount.

Under normal pumping operation of pump 10, the pressure required to open the spring loaded check valve 21 is more than the pressure in the conduit 20 when the pilot operated valve 23 is open. Hence, it can also be said that the pressure required to open valve 21 is greater than the normal pressure drop across valve 23 when it is open. This valve arrangement permits the hydraulic circuit to operate as an open-loop system when the pump 10 is driving the motor 12. In this situation, the pump 10 draws fluid from the sump 14 through the check valve 15 and conduit 16 and supplies this fluid under pressure through the conduit 17 to the

motor 12. Since there is a positive pressure at the point 25 at which the pilot line 24 is connected to the conduit 17, the pilot operated check valve 23 is open and the discharge from the motor 12 is through the conduit 20, conduit 22, and the pilot operated check valve 23 to the open sump 14, for cooling of the fluid. The high opening pressure of the spring loaded check valve 21 holds this valve in a closed position. Thus, the path of flow of the hydraulic fluid under normal pumping conditions is that indicated by the solid arrows 28 in the drawing.

When an over-run condition is encountered, that is when the pump output is reduced to an amount less than that required by the motor at its then rotating speed, the load 13 then acts as a driving force on the motor 12, the pressure in the pump outlet conduit 17 drops to close to 0 psi gage or below. As a result, the pilot operated check valve 23 loses the control pressure through the pilot line 24 holding it open and this check valve 23 then closes. With valve 23 closed, the output pressure of the hydraulic motor 12 in line 23 is now forced through the valve 21 to the pump inlet conduit 16, the check valve 15 preventing the flow of fluid back into the sump 14. The fluid flow path is now through the motor 12, conduit 20, conduit 16, pump 10, and conduit 17, forcing the pump 10 and its driving means 11 to absorb energy from the system. Conduit 26 and a normally closed spring check valve 27 communicate the sump with the inlet of motor 12 so that when motor 12 is in an overrunning condition, check valve 27 opens and permits the motor 12, in effect causing a suction, to draw fluid from the sump 14 through conduit 26. The fluid path during an overrunning condition is indicated in the drawing by the dashed arrows 29.

It will be seen that under normal operating conditions the sump or tank 14 forms a part of 21 the hydraulic circuit, and while only a single sump 14 is illustrated it should be clearly understood that separate sumps for each of the conduits would meet the objects of the invention. The heat in the fluid discharged from the motor 12 into the sump 14 is rapidly dissipated into the volume of fluid in the sump. Also, the entire sump or tank 14 provides a large radiating surface to further cool the hydraulic fluid. It has been found that this cooling is adequate to maintain a conventional hydraulic oil or fluid at temperatures below a critical temperature without the need for other radiating or heat exchange means.

The need for precharge pumps is also eliminated in the circuit described above. Under normal operating conditions the conduit 16 and check valve 15 provide a fully charged fluid supply path for the pump 10. When the motor 12 is overrunning, that is, when it is operating in a pumping manner, the conduit 26 and check valve 27 provide a fluid supply path for the system, but the conduit 16 above and below check valve 15 still remains fully charged.

While the invention has been described with reference to the preferred embodiment obvious modifications and alterations may be made thereto. Reference should therefore be had to the appended claims in determining the true scope of the invention.

What is claimed is:

1. A hydrostatic transmission, comprising:
 - a positive displacement hydraulic pump;
 - a positive displacement hydraulic motor;

- a sump;
- a first conduit connecting the pump outlet to the motor input;
- a second conduit connecting the sump to the pump inlet;
- a third conduit connecting the motor output to the sump;
- a fourth conduit connecting the motor outlet to the pump input; the improvement which comprises valve means in the third and fourth conduits and operative to close the third conduit and open the fourth conduit only when the motor is operating in an overrunning manner.

2. The improvement of claim 1 wherein the valve means includes a first normally open valve in the third conduit and a spring-biased check valve in the fourth conduit, the opening pressure of the spring-biased check valve being greater than the pressure drop across the first valve when the first valve is open.

3. The improvement of claim 2 wherein the first valve is a pilot operated check valve, the operation of the first valve being controlled by the pressure in the first conduit.

4. The improvement of claim 1 further including a check valve in the second conduit operative to permit fluid flow from the sump to the inlet of the pump while preventing reverse flow.

5. A hydrostatic transmission including a positive displacement pump and a positive displacement hydraulic motor, comprising:

- means to drive the pump, means driven by the motor;
- a first conduit connecting the outlet of the pump to the inlet of the motor;
- a hydraulic fluid sump;
- a second conduit connecting fluid in the sump to the inlet of the pump;
- a third conduit connecting the outlet of the motor to the sump;
- a fourth conduit connecting the second and third conduits; and
- a normally open valve in the third conduit between the sump and the point of connection of the fourth conduit thereto; a normally closed valve in the fourth conduit between the second and third conduit connections thereto; the normally open valve closing and the normally closed valve opening directly dependent upon the fluid pressure in the first conduit.

6. The hydrostatic transmission according to claim 5 wherein the normally closed valve is a spring-biased check valve having an opening pressure greater than the pressure across the normally open valve when the latter is open.

7. The hydrostatic transmission according to claim 5 wherein the normally open valve is a pilot controlled check valve responsive to hydraulic pressure in the first conduit.

8. The hydrostatic transmission according to claim 7 wherein the normally open valve closes when the pressure in the first conduit falls to approximately 0 psi.

9. The hydrostatic transmission according to claim 5 which includes:

- a fifth conduit connected to the first conduit, and to the sump, and
- a normally closed spring loaded check valve in said fifth conduit permitting flow only from the sump to

the first conduit dependent on the fluid pressure in the first conduit.

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