Book 2, Chapter 11: Flow divider circuits

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When you must to split a single hydraulic line into two or more identical flow paths, a tee or several tees can be the first solution. However, if the resistance in all the branches is not identical, flow can vary greatly in each path. Adding flow controls at the tee outlets makes it possible to change resistance and equalize flow in each branch, but as the machine operates, work resistance changes often require constant flow modifications. A device called a *flow divider* splits flow and compensates for pressure differences in most cases. A flow divider can split flow equally, unequally, and into more than two paths. One design maintains a constant flow for one outlet and directs any excess flow to a second outlet.

Fig 11-1

Figure 11-1 pictures the ISO symbol for a flow-dividing valve. While the ISO symbol shows the function of the valve, it does not indicate which design it is. Fluid entering the flow divider splits and passes to both outlets equally. Figure 11-2 shows the symbol for a spool -type flow-divider and gives a better indication of the valve's operation. Note that a spool-type flow divider will not allow reverse flow. When using a spool-type flow divider to synchronize cylinders, add check valves to pass reverse flow. However, when the cylinders reverse, there is no synchronization with a spool-type flow divider.

Figure 11-1. ISO symbol for flow divider.

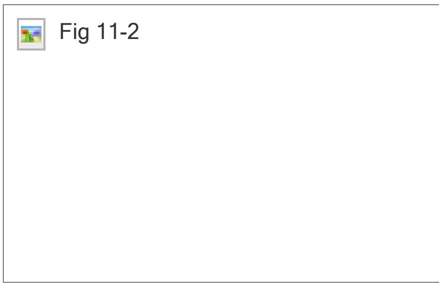


Figure 11-2. Spool-type flow divider.

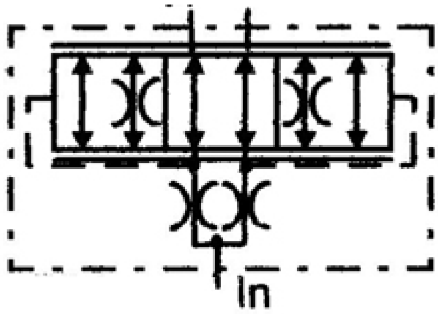


Figure 11-3. Spool-type flow divider and combiner.

Figure 11-3 shows a divider/combiner that synchronizes actuators in both directions of travel. It splits pump flow to the actuators and also assures that equal reverse flow returns from both cylinder ports.

Figure 11-4 pictures a flow divider with bypass relief valves that allow a lagging cylinder to complete its stroke. Reverse-flow check valves allow free flow around the divider spool while the actuator returns.

Figures 11-5 and 11-6 show a priority flow-divider symbol. Port *CF* (controlled flow) of this flow divider always has the same flow when the pump is producing that flow or more. Excess pump flow goes through port *EF* (excess flow) to tank — or to another circuit.

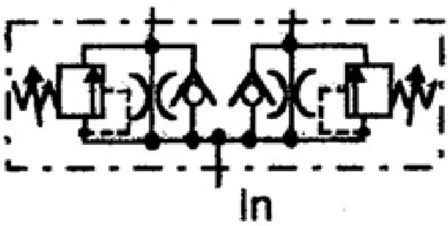
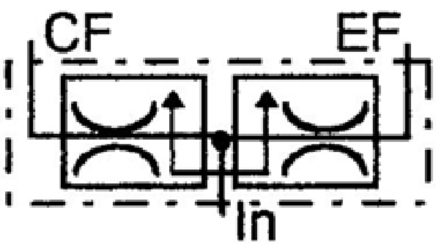


Figure 11-4. Spool-type flow divider with bypass reliefs and check valves.

Figures 11-7 and 11-8 show motor-type flow-divider symbols (as drawn by the manufacturers). This type flow divider is more efficient in most circuits. Motor-type flow dividers also work well in flow- and/or pressure-intensification circuits. They are available with multiple outlet ports and/or unequal flows.

Spool-type flow dividers and circuits

Spool-type flow dividers split flow through pressure-compensated fixed orifices. The pressure-compensation feature ensures near-equal flow through the orifices — even when inlet and/or outlet pressures fluctuate.



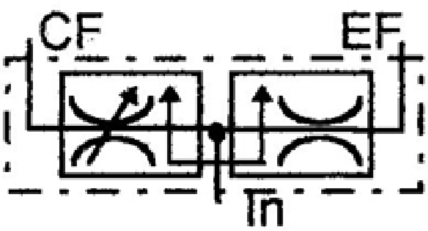


Figure 11-5. Fixed-flow spool-type priority flow divider.

Figure 11-6. Variable spool-type priority flow divider.

Spool-type flow dividers can split flow equally or unequally, according to the orifice sizes. Always use spool-type flow dividers at or near their rated flow. Because most designs use fixed orifices, equality of flow is poor when used below their rated flow. If flow exceeds the rating of the valve, high pressure drop causes poor performance and fluid heating.

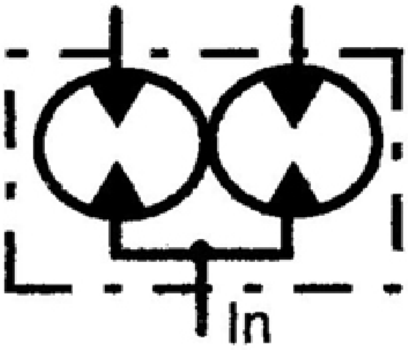


Figure 11-7. Motor-type flow divider.

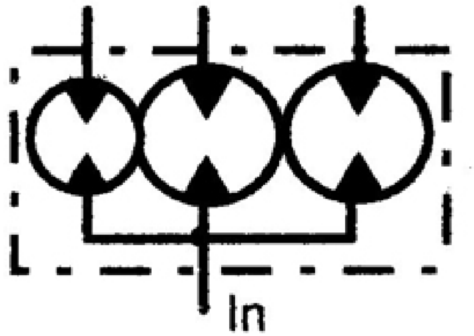


Figure 11-8. Unequal, triple-outlet motor-type flow divider.

The dividing accuracy of spool-type flow dividers can be as close as ±5%, depending on the pressure difference at the outlet ports.

Figure 11-9 shows a spool-type flow divider splitting pump flow equally. With this circuit, flow to each directional valve is nearly equal, even with one cylinder working at high pressure while the other cylinder is at low pressure or stopped by a centered valve.

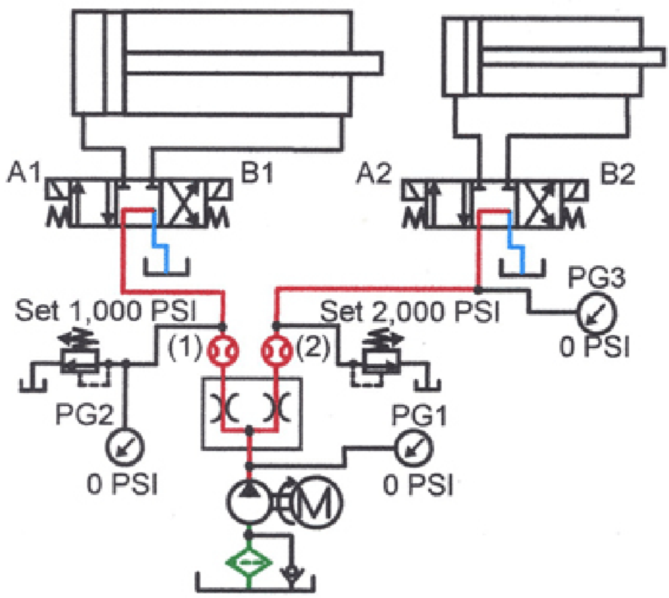


Figure 11-9. Spool-type flow divider piped to split pump flow. (Shown at rest with pump running.)

In Figure 11-10, fluid from port 1 flows to tank through the directional valve while fluid from port 2 drives a cylinder. Pressure at port 1 is 0 psi while pressure at port 2 is 1500 psi. Under these conditions, pressure at the flow divider inlet also is 1500 psi. Pressure at the inlet of a spool-type flow divider is always equal to the highest-pressure outlet. This condition generates a lot of heat because pressurized oil leaving port 1 is not doing work. It is best to use a spool-type flow divider in circuits where both outlet ports are at or near the same pressure. The higher the pressure variation, the greater the energy wasted as heat with spool -type flow dividers. When outlet pressures continuously vary by more than 300 to 500 psi, it is best to use a motor-type flow divider.

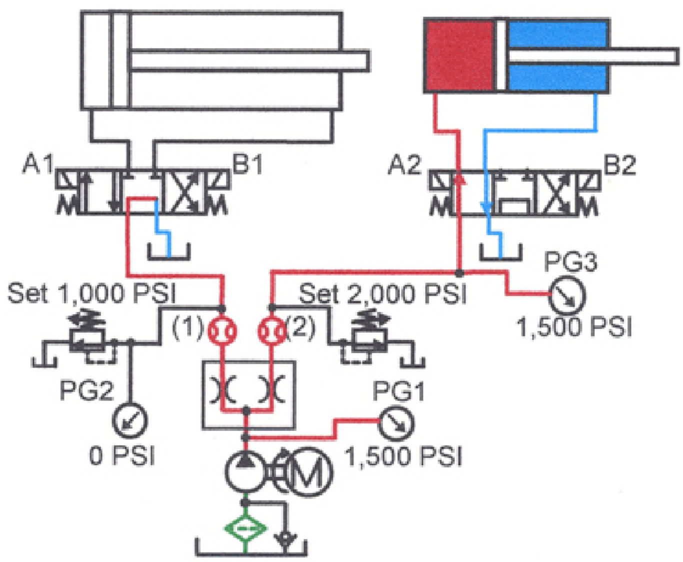


Figure 11-10. Spool-type flow divider piped to split pump flow. (Shown with right-hand cylinder extending.)

When splitting flow into more than two paths, add another spool-type flow divider to each outlet of the first divider. Figure 11-11 shows a synchronizing circuit for four unidirectional hydraulic motors. Flow split equally by the first spool-type flow divider goes to two more spool-type flow dividers. The second pair of spool-type flow dividers split the half flow from the first spool-type flow divider, and sends equal flow to the four motors.

When using spool-type flow dividers for equal flow, the total number of dividers must be an odd number. If used in any even combination, flow will not be equal from all outlets -- unless the first divider has unequal flow from its outlets.

To get three equal outputs with spool-type flow dividers use one with unequal outputs, say 33.3% and 66.7%. Send flow from the 33.3% side to power the first actuator. Send flow from the 66.7% side to an equal-flow divider. Flows from the equal flow divider outlets is now 33.3% of total pump flow, so all three outputs are the same.

Notice that these circuits cannot handle reverse flow. Reverse flow through a spool-type flow divider will lock up one actuator when return pressure differs at the outlet ports.

Also notice that each outlet of a flow divider can have a different pressure. Figure 11 -9 shows outlet 1 with a relief valve set at 1500 psi, and outlet 2 set at 2000 psi. (If both cylinders operate at the same pressure, substitute a single relief valve at the pump.) However, if both cylinders are moving and one of them stalls at 2000 psi, both cylinders will stop. The relief valve arrangement in Figure 11-11 allows any motor needing more than 2000 psi to stop while all other motors continue turning.

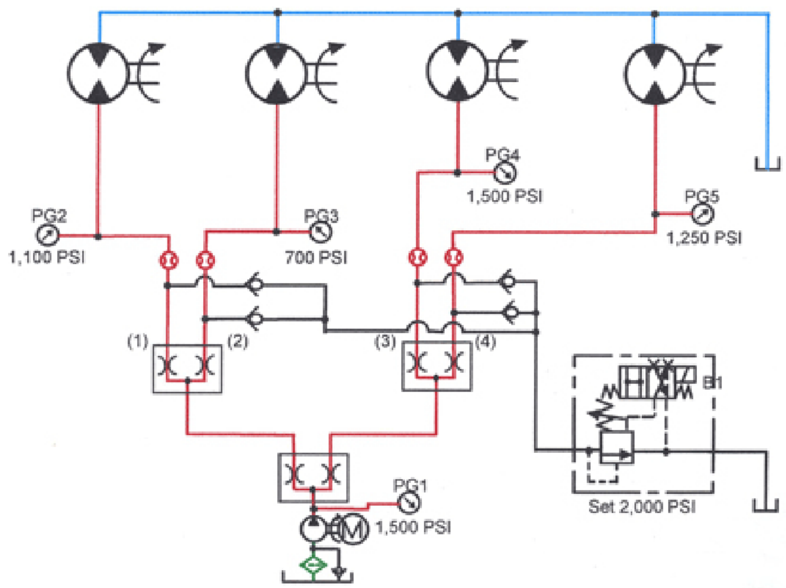


Figure 11-11. Spool-type flow divider piped to split pump flow into four equal parts (Shown with pump running.)

Spool-type flow divider/combiners

Spool-type flow dividers only allow flow in one direction. From the symbol in Figure 11-2, it is plain that reverse flow would lock up one of the cylinders. The cylinder that needs less resistance actually gets more. In a circuit where flow must go both ways, use a check valve to bypass the flow divider.

Figure 11-12 shows spool-type flow dividers in a circuit that synchronizes two cylinders. As the cylinders extend, the flow divider splits the flow and cylinder speed is nearly the same. When the cylinders retract, bypass check valves allow fluid to go around the divider. There is no synchronization from the cap-end flow divider at this time. A second flow divider with bypass check valves on the rod-end ports (as shown) is necessary for identical movement while retracting. As depicted in Figure 11-4, some flow dividers come with integral bypass check valves. Integral bypass check valves save piping time, have fewer leaks, and are more compact.

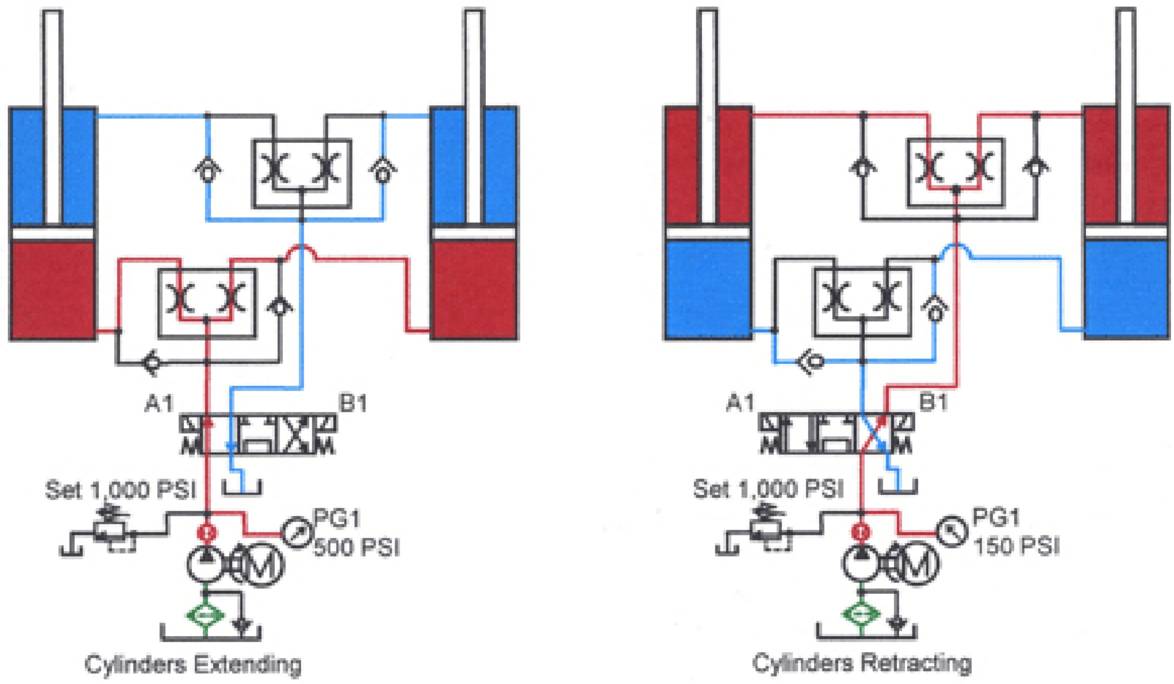


Figure 11-12. Spool-type flow divider arranged to synchronize two cylinders.

Because flow dividers are not 100% accurate, one of the cylinders may lag. Because there is internal leakage past the spool, any flow divider will let the lagging cylinder continue its travel. Because of the bypass leakage, the speed of the lagging cylinder while it is going to the end of its stroke is very slow. Integral relief valves (as shown in Figure 11-4) allow the lagging cylinder to catch up quickly. Set these relief valves between 50 and 150 psi. Once the pressure difference across the valve reaches this pressure range, fluid bypasses the restricted spool to quickly re-phase the cylinders.

In Figure 11-13, a single flow divider/combiner synchronizes cylinders in both directions of travel. Here a flow divider/combiner replaces the flow divider and check valves in Figure 11-12. Because there is no ANSI symbol for the flow divider/combiner, add bi-directional arrows to the one-way flow-divider symbol. This more-detailed symbol helps to clarify the valve's action. Bi-directional arrows show the divider/combiner function. These detailed symbols come from manufacturers' catalogs and represent their interpretation of their valve's function.

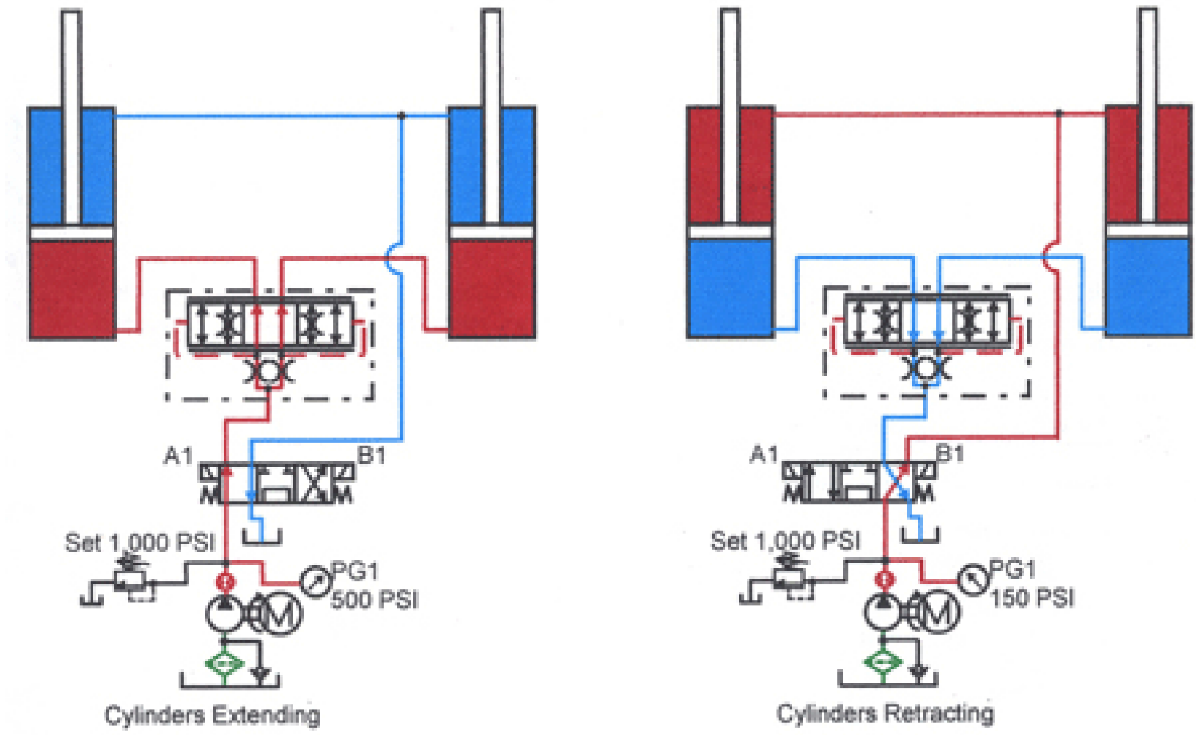


Figure 11-13. Spool-type flow divider/combiner arranged to synchronize two cylinders.

As the cylinders extend, the divider/combiner splits the flow to keep cylinder speeds nearly the same. When the cylinders retract, the divider/combiner shifts internally and equalizes return flow also.

A flow divider/combiner wastes energy the same as a standard flow divider. In essence these devices are infinitely variable pressure-compensated flow control pairs. Any flow control will cause heat because it is a restriction.

Flow dividers or flow divider/combiners are not designed to control running-away loads. For the circuits in Figures 11-12 and 11-13, a counterbalance valve in the line between the directional valve and the flow divider may be necessary if the loads can run away.

Spool-type priority flow dividers

Figure 11-14 shows a typical spool-type priority flow divider circuit. A priority flow divider maintains constant flow from the controlled flow (*CF*) port. Any additional flow passes out the excess flow (*EF*) port. The non-standard symbol in the Figure is one typically found in manufacturers' catalogs. The controlled flow may be fixed or adjustable, according to the circuit needs. The excess flow may be sent to tank or to another circuit as required. (When there is pressure at the excess flow port, make sure the valve design can handle it.)

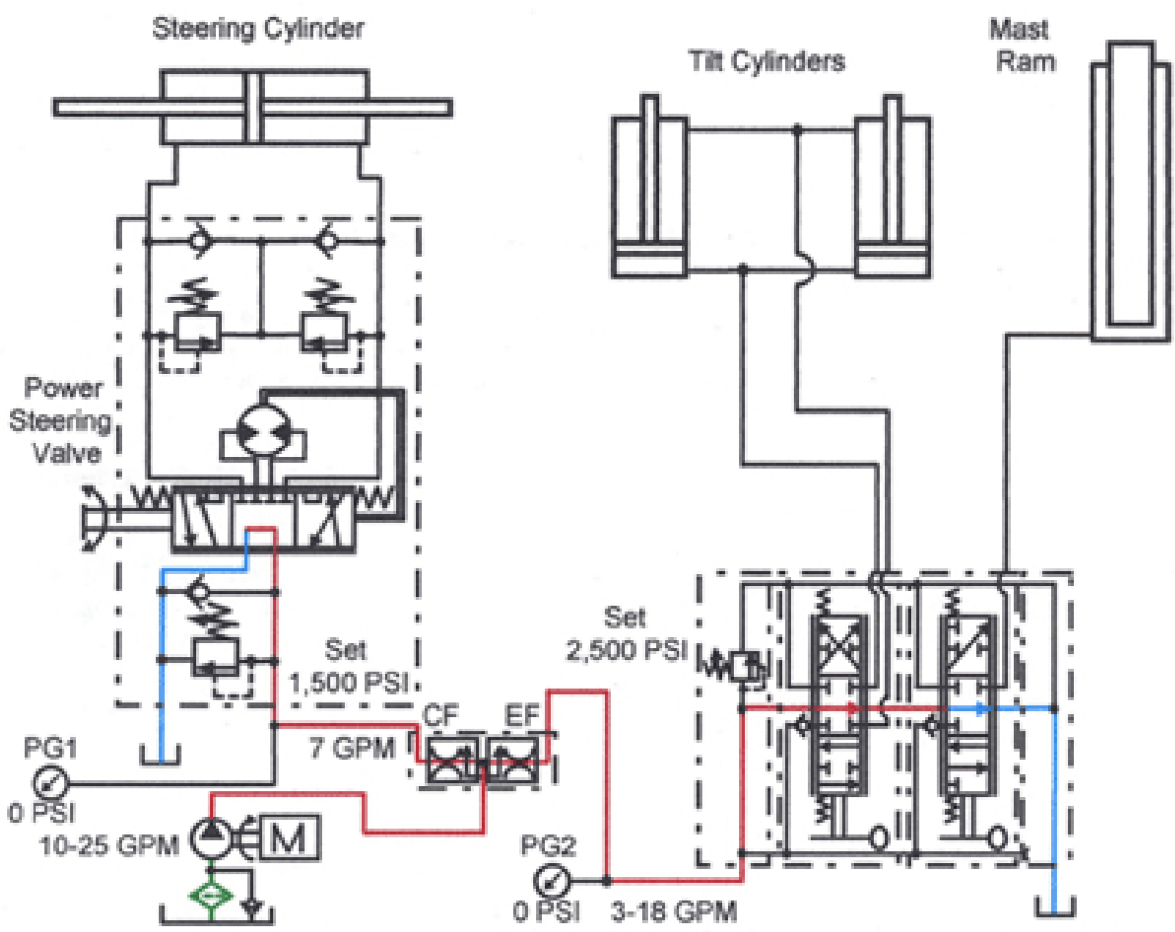


Figure 11-14. Typical lift-truck circuit using spool-type priority flow divider.

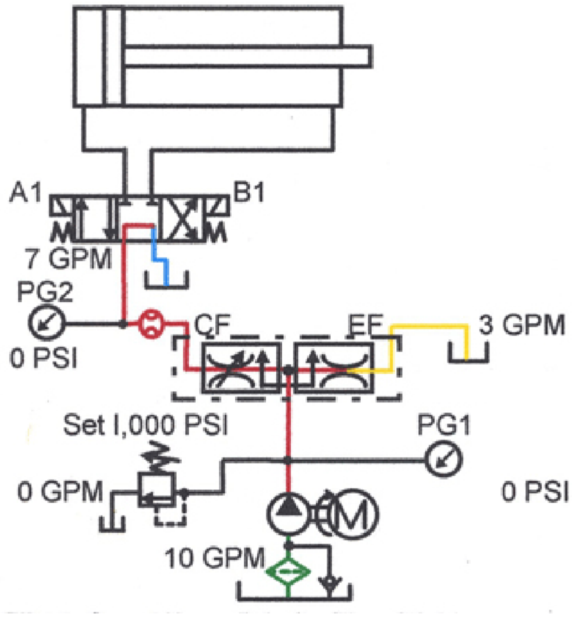
Some priority flow dividers are more like 3-port flow controls and cannot stand backpressure at the *EF* port. Use these flow dividers for bleed-off flow controlling only. With a bleed-off type priority flow divider, pressure at *EF* port causes flow at the *CF* port to fluctuate.

In Figure 11-14, a fixed-orifice priority flow divider is used on a vehicle with power steering and hydraulic actuators. This is the standard circuit for a forklift truck using a fixed-volume pump. The power-steering circuit needs 7 gpm and pump flow at idle is a minimum of 10 gpm. The actuators need as much as 15 gpm for maximum speed.

Figure 11-15. Spool-type priority flow divider arranged to bleed-off excess flow to tank. (Shown with pump running.)

When the vehicle is operating, the power steering circuit will always have at least 7 gpm. When the mast or tilt cylinders need fluid, excess pump flow operates them. Because there is little excess flow at idle, the mast and tilt cylinder's speeds are slow at this time.

The circuit in Figures 11-15 and 11-16 controls the speed of a hydraulic cylinder powered by a fixed-volume pump. The adjustable controlled-flow port of the priority flow divider connects to the cylinder valve, with the excess-flow port piped to tank. This arrangement controls cylinder speed and keeps heat build up low because the pressure in this circuit is only slightly higher than the cylinder needs.



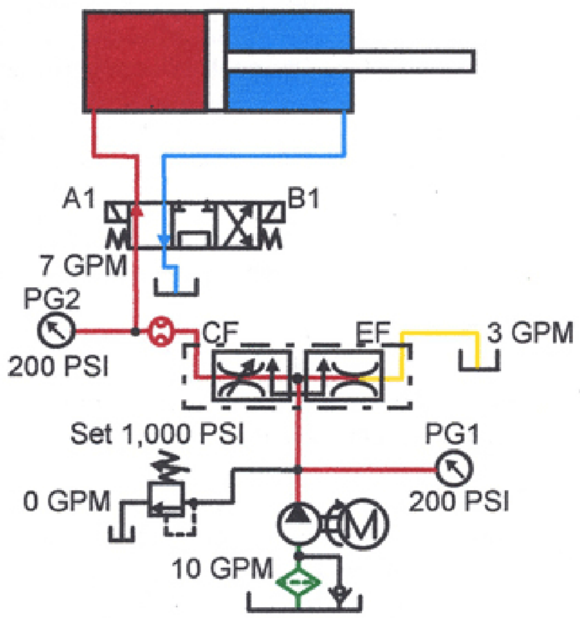


Figure 11-16. Spool-type priority flow divider arranged to bleed-off excess flow to tank. (Shown with cylinder extending.)

Most priority flow dividers are pressure compensating so the priority flow remains constant even when pressure changes occur. As long as there is enough pump output, the controlled flow is constant. Excess flow changes as pump volume varies.

A priority flow divider wastes energy just like any spool-type divider. The inlet pressure to the divider is the same as the highest outlet pressure. When either outlet port is pressurized, the port with little or no pressure is wasting energy and generating heat.

Rotary (motor-type) flow dividers and circuits »

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