

Logic Element Cartridges



Applications

Sun screw-in logic cartridges can be used to create a multitude of circuit functions for various hydraulic systems. They can be used in combinations to provide the functions of directional controls, flow controls, and pressure controls.

Sun offers two functional categories of logic elements:

MODULATING CARTRIDGES act as main stages for relief or pressure reducing functions. When used in conjunction with a fixed or variable orifice (flow control), or a proportional directional valve, they can act as restrictive or bypass type pressure compensators.

SWITCHING CARTRIDGES are used to provide directional control functions. The use of switching cartridges offers reduced system size, fast response, very low leakage, contamination tolerance, and flexible controllability.

In addition to the three familiar types of logic functions in common use today (normally open and normally closed modulating elements, and pilot-to-close switching elements, usually DIN slip-in style), Sun also offers pilot-to-open switching elements. These poppet type, or seated, valves will close and seal positively to both directions of flow in the absence of any pilot signal, allowing true blocked port logic valve circuitry. Sun switching elements are offered in both unbalanced and balanced designs, further enhancing circuit design flexibility.

Controllability

Switching cartridges are pilot operated and are usually controlled with solenoid operated valves. Since each logic element controls only one function, it is possible to control the timing, sequence, and overlap of directional valve functions very accurately by using microprocessors to initiate the pilot signals to each logic element. The magnitude of the pilot pressure, as compared to the work port pressures, must be considered for unbalanced logic elements, whereas a pilot pressure of approximately 300 psi (21 bar) will always be sufficient to operate balanced logic elements. These cartridges can be specified with integral T-8A pilot control cavities, which allow direct mounting of solenoid pilot control valves.

Size Selection

Since each switching cartridge controls only one circuit function, individual cartridges can be sized for the flow requirements in that particular branch of the circuit (e.g. cylinder rod end flow is usually lower than cap end flow. If a single directional spool valve is used, it would have to be sized for the higher cap end flow.) When flows beyond the capability of a single cartridge are required, two cartridges can be mounted in parallel.

Design Concepts, Features, and Circuit Considerations

Modulating Cartridges – LP*C and LR*C

Modulating logic cartridges are used for pressure regulation and pressure compensation. Pressure regulation functions, including pressure relief, pressure reducing, unloading, and sequencing,

can be performed. With an external orifice, these logic cartridges can function as pressure compensators. Sun offers two basic modulating cartridges:

- LP*C normally open modulating cartridges function as main stage reducing valves or restrictive compensators.
- LR*C normally closed modulating cartridges function as main stage relief valves or bypass/bleed-off compensators.

Sun modulating cartridges are of the balanced piston design, and as a result, are inherently stable in operation. These cartridges operate only from flow and/or pressure conditions at port 1, controlled by the pilot pressure at port 3.

As main stage pressure controls, capable of handling high flows with a small pilot flow, these cartridges offer a great deal of circuit flexibility. Pressure control requires a sensing or pilot connection between the work port being controlled, port 1 and a pilot stage that controls the pilot pressure, port 3 (see figure 1). All of the features of ventable pressure controls (i.e. venting, de-venting, multiple pressure settings, etc.) can be incorporated in circuits using these cartridges. Sun's RBAC manually operated direct acting relief valves, RBAP proportional relief valves, and DA*L solenoid valves make excellent pilot controls for these cartridges.

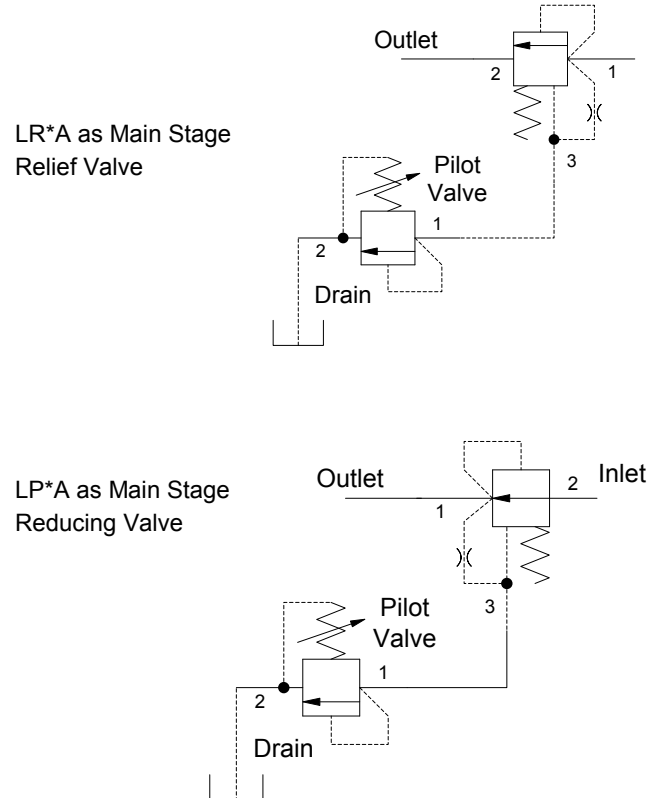


Figure 1: Modulating Cartridges as Main Stage Pressure Controls

As compensators, these modulating cartridges are used to maintain a constant pressure drop across either a fixed or variable orifice, regardless of variations in upstream or downstream pressure. They can function as either normally open restrictive, or normally closed bypass compensators (see figure 2).

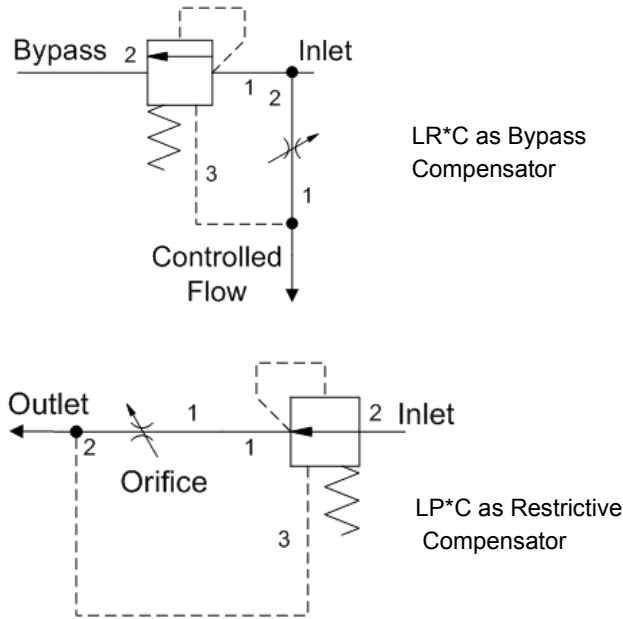


Figure 2: Modulating Cartridges as Pressure Compensators

Unbalanced Switching Cartridges – LO*C and LK*C

These three port switching cartridges are unbalanced poppet, two-way valves with a pilot port, port 3, used to control poppet operation. The operating pilot pressure can be sourced externally, or directly from either work port, port 1 or port 2, depending on the model code selected. Sun offers two basic unbalanced switching cartridges:

- LO*C pilot-to-close (normally open) unbalanced switching cartridges.
- LK*C pilot-to-open (normally closed) unbalanced switching cartridges (see figure 3).

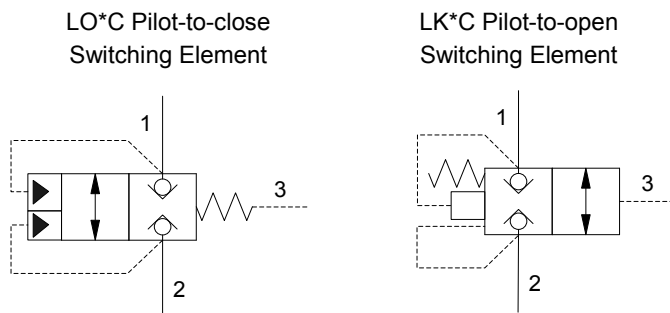


Figure 3: Unbalanced Switching Cartridges

Unbalanced Logic Cartridge Design Considerations

Unbalanced, poppet design, switching cartridge operation is pressure dependant. The opening and closing of the poppet is determined by the force balance on three areas – port 1, port 2, and port 3. Because of this port vs. pressure dependency, **it is essential to consider all aspects of system operation through a complete machine cycle when designing logic circuits.** Unplanned port 1, 2, or 3 pressures, either higher or lower than anticipated, during the work cycle can cause an element to either open or close unexpectedly. These work cycle “surprises” can cause circuit failure with resulting mechanical machine damage, or possibly, physical injury. All possible pressure changes in the complete circuit during a cycle must be considered to ensure a safe and functional system design. Predictable circuits require a pilot pressure that is higher than any of the work port pressures.

Self piloted logic elements are at the root of many application problems. Self piloted LK**’s start to open at 50 psi (3,5 bar) but many not fully open until 300 psi (20 bar). The closing time of self piloted LO**’s is very difficult to predict and can vary by more than an order of magnitude. Self piloted valves with a built in shuttle, L**D’s, have a flow path through the shuttle that is often overlooked.

Operation of LO*C Cartridges

Pressure at port 1 or port 2 tends to open the valve. The bias spring force, together with pilot pressure acting on port 3, tends to close the valve. The valve will open when the forces generated by pressures at ports 1 and 2 are greater than the total force generated at port 3.

Although typical pilot-to-close DIN style switching elements have area ratios $A1 = A2$, and $A3 = A1 + A2$, Sun unbalanced logic cartridges have slightly different ratios which must be considered when designing circuits (see figure 4). For example, when port 3 of an LO*C is vented, the valve will open to flow in either direction when minimum pressures are 50 psi (3,5 bar) at port 1, or 65 psi (4,5 bar) at port 2.

When pilot pressure is applied to port 3, the port 3 area force, which includes the bias spring force, tends to hold the valve closed. The valve will open by venting port 3, or if there is a proportionately higher pressure at port 1 or port 2. From the area ratios listed in figure 5, it can be shown that:

$$\frac{A3}{A1} = 1.8: 1 \text{ or } 1000 \text{ psi (70 bar) at port 3 will hold the valve closed against pressures up to } 1800 \text{ psi (125 bar) at port 1 with port 2 referenced to tank.}$$

$$\frac{A3}{A2} = 2.25: 1 \text{ or } 1000 \text{ psi (70 bar) at port 3 will hold the valve closed against pressures up to } 2250 \text{ psi (157 bar) at port 2 with port 1 referenced to tank.}$$

Operation of LK*C Cartridges

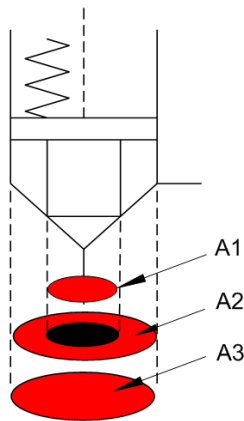
Pressure at port 1 or port 2 tends to close the valve or add to the closing force. Pilot pressure acting on port 3, tends to open the valve. The valve will close when the forces generated by pressures at ports 1 and 2 (plus the bias spring), are greater than the forces generated by pressure at port 3. When port 3 is vented, the valve will close and remain closed, regardless of the pressure at port 1 or port 2.



When pilot pressure is applied to port 3, the port 3 area force, minus the bias spring force, tends to open the valve. The valve will close by venting port 3, or by introducing a proportionately higher pressure at port 1 or port 2. From the area ratios listed in figure 5, it can be shown that:

$$\frac{A_3}{A_1} = 1.8:1 \text{ or } 1000 \text{ psi (70 bar) at port 3 will open the valve against pressures up to 1800 psi (125 bar) at port 1 with port 2 referenced to tank.}$$

$$\frac{A_3}{A_2} = 2.25:1 \text{ or } 1000 \text{ psi (70 bar) at port 3 will open the valve against pressures up to 2250 psi (157 bar) at port 2 with port 1 referenced to tank.}$$



DIN Style	Sun Design
Port 1 (A1) = 100%	Port 1 (A1) = 100%
Port 2 (A2) = 100%	Port 2 (A2) = 80%
Port 3 (A3) = 200%	Port 3 (A3) = 180%

Figure 4: Area Ratio Comparison

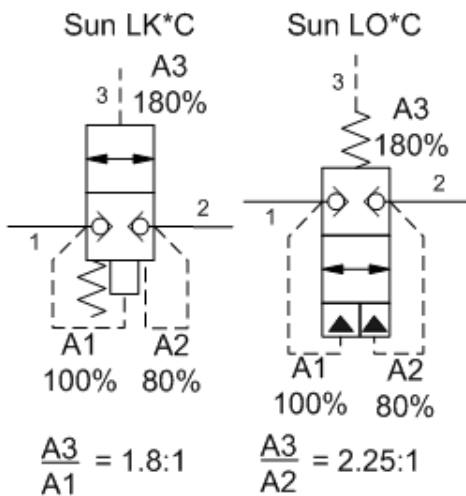


Figure 5: Sun Unbalanced Logic Cartridge Area Ratios

Balanced Switching Cartridges – DO*S and DK*S; DO*R and DK*R

These four port switching cartridges are balanced poppet, two-way valves with a pilot port, port 3 used to control poppet operation. Pressure at port 4 (drain) directly opposes pilot pressure. A minimum external pilot pressure of 300 psi (21 bar) should be available to ensure reliable shifting. The D**S cartridges are direct operated, while the D**R versions are vent-to-operate. There are three port versions of these cartridges available; DO*C or DK*C, to allow interchange with equivalent function, unbalanced logic valves. (The port 4 drain function is accomplished with an external or vent-to-atmosphere connection in the hex body.) Sun offers two basic balanced switching cartridges (each version can be either direct piloted or vent-to-operate):

- DO*S pilot-to-close and DO*R vent-to-close (normally open) balanced switching cartridges.
- DK*S pilot-to-open and DK*R vent-to-open (normally closed) balanced switching cartridges (see figure 6).

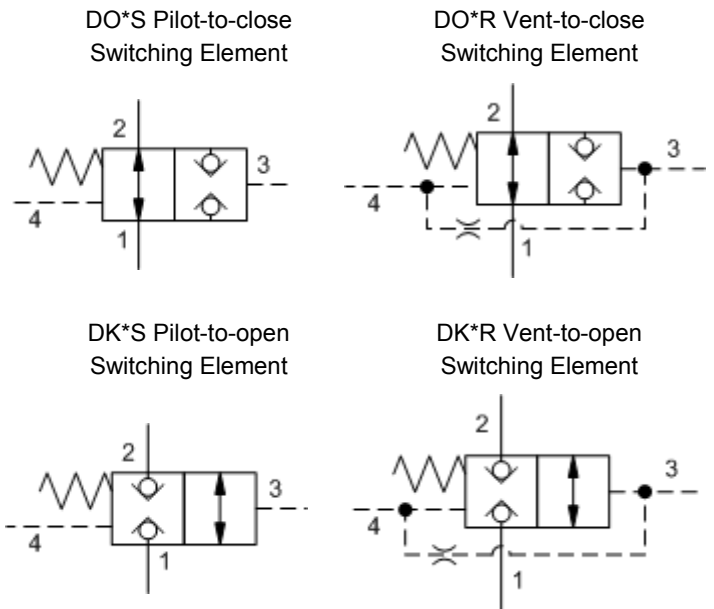


Figure 6: Balanced Switching Cartridges

Balanced Logic Cartridge Design Considerations

Unlike unbalanced logic elements, balanced, poppet design switching cartridge operation is NOT pressure dependant. Pressures at port 1 and port 2 have no effect on the opening and/or closing of the poppet. Only pilot pressure at port 3, compared to the pressure at the drain (port 4), determines the position of the poppet. Because of this balanced design, **it is not as critical to consider all aspects of system operation when designing logic circuits with balanced logic elements.** The only consideration is to make sure there is a minimum available 300 psi (21 bar) pilot pressure differential available when actuation is required. See Figure 7 for a basic comparison of required pilot pressures for unbalanced and balanced logic elements.



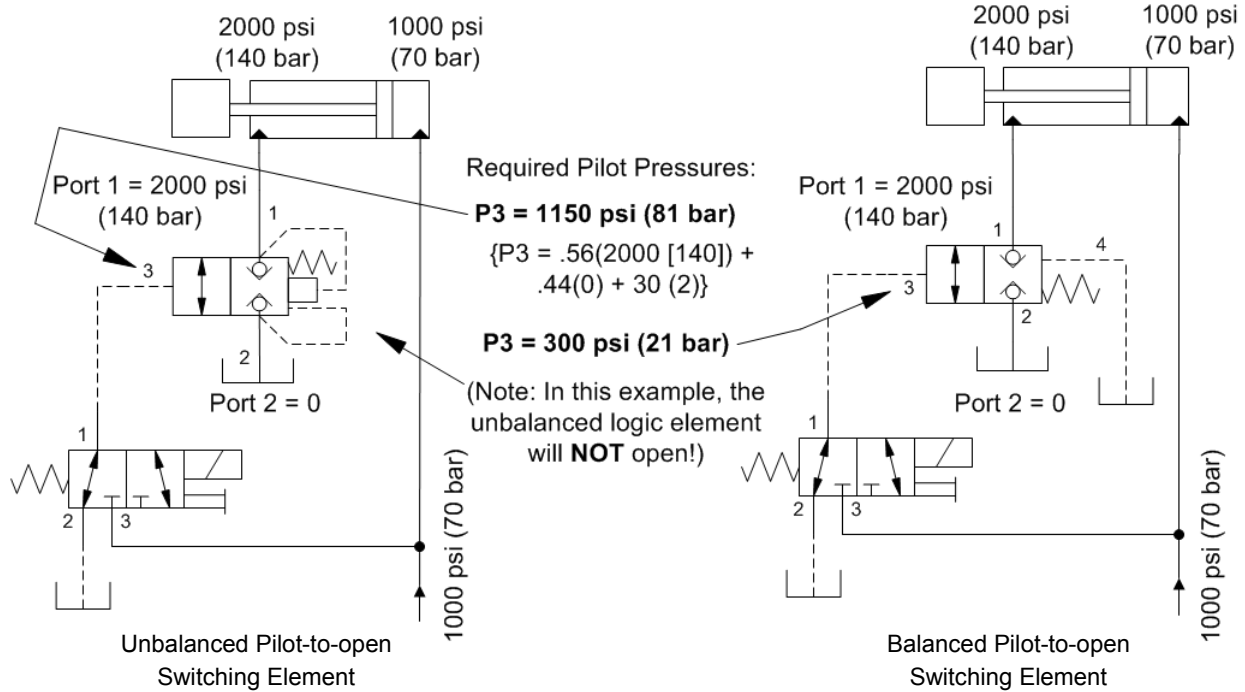
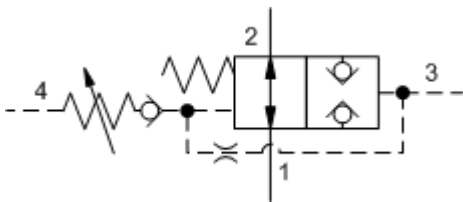


Figure 7: Required Pilot Pressures for Unbalanced vs. Balanced Switching Cartridges

Balanced Switching Cartridges with Adjustable Pilot Pressure – DO*P and DK*P

An adjustable back pressure feature is available in DO*P and DK*P cartridges which allows these balanced switching elements to shift only when a predetermined pilot pressure is available at port 3. These four port switching cartridges are essentially vent-to-operate valves with an adjustable relief in between the internal orifice and the port 4 drain connection. The added back pressure simply increases the required pilot pressure (above the minimum value) on port 3 (see figure 8).

DO*P Pressure Adjustable, Pilot-to-close Switching Element



DK*P Pressure Adjustable, Pilot-to-open Switching Element

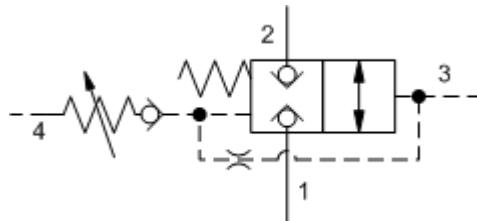
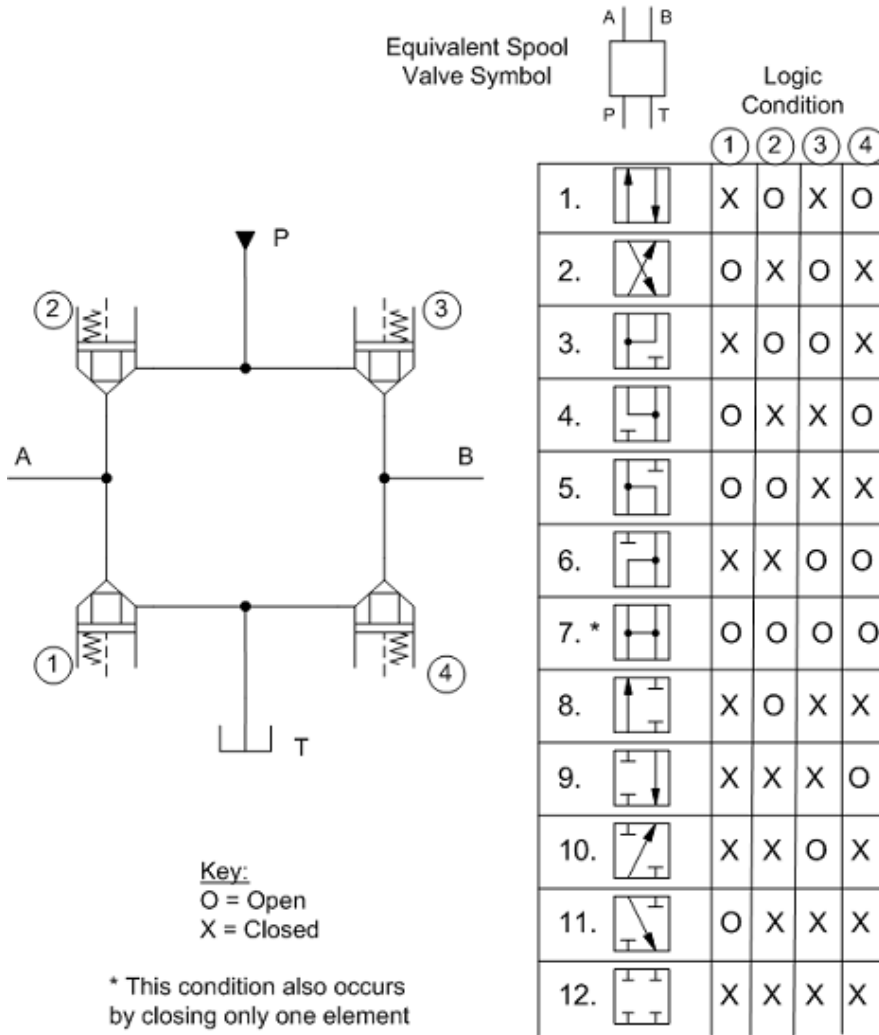


Figure 8: Balanced Pilot Pressure Adjustable Switching Cartridges

Switching Elements as Directional Controls

Four logic switching cartridges are required to duplicate the functions of a spool type, four-way, directional valve; one cartridge for each port – P,T, A, and B. By controlling the opening and closing of each element, twelve flow paths can be obtained. See figure 9 for available 4-way directional circuits. By using logic switching cartridges, it is possible to shift from one flow condition to another without going through any intermediate (or “center”) valve condition or function. The opening of the cartridges can be precisely controlled, allowing smooth flow transition, while most spool type valves have only three operating positions and must always pass through a center condition when changing flow paths. The opening order and shifting condition are rigidly fixed by the spool configuration and overlap.

See figure 9 for the twelve typical logic element 4-way directional valve circuits, using pilot-to-close cartridges.



All Sun switching logic cartridges are of a seated poppet type design, therefore leakage between port 1 and port 2 is essentially zero. Also, all of these cartridges have sealed pilot pistons, thus eliminating possible leakage between the pilot and work ports. Unlike typical DIN style cartridges, either work port of Sun unbalanced logic cartridges can be used for self-piloting without fear of loss of pressure via the pilot section.

Figure 9: Directional Circuits using Pilot-to-close Switching Elements

Decompression using DK*R Balanced Logic Cartridges

Minimizing decompression shock when reversing a cylinder, going from the extend to retract mode, can be a challenge when using either spool type directional valves or common unbalanced logic elements. The design of DK*R vent-to-open balanced logic cartridges, when flowing from port 1 to port 2, makes them an excellent choice for decompressing the cap end of a cylinder when flow is initiated to tank. By controlling the pilot pressure with a reducing valve, total shifting times can be adjusted from approximately 50 to 300 ms. (Please note that the decompression characteristics have nothing to do with the internal orifice.) Because the exposed area does not increase in the opening phase, as with unbalanced designs, work port operating pressures do not directly affect the opening speed of the poppet (although typical spool-type flow forces can have a minimal effect when working with high work port pressures). The final result is that cylinder decompression becomes very consistent and predictable. All Sun vent-to-close or vent-to-open logic cartridges are available with an integral pilot control cavity which can make circuit design more efficient with the resulting manifolds being less costly (see figure 10).

Multiple Logic Cartridges for Higher Flows

Most of Sun's Series 4 logic cartridges can easily handle flows up to 80 gpm (300 L/min), with a 100 psi (7 bar) pressure drop. (LO*J cartridges can handle 120 gpm [480 L/min] with the same 100 psi [7 bar] pressure drop.) With multiple cartridges, the pilot valve must be sized to accommodate the poppet displacements of all of the cartridges.

When using DKJR balanced pilot-to-open cartridges in order to take advantage of their decompression characteristics while opening, the time to close can sometimes be a problem. By using a 3-way pilot valve, fast closing can be accomplished by "short circuiting" the internal orifices in the cartridges, while still retaining the slow or "soft" opening feature. Figure 11 shows a typical three cartridge circuit with controlled decompression in addition to fast closure.

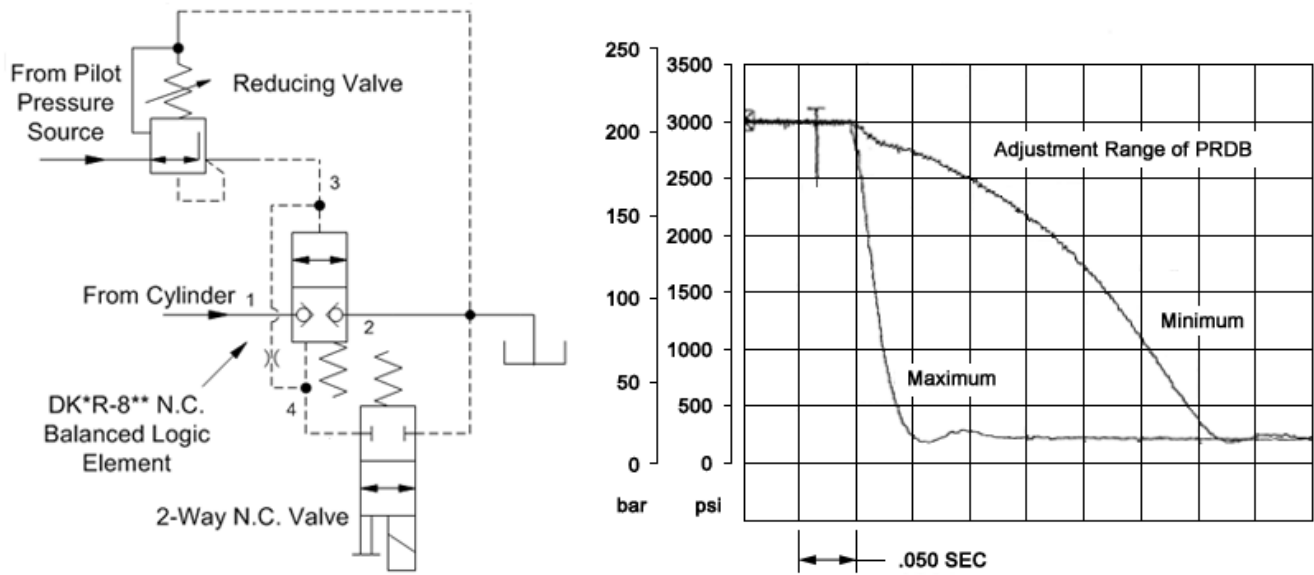


Figure 10: Decompression with a Balanced Vent-to-open Logic Valve

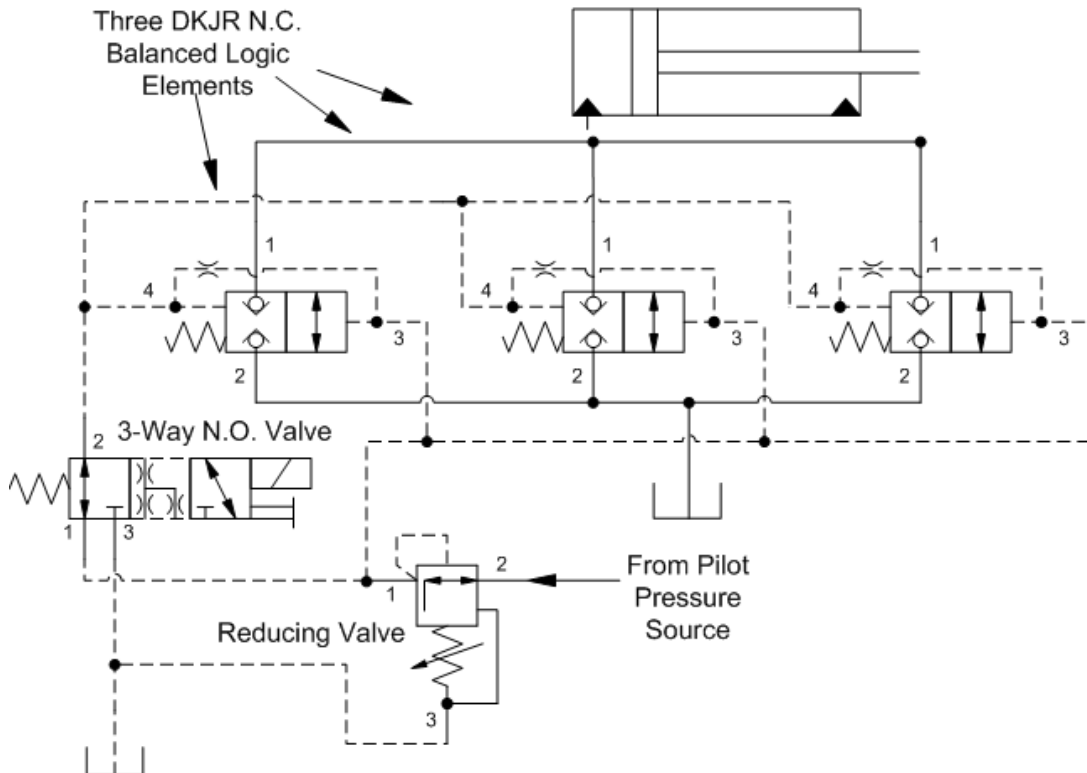


Figure 11: Multiple Logic Cartridges for Higher Flows

Logic Valve Circuit Considerations

When choosing logic cartridges for a typical four-way directional valve circuit, some basic criteria needs to be considered:

- Correct size of each cartridge based on the flow in each leg of the circuit.
- Available pressure source throughout the work cycle for piloting elements.
- Selection and location of pilot valves, based on circuit function.
- Type, or function, (i.e. pilot-to-open, pilot-to-close, balanced or unbalanced, modulating) of logic cartridge for each position in the circuit.

In figure 12, a common four-way directional cylinder circuit is shown for reference. In this circuit, it is assumed that regeneration is desired and that the cylinder has a 2:1 area ratio. The circuit also includes a decompression feature (cartridge 1), plus cartridge piloting on the cap end of the cylinder to ensure a “zero leak” or non-reversal condition (cartridge 2), when no retract command is present. Also recommended with this type of circuit, is a pressure limiting element at the rod-end-to-tank position (cartridge 4) in the circuit. Adding this relief function protects the system from cylinder induced pressure intensification. With regard to cartridge sizing, cartridges 3 and 4 are rated at half the flow capacity of cartridges 1 and 2, which are both rated at double the pump flow.

Logic Cartridge Variations

Four Port Bypass/Restrictive, Priority Modulating Elements – LH*A

Sun LH*A bypass/restrictive modulating elements, when combined with an external orifice, create a bypass/restrictive flow control. Input flow at port 3 is first directed to priority, or control port 2, with any excess oil going to port 4. The down stream, or after orifice, signal is connected to port 1. Both pressure and flow are controlled on the priority side of the circuit regardless of the pressure in the bypass circuit. Unlike other Sun “F” series bypass/restrictive priority flow controls, the priority flow can be turned off, or dead headed, allowing all flow to be available at port 4. The dead headed, or reduced, priority pressure is determined by a small pilot relief valve in the signal circuit (see figures 13 and 14).

Be aware that the priority flow pressure at port 2, should not be allowed to go lower than the specified differential pressure setting, 75 or 100 psi (5 or 7 bar), or the valve will not be able to shift to the bypass mode.

Performance parameters include:

- Priority flow can be turned on or off with a pilot sized solenoid valve.
- Bypass pressure at port 4 can be higher than the pressure at control port 2.
- These valves work equally well in either open or closed center systems.

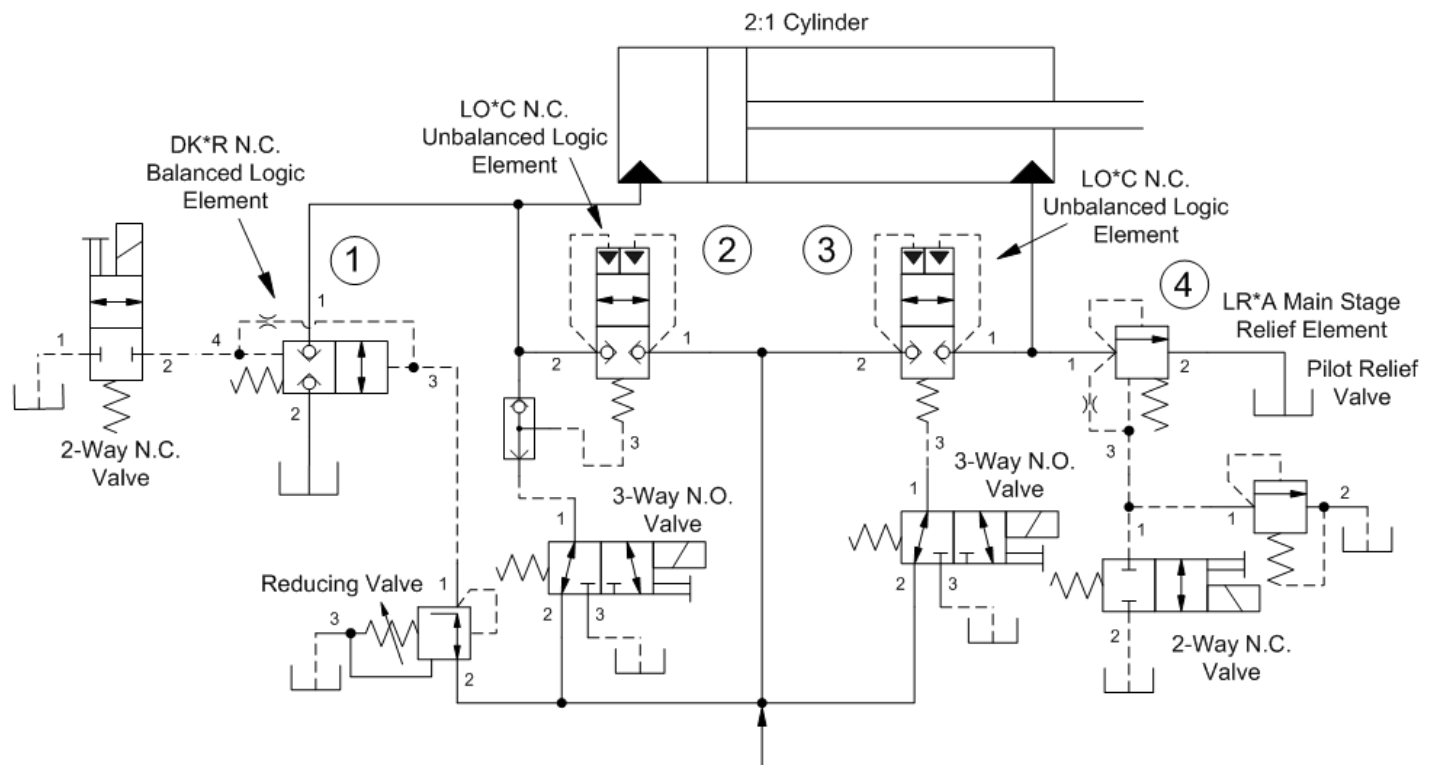


Figure 12: Typical 4-way Directional Cylinder Circuit using Logic Cartridges (incorporates decompression, zero leak at cylinder cap end, over pressure protection on rod end, and regeneration capability)

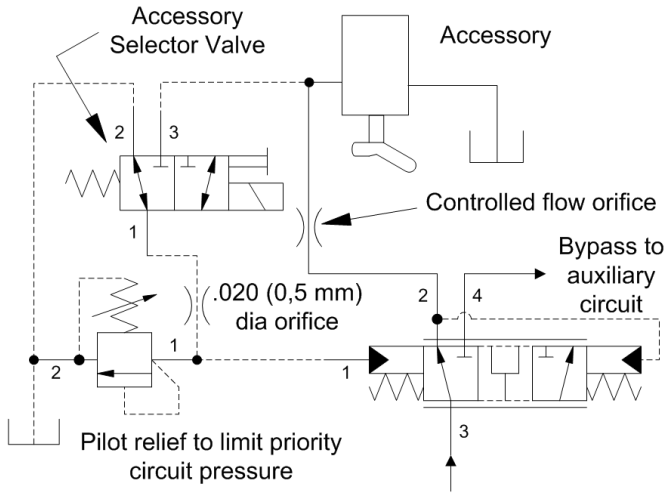


Figure 13: Using an LH*A Cartridge to Supply an Accessory Circuit

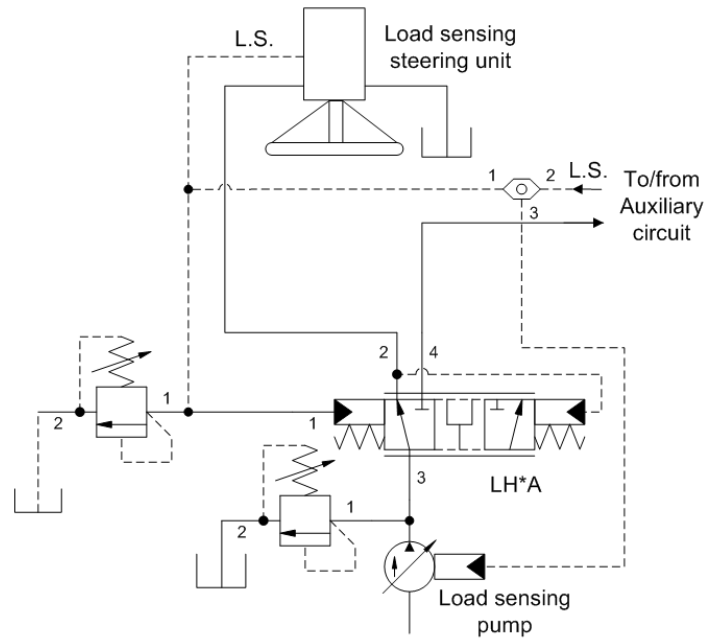


Figure 14: Using an LH*A in a closed Center Load Sensing Circuit

Four Port Bi-directional Compensator Cartridge – LH*T

Sun LH*T modulating elements are bi-directional, normally open compensators. They are used in conjunction with an external fixed, or variable, orifice to create a bi-directional, pressure compensated flow control. There are three control pressure differential pressures available; 50, 75, and 100 psi. (3,5, 5, and 7 bar). Although they are straight forward devices, **it is important that sensing pilot port 1 be connected between the compensator and the orifice**, with sensing pilot port 4 being connected to the other side of the orifice. Figure 15 shows a typical circuit configuration.

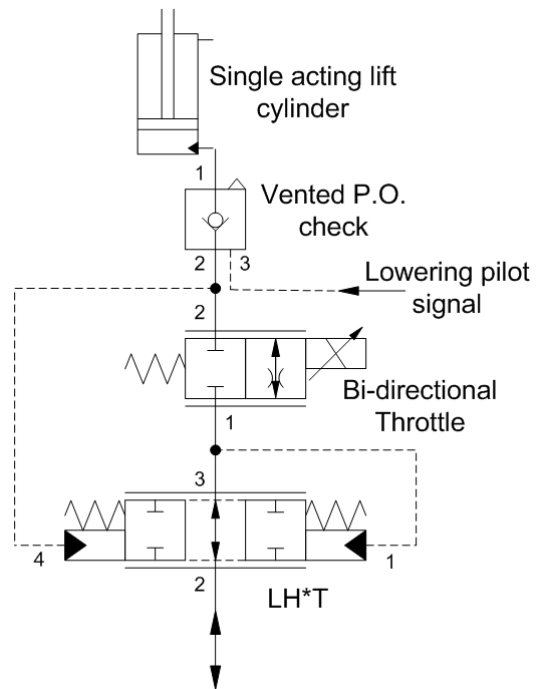


Figure 15: Bi-directional Compensator in a Single Acting Cylinder Lift Circuit

Logic Element Cartridge Valves Overview

Function	Description	Nominal Capacity	Model	Cavity	Symbol
Balanced Poppet	Normally Closed, Direct Operated	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDS DKFS DKHS DKJS	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Closed, Vent to Operate	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDR DKFR DKHR DKJR	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Closed, Vent to Operate, With Integral Pilot Control Cavity	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDR8 DKFR8 DKHR8 DKJR8	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Closed, Pressure Adjustable	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDP DKFP DKHP DKJP	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Open, Direct Operated	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODS DOFS DOHS DOJS	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Open, Vent to Operate	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODR DOFR DOHR DOJR	T-21A T-22A T-23A T-24A	
Balanced Poppet	Normally Open, Vent to Operate, With Integral Pilot Control Cavity	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODR8 DOFR8 DOHR8 DOJR8	T-21A T-22A T-23A T-24A	

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Function	Description	Nominal Capacity	Model	Cavity	Symbol
Balanced Poppet	Normally Open, Pressure Adjustable	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODP DOFP DOHP DOJP	T-21A T-22A T-23A T-24A	
Balanced Poppet, 3 Port	Normally Closed, Direct Operated	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDC DKFC DKHC DKJC	T-11A T-2A T-17A T-19A	
Balanced Poppet, 3 Port	Normally Closed, Vent to Operate	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DKDD DKFD DKHD DKJD	T-11A T-2A T-17A T-19A	
Balanced Poppet, 3 Port	Normally Open, Direct Operated	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODC DOFC DOHC DOJC	T-11A T-2A T-17A T-19A	
Balanced Poppet, 3 Port	Normally Open, Vent to Operate	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	DODD DOFD DOHD DOJD	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Pilot-to-close, Spring Biased Closed	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODC LOFC LOHC LOJC	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 1	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODA LOFA LOHA LOJA	T-11A T-2A T-17A T-19A	

Logic Element Cartridge Valves Overview

Function	Description	Nominal Capacity	Model	Cavity	Symbol
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 2	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODB LOFB LOHB LOJB	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 1 or port 2	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODD LOFD LOHD LOJD	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 1 and integral pilot control cavity	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODA8 LOFA8 LOHA8 LOJA8	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 2 and integral pilot control cavity	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODB8 LOFB8 LOHB8 LOJB8	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Vent-to-open, Spring Biased Closed, with pilot source from port 1 or 2 and integral pilot control cavity	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODD8 LOFD8 LOHD8 LOJD8	T-11A T-2A T-17A T-19A	

Logic Element Cartridge Valves Overview

Function	Description	Nominal Capacity	Model	Cavity	Symbol
Unbalanced Poppet	Pilot-to-close, Spring Biased Open	25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (380 L/min.) 200 gpm (760 L/min.)	LODO LOFO LOHO LOJO	T-11A T-2A T-17A T-19A	
Unbalanced Poppet	Pilot-to-open, Spring Biased Closed	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LKDC LKFC LKHC LKJC	T-11A T-2A T-17A T-19A	
Modulating	Normally Closed	7.5 gpm (30 L/min.) 15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LRBC LRDC LRFC LRHC LRJC	T-163A T-11A T-2A T-17A T-19A	
Modulating	Normally closed, Pilot Source from port 1	7.5 gpm (30 L/min.) 15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LRBA LRDA LRFA LRHA LRJA	T-163A T-11A T-2A T-17A T-19A	
Modulating	Normally Open	7.5 gpm (30 L/min.) 15 gpm (60 L/min.) 30 gpm (120 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LPBC LPDC LPFC LPFCL LPHC LPJC	T-163A T-11A T-2A T-2A T-17A T-19A	

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Function	Description	Nominal Capacity	Model	Cavity	Symbol
Modulating	Normally Open, Pilot Source from port 1	7.5 gpm (30 L/min.) 15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LPBA LPDA LPFA LPHA LPJA	T-163A T-11A T-2A T-17A T-19A	
Modulating	Bi-directional	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.)	LHDT LHFT LHHT	T-31A T-32A T-33A	
Modulating	Bypass/Restrictive	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	LHDA LHFA LHHA LHJA	T-31A T-32A T-33A T-34A	