HYDRAULICS AND PNEUMATICS

Chapter – 2

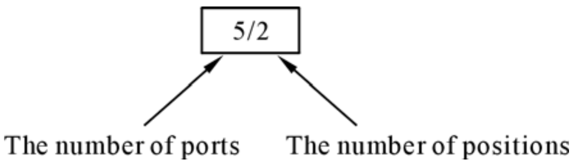
UNIT IV - PNEUMATIC AND ELECTRO PNEUMATIC SYSTEMS

Air control Valves, Quick Exhaust Valves, Pneumatic actuators, Design of Pneumatic circuit – Cascade method.

AIR CONTROL VALVES:

Directional control valve

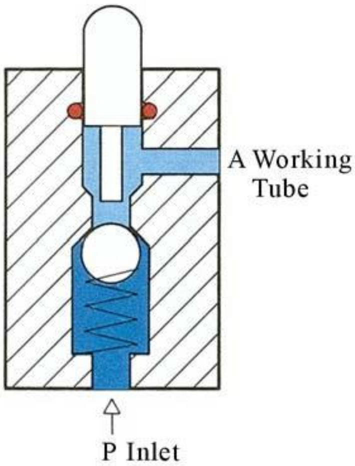
Directional control valves ensure the flow of air between air ports by opening, closing and switching their internal connections. Their classification is determined by the number of ports, the number of switching positions, the normal position of the valve and its method of operation. Common types of directional control valves

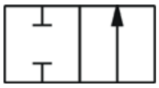


include 2/2, 3/2, 5/2, etc. The first number represents the number of ports; the second number represents the number of positions. A directional control valve that has two ports and five positions can be represented by the drawing in Fig. 8, as well as its own unique pneumatic symbol.

2/2 Directional control valve

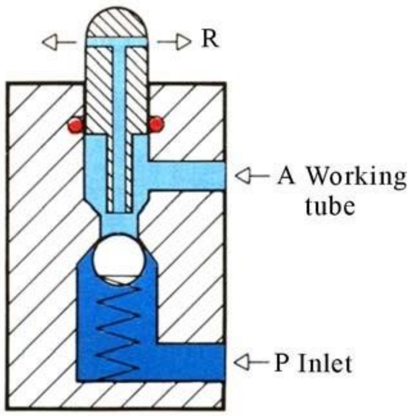
The structure of a 2/2 directional control valve is very simple. It uses the thrust from the spring to open and close the valve, stopping compressed air from flowing towards working tube 'A' from air inlet 'P'. When a force is applied to the control axis, the valve will be pushed open, connecting 'P' with 'A' . The force applied to the control axis has to overcome both air pressure and the repulsive force of the spring. The control valve can be driven manually or mechanically, and restored to its original position by the spring.

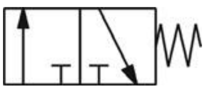




3/2 Directional control valve

A 3/2 directional control valve can be used to control a single acting cylinder . The open valves in the middle will close until 'P' and 'A' are connected together. Then another valve will open the sealed base between 'A' and 'R' (exhaust). The valves can be driven manually, mechanically, electrically or pneumatically. 3/2 directional control valves can further be divided into two classes: Normally open type (N.O.) and normally closed type (N.C.).



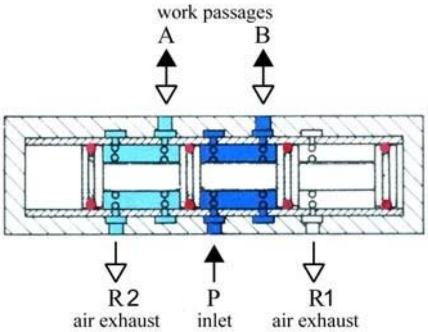


Symbol – NC type

Symbol – NO type

5/2 Directional control valve

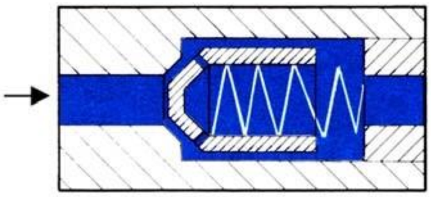
When a pressure pulse is input into the pressure control port 'P', the spool will move to the left, connecting inlet 'P' and work passage 'B'. Work passage 'A' will then make a release of air through ‘R1’ and ‘R2’. The directional valves will remain in this operational position until signals of the contrary are received. Therefore, this type of directional control valves is said to have the function of ‘memory’.



Symbol

NON-RETURN VALVE

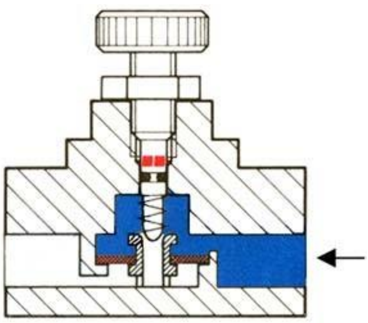
non-return valve allows air to flow in one direction only. When air flows in the opposite direction, the valve will close. Another name for non-return valve is poppet valve.

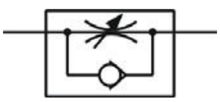


Symbol

Flow control valve

A flow control valve is formed by a non-return valve and a variable throttle

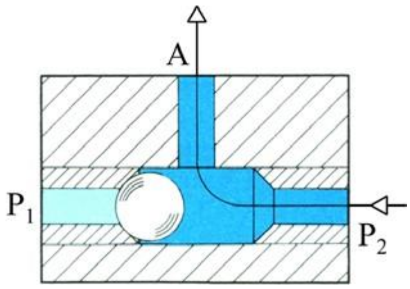


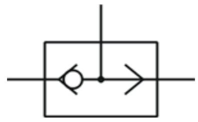


Symbol

Shuttle valve

Shuttle valves are also known as double control or single control non-return valves. A shuttle valve has two air inlets ‘P_1’ and ‘P_2’ and one air outlet ‘A’. When compressed air enters through ‘P_1’, the sphere will seal and block the other inlet ‘P_2’. Air can then flow from ‘P_1’ to ‘A’. When the contrary happens, the sphere will block inlet ‘P_1’, allowing air to flow from ‘P_2’ to ‘A’ only.



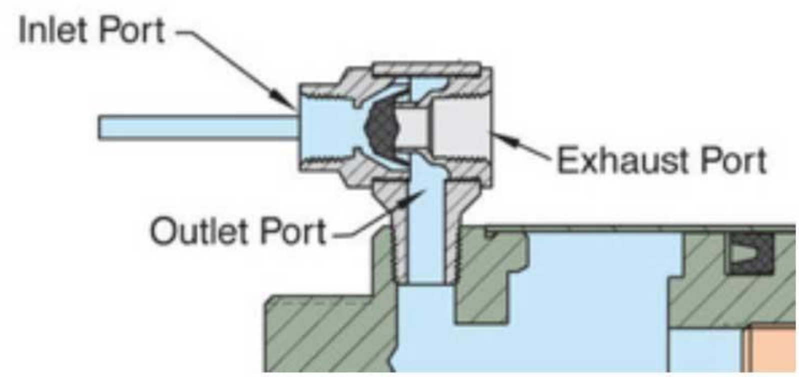


Symbol

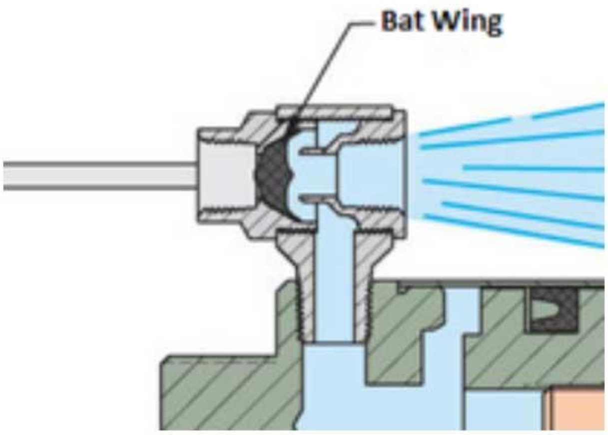
QUICK EXHAUST VALVES:

Quick exhaust valves work by providing a rapid exhaust of controlled air when placed directly onto an air cylinder after the control valve. The seal inside Clippard's quick exhaust valve is shaped like a bat wing. When air pressure is sent to the cylinder, it hits the back side of the seal and pushes the front side against the exhaust port. This seals it off and allows air to enter the cylinder.

When the control valve is shifted, the bat wing design of the seal begins to catch the exhausting air and shifts itself over to block off the original inlet. This allows all the exhaust air to immediately dump out the exhaust port.



When air enters into the cylinder



When air goes to atmosphere

PNEUMATICS ACTUATORS

Pneumatic actuators are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work. In other words, Actuators are used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston. The pressurised air from the compressor is supplied to reservoir. The pressurised air from storage is supplied to pneumatic actuator to do work.

The air cylinder is a simple and efficient device for providing linear thrust or straight line motions with a rapid speed of response. Friction losses are low, seldom exceeds 5 % with a cylinder in good condition, and cylinders are particularly suitable for single purpose applications and /or where rapid movement is required. They are also suitable for use under conditions which preclude the employment of hydraulic cylinders that is at high ambient temperature of up to 200 to 250

Their chief limitation is that the elastic nature of the compressed air makes them unsuitable for powering movement where absolutely steady forces or motions are required applied against a fluctuating load, or where extreme accuracy of feed is necessary. The air cylinder is also inherently limited in thrust output by the relatively low supply pressure so that production of high output forcescan only be achieved by a large size of the cylinders.

TYPES OF PNEUMATICS ACTUATORS

Pneumatic cylinders can be used to get linear, rotary and oscillatory motion. There are three types ofpneumatic actuator: they are

i) Linear Actuator or Pneumatic cylinders

ii) Rotary Actuator or Air motors

iii) Limited angle Actuators

Types of Pneumatic cylinders /Linear actuators

Pneumatic cylinders are devices for converting the air pressure into linear mechanical force and motion. The pneumatic cylinders are basically used for single purpose application such as clamping, stamping, transferring, branching, allocating, ejecting, metering, tilting, bending, turning and many other applications.

The different classification scheme of the pneumatic cylinders are given below

1. Based on application for which air cylinders are used

i) Light duty air cylinders

ii) Medium duty air cylinders

iii) Heavy duty air cylinders

2. Based on the cylinder action

i) Single acting cylinder

ii) Double acting cylinder

- Single rod type double acting cylinder
- Double rod type double acting cylinder

3. Based on cylinder's movement

i) Rotating type air cylinder

ii) Non rotating type air cylinder

4. Based on the cylinder's design

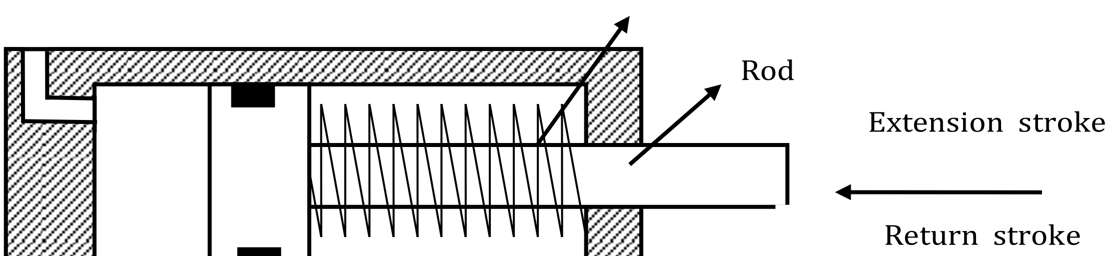
- Telescopic cylinder
- Tandem cylinder
- Rod less cylinder
- Cable cylinder,
- Sealing band Cylinder with slotted cylinder barrel
- Cylinder with Magnetically Coupled Slide
- Impact cylinder
- Duplex cylinders
- Cylinders with sensors

Single acting cylinders.

Single acting cylinder has one working port. Forward motion of the piston is obtained by supplying compressed air to working port. Return motion of piston is obtained by spring placed on the rod side of the cylinder. Schematic diagram of single acting cylinder is shown in Figure .

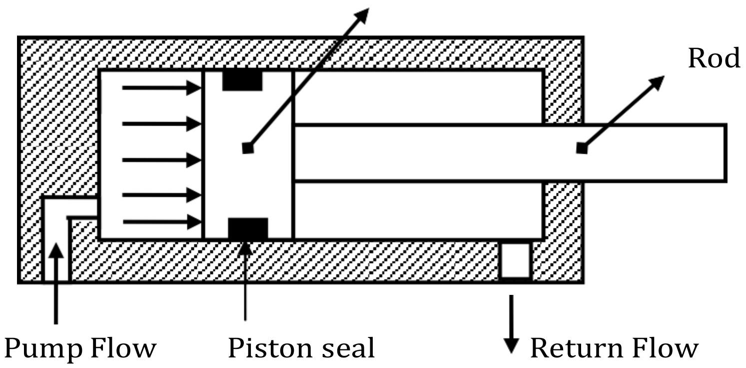
Single acting cylinders are used where force is required to be exerted only in one direction. Such as clamping, feeding, sorting, locking, ejecting, braking etc.,

Single acting cylinder is usually available in short stroke lengths [maximum length up to 80 mm] dueto the natural length of the spring. Single Acting Cylinder exert force only in one direction. Single acting cylinders require only about half the air volume consumed by a double acting cylinder for one operating cycle.



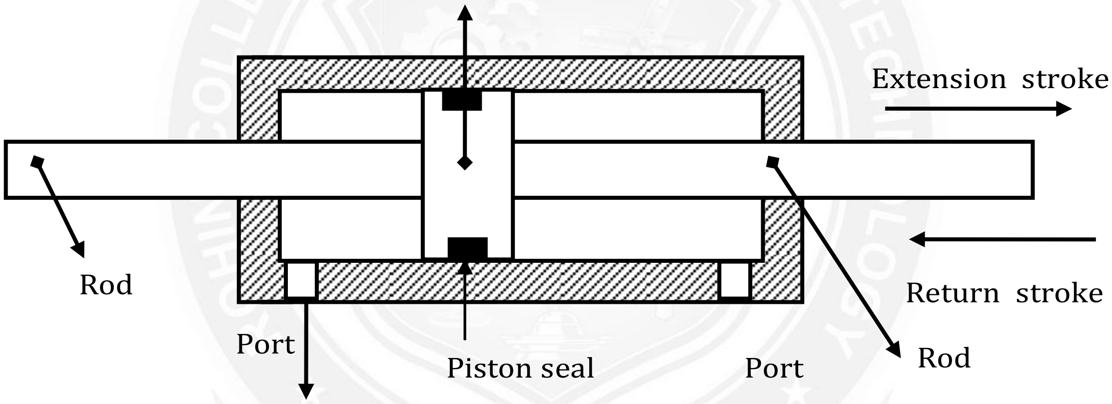
DOUBLE ACTING CYLINDERS

Schematic diagram of double acting cylinder is shown in Figure 1.6. Double Acting Cylinders are equipped with two working ports- one on the piston side and the other on the rod side. To achieve forward motion of the cylinder, compressed air is admitted on the piston side and the rod side is connected to exhaust. During return motion supply air admitted at the rod side while the piston side volume is connected to the exhaust. Force is exerted by the piston both during forward and return motion of cylinder. Double acting cylinders are available in diameters from few mm to around 300 mm and stroke lengths of few mm up to 2 meters



Double acting cylinder with piston rod on both sides

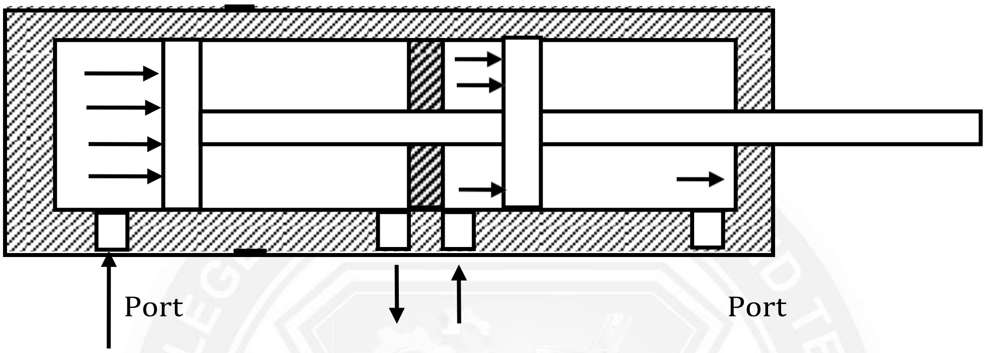
A double acting cylinder with piston rod on both sides (Figure 1.9) is a cylinder with rod extending from both ends. This cylinder can be used in an application where work can be done by both ends of the cylinder, thereby making the cylinder more productive. Double rod cylinders can withstand higher side loads because they have an extra bearing one on each rod to withstand the loading. Double rod cylinders are used when there is bending load and accurate alignment and maximum strength is required. A further advantage is that rod is precisely located and may be used to guide the machine member coupled to it, dispensing with external guides or bearing in many cases, most standard production models are available either in single rod or double rod configuration A disadvantage of double rod configuration is that there is a reduction in maximum thrust due to the blanking effect of the rod cross section on the piston area and a slightly larger size of cylinder is required for a given duty. The thus will be the same on the ingoing stroke as that of a single rod double acting cylinder.



Tandem Cylinder

Schematic diagram of Tandem cylinder is shown in Figure . Tandem cylinders are two separate double acting air cylinders arranged in line to one cylinder body so that the power generated by the two is added together, thereby approximately doubling the piston output. A tandem cylinder is used in applications where a large amount of force is required from a small-diameter cylinder. Basically, a tandem cylinder is simply two or more separate cylinders stacked end to end in a unit and with all the pistons mounted on a common piton rod. Pressure is applied to both pistons, resulting in increased force because of the larger area. The drawback is that these cylinders must be longer than a standard cylinder of larger flow rate than a standard cylinder to achieve an equal speed because flow must go to both pistons.

Tandem cylinders are used where large output force is required with appreciable saving in bulk and weight. Tandem cylinders are employed where a small diameter of the assembly is required.



Rotary Actuators

Rotary Actuators are used to achieve angular motion. Rotary actuators are devices which produce high torque output and have a limited rotary movement. Standard rotations are 90°, 180°, and 270°. Rotary actuators are mainly available in three designs.

i) Vane type limited rotation motors

- Single vane rotation motor
- Double vane rotation motor

ii) Rotary Actuator of Rack and Pinion Type

iii) Helix spine rotary actuator

Vane type actuators

Where the torque and motion is all produced in a rotary sense, the construction limits the rotation to less than one rotation.

Piston type actuators are essentially linear actuators mechanically connected to translate the linear force to produce an output torque and rotational movement. These devices are capable of providing an output motion of one revolution or more but not continuous rotation.

Both type give bi-directional output motion, and most produce the same torque in both senses. Also output torque is generally constant throughout the stroke. There is no linkages and lost motion associated with cylinder- crank rod arrangement.

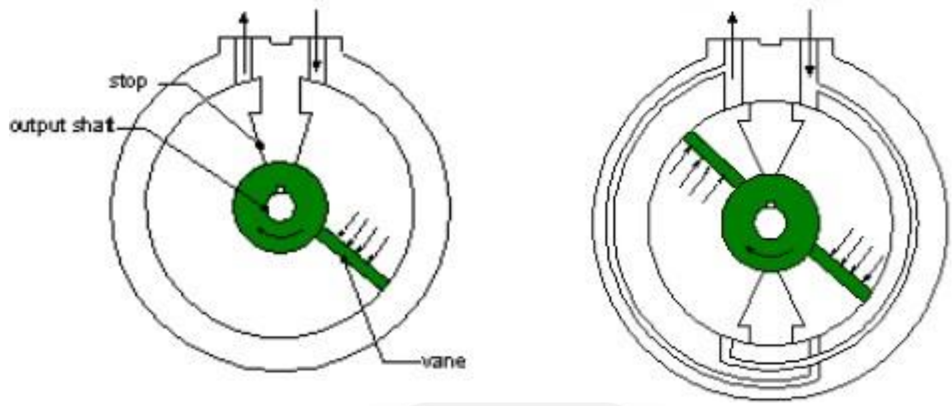
While the most often used actuators for pneumatic drives are cylinders for translational movements, there are many applications that require a turning or twisting movement of up to 360 degrees. Examples are turning components over in a drilling jig, providing a wrist action on a pick-and-place device or operating process valves. They are used in bench grinders, agitators, mixers, feeders, hoists, vibrators, pipe threaders etc.

Single Vane limited rotation actuators

The single vane actuator consists of a cylindrical housing, through which passes a central shaft to which the vane is rigidly attached. The housing has shoe or a stopper fixed to internal diameter of housing as shown in the Figure 1.43(a), thus dividing the interior space into two chambers. Pressurised air enters through port A and rotates the vane in the clockwise direction and air in the other chamber moves out of the port B. Similarly, when the air pressure is applied to the port B, the vane rotates in anti-clockwise direction and air in the other chamber moves out of the port A. Design geometry normally limits the rotary movement of a single vane actuator to about 280 maximum

Double vane limited rotation actuators

It is possible to modify the design to have two vanes fixed to the output shaft 180 ° apart and two fixed stoppers in the casing providing two separate operating halves each with two chambers as shown in Figure 1.43(b). This gives twice the maximum torque output of a single vane device for the same supply pressure. Obviously the maximum angle of rotation is reduced and because of second stopper only 100° is usually possible.



DESIGN OF PNEUMATIC CIRCUIT

When analyzing or designing a pneumatic circuits, the following four important considerations must be taken into account:

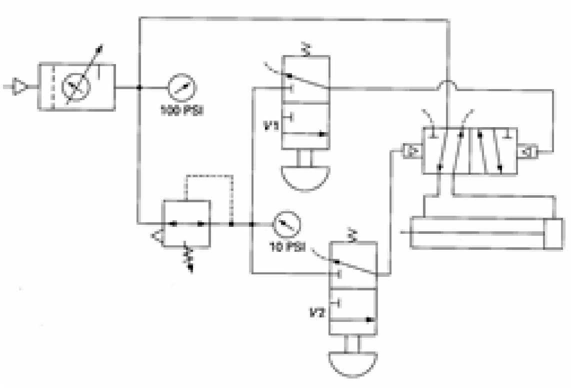
- Safety of operation
- Performance of desired functions
- Efficiency of operation
- Costs

Basics Pneumatic circuits

Air pilot control of double-acting cylinder

Purpose: To operate a double-acting cylinder remotely through the use of an air pilot-actuated DCV.

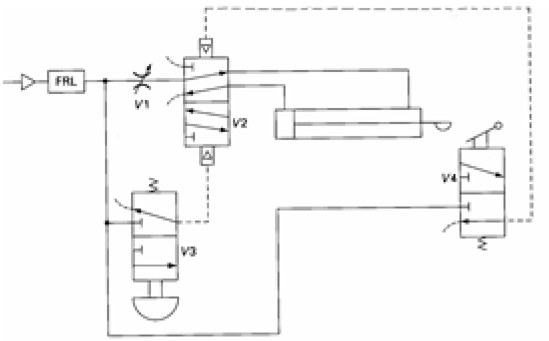
How: Using a low pressure (10 psi) for supplying two push-button valves and activating them manually causes the main DCV to activate for cylinder retraction or extension.



Cylinder Cycle Timing System

Purpose: To provide a timed cylinder extend and retract cycle.

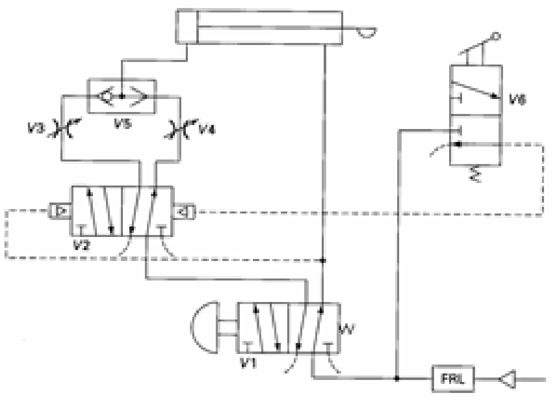
How: When push-button valve V3 is momentarily actuated, valve V2 shifts to extend the cylinder. When the piston rod cam actuates limit valve V4, it shifts V2 into its opposite mode to retract the cylinder. Flow control valve V1 controls the flow-rate and thus cylinder speed.



Two-step Speed Control System

Purpose: To provide a timed cylinder extend and retract cycle.

How: Assuming that flow control valve V3 is adjusted to allow a greater flow-rate than valve V4. Initially the cylinder is fully retracted. When push-button valve V1 is actuated, air goes through valves V2 and V3 and the shuttle valve V5 to extend the cylinder a high speed. When the piston rod cam actuates valve V6, valve V2 shifts. The flow is therefore diverted to valve V4 and through the shuttle valve.

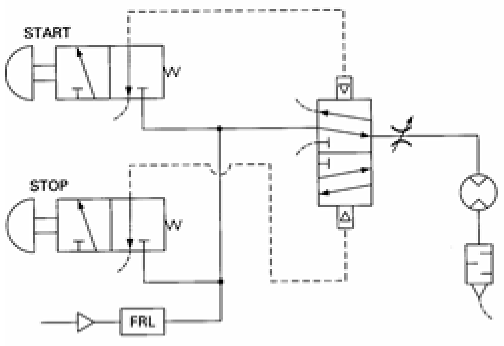


Control of air Motor

Purpose: To control an air motor

How: When the STRAT push- button valve is actuated momentarily, the air pilot valve shifts to supply air to motor.

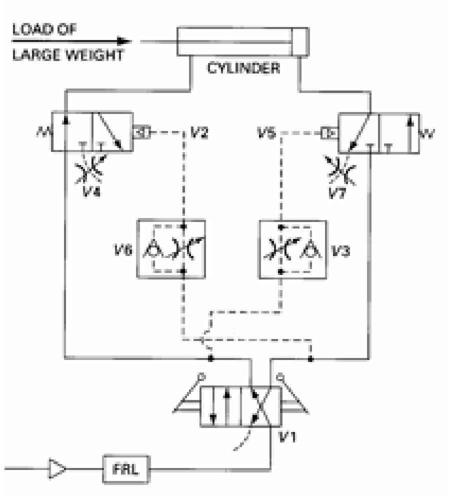
When the STOP push-button valve is actuated momentarily, the air pilot valve shifts into its opposite mode to shut off the supply of air to the motor.



Deceleration Air Cushion of Cylinder

Purpose: To provide an adjustable deceleration air cushion at both ends of the stroke of a cylinder when it drives a load of large weight.

How: Valve V1 supplies air to the rod end of the cylinder and to the pilot of valve V5 through flow control valve V3. Free air exhausting from the blank end of the cylinder permits a fast cylinder-retraction stroke until valve V5 operates due to exhaust is restricted by valve V7. The resulting pressure buildup in the blank end of the cylinder acts as an air cushion to gradually slow down the large weight load.



Cascade Pneumatic Circuit Design

Implementation of a sequence of actions by a full pneumatic circuit is widely used in industries. Many industries like automotive, food, chemical and so on need to use a full pneumatic system due to the hazardous area in the site and limitation of use of the electricity in the system.

Procedure

1. Code the cylinders with letters. Use positive and negative signs to show the cylinders' positions: positive sign to indicate the cylinder is completely extended, and negative sign to indicate the cylinder is completely retracted:

$$A^+B^+B^-C^+A^-C^-$$

2. Split the motion sequence into groups in a way that any letter regardless of its sign appears only once in each group:

$$A^+B^+ / B^-C^+A^- / C^-$$

3. Number the groups:

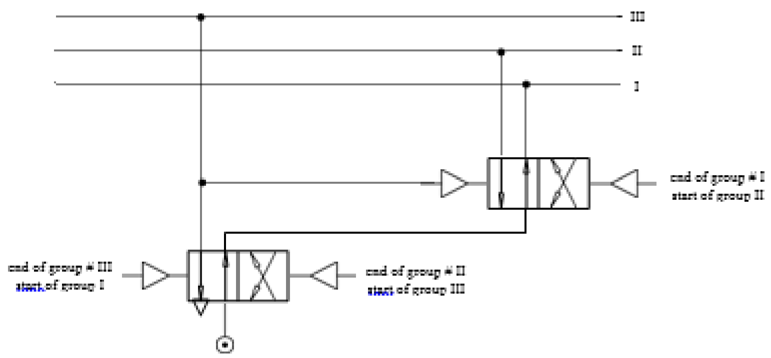
$$A^+B^+ / B^-C^+A^- / C^- \quad I \quad II \quad III$$

4. For each cylinder, consider two limit valves to signal for the start and end of its motion and one 4/2 or 5/2 power valve to operate the cylinder.

5. For the number of groups minus one consider 4/2 directional control valves and connect them in series or cascade as:

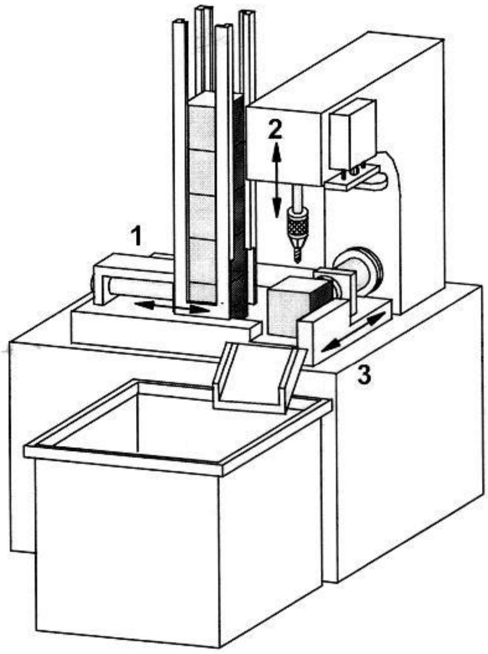
   Connect the pilot line and air port of the first power and limit valve of each group to its associated control line (I, II, III).

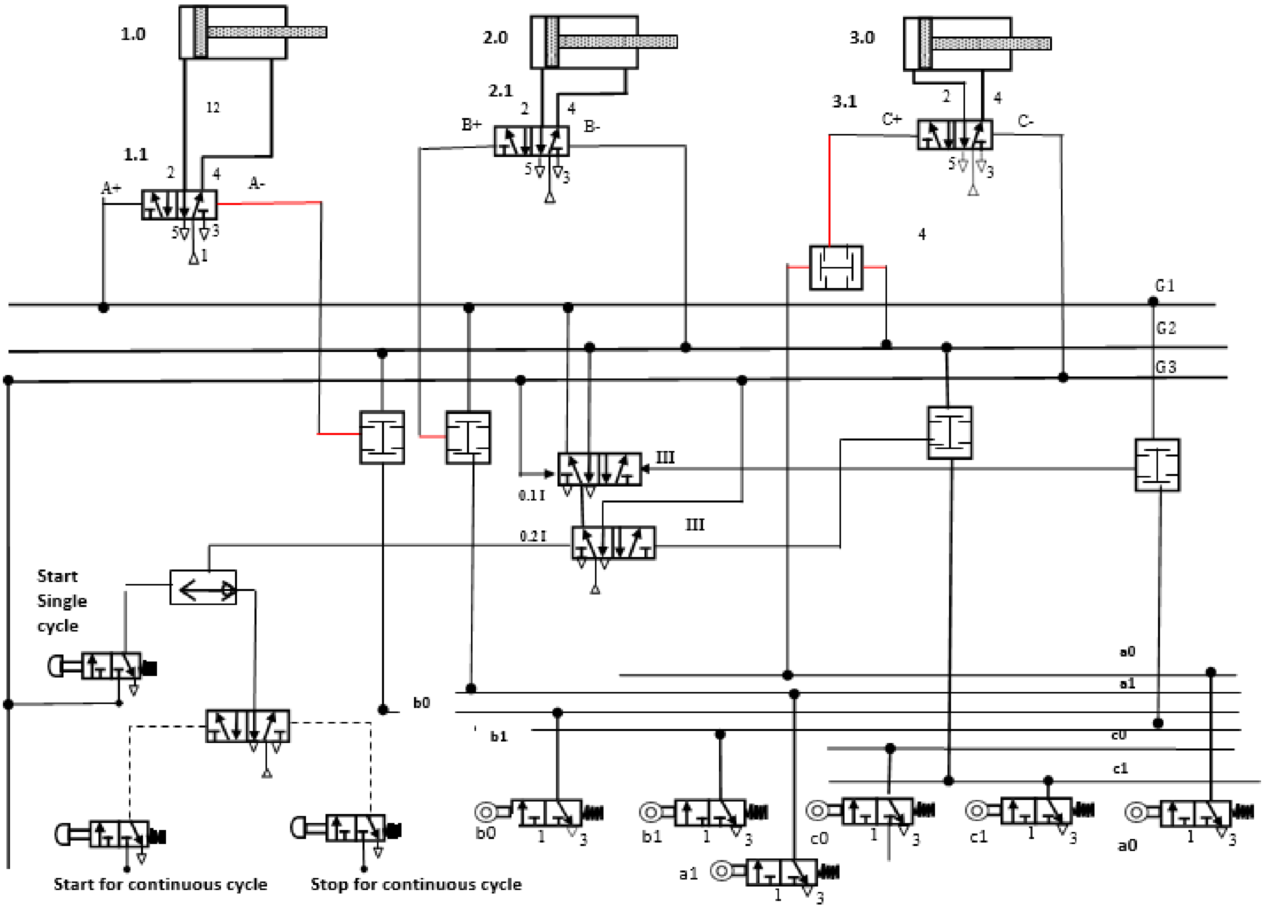
   - Follow the sequence of each group and connect the limit valves to appropriate pilot lines of the power valves.
   - Connect the output of the last limit valve of each group to the pilot line of the group selector valve.
   - Add any extra valves for safety, emergency and resetting purposes.



PROBLEM 1

. Square shaped work has to be drilled using a drilling machine which is pneumatically operated. Work pieces are fed from a gravity magazine to a drilling machine. These work pieces are pushed and clamped by means of clamping cylinder 1.0 (A). hole is drilled by the drilling cylinder 2.0 (B). and work piece is ejected by ejecting cylinder 3.0 (C). The displacement step diagram is shown in Figure1 . The sequence of operation has to be carried out either for one cycle or for continuous cycle with start and stop controls. Develop a pneumatic circuit to implement the given control task.


1
2
3


1.0
2.0
3.0
1.1
2.1
3.1
A+
A-
B+
B-
C+
C-
G1
G2
G3
III
0.1 I
0.2 I
Start
Single
cycle
Start for continuous cycle
Stop for continuous cycle
a0
a1
b0
b1
c0
c1