Exercise 3-1

Directional Control Valves

EXERCISE OBJECTIVE

- To introduce directional control valves and their symbols;
- To describe the operation of normally passing and normally non-passing directional control valves.

DISCUSSION

Directional Control Valves

Directional control valves (DCVs) are used to stop and control the direction of flow in a fluid power branch circuit. They are classified according to the number of positions, the number of ways, and the number of valve ports. There are two-way, three-way, and four-way types. The number of ways corresponds to the number of fluid port connections in one position of the valve. The number of positions corresponds to the number of possible flowpath configurations. As an example, a two-way, two-position directional control valve is shown in Figure 3-1.

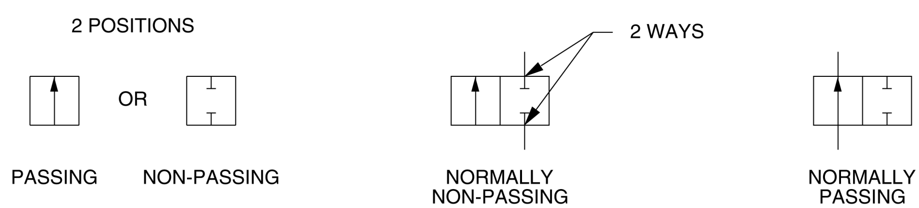

Figure 3-1. 2-Way, 2-Position Directional Control Valve.

The symbol for a directional control valve consists of a separate envelope for each position. The number of ports, or ways, is shown by lines protruding from one of the envelopes. The envelope with lines protruding or with ports identified by a letter or a number shows the flowpath through the valve in the normal, or at rest, position.

A 3-way, 2-position directional control valve has three ports and two possible flowpath configurations. The 3-way, 2-position directional control valve supplied with your trainer can be used in normally passing and normally non-passing applications. It can be used also to provide one of two branch circuits with flow, or select between two power supplies. These four possible uses are shown in Figure 3-2.

Directional Control Valves

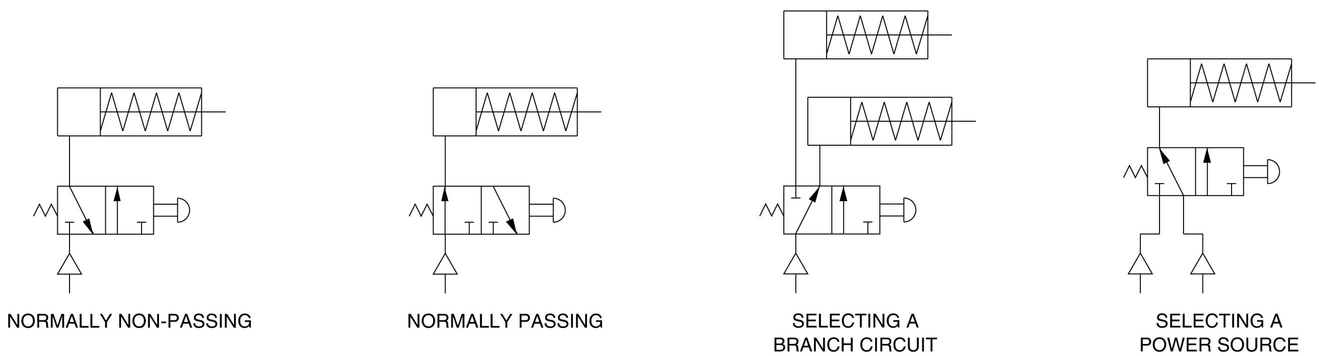

Figure 3-2. 3-Way, 2-Position Directional Control Valve Applications.

The operation of a normally non-passing directional control valve is illustrated in Figure 3-3. When the valve is in its normal position, port 1 is pressurized. Ports 2 and 3 are interconnected through the valve, connecting the branch circuit to the atmosphere. When the spool is shifted, fluid flows from pressurized port 1 to port 2 through the valve, pressurizing the branch circuit. The spring returns the spool to its normal position when the device used to shift the spool is released.

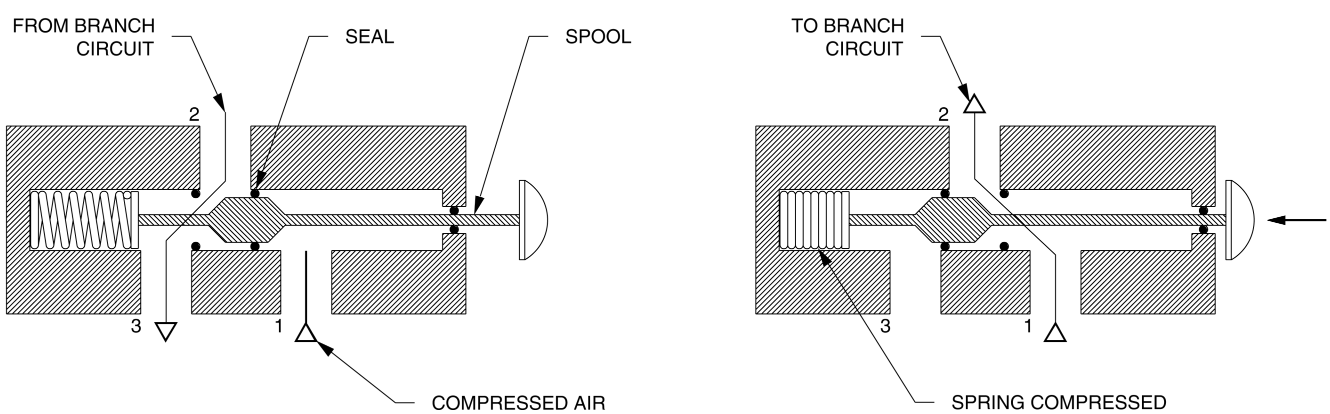

Figure 3-3. 3-Way, 2-Position Directional Control Valve Operation.

A variety of devices, called valve actuators, may be used to shift the spool of directional control valves. The different types are:

- Manual and mechanical: pushbutton, lever, pedal, cam or linkage from a machine member;
- Pilot: a piston moved by pressure, controlled by another directional valve;
- Solenoid: a rod moved by magnetic forces.

Valve actuators are illustrated in Appendix C.

REFERENCE MATERIAL

For additional information on directional control valves, refer to the chapter entitled *Directional Control Valves* in the Parker-Hannifin manual *Industrial Pneumatic Technology.*

Procedure summary

In this exercise, you will verify the operation of a 3-way, 2-position directional control valve.

In the first part of the exercise you will experiment with the normally passing and normally non-passing configurations.

In the last part of the exercise, you will experiment with selection capabilities of a directional control valve.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

☐ 1. Verify the status of the trainer according to the procedure given in Exercise 1-2.

☐ 2. Connect the circuit shown in Figure 3-4. Connect the Conditioning Unit to the NC (normally non-passing) port of the directional control valve.

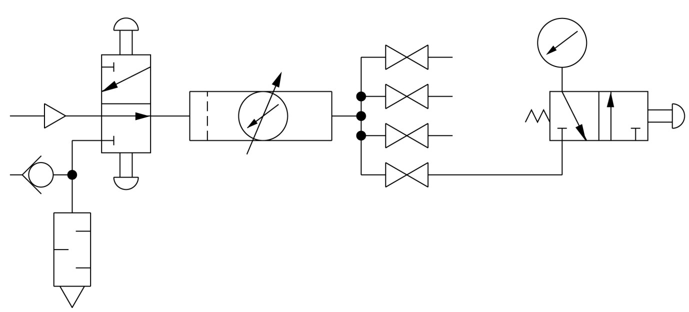

Figure 3-4. Schematic Diagram of a Circuit Using a DCV.

☐ 3. Open the main shutoff valve and the branch shutoff valve at the manifold and set the pressure regulator at 100 kPa (or 15 psi) on the regulated Pressure Gauge.

☐ 4. Record the reading indicated by the Pressure Gauge.

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☐ 5. Push the button on the directional control valve and record the reading indicated by the Pressure Gauge with this position of the button.

____

☐ 6. Close the shutoff valves.

☐ 7. Do your observations confirm that this flow path configuration corresponds to a normally non-passing or a normally passing valve? Explain.

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____
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☐ 8. Modify the circuit by connecting the Conditioning Unit to the NO (normally passing) port of the directional control valve.

☐ 9. Open the shutoff valves and set the pressure regulator at 100 kPa (or 15 psi) on the regulated Pressure Gauge.

☐ 10. Record the reading indicated by the Pressure Gauge.

____

☐ 11. Push the button on the directional control valve and record the reading indicated by the Pressure Gauge with this position of the button.

____

☐ 12. Does this flow path configuration correspond to a normally non-passing or normally passing valve? Explain.

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____
____

☐ 13. Close the shutoff valves and turn the regulator adjusting knob completely counterclockwise.

☐ 14. Modify the circuit as shown in Figure 3-5. Connect the Conditioning Unit to the OUT port of the directional control valve.

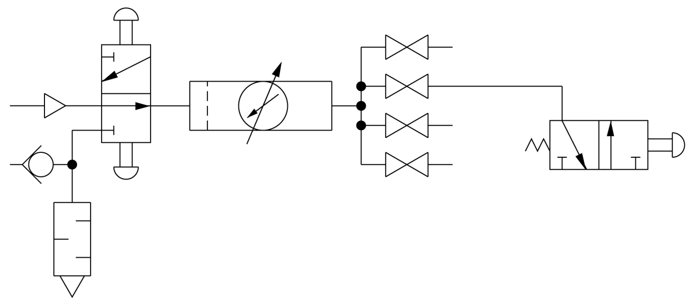

Figure 3-5. Schematic Diagram of a Circuit Using a DCV to Select a Branch Circuit.

☐ 15. Open the shutoff valves and slowly turn the regulator adjusting knob clockwise until you ear some noise generated by compressed air.

☐ 16. Observe by which port compressed air flows.

☐ 17. Push the button on the directional control valve and repeat your observation.

☐ 18. Does the air flow through the same port when the button is pushed?

☐ Yes ☐ No

☐ 19. Do your observations confirm that the directional control valve can be used to select a branch circuit to be pressurized?

☐ Yes ☐ No

☐ 20. Close the shutoff valves.

☐ 21. Modify the circuit as shown in Figure 3-6. Connect the Flow Control Valve to the NC port of the directional control valve and the Conditioning Unit to the NO port.

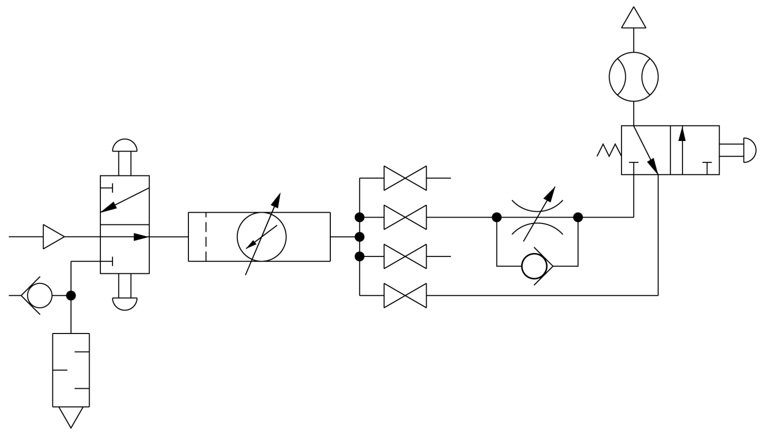

Figure 3-6. Schematic Diagram of a Circuit Using a DCV to Select a Power Source.

☐ 22. Ensure that the Flow Control Valve is fully closed.

☐ 23. Open the required shutoff valves and set the pressure regulator at 200 kPa (or 30 psi) on the regulated Pressure Gauge.

☐ 24. Open partially the Flow Control Valve by turning the control knob three turns counterclockwise. Refer to the mark on the control knob to help you set the correct position.

☐ 25. Record the flow rate indicated by the Flowmeter.

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☐ 26. Push the button on the directional control valve and repeat your observation. Record the flow rate indicated by the Flowmeter while the button is pressed.

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☐ 27. Close the shutoff valves.

☐ 28. Do your observations confirm that the directional control valve allows selection of a power source? Explain.

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____

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☐ 29. On the Conditioning Unit, close the shutoff valves and turn the regulator adjusting knob completely counterclockwise. You should read 0 kPa (or 0 psi) on the regulated Pressure Gauge.

☐ 30. Disconnect and store all tubing and components.

CONCLUSION

In this exercise, you verified the operation of a 3-way, 2-position directional control valve. You have seen that the directional control valve supplied with your trainer can be used in normally passing and normally non-passing applications.

You have also seen that it can be used to provide one of two branch circuits with flow, or select between two power supplies.

You have learned that a variety of devices, called valve actuators, may be used to shift the spool of directional control valves.

REVIEW QUESTIONS

1. A 3-way, 2-position directional control valve cannot be used to

   a. select between two power sources.
   b. select between two branch circuits.
   c. adjust pressure in two branch circuits.
   d. start and stop an actuator.

2. A 3-way, 2-position directional control valve

   a. can be spring return.
   b. can be used to adust pressure in two different branch circuits.
   c. cannot be shifted manually.
   d. has two ports.

3. A 3-way, 2-position directional control valve can have

   a. three envelopes and two fluid ports.
   b. three envelopes and three fluid ports.
   c. two envelopes and three positions.
   d. two envelopes and three fluid ports.

4. The devices used to shift the spool of directional control valves are called

   a. valve actuators.
   b. valve controls.
   c. valve pilots.
   d. levers

5. In a 3-way, 2-position directional control valve, how many flowpath configurations are possible?

   a. 1
   b. 2
   c. 3
   d. 6

Exercise 3-2

Directional and Speed Control of Cylinders

EXERCISE OBJECTIVE

- To introduce the operation of cylinders;
- To learn how to control the direction and speed of cylinders.

DISCUSSION

In fluid power systems, various forms of energy are converted into other forms of energy to do useful work. The devices that convert fluid energy into mechanical energy are called actuators.

A fluid power cylinder is an actuator that converts fluid energy into straight-line or linear mechanical energy. Single-acting cylinders generate forces in a single direction whereas double-acting cylinders generate forces during both extension and retraction of the rod.

The operation of a single-acting, spring-return cylinder is illustrated in Figure 3-7. When flow is directed into the cap end of the cylinder, pressure in the cap end rises until enough force is generated to compress the spring. Air in the rod end is exhausted to atmosphere through the vent port. When the cylinder reaches the end of its stroke, or is stopped by a load, pressure in the cap end rises to the system pressure. When the fluid pressure is relieved, the force of the spring retracts the cylinder. Common single-acting cylinder applications include lifts, clutches, clamps and brakes.

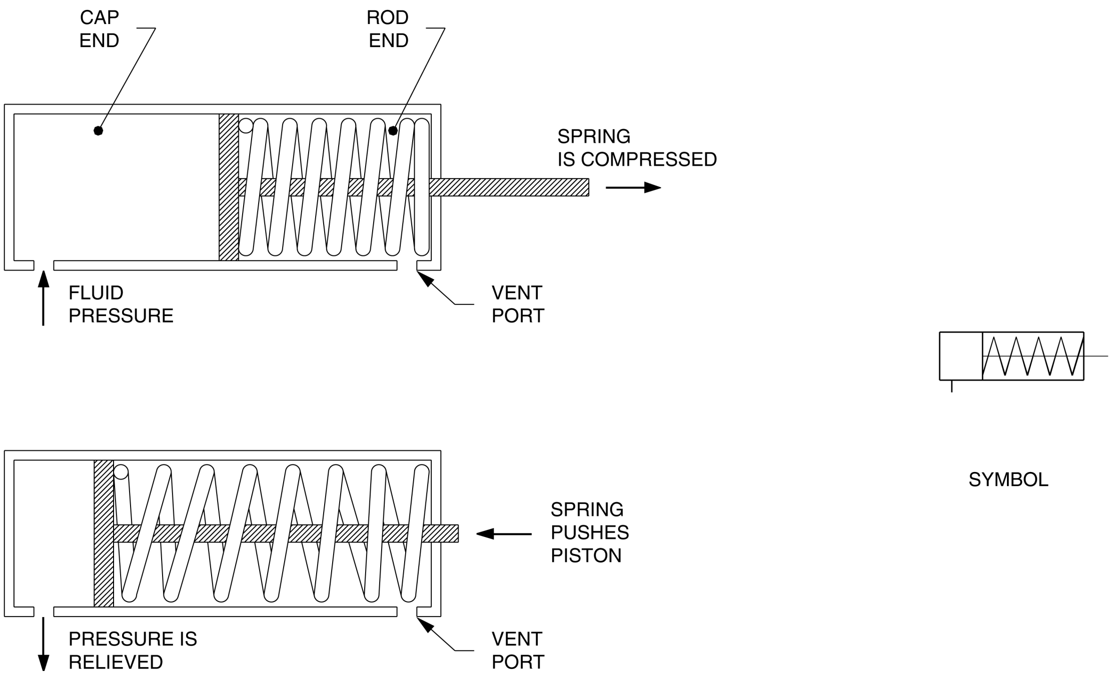

Figure 3-7. Single-Acting, Spring Return Cylinder Operation.

The basic construction of a double-acting cylinder is similar to that of a single-acting cylinder, except that the double-acting cylinder contains two fluid ports instead of one, and does not include a spring. When fluid enters one port of the cylinder, the piston moves toward the other port. A double-acting cylinder is shown in Figure 3-8.

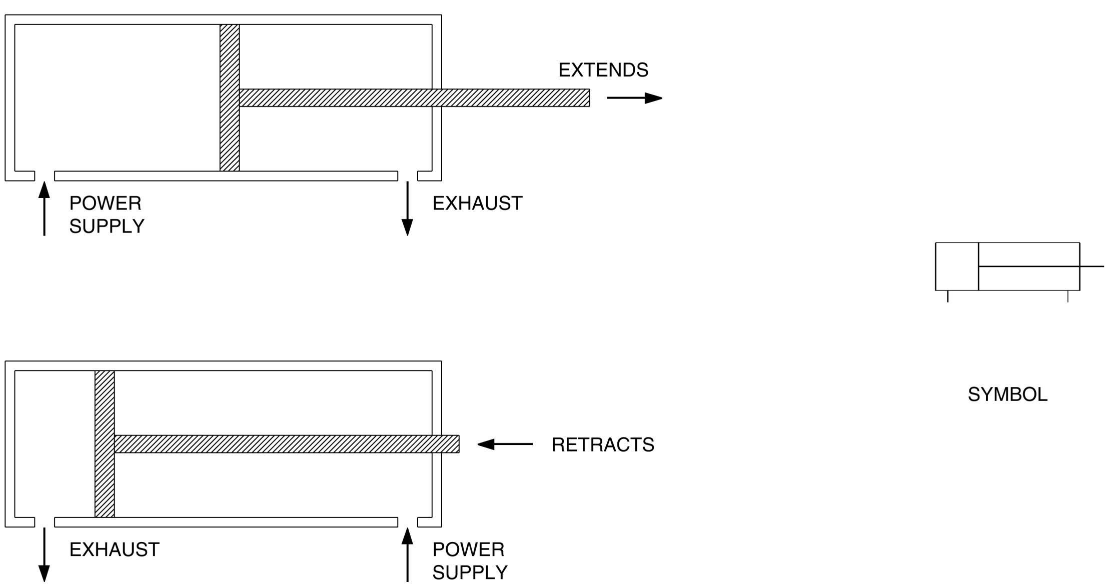

Figure 3-8. Double-Acting Cylinder Operation.

Flow control valves are commonly used to control the speed of fluid power actuators. In some applications, the flow control valve is placed upstream from the actuator. This application is called a meter-in circuit because it controls, or meters, the rate of flow going into the actuator. The meter-in circuit is used to control actuator speed where the actuator constantly works against a load. This means that there is always resistance to flow downstream from the valve.

For example, a cylinder used to push a load might be controlled with the meter-in circuit shown in Figure 3-9. A check valve is often included to allow a rapid return stroke.

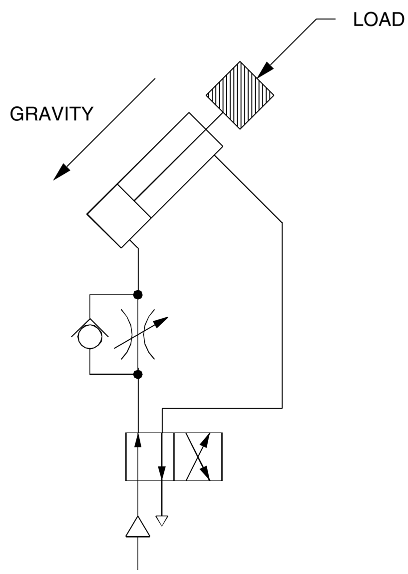

Figure 3-9. Meter-in Circuit.

When the actuator does not constantly work against a load, such as in a drilling operation where the drill breaks through the stock, a meter-out circuit may be used. A meter-out circuit controls the flow rate leaving the actuator. A meter-out circuit that controls the extension speed of a cylinder is shown in Figure 3-10. In this circuit, gravity applies a constant force that attempts to extend the cylinder. If the meter-out needle flow control valve was not included, the cylinder might extend too quickly, creating a runaway condition.

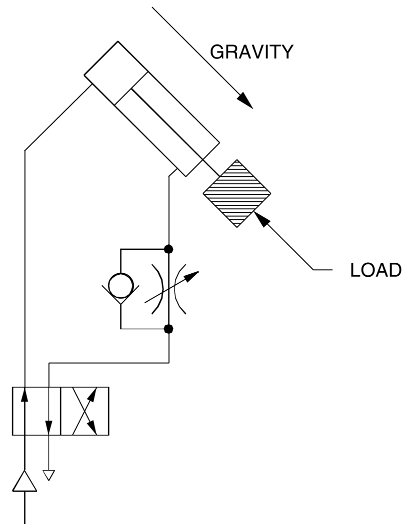

Figure 3-10. Meter-out Circuit.

When independent control of speed is necessary for each direction of travel, two flow control valves must be used: one for each direction. As shown in Figure 3-11, on the extension stroke, air is admitted freely to the cap end of the cylinder through the check valve in flow control valve FCV1, and speed is controlled by metering exhaust air through flow control valve FCV2. On the retraction stroke, air enters freely into the rod end through the check valve in valve FCV2 while exhaust air is metered through valve FCV1. Since the valves FCV1 and FCV2 control the flow rate leaving the actuator, they are connected in a meter-out configuration.

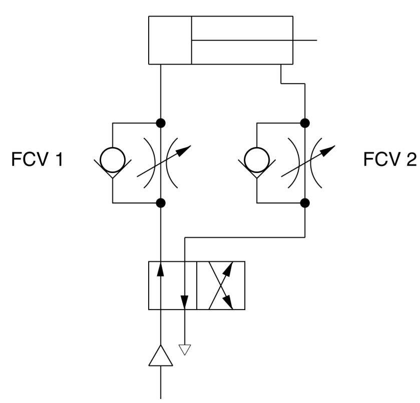

Figure 3-11. Meter-out Both Directions.

Speed control is also achieved using the bypass configuration. In this configuration, a needle valve is connected between the air supply and the cap end of the cylinder as shown in Figure 3-12. The opening of the needle valve controls the flow of compressed air that is exhausted to atmosphere. This configuration is less power efficient but only one needle valve is required to control the speed in both directions.

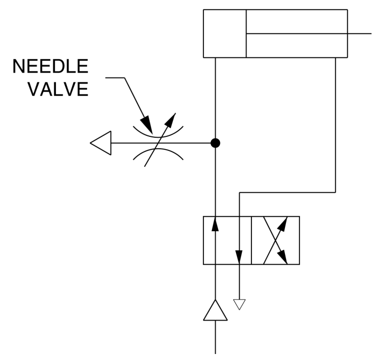

Figure 3-12. Bypass Configuration of Speed Control.

REFERENCE MATERIAL

For additional information, refer to the chapter entitled *Flow Control Valves, Silencers, Quick Exhausts* in the Parker-Hannifin manual *Industrial Pneumatic Technology.*

Procedure summary

In the first part of the exercise, you will control the operation of a cylinder using the meter-in configuration.

In the second part, you will control the operation of the cylinder using the meter-out configuration.

In the last part, you will control the speed of the cylinder in both directions.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

Meter-in Flow Control

☐ 1. Verify the status of the trainer according to the procedure given in Exercise 1-2.

☐ 2. Connect the circuit shown in Figure 3-13.

Note: *Because of the compressibility of air, always use tubes as short as possible between the cylinder and the Flow Control Valve.*

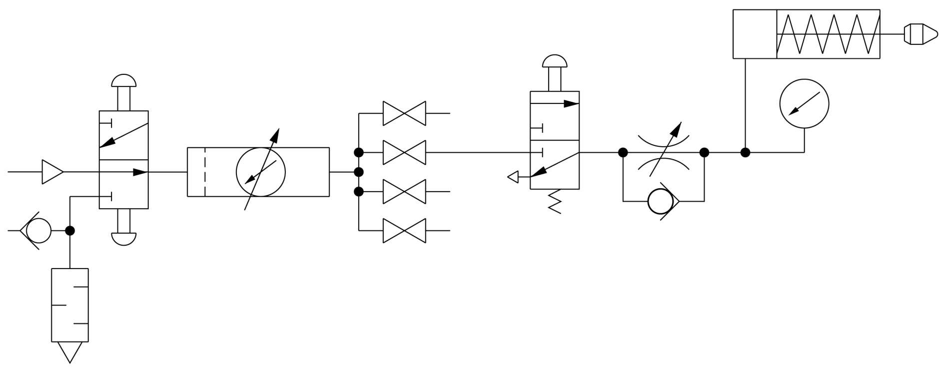

Figure 3-13. Schematic Diagram of the Meter-in Circuit.

☐ 3. Close the Flow Control Valve by turning the control knob fully clockwise. Screw a tip (bullet) to the rod of the cylinder.

☐ 4. Open the main shutoff valve and the branch shutoff valve at the manifold and set the pressure regulator at 500 kPa (or 70 psi) on the regulated Pressure Gauge.

☐ 5. Open the Flow Control Valve by turning the control knob counterclockwise as indicated in Table 3-1. Refer to the mark on the control knob to help you set the correct position.

☐ 6. Push the button on the directional control valve and measure the extension time and retraction time of the piston rod. Record your results in the appropriate cells in Table 3-1. Repeat your measurements to validate your results.

REGULATED PRESSURE: 500 kPa (or 70 psi)		
FLOW CONTROL VALVE	EXTENSION TIME seconds	RETRACTION TIME seconds
¼ turn		
½ turn		
¾ turn		
1 turn		
2 turns		
fully open		

Table 3-1. Meter-in Flow Control.

☐ 7. Explain the relationship between the setting of the Flow Control Valve and the extension time of the rod?

____

____

☐ 8. What do you observe about the retraction time of the rod? Explain.

____

____

____

☐ 9. Close the Flow Control Valve by turning the control knob fully clockwise, then close the shutoff valves.

Meter-out Flow Control

☐ 10. Reverse the tubes at the Flow Control Valve ports to reverse the air flow through the valve.

☐ 11. Open the main shutoff valve and set the pressure regulator at 500 kPa (or 70 psi) on the regulated Pressure Gauge.

☐ 12. Open the Flow Control Valve by turning the control knob counterclockwise as indicated in Table 3-2. Refer to the mark on the control knob to help you set the correct position.

☐ 13. Push the button on the directional control valve and measure the extension time and retraction time of the piston rod. Record your results in the appropriate cells in Table 3-2. Repeat your measurements to validate your results.

REGULATED PRESSURE: 500 kPa (or 70 psi)		
FLOW CONTROL VALVE	EXTENSION TIME seconds	RETRACTION TIME seconds
¼ turn		
½ turn		
¾ turn		
1 turn		
2 turns		
fully open		

Table 3-2. Meter-out Flow Control.

☐ 14. Compare the extension time and retraction time of the cylinder when the Flow Control Valve is open 1 turn counterclockwise? Explain.

____

____

____

☐ 15. Explain the relationship between the setting of the Flow Control Valve and the retraction time of the rod?

____

____

____

☐ 16. Close the shutoff valves and turn the regulator adjusting knob completely counterclockwise.

Speed Control Both Directions

☐ 17. Modify your circuit as shown in Figure 3-14. Be careful to connect the Flow Control Valves in the correct direction.

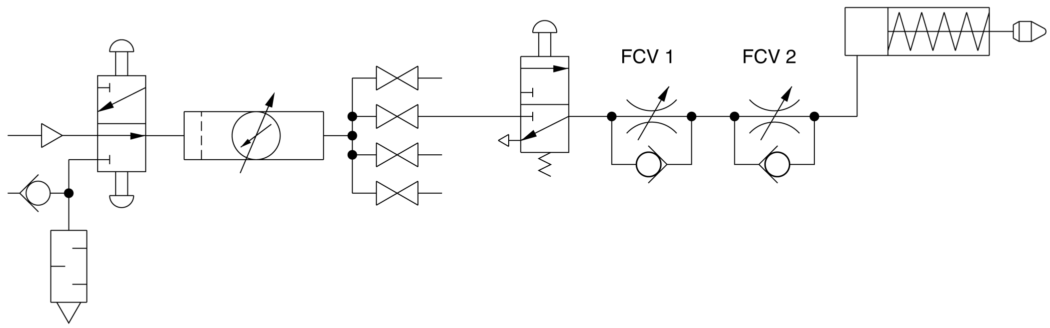

Figure 3-14. Schematic Diagram of a Circuit Using Speed Control Both Directions

☐ 18. Referring to the schematic diagram shown in Figure 3-14, which valve controls the extension speed of the cylinder?

____

☐ 19. Referring to the schematic diagram shown in Figure 3-14, indicate in Table 3-3 how the operation of the cylinder will be affected by the setting combinations of Flow Control Valves FCV1 and FCV2.

FCV1	FCV2	OPERATION OF THE CYLINDER
closed	closed	
open	closed	
closed	open	
open	open	

Table 3-3. Description of the Operation of the Cylinder.

☐ 20. Close the Flow Control Valves by turning the control knob fully clockwise.

☐ 21. Open the main shutoff valve and set the pressure regulator at 300 kPa (or 40 psi) on the regulated Pressure Gauge.

☐ 22. Push the button on the directional control valve while observing the operation of the cylinder. Verify your predictions indicated in Table 3-3.

☐ 23. Repeat your observations for the setting combinations of FCV1 and FCV2 indicated in Table 3-3.

☐ 24. Do your observations confirm your predictions indicated in Table 3-3?

☐ Yes ☐ No

☐ 25. Close the shutoff valves and turn the regulator adjusting knob completely counterclockwise.

☐ 26. Modify your circuit as shown in Figure 3-15. Be careful to connect the Flow Control Valves in the correct direction.

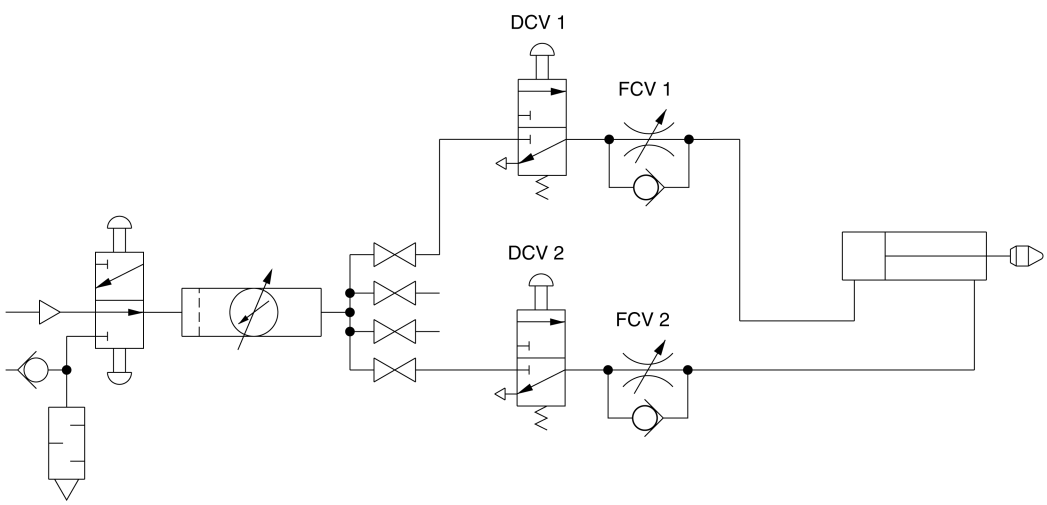

Figure 3-15. Schematic Diagram of a Circuit Using Speed Control Both Directions

☐ 27. Referring to the schematic diagram shown in Figure 3-15, indicate if the circuit is connected in a meter-in or meter-out configuration.

____

☐ 28. Close the Flow Control Valves by turning the control knob fully clockwise.

☐ 29. Open the shutoff valves and set the pressure regulator at 500 kPa (or 70 psi) on the regulated Pressure Gauge.

☐ 30. Which directional control valve must be open to allow the rod of the cylinder to extend?

____

☐ 31. Open the Flow Control Valve FCV1 by turning the control knob fully counterclockwise and open the directional control valve DCV1 by pushing down the button on the valve.

☐ 32. Does the cylinder extend, confirming your prediction indicated in step 30?

☐ Yes ☐ No

☐ 33. Try different setting combinations for FCV1 and FCV2 to obtain an extension time of the rod of 2 s and a retraction time of 1 s.

☐ 34. Does your circuit allow you to set the extension time and retraction time of the cylinder? If not, explain.

____

____

____

☐ 35. Close the shutoff valves and the Flow Control Valves.

☐ 36. Reverse the tubes at the Flow Control Valve ports (both valves) to change the configuration of the circuit. Indicate if the circuit is now connected in a meter-in or meter-out configuration.

____

☐ 37. Indicate which Flow Control Valve controls the extension speed of the cylinder?

____

☐ 38. Verify the operation of your circuit by trying different setting configurations of the Flow Control Valves and verify your prediction made in the previous step.

☐ 39. Adjust FCV1 and FCV2 to obtain an extension time of the rod of 1 s and a retraction time of 2 s.

☐ 40. Does your circuit allow you to set the extension time and retraction time of the cylinder? If not, explain.

____

____

____

☐ 41. On the Conditioning Unit, close the shutoff valves and turn the regulator adjusting knob completely counterclockwise. You should read 0 kPa (or 0 psi) on the regulated Pressure Gauge.

☐ 42. Disconnect and store all tubing and components.

CONCLUSION

In this exercise, you operated single-acting and double-acting cylinders.

You saw that flow control valves are used to control the speed of extension and retraction of the cylinder rods. You verified that the extension and retraction times can be controlled independently using two flow control valves.

You also saw how the meter-in and meter-out configurations can be used to control the operation of cylinders.

REVIEW QUESTIONS

1. A single-acting cylinder

   a. converts fluid power to rotary motion.
   b. can both extend and retract under power.
   c. relies on a spring or a load to return the cylinder to its original position.
   d. requires the use of a 3-way, 3-position directional control valve.

2. Cap-end and rod-end refer to

   a. the two ends of a fluid power cylinder.
   b. the two ends of a fluid power circuit.
   c. single-acting cylinders only.
   d. the fluid ports of a fluid power motor.

3. A double-acting cylinder

   a. requires the use of a 3-way, 3-position directional control valve.
   b. converts linear mechanical energy into rotary mechanical energy during extension and retraction.
   c. contains one fluid port and a breather element.
   d. converts fluid power energy into linear mechanical energy during extension and retraction.

4. The meter-out configuration controls the flow rate

   a. entering an actuator.
   b. leaving an actuator.
   c. entering and leaving an actuator.
   d. None of the above.

5. The meter-in configuration is used to control actuator speed where the actuator constantly works

   a. vertically.
   b. horizontally.
   c. slowly.
   d. against the load.