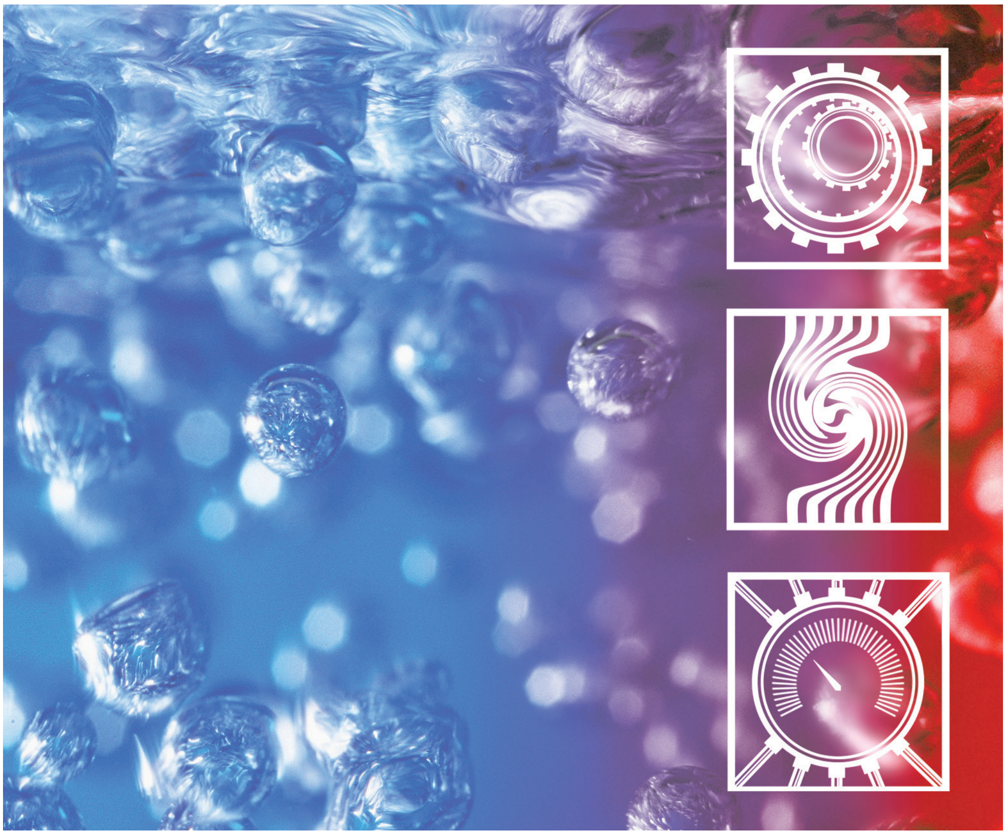
GOVERNMENT OF WESTERN AUSTRALIA

MAINTAIN PNEUMATIC SYSTEM COMPONENTS

MEM18018C

Learner's Guide

Engineering, Mechanical and Electrical



ENG972

MEM18018C

Maintain Pneumatic System Components

Learner's Guide

Training Sector Services
Telephone: 08 6212 9789
Email: sectorcapability.ip@dtwd.wa.gov.au
Website: www.dtwd.wa.gov.au

First published 2009
Second edition 2011
Updated May 2014

ISBN 978-1-74205-242-7

Published by and available from

WestOne Services

GOVERNMENT OF WESTERN AUSTRALIA

1 Prospect Place West Perth WA 6005
Tel: (08) 6212 9700 Fax: (08) 9227 8393
Email: sales@westone.wa.gov.au
Website: www.westone.wa.gov.au

Contents

Introduction

This resource is designed to help the student gain the knowledge and skills required to achieve the competency MEM18018C – *Maintain Pneumatic System Components*. This unit may be assessed on the job, off the job or through a combination of both. The skills covered by this unit can be demonstrated by an individual working alone or as part of a team. The unit consists of the two elements detailed in the table below. This unit can be clustered with MEM15004B – *Perform Inspection.*

MEM18018C – Maintain Pneumatic System Components **Elements and performance criteria**	
Element 1: **Check pneumatic system components**	1.1 System components are identified correctly. 1.2 The characteristics and operational function of each system component are understood. 1.3 The operational function of each component is inspected and tested. 1.4 Correct operation of each component is assessed against specifications.
Element 2: **Identify repair or replace faulty pneumatic system components**	2.1 Faulty system components are localised and malfunction is confirmed by inspection and testing using fluid power principles, procedures and safety requirements. 2.2 Faulty system components are dismantled and repaired to manufacturers'/site specifications. 2.3 Replacement parts are selected from manufacturers' catalogues according to required specifications. 2.4 System components are reassembled and verified for correct operation and tested against specifications. 2.5 Correct operation of the pneumatic system is confirmed to standard operating procedures. 2.6 Appropriate follow-up procedures are adopted according to standard operation procedures. 2.7 Where appropriate, service reports are completed using standard operating procedures.

Recommended resources

Rohner, P 1990, *Pneumatic Control for Industrial Automation,* revised edn, John Wiley & Sons, Brisbane.

Industrial Pneumatic Technology 1992, video series, Parker Hannifin Corporation, Cleveland, Ohio, USA.

Video recordings available from Parker Hannifin (Australia), 9 Carrington Road, Castle Hill, NSW 2154. (Phone: 02-9842-5150; Fax: 02-9842-5111.)

How to use this learner's guide

This resource is your guide to developing the underpinning knowledge and practical skills required to pass this unit of competency. It is divided into six sections. These can be worked through separately (in no particular order) or in sequence. However, Section 1 must be completed first, as it covers pneumatic safety and basic pneumatic principles – on which you will be assessed in the practical activities. Each section has an introduction to the topic area and directs you to undertake tasks, such as reading a section of a reference text or watching a video, before you do the practical activity for that section. Most sections also include review questions. These are designed to allow you to check your understanding of the topic area before you start the practical activity. Your lecturer will question you to assess your underpinning knowledge during the practical assessments.

How you will be assessed

Due to the range of available pneumatic equipment and systems in industry, the practical tasks you will need to undertake to meet the outcomes for this competency will be determined by your assessor. See your assessor for the practical task worksheets applicable to the equipment you are using. You must have a good understanding of the topic area prior to attempting these tasks and you must adhere to the appropriate manuals and precautions. Adherence to safety procedures, correctness of maintenance procedures and underpinning knowledge will also be assessed during these tasks. These assessments can be performed either on or off the job. Your assessor must be a qualified workplace assessor.

Section 1 – Pneumatic safety, principles, seals, conductors and symbols

Safe working with compressed air

Air is all around us and, in normal circumstances, causes little damage. Therefore, working with compressed air is largely a matter of common sense. There are many ways in which air can be used with perfect safety but, sometimes, it is used in ways, which are plainly unsafe.

It is easy to appreciate the dangers of working a machine without a proper guard. It is more difficult to realise the potentially dangerous force of air compressed for factory use. It can be tempting to use a compressed air line to clear a machine of swarf or to dust oneself down after a dirty job. But such practices and, worse still, general horseplay with compressed air, can cause serious injuries which may even result in death.

The greatest danger in dusting oneself down with compressed air lies in the risk of accidental injury to the eyes, ears, nostrils and rectum. If the air enters a scratch or puncture in the skin, however small, it can cause the limb or other affected part to swell alarmingly with severe pain. If it forces its way into the bloodstream, it can make its way into the small blood vessels of the brain, burst some of these and cause death. If used to dust a worker’s hair, compressed air may enter the body through minute punctures in the scalp or enter the ears and cause perforation of the ear drums. Clothing offers no protection.

A pressure strong enough to dust or clean is certainly strong enough to enter the skin and penetrate the body. Even a low pressure of 70–100 kPa (10–15 psi) has been known to cause serious injury. It has been estimated that a pressure of only 25 kPa (4 psi) would rupture the bowel.

Compressed air must be handled with care. Horseplay with the hose, however innocently it may begin, may end with disastrous consequences. It may be amusing to direct a jet of air at a fellow worker – but this has been known to produce severe internal injury resulting in death.

In addition to observing the safety factors mentioned above, before attempting to perform any testing or checks on a system or dismantling pneumatic components, you should ensure that working conditions are safe.

The following rules must be observed. They are essential for safety – and will be included in the competency assessment:

1. **Isolate** the compressor from external power supplies.
2. Use the 'tag system' to prevent other people from attempting to operate the compressor. This is most important if you are to leave the compressor unattended.
3. Provide support for pressure-held loads that could fall when pressure is removed through disconnection of the working unit.
4. Relieve the system pressure and vent the receiver. It is dangerous to remove a hose that contains air under pressure. Operate valves each way after the compressor has been switched off and the system is at rest, to bleed it of any line pressures.
5. When working with mobile compressors, ensure there is enough space in the workshop to conduct the maintenance procedure and that the compressor is positioned on level ground with the park brake applied.
6. Keep the work area tidy. Use drain trays under compressor equipment and, if any oil spillage occurs, clean it up immediately.
7. Never service a pneumatic system while the motor, compressor or actuators are operating – unless absolutely necessary.
8. To ensure control of the unit, keep the pneumatics in proper adjustment.
9. When washing parts, use a non-volatile cleaning solvent that is compatible with the pneumatic system.
10. Be sure all air-line connections are tight and lines are not damaged. Air escaping under pressure is noisy and can cause personal injury.

Activity 1 – Pneumatic safety

The following questions are designed to allow you to determine your understanding of pneumatic safety before you apply it to your practical activities.

When you have completed this activity, check your answers with your lecturer or workshop supervisor.

Question 1

List four safety factors that must be considered before working on a pneumatic system.

1. ____

2. ____

3. ____

4. ____

Question 2

Explain why compressed air can be fatal if directed onto the skin.

____

____

Question 3

Explain why compressed air should not be used to clean down machines.

____

____

____

Question 4

State the procedure for isolating a pneumatic machine prior to removing a component for servicing.

____

____

____

____

____

Introduction to pneumatics

Compressed air is one of the oldest forms of energy known to man and applied to enhance his work capability.

The deliberate utilisation of air as a medium can be traced back thousands of years.

The first man whom we know with certainty to have engaged himself with pneumatics – that is, the use of compressed air as a medium – was the Greek, Ktesibios. More than 2000 years ago, he built a compressed-air-impulse catapult. One of the first writings concerning the application of compressed air as energy dates back to the first century AD and describes devices which were driven by compressed air.

But it was not until the last century that the behaviour and fundamental characteristics of compressed air were researched systematically. Real, practical application of pneumatics in industrial production dates back only to about 1950.

There were, of course, some other earlier applications in areas such as the mining and construction industries and on the railways (compressed air brakes).

The true and worldwide introduction of pneumatics in industry, however, began only when the need for automation and rationalisation of operational sequences continued to increase. In spite of initial rejection, which in the main was due to ignorance and lack of education, the fields of application continued to expand.

Today, it is not possible to imagine modern factories being without compressed air. Compressed air equipment is an everyday feature in almost every factory, because it allows for the operation of many labour-saving devices and machines.

The following are a few typical examples of equipment that may be operated by compressed air:

Industrial hand tools	**Industrial machines** (for)
drills	assembling
grinders	food processing
screwdrivers	wood working
wrenches	die casting
polishers	transferring (conveyors)
chipping hammers	printing
jack hammers	spray painting
	mining
	packaging

What is a pneumatic machine?

A pneumatic system is a fluid power system which uses the energy of a prime mover (electric or diesel motor) to drive a compressor to produce air at a pressure higher than atmospheric.

Potential energy is stored within the compressed air, which is confined in the storage and distribution systems. When the air is used to operate a machine or tool, it will expand and release its energy. The power obtained from the tool is related to the pneumatic system's operating pressure and the air-flow rate.

Air-generation devices are often very expensive and it is important that the operator, or person in charge of the equipment, can recognise minor faults before a major breakdown occurs. They should also be able to carry out preventative maintenance checks on equipment. It may also be necessary for the operator to carry out minor repairs on pneumatic devices to avoid expensive parts becoming permanently damaged.

This competency unit provides theoretical and practical training for people responsible for the operation and maintenance of pneumatic equipment at the trade level.

Advantages of pneumatic systems

1. Air is readily available as a fluid medium and may be returned to the atmosphere after the energy is consumed.
2. Compressed air energy can be stored (in a receiver) so that large quantities of energy are available for instant use from a relatively small compressor.
3. Compressed air can be transported quickly and efficiently from the generation source to the point of application.
4. Generally, factories are equipped with a centralised compressor and distribution system and therefore it is easy to obtain an air-power energy source.
5. Air leaks in a pneumatic system, although wasteful and hence undesirable, constitute no serious safety hazard. Also, clean and dry compressed air will not contaminate a food processing line if leakage occurs.
6. Compressed air is easy to control and can be used to meet a wide variety of speed and power requirements.
7. Compared to their hydraulic counterparts, pneumatic components are comparatively easy to design and inexpensive to produce and service.
8. Compressed air equipment is not damaged by overloading (an air motor or linear actuator will not 'burn out' if it is stalled).
9. Compressed air equipment will operate at temperatures up to 150 °C.

Disadvantages of pneumatic systems

1. Raw air must be treated (cleaned, dried and lubricated) to protect the control valves and working elements.
2. Silencers must be used on all valve exhaust ports to minimise operating noise.
3. Pneumatic machines operate at comparatively low pressures and are confined to light-duty applications (400 to 700 kPa).
4. Due to the compressibility of air, it is difficult to achieve constant piston speeds from cylinders.
5. As air has low fluid resistance, it will escape from any gap or clearance passage. Therefore, most valves require seals to minimise spool or poppet leakage.

Recommended reading

Chapter 1, on 'Physical principles in pneumatics', in *Pneumatic Control for Industrial Automation* (Rohner).

Recommended viewing

Industrial Pneumatic Technology video series:
'Force Transmission Through a Fluid (Lessons 1 & 2)'.

Units of measurement used in pneumatics

You need to be familiar with certain metric units of measurement in order to understand pneumatic principles and what actually happens in the pneumatic systems you will be working on. The following are the basic parameters and units of measurement used in pneumatics and discussed in this resource:

- force – which is measured in Newtons (N)
- area – which is measured in square metres (m^2)
- pressure – which is measured in Pascals (Pa)
- flow – which is measured in cubic metres per minute (m^3/min)
- time – which is measured in seconds (s)
- volume – which is measured in cubic metres (m^3)
- length – which is measured in metres (m)
- velocity – which is measured in metres per second (m/s).

The table below shows equivalent values which are useful to know:

1 megapascal (MPa)	**kilopascals (kPa)**	**Pascals (Pa)**	**bar**
	1000	1 000 000	10

1 cubic metre (m^3)	**litres (L)**	**cubic centimetres (cm^3 or cc)**	**millilitres (mL)**
	1000	1 000 000	1 000 000

1 litre (L)	**cubic centimetres**	**millilitres**	**cubic decimetres (dm^3)**
	1000	1000	1

Table 1

Force

Force is an effort capable of causing a load to move or stopping it from moving. The unit of measurement is the *Newton*, a force which can be best appreciated by placing a mass of one kilogram in your hands, as illustrated below. The sensation you experience by supporting the weight is caused by a force of approximately 10 Newtons, which your hands have to provide to prevent the one kilogram mass from falling due to gravity (at an acceleration rate of 9.81 metres per second).

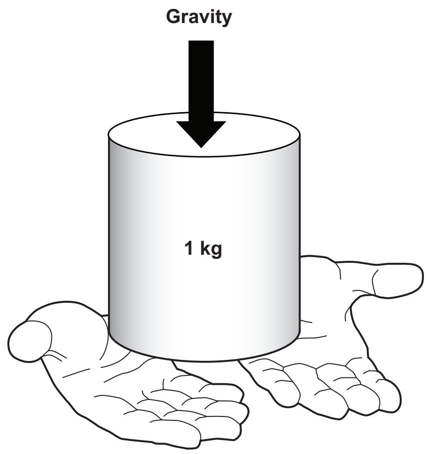
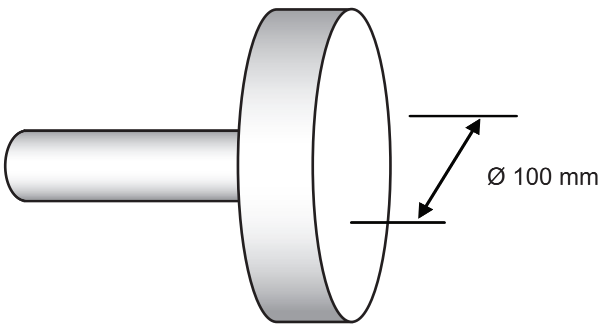


Figure 1: Force = mass x acceleration (in this case, acceleration due to gravity)

A force of one Newton is that which, if applied to a mass of one kilogram, would give it an acceleration rate of one metre per second.

Area

In the context of pneumatics, area is the surface over which the force is applied. Its unit of measurement is the *square metre*. The example below shows how to calculate the surface area of a pneumatic piston with a diameter of 100 mm (or 0.1 m).



$$\text{Area} = \frac{\pi \times d^2}{4}$$

$$\text{Area} = \frac{\pi \times 0.1^2}{6}$$

Note: We must convert millimetres to metres and so divide by 1000.
The value of π is approximately 3.14.

$$\text{Area} = \frac{\pi \times 0.01}{4}$$

$$\text{Area} = \frac{0.0314}{4}$$

$$\underline{\textbf{Area = 0.00785 m}^2}$$

Pressure

Pressure is produced when a force is applied over an area. The unit of measurement is the *Pascal*, which is equivalent to the force of one Newton applied over an area of one square metre.

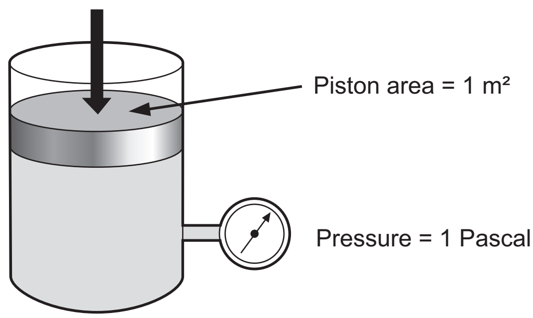
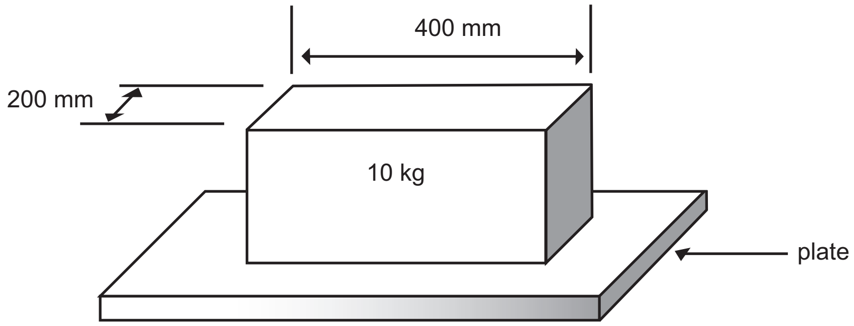


Figure 2: Pressure $= \dfrac{\text{Force}}{\text{area}}$

Example



The pressure applied by the 10-kilogram block on the plate illustrated above would be calculated as follows:

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

Note: The force exerted by the mass is found by multiplying the kilogram value by the acceleration due to gravity (9.81 m/s^2). We must also convert the block's dimensions to metres.

$$\text{Pressure} = \frac{10\text{ kg} \times 9.81\text{ m/s}^2}{0.2\text{ m} \times 0.4\text{ m}}$$

$$\text{Pressure} = \frac{98.1}{0.08}$$

$$\text{Pressure} = 1226.25 \text{ pascals (Pa)}$$

or **1.226 kPa**

One Pascal is actually a very small degree of pressure. At sea level, an atmospheric pressure of 101.3 kPa, or one atmosphere, is acting on your body. Other units of pressure commonly used are the:

kilopascal – 1 kPa is equal to 1000 Pascals (*kilo* means '× 1000')

bar – 1 bar is equal to 100 000 Pascals or 100 kPa

megapascal – 1 MPa is equal to 1 000 000 Pascals (*mega* means '× 1 000 000').

Note: The imperial unit of pressure (pounds per square inch or *psi*) is also used in some industries and some of you may be familiar with this. However, you are encouraged to work in SI (System International) metric units, as this is the Australian Standard.

To convert *psi* to *kPa*, multiply by 6.89476.
For example, 100 psi is equal to 689.476 kPa.

Because fluids have no shape of their own, they will take the shape of the container and, in a contained fluid, pressure is transmitted equally in all directions. We can use these principles to transmit power and multiply a force.

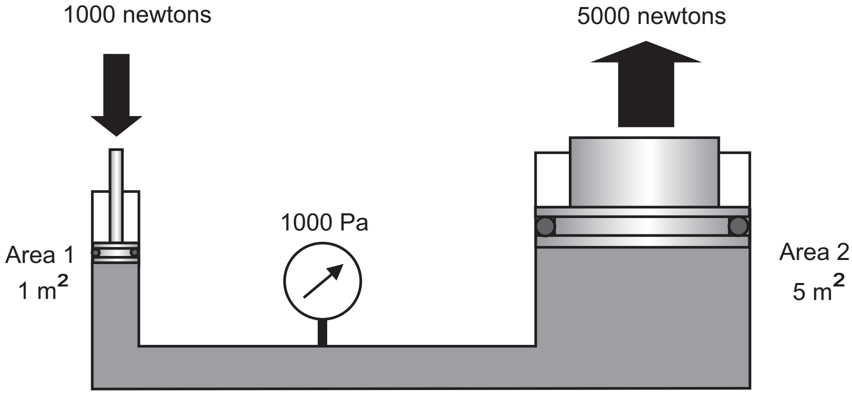


Figure 3: Force multiplication

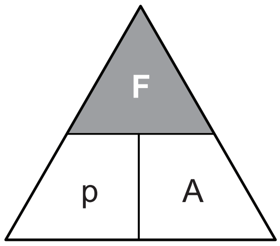
For example, as illustrated above, if a 1000 Newton force is applied to a piston with a surface area of one square metre, it will produce a pressure of 1000 Pascals, as demonstrated by the following calculation.

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{1000\,\text{N}}{1\,\text{m}^2} = 1000\ \text{Pa}$$

Pascal's laws of fluid pressures states that this same pressure is transmitted to all points of the container – that is, it acts equally in all directions and at right angles to any surface in contact with the fluid. Therefore, this pressure is also applied to the five-square-metre piston, achieving a five-fold multiplication of the original force, as shown in the calculation below.

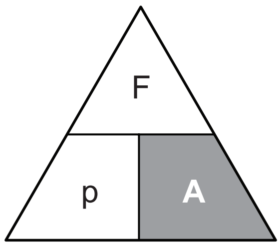
$$\text{Force} = \text{pressure} \times \text{area} = 1000\ \text{Pa} \times 5\,\text{m}^2 = 5000\ \text{N}$$

The relationships between force, pressure and area can easily be remembered by placing the parameters in a triangle in various ways, as shown below.

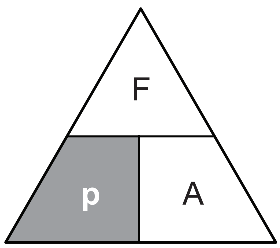


where: F = force
p = pressure
A = area

Looking at the triangle above, if we cover up the F, we can see that force = pressure × area.



Now from the triangle we can see that area = $\frac{\text{force}}{\text{pressure}}$



From this triangle we can see that pressure = $\frac{\text{force}}{\text{area}}$

Laws governing compressed air

Atmospheric pressure

The Earth's atmosphere is a sea of air which contains approximately 78 per cent nitrogen, 20 per cent oxygen, four per cent water vapour and smaller quantities of a number of other gases such as argon, carbon dioxide, neon, helium etc. This envelope of gas exerts a pressure on everything about us and its value is dependent upon its position above or below sea level. For example, at sea level the average atmospheric pressure is 101.3 kilopascals. However, on top of a mountain 1500 metres high, the pressure is 84 kilopascals and in Death Valley (America), which is 85 metres below sea level, the pressure is 105 kilopascals.

Therefore, the term 'atmospheric pressure' refers to the gravity force exerted per unit area by the mass of air above us. As we ascend, the pressure decreases because the mass of air above us decreases.

Gauge pressure

The term 'gauge pressure' refers to the pressure reading on gauges used to measure the pressure of gases in vessels such as oxygen cylinders, air receivers etc. These gauges are calibrated to show pressures above or below atmospheric pressure. A gauge reading of 300 kPa indicates that the pressure of a gas is really 300 kPa above normal atmospheric pressure.

Absolute pressure

Absolute pressure is the sum of atmospheric pressure and gauge pressure. In other words, absolute pressure is the total pressure above a perfect vacuum. Gauges that read absolute pressures usually have the letter 'A' inscribed on the gauge face.

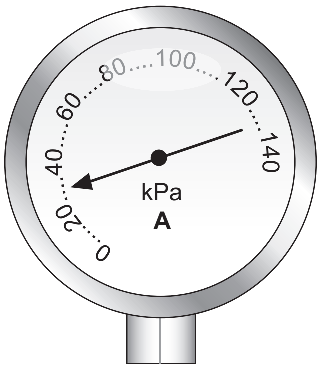


Figure 4: Absolute pressure = atmospheric pressure + gauge pressure

Note: Absolute pressure must be used for all calculations involving pressure, volume and temperature relationships.

Temperature scales

There are various systems for measuring temperature, the three major ones using the following units:

- degrees Celsius (Celsius or centigrade scale)
- degrees Fahrenheit (Fahrenheit scale)
- kelvins (Kelvin or absolute temperature scale). It should be noted that, when doing calculations for compressed air, this is the temperature scale that should be used.

Listed below are four useful formulas for converting temperatures between scales.

1. Celsius to Fahrenheit

$$°F = [\frac{9}{5} °C] + 32$$

2. Fahrenheit to Celsius

$$°C = \frac{5}{9} [°F - 32]$$

3. Celsius to Kelvin

$$K = °C + 273$$

4. Kelvin to Celsius

$$°C = K - 273$$

Boyle's Law

Robert Boyle (1627–1691), an Irish chemist and physicist, studied the compression and expansion of air and other gases and formulated what is now known as Boyle's Law. Boyle's Law states that 'if the temperature of a confined mass of gas is kept constant, the absolute pressure will vary inversely with the volume'. Boyle's Law may be written as:

$$V_1 P_1 = V_2 P_2$$

where:
P_1 = initial pressure in Pascals (absolute)
P_2 = final pressure in Pascals (absolute)
V_1 = initial volume in m^3
V_2 = final volume in m^3

A practical application of Boyle's Law is the gas-type pneumatic accumulator. The relationship between the absolute pressure and the volume of the gas-filled bladder obeys Boyle's Law – that is, product of absolute pressure and volume both before and after compression is the same.

Example – Boyle's Law

The gas volume of a pneumatic accumulator is 1 litre with a nitrogen pre-charge pressure of 8 MPa. Calculate the nitrogen pressure if the unit's gas volume is reduced to 0.5 litres when the accumulator is charged with oil.

$P_1 V_1 = P_2 V_2$ where:

$P_1 = 8000 + 101.3 = 8101.3$ kPa (absolute)

$V_1 = 1$ litre

$P_2 = ?$

$V_2 = 0.5$ litres

therefore $P_2 = \dfrac{8101.3 \text{ x } 1}{0.5} = 16\,202.3$ kPa (absolute)

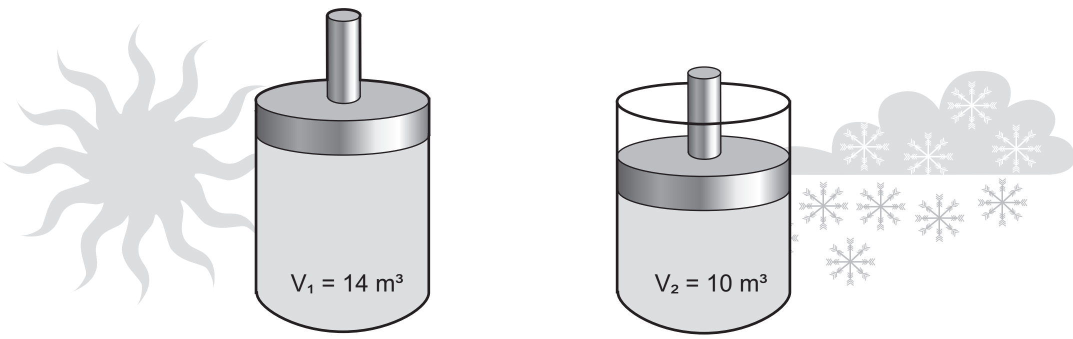
It is more common to express pressure in a vessel as gauge pressure.

gauge pressure $= 16\,202.3$ kPa $-$ 101.3 kPa

therefore $P_2 = 16\,101$ kPa

Charles' Law

Charles' Law states that, provided pressure remains constant, the volume of a gas changes in direct proportion to changes in absolute temperature – that is, as the temperature increases so does the volume. This principle is illustrated in the figure below.



$T_1 = 363$ K (90 °C) $T_2 = 287$ K (14 °C)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where: T_1 = initial temperature in kelvins (absolute temperature)

T_2 = final temperature in kelvins (absolute)

V_1 = initial volume in m^3

V_2 = final volume in m^3

Note: To solve a problem using Charles' Law, the absolute value for temperature (on the Kelvin scale) must be used and it is assumed that pressure remains constant.

The following example shows how a gas volume will increase with an increase in temperature.

Example – Charles' Law

A balloon with a gas volume of 0.8 m^3 at a temperature of 20 °C is heated to a temperature of 90 °C. What will be the balloon's gas volume if the pressure remains constant?

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

where: T_1 = initial temperature of 20 °C = 20 °C + 273 = 293 K

T_2 = final temperature of 90 °C = 90 + 273 = 363 K

V_1 = initial volume of 0.8 m^3

V_2 = final volume of ?

$$V_2 = \frac{V_1 \times T_2}{T_1}$$

$$V_2 = \frac{0.8 \times 363}{293}$$

$$V_2 = \frac{290.4}{293}$$

$$V_2 = 0.991 \text{ m}^3$$

The Combined Gas Law

Boyle's and Charles' Laws may be combined for any mass of air or other gas. In practice, when a given mass of air is compressed or allowed to expand, it undergoes a change in respect to its volume, its temperature and its pressure. To understand what is happening inside an air compressor, volume, temperature and pressure must all be considered. In such a situation, both Boyle's and Charles' Laws are inadequate and another law, known as the *Combined Gas Law,* is used and may be expressed as:

$$\frac{V_1\ P_1}{T_1} = \frac{V_2\ P_2}{T_2}$$

Note: For all calculations, temperature must be absolute and constant and all pressure values must be absolute.

Example – Combined Gas Law

Find the gauge pressure in a pneumatic cylinder if 2 m^3 of air – at 200 kPa (gauge) and 20 °C – is compressed to 0.8 m^3 with a temperature of 25 °C.

$V_1 = 2\ \text{m}^3$

$P_1 = 200 + 101.3 = 301.3$ kPa (absolute)

$T_1 = 20 + 273 = 293$ K

$V_2 = 0.8\ \text{m}^3$

$P_2 = ?$

$T_2 = 25 + 273 = 298$ K

$$\frac{V_1\ P_1}{T_1} = \frac{V_2\ P_2}{T_2}$$

therefore $P_2 = \dfrac{V_1\ P_1\ T_2}{V_2\ T_1}$

$$P_2 = \frac{2 \times 301.3 \times 298}{0.8 \times 293}$$

$$P_2 = \frac{179574.8}{234.4}$$

$P_2 = 766.1$ kPa (absolute)

$P_2 = 766.1 - 101.3$ (to get gauge pressure)

$P_2 = 664.8$ kPa (gauge)

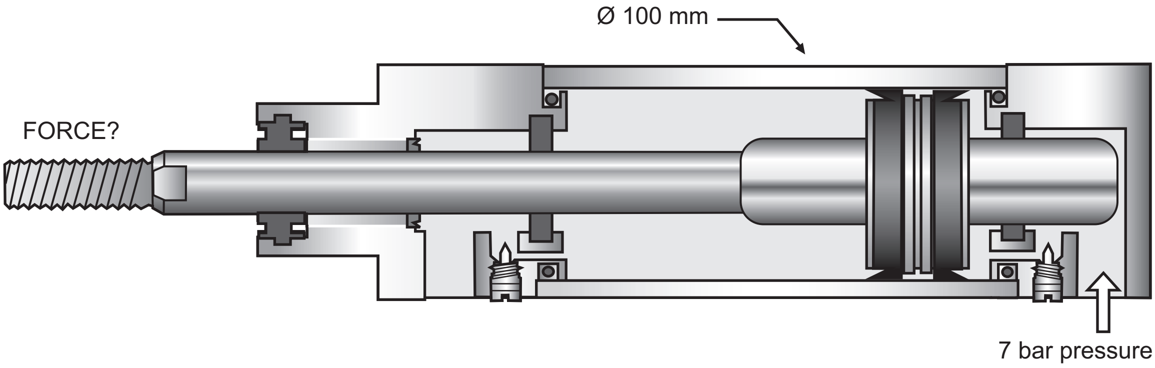
Pneumatic calculations

Pneumatics is an engineering science that deals with the conveyance of air through pipes and the application of the force exerted by moving or static air. Calculations relating to force, pressure, area, revolutions (per minute) and torque are a useful tool in establishing what to expect in performance from pneumatic components, especially if you are troubleshooting. You will use these calculations when you do the practical activities on pneumatic actuators in Section 2.

Sample calculations

Example 1 – Force

Find how much extension force can be exerted by a pneumatic cylinder if the applied system pressure is 7 bar and the actuator has a bore diameter of 100 mm.



From your readings on fluid power principles, you would understand that force is a product of pressure and area as shown below.

Force $=$ pressure $\times$ area.

$$\text{Force} = 7 \text{ bar} \times \frac{\pi \times 0.1^2}{4}$$ (remember to convert millimetres to metres.)

$$\text{Force} = 700\,000 \text{ Pa} \times \frac{\pi \times 0.1^2}{4}$$

Force $=$ 5497.78 newtons *or* ...

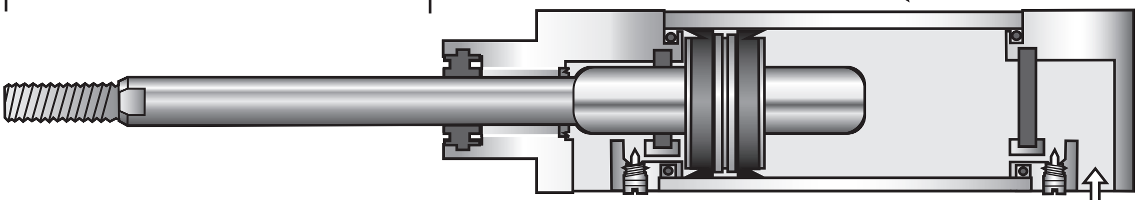
Force = 55 kN

This is the force (neglecting seal friction) that can be expected at the end of the cylinder rod when it extends. This force can be used for clamping, lifting or moving an object.

To find out what mass (in kilograms) the cylinder can move, simply divide the force by 9.81.

Example 2 – Time

Calculate the time that the cylinder (in Example 1) would be expected to take to extend if the air flow applied to the cylinder was 0.012 m^3 per minute and the cylinder had a 500 mm stroke.



$$\text{Time} = \frac{\text{volume of cylinder}}{\text{air flow}}$$

$$\text{Time} = \frac{\text{area} \times \text{stroke length}}{\text{air flow}}$$

$$\text{Time} = \frac{0.007854\ m^2 \times 0.5\ m}{0.012\ m^3/\text{min}}$$

Note: The area was calculated in Example 1.

$$\text{Time} = \frac{0.003927\ m^3}{0.012\ m^3/\text{min}}$$

Time = 0.327 minutes or 19.6 seconds

Note: These calculations do not take into account frictional losses and loss of volumetric efficiency caused through wear.

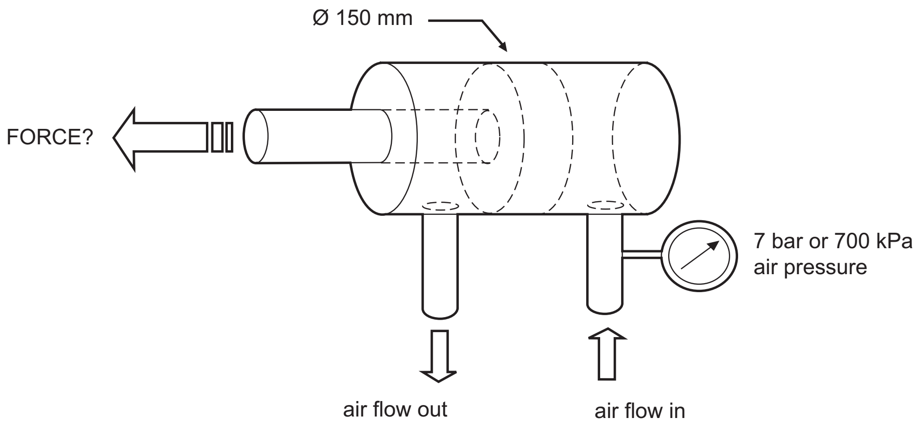
Activity 2 – Pneumatic principles

The following questions are designed to determine your understanding of pneumatic principles before you apply it to your practical activities in Section 2.

Show all your calculations.

Question 1

Calculate the force produced by the pneumatic cylinder shown below.



Question 2

Calculate the expected time for a Ø 80 mm cylinder with a 500 mm stroke to extend if the supplied air flow to the cylinder was 0.150 m^3/min.

Answers

1. 12.370 kN
2. 1.05 seconds.

Seals

Introduction

Excessive leakage in a pneumatic circuit reduces efficiency and results in power loss or creates a housekeeping problem or both. Here you will be introduced to the main types of seal and their applications. You will be required to identify, inspect and change seals in your practical tasks on compressors, actuators, pressure valves and directional control valves.

> ***Recommended reading***
>
> Pages 40–41, on 'Seals in pneumatic actuators', in *Pneumatic Control for Industrial Automation* (Rohner).

From your readings you would have learnt that pneumatic seals prevent leakage by closing off air passageways. They seal gaps to prevent fluid loss. Seals have two general types of application, static and dynamic, as illustrated below.

Static seals

A static seal is one that is compressed between two rigidly connected parts to seal the fluid passage and has a compression of approximately 25 per cent.

Dynamic seals

A dynamic seal is one that is installed between two parts that move relative to one another, for example on a rotating shaft or a sliding piston. The sealing principle requires the seal to be compressed slightly (approximately 10 per cent) during installation. The seal is allowed to flex in the sealing chamber and a mechanical or fluid pressure forces the seal to distort and block the passageway. These seals require lubrication during movement or sealing.

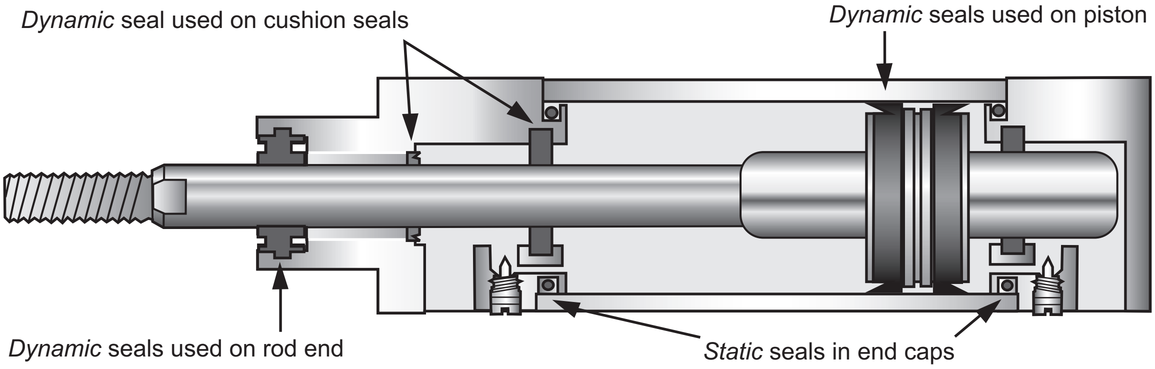


Figure 5: Dynamic and static seals

Fluid conductors

Pneumatic tube and hose sizing

Air flow through a tube or hose affects system performance and component life. The wrong size of hose or tube can result in the following problems:

- reduced pressure
- vibration
- slow actuator response
- turbulent flow
- high back pressure.

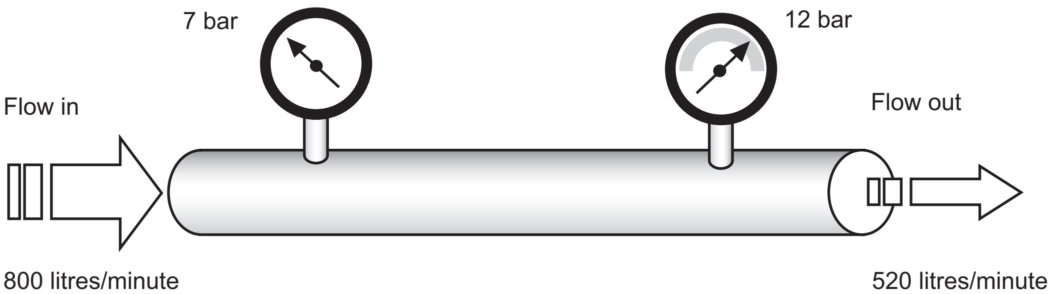


Figure 6: Effects of incorrect line sizing

Figure 6 illustrates how high back-pressure can be caused by incorrect line sizing. Not only is there an increase in back-pressure but also the flow rate is reduced, which would result in reduced actuator speed.

Piping, joints and fittings

The main types of pipe and other fluid conductors used in pneumatic systems are as follows.

Steel pipe – Inexpensive steel pipe is often used for pipe over 13 millimetres in diameter (half-inch) in fixed installations where the air is conducted along straight paths and use can be made of welding fittings. Small-diameter pipe is connected with threaded joints, whereas large-diameter pipes are connected with flange joints.

Copper and brass pipes – These are often used when corrosion resistance, heat resistance and high rigidity are required. Annealed copper pipes have good formability for bending. Brass pipes have higher strength than copper pipes but cannot be worked as easily because of their high strain-hardening nature.

Stainless steel pipes have poor formability and are primarily used where very large diameter pipes and straight pipes are necessary.

Nylon tube – This is suitable where small-diameter pneumatic tubing is necessary. This is because of its good corrosive resistance, high strength and medium hardness, despite its poor heat resistance. However, it cannot be used where it would undergo shock, since it is easily deformed by a strong force. Because its rigidity is very low, it cannot support a filter without additional support. There are metric and imperial diameter dimensions available, so combinations of tubing and joints must be examined carefully. In addition, soft polyurethane tube is usually used for tubing under six millimetres in diameter.

Rubber hose – Since rubber hose has good elasticity, it is the most suitable where an operator, using air-actuated tools, needs to pull the hose to different positions.

Screw-type joints – There are external threads on the ends of pipes and internal threads in the joint fittings. They are connected by screwing the pipe into the fitting. Generally a tapered thread is used for piping, which makes the joint seal sufficiently. Even though high-precision tapered threads can achieve a good seal, sealing cement or sealing tape is used for a much better connection.

Flange joints – A flange is formed or welded at the end of a pipe and is then connected to the flat surface of another flange. Flanges are usually welded to piping but sometimes brazing or bolts are used. Since flange joints can be easily connected or disconnected and sealed with a gasket, they are commonly used for piping around compressors and very large diameter pipes.

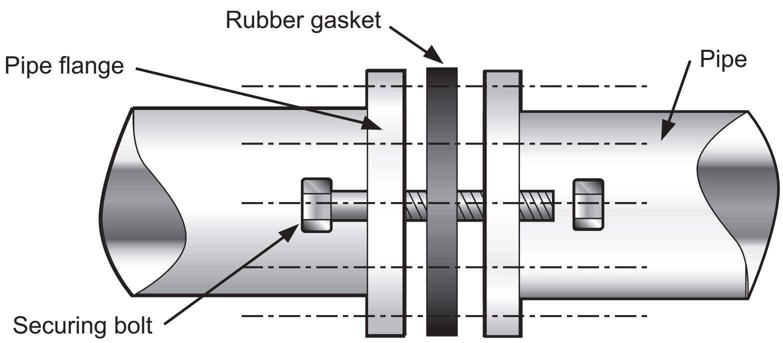


Figure 7: Flange joint

Flare fittings – By enlarging the end of a thin-walled steel pipe or copper tubing in a flare shape and pressing this part together with a flare fitting, sealing and connection is achieved.

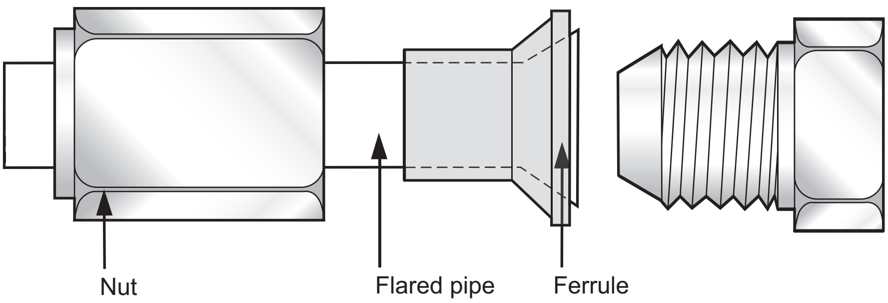


Figure 8: Flare fitting

Flareless fittings – There are three main types of flareless fitting. One type has an olive ferrule made from a soft material on the outside of the pipe. A nut presses the olive ferrule onto the pipe. Another type has a hard olive ferrule with teeth that grip the pipe. A third type has both characteristics. Flareless fittings are used for nylon tube and soft copper pipe. One example is illustrated below.

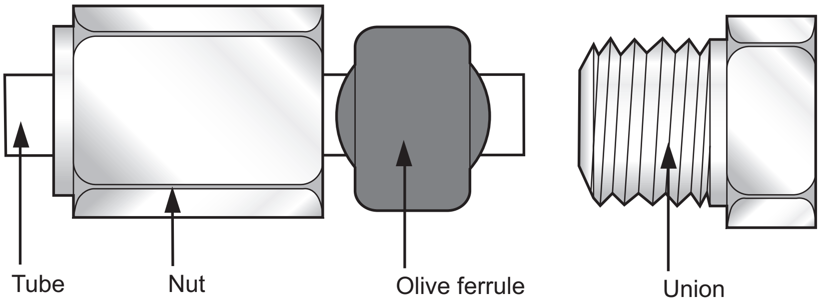


Figure 9: Flareless fitting

Recently, various kinds of 'one-touch' flareless fittings – that can be connected simply by inserting the tubing – have been developed to improve workability. Their use is rapidly increasing.

Figure 10 shows an example. When a tube is inserted, a concentric ring grips it. The tube can be easily pulled out after releasing the grip of the concentric ring by pushing a release button.

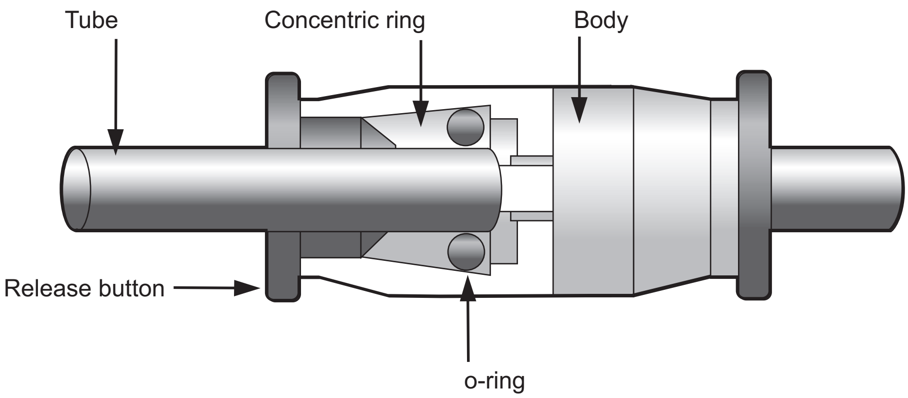


Figure 10: Flareless fitting (one-touch)

Joining rubber hose – Generally, a joiner shaped as illustrated below is inserted into the rubber hose. This type of fitting is called a hose barb. A hose clamp ring is used for tightening from the outside of the hose to seal the joint.

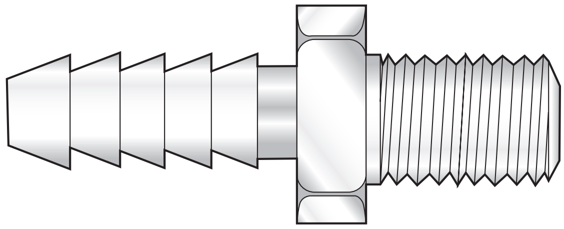


Figure 11: Hose barb

Considerations in setting up piping between pneumatic equipment

Direct piping using steel pipe

1. A precisely tapered thread on pipe should be cut by a special threading machine. The inside of the pipe should be flushed completely by using compressed air.
2. When the threaded portion needs to be wound with one or two layers of sealing tape, one or two pitches of the thread must be left without any sealing tape. Sealing tape is pressed onto the thread by using your fingertips. If the sealing tape is wound to the end of the thread, part of the tape will be cut off when the pipe is screwed into a fitting – which can lead to failure of equipment.
3. An alternative to thread tape is thread sealant. A proper amount of liquid sealing cement must be carefully applied on the threaded portion of the pipe, leaving one or two pitches of thread without any cement. It should not be applied on the internal threads of equipment, because this might lead to malfunction of equipment sliding parts due to excess sealing cement entering the system.
4. Where convenience of maintenance, such as inspection and exchange of equipment is a factor, union joints should be used. This will save time by allowing localised disconnection instead of disconnecting all the pipes.
5. Sealing is relatively simple, since pneumatic pressure is very low compared with hydraulic pressure. Since pneumatic equipment is often made from aluminium and die castings, excessive force may cause cracks in threaded portions. Therefore, they should not be tightened with excessive force. Extra care must be taken where sealing tape is used, because the torque required to tighten the joint will be greatly reduced due to the low-friction properties of the tape.

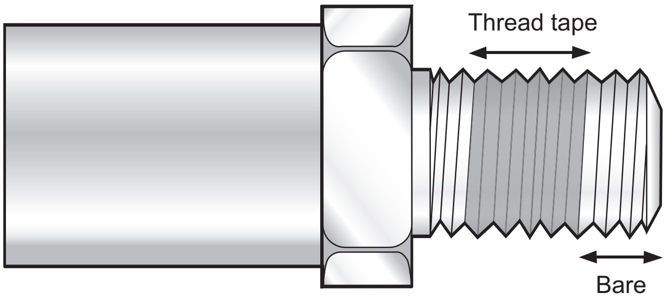


Figure 12: Using thread tape

Piping by using fittings

Nylon and soft copper tube are connected by the use of fittings. When connecting these fittings, the sealing methods mentioned in paragraphs 2, 3 and 5 above can be applied.

Tubing should be cut with a proper tube cutter in such a way that the end surface of tube is perpendicular to the axial direction. If tubing is cut with pliers, nippers or scissors (metal saw for copper tube), the tube end will be distorted or chips will be left in the tubing. This will cause sealing failure and malfunction of equipment. When using one-touch fittings, the catalogue and user's manual should be consulted. The tubing should be inserted correctly – otherwise problems such as sealing failure or difficulty of connection and disconnection will occur. Remember that the tubing should be flushed before being connected to equipment.

> ***Recommended reading***
>
> Chapter 15, pages 237–38, on 'Choice of pipe material', and Chapter 16, pages 243–44, on 'Tubing and air line fittings', in *Pneumatic Control for Industrial Automation* (Rohner).

Activity 3 – Fluid conductors and seals

The following questions are designed to allow you to check your understanding of fluid conductors, joints, fittings and seals. Answer by ticking one box among the choices provided for each.

Question 1

The type of fitting used to connect a rubber hose would be a:

☐ a) quick-connect coupling

☐ b) barbed fitting

☐ c) flared fitting

☐ d) flareless fitting.

Question 2

The use of steel pipe is desirable:

☐ a) where the fluid is conducted along straight paths

☐ b) because of its low cost

☐ c) where use can be made of welded fittings

☐ d) all of the above.

Question 3

A rod wiper seal:

☐ a) prevents air from leaking from the cylinder

☐ b) prevents dirt from entering the cylinder

☐ c) is a static seal

☐ d) all of the above.

Question 4

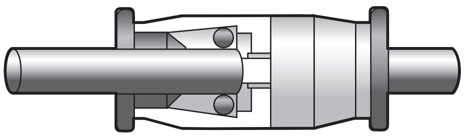
Identify the type of pneumatic fitting illustrated.

☐ a) push-in clamped

☐ b) tapered barb

☐ c) push-in flared

☐ d) one-touch flareless.



Question 5

Dynamic seals are used:

☐ a) to seal stationary components

☐ b) to seal between moving components

☐ c) only in high-temperature areas

☐ d) on cylinder cap ends.

Question 6

When matching pneumatic fittings and components, the pneumatic technician will need to check:

☐ a) type of thread

☐ b) angle of any sealing face (seat angle)

☐ c) pressure rating

☐ d) all of the above.

Question 7

When the air pressure in a pneumatic hose increases, the diameter of the hose:

☐ a) increases and length decreases

☐ b) decreases and length increases

☐ c) increases and length increases

☐ d) decreases and length decreases.

Question 8

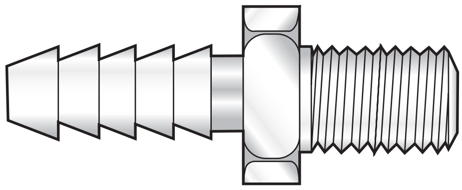
The pneumatic fitting illustrated is used to connect which of the following?

☐ a) steel pipes

☐ b) copper tubes

☐ c) rubber hoses

☐ d) stainless steel tubes.



Question 9

Bends, restrictions and the use of excess fittings in air pipework will cause:

☐ a) turbulent flow

☐ b) laminar flow

☐ c) pressure drops

☐ d) *a)* and *c)*.

Answers

1. b	2. d	3. b
4. d	5. b	6. d
7. a	8. c	9. d

Symbols for pneumatic components

The installation, modification and troubleshooting of a pneumatic system require an understanding of pneumatic circuit drawings. Before working on a pneumatic system, you should obtain and trace through the circuit drawing to ensure that any potential hazards are identified so precautions can be taken to avoid personal injury and damage to equipment. It is therefore necessary for you to both be capable of identifying components and know their function in a circuit.

> ***Recommended reading***
>
> Page 246, on 'Industrial pneumatic symbols', in *Pneumatic Control for Industrial Automation* (Rohner).

Circuit symbols

With today's industrial applications of fluid power technology, the serviceman may encounter pneumatic machines ranging from the simplest hand drill to programmable industrial robots. For the serviceman to diagnose and locate a fault in a pneumatic system, he must know the relationship between the pneumatic components and the fluid flow when the system is in all possible operating positions.

To understand the system effectively under any operating conditions, the serviceman requires certain aids; the most important of these is a diagram of the pneumatic circuit.

Pneumatic symbols are used throughout the world as the basis of a shorthand form of pictorial circuit drawing. This use of particular geometric forms allows the circuit designer to convey a standardised and clear message to any person, regardless of any language differences. The various symbols indicate each component's function, its connected pipework and its relationship to the system's operation.

Knowledge of these simplified pneumatic symbols will allow you to read, translate and understand circuit diagrams.

A 'symbol' consists of a geometric shape – containing a number of lines, letters and/or abbreviations – that identifies the purpose or method of operation of the component represented.

Symbol rules

The first step in circuit analysis is to remember the following four rules of symbol use:

1. A pneumatic symbol shows the fluid connection ports, flow paths and the function of the component represented. The symbol does not show the actual construction of valves – that is, whether they are of the direct or pilot-operated type. Further, a valve's flow or pressure settings are not supplied on a circuit diagram.
2. A symbol does not indicate the physical location of the connection ports or the position of control elements on the actual component.
3. With certain obvious exceptions, the reservoir and accumulator symbols may be rotated or reversed without altering their meaning.
4. Arrows are used within the symbol envelope to indicate the direction of air flow through the component represented. Double-ended arrows are used to indicate two-way directional flow.

Lines

A pneumatic circuit consists of a number of individual components connected by a series of fluid conductors.

In a drawing of a circuit, the lines between and around the component symbols may be classified into four general types.

Solid lines between circuit components represent working lines. The working line could be a pipe, tube or hose and conveys either high or low-pressure fluid.

A **long-dash line** connecting a component to the major fluid conductor represents a pilot line. This pilot line is used for pressure sensing and has a much smaller fluid-carrying capacity than normal working lines.

A **long-and-short-dash chain line**, or component-enclosure line, is drawn in a rectangular form around a group of symbols to indicate the limits of the components contained in one body assembly.

Circles

Circles are widely used in pneumatic circuit drawings. Size is one factor used to signify different components.

Large circles are used to indicate motors and compressors. A triangle within the circle is used to indicate whether the unit is a compressor (air pump) – with the flow leaving the component – or a motor (flow entering the component). A prime mover that drives a compressor (electric motor) has the letter 'M' in the circle. The symbols for these three components are illustrated below.

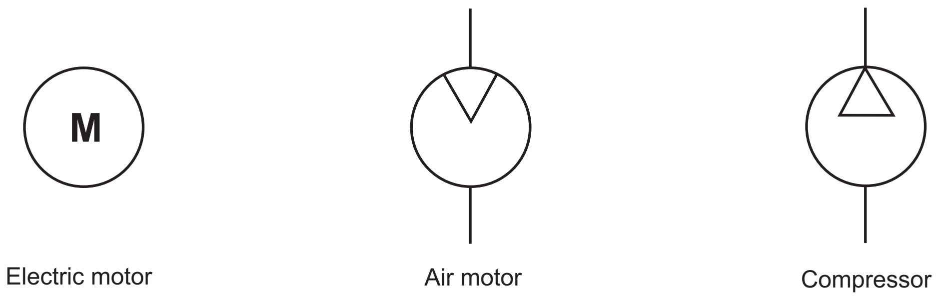


Figure 13

If the component is uni-directional (operates one way), the symbol has only one triangle. A reversible or bi-directional motor is indicated by a triangle drawn at both of the main connection ports, as illustrated below.

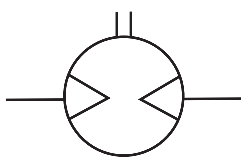


Figure 14: Bi-directional motor

Small circles are used to indicate a miscellaneous range of minor components, starting from a simple mechanical roller used as a valve actuator to check valves and gauges. The following activity is designed to give you a brief summary of some of the more common auxiliary components identified with circles.

Activity 4 – Circle symbols

Recommended reading

Read pages 246–250, on 'Industrial pneumatic symbols', in *Pneumatic Control for Industrial Automation* (Rohner).

Then complete the table below by drawing the circle symbol for each of the miscellaneous components listed.

Component	Symbol
Pressure gauge	
Temperature gauge	
Flow meter	
Visual indicator	

Component	Symbol
Check valve	
Pressure source	
Cam roller	
Line connection	

Squares

A **single square** (or envelope) indicates a circuit control valve for controlling the air flow or pressure. The valve's construction will allow it a number of possible positions between its two extremes of fully closed and fully open. This provides for variable control across one or more of its fluid ports, to ensure delivery of the required pressure and/or flow for the circuit.

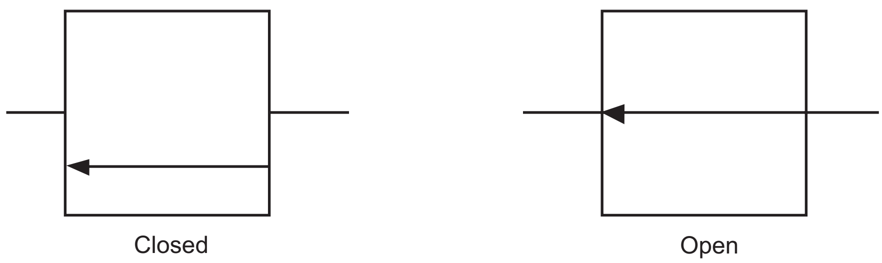


Figure 15: Circuit control valve symbols

Two or more squares (envelopes) indicate a directional control valve having as many finite positions as there are squares. In the circuit drawing, the pipes are normally shown connected to the box representing the valve's non-activated position.

When describing a valve, it is standard practice to identify the number of ports first, followed by the number of valve positions and then configuration type.

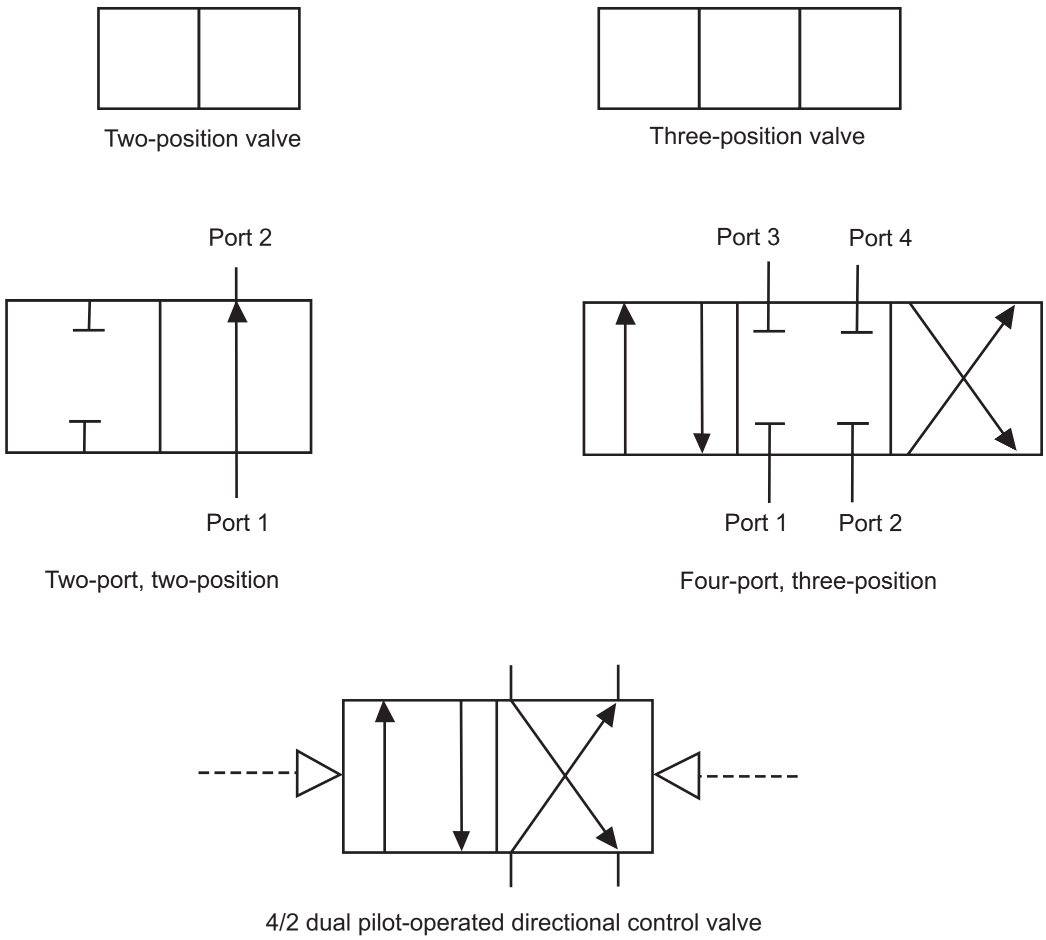


Figure 16: Directional control valve symbols

To move a valve's spool to operating or neutral positions, various valve-actuation methods are used. Typical examples include:

- hand levers and other manual means
- springs
- pneumatic pressure
- electric solenoids
- foot pedals
- air pressure
- detents.

Activity 5 – Valve actuator symbols

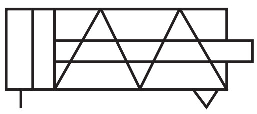
In the table below, sketch the symbols for the following types of valve spool actuators. Ask your supervisor to check your answers.

Actuator	Symbol
Lever	
Mechanical roller	
Air pilot	
Push button	

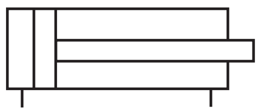
Actuator	Symbol
Spring	
Detent	
Solenoid	
Foot pedal	

Rectangles

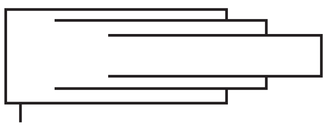
In circuit drawings, rectangles represent pneumatic cylinders, which are used to convert fluid energy into linear energy. These cylinders may be divided into three major classes – single-acting, double-acting and telescopic. Symbols for an example of each are illustrated below.



Single-acting, spring-return



Double-acting



Single-acting, telescopic

Figure 17: Pneumatic cylinder representation

Diamonds

Circuit components represented by diamond-shaped figures can be generally classified as conditioning apparatus. They include filters, lubricators, driers, water separators and air coolers (heat exchangers). Symbols for these components are illustrated below.

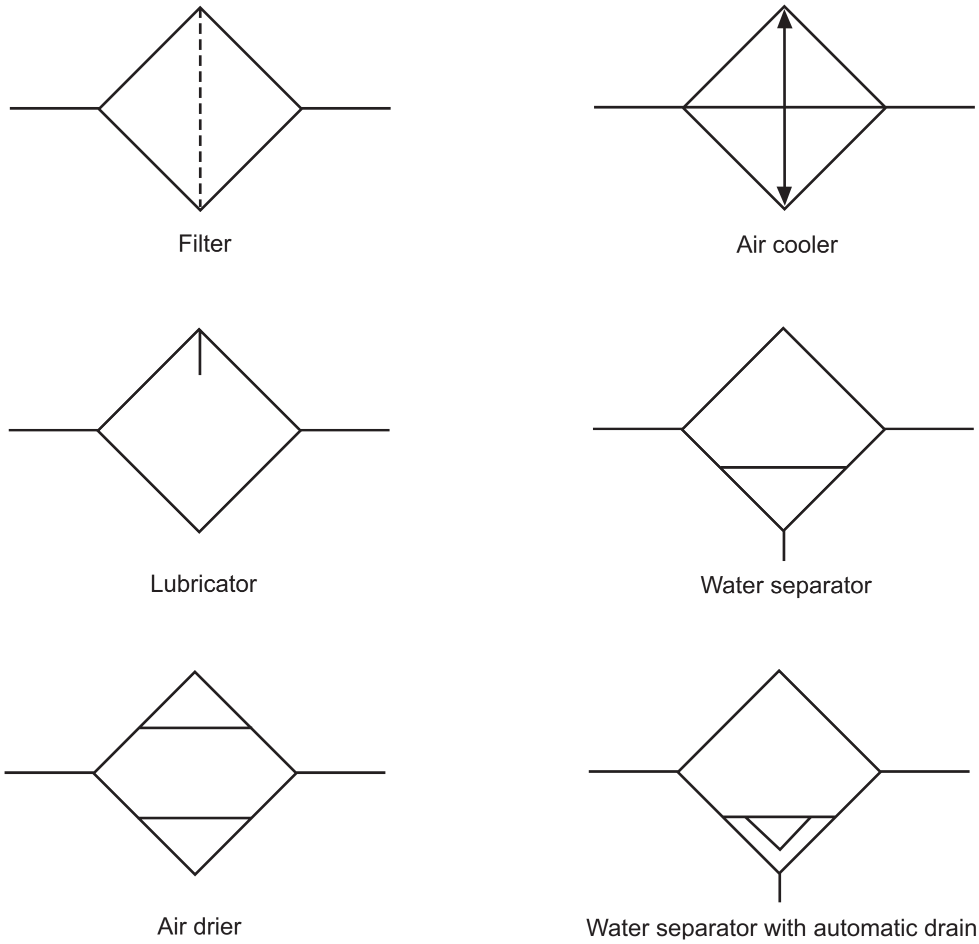


Figure 18: Symbols for conditioning components

Miscellaneous symbols

A variety of other particular symbols are commonly used in pneumatic circuit drawings. The main ones are illustrated below.

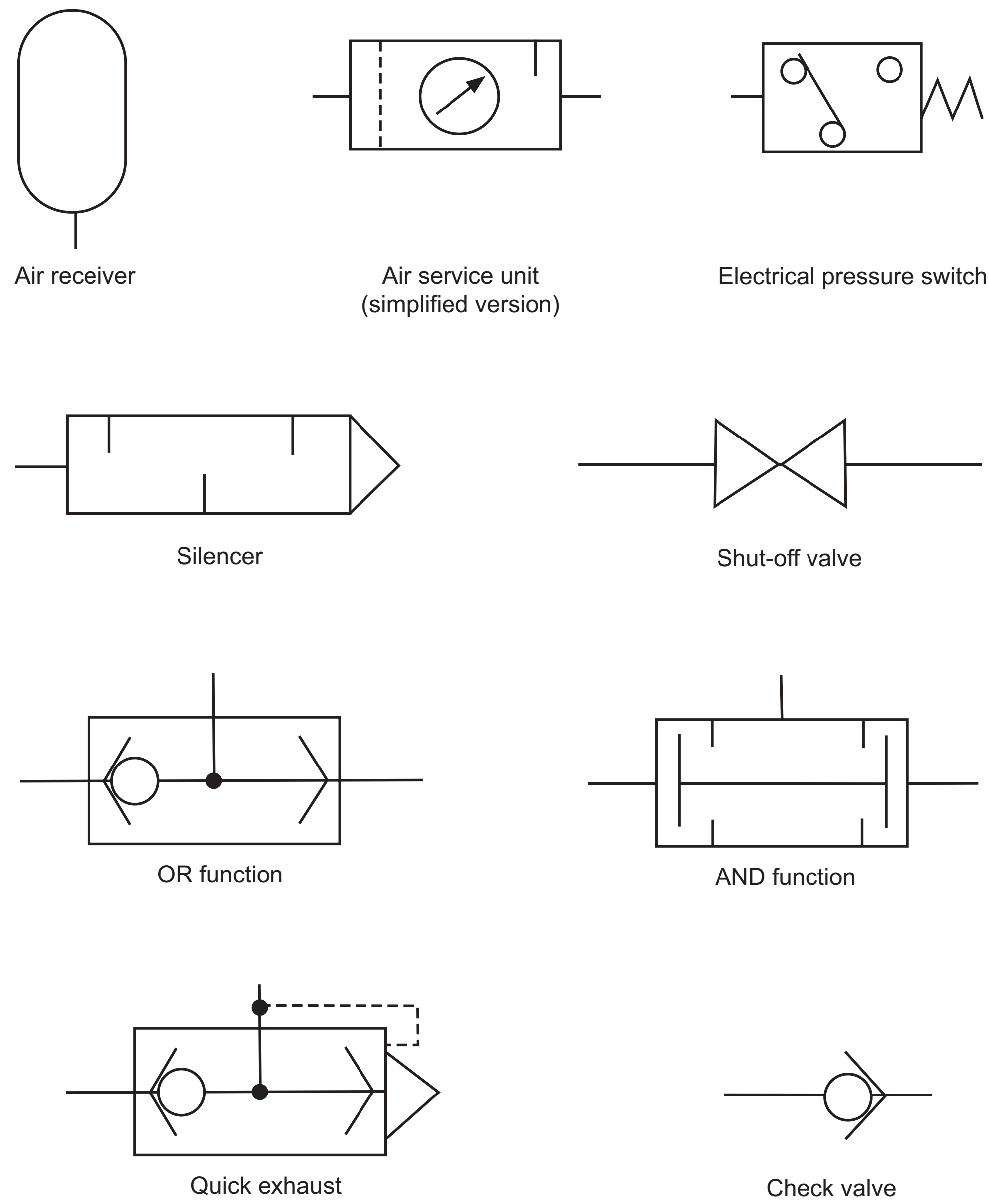


Figure 19: Miscellaneous symbols

Points to remember

In addition to your recommended readings, the following points will help you to understand a pneumatic system from a circuit drawing.

1. The starting point in circuit reading is the pressure source and the termination point is the actuator.
2. The control valves are shown in the de-energised or neutral position.
3. When tracing the circuit's operation, mentally move the valve envelopes into the positions required to give the desired flow.
4. Arrows are used in the envelopes to indicate fluid flow direction.
5. Fluid flow will take the path of least resistance.
6. Identify the type of fluid lines connecting the components in the circuit diagram.

Valve port identification

When connecting lines to a pneumatic component either on a circuit drawing or during final field installation, each port should be clearly marked. The tradesman is required to deduce a valve's different operation position and air-flow paths by imagining the drawn squares to be displaced so the pipe connections correspond with the valve's inlet and return air paths. The valve port marking must use either an alpha or numeric coding, as shown in the table below.

Component	Alpha codes	Numeric codes
Working lines	A, B, C ...	2, 4, 6 ...
Power connection	P	1
Exhaust ports	R, S, T ...	3, 5, 7 ...
Pilot lines	X, Y, Z	12, 14, 16
Leakage lines	L	9

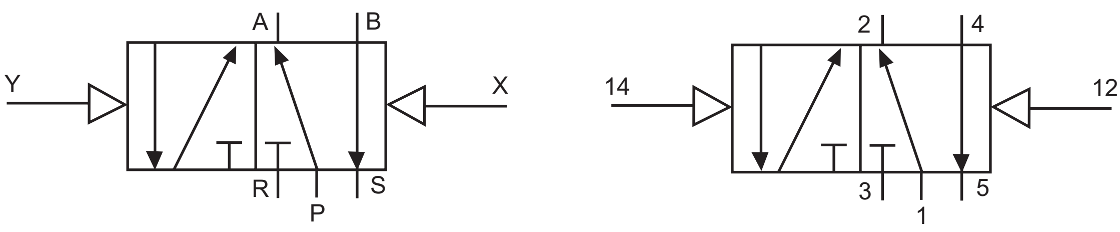


Figure 20: Valve port identification

When designing pilot-operated circuits, you should remember that a control signal at port 12 (X) will give an air supply out of service port 2 (A) and vice-versa. A control signal at port 14 (Y) will give an air supply out service port 4 (B).

Note: When drawing and laying out circuits, it is normal practice to connect service port 4 (B) to retract the cylinder, while service port 2 extends it.

Component numbering

In order to identify components and their function and location in a circuit, numeric and alpha codes are used in circuit drawings.

The numbering system in the following circuit diagram incorporates, for each individual element, an initial working group number followed by an element identification number, as shown below:

0.1	energy supply unit (ASU)
1.0, 2.0, 3.0 etc	working element (cylinder, motor)
1.1, 2.1, 3.1 etc	control element (DCV)
1.01, 1.02 etc	elements between the control element and working element
1.2, 2.4, 3.2 etc	elements which influence the advance stroke of the cylinder
1.3, 1.5, 2.3 etc	elements which influence the return stroke of the cylinder.

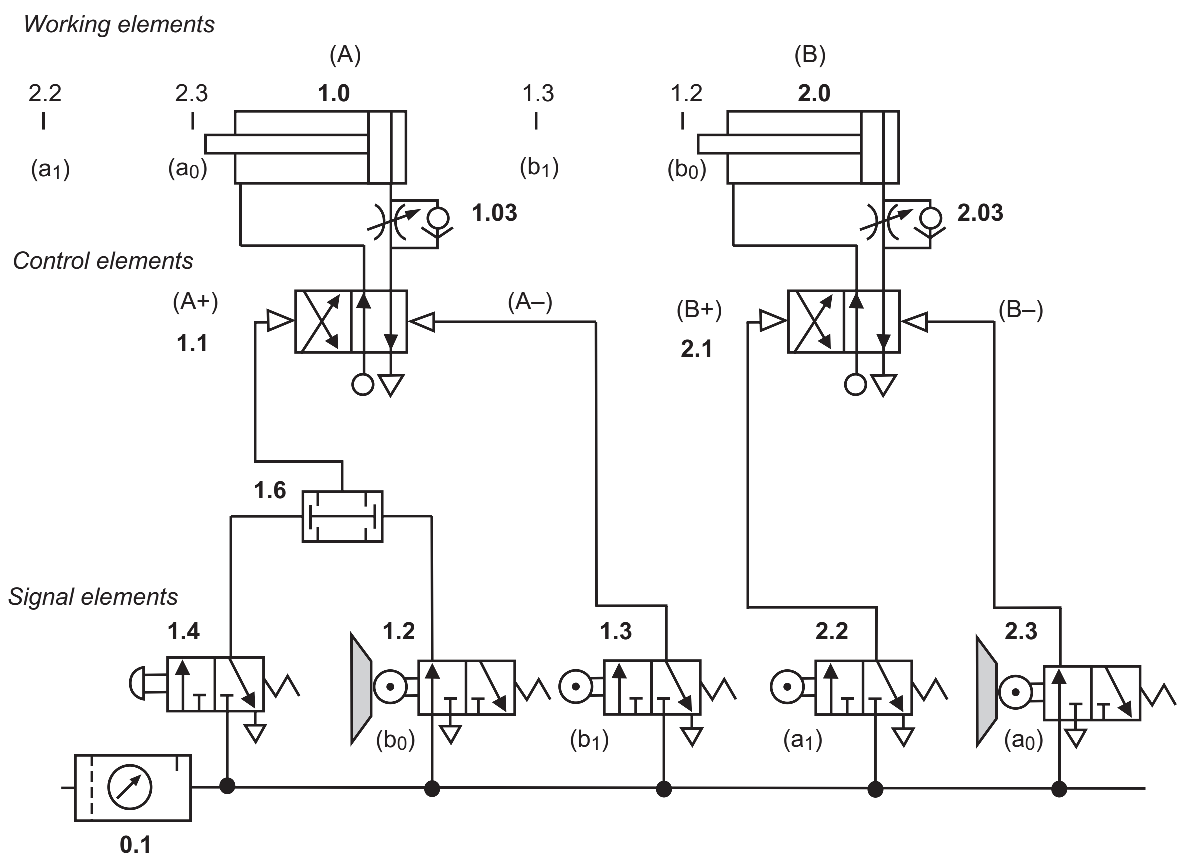
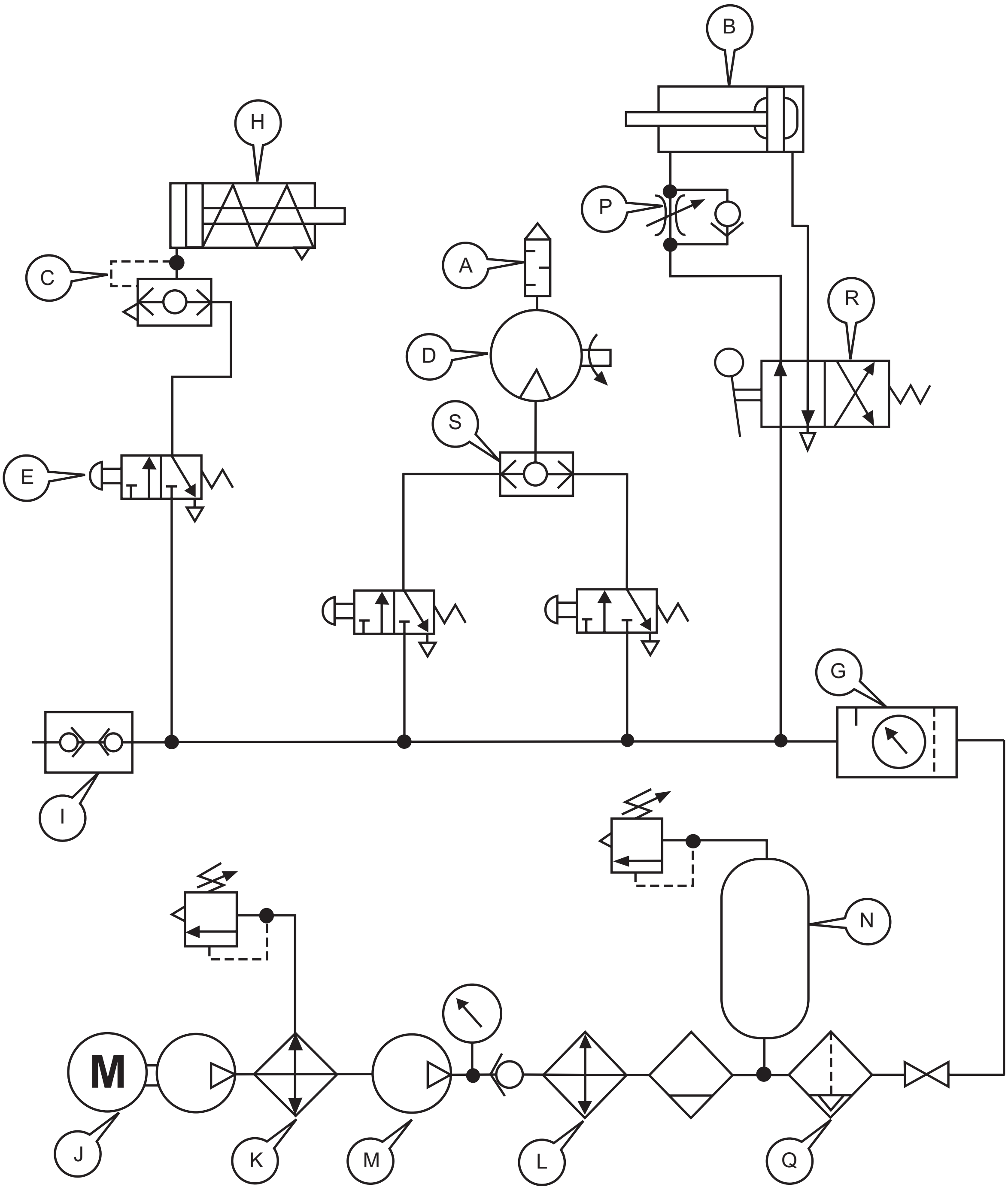


Figure 21: Component numbering

Activity 6 – Circuit diagram reading

The following questions are designed to allow you to check your understanding of circuit drawings.

Study the pneumatic circuit shown below and then answer each of the following by selecting one of the choices provided and ticking the appropriate box.



Question 1

The pneumatic circuit symbol for Item J indicates a:

☐ a) diesel engine

☐ b) rotary engine

☐ c) mechanical gearbox

☐ d) AC electric motor

Question 2

As indicated by its symbol, which of the following is a four-two directional control valve?

☐ a) Item R

☐ b) Item E

☐ c) Item I

☐ d) Item P

Question 3

Which of the following is a flow control valve?

☐ a) Item E

☐ b) Item A

☐ c) Item P

☐ d) Item I

Question 4

The pneumatic circuit symbol representing Item B indicates a:

☐ a) pneumatic motor

☐ b) single-acting cylinder

☐ c) double-acting cylinder

☐ d) rotary cylinder

Question 5

Identify any intercooler/s among the following.

☐ a) Item L

☐ b) Item Q

☐ c) Item N

☐ d) Item K

Question 6

The purpose of Item P in the machine's pneumatic circuit is to:

☐ a) extend Item B at controlled speed

☐ b) retract Item B at controlled speed

☐ c) retract Item B rapidly

☐ d) extend Item B rapidly

Question 7

As indicated by its symbol, which of the following is a pneumatic motor?

☐ a) Item M

☐ b) Item J

☐ c) Item D

☐ d) Item A

Question 8

Which of the following is an 'OR' or shuttle valve?

☐ a) Item C

☐ b) Item S

☐ c) Item A

☐ d) Item R

Question 9

The purpose of Item Q in the machine's pneumatic circuit is to:

☐ a) remove oil

☐ b) remove water

☐ c) remove air

☐ d) all the above

Question 10

Which of the following is an air receiver?

☐ a) Item G

☐ b) Item C

☐ c) Item I

☐ d) Item N

Question 11

Item L is an:

☐ a) aftercooler

☐ b) air drier

☐ c) intercooler

☐ d) air service unit

Question 12

Item G is a:

☐ a) air-line lubricator

☐ b) temperature-compensated flow control

☐ c) pressure regulator with bypass

☐ d) air service unit

Section 2 – Pneumatic actuators

Introduction

The function of an actuator is to convert pneumatic energy – that is, the potential energy stored in compressed air – to mechanical energy.

An actuator may be linear or rotary. A linear actuator (cylinder) produces force and motion in a straight line, while a rotary actuator (motor) produces torque and rotating motion.

Recommended reading

Chapter 3, pages 36–59, on ‘Linear actuators’, in *Pneumatic Control for Industrial Automation* (Rohner).

Chapter 5, pages 68–77, on ‘Air motors – rotary actuators’, in *Pneumatic Control for Industrial Automation* (Rohner).

Recommended viewing

Industrial Pneumatic Technology video series:
‘Check Valves, Cylinders and Motors’.

You will have noted that linear actuators are more commonly called pneumatic cylinders. The mechanical force and feed are in a linear direction.

Rotary actuators (or air motors) are distinct from semi-rotary actuators, as these devices rotate less than 720°. Air motors produce a continuous torque and are generally of the vane, gear, piston, turbine or roots blower design. Piston motors can be of an axial or radial design configured to produce a rotary output at a shaft. In the case of percussive-type hand tools, the piston does not rotate but is reciprocating in action.

Linear actuators

Linear actuators are more commonly called pneumatic cylinders or rams – and the mechanical force and feed are in a linear direction. They are used for clamping and lifting and for traverse and feed motions.

The main types of pneumatic cylinder are single-acting and double-acting.

Single-acting cylinders

Single-acting cylinders have a power stroke in one direction only.

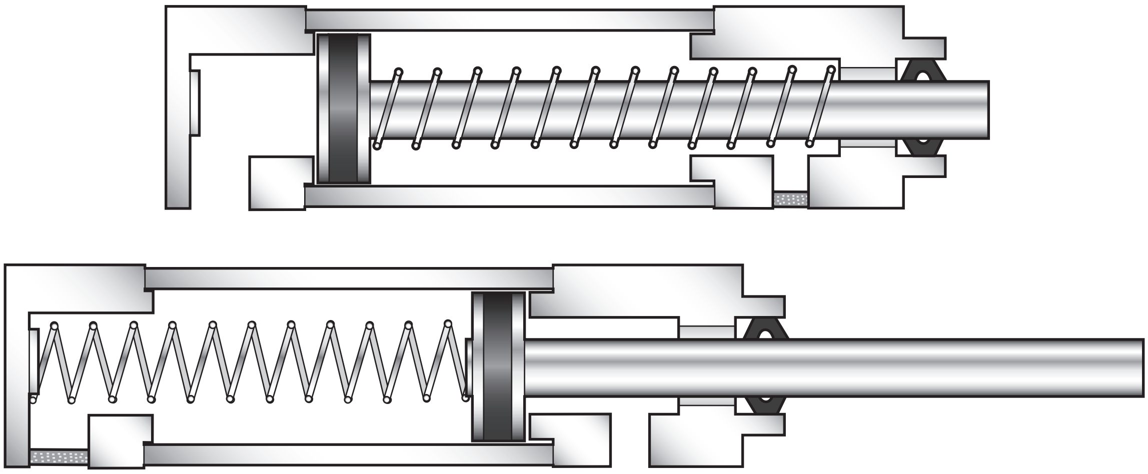


Figure 22: Single-acting cylinder using pneumatic pressure for extension

The cylinder illustrated above uses pneumatic pressure to extend the rod and a spring to return the piston and rod.

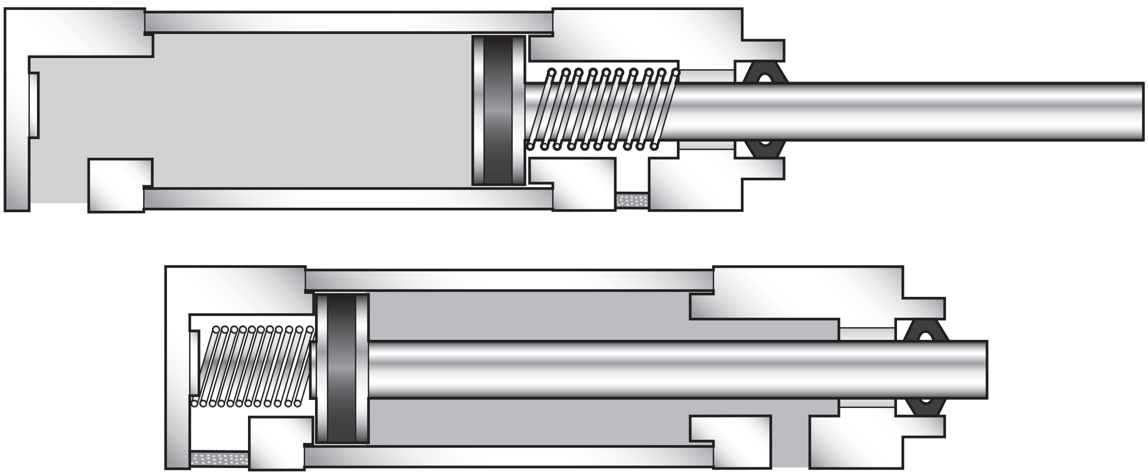


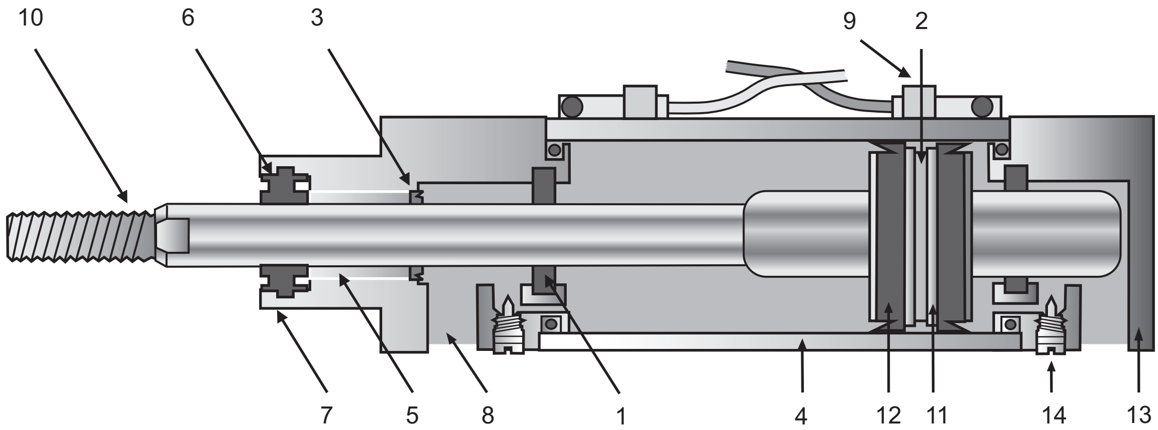
Figure 23: Single-acting cylinder using pneumatic pressure for retraction

The cylinder illustrated above uses pneumatic pressure to retract the rod and a spring to extend it by pushing on the piston.

Double-acting cylinders

Double-acting cylinders use pneumatic pressure to both extend and retract the rod.

The main parts of a double-acting cylinder are illustrated below.



1. cushion seal
2. magnet
3. cushion sleeve
4. barrel
5. bush
6. rod and wiper seal
7. front (rod) end cover
8. front port
9. reed switch
10. piston rod
11. wear ring
12. piston seal
13. rear end (cap/head) cover
14. cushion screw

Figure 24: Structure of double-acting cylinder

Cylinder creep can occur when air leaks past the piston seals. This internal leakage in the cylinder can result in undesirable movement of the cylinder's piston.

Cylinder cushions are often installed at one or both ends of a cylinder to slow the piston down near the end of the stroke. They prevent the piston from hammering against the end cap by trapping fluid and decelerating the piston.

Tandem cylinders

Tandem cylinders are used as an alternative to a larger bore cylinder where there are space restrictions. They will double the pull and nearly double the thrust for a given bore.

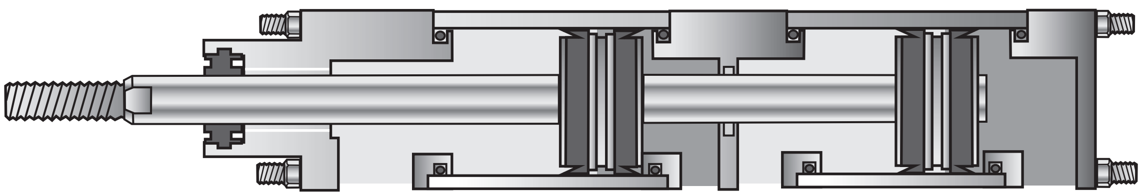


Figure 25: Tandem cylinder

Through-rod cylinders

These are also known as double-rod cylinders and produce equal force and speed in both directions. This is because the effective piston areas and cylinder volumes are the same.

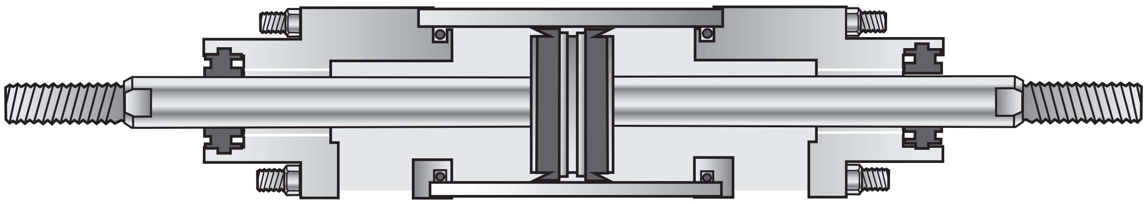


Figure 26: Through-rod cylinder

Duplex cylinders

Unlike the tandem cylinder, the duplex cylinder has piston rods that are not joined and the rear cylinder has a shorter stroke.

Approximately a doubling of starting thrust is achieved and maintained throughout the stroke of the shorter cylinder.

The intermediate position of the cylinder can be set by the short cylinder only.

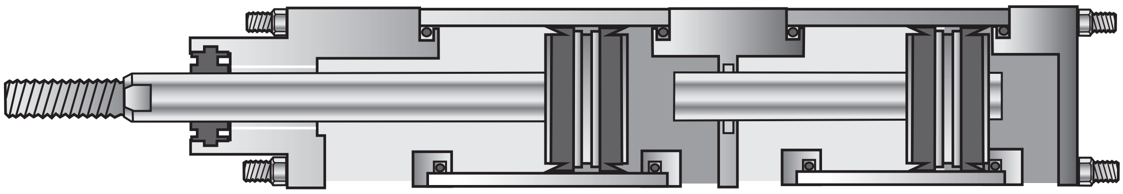


Figure 27: Duplex cylinder

Rotary actuators (motors)

A pneumatic motor converts potential energy stored in a fluid to continuous mechanical rotary motion and torque. The design and operation of pneumatic motors resemble in many respects those of pneumatic pumps.

All pneumatic motors have several design features in common. All must have a driving surface area subject to pressure differential. In gear, vane and rotary abutment motors, this surface is rectangular. In radial and axial piston motors, the surface is circular. This surface area must be connected mechanically to an output shaft and there must be a way of timing the porting of the pressure fluid to the pressure surface to provide continuous rotation.

A rotary actuator, or fluid motor, may use either sliding vanes, gears or pistons to convert the pneumatic energy to a mechanical rotary movement.

The circuit symbols shown below are for rotary actuators.

Figure 28: Rotary actuator symbols

Vane motors

Vane motors consist of a rotor, ring, vanes and a port plate which has kidney-shaped ports to allow the fluid into and out of the motor. As a combined unit, the rotor, vanes and ring are called a cartridge.

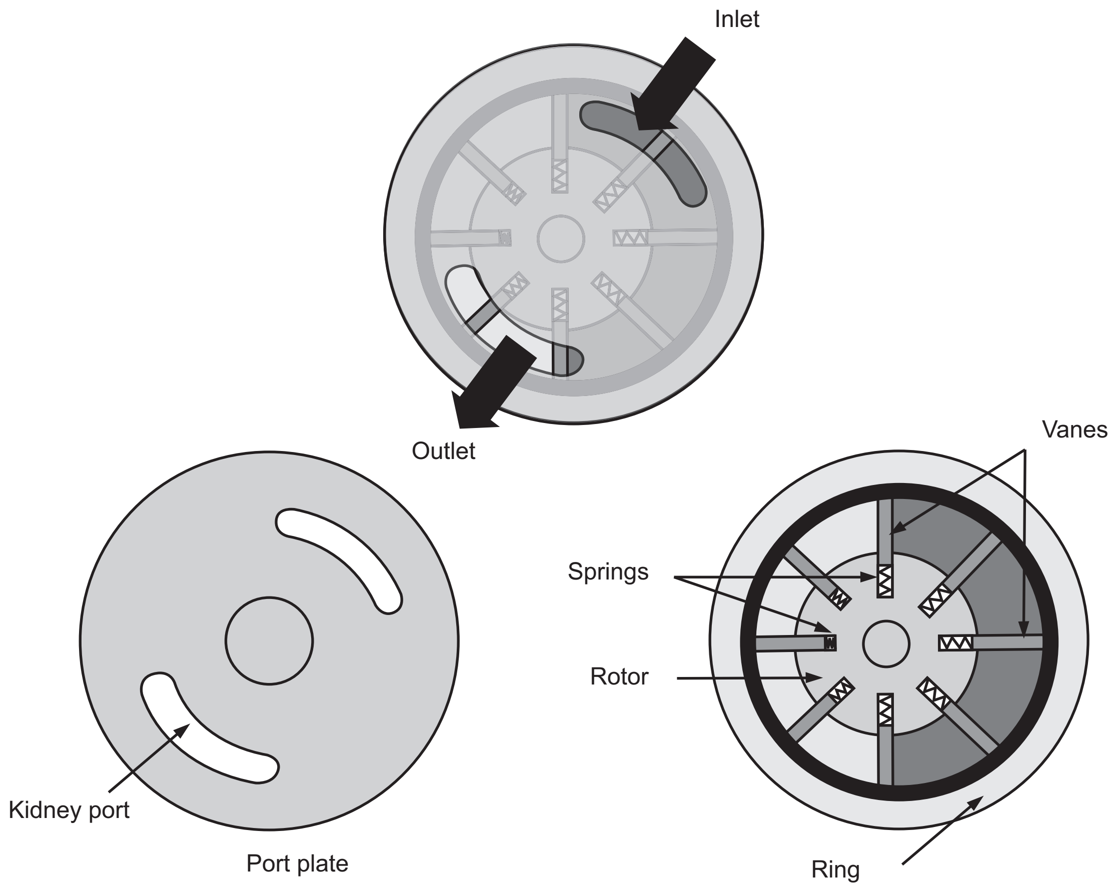


Figure 29: Vane motor structure – plan views

Vane motors are positive-displacement motors that produce torque from the pneumatic pressure acting upon their vanes. The vanes are held in place, and allowed to slide, by a rotor. The vanes are held against the cam ring by pneumatic pressure – plus spring and centrifugal force. The rotor is attached to a splined drive shaft which drives the load, as illustrated below.

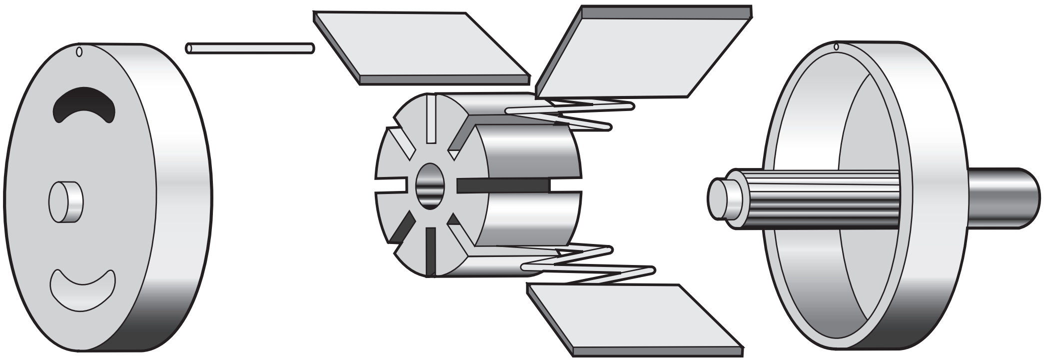


Figure 30: Exploded view of a vane motor

Gear motors

Gear motors are also positive displacement, with rotation and torque a result of the pneumatic pressure acting upon the gear teeth, as shown below. The main parts of an external gear motor are also illustrated.

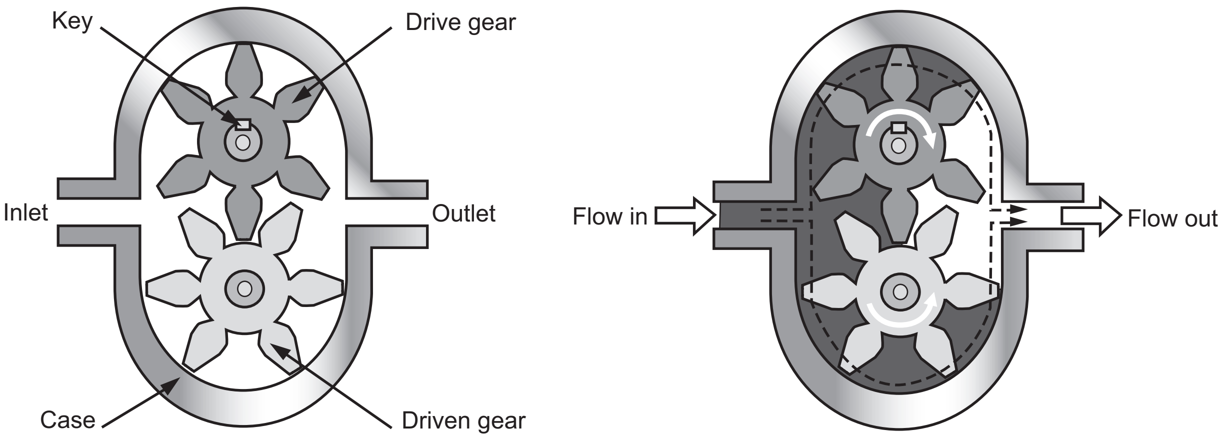


Figure 31: Structure and operation of a gear motor

The gear motor consists of two spur gears and a housing or case. The drive gear is attached to the output shaft which provides the drive to the load.

Piston motors

Piston motors may be either axial or radial in configuration. Both types are positive-displacement motors. Radial piston motors are usually used where high torque at a relatively low speed is required. The main parts of an axial piston motor are illustrated below.

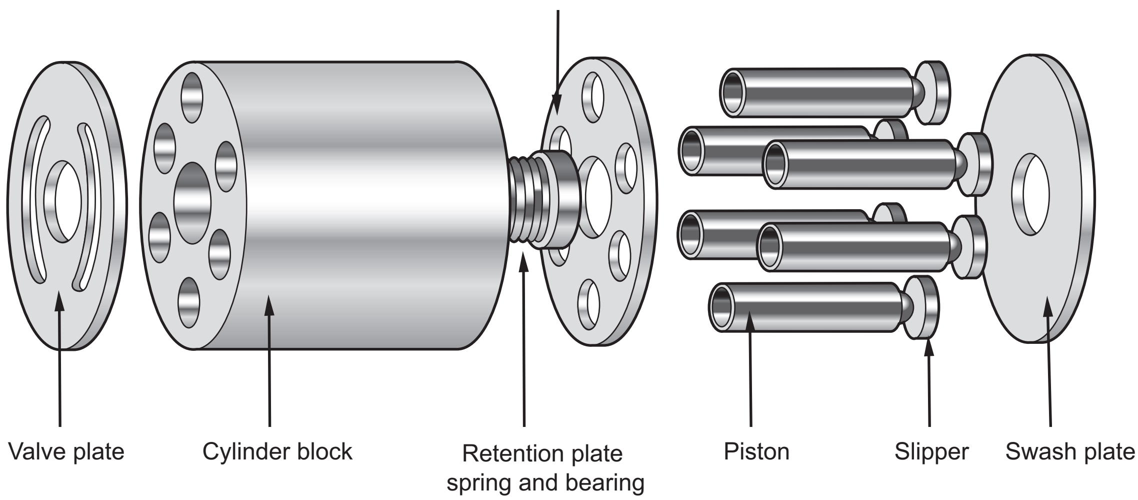


Figure 32: Structure of an axial piston motor

The valve plate has kidney-shaped ports to allow air time to enter and discharge from the cylinder block. The cylinder block houses the pistons, which are allowed to slide axially inside the block. Attached to the pistons are the slippers. These ride on the swash plate and are held in place by a retention plate which is spring-loaded. Once the motor is running, pneumatic pressure also holds the slippers and pistons onto the swash plate.

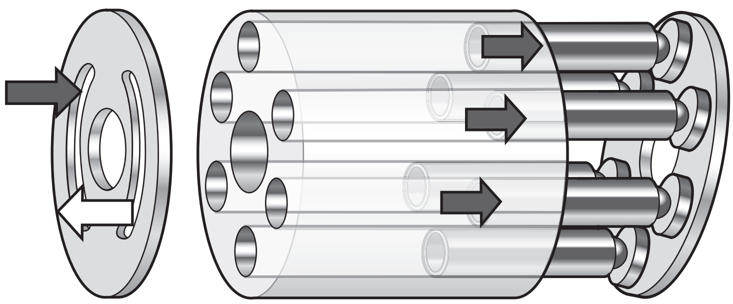


Figure 33: Piston extension in axial piston motor

When pressure is applied to the motor as illustrated above, the pistons push against the swash plate, which is at an inclined angle. This produces a tangential force, which causes the slippers to ride up the inclined surface. The pistons and cylinder block begin to rotate and produce torque, as illustrated in the following figure. To change the direction of rotation, the air flow to the motor is reversed.

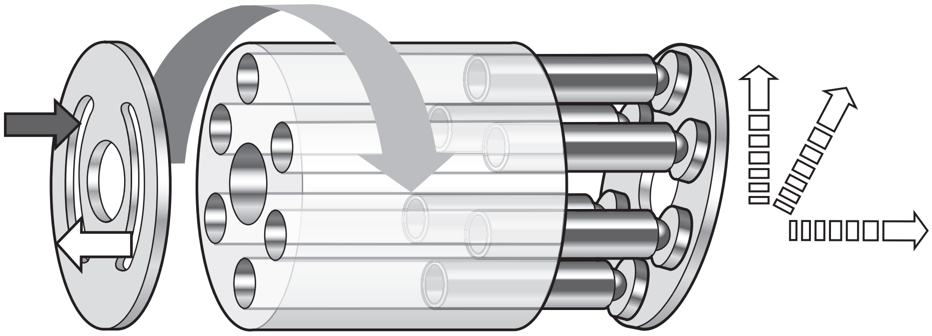


Figure 34: Tangential forces causes rotation in motor

The cylinder block is splined to a drive shaft, the rotation of which can be used to drive a load.

Torque

Two terms commonly used in relation to motors are **running torque** and **start-up (breakaway) torque**. Running torque is the torque that is required by the motor to keep the load moving. Start-up torque is the torque required to overcome the inertia and internal friction of the motor and drive train to accelerate the load from a stationary position. Generally, start-up torque is much higher than the running torque. Torque is the force acting at a radial distance measured from the centre of the drive shaft and can be calculated using the formula below.

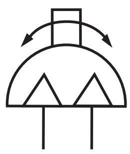
Motor torque (Nm) = F x R x η_{HM}

where F = is the force applied (in Newtons)

R = is the radial distance measured from the centre of the motor shaft in metres

η_{HM} is the hydro-mechanical efficiency of the motor (expressed as a percentage).

Semi-rotary actuators



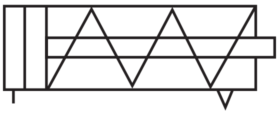
The circuit symbol shown above is for ‘semi-rotary cylinders’. The semi-rotary cylinder’s design may use a double-acting cylinder (with a gear-tooth profile cut into the rod to rotate the shaft) or a vane cylinder. These units are used in circuit applications where the actuator’s output is to have a limited rotation in a clockwise or anti-clockwise direction. The commercially available ranges of rotation are 45°, 90°, 180°, 290°, and 720°. However, it is possible to adjust the actuator’s actual rotation to suit a particular application by adjusting two screws.

Activity 7 – Pneumatic actuators

The following questions are designed to determine your understanding of pneumatic actuators before you apply it to your practical activities. Most are 'multiple choice', which you should answer by selecting one of the options and ticking the appropriate box.

Question 1

In single-acting actuators as illustrated below:



☐ a) air pressure is required to return the rod

☐ b) the extension force is increased by the opposing spring force

☐ c) the cylinder extends and retracts at the same speed

☐ d) the retraction force is greater than the extension force

☐ e) the extension force is reduced by the opposing spring force.

Question 2

Cylinder end-position cushioning:

☐ a) can only be fitted to the rod end

☐ b) requires a pressure-reducing valve

☐ c) allows for controlled deceleration at the end of its stroke

☐ d) all of the above.

Question 3

The pneumatic symbol illustrated below represents a:

☐ a) double-acting cylinder with impact stroke

☐ b) single-acting cylinder with magnetic piston

☐ c) double-acting telescopic cylinder with impact stroke

☐ d) double-acting cylinder with cushioning at both ends

☐ e) double-acting cylinder with cushioning at one end.

Question 4

When compared to standard double-acting actuators, rodless actuators:

☐ a) can be considered to be leak-proof

☐ b) can incorporate a magnetic piston

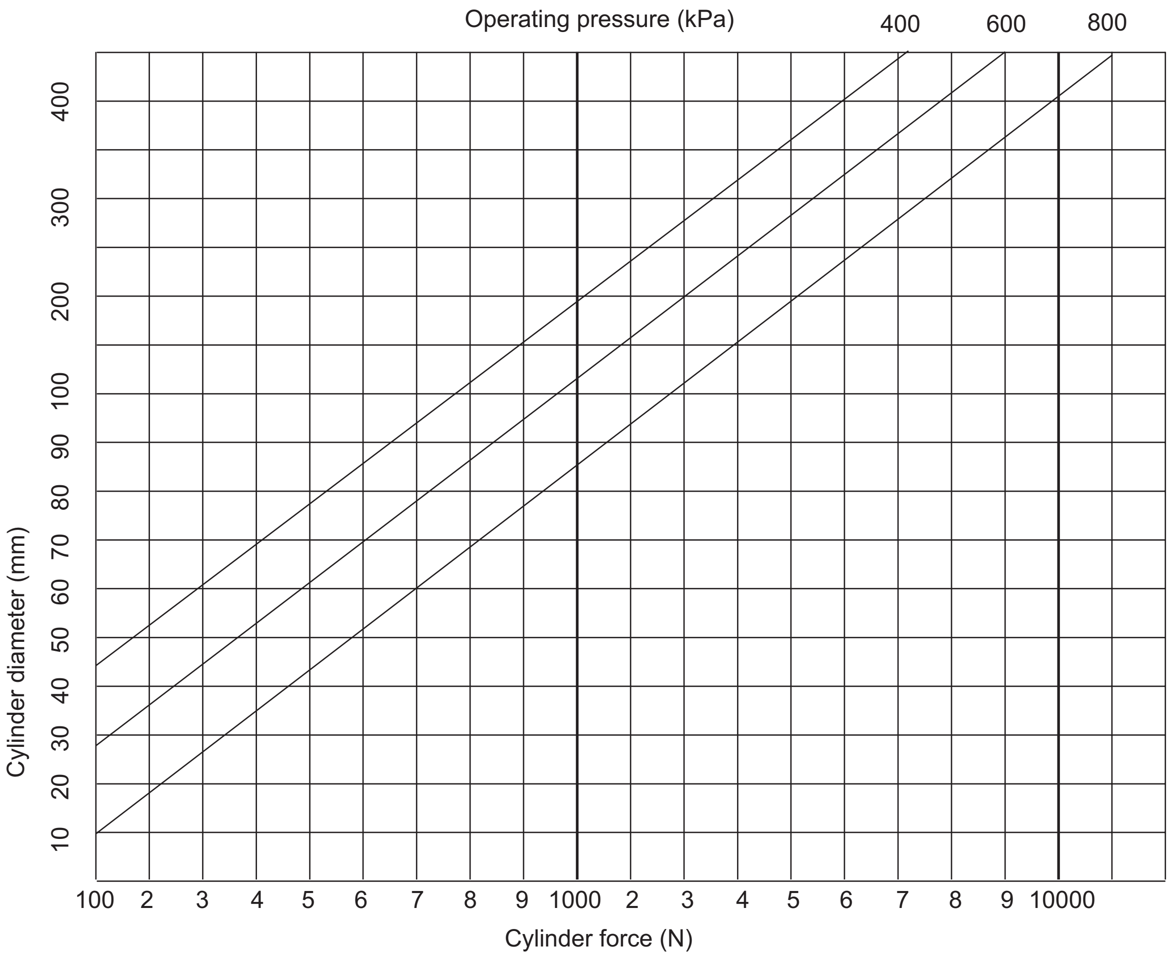
☐ c) provide longer sealing life

☐ d) require air supplied at one end only

☐ e) have all characteristics described in *a*, *b* and *c*.

Question 5

From the cylinder selection chart below, select a suitably sized cylinder for delivering an outgoing force of 700 N at an operating pressure of 800 kPa.



☐ a) 28 mm diameter

☐ b) 35 mm diameter

☐ c) 60 mm diameter

☐ d) 100 mm diameter.

Question 6

During start up of a vane motor, the vanes' tip sealing can be controlled by:

☐ a) centrifugal force

☐ b) air pressure

☐ c) spring force and air pressure

☐ d) spring force

☐ e) pneumatic pressure.

Question 7

The advantages of typical air motors are that they:

☐ a) can be stalled without damage

☐ b) have high start-up torque but have low torque when stalled

☐ c) can be easily stalled

☐ d) are efficient when operated at low pressures.

Question 8

Which of the following is the symbol for a bi-directional air motor?

☐ a)

☐ b)

☐ c)

☐ d)

Question 9

Sketch the pneumatic symbol for a semi-rotary actuator in the space below:

Question 10

A type of air motor that operates at very high rpm but has low torque is a:

☐ a) gear motor

☐ b) turbine motor

☐ c) piston motor

☐ d) none of the above.

Question 11

The breakaway torque of a typical air motor is:

☐ a) the same as the motor's running torque

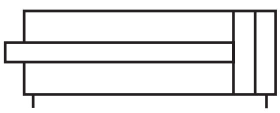
☐ b) less than the motor's running torque

☐ c) greater than the motor's running torque

☐ d) the sum of the motor's running torque and start-up torque.

Question 12

In actuators like that illustrated below:



☐ a) the retraction force is greater than the extension force

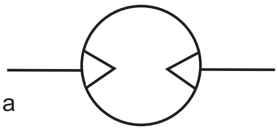
☐ b) the cylinder extends and retracts at the same speed

☐ c) extension force is greater than retraction force

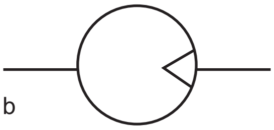
☐ d) air pressure is required to return the cylinder.

Question 13

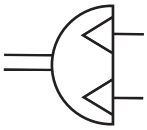
Which of the following pneumatic symbols represents a uni-directional air motor?



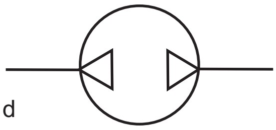
a



b



c



d

- ☐ a)
- ☐ b)
- ☐ c)
- ☐ d)

Section 3 – Compressors

Introduction

An air compressor is a machine that takes in air at a low pressure (usually atmospheric) and compresses it to a higher pressure. The compressor converts the mechanical energy of a prime mover, such as an electric motor or an internal combustion engine, into the potential energy of compressed air. This is then used to operate a machine by activating a pneumatic cylinder or rotating a pneumatic motor. The figure below illustrates the standard symbols used to identify prime movers and compressors.

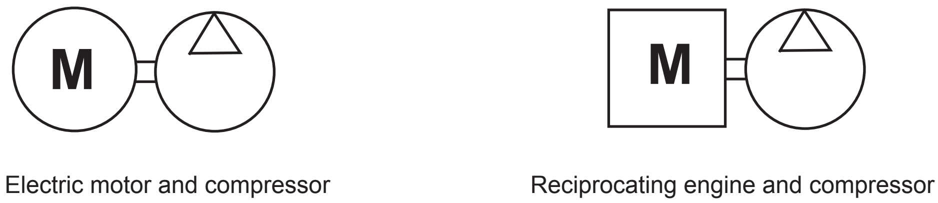


Figure 35: Prime mover and compressor symbols

> ***Recommended reading***
>
> Chapter 13, pages 205–223, on 'Air compression', in *Pneumatic Control for Industrial Automation* (Rohner).

The following is a summary of the topic area you have just covered in your reference text and is designed to consolidate what you have just learnt.

Compressor types

Compressors fall into two main categories: positive displacement and dynamic (non-positive displacement), as illustrated below.

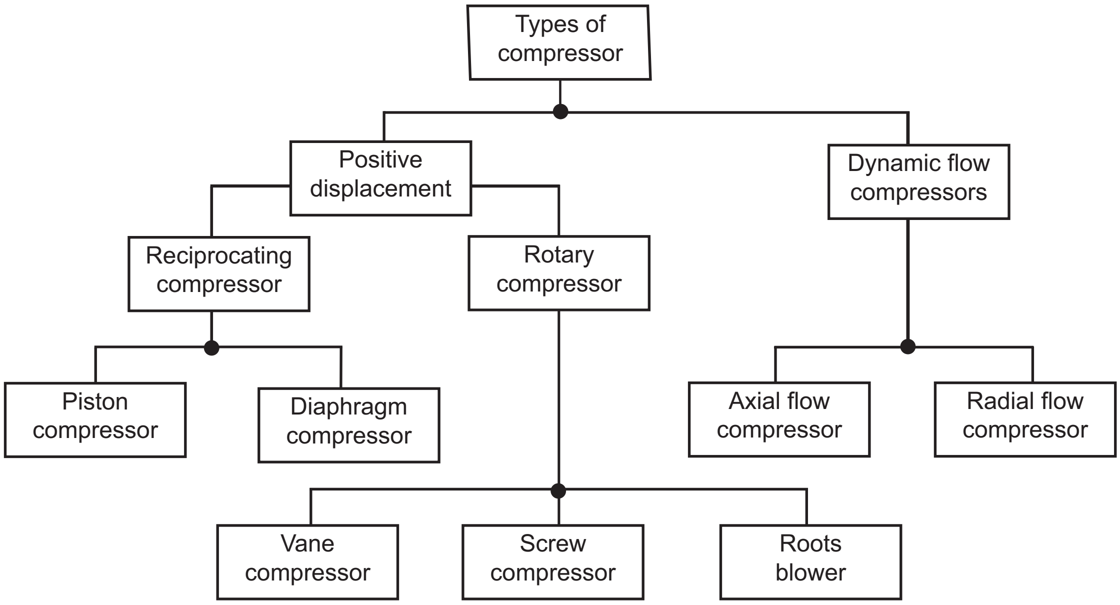


Figure 36: Main compressor groupings

Principles of operation

Positive-displacement compressors produce a pulsating flow but provide a positive internal seal against slippage – and the compressor's flow variation is negligible when compared with system pressure variation. If the compressor's discharge is fully restricted, the flow will still continue, so positive-displacement compressors must have some avenue for the fluid medium to return to the atmosphere. This is generally achieved by the installation of a relief valve on the compressor's discharge line or receiver. This valve opens if the compressor's discharge flow is halted or restricted, allowing the pressurised air flow access to the atmosphere and thus providing a safety release.

Displacement compressors draw successive volumes of air into a confined space and compress the air by reducing its volume. This reduction in volume is accompanied by increases in pressure and temperature. Positive-displacement compressors are further classified as either rotary or reciprocating.

Dynamic compressors compress air by using a high-speed rotating element to accelerate the air. This type of compressor draws in air continuously and speeds it up and imparts a high kinetic energy. Some of this energy is converted to pressure energy when the air slows down again and the remainder is converted to heat. Dynamic compressors are further classified as radial flow or axial flow.

Compressors are made up of one or more basic elements. Those with one element, or several elements working in parallel, are classified as single-stage compressors.

However, many applications for compressors involve conditions beyond the capabilities of single-stage compressors, because high compression ratios may cause excessive temperature in discharged air or other design problems.

During compression, air temperature increases with pressure. As the temperature rises, the work required to keep compressing the air increases. To overcome this problem, air can be compressed in stages, with the heat of compression being reduced between each stage.

Cooling the air between stages reduces its volume and temperature before it enters the next stage. This improves the volumetric efficiency, which reduces the cost of air compression.

Each stage is a basic compressor within itself and is sized to operate in series with one or more other elements. Although they are individual units, they are generally driven from a single power source.

Positive-displacement compressors

Positive-displacement compressors are divided into two main groups – reciprocating (including piston and diaphragm compressors) and rotary (including vane and screw compressors and roots blowers).

1. Reciprocating compressors

These machines are designed to cover a wide range of operating pressures. The operating cycle is that air is drawn through the suction valve at low pressure, is compressed in the cylinder (or cylinders) to the desired pressure and then discharged to an air receiver.

An essential feature of a well-designed reciprocating compressor is that the clearance between the piston and cylinder cover at top dead centre is kept to the smallest, practical limit – because, when the piston starts its suction stroke, all the air trapped in the clearance space has to 're-expand' to atmospheric pressure before any new air can be admitted to the cylinder. A large clearance would seriously affect efficiency, because air admission could not start until the piston had travelled a considerable distance of its stroke.

Another essential feature is that the piston be airtight; so the piston rings need very careful fitting – otherwise leakage past the rings will occur with resultant loss of efficiency. Pistons are usually fitted with ground, centrifugally cast rings, which, bedding with equal pressure at all points in the ground and honed cast-iron cylinders, reduce frictional losses to a minimum. Also fitted are large water jackets enveloping the cylinders, to help in heat reduction.

a) Reciprocating piston compressors

These are the oldest and, for small and medium power requirements, still the most common type of air compressor used in industry. A reciprocating piston compressor is similar in construction to an internal combustion engine, the main difference being the construction of the inlet and delivery valves, as illustrated below.

The reciprocating compressor uses automatic spring-loaded valves, which open only when a pressure differential exists across them. Inlet valves open when the pressure in the cylinder is slightly less than the intake pressure and delivery valves open when the pressure in the cylinder is slightly higher than the discharge pressure.

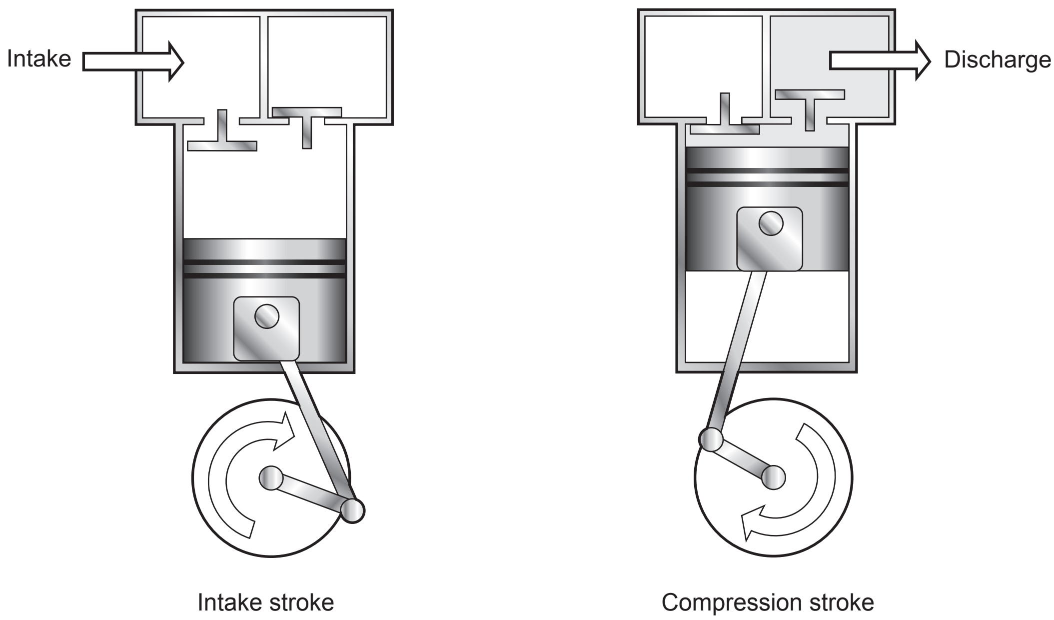


Figure 37: Single-stage reciprocating compressor

A two-stage piston compressor compresses air in two separate steps, using pistons with different diameters. The piston with the larger diameter performs the first stage of compression. The smaller piston compresses air in the second stage. As the crankshaft is turned by its prime mover, the large-diameter piston strokes downward. Air enters the chamber from the atmosphere through the open inlet valve. When the piston starts its upward movement, the inlet valve closes. Air is compressed (and heated) until a certain pressure is reached, at which point the outlet valve opens, discharging hot, compressed air. This air is then directed by means of a tube, called an intercooler, to the second-stage piston. The air is cooled by means of air blowing over the tube or water flowing across the tube. By the time it reaches the second-stage piston, a great portion of the heat from first-stage compression has been dissipated.

The cooler air is now ready to be compressed a second time. With compressed air at its inlet, the smaller-diameter piston is pulled downward. Compressed air fills the chamber and the inlet valve closes. The piston is stroked upward, compressing the air further. As it discharges from the compressor, the compressed air is at an elevated temperature. But it is not nearly as much above ambient temperature as it would be if one stage were used for the same output. Two-stage compressors do not waste as much energy in compressing air as single-stage units.

b) Diaphragm compressors

This type of compressor belongs to the piston compressor group. The piston is separated from the suction chamber by a diaphragm – so the air does not come into contact with the reciprocating parts. Thus, the air is always kept free of oil. For this reason its use is preferred in the foodstuffs, pharmaceutical and chemical industries.

2. Rotary compressors

a) Vane or sliding vane rotary compressors employ an eccentrically mounted rotor which rotates in a cylindrical housing that has inlet and outlet slots. The advantages of this type of compressor are its compact dimensions, its quiet running and smooth, steady air delivery.

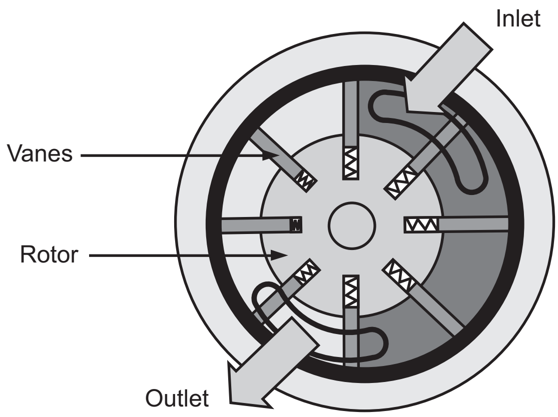


Figure 38: Sliding vane rotary compressor

Sliding vanes are contained in slots in the rotor and form chambers with the cylindrical wall. When rotating, the centrifugal energy forces the vanes against the wall and, owing to the shape of the housing, the chambers are increased or reduced in size.

b) Screw compressors consist of two intermeshing rotors, one having a convex profile and the other a concave profile. There are fine tolerances both between the screws themselves and between them and the surrounding casing. The screws are usually kept from contacting each other by timing gears. Air enters one end of the casing, is trapped between the screw flutes and forced out of the compressor outlet. These compressors typically operate at high revolutions-per-minute rates.

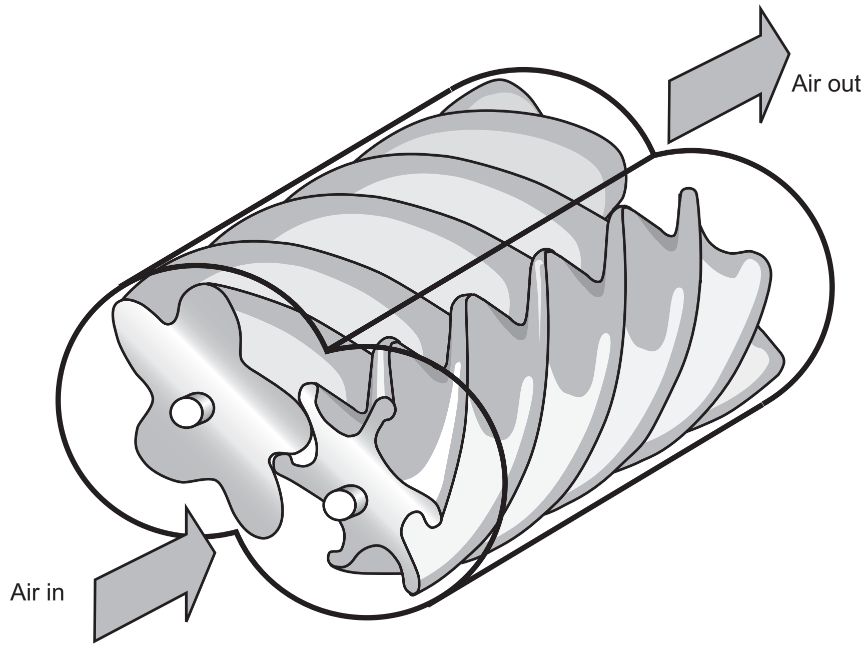


Figure 39: Screw compressor

c) In the **roots blower** type of compressor, the air is conveyed from one side to the other without any change in volume. It is trapped between two lobes and the compressor casing and transported to the outlet. The rotating lobes are prevented from contacting each other by timing gears and the lobes' edges produce the necessary sealing on the pressure side.

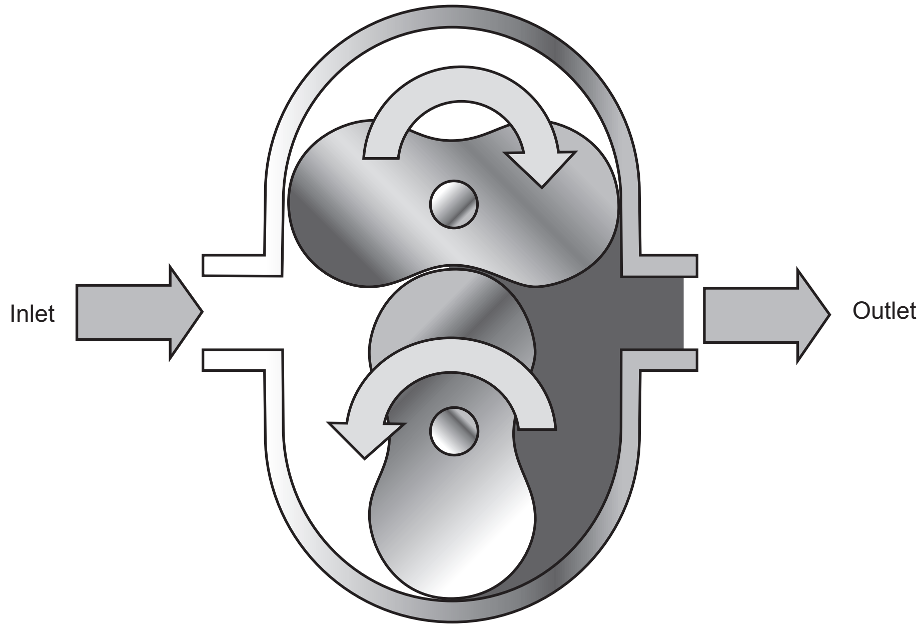


Figure 40: Operation of a roots blower

Dynamic compressors

Radial flow compressors

This type of compressor is properly called a blower. It delivers large quantities of air at low pressure, with a stage pressure ratio of four being about the maximum feasible. The principle of operation is that, when the shaft is rotated, the effect of centrifugal force upon the air within the impeller causes its compression and, at the same time, induces it to flow through the impeller. Air enters the eye of the impeller and is accelerated radially by the rotating impeller. As the air leaves the impeller, it enters a divergent, shaped duct prior to exiting the compressor. This decreases the air's velocity and further increases its pressure.

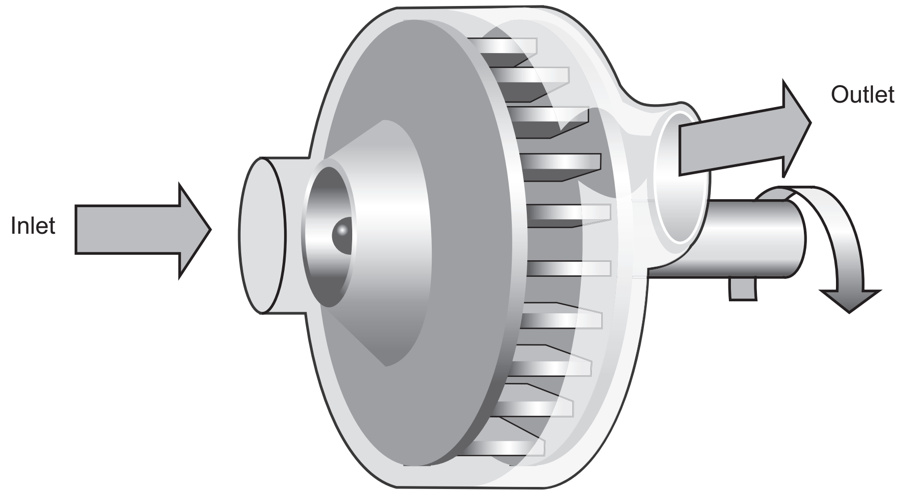


Figure 41: Radial flow compressor

Axial flow compressors

This type of compressor is properly called a turbine. It delivers large quantities of air at high velocity. It can have many rotors to increase efficiency. The rotors have blades which accelerate the air along the axis of the compressor. These compressors can rotate at up to 100 000 rpm.

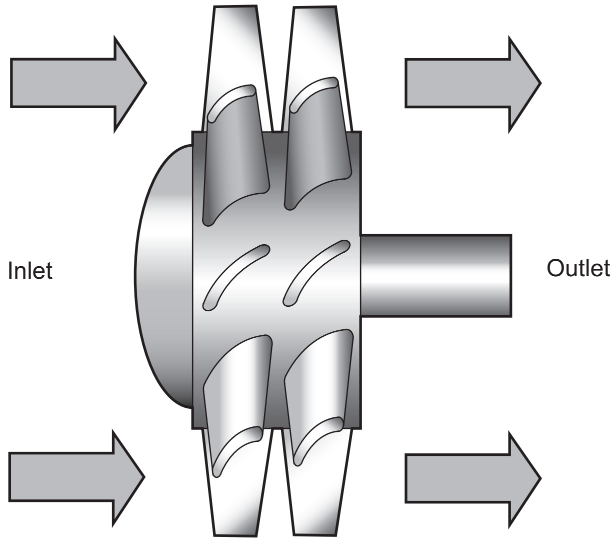


Figure 42: Operation of axial flow compressor (turbine)

Compressor capacity

This unit of competency is concerned with displacement compressors only – and, in particular, reciprocating piston, sliding vane and rotary screw types. In practice, the selection of a compressor is based on two major factors: free air delivery (FAD) and working pressure.

The rating of an air compressor is determined by comparing its discharge flow rate to the rate at which air is drawn in from the atmosphere. This latter factor is called *free air delivery* (FAD) – it is the amount of air (at atmospheric condition) that can be drawn into the inlet of a compressor. It is a standardised measure used to express the capacity of air compressors.

To determine the free air delivery of a compressor the following information is required:

- the atmospheric pressure at the inlet of the compressor (P_1)
- the air temperature at the inlet side (T_1)
- the compressor discharge pressure (P_2)
- the discharge air temperature (T_2)
- the volume of the air discharged (V_2), from the compressor.

FAD can be obtained by working back from the discharge volume, relating its pressure and temperature to inlet conditions using the Combined or Ideal Gas Law, as shown below where V_1 is the amount of FAD.

$$V_1 = \frac{V_2 P_2 T_1}{P_1 T_2}$$

Compressor accessories

Intercoolers

The most effective way of controlling air temperature between the stages of a multi-stage air compressor is by the use of intercoolers. Intercooling is used to achieve the following:

- reduce the temperature of the air between stages
- reduce the volume of the air to be compressed in the succeeding stage
- condense water vapour *and*
- reduce the power requirements of the prime mover.

An intercooler is a heat exchanger which generally employs the same cooling medium as the compressor which it serves. For example, water-cooled compressors use water-cooled intercoolers and air-cooled compressors use air-cooled intercoolers.

Air-cooled intercoolers may have a small number of finned tubes through which the hot air passes under pressure or may be of the radiator type with many tubes. Cooling air is forced over the fins to dissipate the heat.

Water-cooled intercoolers may consist of a nest of tubes enclosed in a shell or casing. The cooling water flows through the tubes as the hot air passes through the casing. In other types, the air flows through the tubes with the water outside. Whichever method is used, water flow is generally in the opposite direction to air flow. Perfect intercooling is attained when the temperature of the air leaving each stage is equal to the inlet air temperature.

Intercoolers require periodic maintenance to ensure the cooling mechanism is operating efficiently. The fins of air-cooled intercoolers should be kept clean. Water-cooled intercoolers should have clear water passages that are free of scale and other foreign materials that may reduce their efficiency. An example of a compressor with an intercooler is illustrated in the following figure.

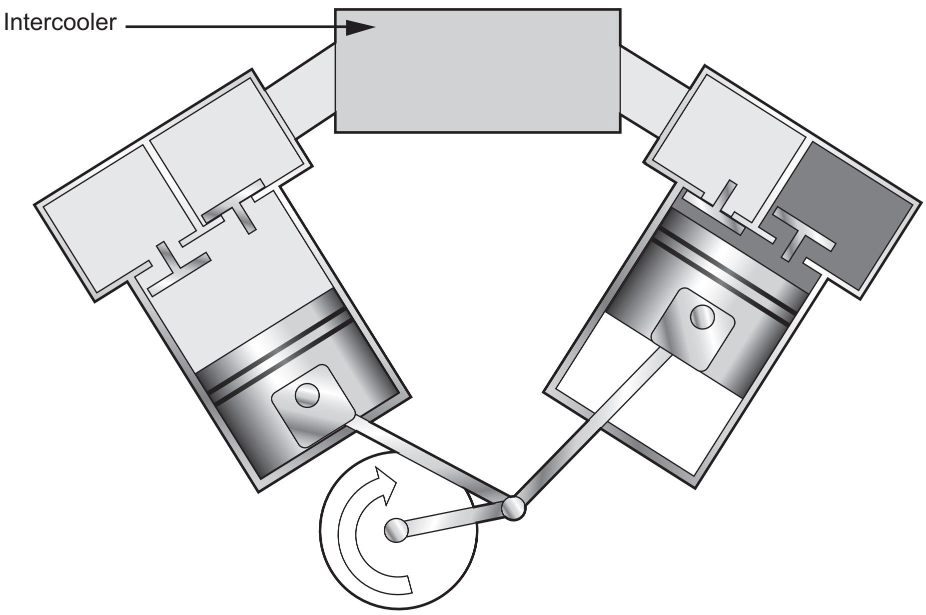


Figure 43: Reciprocating compressor with intercooler

A pressure-relief valve must be fitted to an intercooler and should be manually operated regularly. Automatic drains should also be checked for correct operation.

Intake filters

To ensure reliable operation, a compressor should always be supplied with clean, cool and dry air at the intake. Without filtration, abrasive pollutants in the air would become suspended in the lubrication oil and cause wear on cylinders, piston rings, bearings etc. A good air filter should satisfy the following requirements:

- High separation efficiency – the filter should permit large quantities of pollutants to collect on the filter element without significantly reducing its other properties.
- Good accumulation capacity – this prolongs the intervals between filter cleaning.
- Low air resistance – the resistance exerted by a filter varies slightly with the type. Oil-bath filters have a pressure drop across the element of 15 millibars.

Control methods

The demand for air in most factories fluctuates throughout the day, so some type of control system is needed to match supply and demand. Where no air is sometimes required, or demand small, an automatic stop–start system may be used.

Other methods of controlling compressors include:

- inlet throttling
- bypass control
- exhaust regulation
- variable speed control
- bypass/blow-off.

After coolers

When air is compressed, the reduction in volume is accompanied by a substantial rise in temperature. Heat is an undesirable by-product of compression. If the hot air was delivered directly from the compressor, the discharge pipe would lengthen due to heat-related expansion. On shutdown, the pipe would contract as it cooled. The repeated cycle of expansion and contraction would result in leaking joints and inefficiency due to air loss. So, instead of passing hot air directly into an air receiver, the air is generally passed through an aftercooler.

An aftercooler is a heat exchanger and, as its name implies, it removes the heat of compression from the air after it leaves the final stage of the compressor. Aftercoolers may be air-cooled or water-cooled. The method of cooling generally depends on the type of cooling used for the compressor; air-cooled aftercoolers are generally used with air-cooled compressors. The temperature of the compressed air leaving the aftercooler is usually about 100 ºC above that of the cooling water inlet – or 120–160 ºC above ambient temperature when an air-cooled aftercooler is used.

Apart from removing excess heat from compressed air, cooling also reduces the moisture-carrying capacity of the air. Provided they are correctly sized, aftercoolers can separate up to 90 per cent of the water originally contained in the intake air. An aftercooler should be fitted with an efficient water separator, preferably with an automatic drain valve.

Air leaving an aftercooler is generally dry enough for most applications. However, some operations require drier air, in which case air dryers are used. The three main types of air dryer are:

- refrigerant
- absorption
- adsorption.

Activity 8 – Air compressors

The following questions are designed to determine your understanding of air compressors before you apply it to your practical activities. Most are 'multiple choice', which you should answer by selecting one of the options and ticking the relevant box.

Question 1

Name the two main classifications of air compressors

______________________________ and ______________________________

Question 2

Multi-staging of compression is done to:

☐ a) reduce air temperature

☐ b) obtain better efficiency

☐ c) reduce noise levels

☐ d) increase air temperature

☐ e) remove condensate from the system

☐ f) increase the air velocity to the speed of sound.

Question 3

Identify the type of pneumatic compressor illustrated below.

☐ a) reciprocating

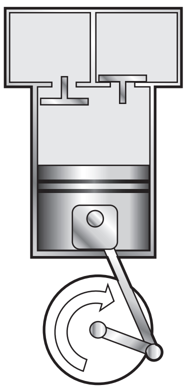
☐ b) positive displacement

☐ c) screw

☐ d) dynamic

☐ e) *a* and *d*

☐ f) *a* and *b.*



Question 4

A compressor intercooler is located:

☐ a) after the final stage of compression

☐ b) between stages of compression

☐ c) at the compressor inlet

☐ d) after the air receiver.

Question 5

Dynamic rotary compressors:

☐ a) provide pulsation-free air delivery

☐ b) have a positive seal between the moving member and the housing

☐ c) are oil-flooded compressors

☐ d) produce low volume at high pressure.

Question 6

Diaphragm compressors usually:

☐ a) are rotary-type compressors

☐ b) provide oil-free air

☐ c) have no inlet and outlet valves

☐ d) are usually multi-staged

☐ e) deliver pulsating air

☐ f) *b* and *e*.

Question 7

Some rotary screw compressors:

☐ a) use gears to synchronise the screws

☐ b) can be oil-flooded

☐ c) can be oil-free

☐ d) may incorporate an oil separator

☐ e) all of the above

☐ f) are considered to be dynamic-type compressors.

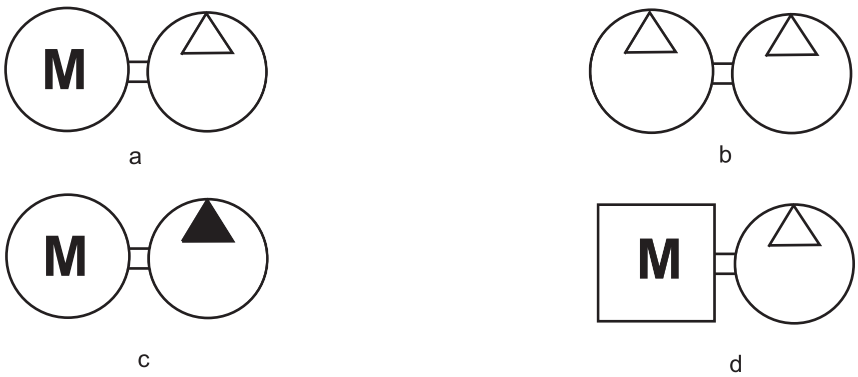
Question 8

Vane compressors:

- ☐ a) operate at high rpm for vane tip sealing
- ☐ b) can be oil-flooded
- ☐ c) are considered to be positive displacement
- ☐ d) *a* and *c*
- ☐ e) all of the above.

Question 9

Identify an electric-motor-driven compressor from the fluid power symbols below.



- ☐ a)
- ☐ b)
- ☐ c)
- ☐ d)

Question 10

In a multi-stage reciprocating compressor, the size of the pistons:

- ☐ a) gets larger as the stages of compression increase
- ☐ b) remains the same as the stages of compression increase
- ☐ c) becomes smaller as the stages of compression increase
- ☐ d) alternates as the stages of compression increase.

Section 4 – Pneumatic control valves

In this section you will be studying several types of control valve. Pneumatic control valves are used to control the velocity and direction of air flow through a pneumatic system.

Recommended reading

Chapter 2, pages 10–35, on 'Direction control valves', in *Pneumatic Control for Industrial Automation* (Rohner).

Chapter 4, pages 60–67, on 'Flow controls', in *Pneumatic Control for Industrial Automation* (Rohner).

Recommended viewing

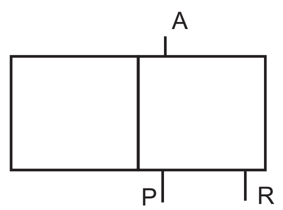
Industrial Pneumatic Technology video series: 'Control of Pneumatic Energy'.

Activity 9 – Control valves

The following questions are designed to allow you to check your understanding of pneumatic control valves. Many are 'multiple choice' questions, which you should answer by selecting one of the options provided and ticking the relevant box.

Question 1

Sketch the symbol for a 3/2 NC push-button directional control valve operated with spring return.



Question 2

A check valve is used in conjunction with a flow-control valve to:

☐ a) allow flow control in both directions

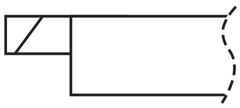
☐ b) regulate flow and free reverse flow

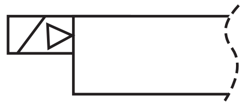
☐ c) allow temperature-compensated flow

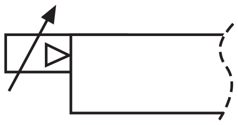
☐ d) allow pressure-compensated flow.

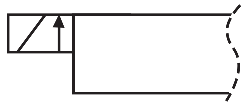
Question 3

Which of the following diagrams represents an electrically activated pilot-operated valve actuator?

a) 

b) 

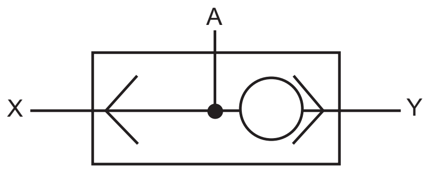
c) 

d) 

- ☐ a)
- ☐ b)
- ☐ c)
- ☐ d)

Question 4

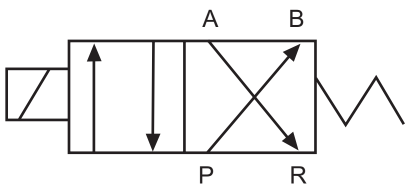
The component illustrated at right is a:



- ☐ a) check valve
- ☐ b) flow-control valve
- ☐ c) pilot-operated check valve
- ☐ d) shuttle valve.

Question 5

The component illustrated at right is a:



- ☐ a) 4/2 pilot-operated directional control valve
- ☐ b) 4/4 solenoid-operated directional control valve
- ☐ c) 2/4 spring-operated directional control valve
- ☐ d) 4/2 solenoid-operated directional control valve.

Question 6

Another name for an 'AND' valve is a:

- ☐ a) shuttle valve
- ☐ b) disc valve
- ☐ c) two-pressure valve
- ☐ d) memory valve.

Question 7

A 5/2 toggle-disc directional control valve is a:

☐ a) memory valve

☐ b) poppet valve

☐ c) flat slide valve

☐ d) spool valve.

Question 8

Placing two normally closed (NC) 3/2 directional control valves in series can have the same effect as a:

☐ a) time-delay valve

☐ b) quick-exhaust valve

☐ c) AND-function valve

☐ d) impulse valve.

Question 9

An impulse valve is used in a pneumatic circuit to:

☐ a) eliminate opposing signals

☐ b) act as a time delay

☐ c) slow down cylinder extension

☐ d) regulate air pressure.

Question 10

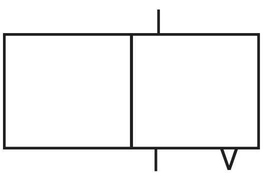
Complete the following statement. One feature of a toggle-disc DCV is its...

Question 11

Name the type of DCV that has the capability to automatically adjust for wear.

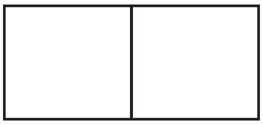
Question 12

Complete the symbol for a time-delay valve.



Question 13

Complete the symbol for a pressure-sensing valve.



Question 14

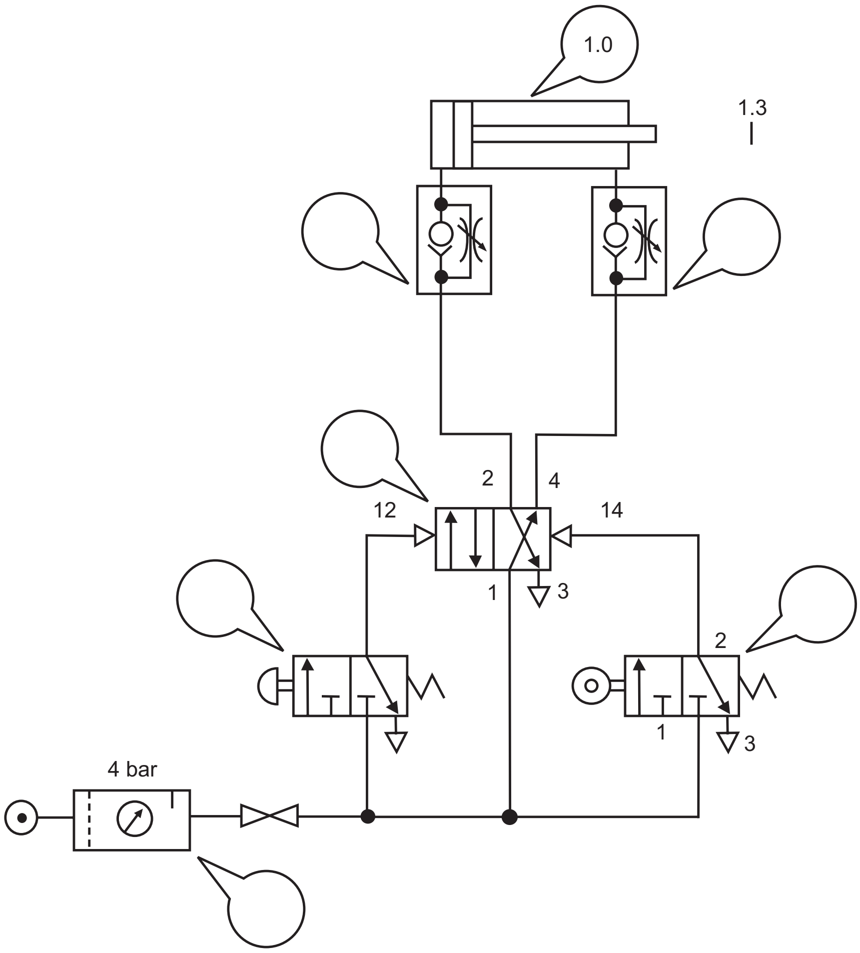
Sketch the symbol for a two-pressure valve (AND valve).

Question 15

Sketch the symbol for a shuttle valve (OR valve).

Question 16

Complete the numeric labelling of the pneumatic circuit illustrated below, using the blank labels provided.



Section 5 – Air service units

Air service units (ASU) – or filter, regulator, lubricator units (FRL) – are used to perform the following system functions:

- filter the air and remove condensate (water) prior to use and thus provide the pneumatic machine or tool with clean air
- limit maximum system pressure in a pneumatic circuit and thus provide the pneumatic machine or tool with the correct working pressure
- provide working elements with the correct amount of lubrication where required.

Recommended reading

Chapter 12, pages 193–203, on 'Compressed air servicing', in *Pneumatic Control for Industrial Automation* (Rohner).

Recommended viewing

Industrial Pneumatic Technology video series:
'Pressure Control Valves'.

To summarise what you have covered in your readings, the main points are as follows.

- The ASU can consist of three units, which can be separate components or combined as a module to meet the needs of the system.
- Where oil-free air is required, the lubricator may not be used.
- The filtration unit is generally rated 40 to 60 microns, depending upon system requirements.
- The filter not only removes contaminants from the air but also separates condensate.
- Filters can have a manual or automatic drain to remove any condensate trapped in the filter bowl.
- Because filter bowls can be made of polycarbonates, care must be taken to ensure that these parts are not exposed to volatile chemicals such as acetone.
- Polycarbonate bowls should be cleaned with soapy water and thoroughly dried.
- The filter may be incorporated with a pressure regulator (pressure-reducing valve) in one modular unit.
- The pressure-reducing valve (regulator) is a normally-open valve that senses downstream pressure.
- The pressure regulator can be provided with a secondary relief function.
- Air-line lubricators work on a venturi principle and can be of the oil fog or mist type.

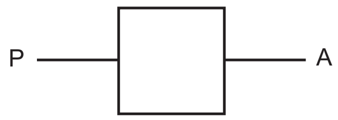
- The lubricator should be located as close as possible to the pneumatic machine to prevent the oil from coalescing (and returning to a liquid state) in the air lines.
- Only the correct type of lubricant (usually light mineral oil) and oil-feed rate should be used.
- Ideally, the air service unit should be located as close as possible to the machine.

Activity 10 – Air service units

The following questions are designed to determine your understanding of air service unit principles before you apply them to your practical activities and undertake your underpinning knowledge assessment for this section.

Question 1

Complete the following sketch of the simplified symbol for an ASU.



Question 2

Complete the following statement.

An air-line filter is used to remove ___________________ and ___________________

Question 3

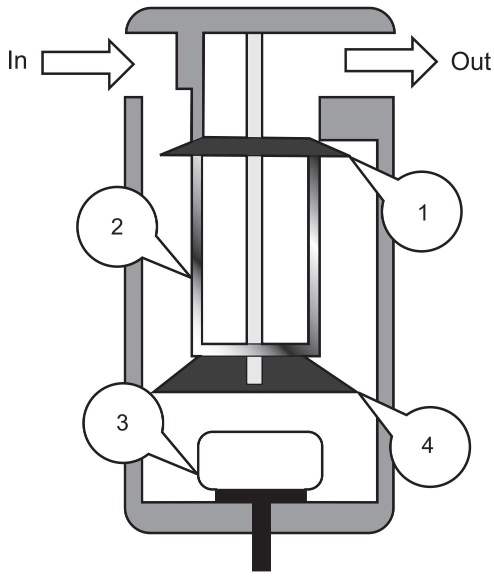
In the space below, sketch the symbol for an air-line filter with automatic drain.

Question 4

Item 1 in the figure opposite is a:

Question 5

The function of the above item is to:



Question 6

Item 2 in the figure opposite is a:

Question 7

Item 3 in the figure opposite is a:

Question 8

Item 4 in the figure opposite is a:

Question 9

Polycarbonate filter and lubricator bowls should be cleaned with:

☐ a) soapy water

☐ b) solvents

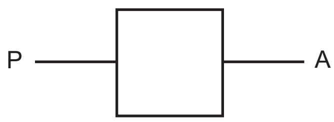
☐ c) acetone

☐ d) mild abrasives

☐ e) ammonia.

Question 10

Complete the following sketch of the symbol for a pressure-reducing valve (regulator).



Question 11

A pressure-reducing valve (regulator):

☐ a) is a normally-closed valve

☐ b) senses downstream pressure

☐ c) is located after a lubricator

☐ d) can be used as a logic valve.

Question 12

Name the two main types of air-line lubricator.

a. ____

b. ____

Question 13

What is the purpose of the baffle in an ASU?

____

____

Section 6 – Pneumatic circuit construction (optional exercises)

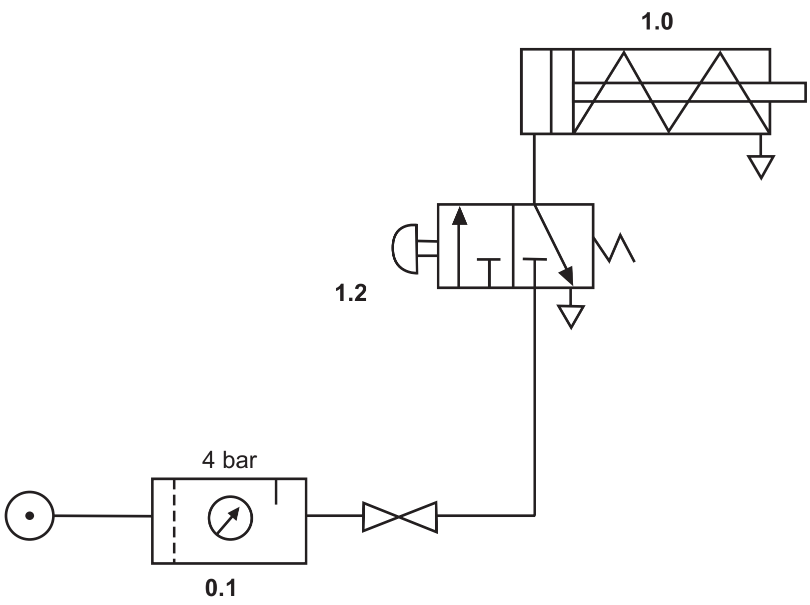
The following exercises are designed to familiarise the learner with pneumatic components and their function in a system. These exercises are non-assessable and, although recommended, are optional.

Read the following notes before constructing the circuits on the pneumatic trainers.

1. Examine the pneumatic circuit starting at the air supply and finishing at the actuator, ensuring circuit operation and component identification is understood.
2. Locate the pneumatic components and mount them on the circuit trainer board.
3. Fit an isolation valve to the pressure connection of the air service unit (ASU) on the trainer. (This valve must be closed during circuit construction to isolate the pressure line.)
4. Select suitable hoses and connect to the circuit components.
5. On completion of circuit construction, check the following:
    - air-flow paths
    - that connection of hoses is correct (they are not kinked or twisted)
    - that hose bends are larger than their minimum radiuses.
6. Start the trainer and test the circuit by operating the directional control valves. If the circuit does not operate correctly, check the following:
    - that all hoses are correctly connected
    - that the correct components have been selected
    - that all the components on the circuit drawing have been included in the circuit construction
    - that the air supply is connected
    - for system pressure (4 bar is sufficient).

Circuit 1

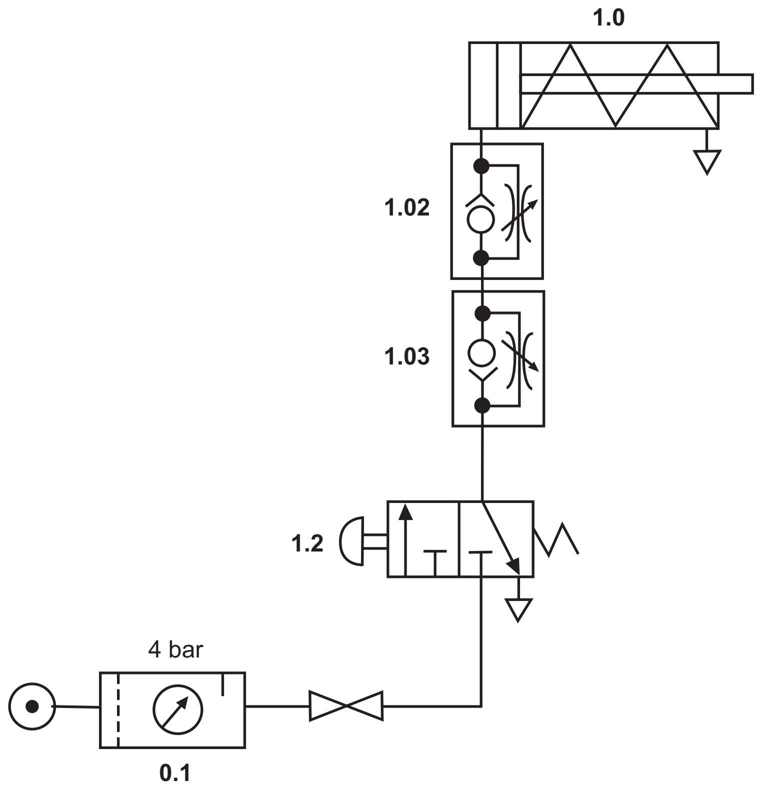
The piston of a single-acting cylinder is to move out when a button is pressed and return when the button is released.



Note: Any manual activation device for the DCV may be used – including push-button, lever-operated etc.

Circuit 2

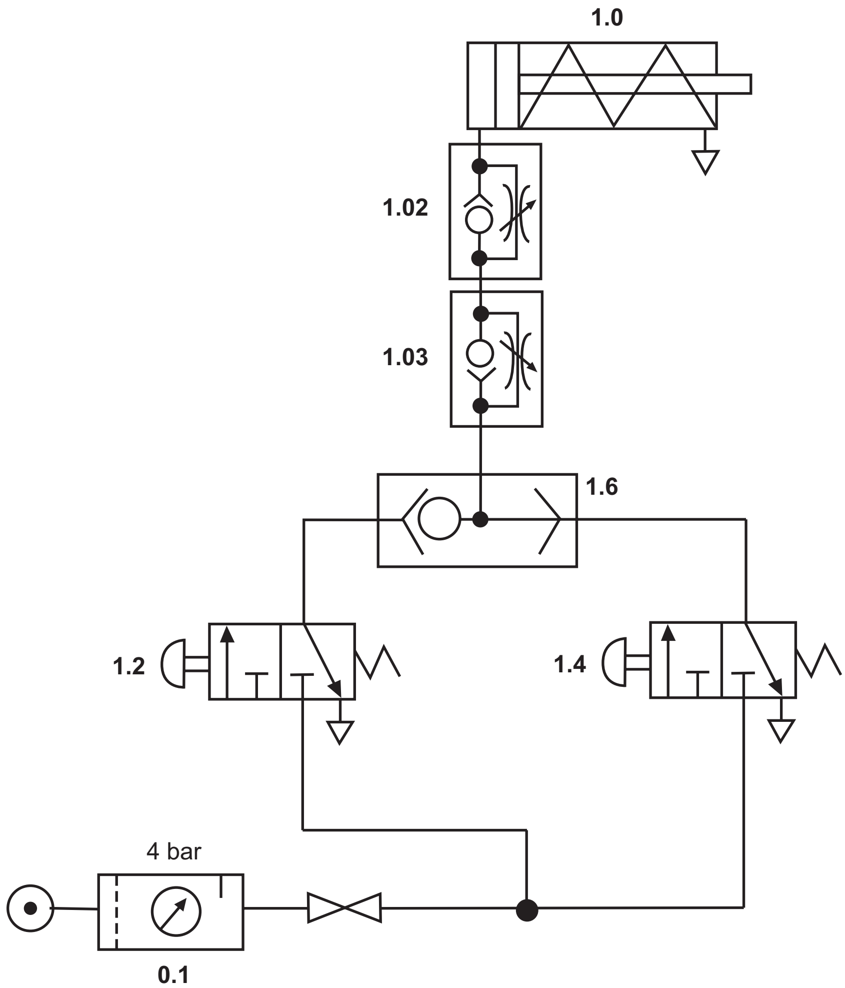
The piston of a single-acting cylinder is to move out when a button is pressed and return when the button is released, with speed control in both directions.



Note: Any manual activation device for the DCV may be used – including push-button, lever operated etc.

Circuit 3

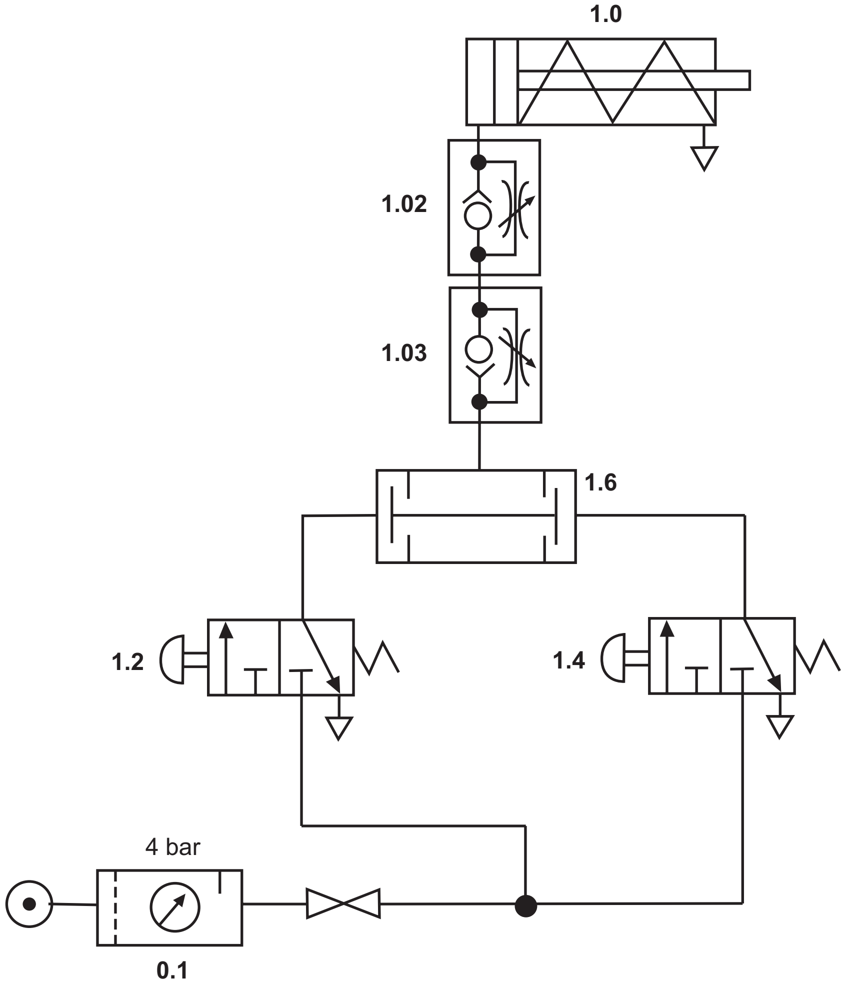
The piston of a single-acting cylinder is to move out when either of the control valves are actuated and return when they are released, with speed control in both directions.



Note: Any manual activation device for the DCV may be used – including push-button, lever-operated etc.

Circuit 4

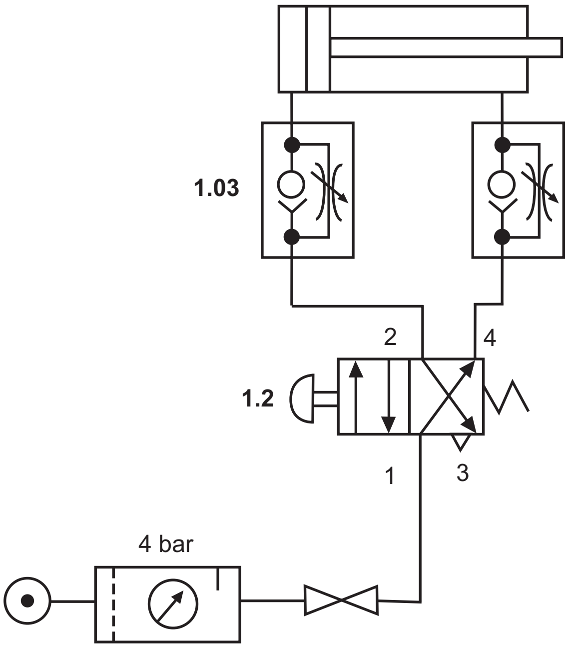
The piston of a single-acting cylinder is to move out only when both of the control valves are actuated and return when they are released, with speed control in both directions.



Note: Any manual activation device for the DCV may be used – including push-button, lever-operated etc.

Circuit 5

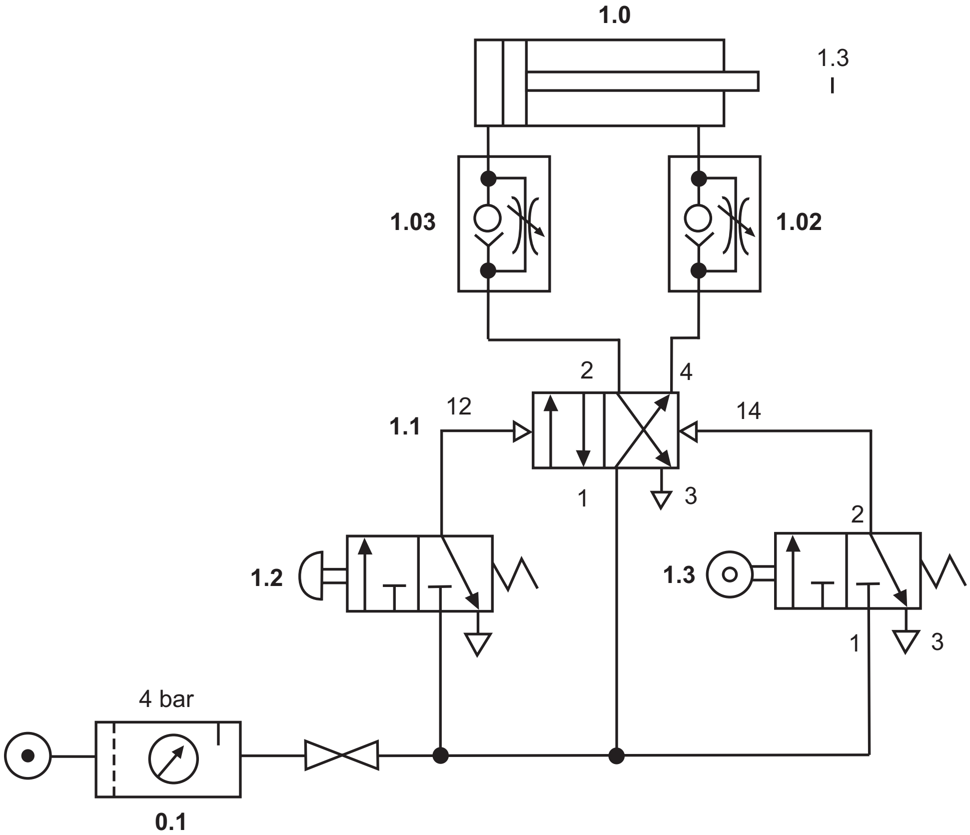
The piston of a double-acting cylinder is to move when both of the control valves are actuated and return when they are released, with speed control in both directions.



Note: Any manual activation device for DCV 1.2 may be used – including push-button, lever-operated etc.

Circuit 6

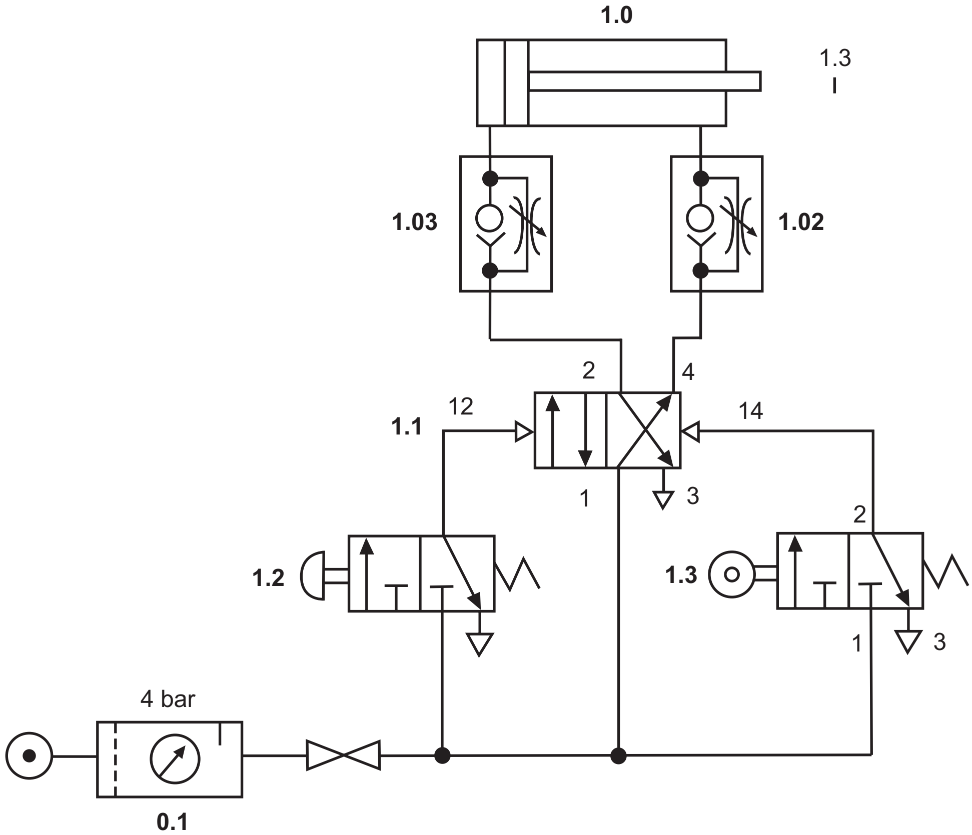
The piston of a double-acting cylinder is to extend when DCV 1.2 is activated and retract when DCV 1.3 is activated. The cylinder is to have speed control in both directions.



Note: Any manual activation device for the DCVs 1.2 and 1.3 may be used – including push-button, lever-operated etc.

Circuit 7

The piston of a double-acting cylinder is to extend when DCV 1.2 is activated and retract automatically when DCV 1.3 is activated. The cylinder is to have speed control in both directions.

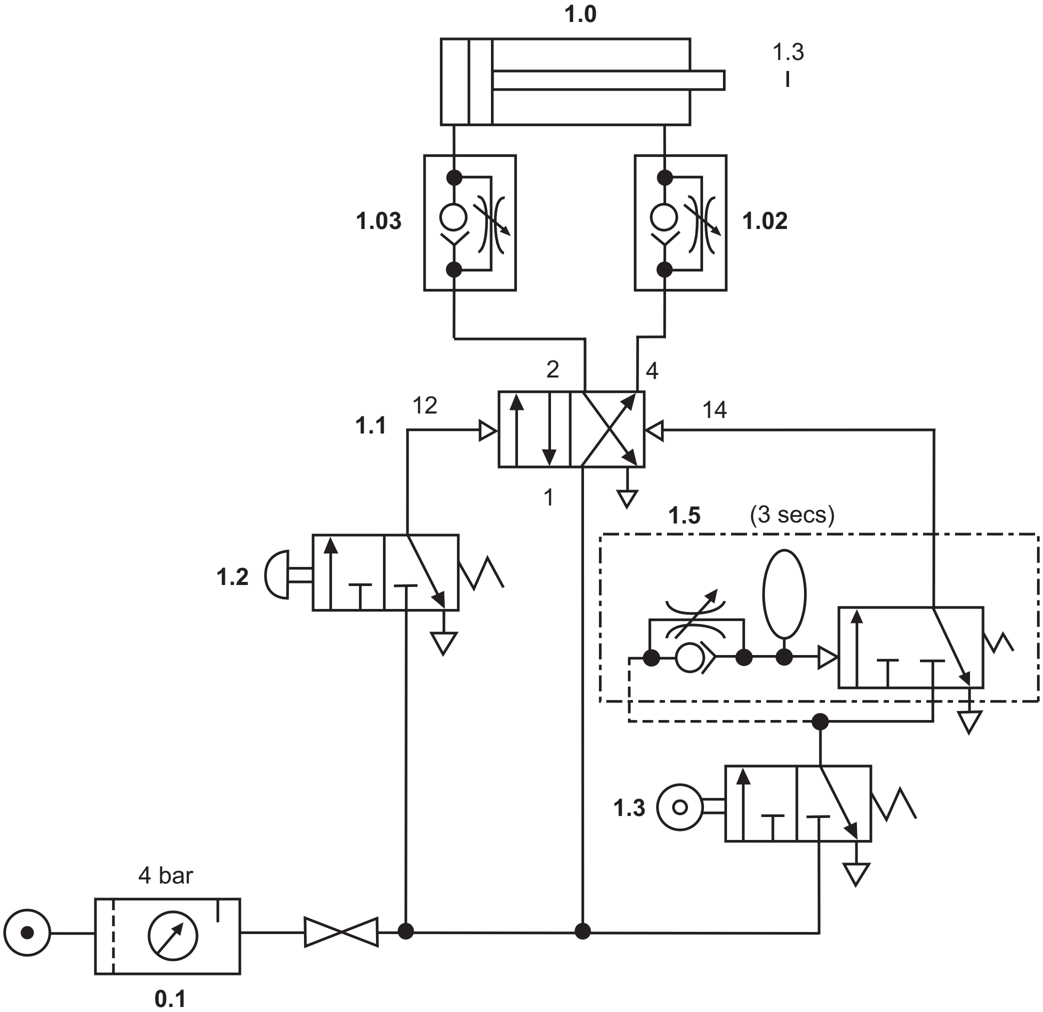


Note: Any manual activation device for the DCV 1.2 may be used – including push-button, lever-operated etc.

A 4/2 or 5/2 DCV may be used for 1.1.

Circuit 8

The piston of a double-acting cylinder is to extend when DCV 1.2 is activated and retract automatically after three seconds when 1.3 is activated. The cylinder is to have speed control in both directions.

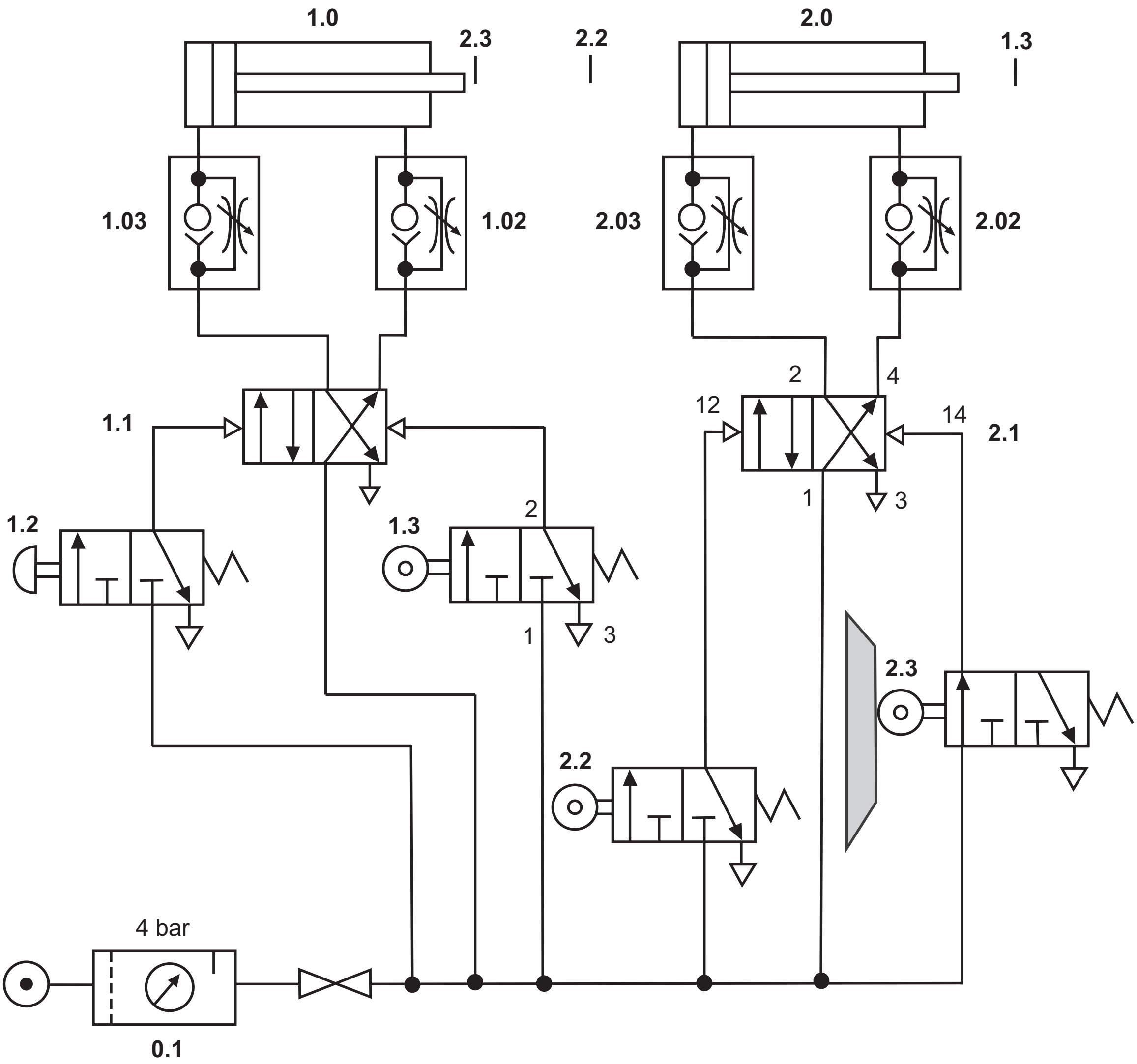


Note: Any manual activation device for the DCV 1.2 may be used – including push-button, lever-operated etc.

A 4/2 or 5/2 DCV may be used for 1.1.

Circuit 9

The piston of double-acting cylinder 1.0 is to extend when DCV 1.2 is activated. When DCV 2.2 is activated, cylinder 2.0 will also extend. When cylinder 2.0 has extended, it will activate 1.3 which will cause cylinder 1.0 to retract. When cylinder 1.0 has retracted, it will activate 2.3 which will cause cylinder 2.0 to retract. The cylinders are to have speed control in both directions. The sequence of operation is: 1.0 extend, 2.0 extend, 1.0 retract, 2.0 retract.



Note: A 4/2 or 5/2 DCV may be used for 1.1.

Answers

Section 1

1. d 2. a 3. c

4. c 5. d 6. a

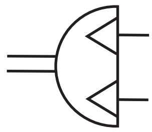
7. c 8. b 9. b

10. d 11. a 12. d

Section 2

1. e 2. c 3. d

4. e 5. c 6. c

7. a 8. a 9. 

10. b 11. c 12. c

13. b

Section 3

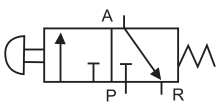
1. *Dynamic and positive displacement* 2. b

3. f 4. b 5. a

6. f 7. e 8. e

9. a 10. c

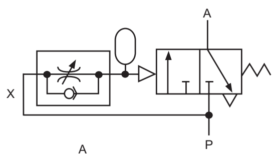
Section 4

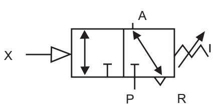
1. 

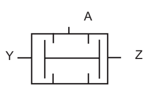
2. b 3. b

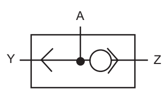
4. d 5. d 6. c

7. a 8. c 9. a

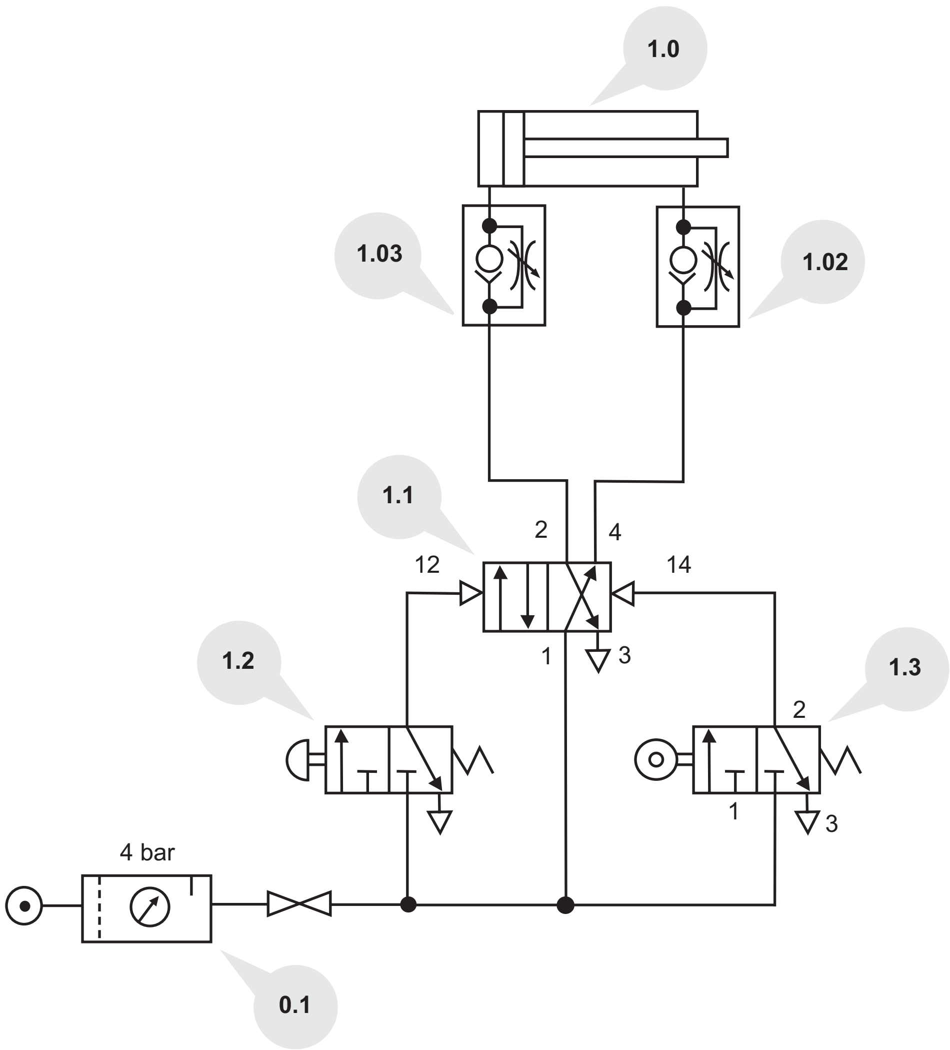
10. fast response time 11. flat slide valve 12. 

13. 

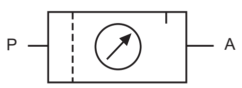
14. 

15. 

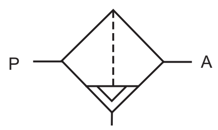
16.



Section 5

1. 

2. Condensate and dust

3. 

4. Swirl vanes

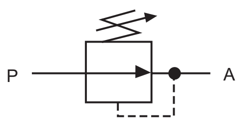
5. Create swirling action of the air

6. Filter

7. Automatic drain

8. Baffle

9. a

10. 

11. b

12. Fog and mist

13. To create a ‘quiet’ zone

MAINTAIN PNEUMATIC SYSTEM COMPONENTS MEM18018C

Learner's Guide

This workbook is part of a series of resources developed for students undertaking units from Certificate IV in Engineering (Fluid Power). It covers content and activities derived from the unit MEM18018C Maintain pneumatic system components.

CATEGORY
Engineering, Mechanical and Electrical

TRAINING PACKAGE
- MEM05 – Metal and Engineering

COURSE/QUALIFICATION
- MEM40105 Certificate IV in Engineering (Fluid Power)

UNITS OF COMPETENCY
- MEM18018C Maintain pneumatic system components

RELATED PRODUCTS
- ENG704 – Certificate IV in Engineering (Fluid Power) Assessment Tools (CD)
- ENG705 – Certificate IV in Engineering (Fluid Power) Practical Workbook 1
- ENG706 – Certificate IV in Engineering (Fluid Power) Practical Workbook 2
- ENG707 – Certificate IV in Engineering (Fluid Power) Student Workbook 1
- ENG708 – Certificate IV in Engineering (Fluid Power) Student Workbook 2
- ENG709 – Certificate IV in Engineering (Fluid Power) Student Workbook 3
- ENG710 – Certificate IV in Engineering (Fluid Power) Student Workbook 4
- ENG970 – Maintain Hydraulic System Components Learner's Guide
- ENG971 – Maintain Hydraulic Systems Learner's Guide
- ENG973 – Maintain Pneumatic Systems Learner's Guide

GOVERNMENT OF WESTERN AUSTRALIA

ORDERING INFORMATION:
Contact WestOne Services on Tel: (08) 6212 9700 Fax: (08) 9227 8393 Email: sales@westone.wa.gov.au
Orders can also be placed through the website: www.westone.wa.gov.au

ENG972 MAINTAIN PNEUMATIC SYSTEM COMPONENTS LEARNER'S GUIDE
ISBN 978-1-74205-242-7
9 781742 052427