Lecture 39

SINGLE ACTUATOR CIRCUITS

Learning Objectives

Upon completion of this chapter, Student should be able to

- Differentiate between pneumatic circuit and pneumatic circuit diagram
- State basic rules used in design of pneumatic circuits
- Explain the memory, delay, OR , AND and NOT functions
- Explain the direct and indirect control of single acting cylinder
- Explain the direct and indirect control of double acting cylinder
- Differentiate supply and exhaust air throttling
- Study various methods of checking end positions of a cylinder
- Design pressure and time dependant circuits

1.1 Pneumatic circuit and pneumatic circuit diagram.

Pneumatic control systems can be designed in the form of pneumatic circuits. A pneumatic circuit is formed by various pneumatic components, such as cylinders, directional control valves, flow control valves, pressure regulator, signal processing elements such as shuttle valve, two pressure valve etc. Pneumatic circuits have the following functions

- To control the entry and exit of compressed air in the cylinders.
- To use one valve to control another valve
- To control actuators or any other pneumatic devices

A pneumatic circuit diagram uses pneumatic symbols to describe its design. Some basic rules must be followed when drawing pneumatic diagrams.

To be able to design pneumatic circuits, it is better for one to have basic knowledge on the designing simple pneumatic circuits. With this foundation, one would be able to move on to the designing more complicated circuits involving many more cylinders.

1.2 SINGLE ACTING CYLINDER CONTROL

1.2.1 DIRECT CONTROL OF SINGLE ACTING CYLINDER.

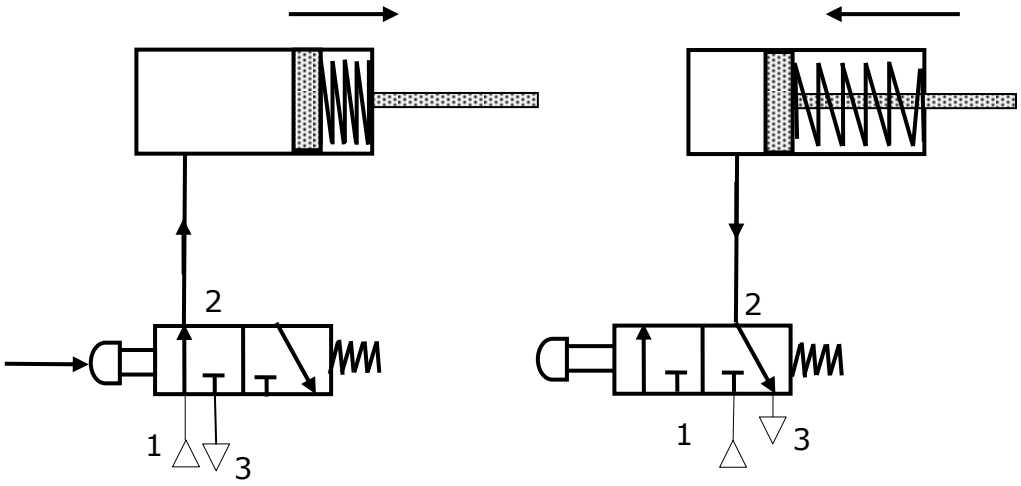


Figure 1.1 Direct control of a single acting cylinder

Pneumatic cylinders can be directly controlled by actuation of final directional control valve (Figure 1.1). These valves can be controlled manually or electrically. This circuit can be used for small cylinders as well as cylinders which operates at low speeds where the flow rate requirements are less. When the directional control valve is actuated by push button, the valve switches over to the open position, communicating working source to the cylinder volume. This results in the forward motion of the piston. When the push button is released, the reset spring of the valve restores the valve to the initial position [closed]. The cylinder space is connected to exhaust port there by piston retracts either due to spring or supply pressure applied from the other port.

Example 1: A small single acting cylinder is to extend and clamp a work piece when a push button is pressed. As long as the push button is activated, the cylinder should remain in the clamped position. If the push button is released, the clamp is to retract. Use additional start button. Schematic diagram of the setup is shown in Figure 1.2

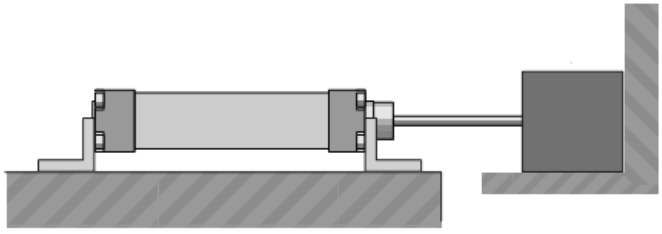


Figure 1.2

Solution

The control valve used for the single acting cylinder is the 3/2 way valve. In this case, since the cylinder is of small capacity, the operation can be directly controlled by a push button 3/2 way directional control valve with spring return.

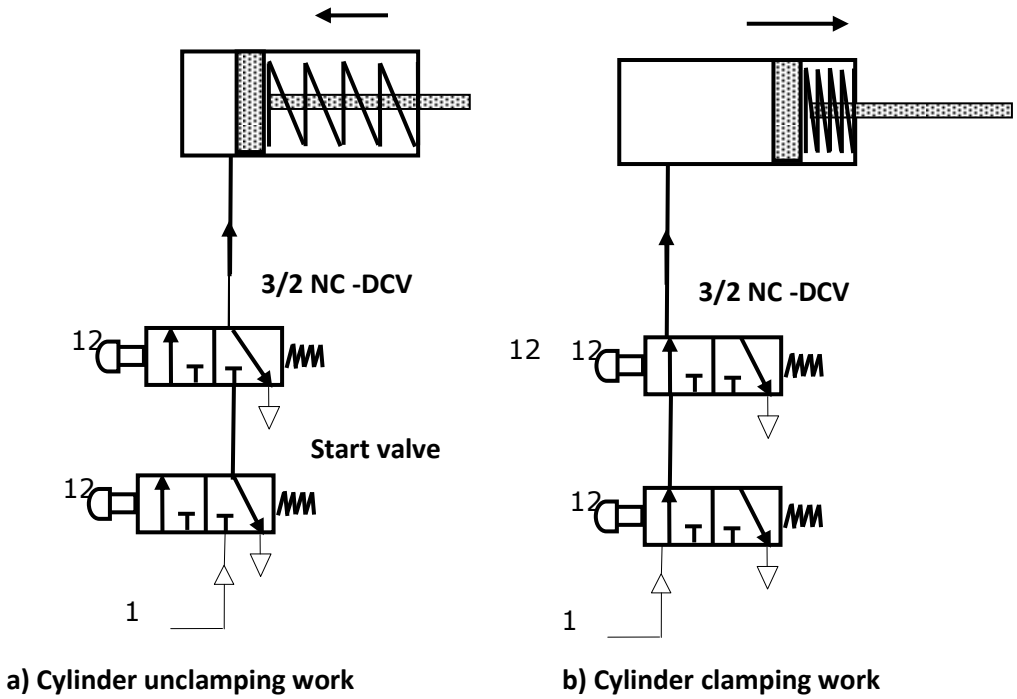


Figure 1.3

When start button and 3/2 NC valve is operated, cylinder moves forward to clamp the work piece. When start button and 3/2 way valve is released cylinder comes back to the retracted position as shown in **Figure 1.3**

1.2.2 INDIRECT CONTROL OF SINGLE ACTING CYLINDER

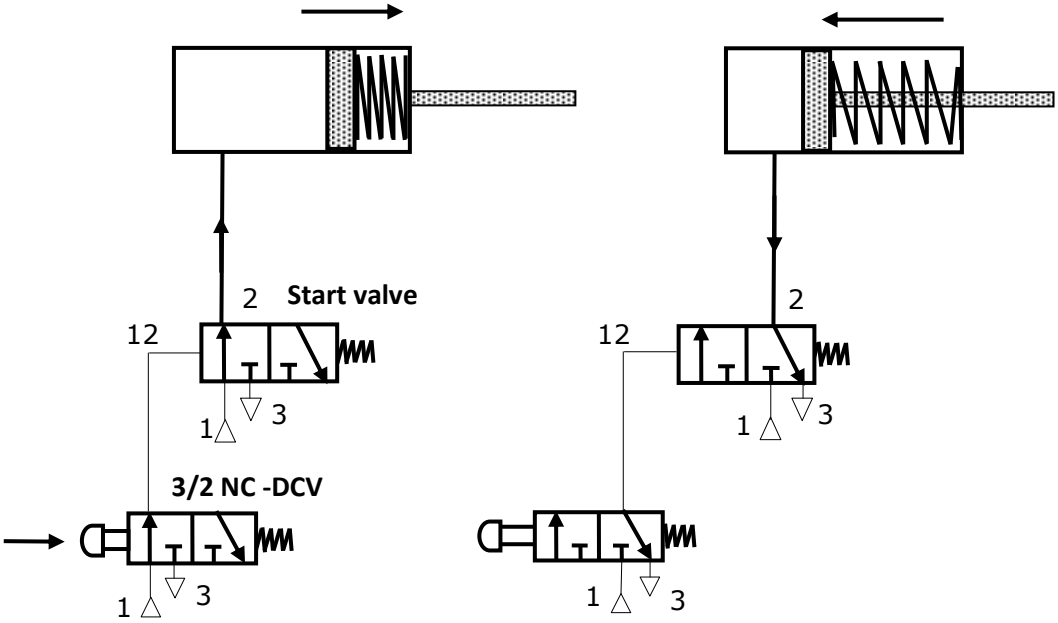


Figure 1.4 Indirect control of a single acting cylinder

This type of circuit (Figure 1.4) is suitable for large single cylinders as well as cylinders operating at high speeds. The final pilot control valve is actuated by normally closed 3/2 push button operated valve. The final control valves handle large quantity of air. When the push button is pressed, 3/2 normally closed valve generate a pilot signal 12 which controls the final valve thereby connecting the working medium to piston side of the cylinder so as to advance the cylinder. When the push button is released, pilot air from final valve is vented to atmosphere through 3/2 NC – DCV.

The signal pressure required can be around 1-1.5 bar. The working pressure passing through the final control valve depends on the force requirement which will be around 4-6 bar. Indirect control as permits processing of input signals. Single piloted valves are rarely used in applications where the piston has to retract immediately on taking out the set pilot signal.

Example 2: A large single acting cylinder is to extend and clamp a work piece when a push button is pressed. As long as the push button is activated, the cylinder should remain in the clamped position. If the push button is released, the clamp is to retract. Use additional start button.

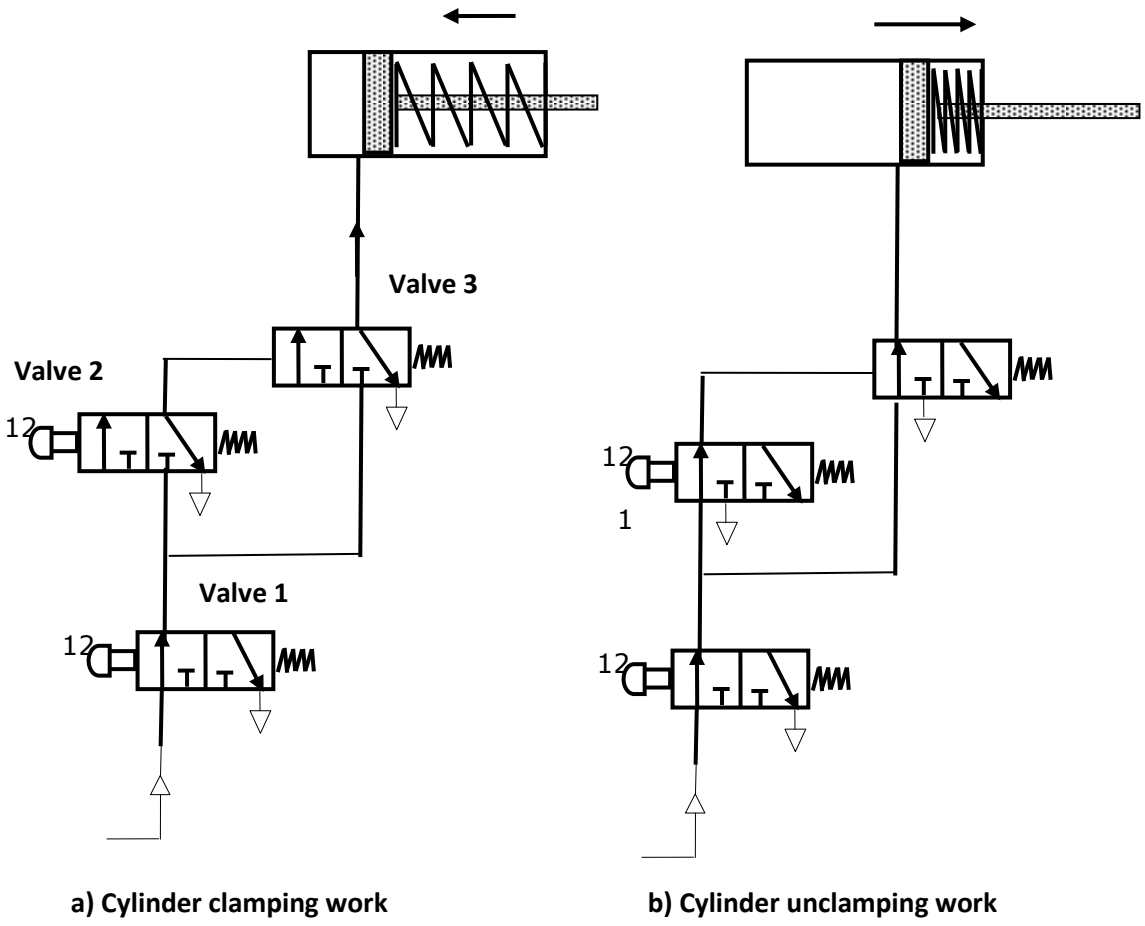


Figure 1.5

The control valve used for the single acting cylinder is the 3/2 way valve. In this case, since the cylinder is of large capacity, the operation cannot be directly controlled by a push button 3/2 way directional control valve with spring return. Indirect control is to be used as shown in the Figure 1.5

Valve 2 is a small capacity valve which controls the large capacity valve 3. When the valve 2 is unactuated the cylinder is in the retracted condition. When the valve 2 is actuated the cylinder is in the extended position to clamp the work piece.

1.2.3 CONTROL OF SINGLE ACTING CYLINDER USING "OR" VALVE

Shuttle valve is also known as double control valve or double check valve. A shuttle valve has two inlets and one outlet (Figure 1.6). At any one time, flow is shut off in the direction of whichever inlet is unloaded and is open from the loaded inlet to the outlet. This valve is also called an OR valve. A shuttle valve may be installed for example, when the cylinder or valve is to be actuated from two points, which may be remote from one another.

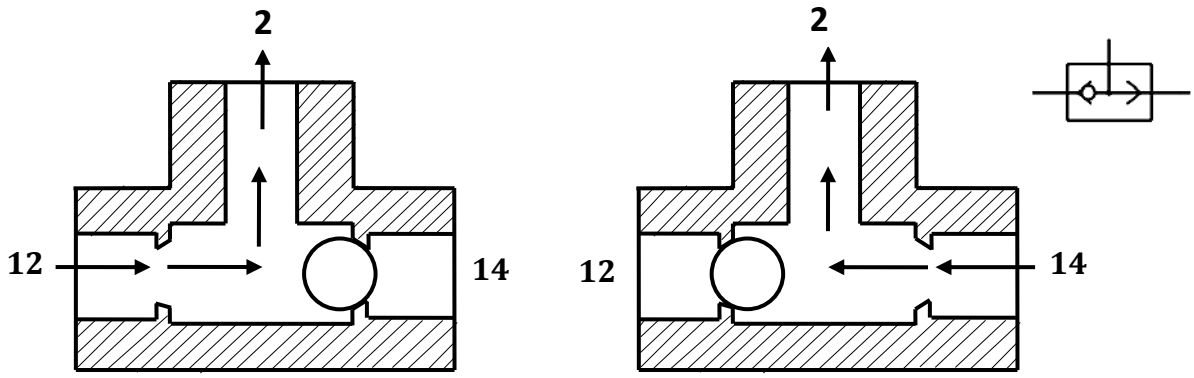


Figure 1.6 Shuttle valve (OR valve)

The single acting cylinder in Figure 1.7 can be operated by two different circuits. Examples include manual operation and relying on automatic circuit signals, that is, when either control valve ① or control valve ② is operated, the cylinder will work. Therefore, the circuit in Figure 1.7 possesses the OR function.

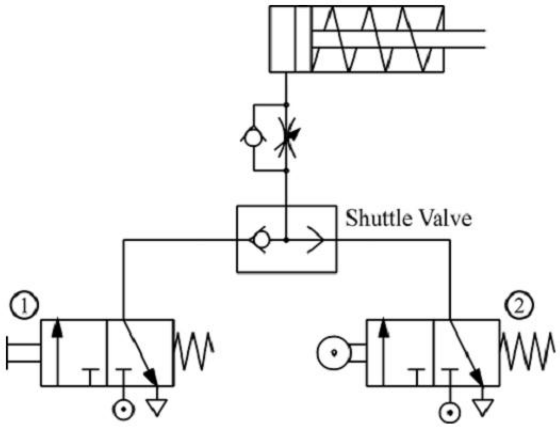


Figure 1.7 Control of a single acting cylinder using OR valve

1.2.4 CONTROL OF SINGLE ACTING CYLINDER USING "AND" VALVE

This valve is the pneumatic AND valve. It is also derivate of Non Return Valve. A two pressure valve requires two pressurised inputs to allow an output from itself. The cross sectional views of two pressure valve in two positions are given in **Figure 1.8** As shown in the **Figure 1.8**, this valve has two inputs 12 and 14 and one output 2. If the compressed air is applied to either 12 or input 14, the spool moves to block the flow, and no signal appears at output 2. If signals are applied to both the inputs 12 and 14, the compressed air flows through the valve, and the signal appears at output 2.

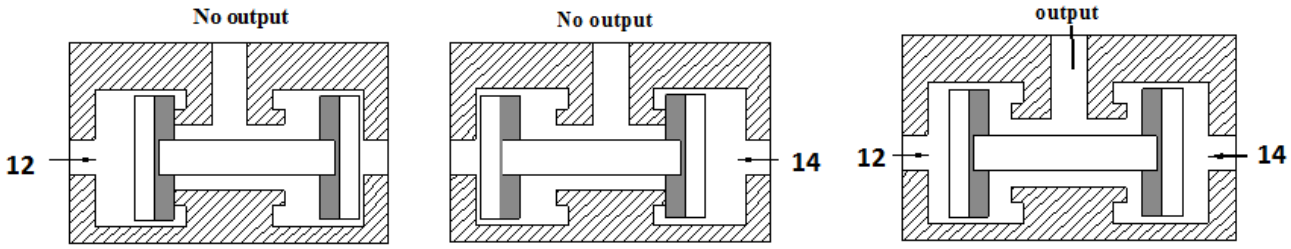


Figure 1.8 control of a single acting cylinder using OR valve

Another name for an AND function is interlock control. This means control is possible only when two conditions are satisfied. A classic example is a pneumatic system that works only when its safety door is closed and its manual control valve is operated. The flow passage will open only when both control valves are operated. **Figure 1.9** shows the circuit diagram of an AND function circuit. The cylinder will work only when both valve ① and ② are operated.

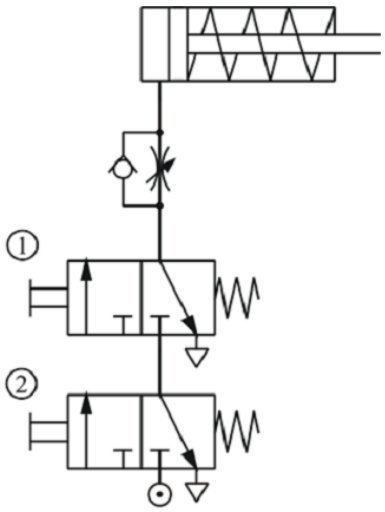


Figure 1.9 Control of a single acting cylinder using AND valve

1.2.5 CONTROL OF SINGLE ACTING CYLINDER USING "NOT" VALVE

Another name for a NOT function is inverse control. In order to hold or lock an operating conveyor or a similar machine, the cylinder must be locked until a signal for cancelling the lock is received. Therefore, the signal for cancelling the lock should be operated by a normally open type control valve. However, to cancel the lock, the same signal must also cancel the locks on other devices, like the indication signal ③. **Figure 1.10** shows how the normally closed type control valve ① can be used to cut off the normally open type control valve ② and achieve the goal of changing the signal.

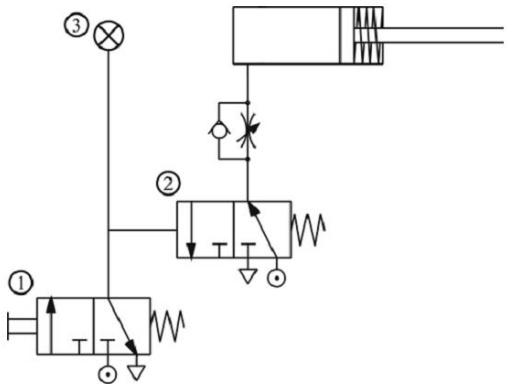


Figure 1.10 Control of a single acting cylinder using NOT valve

1.3 DIRECT CONTROL OF DOUBLE ACTING CYLINDER

The only difference between a single acting cylinder and a double acting cylinder is that a double acting cylinder uses a 5/2 directional control valve instead of a 3/2 directional control valve (**Figure 1.11**). Usually, when a double acting cylinder is not operated, outlet 'B' and inlet 'P' will be connected. In this circuit, whenever the operation button is pushed manually, the double acting cylinder will move back and forth once

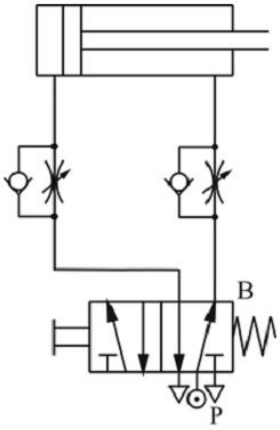


Figure 1.11 Direct control of a double acting cylinder

In order to control the speed in both directions, flow control valves are connected to the inlets on both sides of the cylinder. The direction of the flow control valve is opposite to that of the release of air by the flow control valve of the single acting cylinder. Compared to the throttle inlet, the flow control valve is tougher and more stable. Connecting the circuit in this way allows the input of sufficient air pressure and energy to drive the piston.

Example 3: Pneumatic system is to be designed to operate a door of public transport vehicles. (**Figure 1.12**). Assuming that the opening and closing of the doors are controlled by two button switches ON and OFF. When the button switch ON is pressed, the door will open. When the button switch OFF is pushed, the doors will close.

Solution.

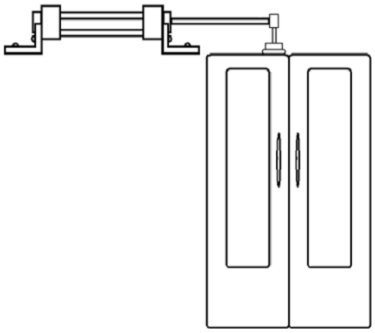


Figure 1.12 Operation of pneumatic system that controls the door of vehicle

Solution

Solution is given in Figure 1.13, which is self explanatory

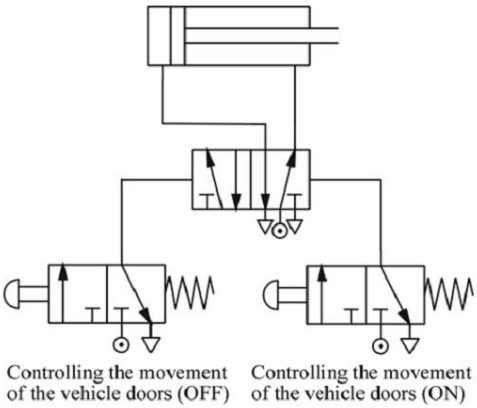


Figure 1.13 Pneumatic circuit to control the door of vehicle

1.3.1 IN DIRECT CONTROL OF DOUBLE ACTING CYLINDER USING MEMORY VALVE

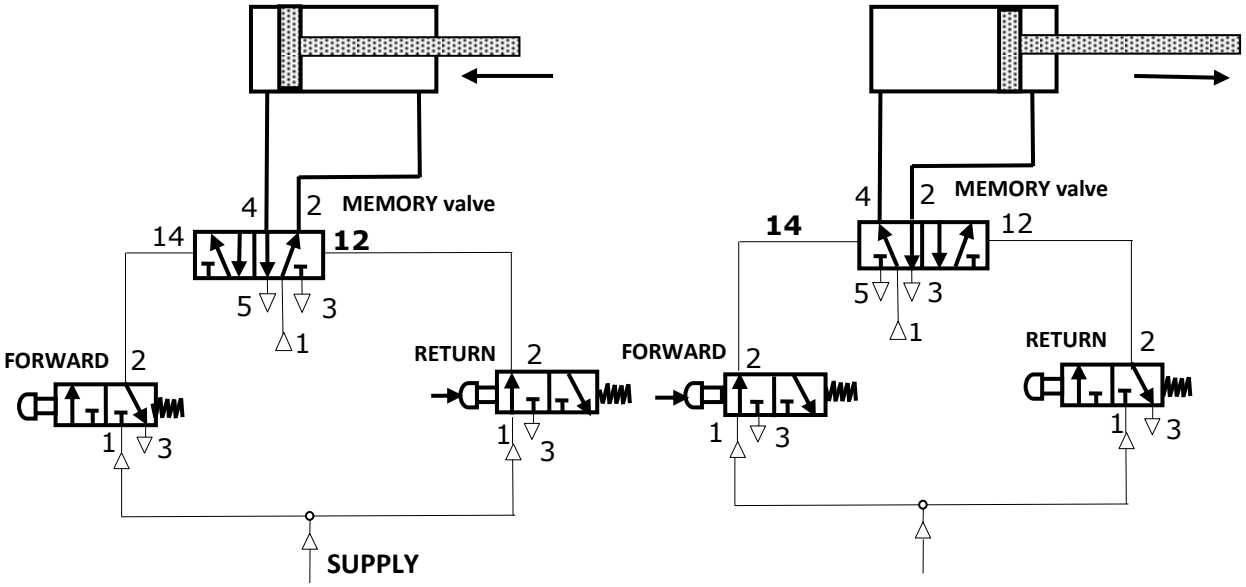


Figure 1.14 Indirect control of Double acting cylinder using memory valve

When the 3/2 way valve meant for Forward motion (Figure 1.14b) is pressed, the 5/2 memory valve switches over through the signal applied to its pilot port 14. The piston travels out and remains in the forward end position. Double piloted valve is also called as the Memory valve because now even if this push button meant Forward is released the final 5/2 control valve remains in the actuated status as the both the pilot ports of 5/2 valves are exposed to the atmosphere pressure and the piston remains in the forward end position.

When the 3/2 way valve meant for return motion (Figure 1.14a) is pressed, the 5/2 way valve switches back to initial position through the signal applied to its pilot port 12. The piston then returns to its initial position and remains in the rear end position. Now even if the Return push button is released the status of the cylinder will not change.

The circuit is called a memory circuit because it uses a 5/2 way double pilot memory valve. 5/2 way valve can remember the last signal applied in terms of the position of the spool in the absence of reset springs, thus memorising or storing the pneumatic signal. Double piloted 4/2 way valve also can be used as memory valve

1.4 SUPPLY AIR THROTTLING AND EXHAUST AIR THROTTLING

It is always necessary to reduce the speed of cylinder from maximum speed based on selected size of final control valve to the nominal speed depending on the application. Speed control of Pneumatic Cylinders can be conveniently achieved by regulating the flow rate supply or exhaust air. The volume flow rate of air can be controlled by using flow control valves which can be either two way flow control valve or one way flow control valve

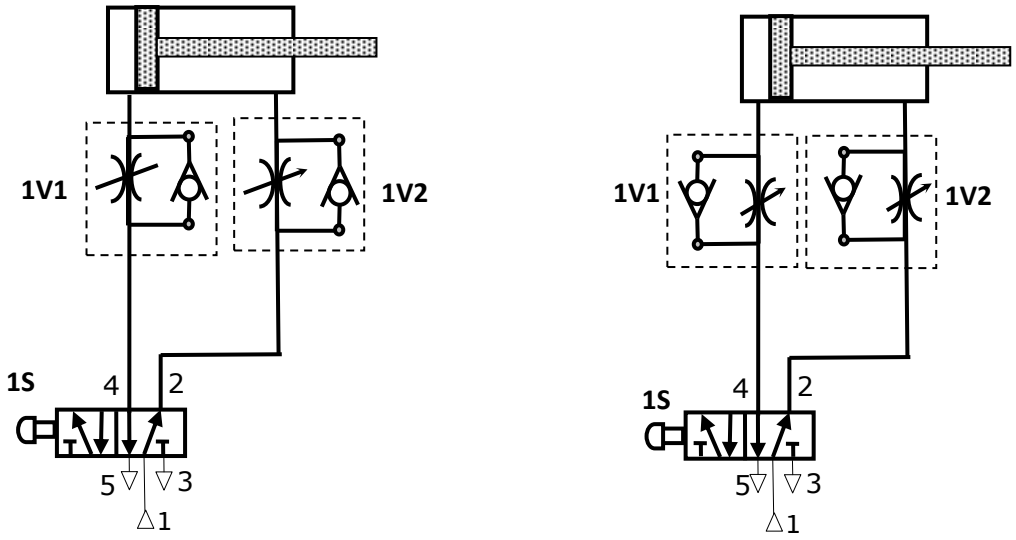
There are two types of throttling circuits for double acting cylinders:

i) Supply air throttling

ii) Exhaust air throttling

1.4.1 Supply air throttling.

This method of speed control of double acting cylinders is also called meter –in circuit (Figure 1.15a). For supply air throttling, one way flow control valves are installed so that air entering the cylinder is throttled. The exhaust air can escape freely through the check valve of the throttle valve on the outlet side of the cylinder. There is no air cushion on the exhaust side of the cylinder piston with this throttling arrangement. As a result, considerable differences in stroking velocity may be obtained even with very small variations of load on the piston rod. Any load in the direction of operating motion will accelerate the piston above the set velocity. Therefore supply air throttling can be used for single acting and small volume cylinders.



a) Supply air throttling b)Exhaust air throttling

Figure 1.15 Throttling Circuits

1.4.2 Exhaust air throttling.

This method of speed control of double acting cylinders is also called meter-out (Figure 1.15b). In exhaust air throttling throttle relief valves are installed between the cylinder and the main valve in such a way that the exhaust air leaving the cylinder is throttled in both directions of the motion of the cylinder. The supply air can pass freely through the corresponding check valves in each case. In this case, the piston is loaded between two cushions of air while the cylinder is in motion and hence a smooth motion of the cylinder can be obtained. The first cushion effect is due to supply air entering the cylinder through check valve, and second cushion effect is due to the exhaust air leaving the cylinder through the throttle valve at a slower rate. Therefore, exhaust air throttling is practically used for the speed control of double acting cylinders. Arranging throttle valves in this way contributes substantially to the improvement of feed behaviour.

1.5 VARIOUS METHODS OF CHECKING END POSITION OF A CYLINDER

The following methods are commonly used to know the end positions of piston in the cylinder:

a) Mechanically operated limit switches
   i) Roller lever type ii) Idle return roller type
b) Reed sensors – Normally used in cylinder with magnetically coupled slide
   i) With Electrical output ii) With pneumatic output
c) Electrical proximity switches
d) Pneumatic Signal generators

In this chapter we shall only discuss use of limit switches to get the end position of piston in the cylinder.

1.5.1 Use of Limit Switches

S1 and S2 are the limit switches corresponding to home position and extended position. Although they are located in the path of the movement of piston rod, normal practice is to represent the symbol of the limit switches on either side of the 3/2 way control valve without put signals connected to the pilot ports of the valve.(in this Figure 1.16 pilot signals actuations are shown for clarity) The limit switches of Roller lever type are essentially 3/2 way ball seat or disc seat type of valves handling pneumatic signals. These are available with direct actuation type and internally pilot actuation type versions. Limit switches of idle return roller type are used for actuation only in one direction are used as signal elimination device in case of signal overlap.

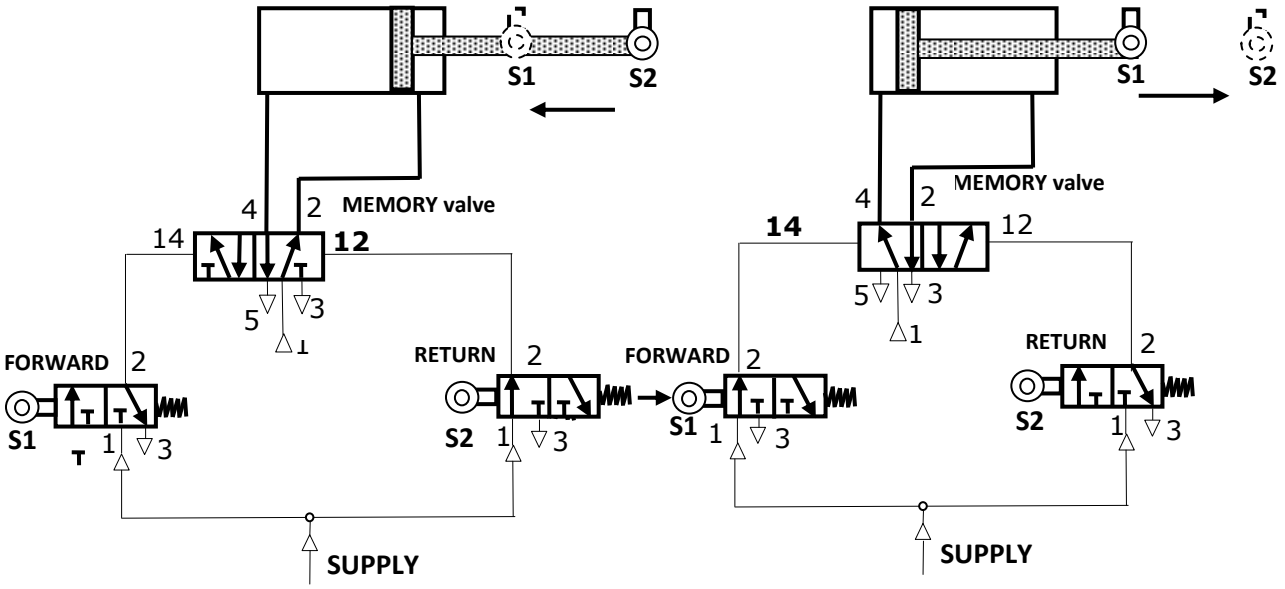


Figure 1.16 : Use of limit switches in pneumatic circuits

1.6 PRESSURE DEPENDENT CONTROLS

Pressure sequence valve is essentially a switch on or off valve. Sequence Valve generates a pneumatic signal if the sensing pressure [signal input] is more than the desired set pressure. This generated output signal is used to control the movement of cylinder by using it as a set signal or reset signal to the final control valve to obtain forward or return motion respectively. Used for applications such as bonding cylinders, clamping cylinder etc. to ensure desired minimum pressure in the cylinder. This is a combination valve, having two sections. One of the section is a 3/2 directional control and the other a pressure control valve. Schematic diagram of pressure sequence vavle is shown in Figure 1.17

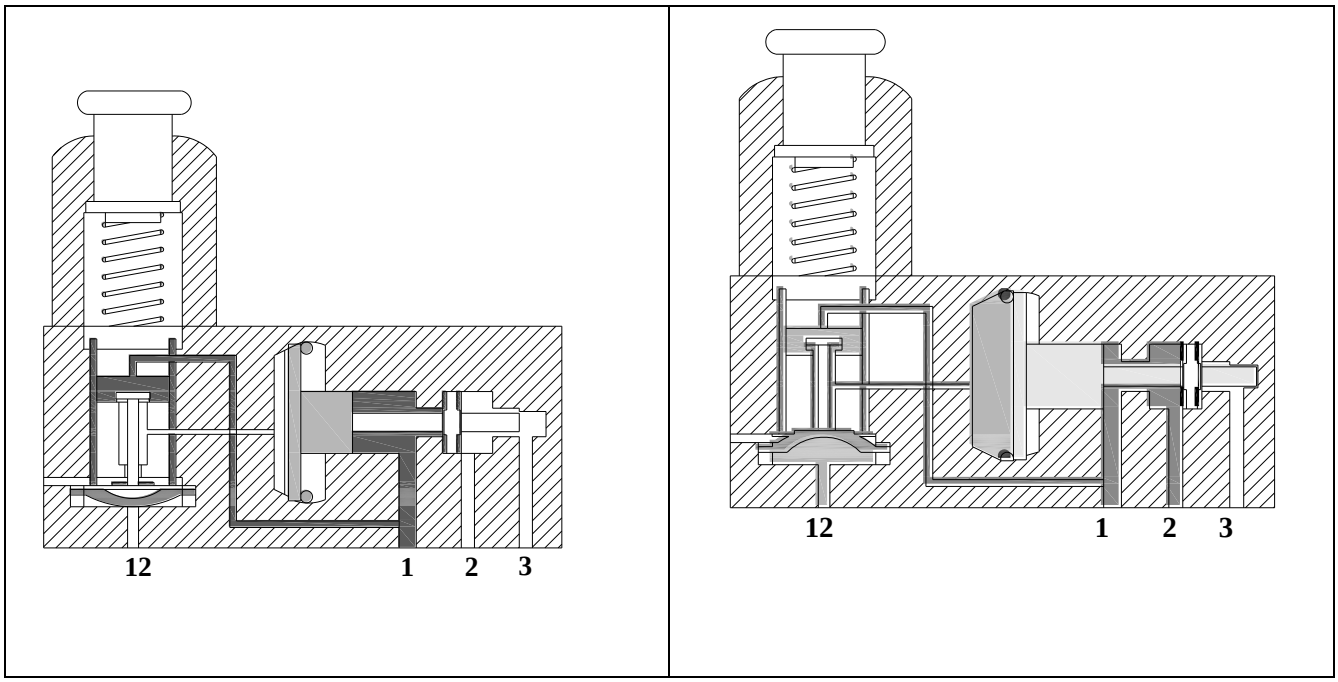


Figure 1.17: Pressure dependant control valve

Sensing pressure signal is introduced at port 12. Manual adjustment of pressure setting is done with the help of a cap screw/knob which is spring loaded. Clock wise rotation of knob results setting for higher pressure setting and anticlockwise rotation of knob results in lower pressure setting. The right section is basically a 3/2 directional control valve [NC] - pilot operated using pressure signal derived from left section.

The cross sectional views and symbols of a pressure sequence valve is shown in Figure. This valve consists of a 3/2 directional control valve and a pressure control valve. The principle of operation of a sequence valve is that outlet of sequence valve remains closed until pressure upstream of it builds up to a predetermined value. When a pre-set pilot pressure is reached within the valve at port 12(due to the building up of the line pressure after the cylinder piston reaches the end of its stroke), the spring loaded piston is unseated. The resulting pilot pressure actuates the integrated 3/2 directional

control valve of the pressure sequence valve and generates an output signal which connects port 1 to 2. Note that when the piston is seated, the piston area in the 3/2 directional valve, that is exposed to the pilot pressure, is held to a minimum. This helps reduce the restraining force. When the pressure, however, unseats the piston, a large piston area is exposed to pressure, and the piston is held wide open. The adjusting screw on the top of the valve sets the pressure.

Example 11: A double acting cylinder is used to press together glued components (Estimated pressure is around 4 bar). Upon pressing a push button, the clamping cylinder is to extend and trip the roller valve. One the fully extended position of the cylinder has been reached and sufficient clamping force has been developed, the cylinder is to retract to the initial position, develop a pneumatic circuit using a pressure sequence valve.

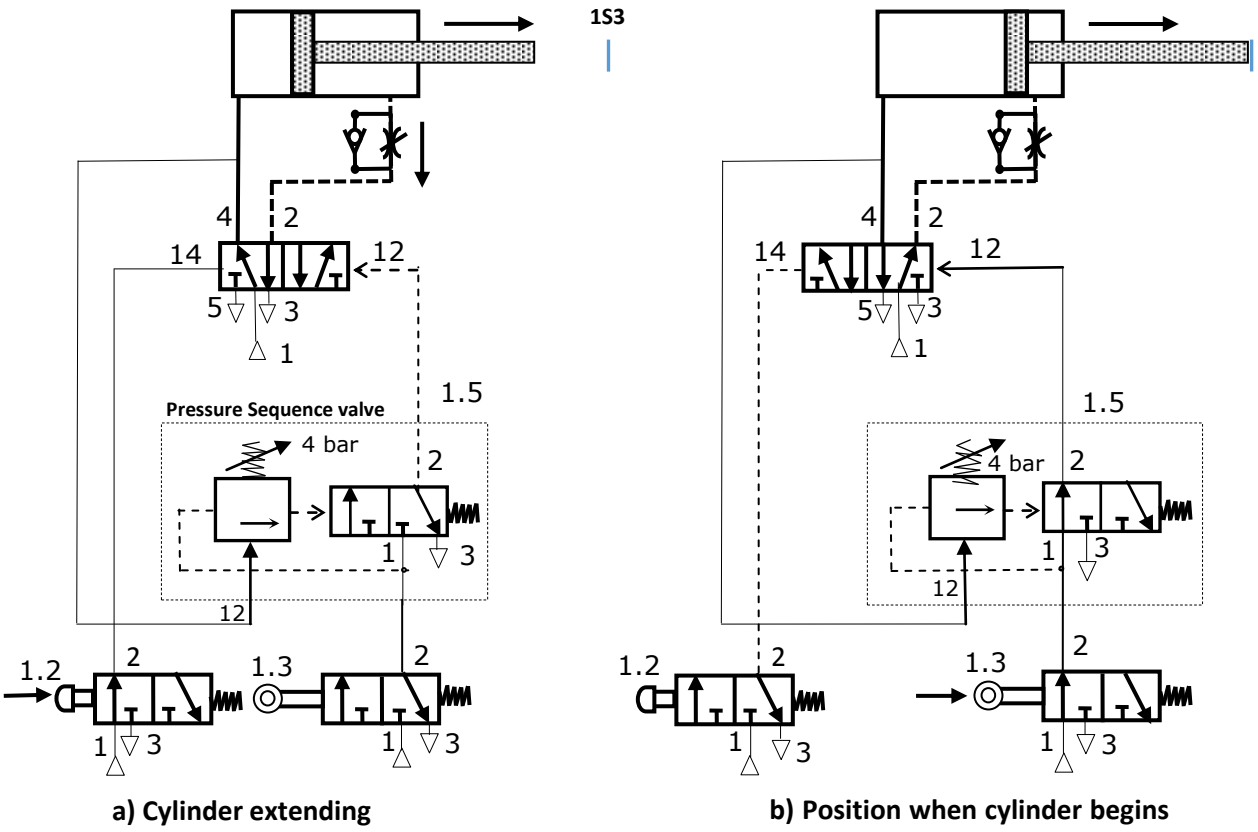


Figure 1.18 Pressure dependant control valve

The two position of the pneumatic circuit for the control task, when the cylinder is extending and when the cylinder is fully extended, are shown in Figure 1.18. The pressure in the sequence valve is set to working pressure of 4 bar, and the signal input to the pressure sequence valve is tapped from the power line from port 4 of valve 1.1 to the cylinder to gauge the pressure on the piston side of the cylinder. As shown in the Figure 1.18 valve 1.2 initiates the forward motion of the cylinder. While

the cylinder is moving forward, the pressure in the power line from port 4 of valve 1.1 to the cylinder will not built up to the working pressure. Only after the cylinder is fully extended, will the maximum pressure in the line built up resulting in sufficient pressure to glue. When the set pressure in the sequence valve is reached, the integrated 3/2 directional control valve is actuated, generating an output signal. This signal is used to reset the final control element 1.1 and thus causing the return motion of the cylinder.

1.7 TIME DEPENDENT CONTROLS

Pneumatic timers are used to create time delay of signals in pilot operated circuits. Available as normally closed timers and normally open timers. Usually pneumatic timers are on delay timers. Delay of signals is very commonly experienced in applications such as bonding of two pieces. Normally open pneumatic timers are also used in signal elimination. Normally open pneumatic timers are used as safety device in two hand blocks

Time delay valve is a combination of a pneumatically actuated 3/2 direction control valve, an air reservoir and a throttle relief valve. The time delay function is obtained by controlling the air flow rate to or from the reservoir by using the throttle valve. Adjustment of throttle valve permits fine control of time delay between minimum and maximum times. In pneumatic time delay valves, typical time delays in the range 5-30 seconds are possible. The time delay can be extended with the addition of external reservoir.

Pneumatic timer can be classified as

1. On –delay timer
2. Off – delay timer

In on-delay timer, the 3/2 DCV is actuated after a delay with reference to the application of pilot signal and is rest immediately on the application of the pilot signal. In off delay timer, the 3/2 DCV is actuated immediately on the application of the pilot signal and is reset only after a delay with reference to the release of the pilot signal.

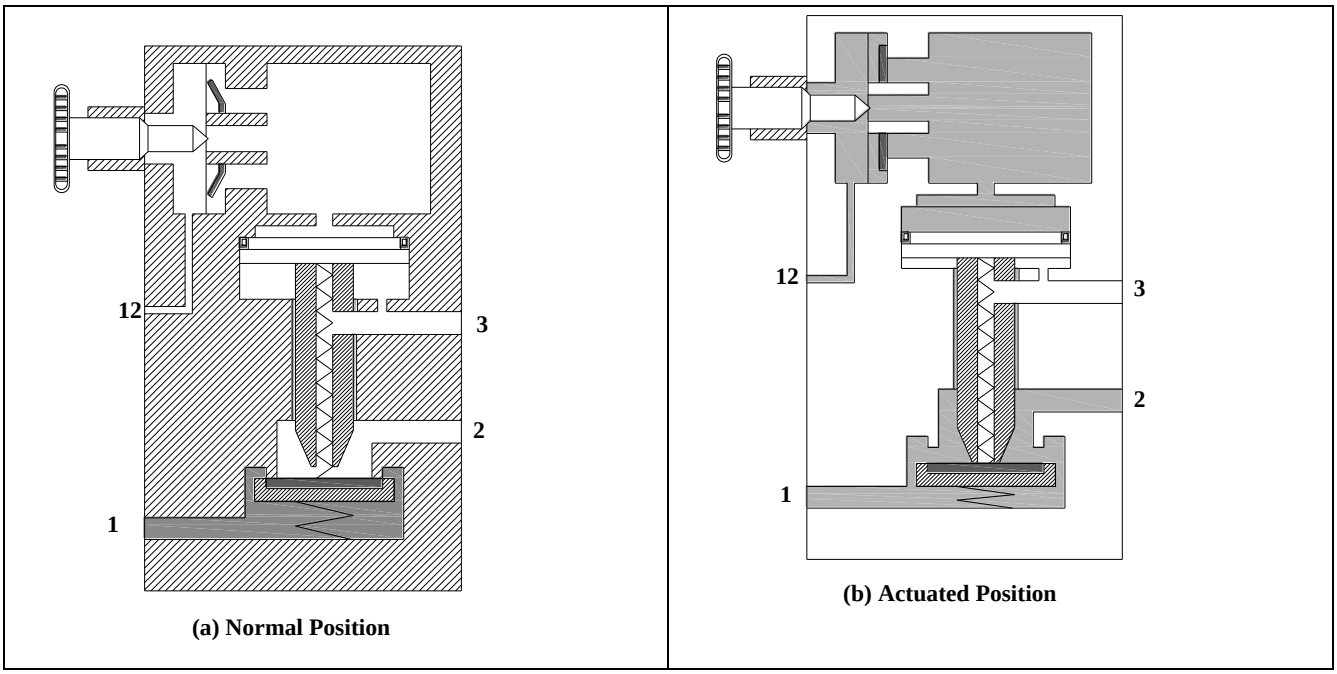
Pneumatic timers can also be classified according to type of pneumatically actuated 3/2 DCv as:

1) Time delay valve, NC type
2) Time delay valve, NO type.

Time delay valve, NC type. The constructions of an on-delay timer (NC) type in the normal and actuated are shown in Figure 1.19 It can be seen that 3/2 DCV operates in the on delay mode permanently. But, in some designs, the valve can be operated in the off-delay mode by connecting

the check valve in reverse direction. For this purpose, the ports of the throttle check valve should be brought out.

Time delay valve, NO type. The construction and function of an on-delay timer (NO) type is similar to that of an on-delay timer (NC) type except for the type of 3/2 DCV valve. In the on-delay valve (NO) type, a 3/2 DCV (NO) type is used whereas in the on-delay timer (NC) type, a 3/2 DCV (NC) type is used. Timing diagrams for all four type of Pneumatic delay valve is given in Table 1.1

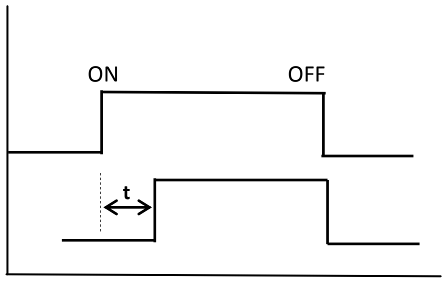
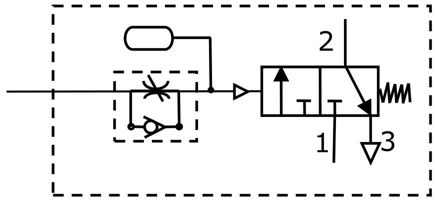
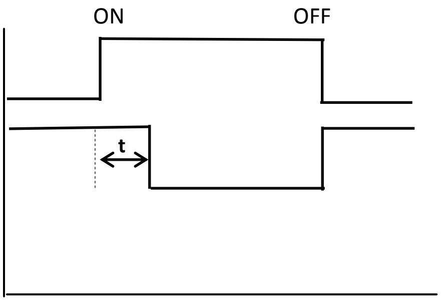
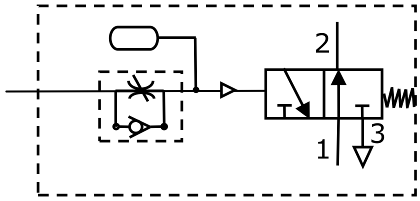
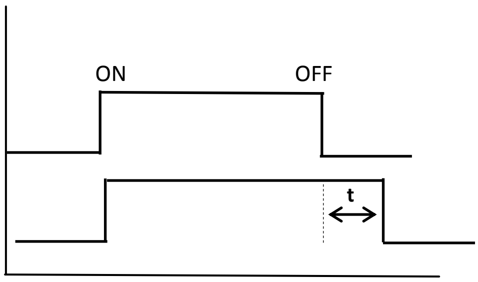
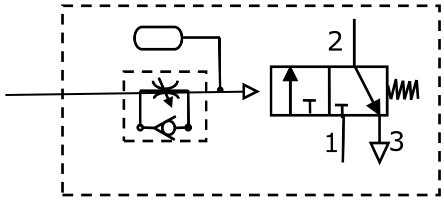
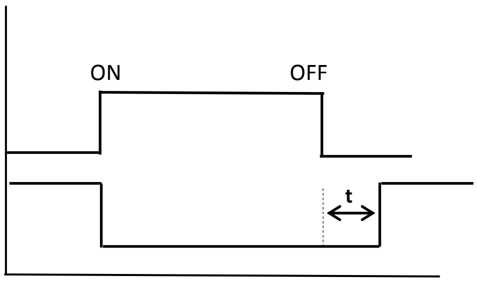
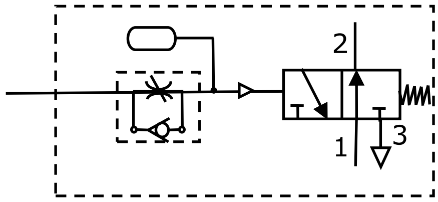


(a) Normal Position

(b) Actuated Position

Figure 1.19

Table 1.1 Timing diagrams for all four type of Pneumatic delay valve

Timing diagram	Symbol
	
	
	
	

Example 12: A double acting cylinder is used to press together glued components . Upon operation of a press button, the clamping cylinder slowly advances. Once the fully extended position is reached , the cylinder is to remain for a time of t = 6 seconds and then immediately retract to the initial position. A new start cycle is only possible after the cylinder has fully retracted and after a delay of 5 seconds. During this delay the finished part is manually removed and replaced with new parts for gluing. The retracting speed should be fast, but adjustable.

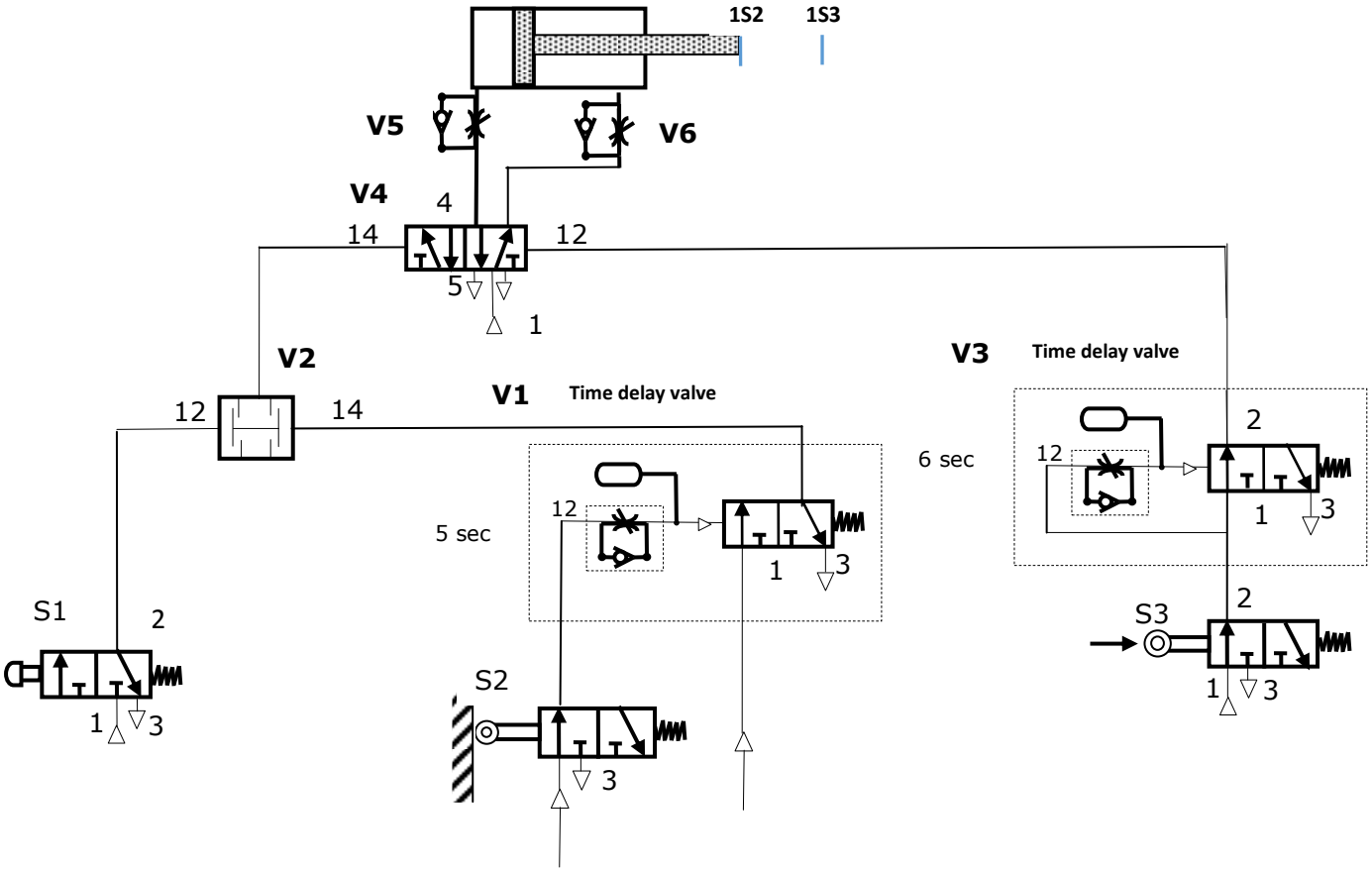


Figure 1.20

If the push button S1 is actuated for a sufficiently long time period (t = 5 second) then the air reservoir of time delay valve V1 is filled and corresponding 3/2 valve is switched, following which a signal is applied at input 1 of the dual pressure valve V2.

If the push button S1 is actuated, the AND condition at the dual pressure valve is met. A signal is applied at the control port 12 of the control element V4. The valve V4 switches, pressure is applied to the piston side of the cylinder 1A and the piston rod advances. After as short advancing distances, the limit switch S2 is released, pressure is reduced in the air reservoir of the time delay valve V1 via the roller lever valve S2, and the integrated 3/2 way valve switches back to its initial position. The

AND condition at the dual pressure valve is now no longer met. Actuation of the push button S1 becomes ineffective.

Upon reaching the advancing position, the piston rod actuates the roller lever S3. The pressure line to the time delay valve V3 is now released and pressure in the air reservoir is increased. The rate of pressure increase is adjustable via the integrated flow control valve. When the switching pressure has been reached, the integrated 3/2 way valve switches and a signal is applied at the control port 12 of the final control element V4. The valve V4 reverses and the piston rod retracts. Upon release of the limit switch S3, the time delay valve V3 Switches to its initial position again.

The limit switch S2 is actuated, when the piston rod reaches its initial position, the pressure in the air reservoir of the time delay V1 starts to increase until the switching pressure has been reached after t = 5 seconds. The integrated 3/2 way valve switches. The initial status of the system is now reached again and a new cycle can be started. The piston rod speed is set at the restrictors of the one way flow control valves V5 and V6.

Objective Type Questions

1. For relatively small single acting and double acting cylinder ------- type of control is preferred.
2. A single acting pneumatic cylinder or a non-reversing air motor can be controlled by ---- way valve as the signal output unit. When a four way control valve is used one outlet port is ----------
3. Double acting cylinders can be controlled by two –three way valve or .....way valve.
4. Throttle relief valve or throttle check valve is used to control the ---------- in pneumatic circuits.
5. In supply air throttling, air ---------- the cylinder is throttled
6. Shuttle valve or double check valve can be used as logic ----- Valve.

1. In ---------- pneumatic timer, the 3/2 DC valve is actuated after a delay with reference to the application of the pilot signal and is reset immediately after the release of the pilot signal.

8. The pressure sequence valve is a combination of two valves, that is adjustable pressure ---------- valve and a 3/2 direction control valve.

9. As per ISO 5599 pilot lines ports are designated using 12 or ----------

10. The most important threads used on pneumatic valves are metric thread(M), National pipe thread (NPT) , Unified fine thread(UNF) and -------- (BSP~G)

State True or False

1. For large single acting or double acting cylinder we prefer to use direct control

2. Supply air throttling is used only for the speed control of single acting cylinders and small volume cylinders.

3 Exhaust air throttling is practically used in all double acting cylinder due to double cushioning effect.

4. Double piloted 4/2 and 5/2 valves can be used as memory valves in pneumatic circuit design

5. There is no possibility of signal conflict in memory valves.

6. Two pressure valve can be used as not valve in pneumatic circuit design

7. Return speed of the double acting cylinder can be increased by means of quick exhaust valve.

8. In off time delay timer, the 3/2 DC valve is actuated immediately on the application of the pilot signal and is reset only after a delay with reference to the release of the pilot signal.

9. There are four possible combinations of pneumatic delay timer using NO and NC control.

10. ISO 5599 systems recommend alpha numeric port designation for direction control valves

Review Questions

1. Where are three way and four way valves used?

2. List the basic five rules that are important in design of pneumatic circuits.

3. State three types of signal processing elements used in pneumatic control

4. Explain the working of NOT valve, give one application of it.

5. Mention few applications of AND and OR valve

6. What are the functions of pneumatic timer delay valves

7. How are timer delay valves classified

8. Differentiate between ON time delay and OFF time delay with help of symbols

9. Explain with the help of neat sketch the construction and working of pressure sequence valve

10. Give two applications of pressure sequence valve and time delay valve.

11. Compare and contrast two way valve and shuttle valve. Mention its application.

12 Differentiate between supply air throttling and exhaust air throttling

13. Why exhaust air throttling is practically used for speed control of the double acting cylinder.

14. What is the advantage of internal pilot valve in pneumatic valves.

15. State the difference between the final control element and signal element

Answers

Fill in the Blanks

1. direct
2. three / plugged
3. four/five
4. flow(speed)
5. entering
6. OR
7. On time delay
8. Relief
9. 14
10. British standard pipe thread (BSP~G)

State True or False

1. False
2. True
3. True
4. True
5. False
6. False
7. True
8. True
9. True
10. False