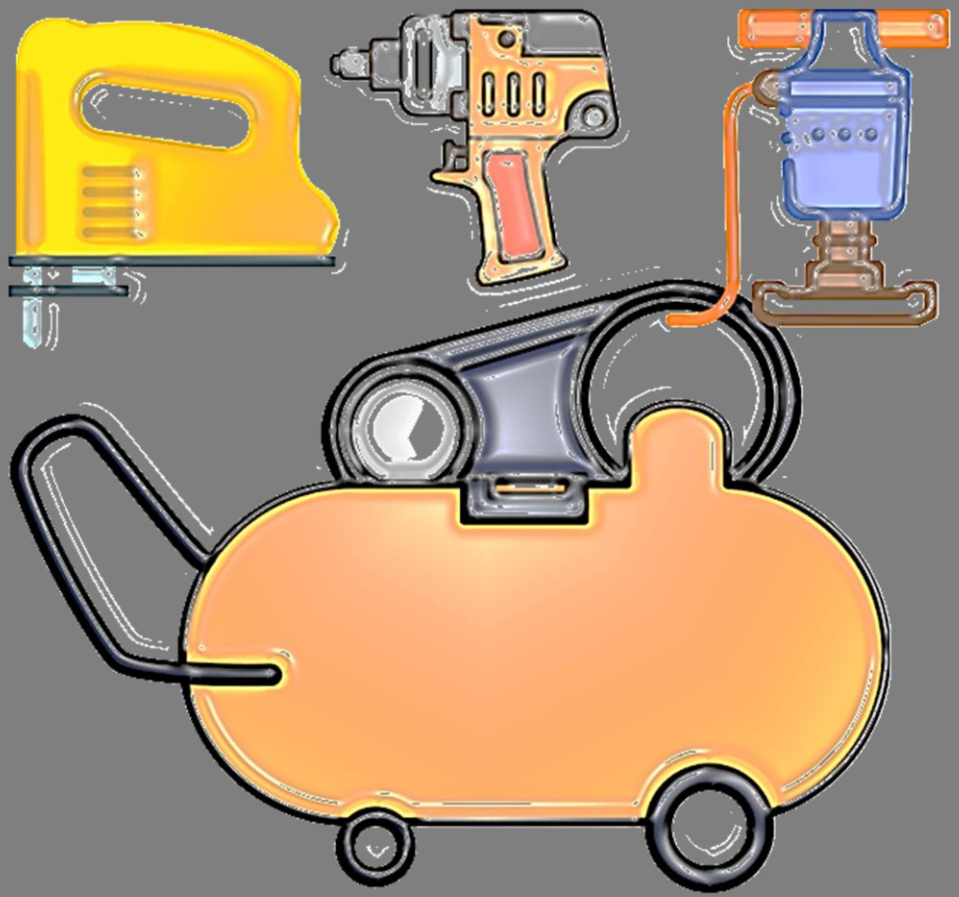
BASIC PNEUMATIC QUICK GUIDE

FOR DIPLOMA LEVEL



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Preface

Praise our gratitude to the presence of God Almighty. By His grace and guidance, the author was able to complete a scientific work entitled "BASIC PNEUMATIC QUICK GUIDE for Diploma level." Not forgetting the author to thank Mr. Roshaizul Nizam as an e-Learning officer who has assisted the author in producing this scholarly work. The author also thanks the friends who have contributed to the making of this scientific work. This scholarly paper provides guidance in the learning of Pneumatic especially mechanical engineering. The author realizes there are shortcomings in this scientific work. Therefore, suggestions and criticism are always expected for the improvement of the author's work. The author also hopes that this scholarly work will be able to provide additional knowledge to students and anyone who wants to know the basics of the pneumatic system.

November 2021

Authors

ABSTRACT

Pneumatics represent well-developed technologies where components are available from a wide range of suppliers in modular form, enabling the engineering design to specify a bespoke system for a particular application. Pneumatics are useful for the actuation of diverse elements from brakes and valves to robotics and machine tools. This book introduces both technologies and the principal components of pneumatic. A wide range of industrial applications require substances, objects, or components to be moved from one location to another. With the availability of such materials, it is hoped that students and readers will be able to apply the correct pneumatic method in daily life as well as in industry.

TABLE OF CONTENT

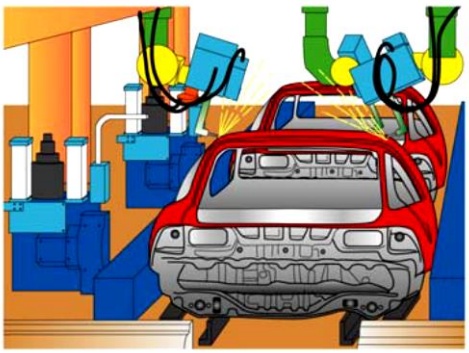
1.0 INTRODUCTION

1.1 Pneumatic System

Do you know what a pneumatic system is? ***Pneu*** is derived from a Greek word which means wind, while ***matic*** referring to the power. Therefore, the pneumatic system may be construed as a system driven by wind power.

Pneumatic systems use compressed air as the power transfer media. Compressed air is ambient air that has been compressed by using an air compressor electric motor operated.

Pneumatic systems are extensively used in electronic component assembly industry, food processing machines, pneumatic tools like drilling machine, air motors and others. For example, a pneumatic system is also used by buses in automatic door system and also on the brakes (Majumdar, 1996).



a) Automobile production lines

b) Automatic machine

Figure 1: Common pneumatic systems used in the industrial sector

Within the ring main there are four main components operating the functionality of the system:

- Cylinders
- Valves
- FRLs
- Fittings and Tubing

The cylinder is the external output, the end result or the movement you are setting out to achieve.

The **valves** are the control element within the system. For example, how fast? How many movements do you require from the cylinder?

FRL's refer to the preparation of the air. The air must be cleaned, filtered and regulated or maybe even lubricated before it is channelled into the system. To do this we use a filter, regulator lubricator (FRL).

Fittings and tubing are self-explanatory, they are the connections and pipes that connect the system together

1.1.1 Pneumatic Control in the Industry

Pneumatic systems are used in many places in our everyday world, including train doors, automatic production lines, mechanical clamps, and more. A pneumatic system uses air that is compressed in order to transmit and control energy. There are many advantages to using pneumatic controls, particularly in the industrial and manufacturing sector for powering automation in machines.

A variety of pneumatic components are used throughout the medical device industry due to the cleanliness of compressed air in comparison to hydraulic oils. When developing custom products for use in these applications, engineers can often consolidate these components into a manifold system or valve block which offers even less opportunity for system contamination. Integrating components through good design not only improves the appearance of the circuit but also eliminates potential leak points and eases system assembly.

Besides industrial uses in construction, fabrication and mining, pneumatic machines have found other functions to serve as well. Dentists use pneumatic systems to power their dental tools. Pneumatics is also used to send signals to control equipment in much the way that electronics do.

Another application of pneumatic system:

IN DAILY LIFE	IN INDUSTRIAL	IN CARRYING AND WORKING OPERATION
Air Gun	Clamping	Drilling
Insect Spray	Shifting	Turning
Jack Air	Positioning	Milling
Door Bus	Packaging	Sawing
Spray Paint	Sorting of Parts	Finishing
Grinder	Stacking of Component	Forming

1.1.2 Pros and Cons of Pneumatic System

There are many advantages to using a pneumatic instrument, which is why it remains popular in many applications. Despite these disadvantages, however, modern machines still use pneumatics because it is reliable. Below are some of advantages and disadvantages of pneumatic system.

ADVANTAGES	DISADVANTAGES
Easily extended for long distances and easily stored. It is easily available and unrestricted.	Compressed air systems require careful preparation.
Air is not subject to temperature and non-flammable	Air out of the compression process produce a lot of noise.
Can provide an effective way to force multiplication, scalable and no load problems.	Although lower maintenance cost but high preparation costs (To remove contaminants).
Air can provide flexibility in machine control	Requirement forces are limited, from 20 kN - 30 kN.
Can provide a rapid response to start and stop control.	Compressibility cannot produce a constant piston speed and uniform.
Air does not require a back-flow. The air is clean; the leakage will not pollute the environment.	To be a source of power, compressed air can be expensive.
Low volume of air, so the movement more quickly than the hydraulic oil.	It uses a lot of pipes.
Pneumatic system components easily constructed when compared with other systems.	

1.1.3 Structural Block and Signal Flow

The elements in the system are represented by symbols which indicate the function of the element.

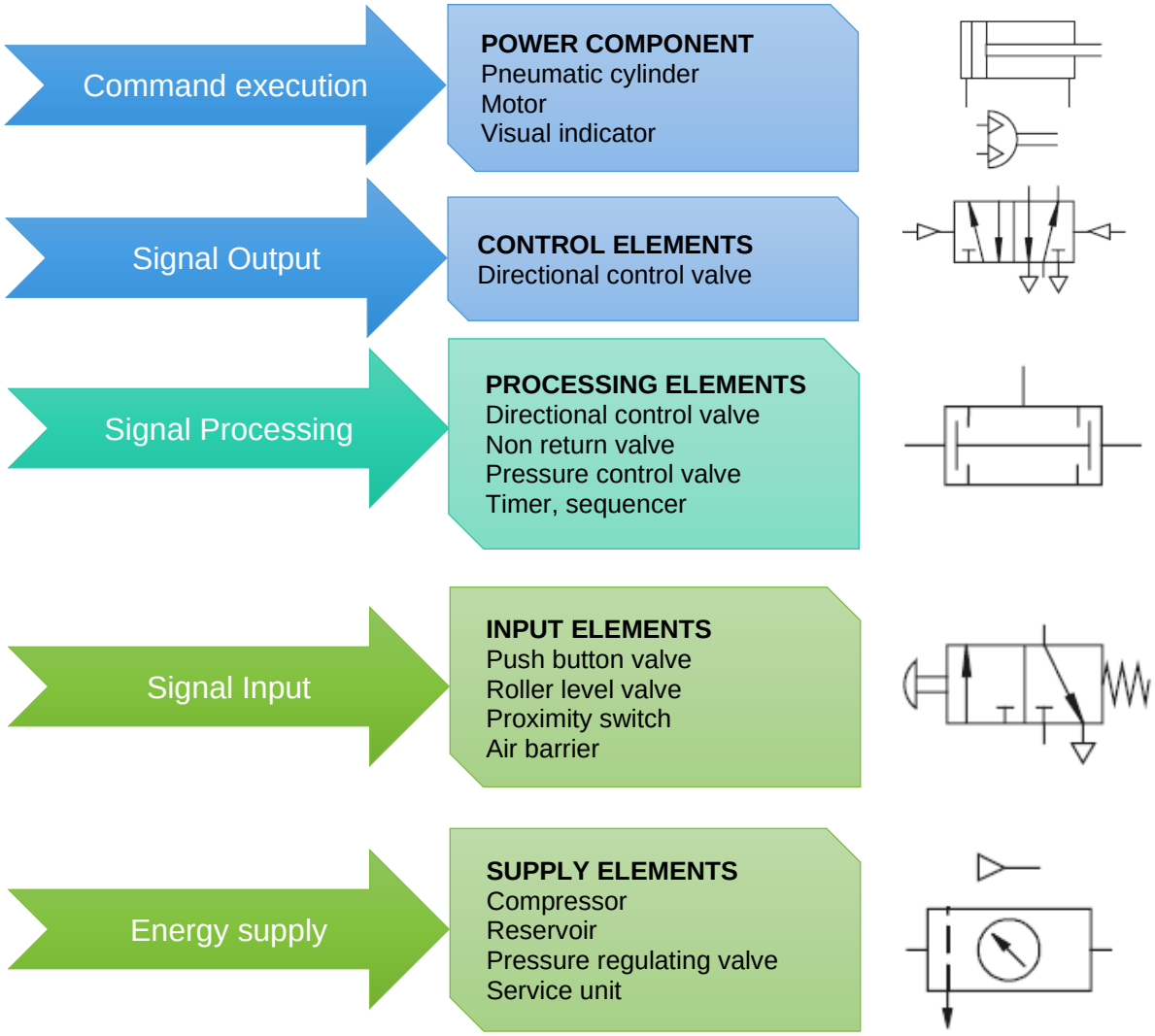


Figure 2: Pneumatic control system

A block diagram of the pneumatic system components is shown in Figure 1.1 below

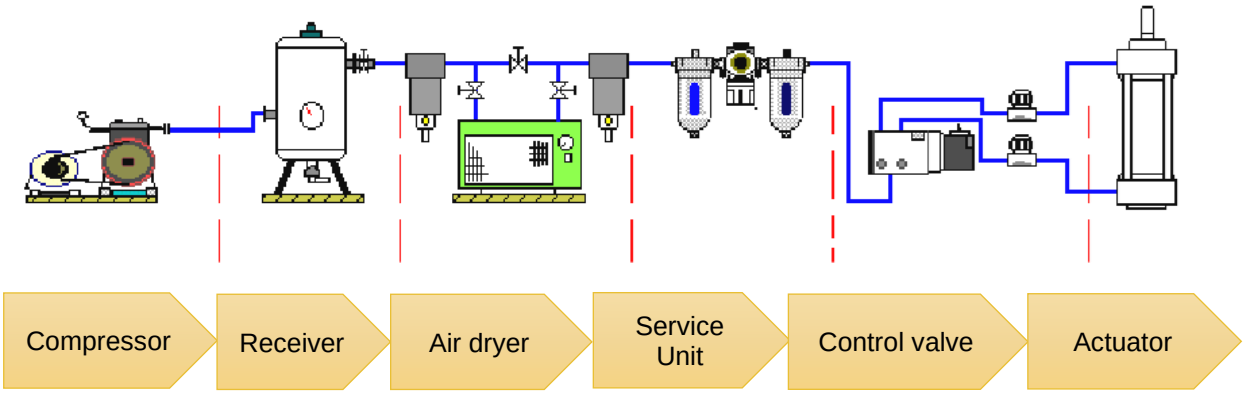


Figure 3: Block Pneumatic system components

Component	Function
Compressor	Serves to collect and compressing air from the outside to specific pressure. For example, a typical compressor is rotation and reciprocating type.
Receiver	Works to keep the air that has been compressed and dried before being sent to the system. Air receiver is also known as an air tube. It can control the air pressure in it
Air dryer	Function for dry air that has been compressed. Dry air is necessary to prevent rusting pneumatic components.
Service Unit	Service unit consists of three components, pressure regulator, pressure gauge and lubricant. It works to control the air pressure and air lubricate before being sent to the system. In other words it is known FRL unit
Control valve	It works to control the direction of motion of an actuator
Actuator	Known as power component. It is the last component in the system. Function to do the work as was required. Actuators can be further broken down into groups: Linear actuators – Single-acting cylinder – Double-acting cylinder Rotary actuators – Air motors – Rotary actuators

1.1.4 ISO Standard Symbol

The development of pneumatic systems is assisted by a uniform approach to the representation of the elements and the circuits. The symbols used for the individual elements must display the following characteristics:

- Function
- Actuation and return actuation methods
- Number of connections
- Number of switching positions
- General operating principle
- Simplified representation of the flow path

A symbol does not represent the following characteristics:

- Size or dimensions of the component
- Particular manufacturer, methods of construction or costs
- Operation of the ports
- Any physical details of the elements
- Any unions or connections other than junctions

The standard used is **ISO DIN 1219**

The number of position and flow boxes that make up a valve symbol indicate the number of positions the valve has. Flow is indicated by the arrows in each box. These arrows represent the flow paths the valve has when it is in that position.

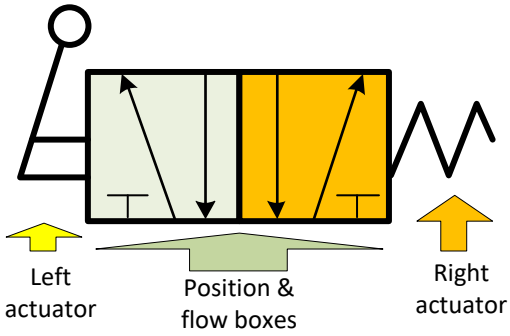


Figure 4: 2 Position, Lever Actuated, Spring Return Valve

The number of ports is shown by the number of end points in a given box. Count only the ports in one flow box per symbol (the other boxes just show different states of the same valve)

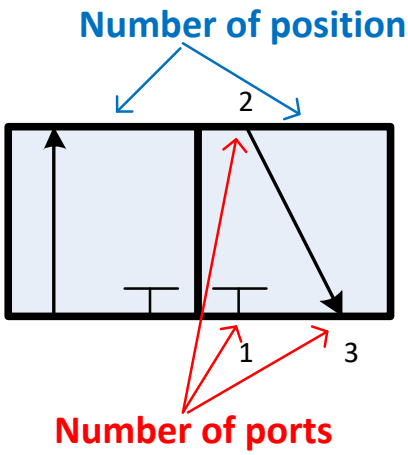


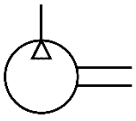
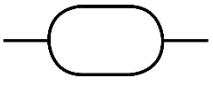
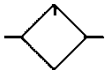
Figure 5: label between position and ports

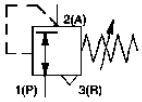
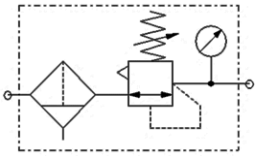
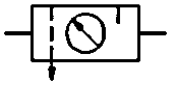
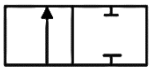
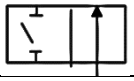
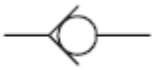
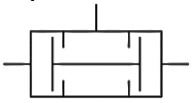
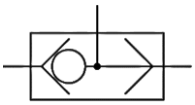
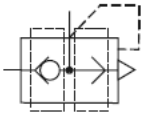
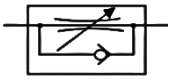
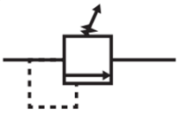
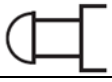
Valves are also referred to by the number of "ways" that air can enter or exit the valve. In most situations the number of ports and ways are the same for a given valve.

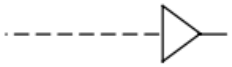
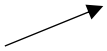
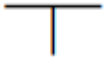
Basics of the ISO symbols:

- Each position the valve can take is represented by a square.
- The number of squares tells you the number of positions the valve can take.
- The air pathways are represented by lines.
- The direction of the airflow is represented by an arrow.
- In case air flows in both directions there is a double arrow.
- Closed ports are displayed as a T.
- The ports carry numbers. The numbers are only shown in the square with the basic position of the valve.
- The type of actuation is also symbolized.

Table 1: Standard ISO DIN 1219 pneumatic symbol

PART	**Equipment & Symbol**	
Energy supply	Compressor with fixed capacity 	Air receiver 
Air service equipment	Air filter 	Air lubricator 

PART	Equipment & Symbol	
	Pressure regulator 	Pressure gauge/ pressure meter 
	FRL unit 	FRL simplified 
Directional control valves	2 position, 2 way, 2 ported, close 	2 position, 2 way, 2 ported, open 
	2 position, 3 way, 3 ported 	2 position, 4 way, 4 ported 
	2 position, 3 way, 3 ported 	3 position, 4 way, 4 ported, center closed 
Valve	Check valve/ non return valve 	Dual pressure valve 
	Shuttle valve 	Quick exhaust valve 
	Flow control, 1 direction 	Relief valve 
Components operated	Manual 	Push button 
	Lever 	Foot operated 
	Mechanical 	Detent 

PART	Equipment & Symbol	
	Spring 	Solenoid 
Others symbol	Connection 	Pneumatic operation signal pressure line 
	flow direction of air 	external port is not connected to the internal parts 
	air input 	Exhaust 

1.2 Air Generation System and Air Distribution System

A compressor can compress air to the required pressures. It can convert the mechanical energy from motors and engines into the potential energy in compressed air (Parr, 2013).

Automotive compressors are combustion engine compressors that use the up-and-down stroke of the piston to allow air in and pressurize the air within the storage tank. Other piston compressors utilize a diaphragm, oil-free piston. These pull air in and pressurize it by not allowing air to escape during the collection period.

These are the most common types of air compressors that are used today by skilled workers and craftsmen. Before the day of motorized engines, air compressors were not what they are today. Unable to store pressurized air, a type of antique air compressor may be found in the blacksmith's foundry bellows. Now the air compressor is capable of building extreme pressures in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

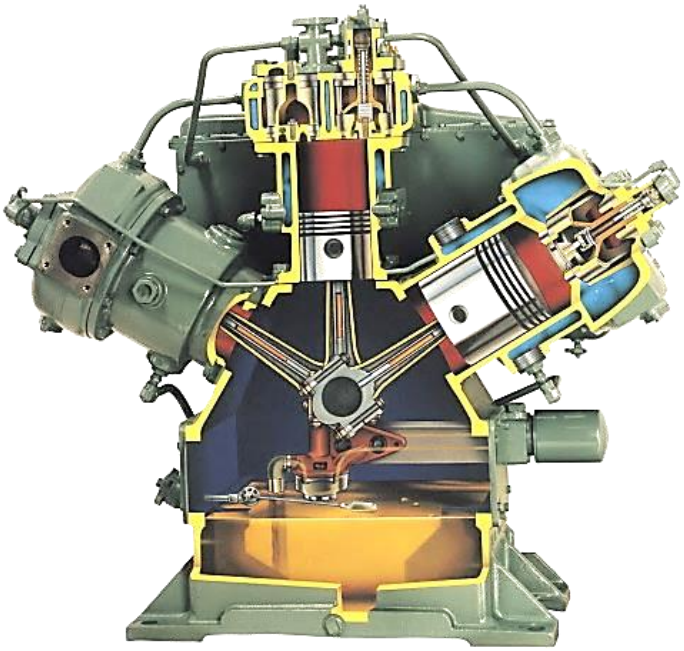


Figure 6: sample of compressor

1.2.1 Types of air compression

There are two basic types of air compressors

a) Reciprocal compressors
    i. One level piston compressor and two levels piston compressor
    ii. Diaphragm compressor
b) Rotation compressors
    i. Slide ram compressor
    ii. Screw compressor

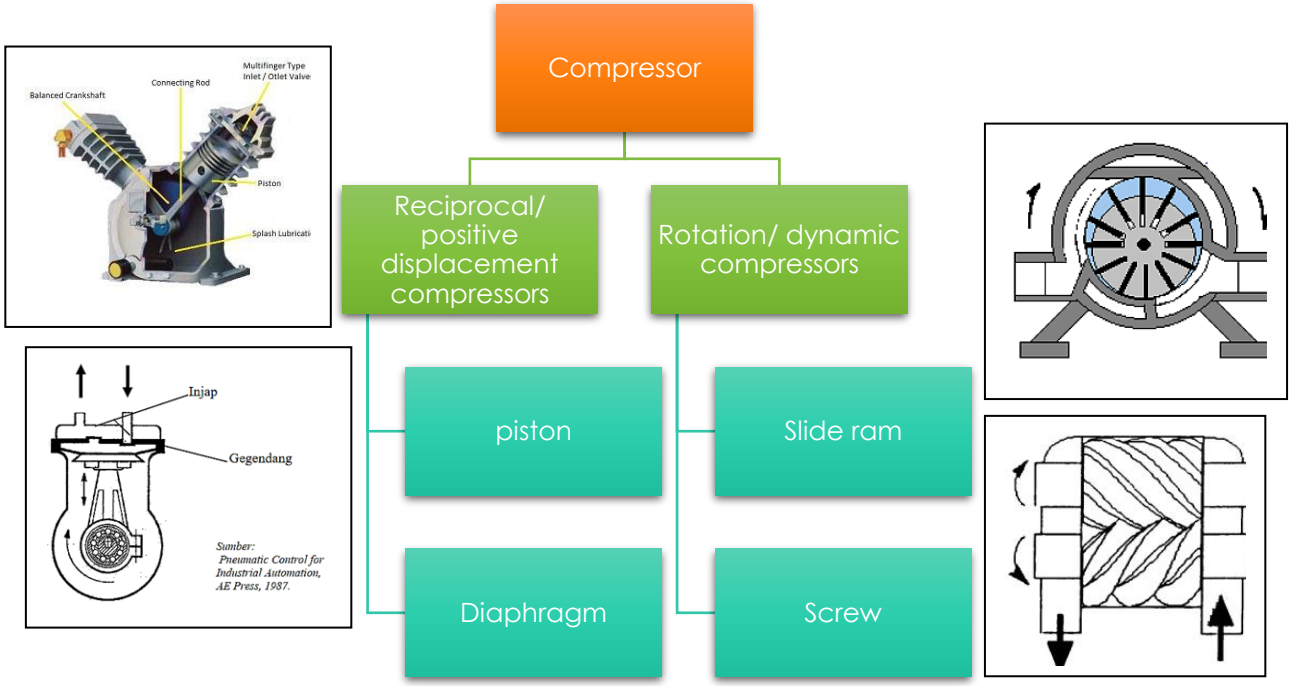


Figure 7: Type of compression

1.2.2 Compressor's accessories

For the continuing performance of control systems and working element, it is necessary to guarantee that the air supply is at the required pressure, dry and clean

a) Air tube
b) Input strainer
   Is to remove all contaminants such as dust and rust particles entering inlet of the air pressure
c) Pressure-relief valve
   Used to control or limit the pressure in a system to ensure the system in the stable condition

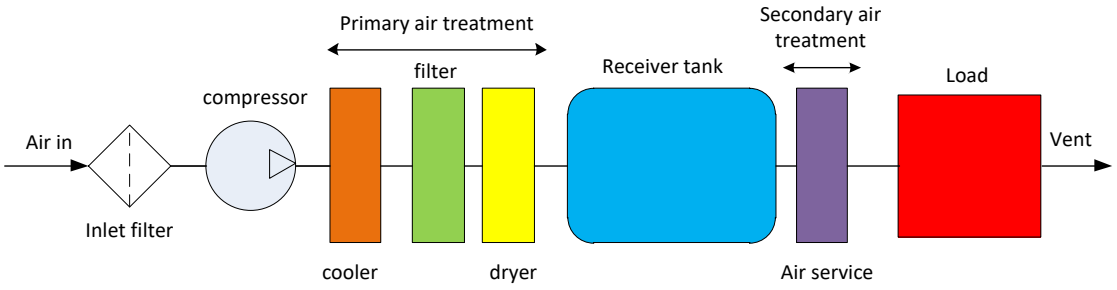
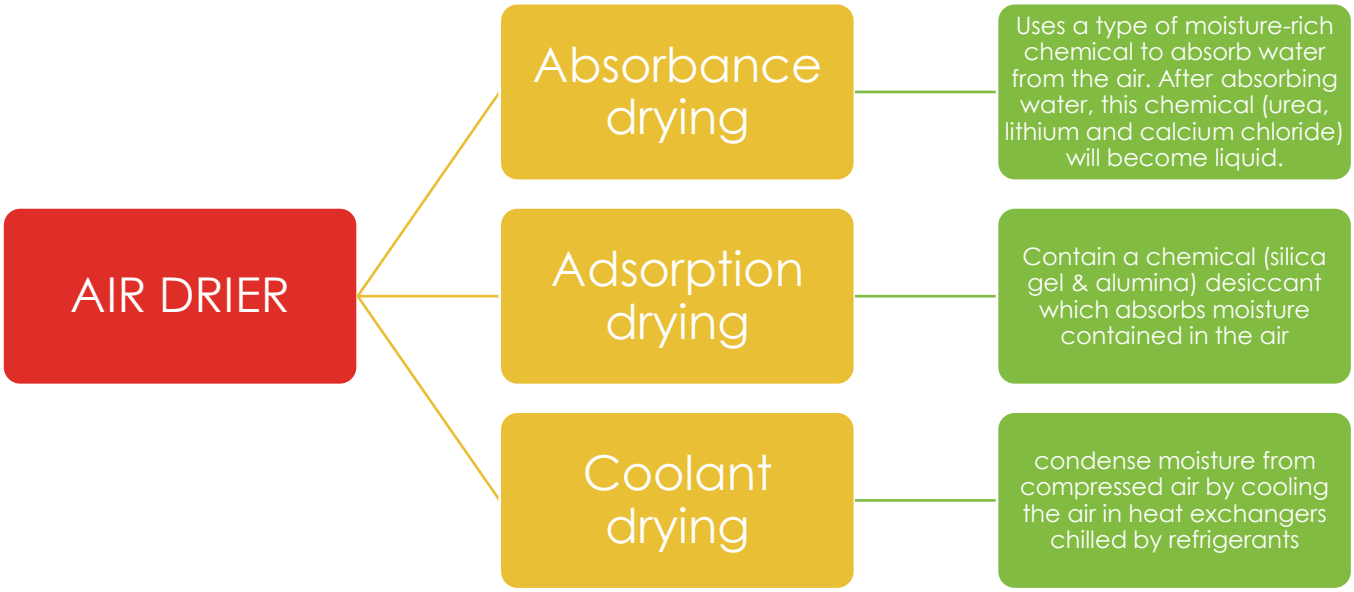


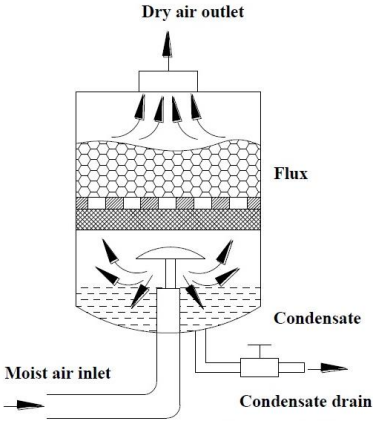
Figure 8: compressed air system

1.2.3 The concept of air dehydration

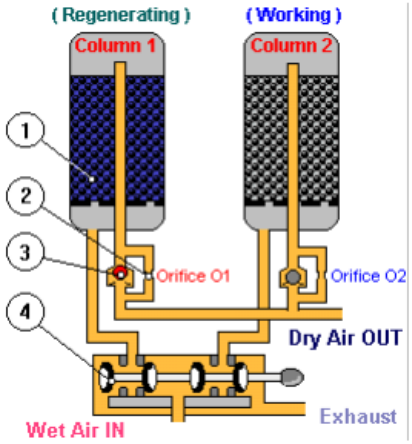
Air dehydration refers to removal of moisture from humid air and is also termed as air dehumidification and air drying

a) Continuous cooler
   i. Air cool – use air
   ii. Water cool – use water
b) Air dryer
   i. Absorbance drying
   ii. Adsorption drying
   iii. Coolant/ Refrigerated drying
   iv. Main line filter

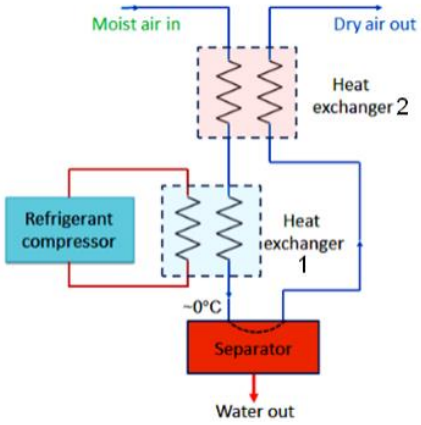




a) Absorbance drying



b) Adsorption drying

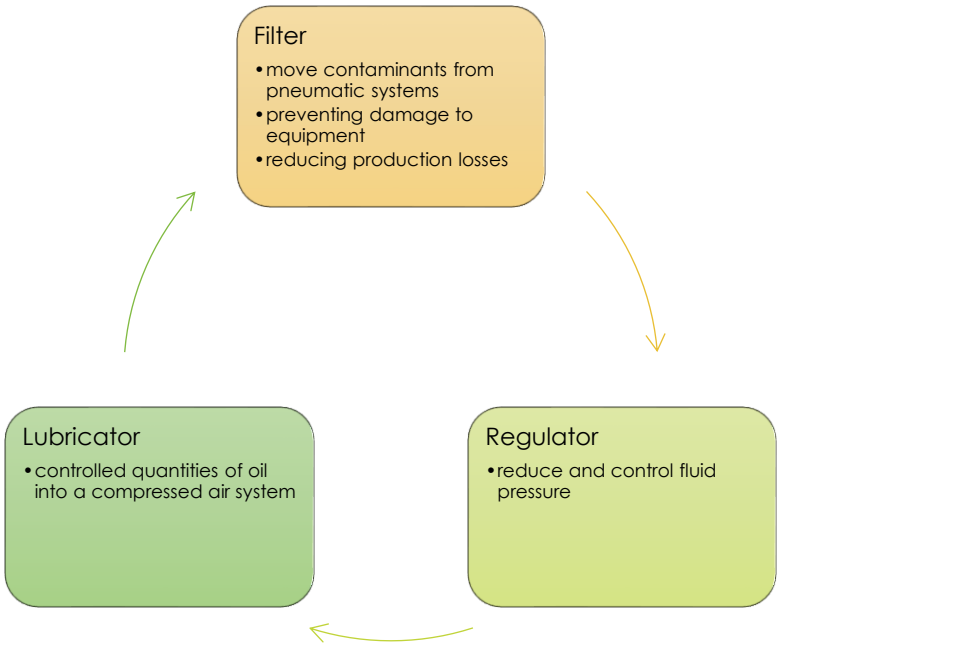


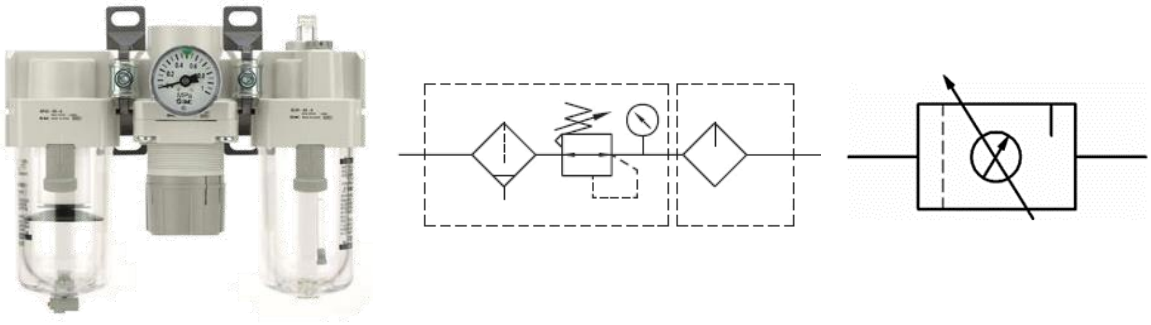
c) Coolant drying

Figure 9: Types of air drier

1.2.4 Filter-Regulator-Lubricant

During the preparation of compressed air, various processes such as filtration, regulation and lubrication are carried out by individual components. The individual components are separator/filter, pressure regulator and lubricator.



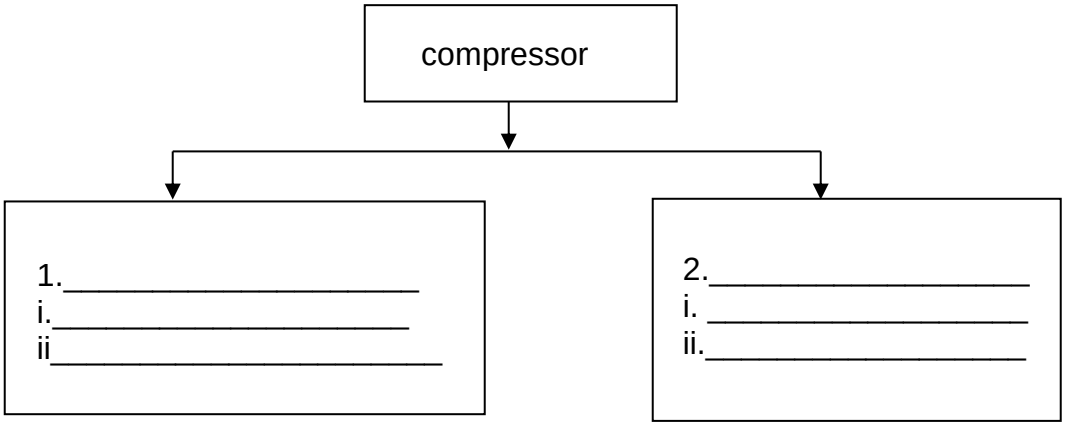


a) actual b) symbol c) simplified

Figure 10: FRL unit and its symbol

1.3 Exercises

1. Fill in the blanks below.



2. State four fittings of a compression system

3. Name 3 parts of a service unit

4. Please fill in your answer in the blanks

a. According to Boyle's Law, when the volume of a mass …… the air pressure will increase.

b. The …… unit is used to measure power.

c. According to Dew Point Law the amount is …… can change according to temperature changes.

d. A measure of the percentage of water in a volume of air is called ……

e. The air supplied to the pneumatic system must be clean of …… and ……

f. Sea level reference point where the air pressure is equal to …… bar.

g. The type of compressor can be divided into two namely …… and ……

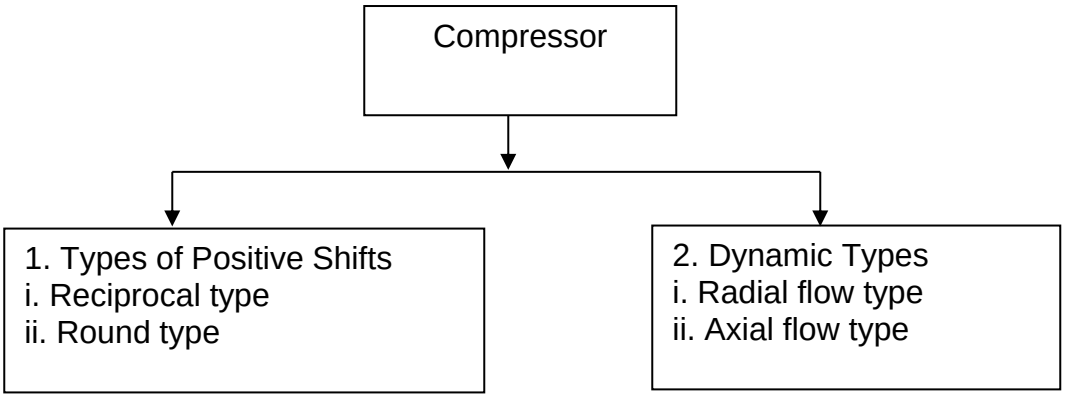
h. Compressor type …… use lubricating oil as protection against leakage.

i. Air tubes are used for ……

j. The function of the air dehydration process is to lower the temperature and ……

1.4 Exercise answer

1. Fill in the blanks below



2. State four fittings of a compression system

1. Suction head and silencer
2. Air Tube
3. Relief valve
4. Service unit or service unit

3. Name 3 parts of a service unit

1. Air Filter
2. Pressure regulator
3. Lubricant

4. Please fill in your answer in the blanks
   a. Lesser
   b. Newton
   c. Water vapour
   d. Relative humidity
   e. Oil, contaminants
   f. 1,013 bar
   g. Positive displacement, dynamic
   h. Screw
   i. The air
   j. Air drying

1.5 Tutorials

1. State TWO (2) main groups of Air Compressors

2. Give the Definition of Air Delivery

3. List FIVE (5) air compression system equipment to ensure that the air compression work can be carried out properly.

4. With the aid of a diagram, explain how an adsorption type dryer works.

5. Briefly explain the working principles of positive displacement and dynamic displacement compressors.

1.6 Tutorial answers

Answer 1
TWO main groups of Air Compressors: -

a) Type of Positive displacement compressor
b) Type of Dynamic compressor

Answer 2
The definition of free air delivery is defined as the delivery of air at different atmospheric conditions from place to place, hence the standard temperature of air is always used and is known as standard free air. For standard air, the pressure is taken to be 1.010 bar and the temperature is 0°C.

Answer 3
The five fittings of the compression system are: -

a) Suction head and silencer
b) Air receiver
c) Air accumulator
d) Service unit or service unit
e) Dryer and cooler

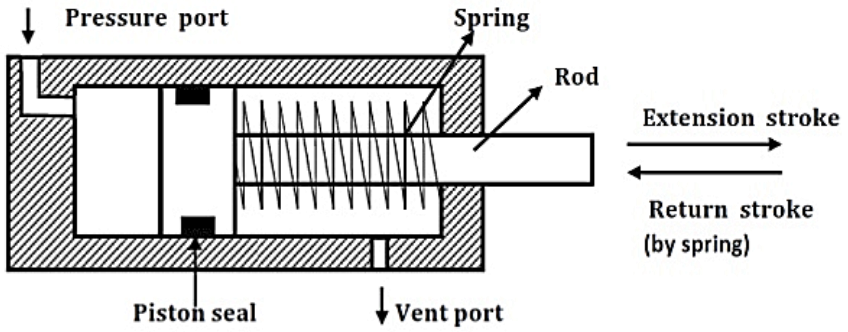
2.0 ELEMENTS IN PNEUMATICS WORKING SYSTEM

2.1 Actuator

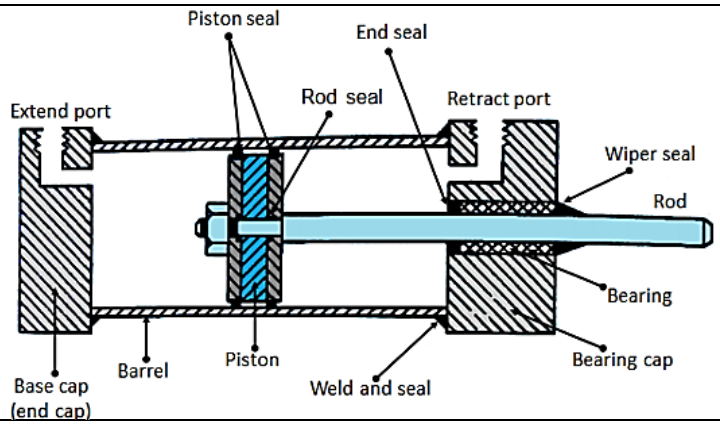
Transform energy (produced by air pressure) into work in linear force or rotation forms (Majumdar, 1996).

2.1.1 Linear cylinder

a. Single acting cylinder

A single acting cylinder is one where the thrust or output force is developed in only one direction	

b. Double acting cylinder

Use the force of air to move in both extend and retract strokes. They have two ports to allow air in, one for outstroke and one for instroke.	

2.1.2 Determination the size of the cylinder.

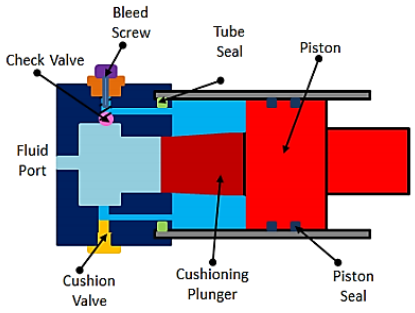
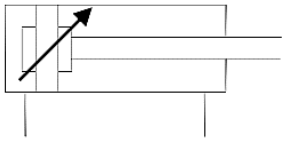
Basic equation: $F = AP$

F = Force (N)
A = Piston cross sectional area (m^2)
P = Air pressure (N/m2)

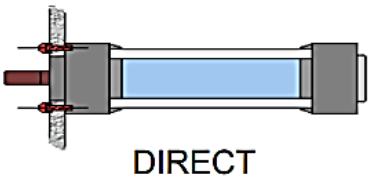
Action of	Single acting	Double acting
Expansion	$F_e = \left[\frac{\pi D^2}{4} P_g\right] - F_s$	$F_e = \left[\frac{\pi D^2}{4} P_g\right]$
Retract	No need	$F_r = \left[\frac{\pi}{4}(D^2 - d^2)\right] P_g$

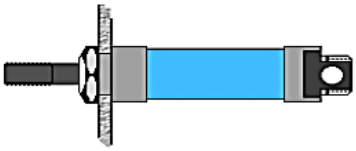
F_e = Expansion Force (N)
F_e = Expansion Force (N)
D = piston diameter (m or cm)
d = piston rod diameter (m or cm)
P_g = relief pressure (bar)
F_s = spring force at final strokes

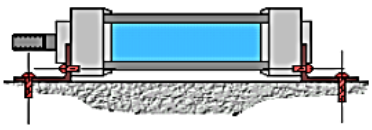
2.1.3 Cushioning

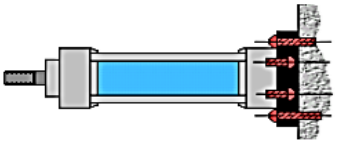
Illustration	Symbol	Descriptions
		• Cushioned cylinder has a built in flow control valve that acts near the end of its stroke. • When cylinders reach the end of their stroke, the pressure rises quickly, creating a shock wave in the hydraulic circuit. • Cushioning is done to reduce this stroke. • Two types of cushioning used in pneumatic system are rubber and air type

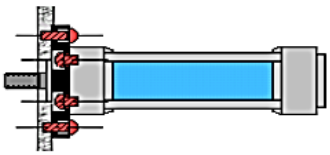
2.1.4 Mounting of cylinder

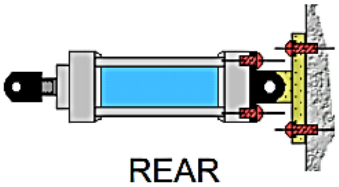

DIRECT

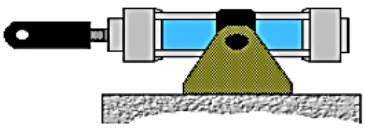

THREADED NECK


FOOT MOUNT

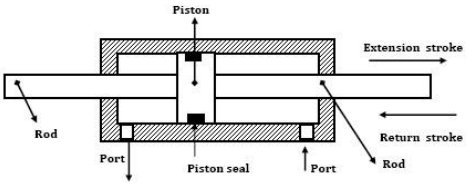
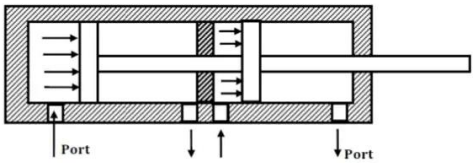
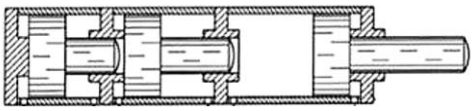
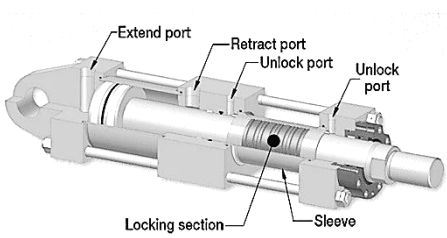

REAR FLANGE


FRONT FLANGE

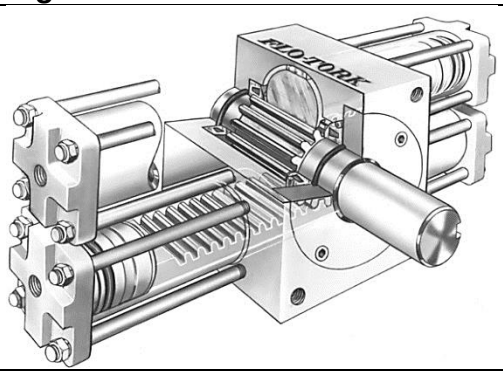

REAR CLEVIS

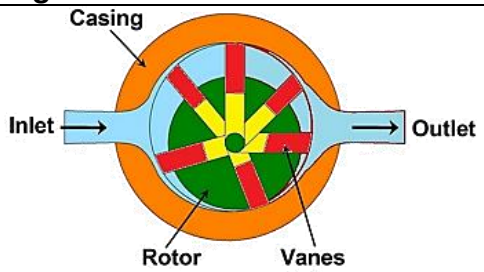

TRUNNION

2.1.5 Special cylinder

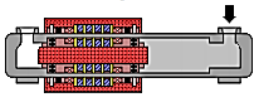
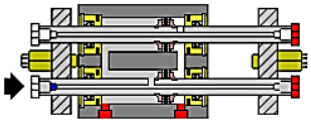
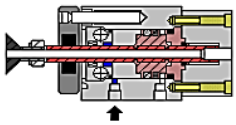
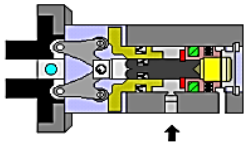
Type	Figure	Description
Twin rod		Twin rod has 2 parts of rod and the cylinder can move to the left and right along the rod. This cylinder usually used to move work piece to a long distance. A plat like a table is placed and locked on top of the cylinder. The table will move together with the cylinder
Lead rod		Lead cylinder has difference features as shown in the diagram. The cylinder is specially designed with internal lubricants to make the movement smooth along the time. It is made from nut/bolt which has a high strength.
Multi-position rod		The multi position cylinder consists of two or several double acting cylinders, which are interconnected. The individual cylinders advance when pressure is applied. In the case of two cylinders with different stroke lengths, four positions are obtained
Locked rod		This cylinder can stop at any part of the cylinder rod and can be locked at that position. Locked mechanism comes from spring, air pressure or both

2.1.6 Rotated actuator:

Type	Figure	Description
rack and pinion		• With this design of double acting cylinder, the piston rod has a gear tooth profile. • The piston rod drives a gear wheel and a rotary movement result from a linear movement. • The range of rotation varies from 45°,90°,180°,270° to 360°

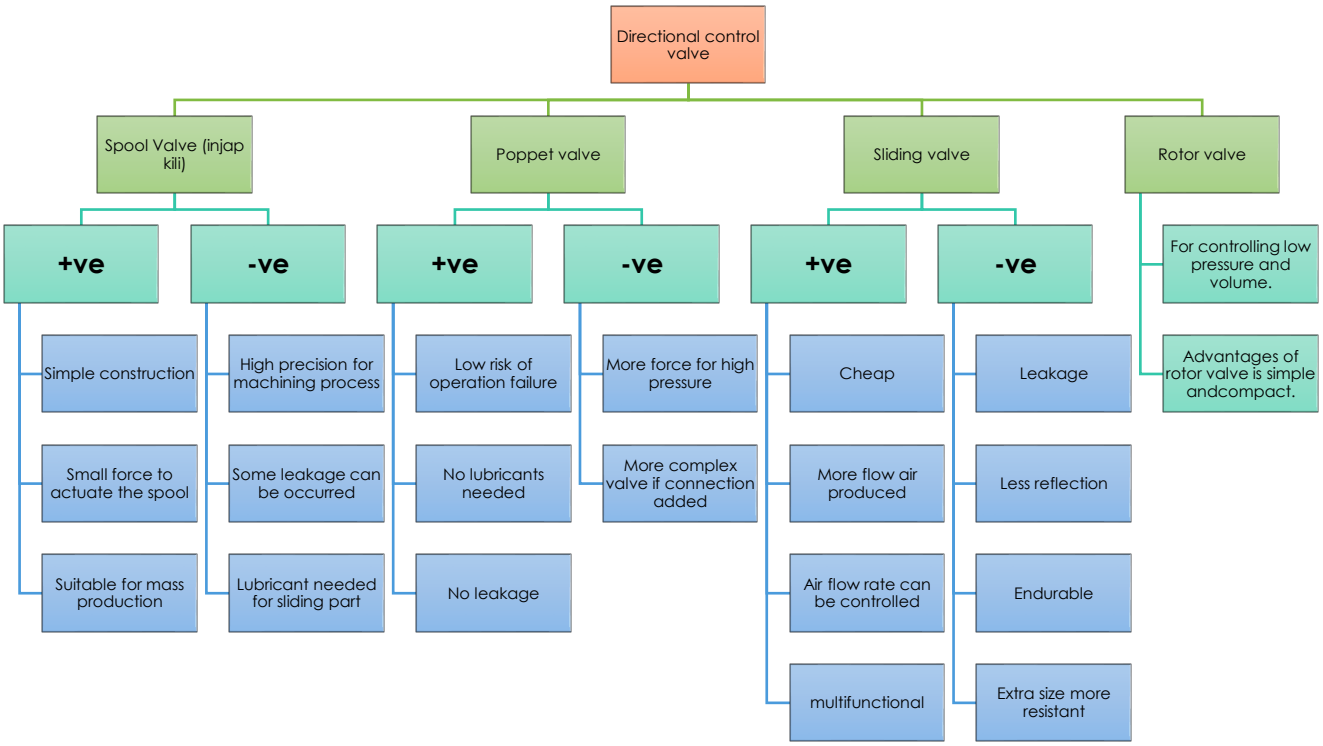
Type	Figure	Description
Ram/ vane		Force is transmitted direct to the drive shaft via a vane
Air motor		a) Devices which transform pneumatic energy into mechanical rotary movement with the possibility of continuous motion. b) Screw driver, drilling machine and grinding machine are examples of air motor usage. c) Air motors are categorized according to design: • Piston motors • Sliding-vane motors • Gear motors • Turbines (high flow)

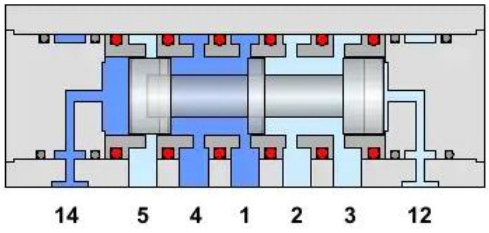
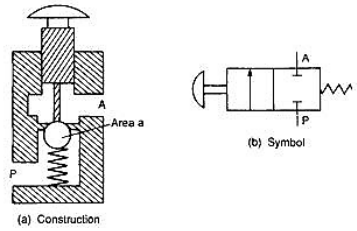
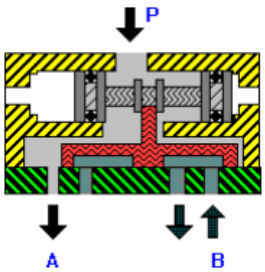
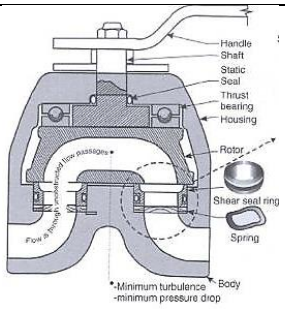
2.1.7 Special actuator

• Rod less Cylinder 	Rod connected to magnet or mechanical
• Slides (production and construction of robot) 	For use in manufacturing industries or robotic
• Hollow Rod Cylinder (pick and place) 	Vacuum distribution at end of cap
• Air Chuck (grippers) 	For use in robotic arm

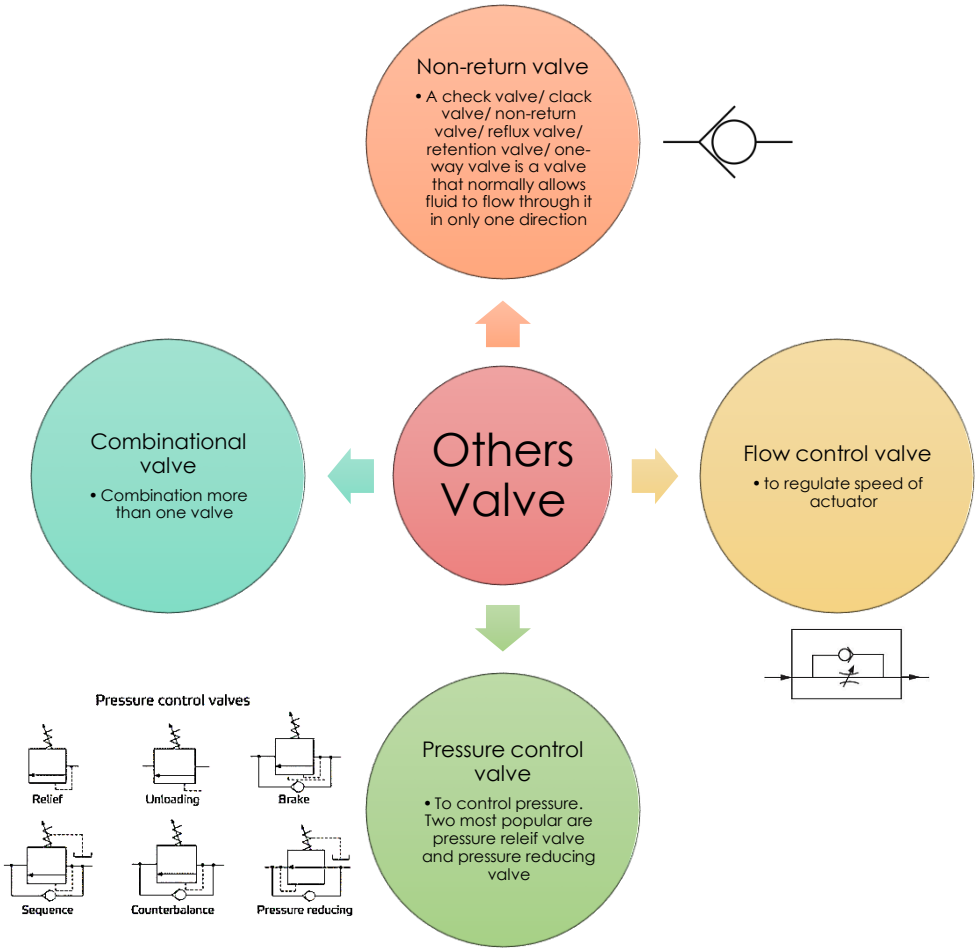
2.2 Directional control valve (DCV)

Directional Control Valves (DCVs) are one of the most fundamental parts of hydraulic and pneumatic systems. DCVs allow fluid flow (hydraulic oil, water or air) into different paths from one or more sources (Parr, 2013; Turner, 2014).

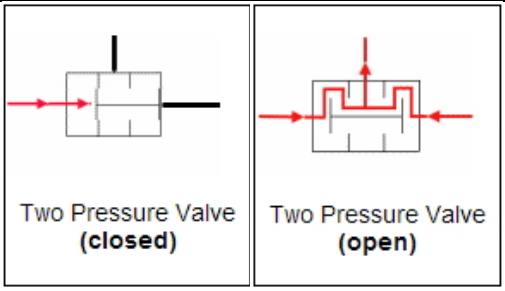


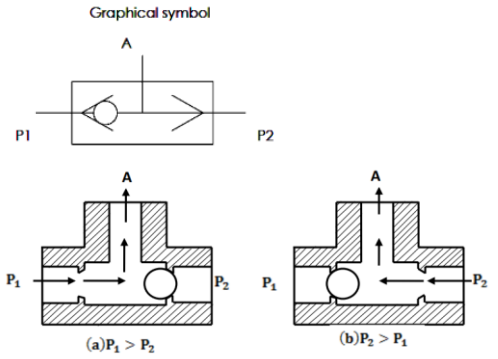
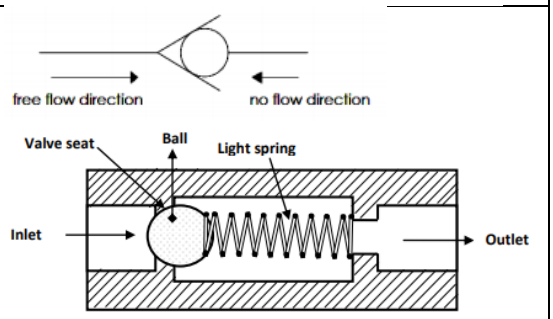
Spool valve	Poppet valve
	
Sliding valve	**Rotor valve**
	

2.2.1 Others valve component and symbol.



2.2.2 Type of non-return valve

Type	Explanation	Graphic explanation
Dual pressure	A two pressure valve requires two pressurised inputs to allow an output from itself. These valve types are commonly associated but not limited to safety circuits, for example a two push button operation system whereby an operator is required to use both hands to activate	

Type	Explanation	Graphic explanation
	two push buttons, this would ensure the operators hands are out of reach of any hazardous operations	
Shuttle valve	A shuttle valve allows two alternate flow sources to be connected in a one-branch circuit.	
Check valve	The simplest DCV is a check valve. A check valve allows flow in one direction but blocks the flow in the opposite direction. It is a two-way valve because it contains two ports.	

2.3 Sensor/ Actuated method

Actuation is the method of moving the valve element from one position to another. Also called **sensor**

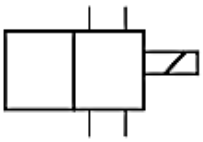
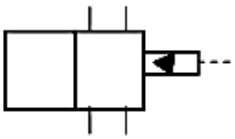
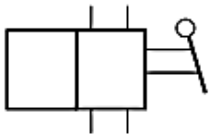
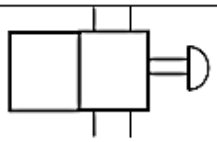
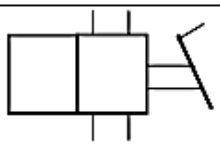
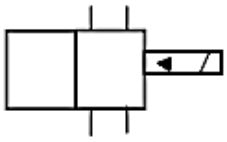
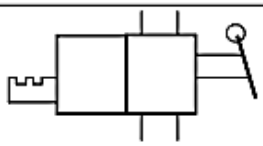
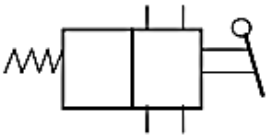
a. ***Manual*** - In manually operated DCVs, the spool is shifted manually by moving a handle pushing a button or stepping on a foot pedal. When the handle is not operated, the spool returns to its original position by means of a spring.

b. ***Mechanical*** - The spool is shifted by mechanical linkages such as cam and rollers

c. ***Pneumatic*** - A DCV can also be shifted by applying a pilot signal (either hydraulic or pneumatic) against a piston at either end of the valve spool. When pilot pressure is introduced, it pushes the piston to shift the spool

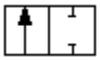
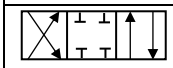
d. ***Electrical*** - When an electric coil or a solenoid is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push the spool of the valve

e. ***Combination*** - Several combinations of actuation are possible using these four basic methods

	Solenoid operated	Electrical
	Pilot operated	Pneumatic
	Manual operated	Manual
	Push button	Manual
	Foot operated	Manual
	Pilot-operated solenoid	Combination
	Two-position detent	Mechanical
	Spring return	Mechanical

2.4 Exercises

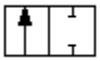
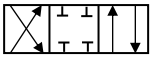
1. In the table below, name the types of valves based on the symbols given:

Symbol	Valves name
	
	
	
	

2. List FOUR (4) methods of moving a valve.
3. State FOUR (4) advantages of using a spool valve.
4. State FOUR (4) disadvantages of using a spool valve.

2.5 Exercise answers

1. In the table below, name the types of valves based on the symbols given

Simbol	Valve name
	valve 4/2
	valve 5/2
	valve 2/2
	valve 4/3

2. FOUR methods of moving the valve are: -
   i. Humans
   ii. Mechanical
   iii. Pneumatics
   iv. Electrical

3. FOUR benefits of using a spool valve are: -
   i. Simple construction.
   ii. The force used to move the spool is small.
   iii. Suitable for mass production.
   iv. The air flow through it is more when compared to other types of valves.

4. FOUR disadvantages of using a spool valve are:
   i. During the machining process, it requires a high precision machining process.
   ii. Slight air leakage may occur on the valve.
   iii. The use of unclean (dusty) air can damage the valve.
   iv. Lubrication is necessary on the sliding part.

2.6 Tutorials

1. State the purpose of cushioning and give THREE (3) main reasons for the need for cushioning.

2. List TWO (2) main functions of each of the following control valves:
a. Pressure control valve
b. Flow control valve
c. Directional control valve

3. Sketch the construction of a two -action type cylinder and label the 4 main components.

4. Give FIVE (5) advantages and TWO (2) disadvantages of poppet type pneumatic valves.

5. Give a description of the pressure control valve with relief.

2.7 Tutorial answers

1. The purpose of cushioning is to absorb kinetic energy, sound as well as protection to the internal components during the sudden stop movement of the piston.

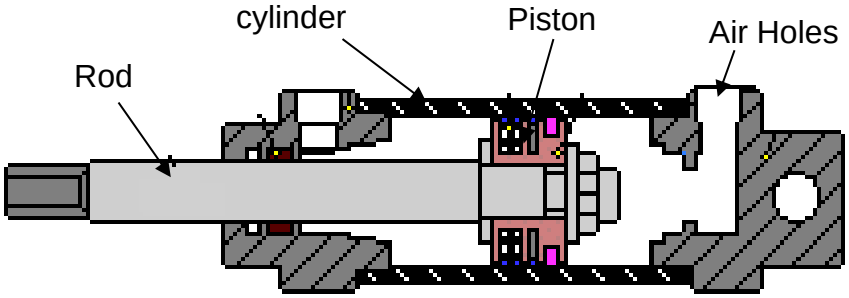
2. There are three main reasons for the need for cushioning:
   i. A shock occurs when the piston stops abruptly
   ii. Noise due to collision between piston and fixture
   iii. Protector to internal components such as pistons, rods and so on.

2. The two main functions of the control valve:
   a) Pressure control valve
      i. Reduces stress to work stress
      ii. Limit stress

   b) Volume control valve
      i. Limit the flow rate
      ii. Controls the speed of movement of the piston stroke.

   c) Directional control valve
      i. Power valve
      ii. Limit switch

3.



4(a). FIVE benefits of poppet valves:
   i. The valve can be opened and closed quickly as it requires only a small amount of movement.
   ii. The risk of operational failure is too small because dirt can be prevented from entering the valve.
   iii. No lubricant is required.
   iv. Easy to make.
   v. No leaks occurred.

4(b). TWO disadvantages of poppet valves:

i. The force to move increases if the pressure increases.

ii. If the connection on the valve needs to be added, the shape of the valve becomes more complex.

5. Pressure Reduction Valve with Relief Function

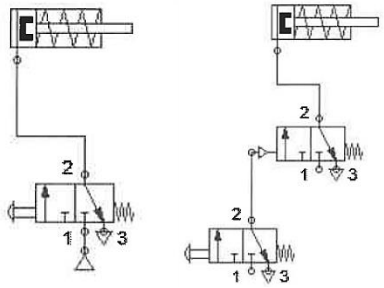
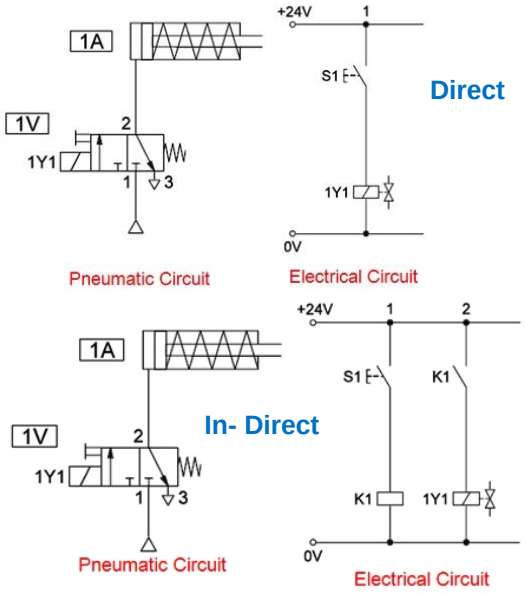
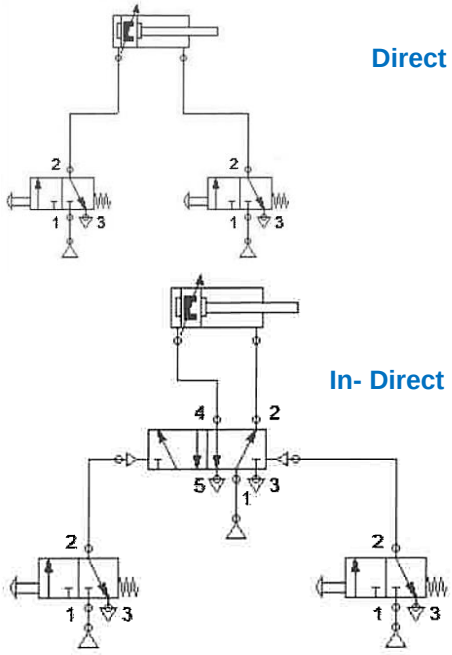
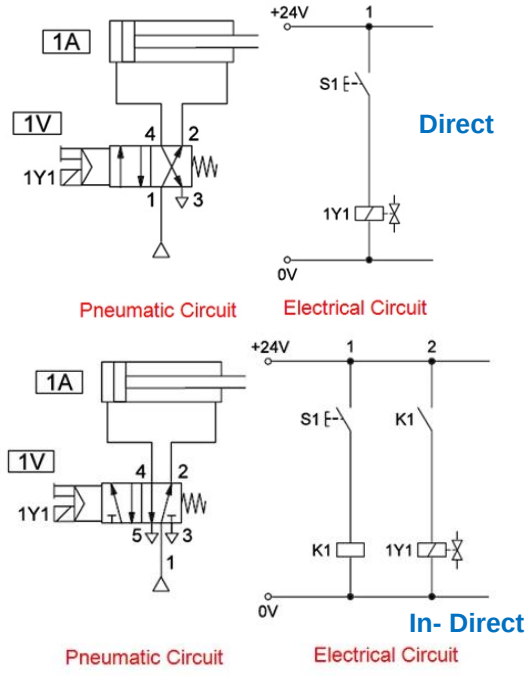
Most pressure relief valves are equipped with a secondary pressure relief function. The construction of this valve is, there is a small hole at the bottom of the diaphragm and an air passage hole at the bottom of the valve. Under normal circumstances the hole at the bottom of the diaphragm is always closed and the air passage space at the bottom of the valve is open to allow wind to pass through it. upward. This movement will cause the diaphragm stem to move upwards and close the flow hole at the bottom of the valve. Such a valve is suitable for use to control the flow of air to the cylinder.

3.0 PNEUMATICS CIRCUIT DESIGN

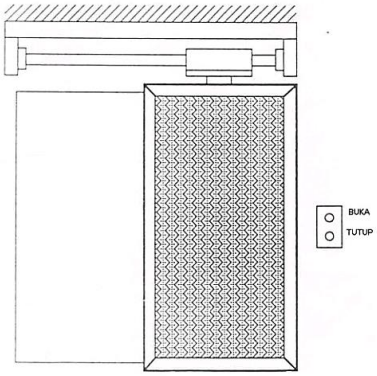
3.1 Movement of the cylinder

There are 2 types of pneumatic circuit (Stacey, 2012)

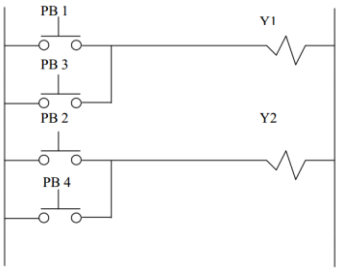
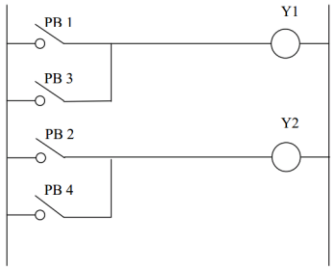
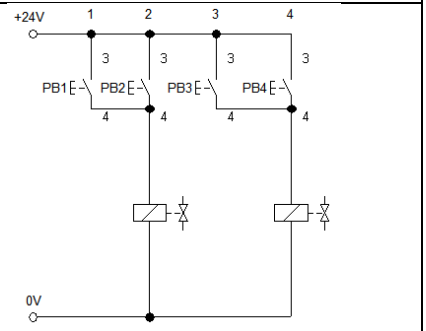
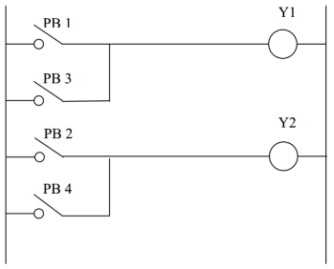
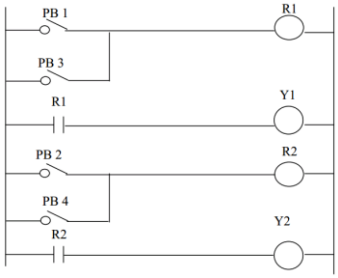
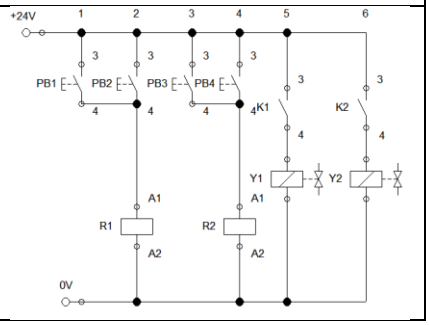
a) Direct
b) In-direct

Actuator	Pneumatic	Electro-pneumatic
Single Acting Cylinder		
Double Acting Cylinder		

In electro-pneumatic circuit, there are 3 types of circuits i.e.: physical circuit, ladder diagram and electric circuit.



Issue:
When one of the switches PB1 or PB2 is pressed then the current will activate the solenoid valve (Y1) and cause the door to open. If the PB3 or PB4 switch is pressed then the door will be closed again.

Method	physical circuit	ladder diagram	electrical circuit
Direct			
In-direct			

3.2 Sequence control for numerous cylinder

Multi cylinder pneumatics circuits can be designed in various methods. There is no universal circuit design method that suits all types of circuits. There are five common methods used by engineering and they are given below (Majumdar, 1996)

a. ***Classic method or Intuitive method***
b. ***Cascade method***
c. ***Step counter method***
d. Karnaugh–veitch method
e. Combinational circuit design

In this section, only the Classic method, Cascade method and Step counter method will be discussed

3.2.1 Multi cylinder sequence/ classic method

In this method, circuit design is done by use of general knowledge of pneumatics following the sequence through intuitively. In general, steps involve:

- Write down sequence and draw motion diagrams
- Draw in cylinders and control valves
- Complete circuits intuitively.

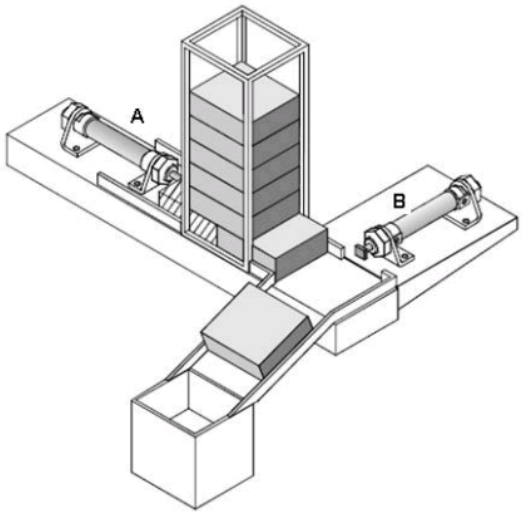


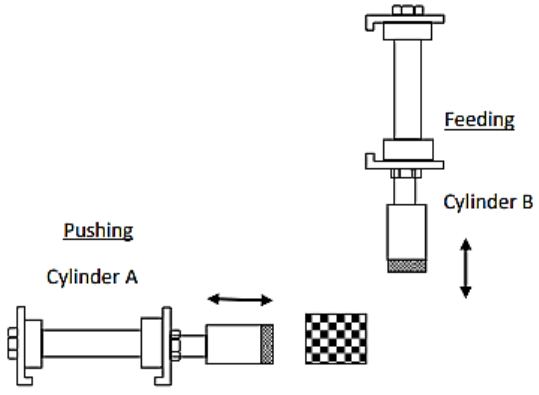
Figure 11: sequence operation

Two cylinders are used to transfer parts from a magazine onto a chute (Figure 9). When a push button is pressed, the first cylinder extends. Pushing the part from the magazine and positions it in preparation for transfer by the second cylinder onto the out feed chute. Once the part is transferred, the first cylinder retracts, followed by the second. Confirmation of all extended and retracted positions are required.

Step 1: Write the statement of the problem:

Let A be the first cylinder (Pushing) and B be second cylinder (feeding) as shown in the Figure 9. First cylinder A extends and brings under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only cylinder B has retracted fully.

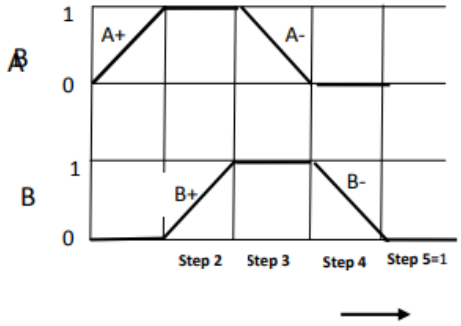
Step 2: Draw the positional layout.



Step3: Represent the control task using notational form

Cylinder A advancing step is designated as A+. Cylinder A retracting step is designated as A-.
Cylinder B advancing step is designated as B+. Cylinder B retracting step is designated as B.
Therefore, given sequence for clamping and stamping is A+B+A-B-.

Step 4 Draw the Displacement – time motion diagram

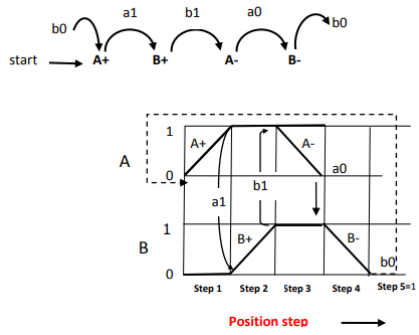


Step 5: Analyse and Draw Pneumatic circuit.

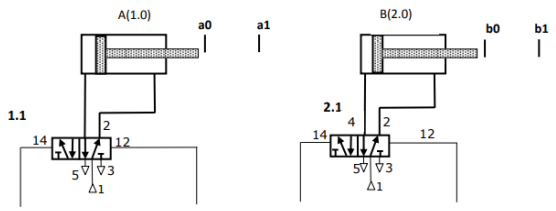
Step 5.1 Analyse input and output signals.

Input Signals	Output Signal
Cylinder A – Limit switch at home position a0 Limit switch at home position a1 Cylinder B - Limit switch at home position b0 Limit switch at home position b1	Forward motion of cylinder A (A+) Return motion of cylinder A (A-) Forward motion of cylinder B(B+) Return motion of cylinder B(B-)

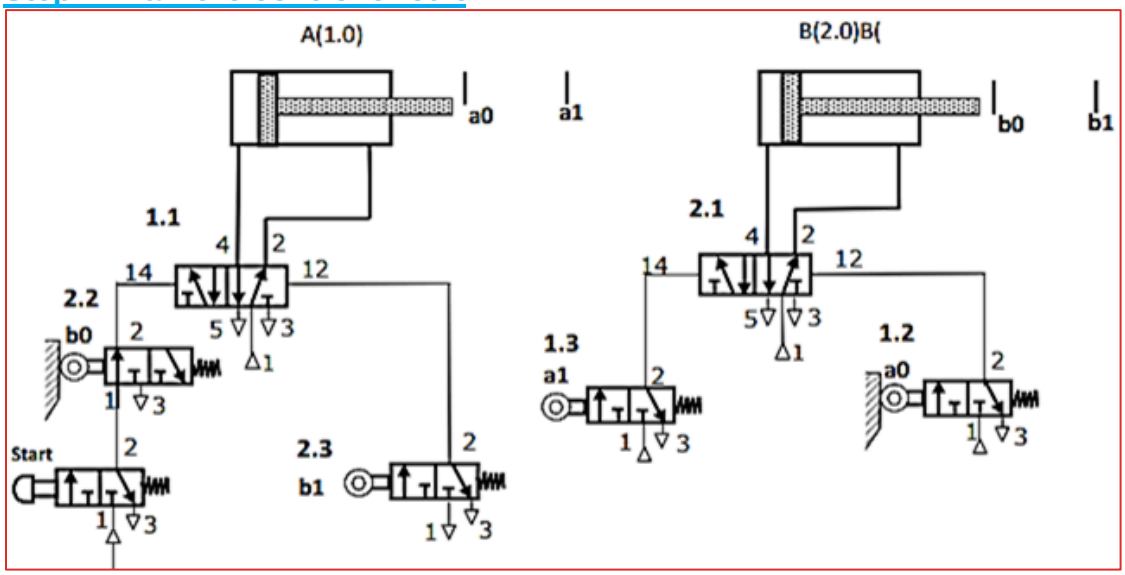
Step 6.2 Using the displacement time/step diagram link input signal and output signal.

	Usually start signal is also required along with b0 signal for obtaining A+ motion. 1. A+ action generates sensor signal a1, which is used for B+ motion 2. B+ action generates sensor signal b1, which is used for A- motion 3. A- action generates sensor signal a0, which is used for B- motion 4. B- action generates sensor signal b0, which is used for B- motion

Step 6 Draw the power circuit (Figure 1.18)

	i) Draw the cylinders A(1.0) and B(2.0). ii) Draw the DCVs 1.1 and 2.1 in unactuated conditions iii) Mark the limit switch positions for cylinders A(1.0) and B(2.0).

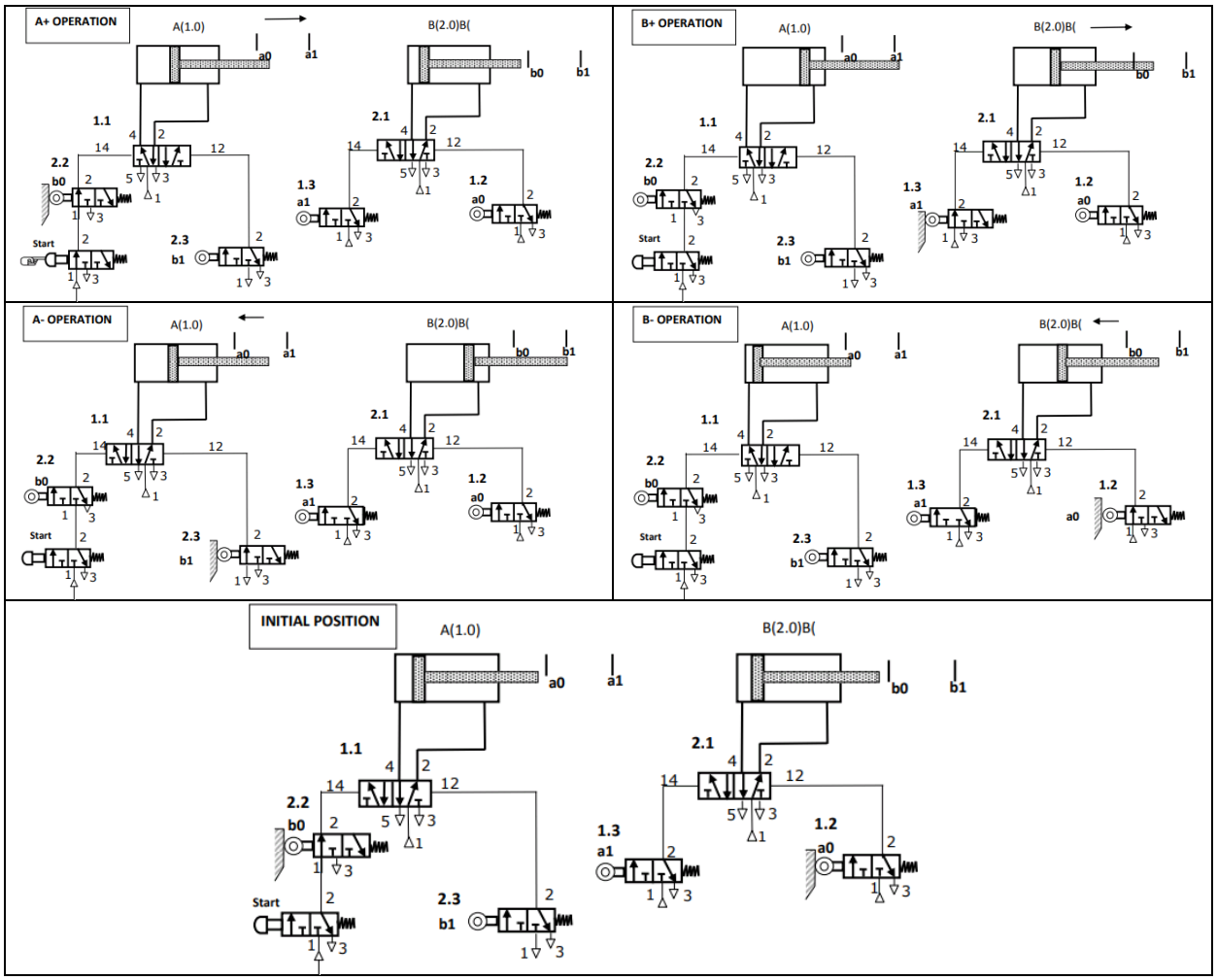
Step 7 Draw the control circuit



Step 8 Analysis of pneumatic circuit

1. When the start button is pressed, the signal appears at port 14 of valve 1.1 through limit switch signal b0.
2. Check for the presence of the signal at the other end (12) of valve 1.1. Notice that the signal is not present at port 12 of valve 1.1. (Because b1 is not pressed). There is no signal conflict and valve 1.1 is able to move. So, A advances to forward position.
3. When cylinder A fully extends, it generates a limit switch signal a1, which is applied to port 14 of the valve 2.1. Cylinder B advances to forward position.
4. Check for the presence of the signal at the other end (12) of valve 2.1. Signal is not present at port 12 of valve 2.1 (because a0 is not pressed, A is already in extended position now) and hence there is no signal conflict
5. Signal applied to port 14 of the valve 2.1 causes the shifting of DCV 2.1 and cylinder B extends
6. When cylinder B fully extends, it generates a limit switch signal b1, which is applied to port 12 of valve 1.1. Cylinder A returns and a0 is pressed. There is no signal conflict, as a0 and a1 are mutually exclusive signals.

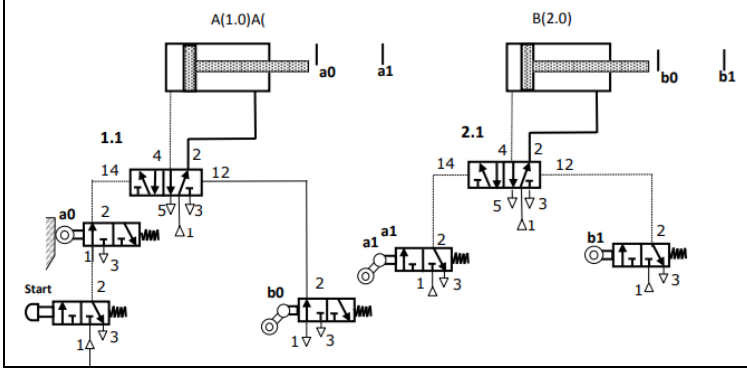
7. When the cylinder A is fully retracted, it generates a limit switch signal a0, which is applied to port 12 of the valve 2.1. Cylinder B retracts



3.2.2 Cascade method (*kaedah litar lata*)

A Bi-stable memory valve or reversing valve can be used to eliminate signal conflicts. Signal conflict is avoided by allowing the signal to be effective only at times when they are needed. Cascading method uses the revering valves (also known group changing valves) and Step counter method uses modular valves.

Example:

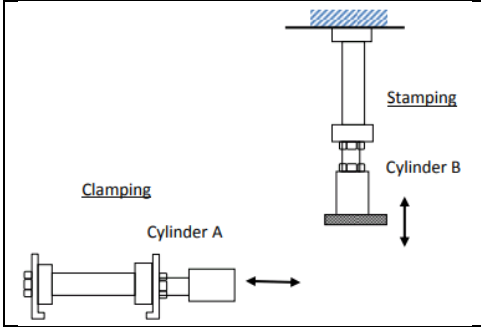
	Develop Pneumatic circuit for A+ B+ B- A- sequence. Avoid signal conflict using idle – return roller.

Answer:

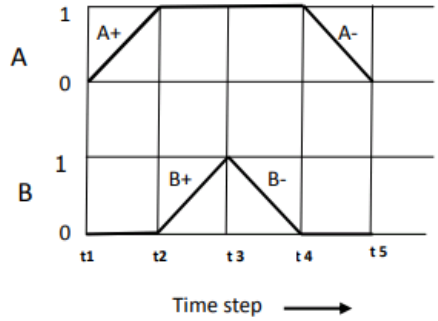
A Bi-stable memory valve or reversing valve can be used to eliminate signal conflicts. Signal conflict is avoided by allowing the signal to be effective only at times when they are needed. So, cascade method is possible

Step 1: Write the statement of the problem:

First cylinder A extends and brings under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only cylinder B has retracted fully.

Step 2: Draw the positional layout	Step3: Represent the control task using notational form
	Cylinder A advancing step is designated as A+ Cylinder A retracting step is designated as A- Cylinder B advancing step is designated as B+ Cylinder B retracting step is designated as B- Given sequence for clamping and stamping is A+B+ B- A-

Step 4 Draw the Displacement –time motion diagram



Step 5: Analyse and Draw Pneumatic circuit.

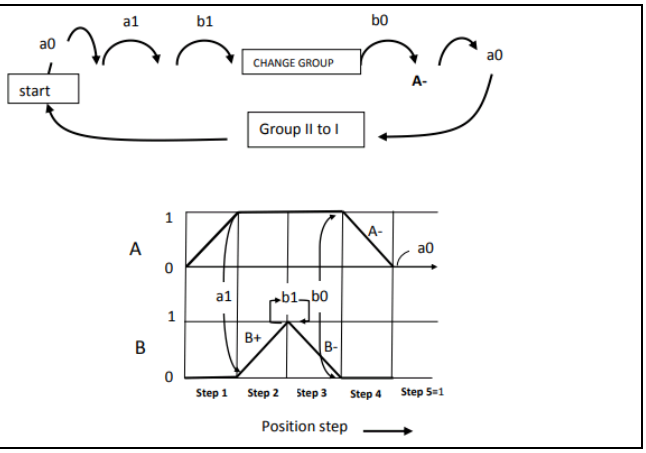
Step 5.1 Analyse input and output signals.

Input Signals	Output Signal
Cylinder A – Limit switch at home position a0 Limit switch at home position a1 Cylinder B - Limit switch at home position b0 Limit switch at home position b1	Forward motion of cylinder A (A+) Return motion of cylinder A (A-) Forward motion of cylinder B (B+) Return motion of cylinder B(B-)

Step 5.2 Using the displacement time/step diagram link input signal and output signal.

Usually start signal is also required along with a0 signal for obtaining A+ motion.

2. A+ action generates sensor signal a1, which is used for B+ motion
3. B+ action generates sensor signal b1, which is used group changing.
4. B- action generates sensor signal b0, which is used for A- motion
5. A- action generates sensor signal a0, which is used for group changing



Step 6 Draw the power circuit (Figure 1.32)

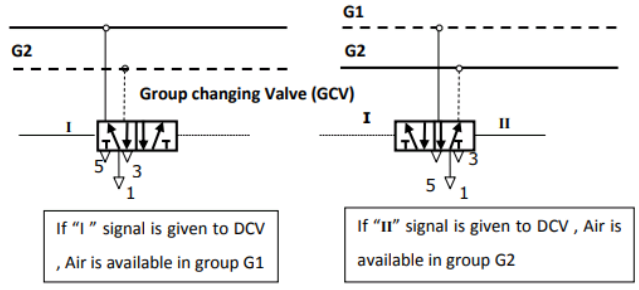
i) Divide the given circuits into groups. Grouping should be done such that there is no signal conflict. Do not put A+ and A- in the same group. Similarly, B+ and B- should not be put in the same group. In other word A+ and A- should belong to different group to avoid signal conflict.

In our example of A+ B+ B- A- we can group as

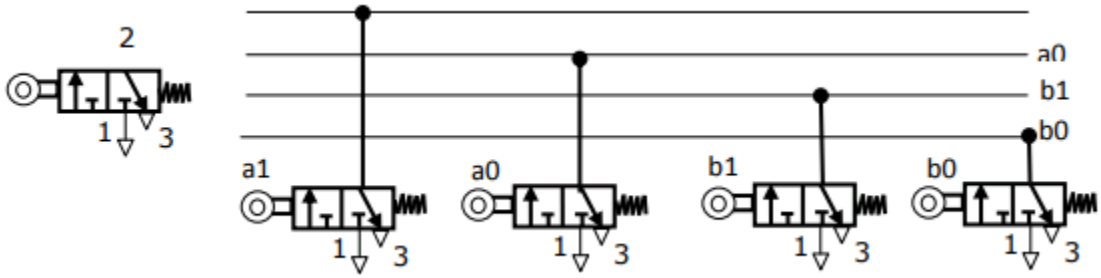
A+ B+	A- B-
Group 1	Group 2

ii) Choose the number of groups changing valve = no of groups -1. In this example, we have 2 groups so we need one group changing valve

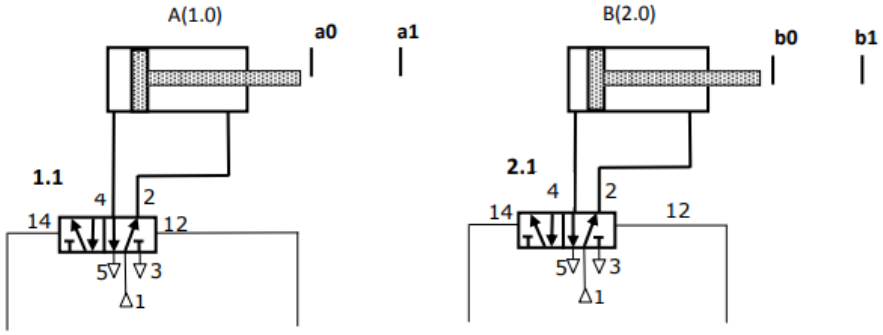
Connect the group changing valve as follows. From the figure it is clear that when the control signals I and II are applied to group changing valve, the air (power) supply changes from Group 1(G1) to Group 2 (G2).



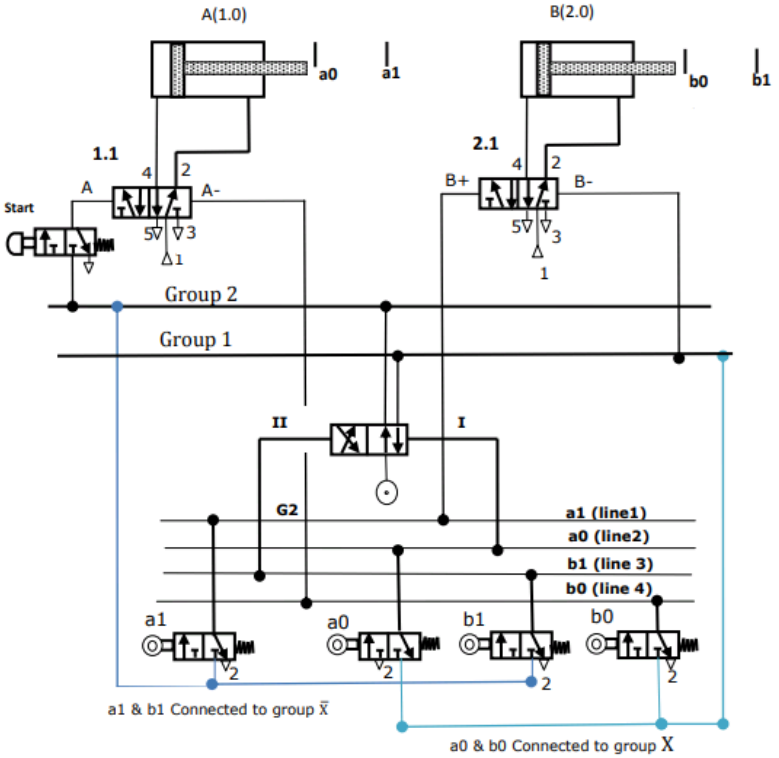
iii) Arrange the limit switch and start button as given below



iv) Draw the power circuit



Step 8 Draw the control circuit



Step 9 Analysis of pneumatic circuit

1. Assume that air is available in the line G2 to start with. (Say from last operation)
2. When the start button is pressed, Air supply from Group G2 is directed to line 2 through actuated limit switch a0. Now the air available in line 2, actuates the Group changing valve (GCV) to switch over to position 1. This switching of the GCV causes air supply to change from G2 to G1.
3. Now the air is available in line G1. The air supply from group G1 is directed to port 14 of the valve 1.1. As there is no possibility of signal conflict here, valve 1.1 switches over causing the A+ action.
4. Sensor a1 is actuated as the result of A+ action, allowing the air supply from the Group G1 to reach to line 1 through a1. Now the air available reaches port 14 of valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B+ action automatically.
5. Sensor b1 is actuated as result of B+ action, allowing the air supply in line 3. Air from line 3 allows the air to reach port 12 of Group changing valve (also called reversing valve). As a result, the Group changing valve switches over, causing the group supply to change from G1 to G2.
6. Now the air is available in G2. Air from G2 acts on port 12 of the Valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B- action automatically.
7. Sensor is actuated as the result of B- action. Now the air is available in line 4. Air from line 4 reach port 12 of the valve 1.1, As there is no possibility of signal conflict here, valve 2.1 switches over, causing A- action automatically.

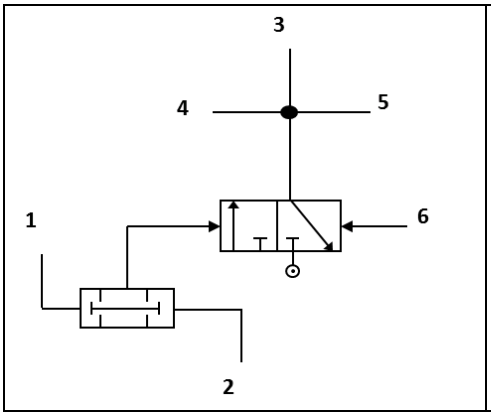
The cascade system provides a straight forward method of designing any sequential circuit.

Following are the important points to note:

a) Present – the system must be set to the last group for start-up
b) Pressure drops- Because the air supply is cascaded, a large circuit can suffer from more pressure drop.
c) Cost – Costly due to additional reversing valves and other hardware

3.2.3 Step counter method

- Designed to prevent the occurrence of opposite signals for two or more cylinders movement.
- The use of Counter Counting Module is very important in step counter circuit.
- Each Step Counting Modulator contains two valves, namely:
  - Pneumatic-injected 3/2 valve.
  - Valve AND
- To build a step counter circuit, you need a step counter module that consisting of a 3/2 valve and a AND valve. It has 6 connection points as shown below. WARNING! You must complete the step counter module as shown in figure below so that not to be confused with the construction of the step counter circuit.

<table>
<tr>
<td> 
</td>
<td>Based on the figure, the numbering system represents the wind direction for a circuit connection.
1. Signal from the previous sequence
2. Signal response from the last step
3. Signal to direction control valve
4. Push back the last 3/2 valve to the initial position
5. Setup signal for upcoming modules
6. 6. The signal push back the 3/2 valve to the initial position</td>
</tr>
</table>

Example

This circuit contains more than one cylinder, such as a cascade circuit, it has a sequence so that the cylinders move according to the specified rules that have been set. The example of sequences is as below:

A +, B +, B-, A-

If you are given the above mentioned sequence and you are required to build the circuit using the step counter method, you first need to make sure how many cylinders you need. Examples of the above sequences require 2 cylinders A and B. Second you need to ensure the number of movements to determine the number of step counter modules required. Examples of sequences above have 4 movements, so this circuit requires 4 step counter modules.

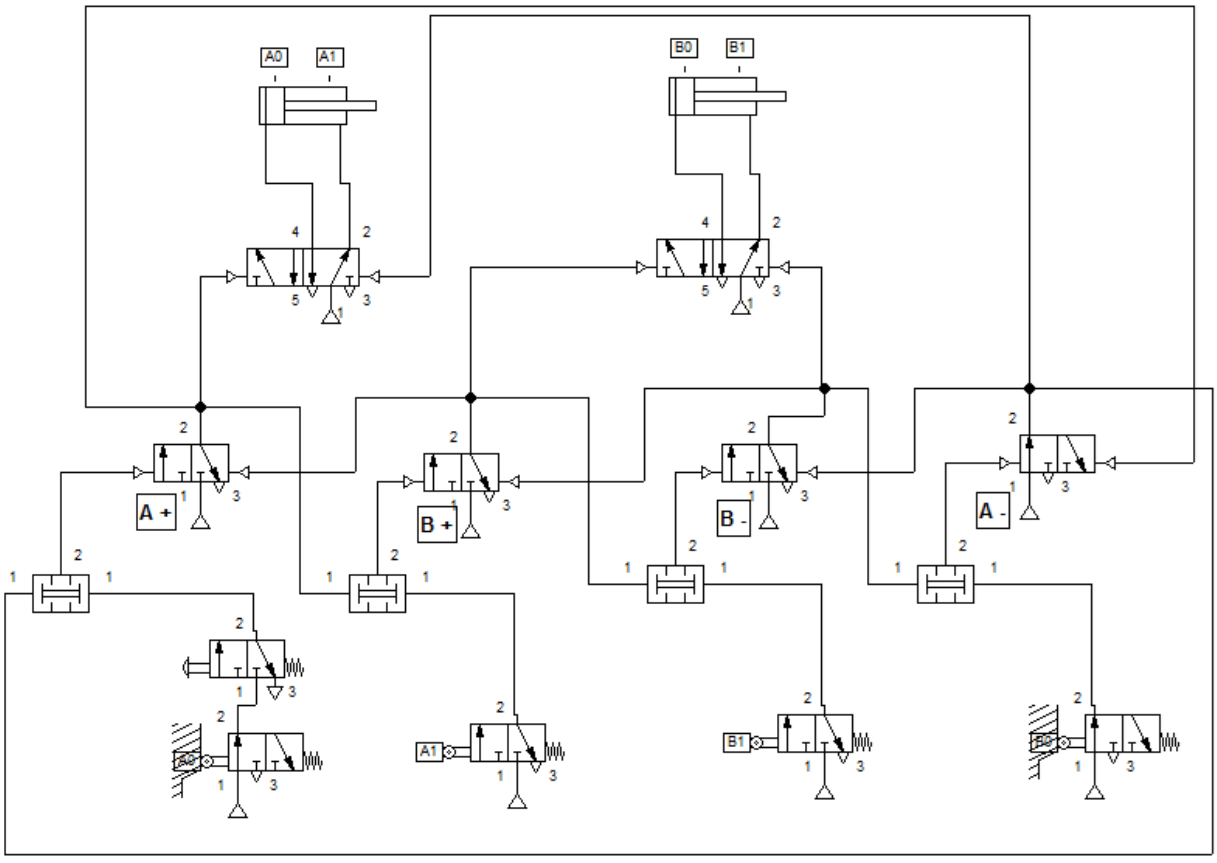
Ans:
To connect the circuit from the module to the power valve, you should follow the steps below.

Signal from step counter module (top)

1. The first module is connected to A1
2. The second module is connected to B1
3. The third module is connected to B0
4. The fourth module is connected to A0

Circuit connections from the step counter module to the valve (bottom)

1. A0 valve is connected to start valve, St and then connected to valve AND on module 1
2. A1 valve is connected to the valve AND on the second module
3. The B1 valve is connected to the valve AND on the third module
4. B0 valve is connected to valve AND on the fourth module



3.3 Exercises

Objective Type Questions

i. Design of circuits using intuitive method is _____ time consuming compared to step counter method.
ii. When hard ware costs are not important but circuit design time must be minimal, then _____ method of the circuit design is used.
iii. Where the hardware costs are paramount, then _____ circuit methods are used.
iv. When absolute fool proofing of circuits is required, _____ circuit methods are used.
v. _____ are used to sense the end position of cylinder movements

State True or False

i. We have to draw all valves in their de-actuated, unpressurised rest position as in electrical switching components
ii. In order to gain fully controlled sequence of all cylinders in a program, it is essential to install end position sensors at all movements end position.
iii. 4/2 or 5/2 double piloted valves are free from signal overlaps.
iv. Step counter method is absolutely free from signal conflicts
v. Time delay and pressure delay functions cannot be used in multicylinder circuit design

3.4 Exercise Answers

Fill in the Blanks

1. More
2. Step counter
3. logic
4. step counter
5. limit switches

State True or False

1. True
2. True
3. False
4. True
5. False

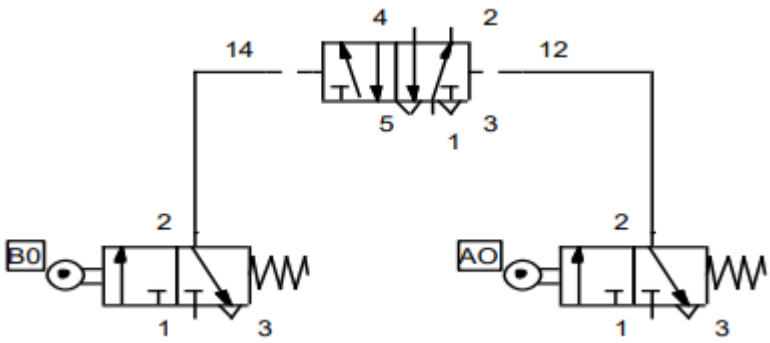
3.5 Tutorials

1. Explain how signal conflict occurs using an example
2. List four ways to overcome signal overlap or signal conflict
3. What are reversing valves?
4. List the conditions for cascading.
5. Draw the figure to show the group changing valves for 5 groups showing clearly input, output and reset signal

3.6 Tutorial Answers

1. Explain how signal conflict occurs using an example

Answer
Signal conflict can occur when simultaneously two active signals appear on both set and reset pilot ports of Final Control Valve. This is due to the required sequencing of cylinder. At the start, both signals AO and BO appear at the same time. This will not result in any change



2. List four ways to overcome signal overlap or signal conflict

Answer
To overcome this problem signal elimination techniques are used as listed below:
• Use of Idle return lever limit switches
• Use of N.O Timers
• Use of Cascading with the help of reversing valves
• Use of Stepper Sequencer modules

3. What are reversing valves?

Answer
Reversing Valves [Double piloted 5/2 way or 4/2 way]. These are signal processing valves which are used to change over from one signal to next signal. Depending on the presence of set or reset signal at the reversing valves, output change over takes place from port 4 to port 2 of the valve. There is no need to examine exact step where signal overlap occurs in the circuit.

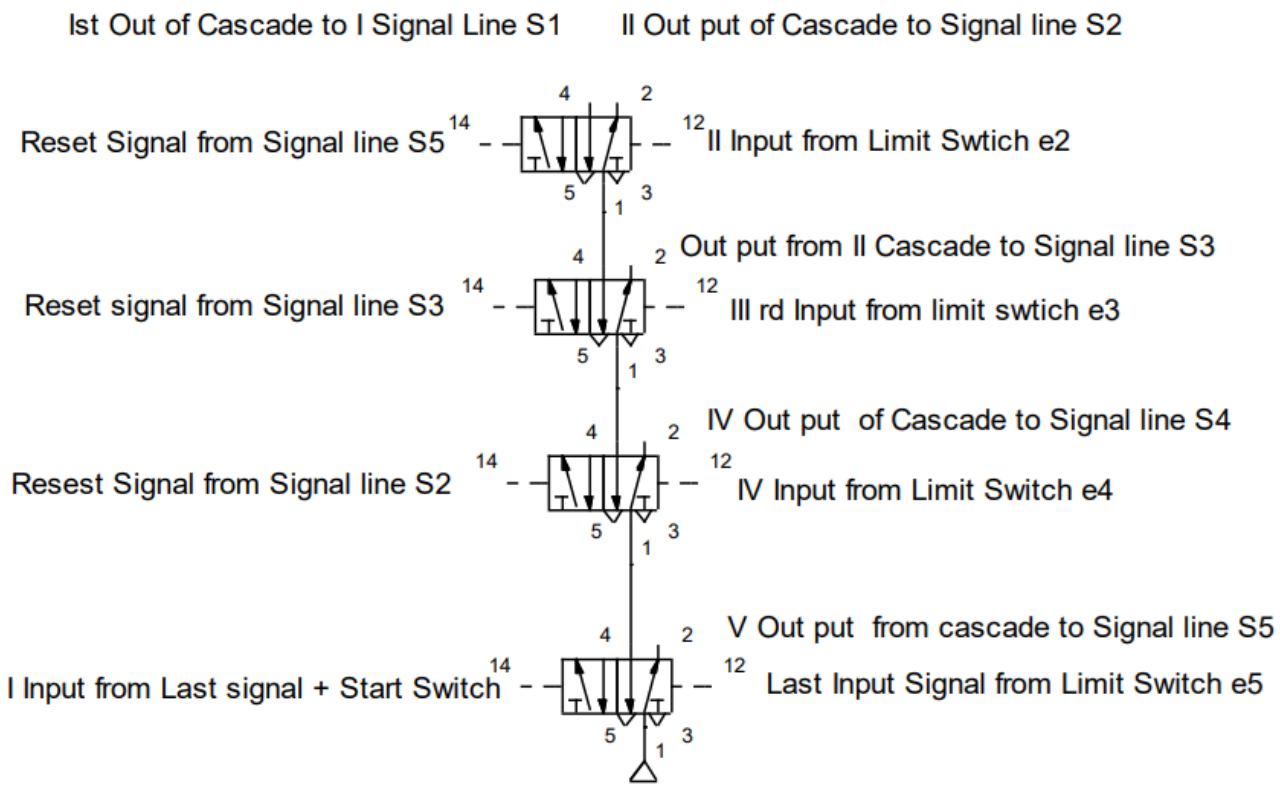
4. List the conditions for cascading

Answer
Conditions for Cascading are
- Number of signal inputs [from limit switches] must be equal to number of output signals [pilot signals to final control valves]

- Each input signal is assigned to a particular output signal
- It should be possible to store an output signal even when the corresponding input signal is no longer present
- Only one output signal may exist at any one point or it must be possible to eliminate any specific output signal
- The input signal should be effective in the same required sequence
- No. of reversing valves required are (n-1), where n is total number signals from limit switches or signal groups

5. Draw the figure to show the group changing valves for 5 groups showing clearly input, output and reset signal.

Answer



REFERENCES

Majumdar, S. R. (1996). *Pneumatic Systems: Principles and Maintenance*. McGraw-Hill. https://books.google.com.my/books?id=k6KLBs2L2AMC

Parr, A. (2013). *Hydraulics and Pneumatics: A technician's and engineer's guide*. Elsevier Science. https://books.google.com.my/books?id=Ws%5C_8BAAAQBAJ

Stacey, C. (2012). *Practical Pneumatics*. CRC Press. https://books.google.com.my/books?id=IN0rBgAAQBAJ

Turner, I. C. (2014). *Engineering Applications of Pneumatics and Hydraulics*. CRC Press. https://books.google.com.my/books?id=RCvKAgAAQBAJ