MENG2520 Pneumatics and Hydraulics

Module 7 – Pneumatic System Design

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Pneumatic System Design

The actuators are the devices which are 'doing the work' and the control devices which direct the work

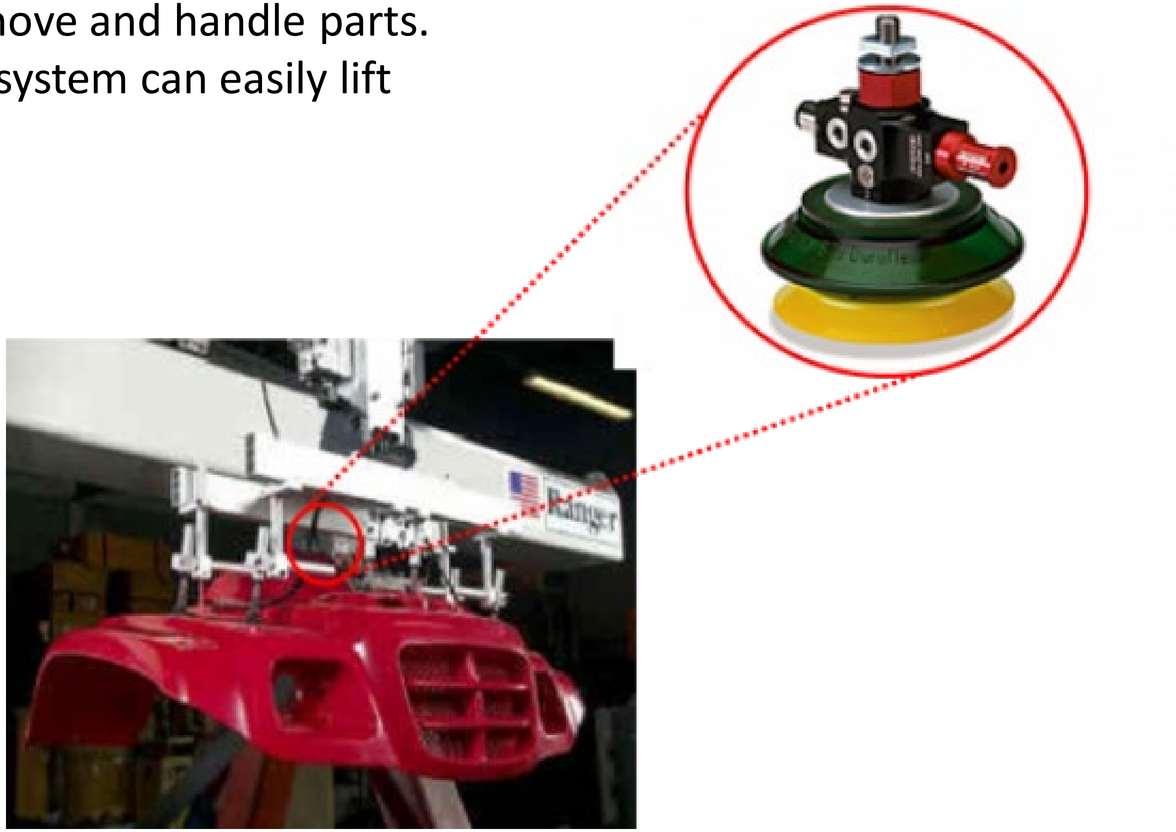
In this Module we will study

- **System design approach**
- **Study of circuit designs**
- **Vacuum systems**

14.7 Vacuum Systems

Vacuum systems are widely used in manufacturing to move and handle parts. Using a Vacuum Generator and Suction Cup, a vacuum system can easily lift parts typically for assembly and palletization.

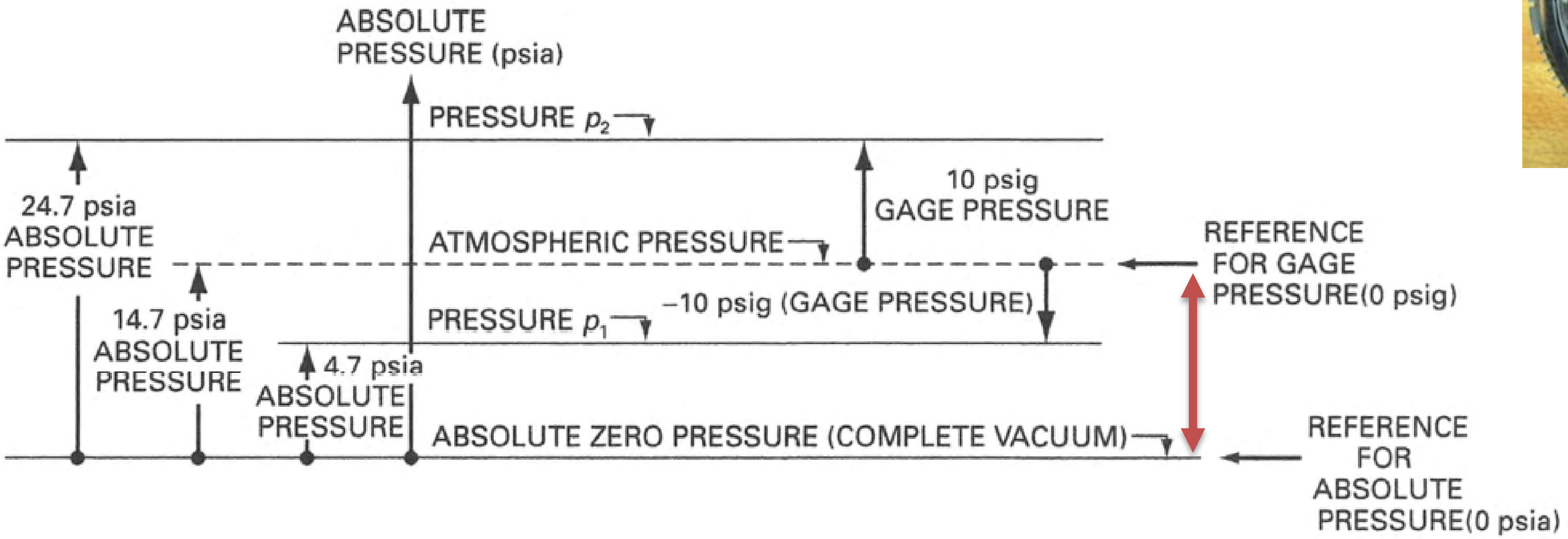
Palletizing Solution - Robotiq



https://www.blowervacuumbestpractices.com/

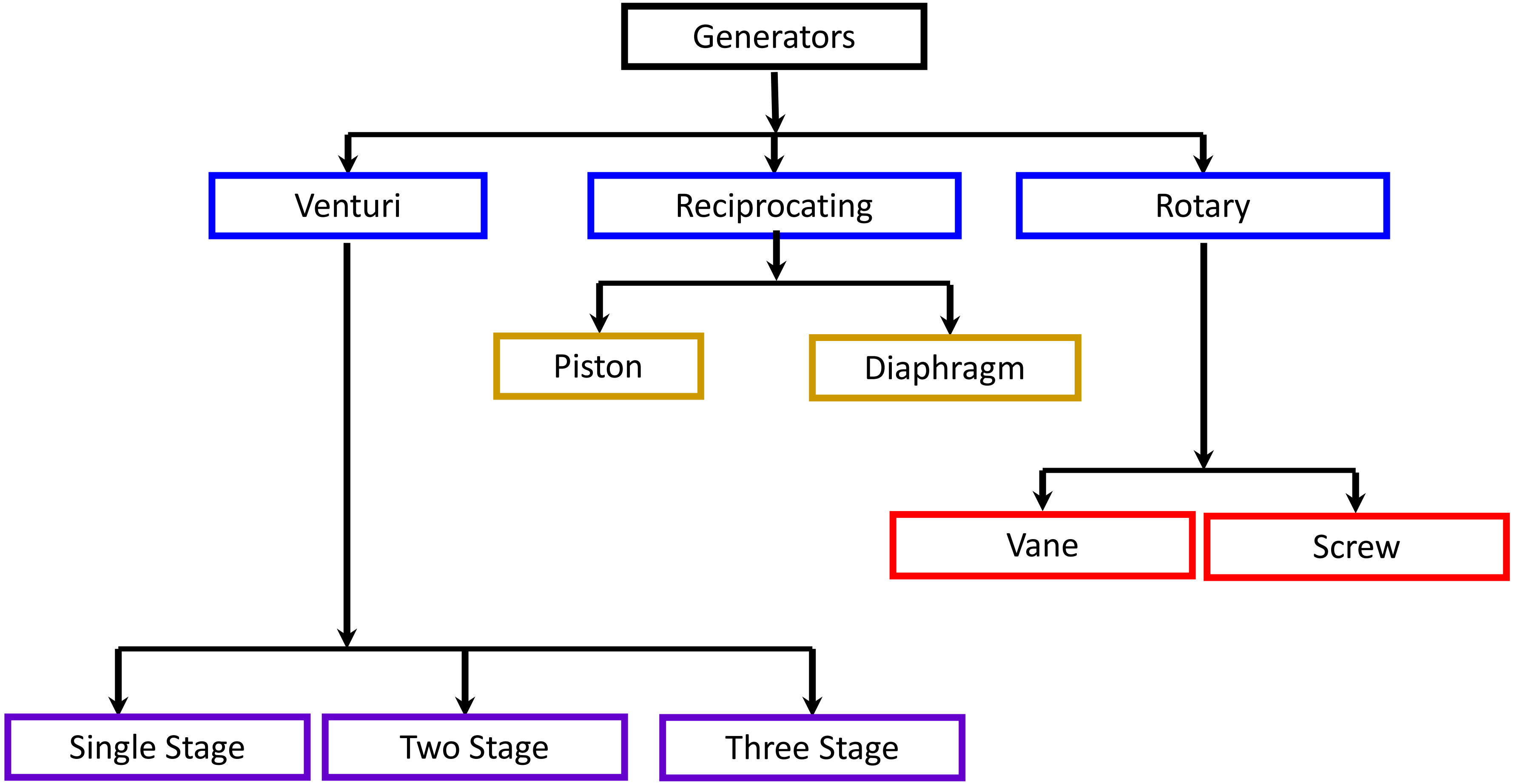
14.7 Vacuum Systems

A vacuum is defined as a pressure below atmosphere. It is still a *positive pressure* relative to absolute zero, but often called a *negative pressure* relative to atmosphere



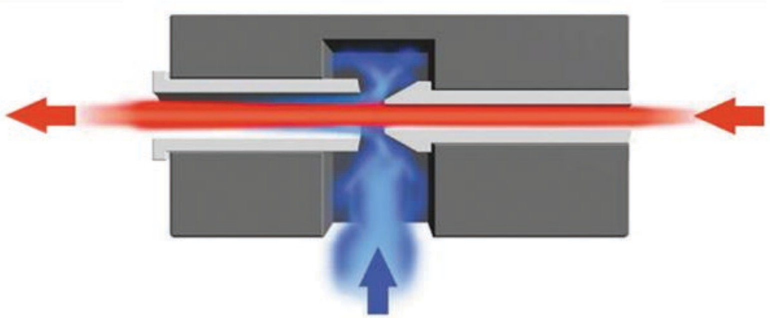
Vacuum Gauge

14.7 Vacuum Generator

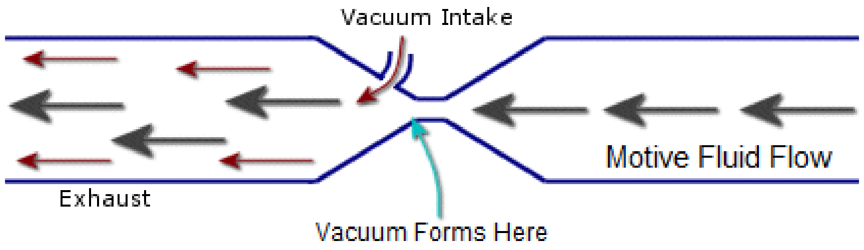


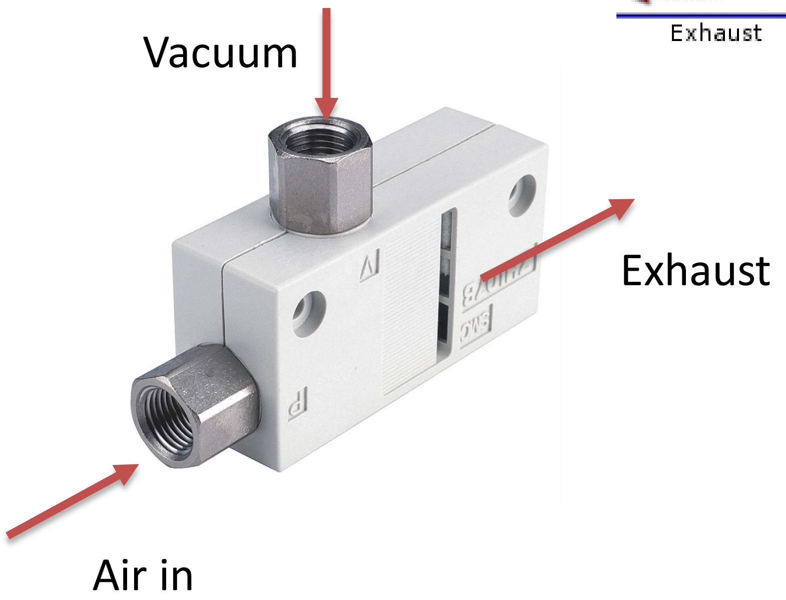
14.7 Venturi Vacuum Generator

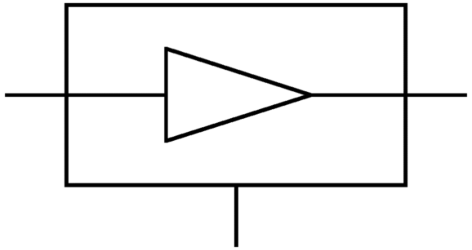
As air is accelerated through the narrowing of the Venuri valve, a negative pressure is created drawing in air, thus creating a vacuum



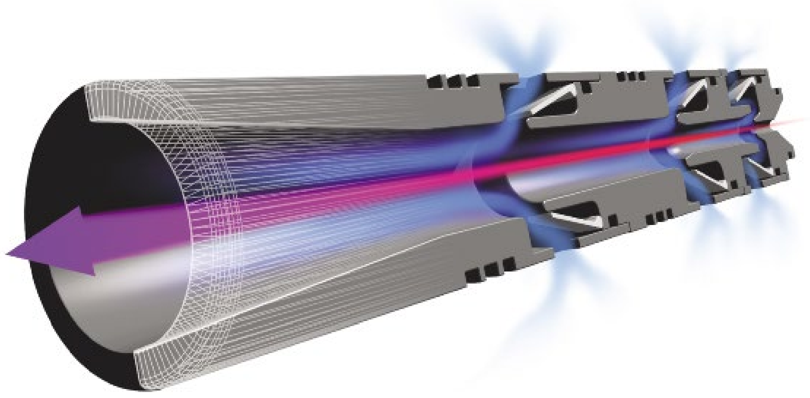
Single Stage Generator







Schematic Symbol



Multi Stage Generator

https://www.globalspec.com/learnmore/manufacturing_process_equipment/vacuum_equipment/vacuum_pumps/venturi_vacuum_generators

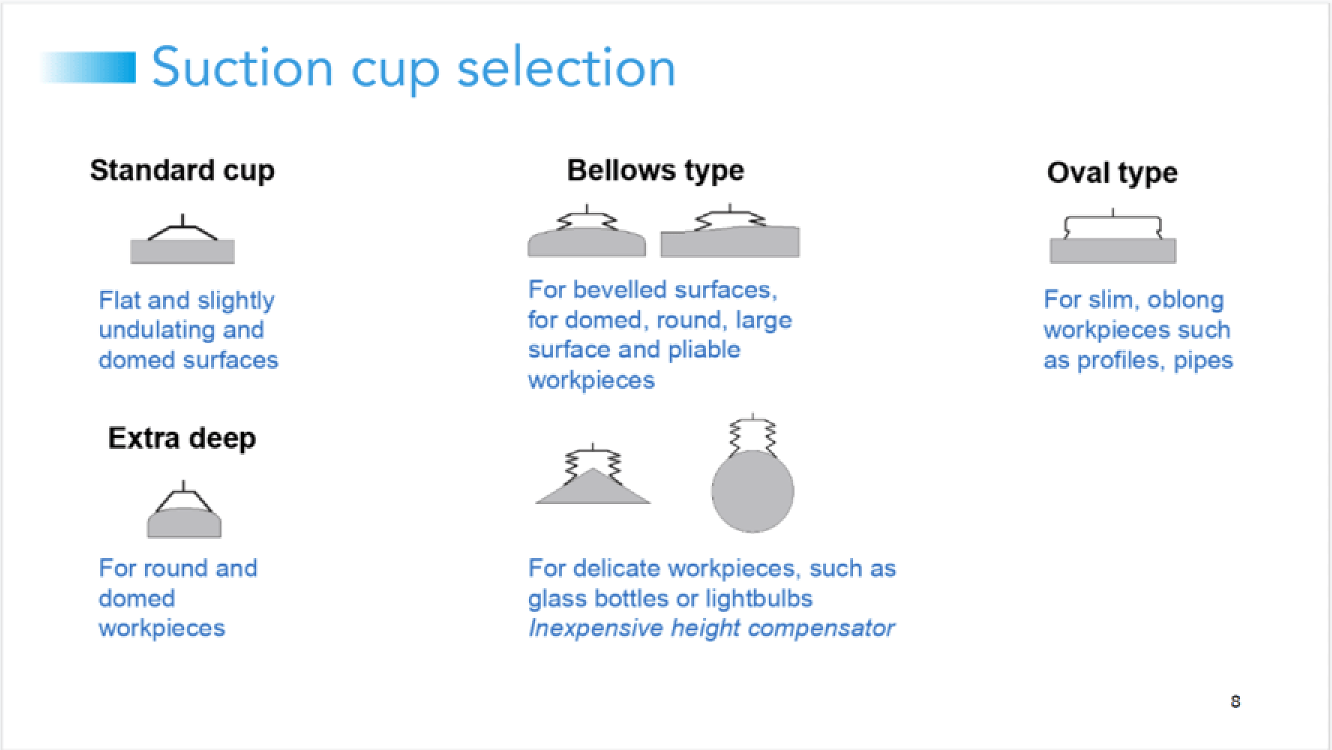
https://www.grainger.ca/

https://www.blowervacuumbestpractices.com/

14.7 Vacuum Cups

Vacuum cups are what interfaces with the work piece and must be compatible with

a) material/substance
b) Size and shape
c) Surface finish



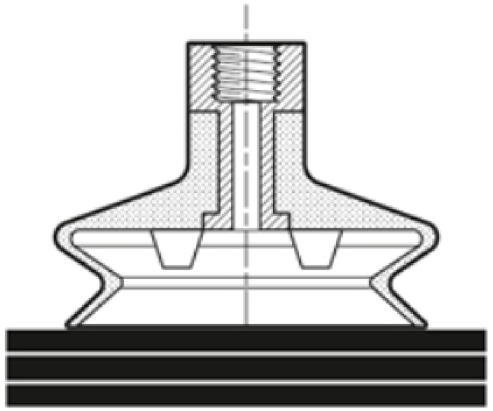
◎: Little or no influence ○: Can be used depending on conditions X: Not suitable

Characteristics / Material	Durometer HS (±5°)	Operating temperature range (°C)	Oil resistance gasoline	Oil resistance benzol	Base resistance	Acid resistance	Weatherability	Ozone resistance	Abrasion resistance	Waterproof	Solvent resistance (Benzene, toluene)
NBR	50°	0 to 120	◎	X	○	○	X	X	◎	○	X
Silicon rubber	40°	–30 to 200	X	X	○	X	◎	◎	X	○	X
Urethane rubber	60°	0 to 60	◎	X	X	X	○	◎	◎	X	X
Fluoro rubber	60°	0 to 250	◎	◎	X	◎	◎	◎	○	◎	◎
Conductive NBR	50°	0 to 100	○	X	○	X	○	X	○	○	X
Conductive silicon rubber	50°	–10 to 200	X	X	○	X	◎	◎	X	○	X

https://blog.robotiq.com/what-are-the-best-types-of-cups-for-your-workpiece

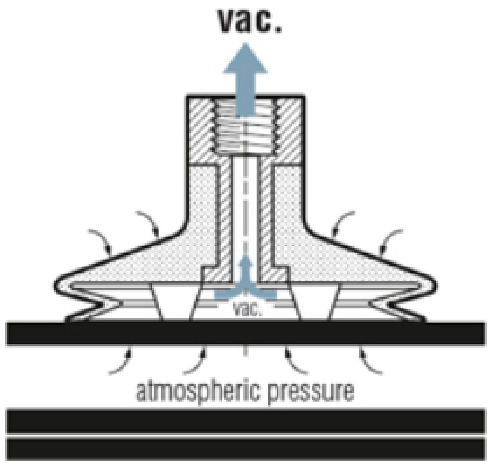
14.7 Vacuum Cup Operation

1- APPROACH



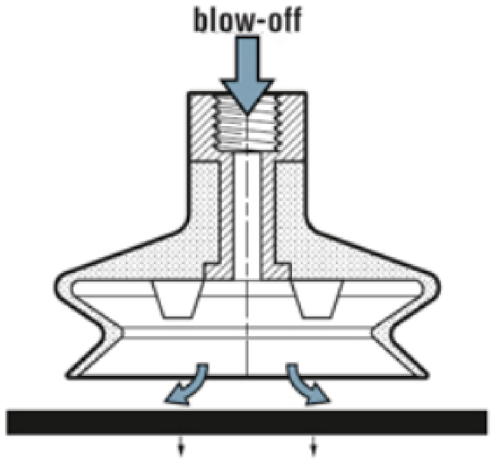
For a shock-free contact with the surface to be gripped, and to configurate to its shape, the suction pad in this instance has 1.5 bellows.

2- GRIPPING



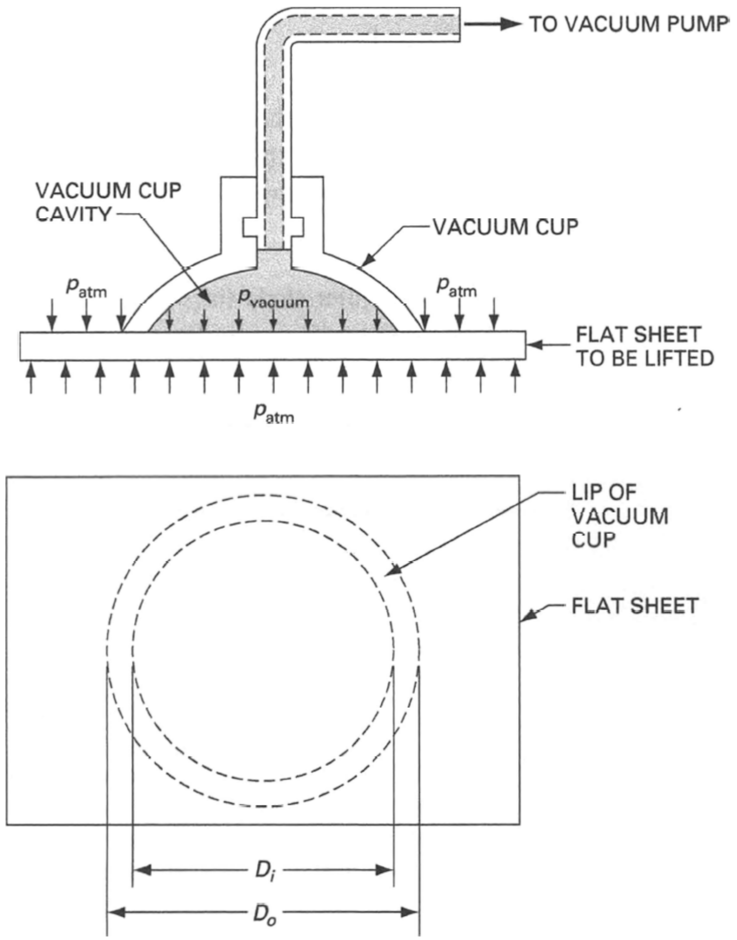
Vacuum is then applied to the suction pad, which lifts the object pushed by atmospheric pressure.
The suction pad and the object then remain binded together throughout the entire process (transfer, packaging, etc).

3- RELEASE



At the end of the suction process, the vacuum is interrupted to release the object.
Most often, an air blow-off will help this process and avoid sticking. This also helps to quicken the move to the next cycle.

14.7 Vacuum Systems



The lifting force is a function of the size of the suction cup and the vacuum generated

$$F = p_{\text{atm}} A_o - p_{\text{suction}} A_i$$

where F = the upward force the suction cup exerts on the flat sheet (lb, N),

p_{atm} = the atmospheric pressure in absolute units (psia, Pa abs),

A_o = the area of the outer circle of the suction cup lip

$= \frac{\pi}{4} D_o^2 (\text{in}^2, \text{m}^2)$,

D_o = the diameter of the suction cup lip outer circle (in, m),

p_{suction} = the suction pressure inside the cup cavity in absolute units (psia, Pa abs),

A_i = the area of the inner circle of the suction cup lip

$= \frac{\pi}{4} D_i^2 (\text{in}^2, \text{m}^2)$,

D_i = the diameter of the suction cup inner lip circle (in, m).

14.7 Vacuum Systems

Example: How heavy an object can be lifted with a suction cup having a 6-in lip outside diameter and a 5-in lip inside diameter with a - 10 psig suction pressure?

a. The suction pressure (which must be in absolute units) equals

$$p_{\text{suction}}\,(\text{abs}) = p_{\text{suction}}\,(\text{gage}) + p_{\text{atm}}$$

$$= -10 + 14.7 = 4.7 \text{ psia}$$

The maximum weight that can be lifted can now be found using Eq. (14-4):

$$F = \text{maximum weight } W = p_{\text{atm}} A_o - p_{\text{suction}} A_i$$

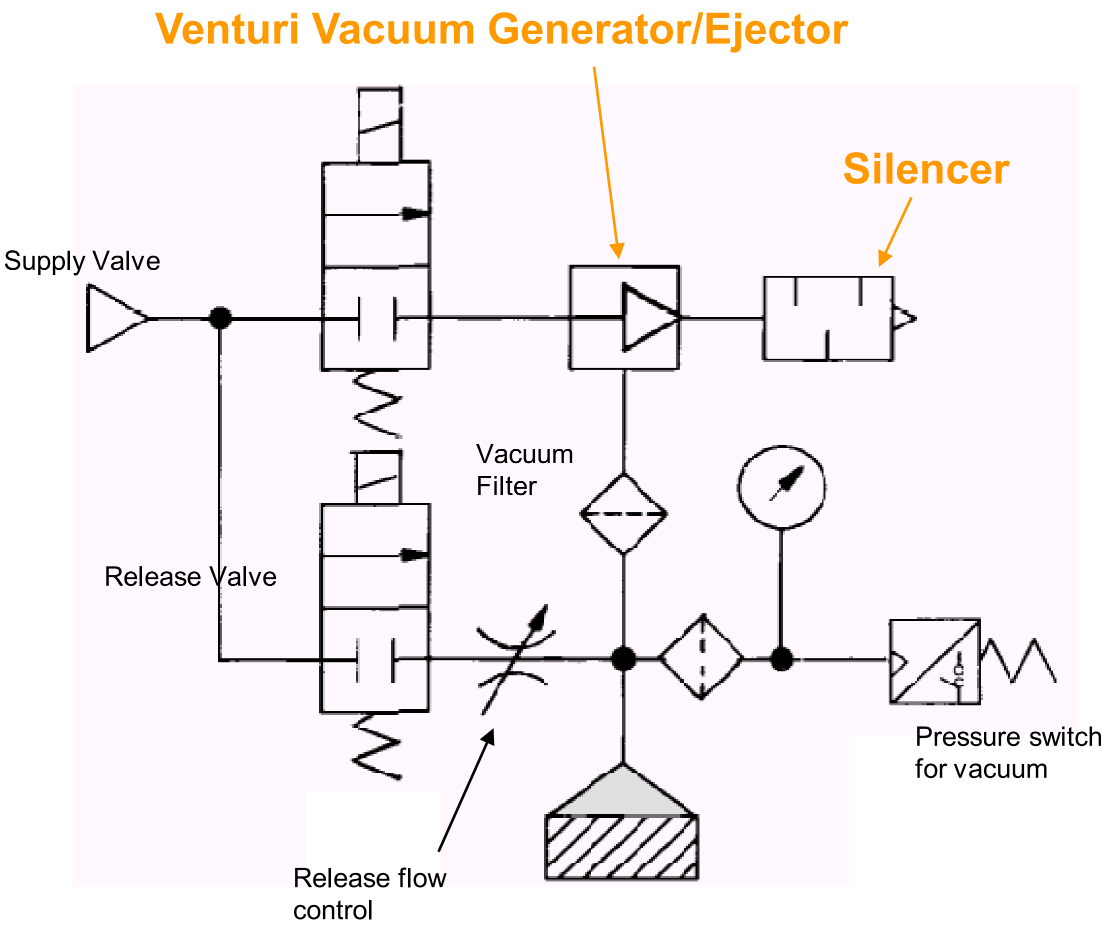
$$= 14.7 \times \frac{\pi}{4}(6)^2 - 4.7 \times \frac{\pi}{4}(5)^2 = 416 - 92 = 324 \text{ lb}$$

Include into this a factor of safety: 4 – 8 times depending upon

a) static vs dynamic operation
b) horizontal vs vertical hold.

14.7 Vacuum Systems

A complete vacuum will include additional control and monitoring equipment



Pneumatic System

Air Compressor – reduces volume of atmospheric air and hence increases its pressure

Air Dryer – reduces moisture from air after compression

Air Tank – stores compressed air and acts an 'infinite' supply for the systems

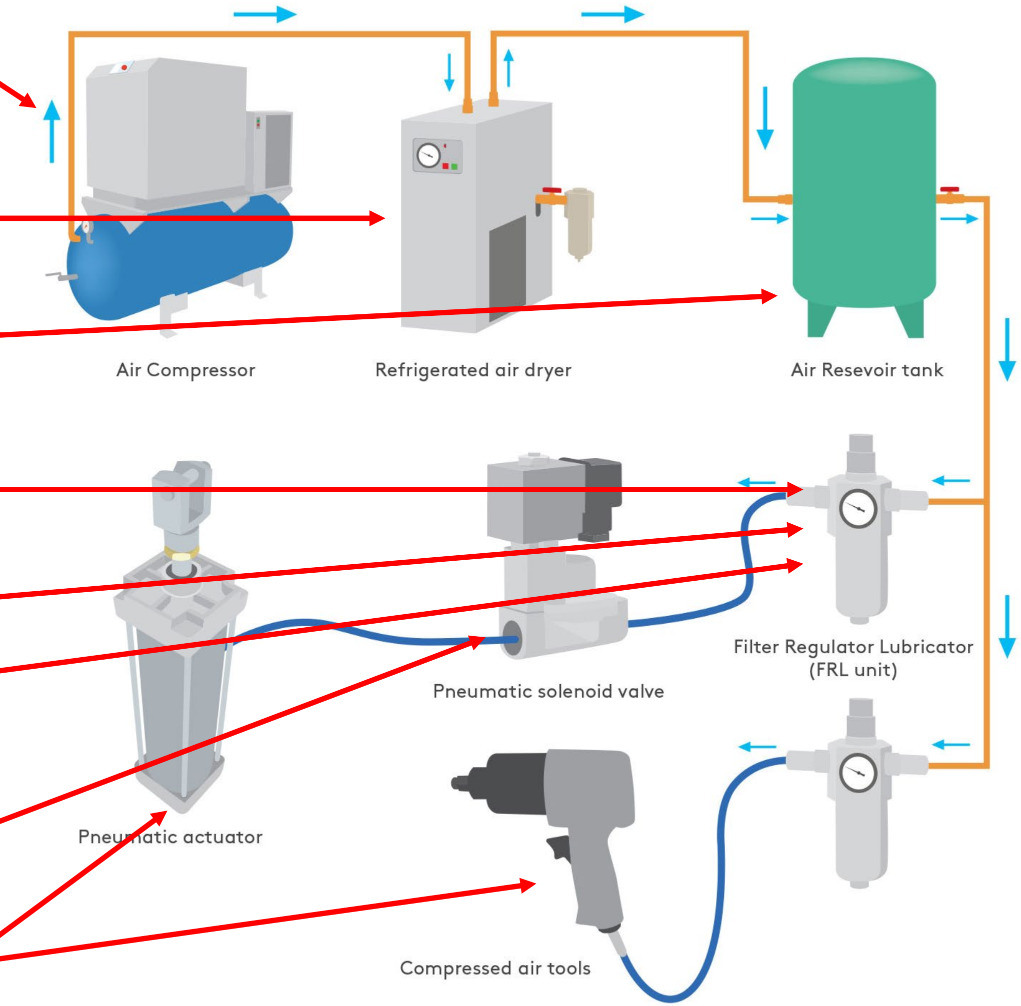
Filter – removes contaminants that can damage DCVs and actuators

Regulator – reduces the pressure to the actuator

Lubricator – adds a fine mist of oil for lubricating the DCV and actuator's moving parts

Valve – controls the direction and movement of the air

Actuator – converts the pneumatic power into mechanical power



https://www.essentracomponents.com/en-gb/news/guides/hydraulics-versus-pneumatics

14 Pneumatic System Design

Pneumatic system design must include various aspects

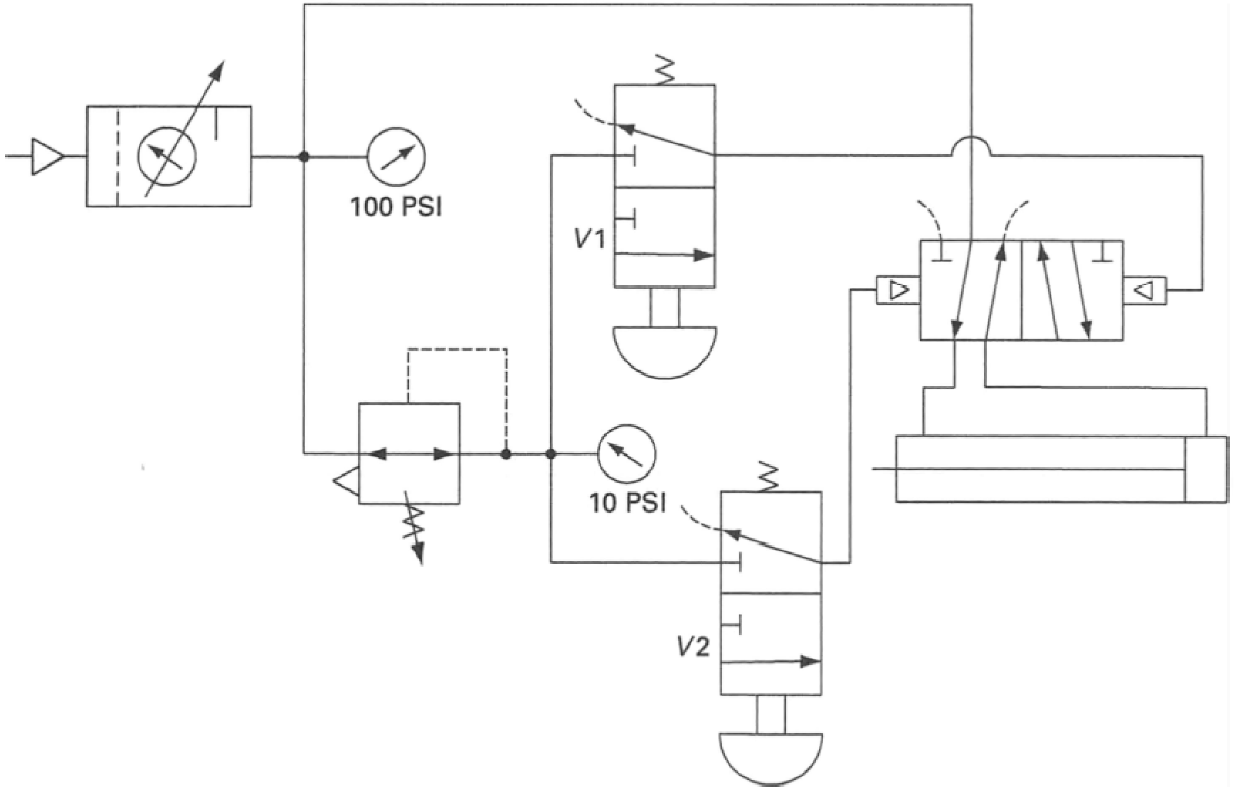
1. **Performance of desired function**
   Does the designed system perform the task it is designed to do? Does it operate repeatedly and reliably within the environment it is intended to operate?

2. **Safety of operation**
   Are there automatic emergency measures and interlocks in the system to respond to failures and prevent unintended operation, for example pilot operated check valves and two-handed operations, fail safe design?

3. **Efficiency of operation**
   Does the system operate efficiently, using correctly sized components, for example high efficiency compressor?

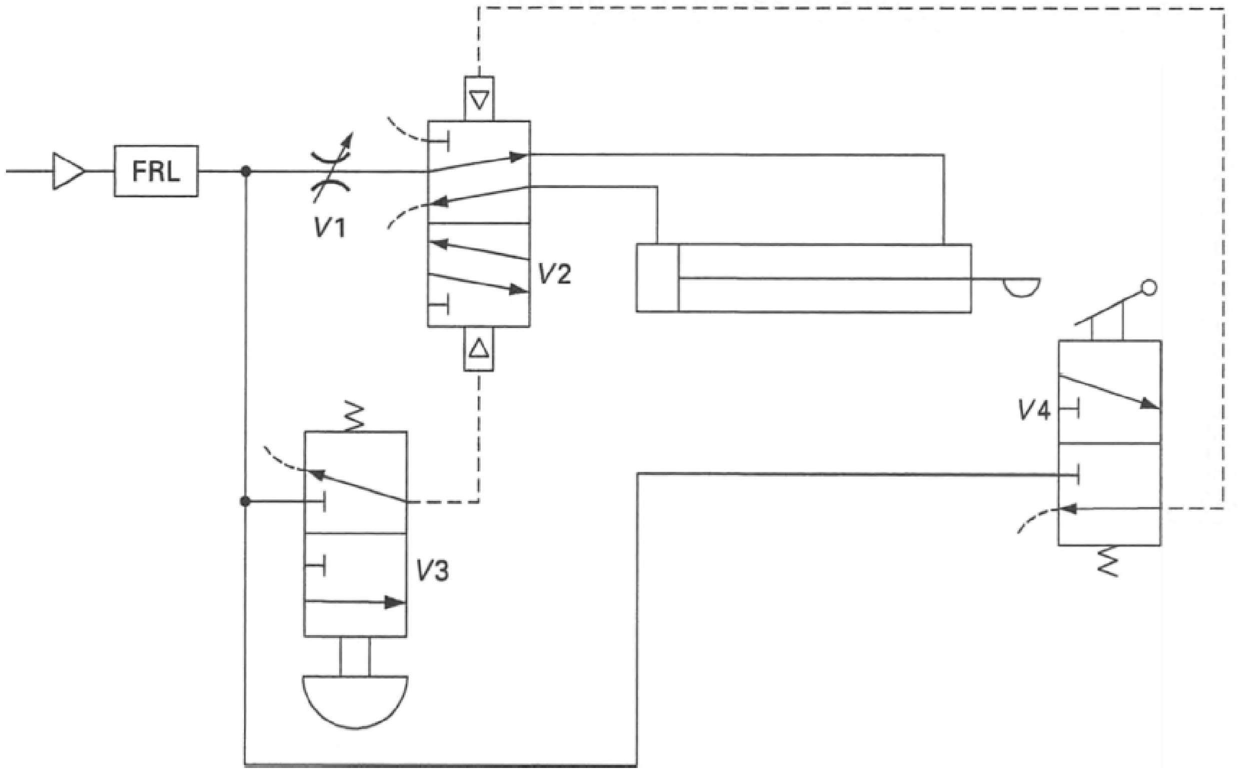
4. **Costs and losses**
   Are losses minimized considering leaks and correctly sized pipes and valves to reduce friction losses?

Air Pilot Control of Double-Acting Cylinder



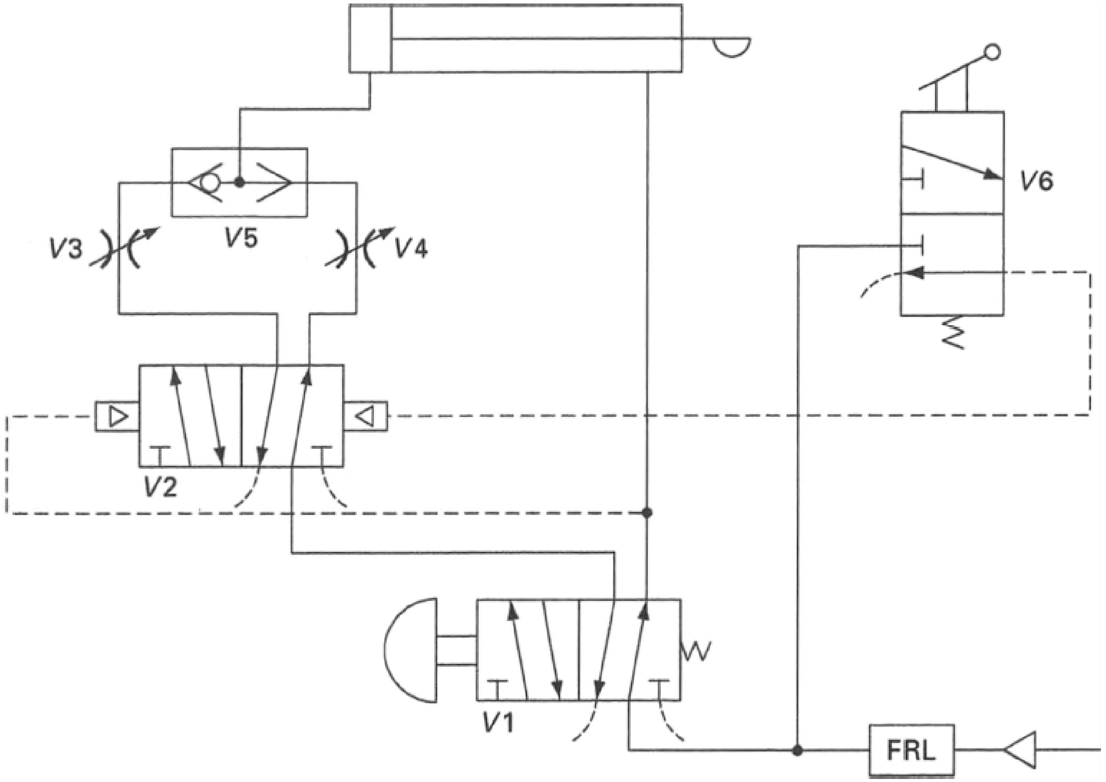
A double-acting cylinder can be remotely operated through the use of an air-pilot-actuated DCV. Push-button valves V1 and V2 are used to direct airflow (at low pressure such as 10 psi) to actuate the air piloted DCV, which directs air at high pressure such as 100 psi to the cylinder. Thus, operating personnel can use low-pressure push-button valves to remotely control the operation of a cylinder that requires high-pressure air for performing its intended function. When V1 is actuated and V2 is in its spring-offset mode, the cylinder extends. Deactivating V1 and then actuating V2 retracts the cylinder.

Cylinder Cycle Timing System



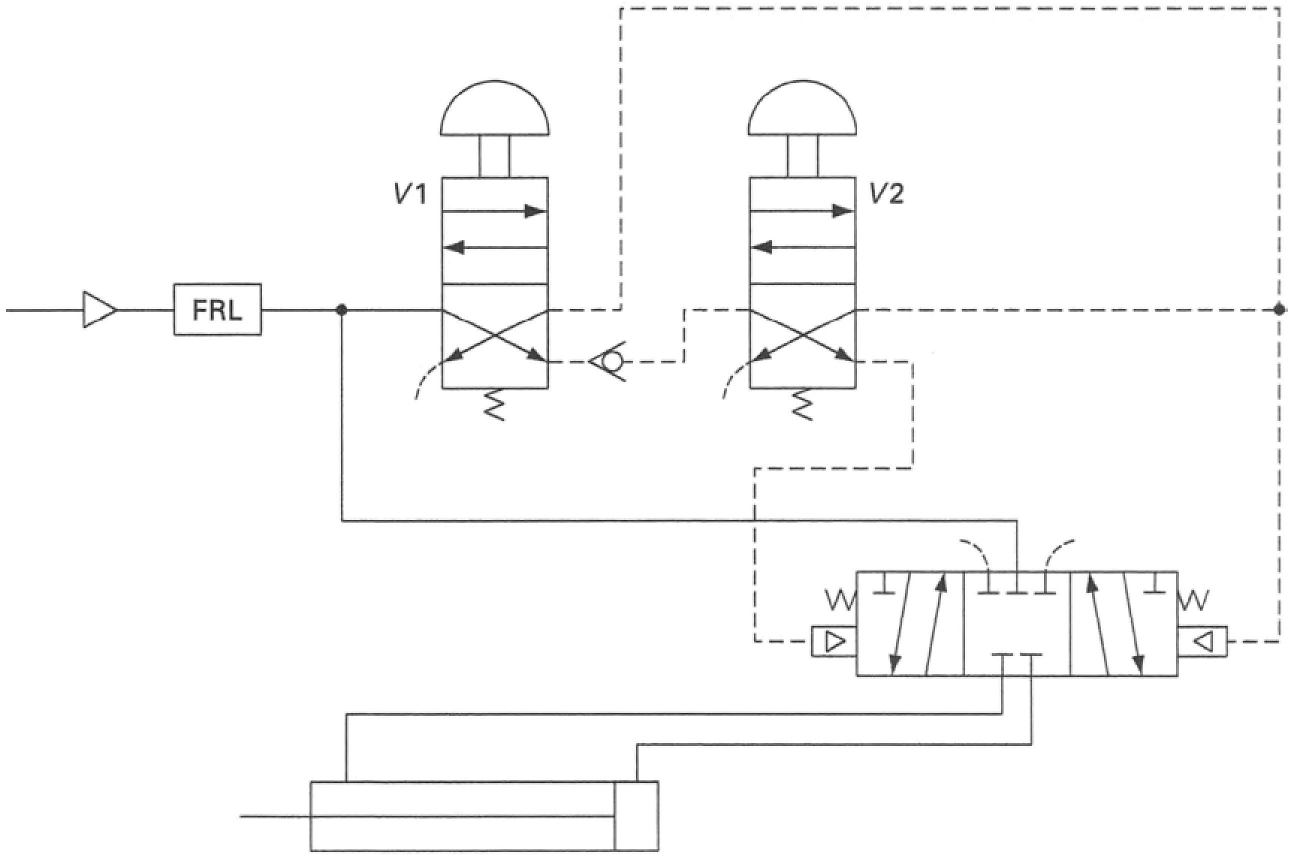
Circuit employs a limit valve to provide a timed cylinder extend and retract cycle. When push-button valve V3 is momentarily actuated, valve V2 shifts to extend the cylinder. When the piston rod cam actuates limit valve V4, it shifts V2 into its opposite mode to retract the cylinder. Flow control valve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

Two-Step Speed Control System



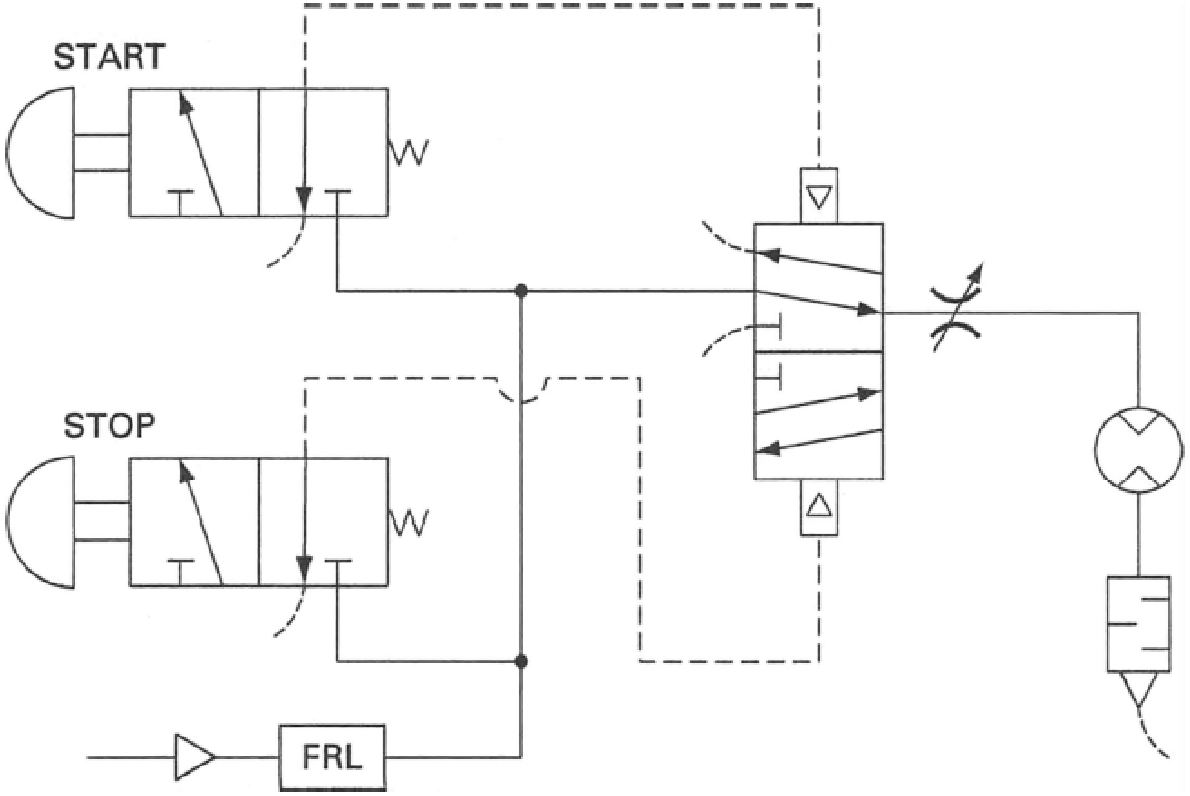
A two-step speed control system. The operation is as follows, assuming that flow control valve V3 is adjusted to allow a greater flow rate than valve V4. Initially, the cylinder is fully retracted. When push-button valve V1 is actuated, airflow goes through valves V2, V3, and the shuttle valve V5 to extend the cylinder at 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. However, due to the low flow setting of valve V4, the extension speed of the cylinder is reduced. After the cylinder has fully extended, valve V1 is released by the operator to cause retraction of the cylinder.

Two-Handed Safety Control



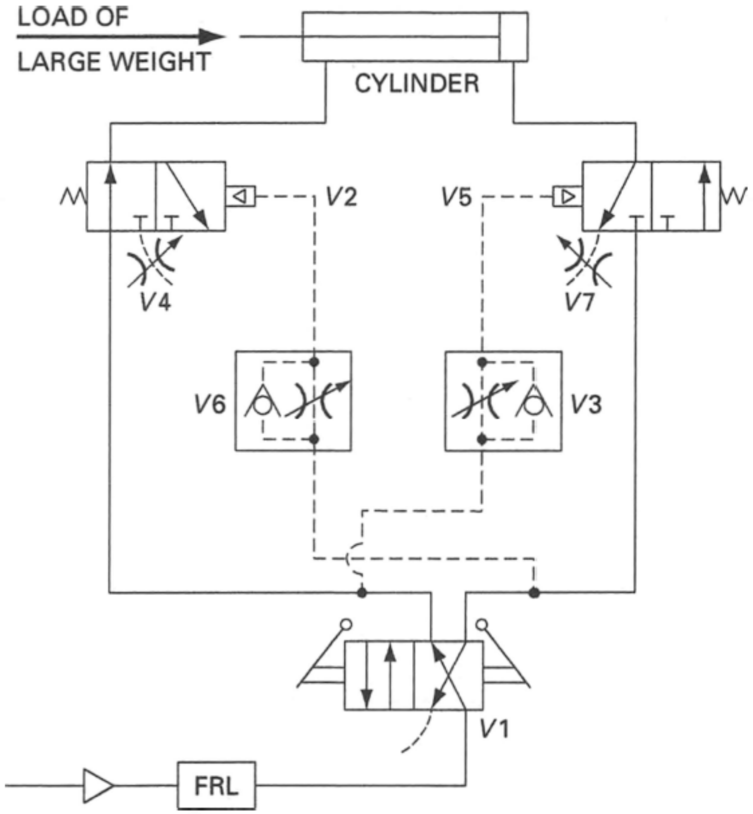
A two-handed safety control circuit. Both palm-button valves (V1 and V2) must be actuated to cause the cylinder to extend. Retraction of the cylinder will not occur unless both palm buttons are released. If both palm-button valves are not operated together, the pilot air to the three-position valve is vented. Hence, this three-way valve goes into its spring-centered mode, and the cylinder is locked.

Control of Air Motor



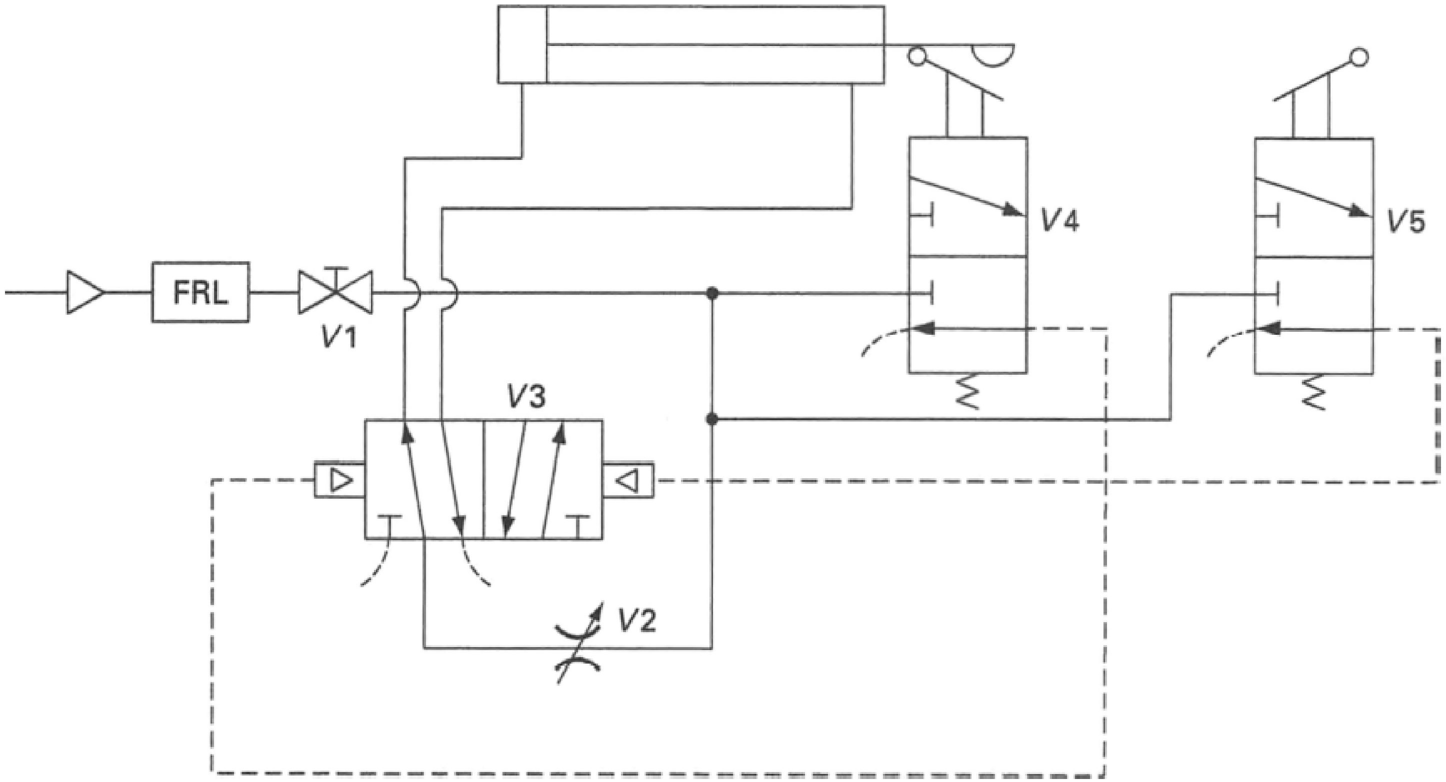
Control of an air motor. The operation is as follows. When the START push-button valve is actuated momentarily, the air pilot valve shifts to supply air to the motor. When the STOP push-button valve is actuated momentarily, the air pilot valve shifts into its opposite mode to shut off the supply of air to the motor. The flow control valve is used to adjust the speed of the motor.

Deceleration Air Cushion of Cylinder



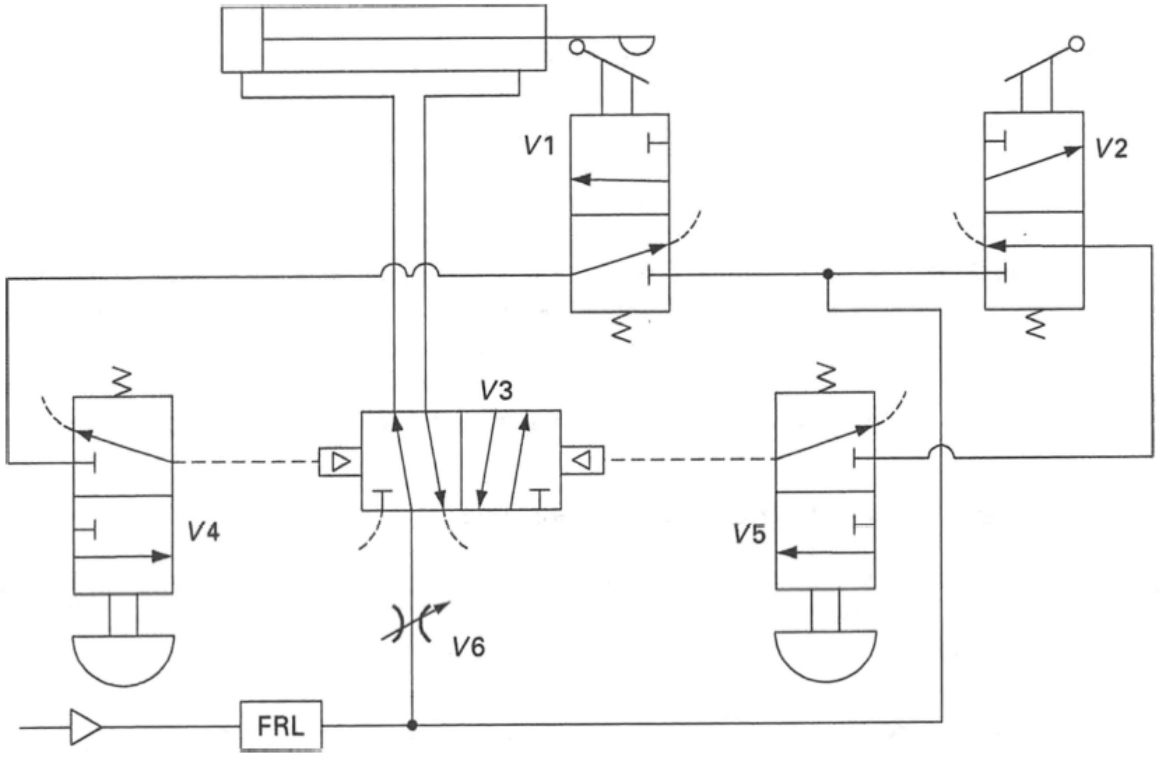
Circuit provides an adjustable deceleration air cushion at both ends of the stroke of a cylinder when it drives a load of large weight. The operation is as follows: Valve V1 supplies air to the rod end of the cylinder and to the pilot of valve V5 through flow control valve V3. Free air exhausting from the blank end of the cylinder permits a fast cylinder-retraction stroke until valve V5 operates due to increased pressure at its pilot. When valve V5 is actuated, the cylinder blank end 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. For the extension stroke, valves V2, V4, and V6 behave in a fashion similar to that of valves V5, V7, and V3.

Cylinder extends and retracts continuously



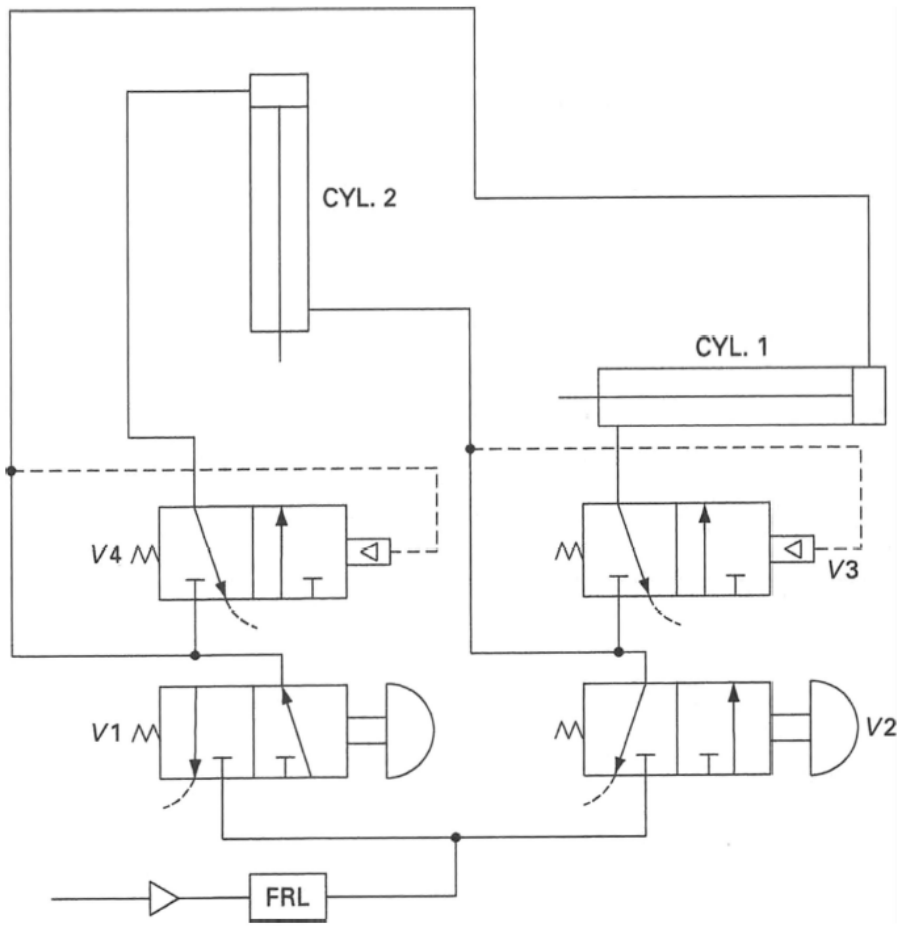
Cylinder extends and retracts continuously. When the air supply valve V1 is turned on, V4 (being depressed) will pass pilot air to V3, and V3 will pass air o the blank side of the cylinder and it will extend. Once it begins to move, it will release V4. At extension, V5 will depress providing pilot air to V3, which will shift and the cylinder will retract, where it depress V4 and the cycle repeats. V2 controls the speed of the cylinder in both extension and retraction.

Controlled cylinder extension and retraction



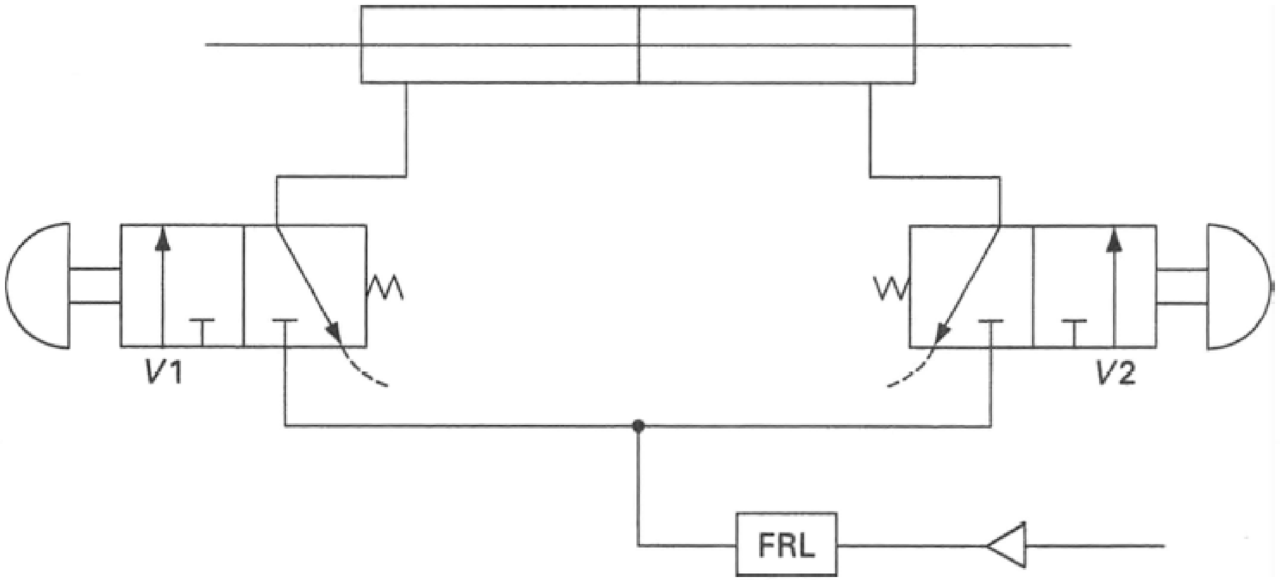
Controlled cylinder extension and retraction. Cylinder extends, with speed controlled by V6. At extension, V2 sends pilot air to V5, and when V5 is pressed, pilot air is sent to V3 which shifts V3 and the cylinder retracts. When retracted, V1 sends pilot air to V3, controlled through V4 to start a new cycle. If both V4 and V5 are held, cycling is continuous.

Cylinder Sequencing



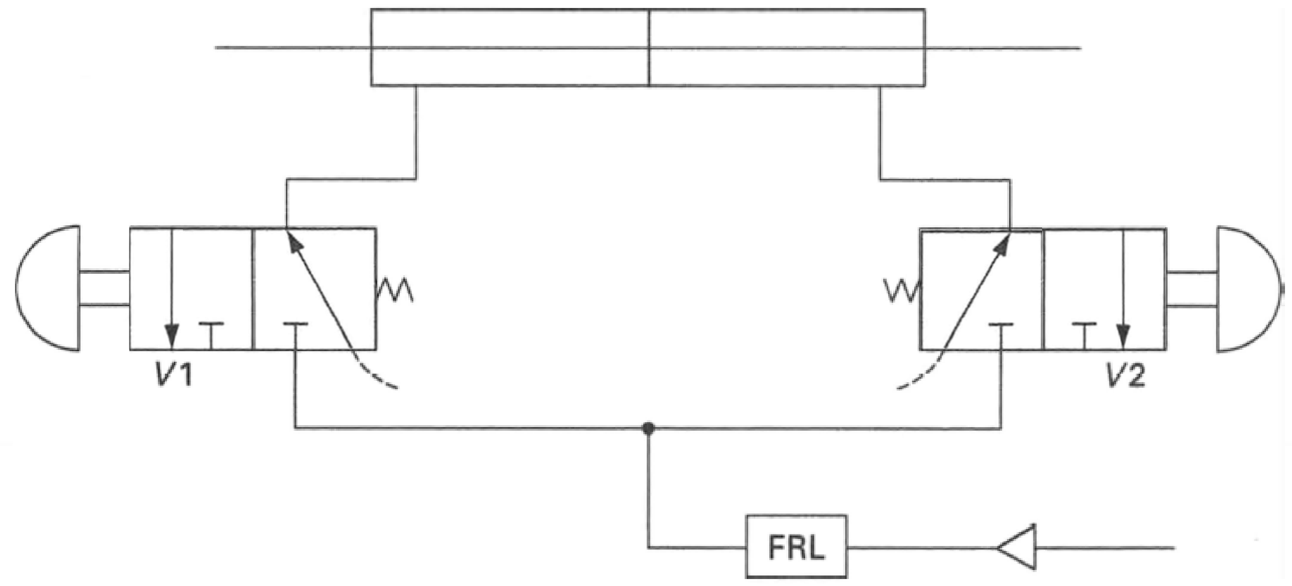
When V1 is pressed, Cylinder 1 extends and once extended the pilot pressure at V4 increases to shift V4 and extends Cylinder 2, and cycle pauses. When V2 is pressed, Cyl 2 retracts, and then V3 shifts to retract Cyl 1. Pressing V1 starts the cycle again.

Double Rod Cylinder (1)



Actuate V1 only: cylinder moves to the right.
Actuate V2 only: cylinder moves to the left.
Actuate both V1 and V2: cylinder is pneumatically locked since both ends are exposed to system air pressure.
Release both V1 and V2: cylinder is free to move since both ends are vented to the atmosphere.

Double Rod Cylinder (2)



For the previous system, the cylinder is free (both
ends vented to the atmosphere) in the unactuated (spring offset) position of the directional control valves. Redesign the system using the same components to accomplish the following operations:

a. The cylinder rod moves left when only VI is actuated.

b. The cylinder rod moves right when only V2 is actuated.

c. The cylinder rod stops moving when a single actuated valve is unactuated (both valves are unactuated).

d. When both valves are actuated, the cylinder is free (both ends are vented to the atmosphere).

Chapter Reading

Chapter 14

All