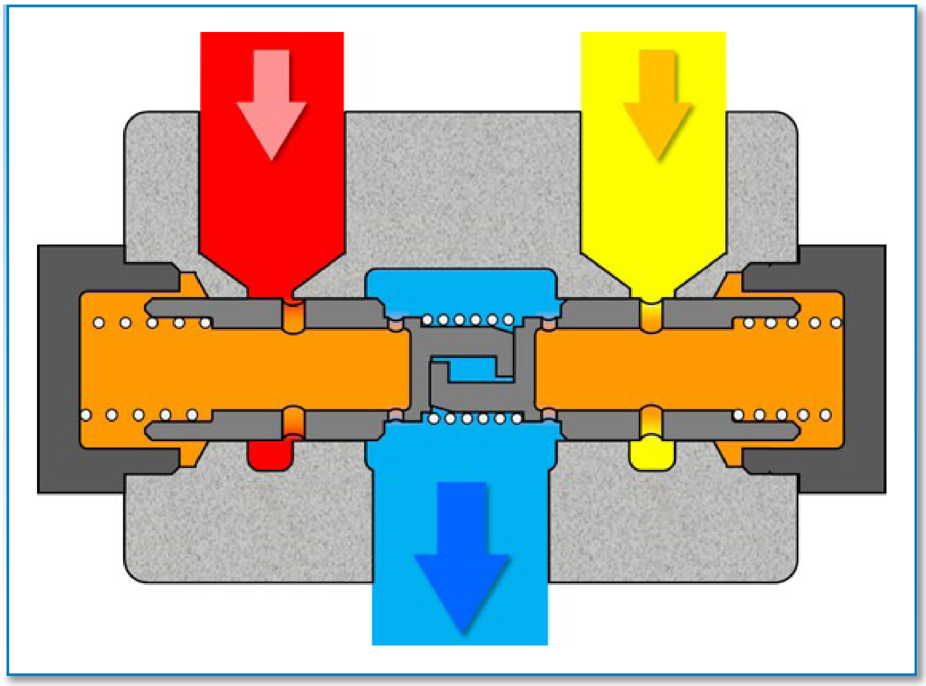
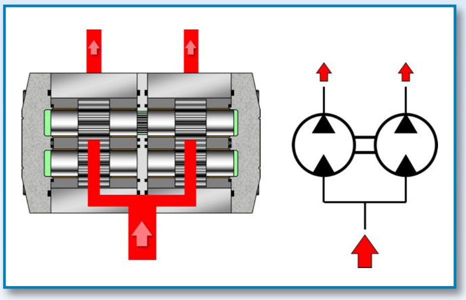
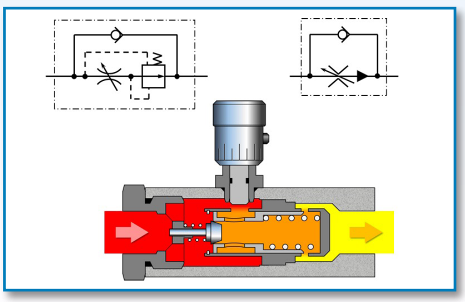
A guide to selecting the right hydraulic flow control valve to optimise system performance and efficiency.

Author:
Steve Skinner

In order to control the speed of a hydraulic actuator (cylinder or motor) it is necessary to vary either its displacement or the actuator flow rate. For a standard hydraulic cylinder, varying its displacement (the amount of cylinder piston movement for a given volume of fluid) is not an option since this is determined by the dimensions of the cylinder when it is manufactured.







BACKGROUND

In order to control the speed of a hydraulic actuator (cylinder or motor) it is necessary to vary either its displacement or the actuator flow rate. For a standard hydraulic cylinder, varying its displacement (the amount of cylinder piston movement for a given volume of fluid) is not an option since this is determined by the dimensions of the cylinder when it is manufactured. Certain types of hydraulic motor however can offer the option for either infinitely variable displacement (between minimum and maximum values) or two discrete displacements (high – low). Of the two, dual-displacement motors are the most common since motors with an infinitely variable displacement capability are relatively complex (and therefore expensive) components. Even dual displacement motors will have a significant cost penalty over equivalent sized fixed displacement units.

For a given pressure differential across the motor ports, changing its displacement will of course also change its torque output (Torque is proportional to Pressure Difference multiplied by Displacement)

In the majority of applications therefore, speed control of an actuator is achieved by varying the actuator flow rate. Here again, two alternatives may exist i.e. either vary the flow of the pump or control the flow by a flow control valve. Varying the pump flow rate requires either a variable displacement pump (again a relatively costly component relative to a fixed displacement equivalent) or a variable speed drive. On mobile equipment, a diesel engine pump drive does of course offer a variable speed capability but normally over a relatively narrow speed range. Variable speed electric drive motors in industrial systems are now becoming increasingly popular and in some applications can show worthwhile benefits in terms of operating efficiency and noise.

However, when two or more actuators have to operate at the same time, a variable flow pump solution for each actuator is unlikely to be an economic solution so some means of dividing and controlling the flow to each actuator is then necessary which is the task carried out by flow control valves. The system designer then has to decide not only what type of flow control valve to use but also its best location within the system i.e. controlling the actuator inlet or outlet flow in either direction of movement. Simply adding a flow control valve to vary an actuator's speed, without considering its effect on the rest of the system, is likely to create inefficiency in the system which means heat. As someone once remarked, an alternative name for a flow control valve is 'a heater'. The correct choice of flow control valve and its location in the system is therefore vital in determining not only the performance of the application but also how energy efficient it is. On equipment that operates over lengthy periods of time, the potential difference between getting it right and getting it wrong can be enormous.

SYSTEM OPTIONS

Before looking at the valve options in detail, it is worth reviewing the perennial issue of whether to control the inlet or outlet flow of an actuator known as meter-in or meter-out flow control.

METER-IN FLOW CONTROL

As its name suggests, meter-in flow control determines the speed of an actuator by restricting the flow of fluid entering its inlet port (fig. 1).

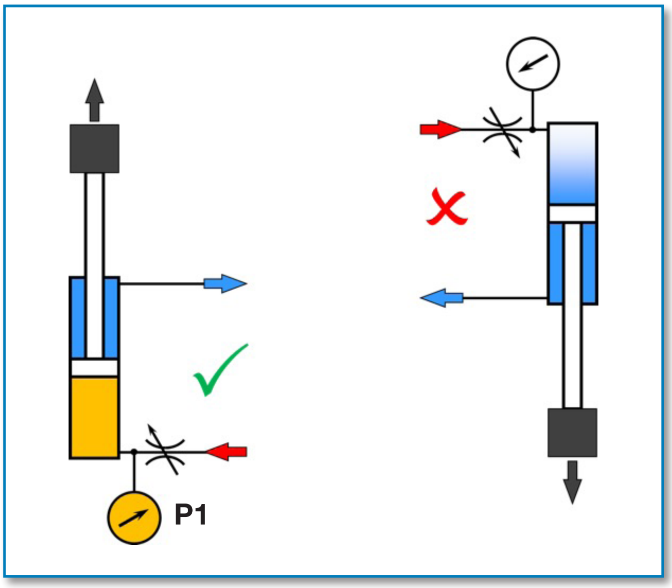


Fig. 1

If the exhaust flow from the actuator remains virtually unrestricted then the pressure at the inlet port of the actuator (P1) will be determined simply by the actuator size and the magnitude of the load, (Force divided by Piston Area in the case of a cylinder). The pressure on the inlet port of the flow control valve however will normally be at full system pressure. In the case of a fixed pump and relief valve system, whatever flow is not being used by actuators must be passing over the relief valve at full relief valve pressure. This could obviously create a problem of inefficiency and heat generation if the required actuator flow is significantly less than the full pump flow. In such situations a pressure compensated variable displacement pump may improve the system efficiency since the pump will now automatically reduce its output to that required by the actuators as determined by the setting of the flow control valves. However, this type of pump will be more costly than a simple fixed displacement pump and in order to reduce the pump flow the pressure at the pump outlet port must still be up to full compensator pressure even though the actuator may at this particular time be only lightly loaded.

A pressure compensated variable pump will therefore be more efficient than a fixed displacement pump when the actuator speed is required to vary (typically in manually controlled mobile applications), but will still be relatively inefficient if the load also varies (since the pump will always be operating at full compensator setting when its output is throttled). Further gains in efficiency can be made by using a load sensing variable pump where the compensator setting is now determined by the actuator load. This is achieved by sensing the load pressure at the actuator and transmitting this back to the pump normally by a small diameter pipe. The pump compensator will then adjust itself to whatever the load pressure is plus a fixed margin which is typically 15 to 25 bar (220 – 350 psi). This fixed margin provides a pressure differential across the flow controlling valves of the actuator (plus system pipework etc.) as well as providing stability of the pump control.

When several actuators operate simultaneously, the highest load pressure can be selected by means of simple shuttle or check valves but of course it does mean that the pump outlet pressure will be determined by whichever actuator requires the highest pressure thus detracting from the efficiency of operation of the lightly loaded actuators.

Meter-in flow control on its own is unsuited to actuators which have negative (run-away) loads since restricting the fluid entering the actuator will have no effect on the actuator speed if the load is acting in the same direction as the movement. This may also have to be considered when the load is normally positive (resistive) but it is required to decelerate the load either to a slower speed or a complete stop. In these cases the mass of the load and the friction forces acting on it need to be taken into account to determine the load inertia effects and therefore how effective meter-in control will be at such times.

METER-OUT FLOW CONTROL

As shown in figure 2, meter-out flow control restricts the exhaust flow from an actuator in order to control its speed.

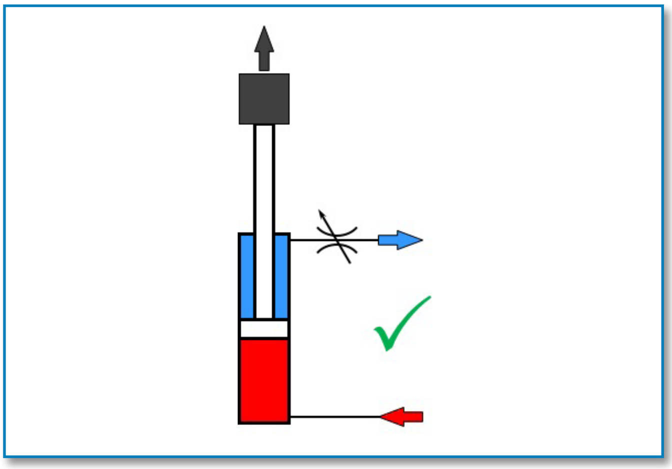


Fig. 2

In terms of efficiency it is no better (but also no worse) than meter-in control. When the exhaust flow is being restricted, the pressure at the inlet port of the actuator will be at full system pressure (relief valve or compensator setting) irrespective of the load being moved. As before, a variable displacement pump will be more efficient than a fixed displacement one but may still produce flow at a pressure significantly higher than that which the load actually requires during certain periods of operation. Furthermore, it is not possible with a meter-out control arrangement to obtain a signal pressure proportional to the load for use with a load sensing pump so the potential for further efficiency gains has diminished compared to a meter-in control system.

Unlike a meter-in control arrangement, meter-out flow control can be used to control the speed of a negatively loaded actuator since the cylinder piston can only move at the rate at which fluid is allowed to escape from the cylinder. It will also provide better control over the deceleration of a positively loaded actuator.

Perhaps the major issue with meter-out flow control used with cylinders however is the potential for pressure intensification. The worst case scenario is illustrated in figure 3 where a meter-out flow control is used on the annulus side of a negatively loaded cylinder to control the extending speed.

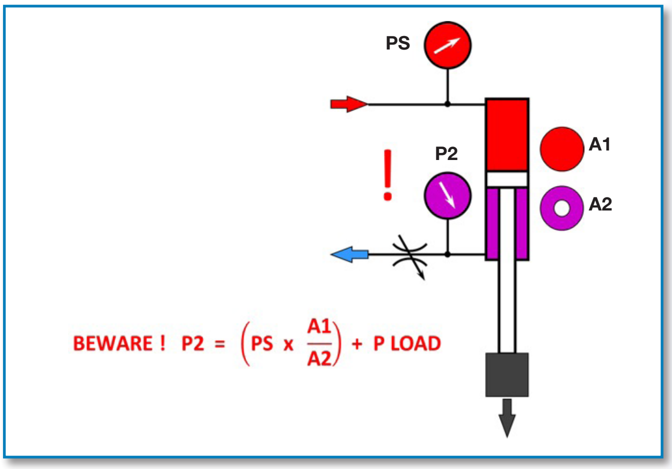


Fig. 3

In this situation, the pressure at the exhaust port of the cylinder will be equal to:

(SYSTEM PRESSURE x PISTON AREA RATIO) + LOAD PRESSURE

Where : AREA RATIO = FULL BORE AREA ÷ ANNULUS AREA

LOAD PRESSURE = WEIGHT or LOAD FORCE ÷ ANNULUS AREA

For example, with a 2:1 ratio cylinder operating at 200 bar (3000 psi) system pressure and a load pressure of 175 bar (2500 psi) the pressure generated at the cylinder outlet port when lowering would be 575 bar (8500 psi). This means that the cylinder, flow control valve plus the hoses, pipework and fittings between the two would have to be rated for at least this pressure. Sometimes, when a hose is replaced on a machine, this fact is overlooked or not appreciated !

BLEED-OFF FLOW CONTROL

There is however a third method of controlling the speed of an actuator which is to still control the inlet flow but this time by bleeding off from the pump flow the flow that is not required to drive the actuator (fig. 4).

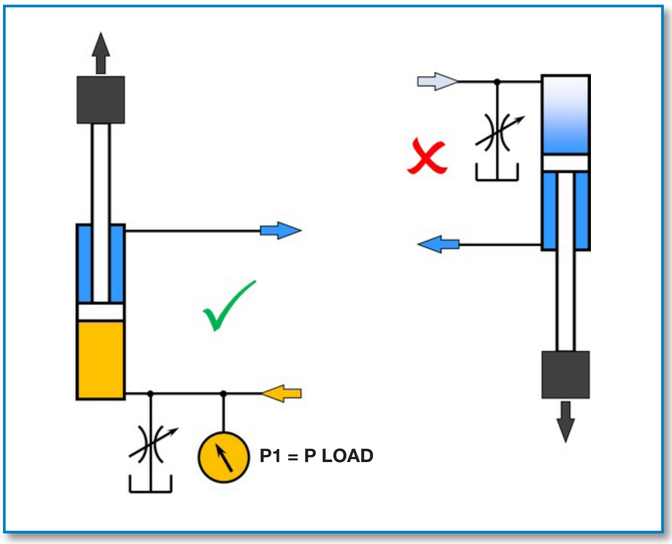


Fig. 4

As with meter-in flow control, this would not be suitable for a negatively loaded actuator neither would it be a sensible method to use with a variable displacement pump (since a variable pump would provide the required amount of flow to start with). At first sight it may also appear a wasteful, and therefore inefficient, approach but with a fixed displacement pump the excess flow (pump flow minus actuator flow) has to go somewhere. With meter-in and meter-out arrangements the excess flow would normally pass across the relief valve at a constant full relief valve pressure. With the bleed-off arrangement, the excess flow passes across the flow control valve but at load pressure not relief valve pressure which means that when the actuator is operating lightly loaded, the heat generated may be reduced significantly. There may however be a loss of control accuracy since it is basically the excess or unwanted flow that is being controlled. If the pump flow itself can vary (due to drive speed fluctuations or pump internal leakage) then the actuator flow will also vary resulting in speed variations.

With a standard bleed-off flow control arrangement the excess flow is diverted back to tank and so it is only possible to operate one actuator at a time. A typical application could therefore be to control a hydraulic motor with a varying load where the efficiency gains could be beneficial over long periods of operation. However, as will be described later, flow control valves are available where the excess flow can be used to operate other machine functions rather than just being diverted back to the reservoir.

In applications where actuator operating speeds and loads can vary significantly (typically in many mobile machinery systems) consideration has to be given to not only maximum speeds and loads but also the corresponding minimum levels. In order to maximise system efficiency this will normally involve the use of load sensing, variable displacement pumps, or where the cost of such components is not warranted, by using flow control valves which enable flow to be controlled with pump outlet pressures close to the load pressure requirements at any one time.

THROTTLE VALVES vs FLOW CONTROL VALVES

Having determined the optimum location for the flow control valve in a system, the next step is to decide whether a simple throttle valve or a pressure compensated flow control valve will be required. A simple throttle valve is no more than a variable restrictor of some sort such as the needle valve shown in figure 5.

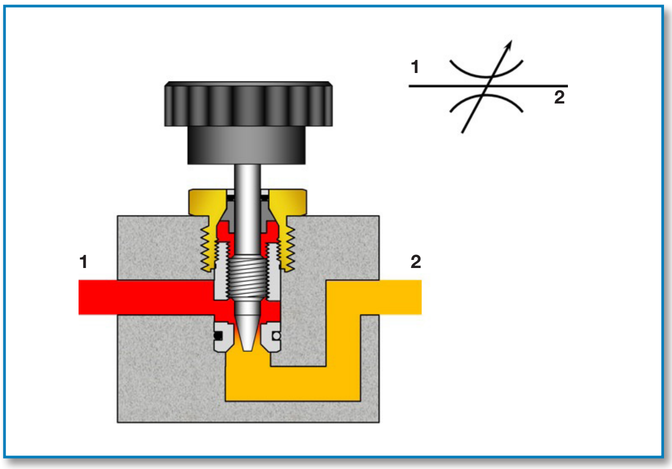


Fig. 5

Adjustment of the needle position varies the area through which the flow has to pass and therefore the throttling effect of the valve. Often a by-pass check valve poppet is included for the reverse direction of flow so that the valve provides restriction in one flow direction but with a free reverse flow. The amount of flow that is able to pass through the valve in the throttled direction is dependent not only on the adjustment of the valve but also the pressure difference across it. It may also depend to a lesser degree upon the viscosity and density of the fluid. Considering the valve used in a meter-in arrangement, the pressure difference across the valve will be dependent upon the system pressure on one side and the load pressure on the other. Assuming the system pressure remains constant, this means that the amount of flow passing through the valve will vary as the load pressure varies. Under light load conditions, when load pressure is low, the valve pressure drop will increase resulting in a higher flow rate and faster speed. Conversely, under heavy load conditions the load pressure will increase resulting in a lower valve pressure drop and slower speed. If the speed of two or more actuators needs to be synchronised (for example, as on the lift platform shown in figure 6), a simple throttle valve therefore will not maintain a constant actuator speed unless the load pressures are equal. This implies equal cylinder loads and equal friction so an off-centre loading of the platform is likely to cause an out-of-level operation.

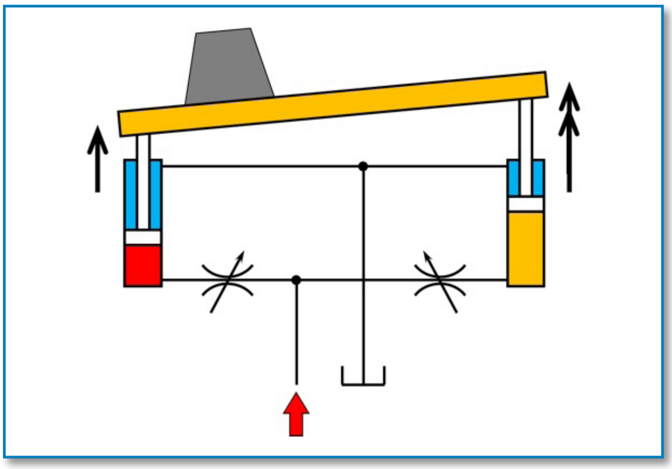


Fig. 6

However, there are many applications where the load and system pressure do not change significantly during machine operation so, provided speed holding is not critical, a simple throttle valve may provide an adequate and cost effective solution in such situations.

Where it is important to maintain a constant actuator speed irrespective of actuator load then a more sophisticated valve is required known generally as a pressure compensated valve. With this type of valve an additional poppet or spool (known as a 'hydrostat') is incorporated in series with the adjustable restrictor and senses the pressure difference across it (fig. 7).

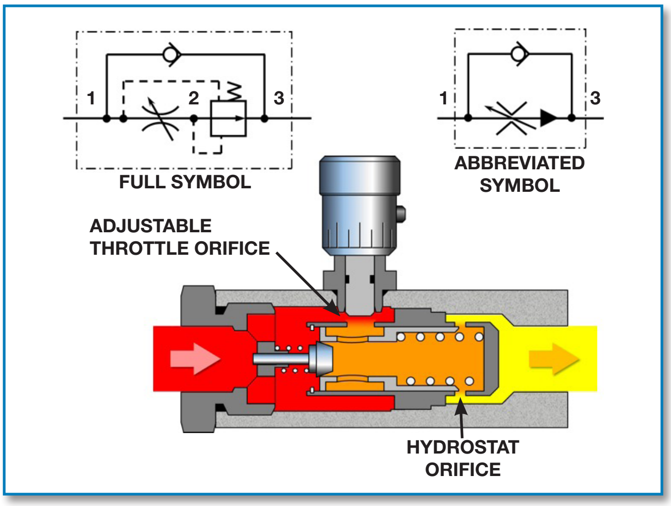


Fig. 7

The hydrostat spool is spring biased to an open position by a relatively light spring (typically around 8 bar / 120 psi) so that as soon as the pressure difference across the restrictor exceeds this value, (which tends to increase the flow through the valve), the hydrostat spool starts to close off creating additional restriction and thereby preventing an increase in flow. So whatever the pressure difference is across the complete valve (above the minimum), the hydrostat will automatically open and close to maintain a constant 8 bar / 120 psi difference across the variable restrictor. Ignoring any change in the fluid properties itself, this means therefore that the flow through the valve will also remain constant irrespective of load or system pressure variations. Using this type of valve on an unequally loaded lift platform therefore would ensure the platform remained level to a degree dependent upon the accuracy of the valves used (fig. 8).

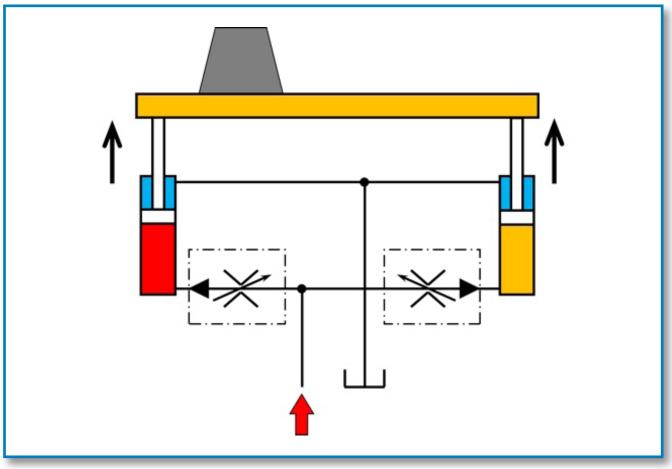


Fig. 8

Obviously there are practical limits to how accurate the valve can perform to maintain a constant flow and at very low pressure drops (below the value of the hydrostat spring) the valve will not compensate. But unless speed holding under varying conditions is absolutely critical, (requiring some form of closed loop control), the pressure compensated flow control will normally perform adequately.

VALVE OPTIONS

The type of valve illustrated in fig. 7 can be used in meter-in, meter-out and to a lesser extent, bleed-off arrangements to maintain the speed of an actuator constant (within the limits of accuracy of the valve) even though the load or supply pressures vary. Since the valve only controls the flow in one direction a second valve will normally be required to control flow in the opposite direction but a free-flow reverse check valve can be incorporated in the flow control valve to simplify the circuitry.

Where flow rates can be established at the prototype stage of a machine's development then a non-adjustable pressure compensated flow control valve can be used which will not only reduce cost but also ensure the machine settings cannot be tampered with. The flow setting of such valves is then specified at the order stage.

FLOW DIVIDERS

When two or more actuators operate simultaneously then a means of sharing the available flow in the required proportions is necessary. In some applications it may be possible to use separate pumps for each actuator, as in the case of the track drives used on some construction vehicles. In general however it is often more economic in terms of space and money to use a common pump for all actuators and to divide the flow as necessary either through a rotary or spool type flow divider. Rotary flow dividers consist basically of two or more hydraulic motors (often gear type) with their shafts mechanically linked so that both rotate at the same speed (fig. 9).

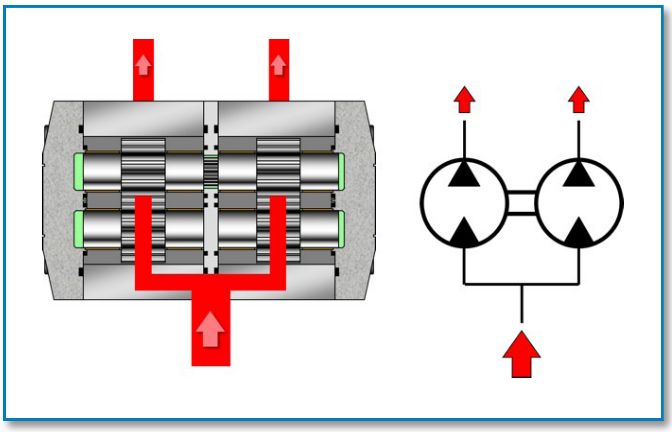


Fig. 9

Assuming the displacement of each motor is the same then both will require the same amount of fluid so the incoming flow will be split 50:50 between the two motor output ports. Using motors of different displacements of course will split the flow in the same ratio as the displacements if this is required. The accuracy of the flow division will depend upon the internal leakage, or slippage of each motor which may vary depending upon the outlet pressure of each motor port as well as variations in manufacturing clearances, wear etc. Rotary flow dividers do have the advantage however that if one output is lightly loaded compared to the other then that section generates a torque output to partly drive the other thus resulting in a lower inlet pressure requirement and very little loss of efficiency.

Spool type flow dividers offer an alternative approach which may often be more compact and lower in cost and figure 10 illustrates a typical example of a pressure compensated, spool type flow divider.

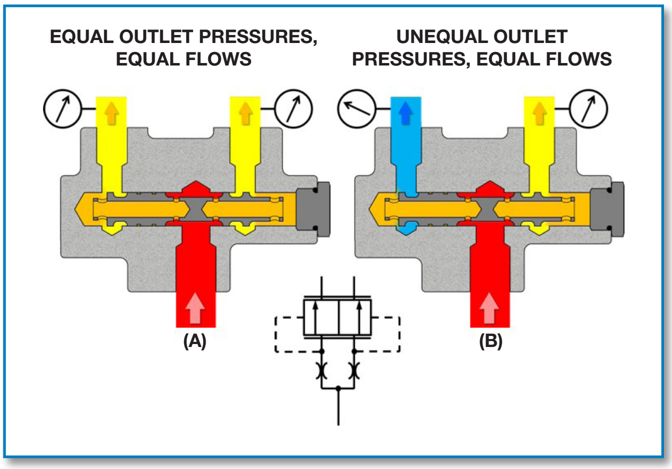


Fig. 10

Flow passing through the valve from inlet to each outlet passes firstly through a fixed restriction created by holes in the spool then through a variable restriction created by the gap between the spool lands and the outlet port openings. If the pressure in both outlets is the same (fig. 10A) then the spool remains in a central position where both variable restrictions are equal, resulting in equal flow to each outlet. If the pressure in one outlet is reduced however (fig. 10B), flow would tend to increase to that outlet resulting in a lower pressure on the left-hand spool end chamber. The unbalanced spool would then tend to move towards the left, partially closing off the variable restriction to the low pressure outlet thus avoiding the tendency for the flow to increase. Irrespective of the pressure levels in the two outlet ports therefore, the valve will adjust the spool position to maintain equal flow to the two outlet ports. If an unequal flow division is required (e.g. a 60:40 split) then the size of the fixed restriction holes can be of different sizes to provide this function.

Unlike a rotary flow divider, if the outlet pressures are different then the inlet pressure must be at the pressure level of the highest outlet plus an additional amount to account for the internal restrictions. Flow passing to the low pressure outlet may then have a significantly higher pressure drop which will generate heat. For efficient operation therefore, spool type flow dividers operate best when the pressure difference between the two outlets is relatively small or where large differences occur only momentarily. An unequally loaded lift platform again is an example of where a flow divider would help to maintain a level movement irrespective of the load position (fig. 11).

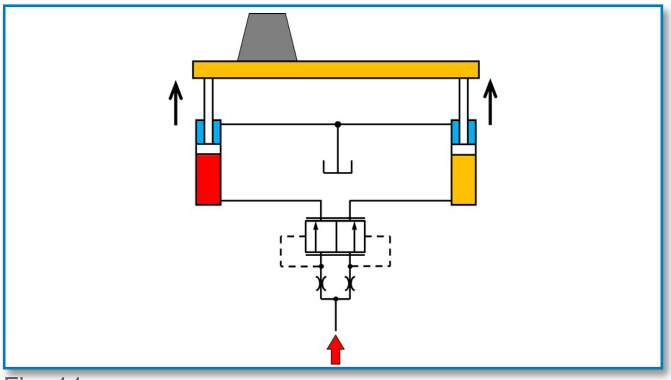


Fig. 11

Furthermore, if it is required to vary the speed of operation of the platform it is only necessary now to vary the single input flow to the flow divider rather than having to adjust and synchronise the setting of two pressure compensated flow control valves as in figure 8.

When synchronising the movement of two cylinders, consideration must be given to the situation where one cylinder reaches the end of its stroke slightly before the other (since all flow dividers possess some degree of inaccuracy). In this situation the flow to both outlets tends to stop as the spool moves to the extreme left or right hand end of its travel. It is then useful to incorporate a sequence valve on the inlet or relief valves on the outlet to enable the cylinder positions to equalise at the end of the stroke. The same situation arises with rotary type flow dividers where relief valves on the outlets are commonly used to limit the pressure intensifying effect of the flow divider when one outlet is operating at low pressure.

Flow dividers can also be used on vehicle drives to provide a 'differential lock' function. Considering a two-wheel drive vehicle as shown in fig. 12, in normal operation the wheel drive motors would be connected in parallel so that each would have the same pressure drop across them and therefore develop the same drive torque.

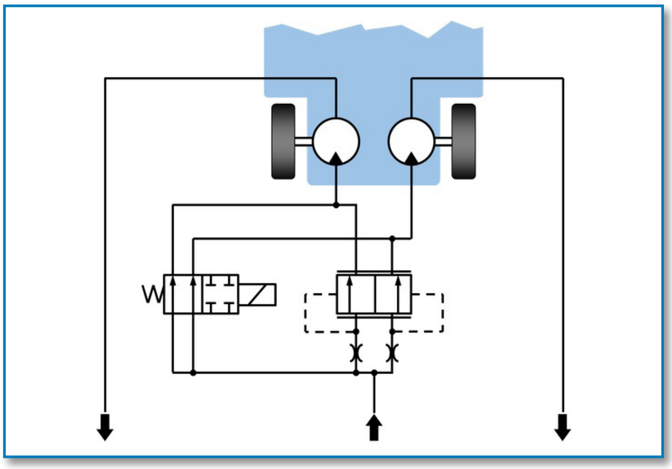


Fig. 12

Since the motors are not locked together mechanically or hydraulically they are also able to turn at different speeds such as would be required when the vehicle turns a corner and each wheel follows a different radius. However, if one wheel loses traction all of the flow tends to pass to the motor driving that wheel which simply spins freely and drive to the opposite wheel is lost. In this situation therefore, the flow divider can be switched into the circuit, (solenoid valve energised), to ensure that each wheel receives half of the available flow and thus providing drive to the wheel that still has traction.

The type of valve illustrated in figure 10 will divide the flow in one direction only so by-pass check valves would be required for a free reverse flow. If it is also required to regulate the flow equally in the reverse direction however then the valve can be modified to become a flow divider-combiner as shown in fig. 13.

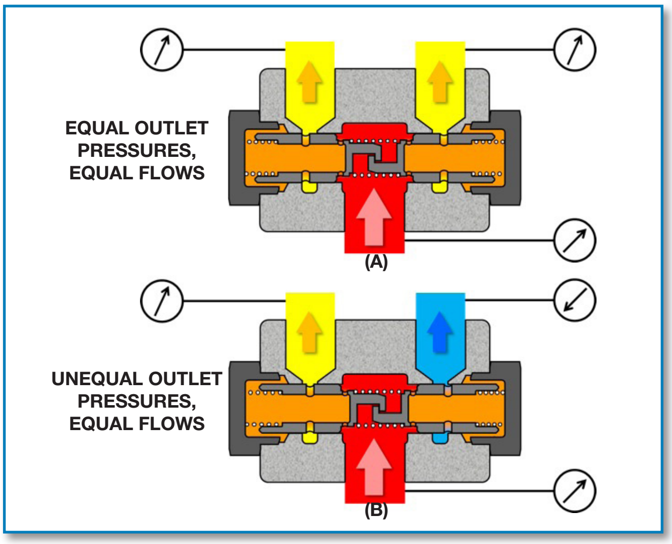


Fig. 13

In this case the valve consists of two spools linked together by a hook arrangement. When acting as a flow divider, flow into port 1 pushes the two spools apart and they act to provide a pressure compensated flow to each outlet port 2 and 3 as described previously. In flow combiner mode, reverse flow enters ports 2 and 3 pushing the spools together which again provides a pressure compensating function as the flows pass through the valve and combine to flow out of port 1 (fig. 14)

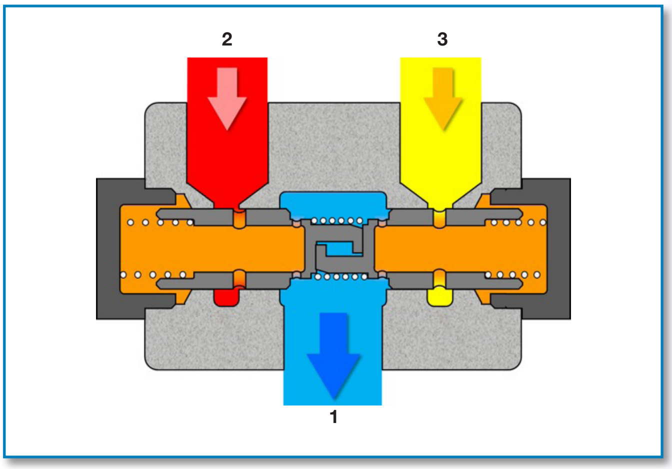


Fig. 14

PRIORITY FLOW DIVIDERS
Priority flow dividers also split a single flow into two components but in this case the primary, pressure compensated output takes priority over the available flow with the remainder passing to the secondary (by-pass) outlet (fig. 15).

If the inlet flow is less than the setting of the valve then all flow passes to the normally open priority port. As inlet flow increases however, and a pre-determined pressure drop is achieved across the adjustable throttle, the spool moves against the spring to limit any further increase in priority flow and diverts the excess to the secondary, by-pass port. The valve therefore provides a pressure compensated flow from the priority port while diverting the remaining flow to the by-pass port.

If the by-pass port is connected back to tank (as shown in figure 16) then the valve provides the accuracy of a meter-in flow control but with a potentially more efficient operation.

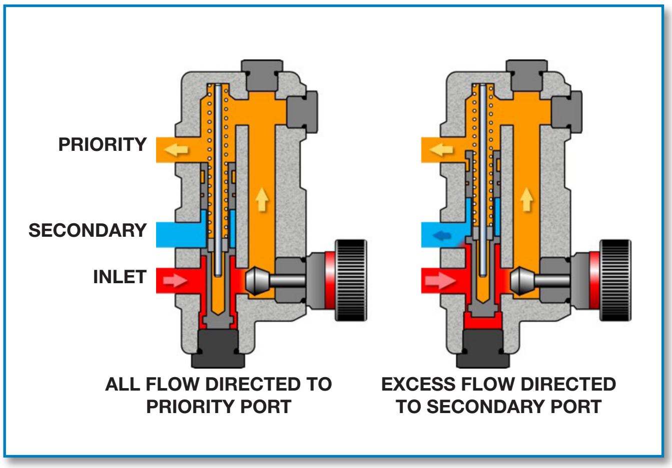


Fig. 15

As described earlier, using a flow control valve with a fixed displacement pump means that the excess flow (i.e. pump flow minus metered flow) has to pass over the system relief valve at full relief valve pressure. If the actuator is lightly loaded then this can create a very inefficient system since the full pump flow is being generated at full relief valve pressure even though the actuator requirement is for a much lower pressure. Using the priority flow divider however, the excess flow from the by-pass port can pass back to tank at a pressure only slightly higher than the load pressure. In this respect the result is similar to that obtained by using a bleed-off flow control but unlike a bleed-off arrangement the actuator flow is being directly controlled rather than the bleed-off flow so the accuracy of the control is better with a pump flow which may be varying. So where the load on an actuator can vary, the flow divider control valve will offer significant efficiency benefits during the lightly loaded periods of operation whilst still retaining good speed holding accuracy.

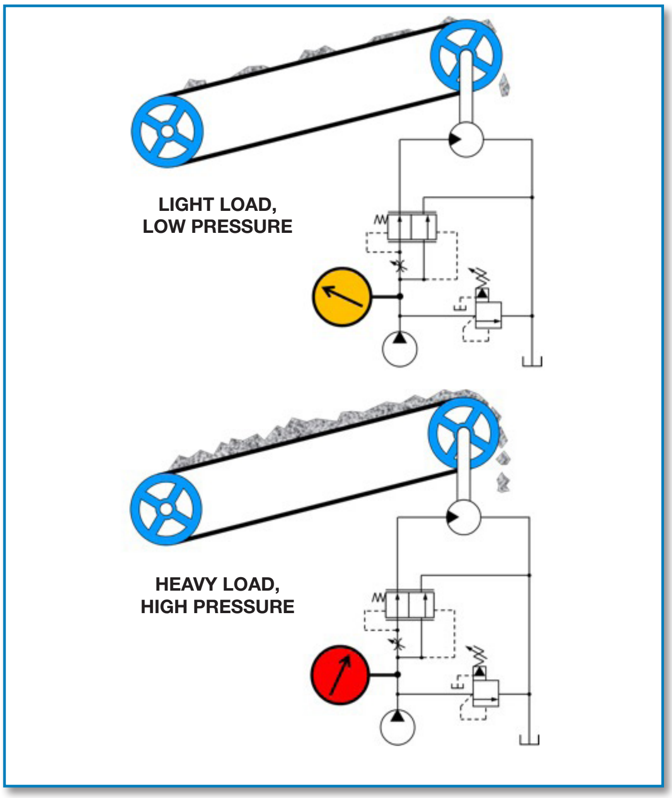


Fig. 16

In other cases the by-pass outlet of a priority flow divider can be used to operate other functions rather than being connected back to tank as illustrated in figure 17.

The inlet flow is then divided into a constant (pressure compensated) flow from the priority port to drive the motor with the remainder (non-compensated) flow directed to the by-pass port to operate a cylinder for example. If the inlet flow varies, caused for example by a variation in engine drive speed to the pump, the priority port flow will not change (provided the inlet flow is still greater than the priority flow setting) but the by-pass flow will increase or decrease accordingly. In some cases the dynamic performance of such valves may also be important i.e. how they react to sudden changes in operating conditions. In the example shown in figure 18 the motor drive pressure required will change suddenly as the load is dropped onto the conveyor.

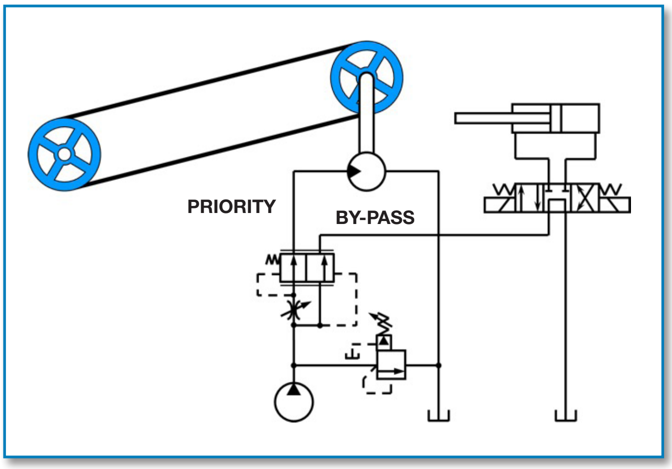


Fig. 17

In such situations the flow divider may have to react fast enough to maintain the priority flow at its set value even though the inlet flow to the valve may drop suddenly due to increased pump slippage or the prime mover drive speed dropping. Figure 19 illustrates the performance of a typical Webtec priority flow divider showing how the priority flow remains virtually constant as the priority port pressure changes suddenly from 25 bar to almost 200 bar. The reduction in flow to the by-pass port being the effect of a reduction in inlet flow. A similar response is achieved if the by-pass port pressure changes suddenly i.e. the effect on the priority flow would be minimal.

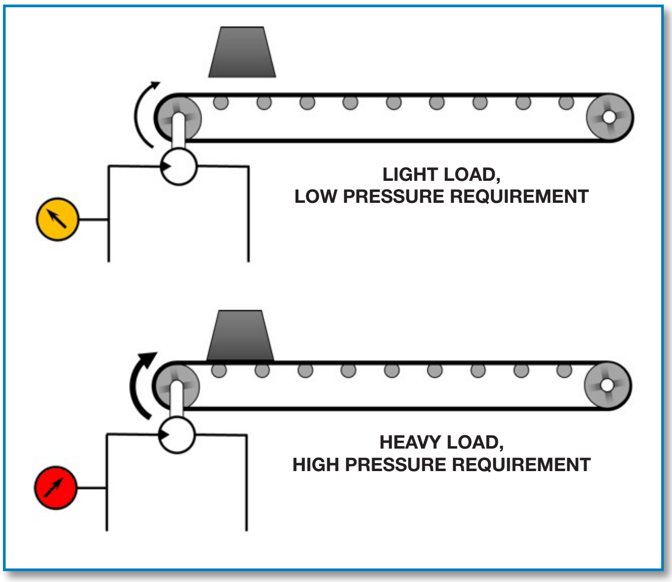


Fig. 18

A fast acting valve, such as illustrated in figure 19, could be prone to oscillation however as the valve sees a step change in outlet pressure resulting in a 'juddering' effect on the actuator operation. Internal damping of the valve components therefore has to be optimised in order to reduce this effect to acceptable levels.

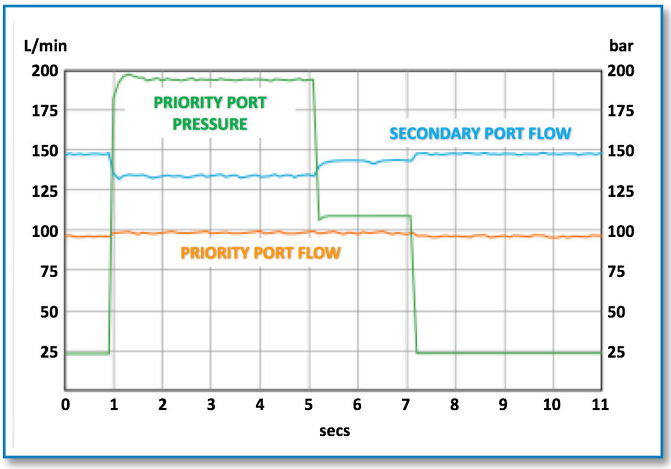


Fig. 19

The priority flow will normally be used for the most important function on the machine or the function where accurate speed holding under varying conditions is critical. For example, priority flow outputs are frequently used to supply a vehicle's steering function with the by-pass flow used for less important auxiliary functions.

CONCLUSION

Faced with the task of controlling an actuator's speed, a hydraulic system designer has many options available. Inevitably the choice will often involve finding the best compromise between equipment cost, running cost and performance. The requirements of a machine tool operating two shifts per day and to high levels of performance will inevitably be different to those of a crop harvester used perhaps for two weeks every year and where precise speed holding is not critical. In order to make the best choice for any application however, the system designer needs to fully understand the operation and application of all of the options available from the humble needle valve to the servo controlled variable displacement pump, and all of the choices in between.

TYPE OF VALVE	FUNCTION	TYPICAL APPLICATION
FIXED ORIFICE	Simple flow limitation but flow will vary if pressure drop varies. Tamper-proof.	Used to limit opening & closing speeds of valve spools and poppets to reduce shock, provide damping etc.
NEEDLE (THROTTLE) VALVE	Simple flow limitation but flow will vary if pressure drop varies. Can be adjusted.	Used to regulate speed of actuators where load does not vary or accurate speed holding is not critical.
PRESSURE COMPENSATED FLOW CONTROL VALVE (FIXED)	Flow control more or less independent of pressure drop. Tamper-proof.	Used to regulate speed of actuators where speed needs to be largely independent of load or supply pressure. Flow rate is pre-determined (non-adjustable)
PRESSURE COMPENSATED FLOW CONTROL VALVE (VARIABLE)	Flow control more or less independent of pressure drop. Adjustable (can be key-locked).	Used to regulate speed of actuators where speed needs to be largely independent of load or supply pressure. Flow rate can be adjusted.
VALVE FLOW DIVIDER	Divides flow into two equal or unequal parts. More or less independent of pressure drops. Single direction flow.	Divides a single pump flow to feed two actuators (typically motors) in a fixed proportion (eg. 50:50, 60:40 etc.) largely independent of actuator pressures.
VALVE FLOW DIVIDER / COMBINER	Divides flow into two or more equal or unequal parts	As above but for bi-directional operation and control of the actuators.
ROTARY FLOW DIVIDER / COMBINER	Provides priority flow to primary outlet, more or less indpendent of pressure drop, with excess flow provided to secondary outlet.	Divides a single pump flow to feed two or more actuators in a fixed proportion. Acts as a flow combiner in reverse direction. Can act as a pressure intensifier if one outlet is at a lower pressure than inlet.
PRIORITY FLOW DIVIDER	Provides priority flow to primary outlet, more or less indpendent of pressure drop, with excess flow provided to secondary outlet.	1. Provides a priority flow to a specific function (eg. vehicle steering) largely independent of pressure, with any excess flow directed to an auxilliary function. 2. Provides a controlled flow to an actuator largely independent of pressure, while spilling off the excess flow back to tank at virtually load pressure (rather than full relief valve pressure). Provides a more efficient control of speed when actuator load varies.

About the Author:
Steve Skinner

Steve Skinner has a degree in Mechanical Engineering from the University of Bath and has been involved in hydraulic fluid power systems for over 40 years including working on circuit design, on-site commissioning, troubleshooting, sales and marketing.

He is also the author of a number of training booklets as well as a book entitled, 'Hydraulic Fluid Power, A Historical Timeline', which he describes as, "a light-hearted ramble through the history of hydraulic fluid power from its birth at the end of the 18th century up to the modern day". To find out more visit:

www.steveskinnerpresentations.co.uk

About Webtec:

We are specialist manufacturers of hydraulic measurement and control products helping to improve the productivity of heavy machinery.

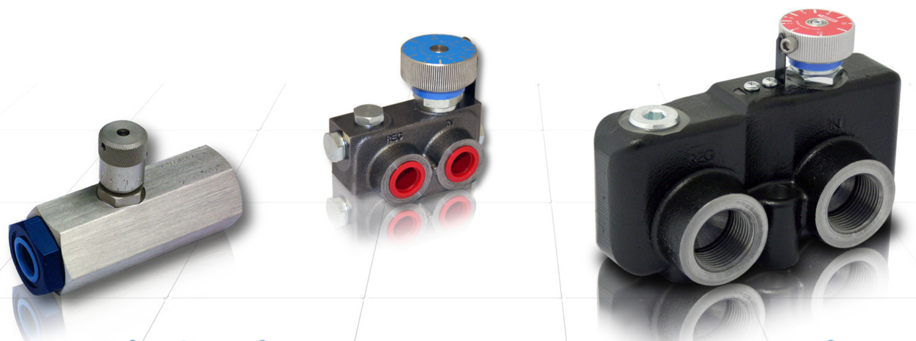
For over 50 years we have been helping customers worldwide in the Industrial, Mobile, and Agricultural sectors to diagnose hydraulic faults, verify hydraulic conditions and achieve repeatable hydraulic control.

For further details and to discuss your manual directional control valve application with a qualified hydraulic sales engineer, please go to

www.webtec.com

Flow Control Valves

Variable Priority Flow Dividers



Hydraulic measurement and control

Milwaukee, WI 53235, USA
Tel: +1 (414) 769-6400
sales-us@webtec.com

St. Ives, Cambs. PE27 3LZ, UK
Tel: +44 (0) 1480 397 400
sales-uk@webtec.com

www.webtec.com

Designed and produced by Webtec - FLOWVAL-ED-ENG-3543.pdf - 11/16