Pilot-Shifted Proportional Cartridges

Introduction

Sun's pilot-shifted proportional directional and throttle valves offer infinite proportional control where flow requirements are higher than the capacity of direct-operated solenoid versions. They offer the convenience of remote controllability with varying capacities up to 100 gpm (400 L/min).

Applications

Pilot-Shifted Proportional Throttle Cartridges

Sun pilot-shifted normally closed throttles are available in two design configurations:

- Single-path, 4-port cartridges with options for adjustable pilot pressure and outlet port bleed down
- Dual-path, 4-port cartridges

The single-path versions are available in four frame sizes and have nominal flow rates of 5 to 60 gpm (20 to 240 L/min). The dual-path versions are available in three frame sizes and have nominal flow rates of 15 to 100 gpm (60 to 400 L/min). Maximum operating pressures are 5000 psi (350 bar) at all work ports and 500 psi (35 bar) at the pilot ports.

Pilot-Shifted Proportional Directional Cartridges

Sun pilot-shifted proportional directional valves are available in three circuit configurations:

- Spring-centered, 4-way, 3-position, 6-port cartridges
- Spring-centered, 3-way, 3-position (selector) 6-port cartridges
- Spring-offset, 3-way, 2-position, 6-port cartridges

The 4-way, 3-position versions are meter-in only and are available in three frame sizes with nominal flow rates of 7 to 80 gpm (28 to 320 L/min). The 3-way, 3-position, selector cartridges are available in two frame sizes and have nominal flow rates of 7 to 35 gpm (28 to 140 L/min). The 3-way, 2-position cartridges are available in one frame size, with nominal flow rates of 7 to 18 gpm (28 to 70 L/min). (Note: Port 5 of the 3-way cartridges, with the exception of the FT*K, is not used as a work port.) Maximum operating pressures are 5000 psi (350 bar) at all work ports and 500 psi (35 bar) at the pilot ports.

Pilot Pressure Control Options

Sun pilot-shifted proportional valves do not offer spool-position feedback sensors and are considered "open-loop" type valves. In all cases, pilot pressure is opposed by a high-rate spring (the spring causes the open loop "feedback"). The valves are designed to respond to the popular pilot pressure ranges, 75-225 psi (5,3-16 bar), available with most manual hydraulic remote controls (HRCs) that are on the market today.

When remote electrical control is desired, Sun PRDL electro-proportional reducing/relieving valves are available. They offer two pressure ranges that are ideally suited for this application: "D", 50-500 psi (3.5-35 bar), and "E", 25-250 psi (1,7-18 bar). The PRDL version, with open transition from reducing to relieving, is the preferred choice for piloting proportional valves.

Technical Tip

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Design Concepts & Features

Pilot-Shifted Proportional Throttles

*Four-Port, Single-Path, Pilot-Shifted Proportional Throttle Valves - FK*A*

The FK*A is a 2-way, 2-position, normally closed proportional throttle. The preferred flow path is 2 to 3. Pilot pressure at port 1 opposes the spring and creates a variable metering orifice between port 2 and port 3 that is proportional to the pressure at port 1. The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes. (See **Figure 1**)

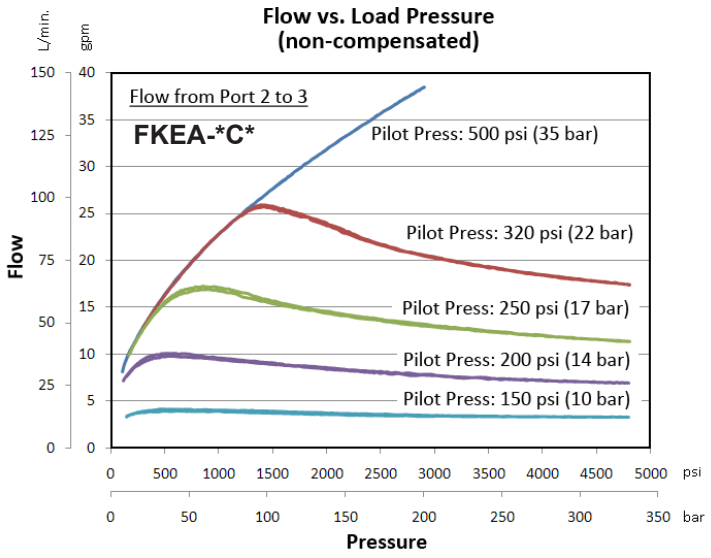

Figure 1

Performance features and parameters include:

- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across the metering orifice, resulting in a constant output flow when varying inlet and load pressures are present. (See **Figure 2** example)
  - For restrictive circuits, use a Sun LP_C-XH*
  - For bypass circuits, use a Sun LR_C-XH*
  - "H" = 200-psi (14-bar) spring.
- Nominal min-to-max pilot pressure range is 100-200 psi (7-14 bar).
- Pressure at port 4 directly opposes pressure at port 1.
- An optional tuning adjustment ("L" control) is available for varying the required pilot pressure for a given flow. The adjustment range is 50 to 300 psi (3,5 bar–20 bar), with 100 psi (7 bar) being the standard setting. (See **Figure 2**)

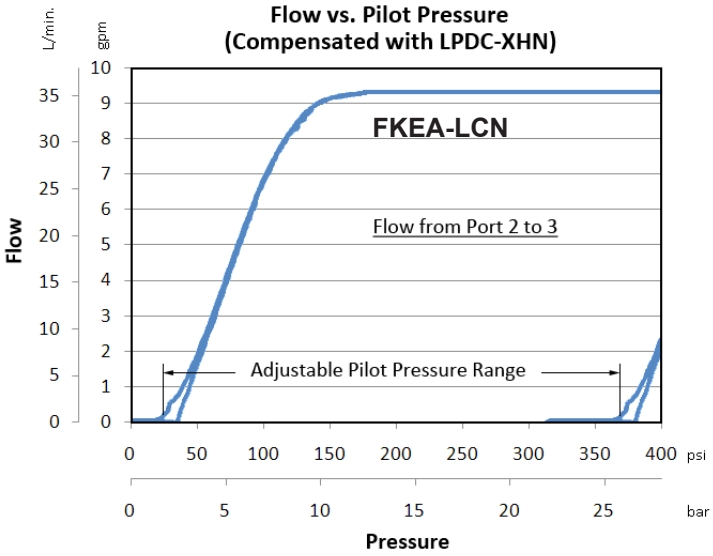

Figure 2

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Design Concepts & Features

Pilot-Shifted Proportional Throttles

*Four-Port, Pilot-Shifted Proportional Throttle Valves with Bleed Down - FK*B*

The FK*B is a 2-way, 2-position, normally closed proportional throttle and is identical to the FK*A, except:

- It offers a bleed from port 3 to port 4 (tank) in the de-energized position.
- There is no bleed flow to tank (parasitic loss) when the valve is modulating.

This is useful in circuits with load holding or LS shuttles where pressure needs to decay on port 3 in the de-energized, NC, position. (See **Figure 3** for circuit symbol.)

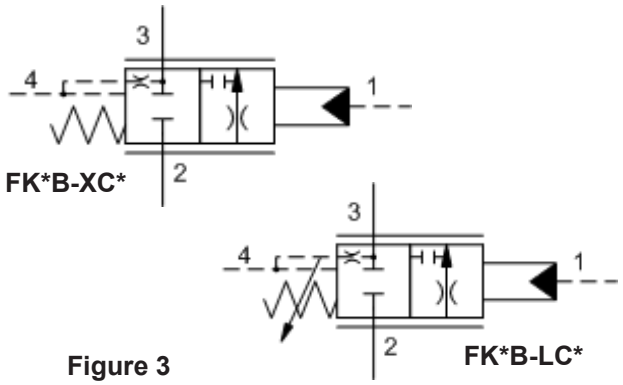

Figure 3

*Four-Port, Dual-Path, Pilot-Shifted Proportional Throttle Valves - FT*A*

The FT*A is a 2-way, 2-position, normally closed proportional throttle. The preferred flow path is 2 to 3. Pilot pressure at port 1 opposes the spring and creates a variable metering orifice between port 2 and port 3 that is proportional to the pressure at port 1. The valve uses a dual-path design where ports 2 and 3 incorporate a double port area. The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes. (See **Figure 4**) Performance features and parameters include:

- The 4-port dual-path cavities are based on the T-5* 6-port cavities. They combine the areas of ports 2+3 (port 2) and ports 4+5 (port 3). The cavities become T-52AD (Series 2), T-53AD (Series 3), and T-54AD (Series 4).

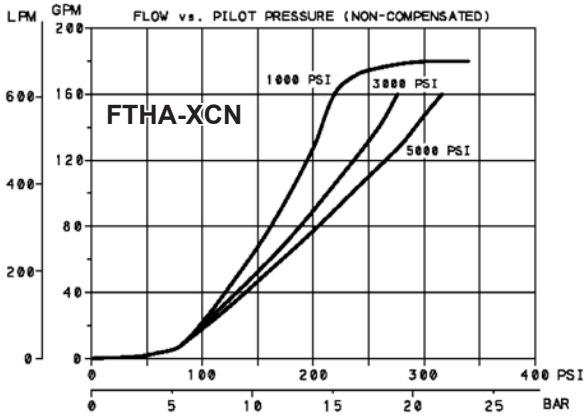

Figure 4

- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across the metering orifice, resulting in a constant output flow when varying inlet and load pressures are present. (See **Figure 5**)
  - For restrictive circuits, use a Sun LP_C-XHN.
  - For bypass circuits, use a Sun LR_C-XHN.
  - "H" = 200-psi (14-bar) spring
- Nominal min-to-max pilot pressure range is 80-250 psi (5,5-17 bar).
- Pressure at port 4 directly opposes pressure at port 1.
- An optional stroke adjustment ("L" control) is available for limiting maximum flow.
- An optional position indicating switch is available on all dual-ported FT*A cartridges (FT*A-ZC*).

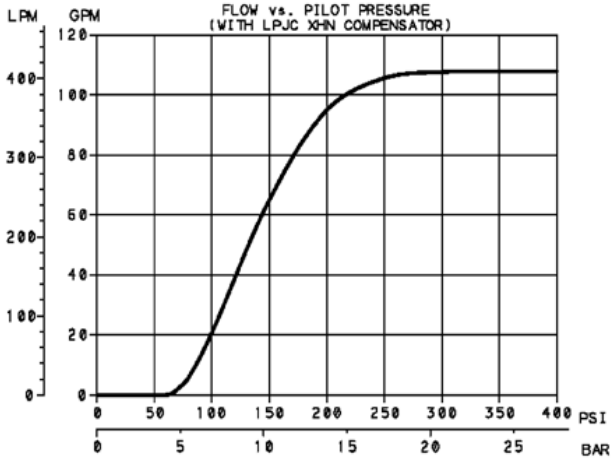

Figure 5

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Design Concepts & Features

Pilot-Shifted Proportional Directional Valves

*Six-Port, 4-way, 3-position, meter-in, Proportional Directional Valves - FT*C*

The FT*C is a 4-way, 3-position, proportional directional valve. The valve is meter-in only and will meter flow from inlet port 3 to work ports 2 or 4. In the center position, the work ports are drained to tank port 5, and inlet port 3 is closed. Pilot pressure at port 1 opposes the centering spring and creates a variable metering orifice between port 3 and port 4 that is proportional to the pressure at port 1. Pilot pressure at port 6 causes the same scenario between ports 3 and 2. The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes. (See **Figure 6**)

Performance features and parameters include:

- **Figure 7** shows the two spool center configurations that are available:
  - "Y" - Port 3 blocked, ports 2 and 4 open to port 5
  - "W" - Port 3 blocked, ports 2 and 4 metered to port 5
- Series 2, 3 and 4 cartridge sizes are available with the following capacities:
  - For Series 2: FTCC = 7 gpm (28 L/min), and FTDC = 18 gpm (70 L/min)
  - For Series 3: FTEC = 12 gpm (45 L/min), and FTFC = 35 gpm (140 L/min)
  - For Series 4: FTHC = 80 gpm (320 L/min)
- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across port 3 to 2 or 3 to 4. The resulting output flow is relatively constant when varying inlet and load pressures are present. A Sun LP_C-XHN ("H" = 200-psi [14-bar] spring) is recommended (See **Figure 8**)

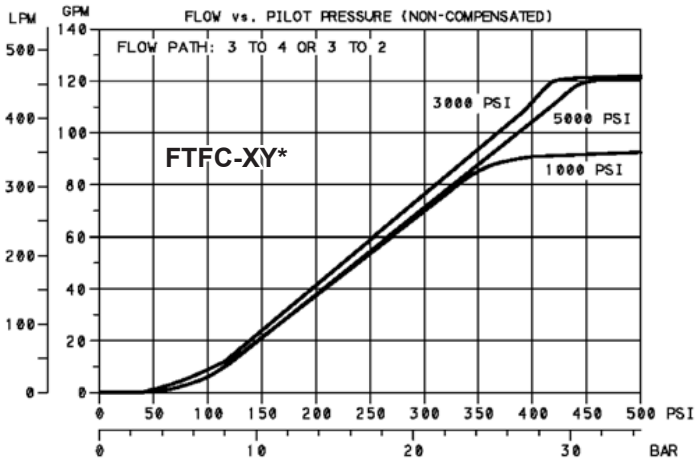

Figure 6

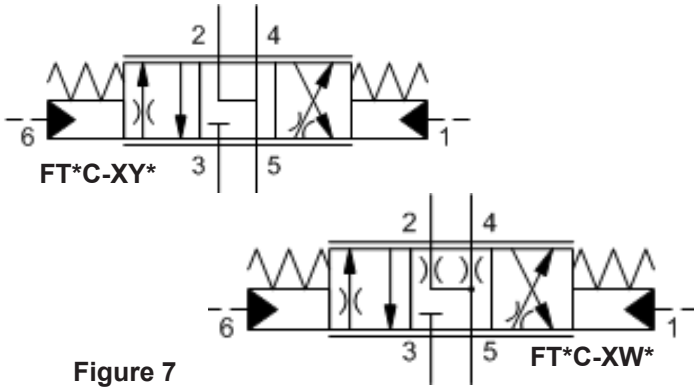

Figure 7

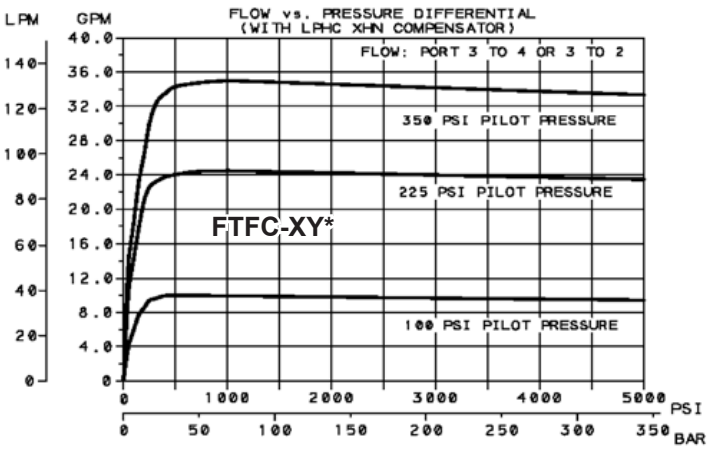

Figure 8

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Design Concepts & Features

*Six-Port, 4-way, 3-position, meter-in, Proportional Directional Valves - FT*C*

(continued from page 4)

- Increasing the compensator pressure setting will increase the maximum output flow. At 400 psi, the maximum output flow of an FTFC-XY* increases from 35 gpm (140 L/min) to 50 gpm (200 L/min). (See **Figure 9** for flows at various pressure drops.)
- Nominal min-to-max pilot pressure range is 80-250 psi (5,5-17 bar).
- Pilot pressures at ports 1 and 6 directly oppose each other.
- Two methods of electrically piloting a 3-posititon, spring centered valve are shown in **Figure 10.**
- The meter-in-only characteristic allows them to be used in combination with counterbalance valves, either in series or with cushion lock function, to provide independent meter-in/meter-out control. (See **Figure 11**)

FTFC-XY*

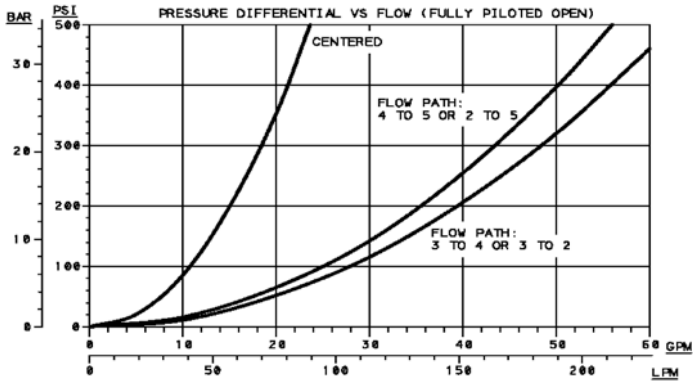
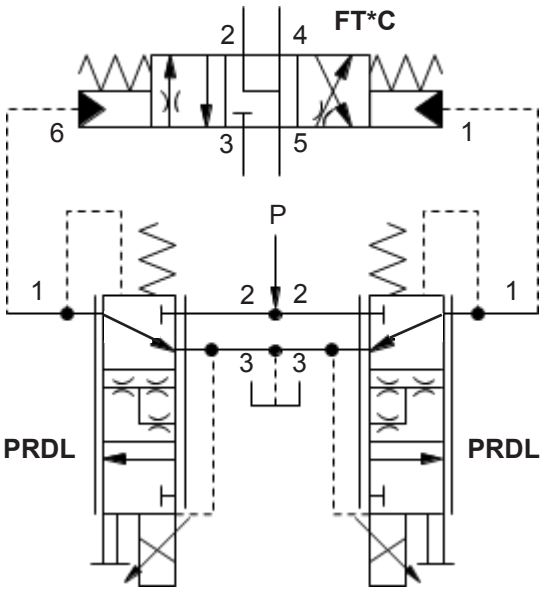


Figure 9

Two Reducer/Relievers



Single Reducer/Reliever Plus Directional

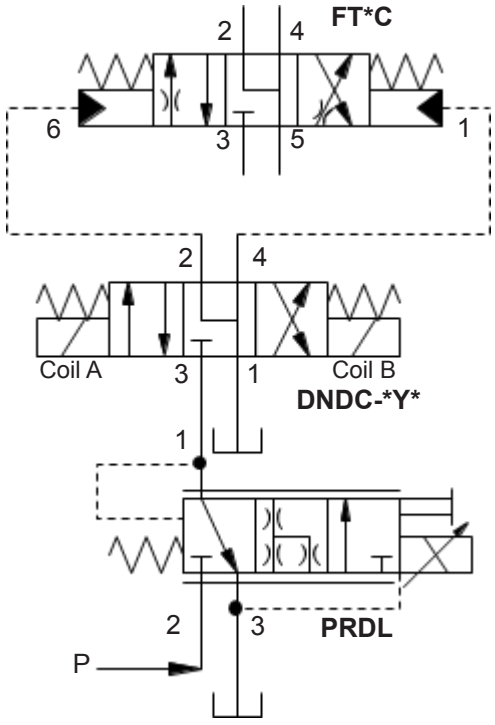


Figure 10
Two Electrical Pilot Control Options

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Design Concepts & Features

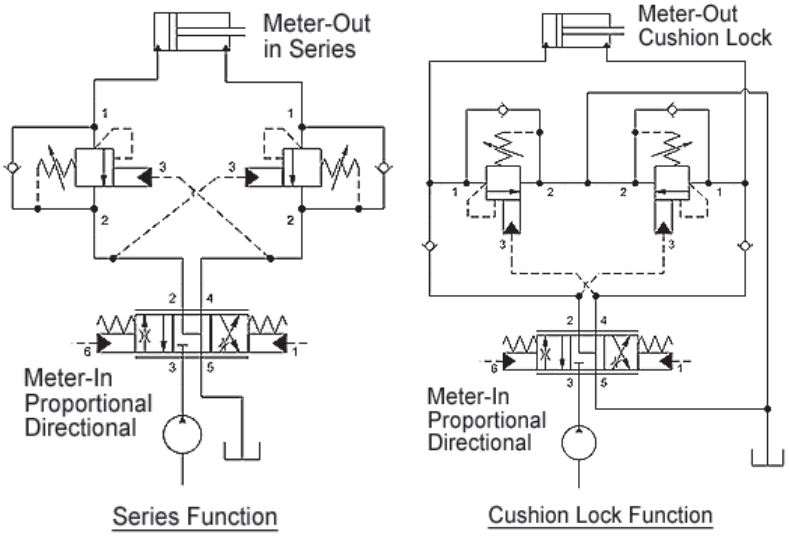

Figure 11
Independent Meter-in/Meter-out Control

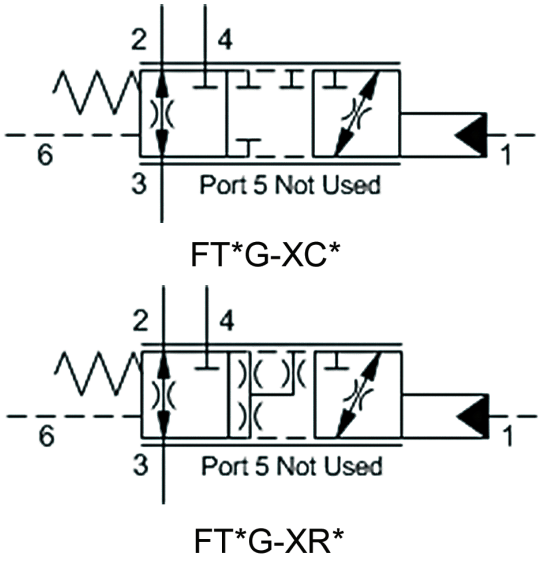

Figure 12

*Six-Port, 3-way, 2-position, meter-in, Proportional Selector Valves - FT*G*

The FT*G is a 3-way, 2-position, proportional directional selector valve. The valve is meter-in only and will meter flow from inlet port 3 to work ports 2 or 4. In the de-energized spring-offset position, a metered path is open between ports 3 and 2, and port 4 is blocked. Pilot pressure at port 1 opposes the spring and creates a variable metering orifice between ports 3 and 4 that is proportional to the pressure at port 1. The spring chamber is drained via port 6. (Port 5 is not used.) The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes.

Performance features and parameters include:

- **Figure 12** shows the two spool cross-over configurations that are available:
  - "C" - Ports 3, 2, and 4 blocked
  - "R" - Ports 3, 2, and 4 opened but metered
- Series 2 frame size is available with two flow capacities offered: FTCG = 7 gpm (28 L/min) & FTDG =18 gpm (70 L/min).
- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across port 3 to 2 or 3 to 4. The resulting output flow is relatively constant when varying inlet and load pressures are present. A Sun LP_C-XHN ("H" = 200-psi [14-bar] spring) is recommended.
- Nominal min-to-max pilot pressure range is 0-290 psi (0-20 bar).
  - Zero flow is obtained at 150 psi with "C" spool (See **Figure 13**).
  - Some flow takes place to both ports 2 and 4 during transition with the "R" spool. **Figure 14** shows flows with pressure differentials of 1000 and 3000 psi (70 and 210 bar).
- Using two FT*G valves can create a 3/4 way function with multiple center conditions depending on connections (See **Figure 15**).
- Any pressure at port 6 directly opposes pilot pressure at port 1.

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Design Concepts & Features

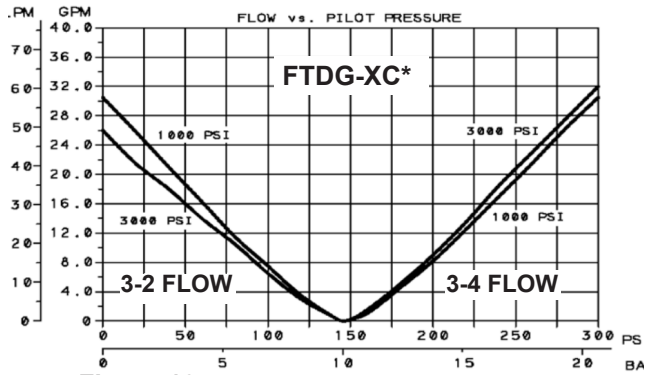

Figure 13

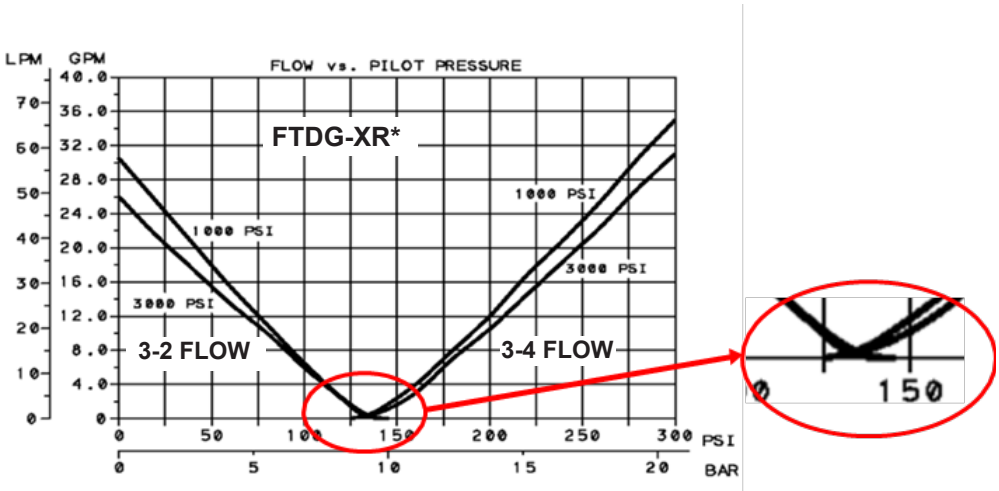

Figure 14

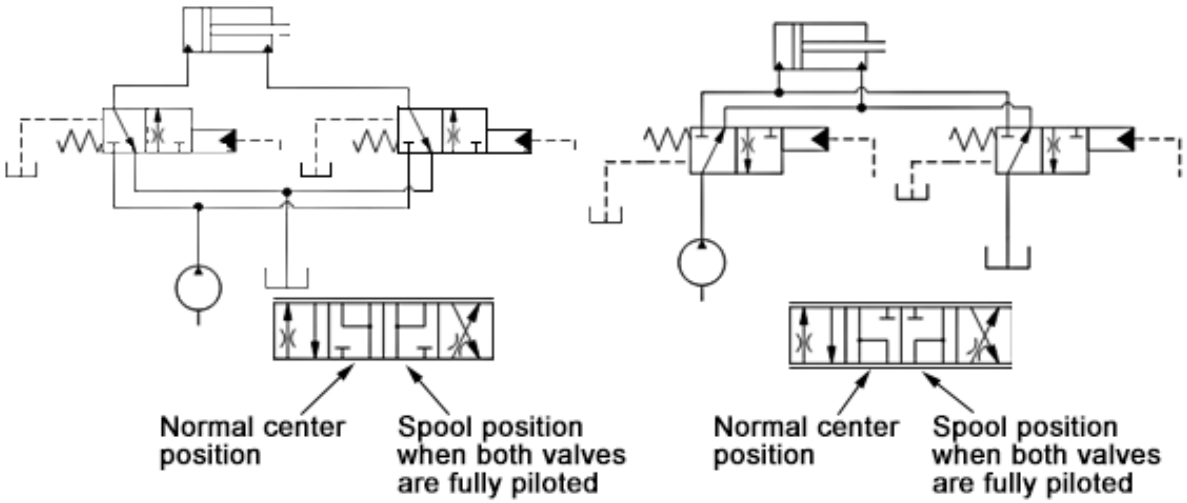

Figure 15
Two 2/3-Way FTDG valves create a 3/4-Way function.
Varying valve orientation creates multiple center conditions.

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Design Concepts & Features

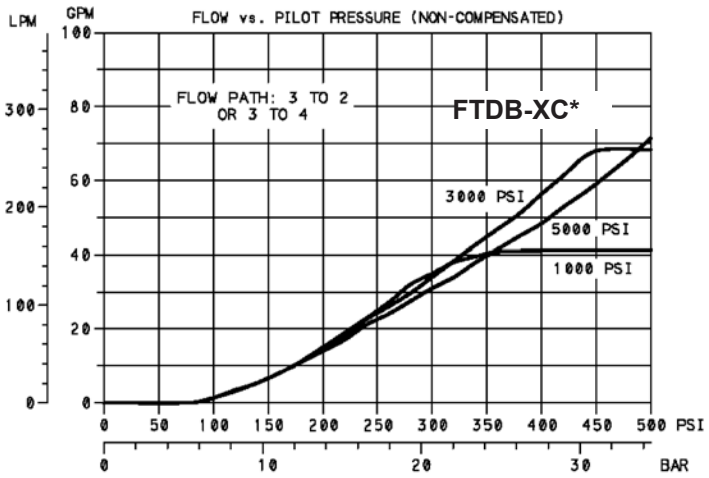

Figure 16

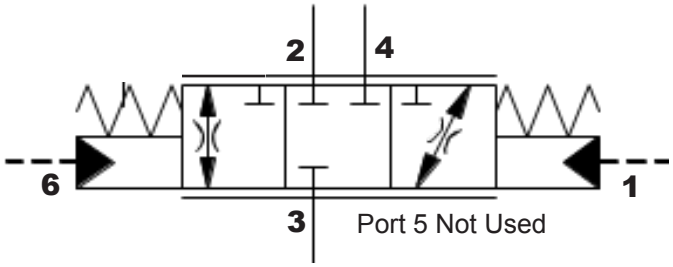

Figure 17 - FTDB-XC*

*Six-Port, 3-way, 3-position, Meter-in, Proportional Selector Valves - FT*B*

The FT*B is a 3-way, 3-position, proportional directional selector valve. The valve is meter-in only and will meter flow from inlet port 3 to work ports 2 or 4. In the center position, all ports are blocked. Pilot pressure at port 1 opposes the centering spring and creates a variable metering orifice between port 3 and port 4 that is proportional to the pressure at port 1. Pilot pressure at port 6 causes the same scenario between ports 3 and 2. (Port 5 is not used.) The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes. (See **Figure 16** example).

Performance features and parameters include:

- **Figure 17** shows the circuit symbol for an FTDB valve.
- Only Series 2 frame size is available and is offered in two flow capacities.
  - FTCB = 7 gpm (28 L/min), and FTDB = 18 gpm (70 L/min)
- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across port 3 to 2 or 3 to 4. The resulting output flow is relatively constant when varying inlet and load pressures are present. A Sun LP_C-XHN (“H” = 200-psi [14-bar] spring) is recommended.
- Nominal min-to-max pilot pressure range is 80-250 psi (5,5-17 bar).
- Two FT*B valves can create a 3/4-way closed center, meter-in/meter-out function. (See **Figure 18**) Note: closed loop control using actuator position feedback is recommended for this type of circuit.
- Pilot pressures at ports 1 and 6 directly oppose each other.

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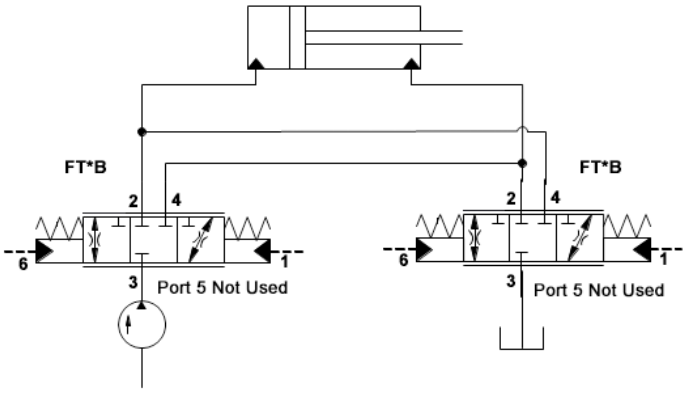

Figure 18 - Two 3/3-Way FT*B valves create a 3/4-Way, closed-center function.

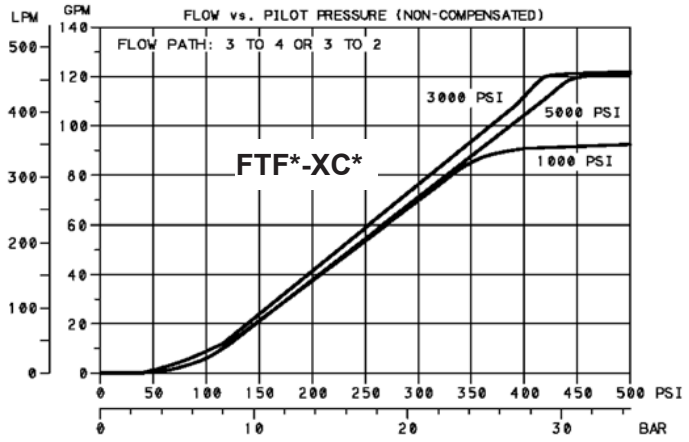

Figure 19

*Six-Port, 3-way, 3-position, Meter-in, Proportional Selector Valves - FT*H*

The FT*H is a 3-way, 3-position, proportional directional selector valve designed to be used primarily in cushion lock circuits. The valve is meter-in only and will meter flow from inlet port 3 to work ports 2 or 4. In the de-energized, spring-centered position, port 3 is blocked and a bleed-down function occurs from ports 2 and 4 to port 1. (Port 5 is not used.) Pilot pressure at port 1 opposes the centering spring and creates a variable metering orifice between port 3 and port 4 that is proportional to the pressure at port 1. Pilot pressure at port 6 causes the same scenario between ports 3 and 2. The force balance (flow forces, spring force, and pilot pressure) results in a degree of partial self-compensation as the load pressure changes. (See **Figure 19**)

Performance features and parameters include:

- **Figure 20** shows the circuit symbol for an FT*H valve.
- Series 2, 3, and 4 cartridge sizes are available with the following capacities:
  - For Series 2: FTCH = 7 gpm (28 L/min), and FTDH = 18 gpm (70 L/min)
  - For Series 3: FTEH = 12 gpm (45 L/min), and FTFH = 35 gpm (140 L/min)
  - For Series 4: FTHH = 80 gpm (320 L/min)
- To increase flow accuracy, an external modulating element (pressure compensator) can be used to maintain a constant pressure drop (200 psi is recommended) across port 3 to 2 or 3 to 4. The resulting output flow is relatively constant when varying inlet and load pressures are present. A Sun LP_C-XHN (“H” = 200-psi [14-bar] spring) is recommended.
- Nominal min-to-max pilot pressure range is 80-350 psi (5,5-24 bar).
- Any pressure at port 6 directly opposes pilot pressure at port 1.
- **Figure 22** shows how the FT*H is used in a typical cushion lock, load sense circuit.

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Design Concepts & Features

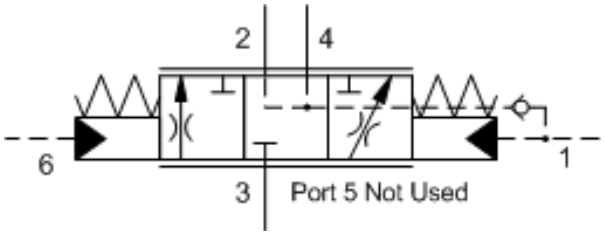

Figure 20 - FT*H-XC

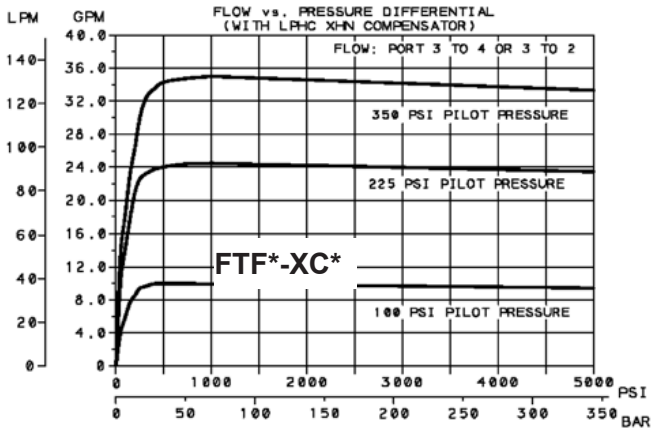

Figure 21

*Six-Port, 3-way, 3-position, meter-in, Proportional Selector Valves - FT*K*

The FT*K is also a 3-way, 3-position, proportional directional selector valve designed to be used primarily in cushion lock circuits. The FT*K valve uses port 5 as a load sense port, and, with this exception, all the other features of the FT*H apply (i.e., **Figures 19** and **21** also apply to the FT*K valve.)

Performance features and parameters in addition to those of the FT*H include:

- **Figure 23** shows the circuit symbol for an FT*K valve with L.S.
- Series 2 and 3 are available in FT*K.
- Using the FT*K valve eliminates the need for a cross port shuttle for load sense pick-up.
- Because port 5 is NOT drained to tank in the center position, a small bleed orifice is required to guarantee that the L.S. signal decays when the valve is de-energized.
- An orifice is not required if:
  - The circuit contains a bleed path between the last shuttle connection and the pump control
  - The involved pump has a control containing an integral L.S. signal bleed path.
- **Figure 24** shows an actual manifold using an FTDK-XCN in a cushion lock circuit with load sensing.

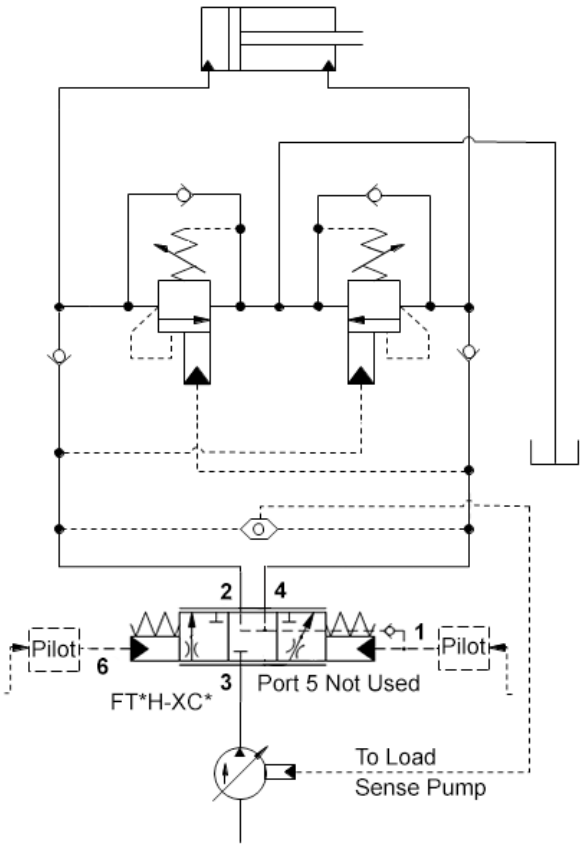

Figure 22
Cushion-Lock Circuit with Load Sense

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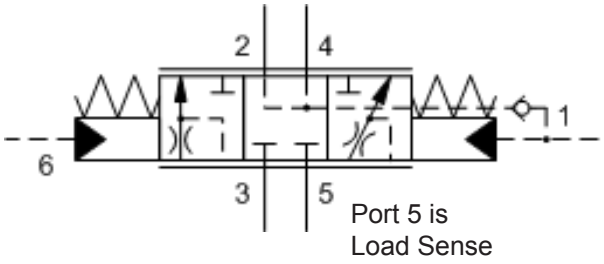


Figure 23 - FT*K-XC

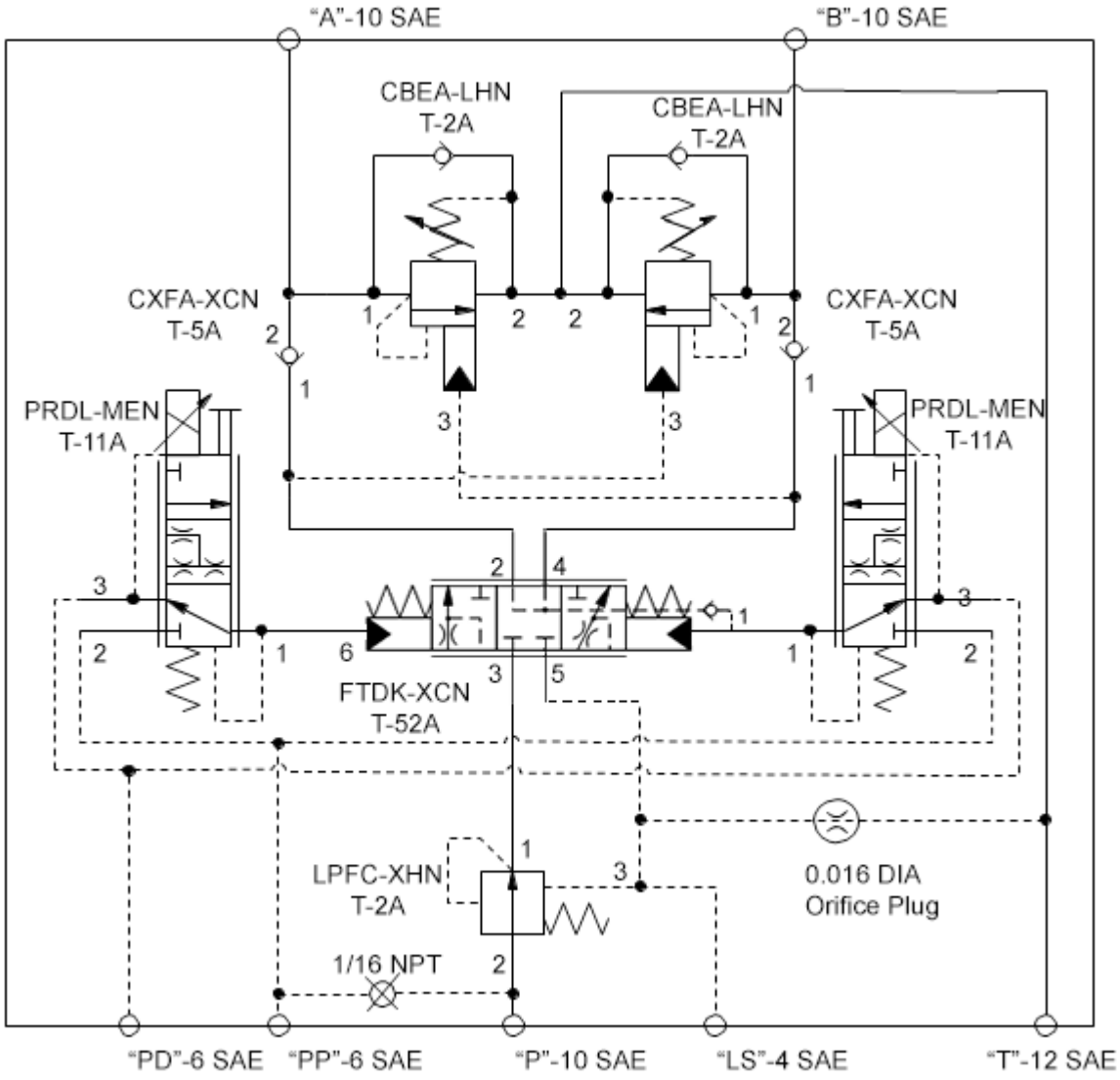
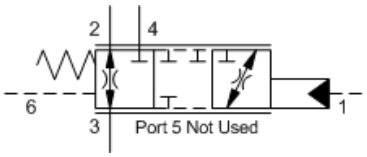
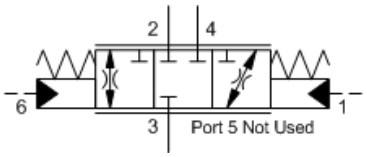
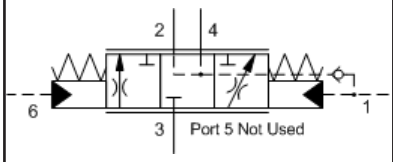
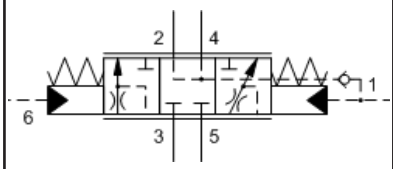
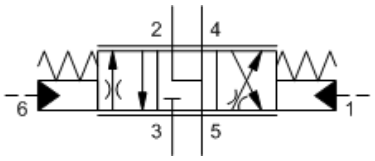
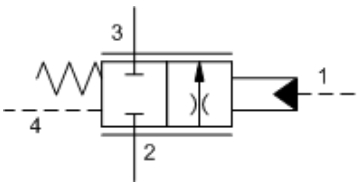
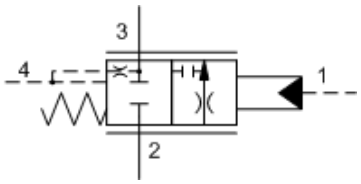
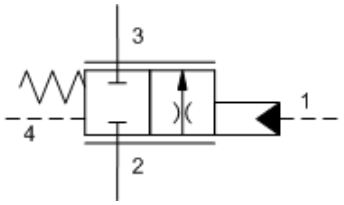


Figure 24 - Complete Proportional Cushion-Lock Manifold with Load Sensing

Pilot-Shifted Proportional Cartridges

FUNCTION	SYMBOL	NOMINAL CAPACITY	CARTRIDGE MODEL	CAVITY
3-way, 2-Pos. Spring-Biased Proportional Selector Valve		7 gpm (28 L/min.) 18 gpm (70 L/min.)	FTCG FTDG	T-52A T-52A
3-way, 3-Pos. Spring-Centered Proportional Selector Valve		7 gpm (28 L/min.) 18 gpm (70 L/min.)	FTCB FTDB	T-52A T-52A
3-way, 3-Pos. Spring-Centered Proportional Directional Valve with Center Bleed-Down		7 gpm (28 L/min.) 18 gpm (70 L/min.) 15 gpm (60 L/min.) 35 gpm (140 L/min.) 80 gpm (320 L/min.)	FTCH FTDH FTEH FTFH FTHH	T-52A T-52A T-53A T-53A T-54A
3-way, 3-Pos. Spring-Centered Proportional Directional Valve with Center Bleed-Down and Load-Sense		7 gpm (28 L/min.) 18 gpm (70 L/min.) 15 gpm (60 L/min.) 35 gpm (140 L/min.)	FTCK FTDK FTEK FTFK	T-52A T-52A T-53A T-53A
4-way, 3-Pos. Spring-Centered Proportional Directional Valve		7 gpm (28 L/min.) 18 gpm (70 L/min.) 12 gpm (45 L/min.) 35 gpm (140 L/min.) 80 gpm (320 L/min.)	FTCC FTDC FTEC FTFC FTHC	T-52A T-52A T-53A T-53A T-54A
2-way, 2-Pos. Spring-Biased, Single-Path Proportional Throttle		5 gpm (20 L/min.) 9 gpm (34 L/min.) 10 gpm (40 L/min.) 20 gpm (80 L/min.) 20 gpm (80 L/min.) 30 gpm (120 L/min.) 40 gpm (160 L/min.) 60 gpm (240 L/min.	FKBA FKCA FKDA FKEA FKFA FKGA FKHA FKIA	T-21A T-21A T-22A T-22A T-23A T-23A T-24A T-24A
2-way, 2-Pos. Spring-Biased, Single-Path Proportional Throttle with Bleed-Down		5 gpm (20 L/min.) 9 gpm (34 L/min.) 10 gpm (40 L/min.) 20 gpm (80 L/min.) 20 gpm (80 L/min.) 30 gpm (120 L/min.) 40 gpm (160 L/min.) 60 gpm (240 L/min.	FKBB FKCB FKDB FKEB FKFB FKGB FKHB FKIB	T-21A T-21A T-22A T-22A T-23A T-23A T-24A T-24A
2-way, 2-Pos. Spring-Biased, Dual-Path Proportional Throttle		15 gpm (60 L/min.) 30 gpm (120 L/min.) 25 gpm (95 L/min.) 50 gpm (200 L/min.) 100 gpm (400 L.min)	FTCA FTDA FTEA FTFA FTHA	T-52AD T-52AD T-53AD T-53AD T-54AD

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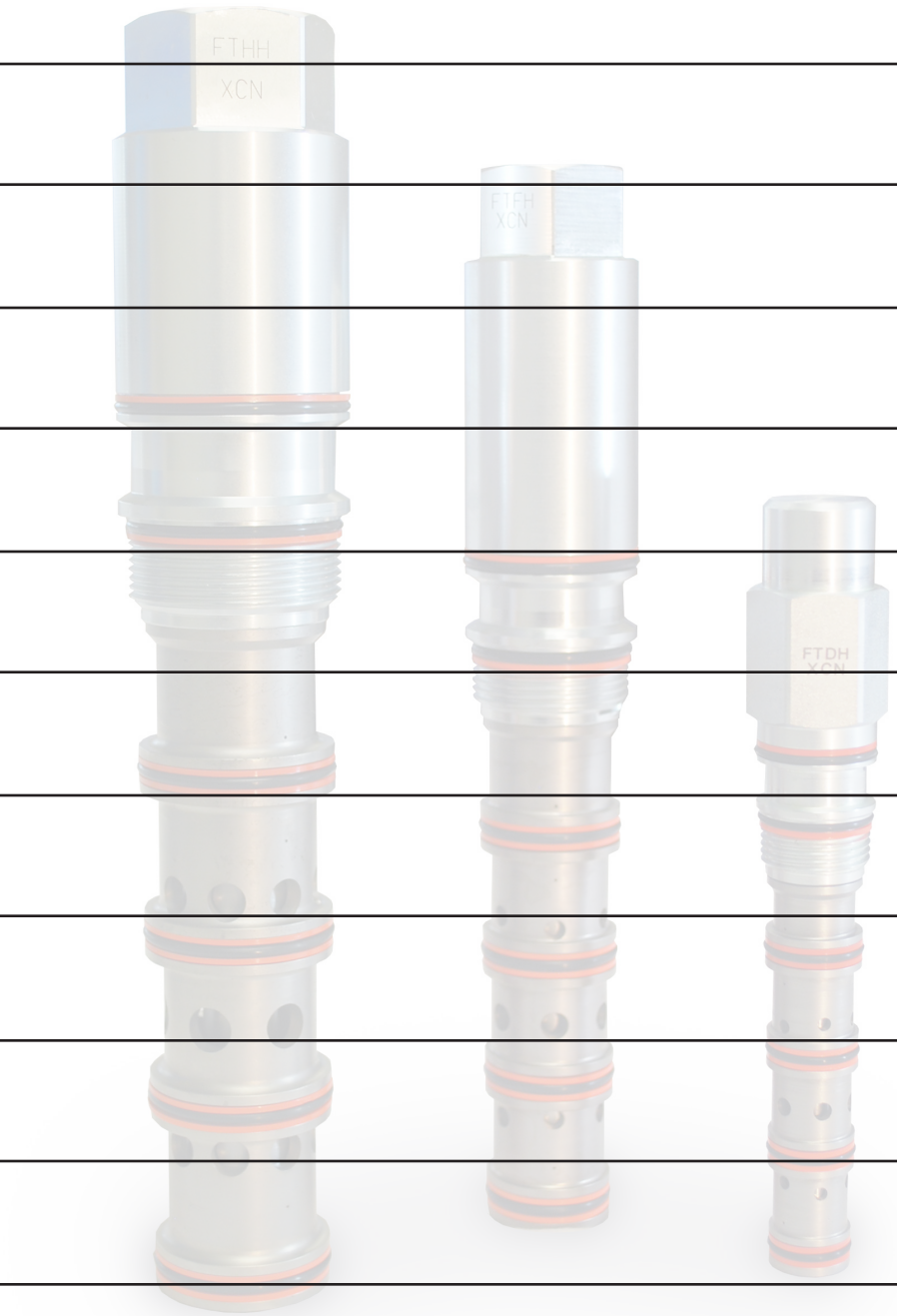
Notes



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