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Load Sensing Hydraulic Systems

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A conventional hydraulic system with a fixed-displacement pump provides a constant flow through the system. When the system develops the set pressure, the pump flow is bypassed through the associated pressure relief valve. As a consequence, the system generates tremendous amount of heat. Even when a variable-displacement pump is employed, the system produces considerable heat. A sophisticated solution to improve the efficiency is to add a load sensing feature to the system.

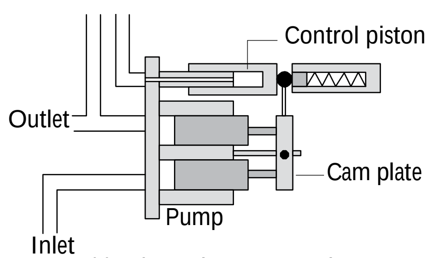
The hydraulic system with a load sensing feature provides only the flow and the pressure as required by the connected load. Controlling both the pressure and the flow allows for a significant reduction in losses, improvement of circuit efficiencies, and enhancement of the service life of the system. The principle of load sensing is widely used in mobile hydraulic systems, including tractor systems, trucks, and cranes. It is also used in many other applications, including machine tool systems and presses.

A Typical Load Sensing (LS) System

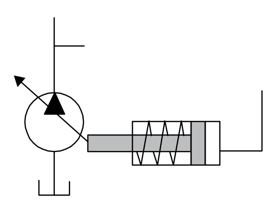
The basic load sensing system typically comprises a variable-displacement load sensing pump, a special compensator, and a load sensing directional control valve with proportional flow characteristics.

Load sensing Variable-displacement pump

In the variable-displacement pump, the flow can be controlled by varying the angle of its cam plate. This type of control can be achieved with the help of the control piston of the cam plate. The pump along with its compensator senses and responds to the varying flow and pressure requirements of the associated hydraulic system.



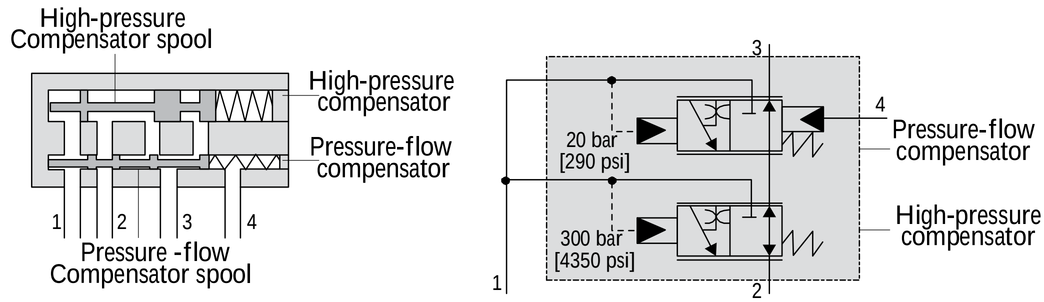
(a) Schematic representation


(b) Equivalent symbolic representation

Symbolic representation of a variable-displacement pump

Pump Compensator

The compensator, when connected to a hydraulic system, senses the pressure and the flow conditions of the system. It consists of a pressure-flow compensator spool that works against a low-pressure spring {say 20 bar [290 psi] spring} and a high-pressure compensator spool that works against a high-pressure spring {say 300 bar [4350 psi] spring}. *[Note: The numerical values are used for easy understanding]*

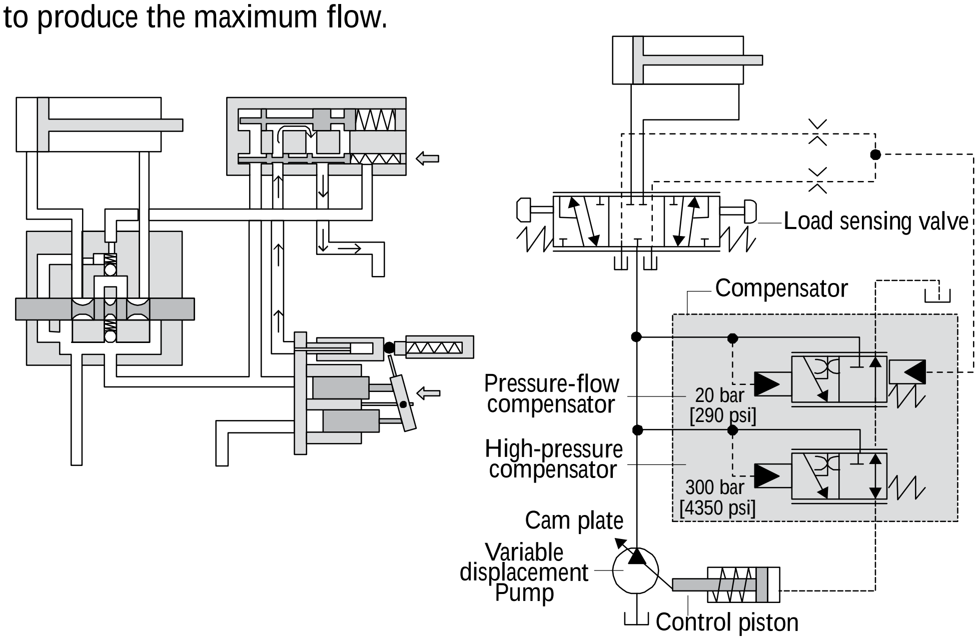


(a) Schematic representation (b) Equivalent symbolic representation

Schematic and symbolic representations of a pump compensator in a load sensing hydraulic pump

Operation of a Load Sensing System

The load sensing system for the control of a hydraulic actuator consists of a variable-displacement pump, a compensator block, and a load-sensing closed-centre directional control valve. The 20 bar [290 psi] spring of the compensator forces the pressure-flow compensator spool towards the left when there is no pressure in the system. This normal position of the spool provides for the fluid a direct passage from the camplate control piston to flow to the reservoir. As there is no fluid pressure acting on the control piston of the pump, the camplate of the pump is forced to move to its maximum angle position. In this position, the pump is ready to produce the maximum flow.



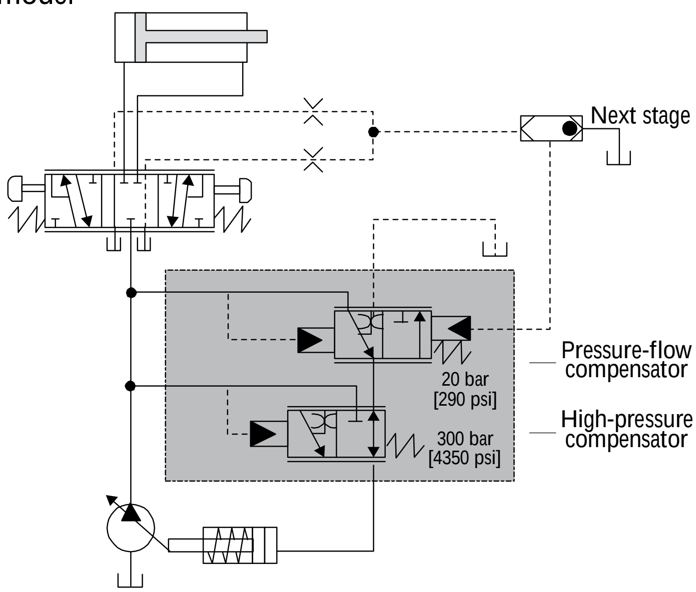
(a) Schematic diagram (b) Equivalent circuit diagram

Schematic and symbolic representations of a simple load sensing system in its initial position

When the pump is switched on, the system will slip into the following modes: (1) low-pressure stand-by mode (when the pump is on and the directional control valve is in its centre position), (2) load-sensing mode (when the directional control valve is actuated and load is moving with the requirement of pressure and flow), and (3) high-pressure stand-by mode during its cycle of operation (when the load comes to a stand-still under pressurized condition).

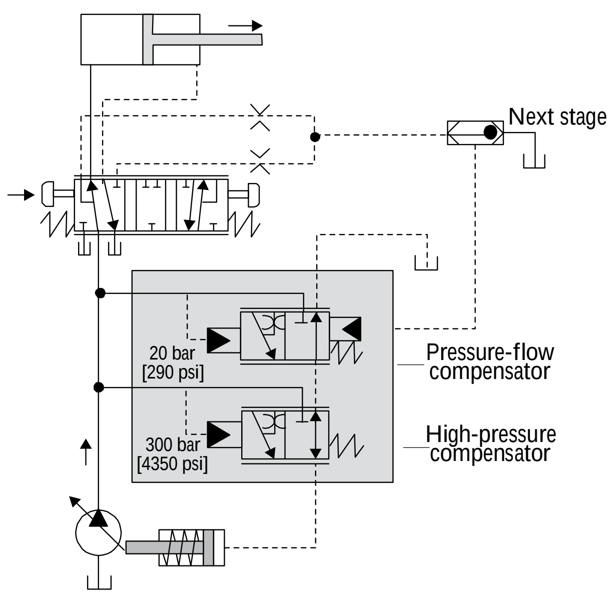
Low-Pressure Standby Mode

Assume that the flow to the actuator is blocked by the closed-centre directional control valve, when the pump is switched on. As soon as the pressure reaches 20 bar [290 psi], the pressure-flow compensator spool moves to the right against the low-pressure spring, and hence, the flow is directed to the camplate control piston. This flow causes the camplate to de-stroke and make the pump to deliver a minimal flow at the low pressure to the idling system for making up the internal leakages. This position of the system is regarded as the low-pressure standby mode.



The load sensing system in the low-pressure stand-by mode

Load Sensing Mode

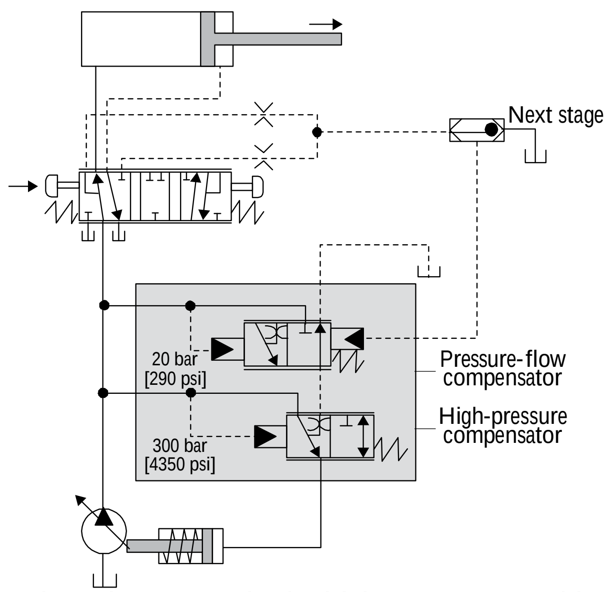


The load sensing system in the load sensing mode

When the spool of the load sensing directional control valve is shifted to its left envelope, the flow is now directed to the cylinder as well as to the right-hand side of the pressure-flow compensator spool. The pilot line senses the higher pressure as demanded by the load. The pilot pressure along with the force of the 20 bar [290 psi] spring moves the pressure-flow compensator spool to the left-hand side and drops the pressure from the camplate control piston. The camplate moves to a position with a greater angle, and the pump begins to produce more flow. The pump now adjusts automatically and delivers the required flow at a higher pressure as per the requirement of the load.

High-pressure Standby Mode

Eventually, the cylinder reaches the end of its stroke, and the system pressure tends to goes up. The pressures on both ends of the pressure-flow compensator spool remain equal as shown in the figure below. The 20 bar [290 psi] spring forces the pressure-flow compensator spool to the left-hand side. When the load pressure reaches the required maximum level (say 300 bar), the high-pressure compensator spool moves to the right-hand side proportionately and directs fluid to the camplate control piston. The piston moves the camplate automatically to its near zero angle position, and the pump stops producing flow to the system. This position is called the high-pressure standby mode, providing just enough flow to make up for internal leakage in the system.



The load sensing system in the high-pressure stand-by mode

Authored by JOJI Parambath, Founder/Director, Fluidsys Training Centre, Bangalore

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Reference:
(1) JOJI PARAMBATH, Industrial Hydraulic Systems – Theory and Practice, Universal Publishers, Boca Raton, USA, 2016. http://www.universal-publishers.com/book.php?method=ISBN&book=1627340580
(2) Document on: 'Load Sensing Systems - Principle of Operation', Eaton Corporation, Hydraulics Division, Eden Prairie, MN, USA.

Note: A comprehensive account of the topic is given in the textbook on 'Industrial Hydraulic Systems-Theory and Practice' by Joji Parambath.

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