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ABSTRACT

This unit on pneumatics, for use in postsecondary programs, is organized in eight sections. Each section consists of information sheets with line drawings and multiple-choice questions for each topic in the sections. Answers are provided at the back of the book. The following topics are covered: (1) introduction--pressure, principles of gases, uses of pneumatics; (2) safety; (3) compressors; (4) air treatment; (5) pneumatic piping systems; (6) pneumatic valves; (7) cylinders; and (8) miscellaneous valves/air logic and diagrams. Knowledge-based competency objectives are provided for each topic. (KC)

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PNEUMATICS

Knowledge-Based Competency Objectives

Section 1: Introduction

1. Distinguish between a gas, liquid, and fluid.
2. Identify the three areas of pressure evident in pneumatic systems.
3. Identify the three basic principles of gases.
4. Know the applications and advantages of pneumatics.

Section 2: Safety

1. Know both personal and equipment safety measures regarding pneumatics.
2. Know the safety color coding for pneumatics.

Section 3: Symbols and Formulas

1. Be familiar with pneumatic symbols and formulas.

Section 4: Compressors

1. Know the various compressor groups, types, and operations.
2. Know the unloading methods for output control.

Section 5: Air Treatment

1. Know the types of driers used in pneumatics.
2. Be familiar with the types of filters used to remove contaminants from air.
3. Know the process of refrigeration.

Section 6: Piping Systems

1. Know the pneumatic piping systems, how to check for air leaks and join pipes.

Section 7: Valves

1. Know the two main categories of valves and the valves that fall into those categories.

2. Know valve functions and operations.

Section 8: Cylinders

1. Know the types of cylinders and their functions.

2. Know the various mounting styles of cylinders.

PNEUMATICS OUTLINE

I. Introduction
- A. Pressure
- B. Principles of Gases
- C. Uses of Pneumatics
- D Advantages and Disadvantages of Using Pneumatics

II. Safety
- A. Personal Safety
- B. Equipment Safety
- C. O.S.H.A.
- D. Solvents
- E. Electrical Shock
- F. General Safety
- G. Sobey Color Code for Pneumatic Systems

III. Compressors
- A. Types of Compressors
  - 1. Positive displacement
    - a. reciprocating piston
    - b. vane
    - c. helical
      - 1. dry
      - 2. oil-flooded
    - d. diaphragm
    - e. lobed-rotor
    - f. single and double acting
  - 2. Dynamic
    - a. radial
    - b. axial flow
- B. Control of Compressor Capacity
  - 1. Common unloading methods for output control
    - a. bypass
    - b. start-stop
    - c. inlet valve regulation
    - d. inlet throttling
    - e. inlet closure
- C. Noise Levels
- D. Compressor Ventilation
- E. Compressor Installation

IV. Air Treatment
- A. Driers
  - 1. absorption
  - 2. adsorption
  - 3. low temperature
- B. Aftercooling
- C. Filters
  - 1. air filters
  - 2. dry filters

D. Receiver Tank

V. Pneumatic Piping Systems
   A. Types of Pipe
      1. plastic
      2. copper
   B. Pipe Systems
      1. grid
      2. decentralized
      3. loop
   C. Joint Types
      1. joining plastic pipe
      2. joining copper pipe
         a. compression joint
         b. flared joint
         c. soldered joint
   D. Installation Requirements
   E. Air Leaks

VI. Pneumatic Valves
   A. Pressure Control Valves
      1. Relief Valves
      2. Reducing Valves
         a. constant reduced pressure valve
         b. fixed-amount reduction valve
   B. Directional Control Valves
      1. check valve
      2. rotary valve
      3. spool valve
      4. two-way directional valve
      5. three-way directional valve
      6. four-way direcitonal valve
      7. valve operation and control
      8. manually operated valves
      9. automatically operated valves
      10. solenoid valves
      11. pilot actuated valves

VII. Cylinders
   A. Types
      1. single-acting cylinders
         a. diaphragm cylinder
         b. rolling diaphragm
      2. double-acting cylinders
         a. vane cylinder
   B. Cylinder Mounting Styles
      1. fixed centerline mounting
      2. fixed noncenterline mounting
      3. pivoted cylinder mountings

VIII. Miscellaneous Valves/Air Logic and Diagrams

A. Quick Exhaust Valves
B. Silencers or Mufflers
C. Air Boosters
D. Air Logic Symbols
E. Actuating Devices Symbols
F. Schematic Diagrams

PNEUMATICS

I. INTRODUCTION TO PNEUMATICS

Pneumatics is derived from the Greek word pneumatikos, which means air or wind. The word has evolved to include any gas under pressure used to perform work. Pneumatics, along with hydraulics, are commonly combined into a larger family of power systems, and referred to as fluid power system. Fluid power systems use gases, liquids, and fluids to transfer energy.

A fluid is a substance that flows easily and tends to take on the shape of its container. A fluid can either be a gas (such as compressed air, nitrogen, or carbon dioxide) or a liquid (such as oil or water). A liquid is a substance that is capable of being poured. An important distinction to remember is that all gases are fluids, but not all fluids are gases. Further, a fluid system that uses gas is a pneumatic system. Pneumatic systems use compressed air to transmit force from one point to another.

A. PRESSURE

Pressure is defined as force divided by the area over which the force is exerted. Pressure can be measured by either pounds per-square-inch gage (PSIG) or pounds per-square-inch absolute (PSIA).

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{\text{lbs.}}{\text{sq. in.}} = \text{PSIG}$$

Atmospheric pressure is measured in pounds per-square-inch (PSI), and at sea level is 14.7 PSI. Atmospheric pressure decreases as altitude increases. Therefore, the pressure of the atmosphere on a 10,000 ft. mountain top will be less than on a beach at sea level.

Pneumatic system pressure is the pressure of the compressed gas working within the system measured in PSI. PSIG readings are the norm and are commonly referred to as PSI. PSIA is primarily used in theoretical applications such as for design criteria.

B. PRINCIPLES OF GASES

Since pneumatic systems refer to tools using gases to create force, it is important to know three basic principles of gases. The first principle is that gases have no shape. Gases take the shape of their container. This makes them easy to pipe anywhere. The second principle is that gases are highly compressible. The third principle is that gas transmits pressure equally in all directions when force is applied. Regardless of a container's shape or size, the amount of pressure transmitted remains the same provided the amount of force is constant.

C. USES OF PNEUMATICS

Some uses of pneumatics can be found listed below.

Air Brake	Drilling	Pressurizing
Air Cylinder	Elevating	Process Control
Air Motor	Forming	Reaming
Chipping	Grinding	Riveting
Clamping	Hoisting	Screw Driving
Conveying	Painting	Stapling

D. ADVANTAGES AND DISADVANTAGES OF USING PNEUMATICS

There are both advantages and disadvantages of using pneumatics.

Some advantages include:

1. Air is readily available and easy to transport.
2. Air is a stable, and therefore safe, gas.
3. Speeds and forces of pneumatic systems vary indefinitely.
4. Pneumatic tools and equipment can handle an overload of pressure without damaging the equipment.

Some disadvantages of pneumatics include:

1. It is difficult to deliver constant compressed air to system tooling.
2. The overall cost of systems and tooling is expensive.

QUESTIONS -- INTRODUCTION

Choose the best answer for the following:

1. ______ ________ means any gas under pressure used to perform work.

    a. Compression
    b. Reciprocation
    c. Pneumatics
    d. Adsorption

2. A ____________ has no distinct shape or volume.

    a. Liquid
    b. Gas
    c. Fluid
    d. All of the above

3. A substance that flows easily and takes the shape of its container is a:

    a. Ice
    b. Fluid
    c. Plastic
    d. Solid

4. Two pressures in a pneumatic system are:

    a. Pneumatic and atmospheric
    b. Atmospheric and vacuum
    c. Pneumatic and atomic
    d. Atmospheric and phosphoric

5. The three principles of gases are:

    a. Gases are highly compressible
    b. Gases have no shape
    c. Gases transmit pressure equally
    d. All of the above
    e. a and b only

II. SAFETY

In working with pneumatic systems, safety conscious personnel and safe operating equipment result in a smooth running, productive operation. Personnel must always read and understand safety rules and regulations before working on specific equipment and before routine maintenance occurs. The following are safety rules workers must be concerned with when working on or around pneumatic systems or compressed air.

A. PERSONAL SAFETY

1. When working on or cleaning compressed air systems, eye protection (i.e. safety goggles or glasses) should be worn.

2. Hearing protection should be worn if long exposures to noise are encountered.

3. Never check for leaks, and never block air in a compressed air system with hands, arms, feet, etc.

4. Never direct compressed air towards or near co-workers or passers-by, as highly pressurized air can pass through skin and cause a great deal of injury or even death.

5. Loose clothing and loose articles of jewelry should not be worn around rotating or energized equipment.

6. Long hair should be tied back so that it does not become caught in equipment.

7. Keep bare skin away from hot equipment to avoid severe skin burns.

8. Make sure appropriate personnel are advised of locations of workers performing maintenance.

9. Workers should avoid working on energized equipment.

B. EQUIPMENT SAFETY

1. Compressed air systems must be deenergized and drained of system pressure before maintenance can be attempted. If necessary, tag out circuit breakers and valves.

2. The condition of pneumatic system hoses, pipes, wiring, and other equipment must be continuously checked for signs of deterioration and wear. Replace equipment if required.

3. Keep all work areas and machinery clean of dirt and oil contaminants.

4. Always use properly sized tanks, valves, and system piping to ensure that equipment will handle system operation pressures properly.

5. Compressed air equipment must be secured or held down while it is being energized, so any possible whipping action concerning flexible hosing can be controlled.

6. New or replacement components should be inspected for flaws or possible defects before installation.

7. For proper and safe operation of pneumatic systems, follow manufacturers installation and repair procedures.

8. Strictly adhere to a regular maintenance schedule and keep all prior records of previously performed maintenance.

9. The correct tools should always be used for the performance of operations regarding pneumatic systems. Substitution and use of improper tools can damage the system.

C. O.S.H.A.

O.S.H.A. stands for the Occupational Safety and Health Act that was established in 1970 within the Federal Department of Labor. This act establishes guidelines and rules that must be followed by employees to ensure the safety and health of workers in all phases of industry. Production should never be an excuse for personnel safety violations. Potential or suspected hazards should be reported to the proper safety officials within your company for further evaluation.

D. SOLVENTS

Even though pneumatic systems do not employ the use of chemical solvents, maintenance or cleaning operations may require their use. Always be aware of manufacturers' directions and safety requirements regarding solvents. Smoking should not be permitted during solvent use as the solvents may be flammable and/or explosive.

E. ELECTRICAL SHOCK

To prevent electrical shock when working with pneumatic systems, make sure the correct breakers are turned off and tagged to prevent inadvertent energization of electrical circuits.

F. GENERAL SAFETY

It is the employers' responsibility to ensure that safety guidelines are followed. Safety regulations should be posted and made available to all employees. It is the employees' responsibility to read, understand, and follow these regulations. The list of safety rules in this section is not all-encompassing. Federal, state, and local rules and regulations must be taken into consideration along with manufacturers' guidelines and company rules regarding safety.

G. SOBEY COLOR CODE FOR PNEUMATIC SYSTEMS

These colors for safety are universally standard for pneumatic systems.

Red = Supply pressure

Orange = Working pressure

Yellow = Metered flow

Blue = Exhaust

Violet = Intensified pressure

QUESTIONS -- SAFETY

Complete the following statements by selecting the best answer.

1. O.S.H.A. stands for:

   a. Occupied Safe Housing Authority
   b. Occupational Safe and Healthy Actions
   c. Occupational Safety and Health Act
   d. Organized Safety Health Activity

2. Although pneumatic systems do not use ____________ in their operations, they may be used for maintenance and cleaning.

   a. Alcohol
   b. Gasoline
   c. Cement
   d. Solvents

3. ____________ should be posted and made available to all employees.

   a. All safety rules and regulations
   b. State rules and regulations
   c. Federal guidelines
   d. State safety practices

4. Working pressure is designated by the color:

   a. Yellow
   b. Orange
   c. Red
   d. Green

5. Supply pressure is designated by the color:

   a. Violet
   b. Black
   c. Yellow
   d. Red

III. COMPRESSORS

Compressors are devices that convert air at atmospheric pressure into pressurized air. The pressurized air is then used to accomplish work.

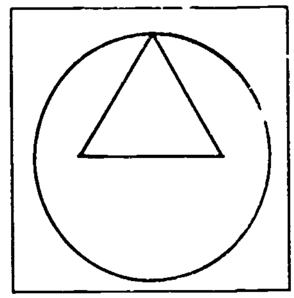


Fig. 1 Compressor Logic Symbol

A partial vacuum at an inlet filter is created by the compressor. This partial vacuum allows the air at atmospheric pressure to flow through an inlet filter into the compressor. The compressor reduces the volume of the air while increasing the air's pressure. Once the air has been compressed, it travels to a storage tank through compressor discharge valves. Only when the tank pressure is low does the compressor operate. When the compressor is running, air flows into the storage tank. The maximum storage tank pressure is preset by a control which shuts the compressor off when the desired pressure is reached. Discharge valves prevent the flow of air back to the compressor.

A. COMPRESSOR TYPES

Compressors can be classified into two groups, <u>positive displacement</u> and <u>dynamic</u>. In positive displacement compressors, pressure increases because of a decrease in the volume of trapped air. In dynamic compressors, pressure increases due to energy added to a moving gas through acceleration. These two groups of compressors can be further classified into types of compressors

1. <u>Positive Displacement Compressor Types</u>
   Positive displacement compressors compress air to high pressures for use in pneumatic power systems. These types of compressors include reciprocating piston, vane, helical, diaphragm, lobed, single and double-acting compressors.

   a. <u>Reciprocating Piston Compressor</u>
      The reciprocating piston compressor is the most common type of positive displacement compressor. These compressors may be lubricated or non-lubricated, depending upon the application. Defined as a cylinder located within a bore, the cylinder is attached to a motor. The reciprocating piston compressor is a single stage compressor, generally used for systems which require 40 - 100 PSIG of compressed air, and in some cases can operate up to 250 PSIG.Operation of this compressor occurs as the piston moves down in the bore.

The intake valve is opened; thus bringing in new air. As the piston begins its upward travel in the bore, the intake valve is closed and the pressure is increased as the piston moves upward. As the pressure within the bore reaches the desired level, the output valve is opened to release the pressurized air.

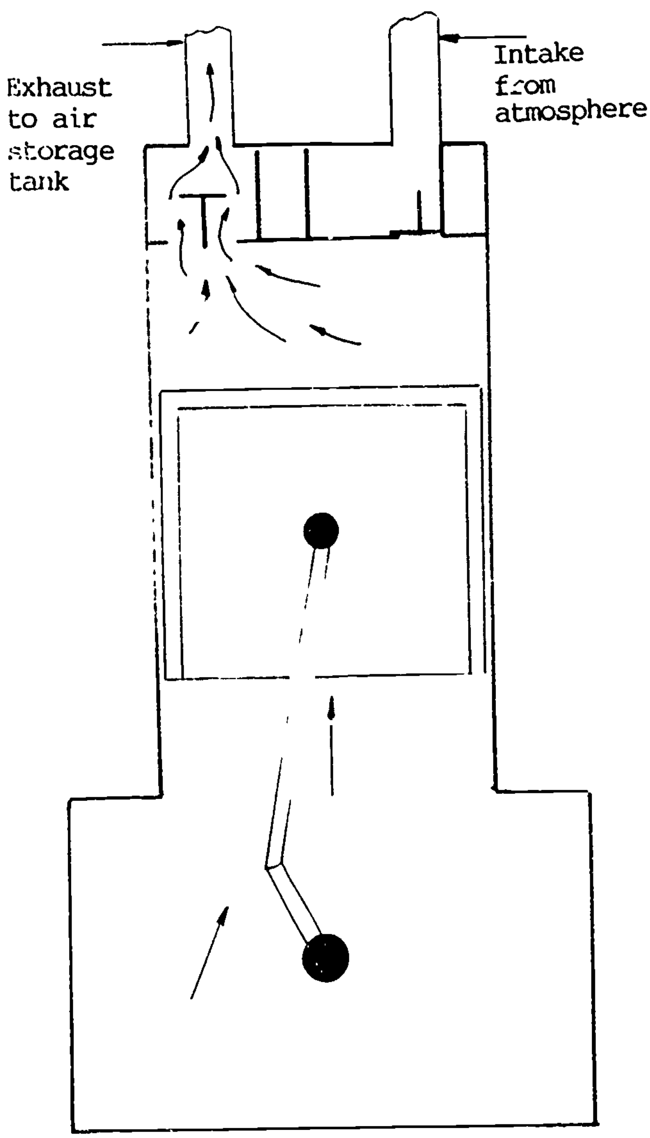


Figure 3 - Compressor, Exhaust Stroke

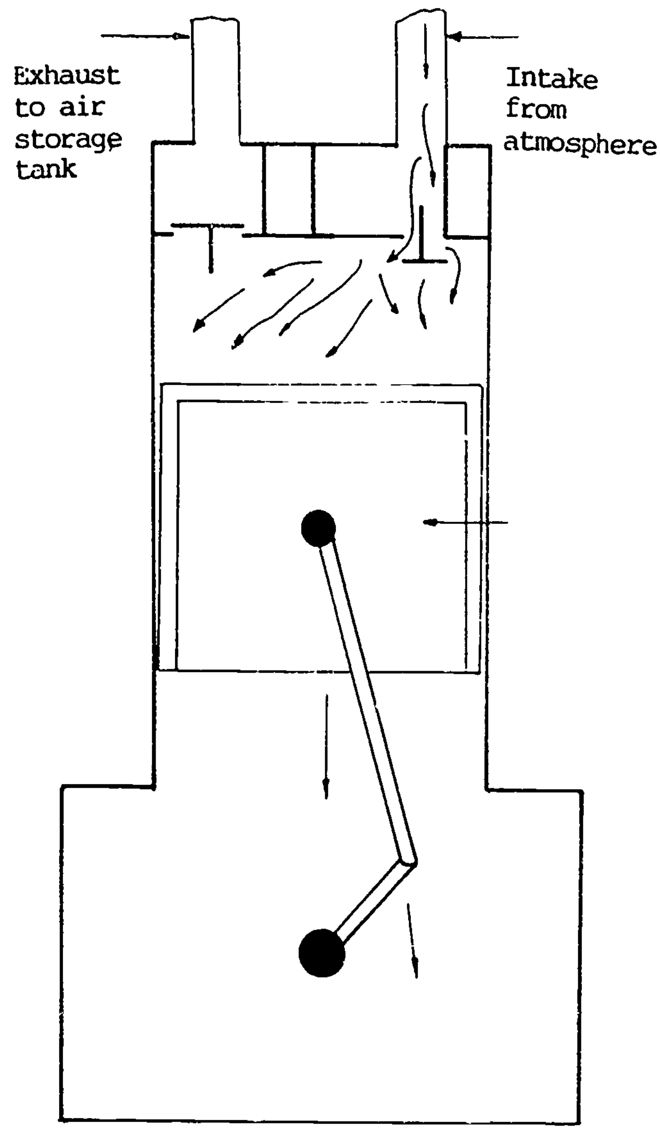
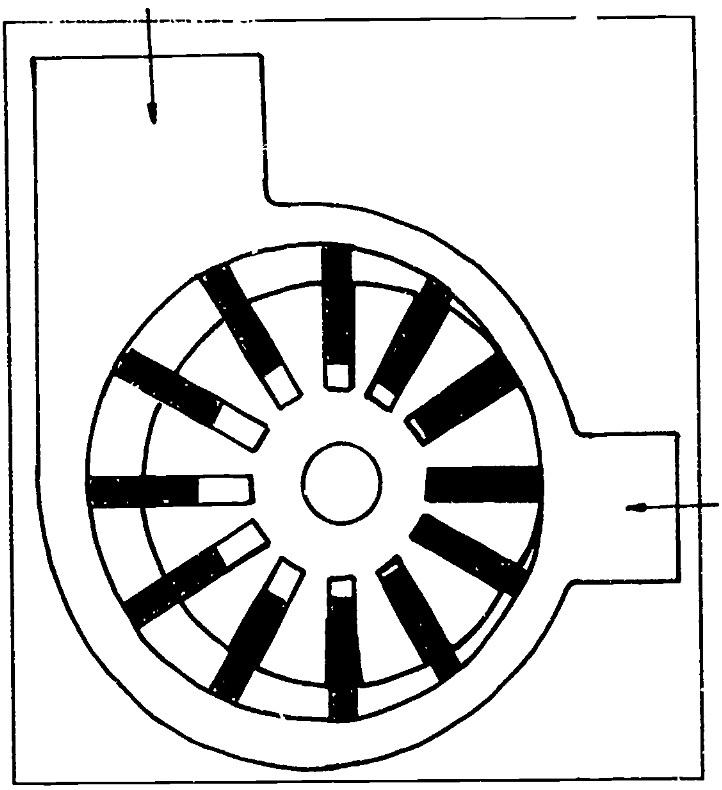


Figure 2 - Compressor, Intake Stroke



b. Vane Compressor

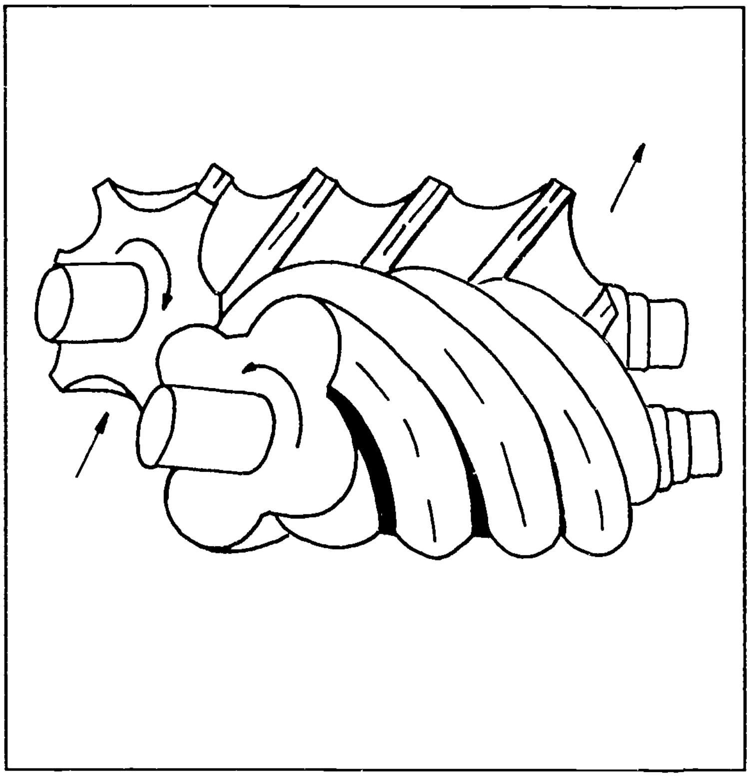
The vane compressors are classified as the most effective of the rotary positive displacement compressors. The pumping action of the compressor is created by vanes tracking along the cirular housing of the compressor.

Fig. 4 - Vane Compressor

As illustrated above, these compressors utilize vanes that are free floating within a rotor that is offset within a circular housing. Vanes are typically made of carbon or cloth embedded in daelonic resin to provide low friction. Vane compressors have low operating costs and may generate pressures up to 150 PSIG. Operation of this compressor occurs as the motor turns the rotor, pulling in non-pressurized air from the intake side of the compressor. The centrifugal force of the rotor rotation keeps an air-tight seal with the vanes touching only the circular housing. The rotor is positioned off center to create both increasing and decreasing volumes of air in the housing as the vanes rotate. As the rotor turns, the vanes create negative air pressure, causing air to be drawn into the compressor. As the rotor continues turning, the vanes limit the air to smaller and smaller spaces. The chamber reduces in size, forcing air out the exhaust and towards the storage tank. Thus the air is compressed and converted into a pressurized form of output. Vane compressors are compact and run quietly, with a smooth and steady delivery of air.

c. <u>Helical compressors</u>
The helical compressor is also referred to as the screw compressor because of the way its two rotors mesh together, resembling two screws.

Fig. 5 - Helical Screw

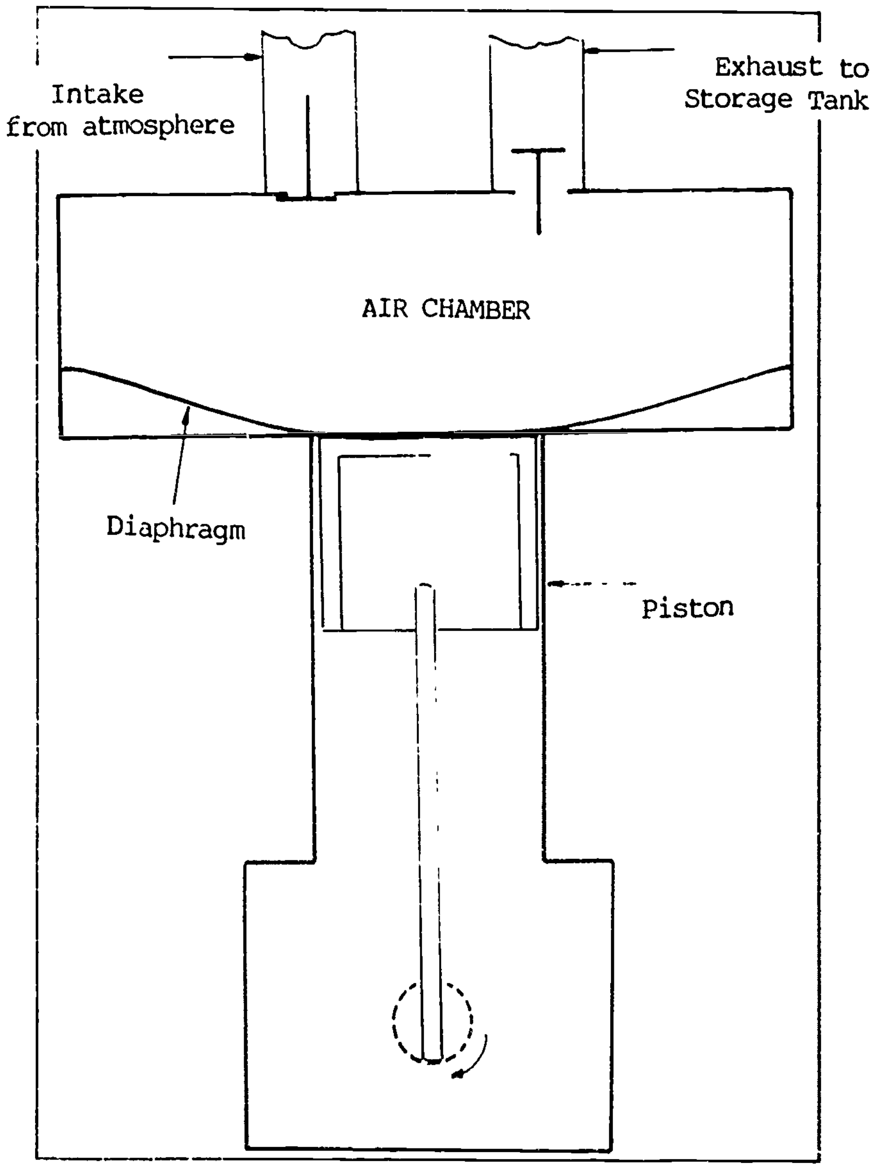


Helical compressors operate by running two meshed rotors together to generate compressed air by drawing air in one end of the compressor and exiting it from the other end. There are two basic types of helical compressors, dry or oil flooded. Both types may deliver up to 125 PSI.

1. **Dry helical compressors** usually do not require lubrication, because of their machined clearance. Timing gears are used to turn the two screws. Dry helical compressors run at high rpm and are very efficient.

2. **Oil flooded helical compressors** do not have timing gears, but lubrication is needed because the screws run on each other and the oil provides an airtight seal. Oil separators must be utilized to keep downstream air clean of oil residue in the compressor.

d. <u>Diaphragm compressors</u>
The diaphragm compressors received their name from the diaphragm part used to intake and export air from the compressor chamber. The diaphragm separates the compressor piston from the air chamber, and its purpose is to prevent air contamination by the lubricating oils of the compressor.



The compressor first lifts the diaphragm to draw air into the compressor chamber. As the diaphragm plate reverses its stroke, the intake valve is closed and the exhaust valve is opened. The volume of the air is reduced, and the air is piped into the storage tank. As the piston moves downward, the diaphragm also moves downward, thus increasing the volume in the air chamber. These compressors have many light duty applications, and operate at roughly 30 to 40 PSIG.

Figure 6 - Diaphragm Compressor

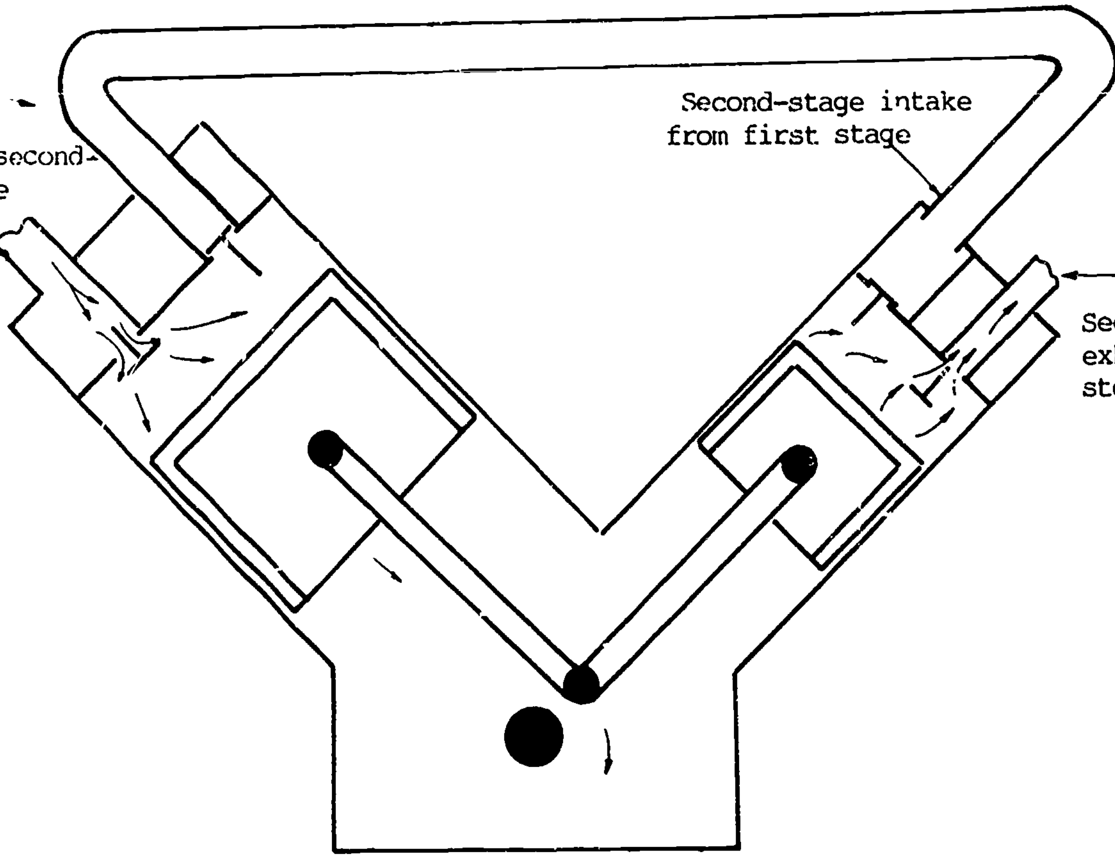


Figure 8 - Two-Stage Compressor

The large piston performs the first compression. As the large piston moves downward in the bore, the intake valve is opened and air is brought into the cylinder at the bottom of the stroke. The inlet valve then closes as the piston moves upward, and the compression begins. The air is compressed until a specific pressure is reached, at which time the outlet valve opens and the pressurized air is directed through the intercooler to the second stage piston. As the small piston reaches the bottom of its stroke, the inlet is closed and the second stage of compression begins. As the small piston moves upward and the appropriate pressure is reused, the valve opens to exhaust the second stage pressurized air.

2. <u>Dynamic Compressor Types</u>
   Dynamic compressors deliver large quantities of air up to 125 PSIG. These compressors are used mainly at a high volume of low pressure air. The two main types of dynamic compressors are <u>radial</u> and <u>axial flow</u>.

a. Radial Compressors

The radial compressor is used at very high speeds to create pressures, but they have a minimum flow capacity. A radial flow compressor, also known as a centrifugal air compressor, is made up of several chambers labeled as stages. Each stage has an impeller located in it. As air enters a stage, the rotating impeller directs the air out of the stage. The air then follows the chamber, and is routed back to the center to proceed to the next stage. Thus, as the air passes through each stage its pressure increases. In the final stage, the air is routed either to a storage tank or to the working part of the pneumatic system.

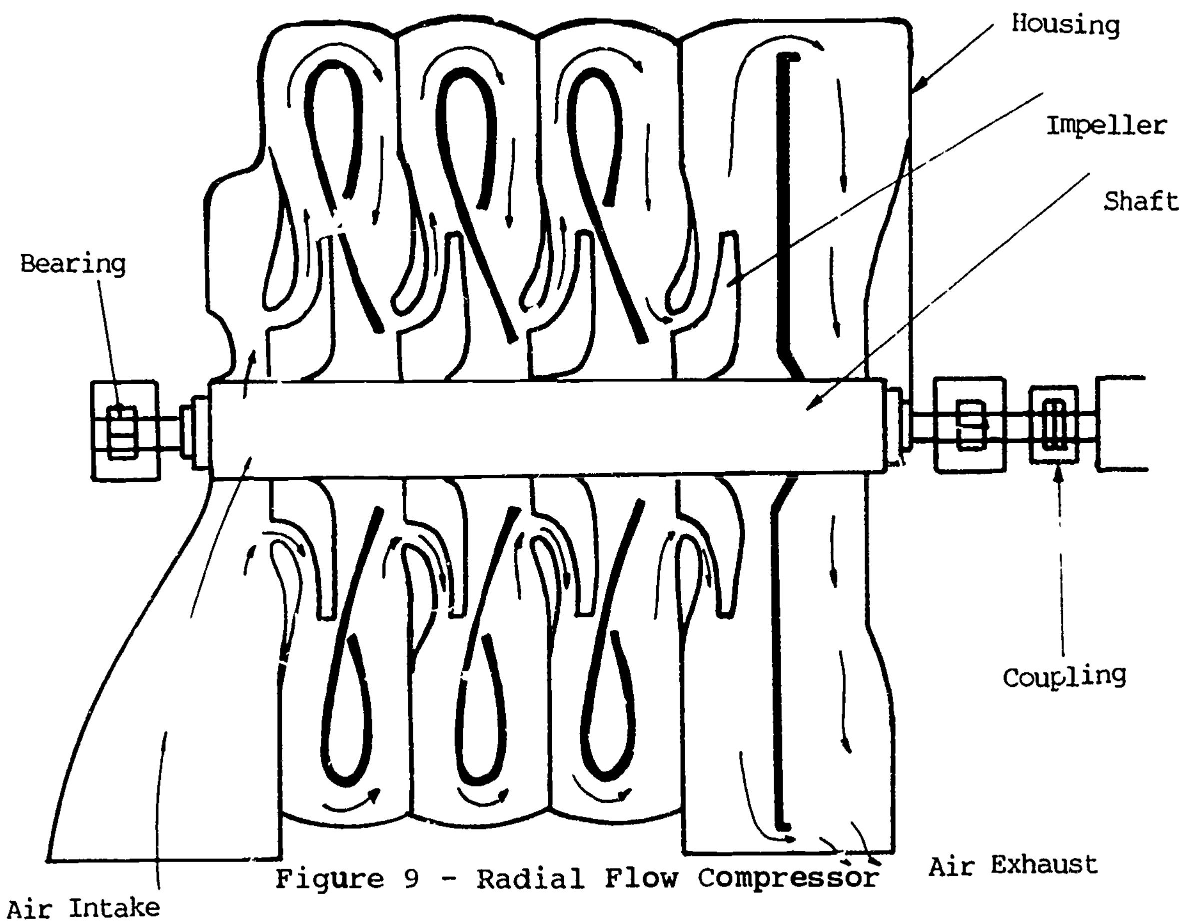


Figure 9 - Radial Flow Compressor

b. Axial Flow Compressors

These compressors are used for high volumes of air, and operate at high speeds. The air flows axially through the compressor. Axial flow compressors have impellers with vanes that rotate at high speeds within the housing of the compressor. As air enters the housing near the center of the impeller it is directed outward by centrifugal force. The housing, due to its shape, funnels the air and creates the pressure of the air.

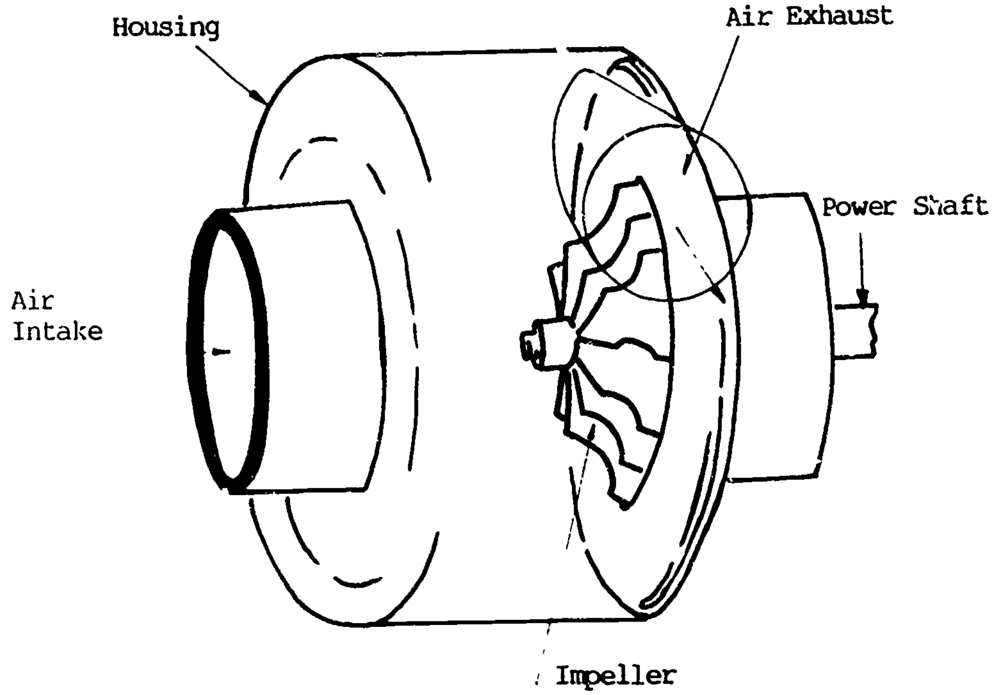


Figure 10 - Axial Flow Compressor

B. CONTROL OF COMPRESSOR CAPACITY

Compressors must be regulated to meet the demands of the pneumatic system. The means by which this is controlled is through the unloading of the compressor by manual or automatic methods. A pressure control sensor is normally used to control output pressure.

There are five common unloading methods for output control:

1. Bypass--This method consists of bleeding highly pressurized excess air into the atmosphere, causing the compressor to continuously run.

2. Start-Stop--This method consists of starting and stopping the compressor as its minimum and maximum pressures are reached. This can be achieved by starting and stopping the motor, but this may cause early motor failure due to the frequency of the start-stop procedures.

3. Inlet valve regulation--In this method, the inlet valve is held open when no demand for air exists. Thus air is allowed to enter and exit in the same location without undergoing compression.

4. Inlet throttling--This method regulates the air admitted into the cylinder by increasing or decreasing the air flow at the inlet port of the compressor. This method requires higher horsepower demand as the compression increases.

5. Inlet closure--In this method, the inlet valve is closed during unloading, which creates an internal vacuum. This method is seldom used in modern compressor systems.

C. NOISE LEVELS

Air Compressors generate noise. Impaired hearing is a concern of every industrial worker and prolonged exposure to certain levels of noise may cause permanent damage. The Occupational Safety and Health Act (O.S.H.A.)

identifies permissible noise levels in the chart below.

PERMISSIBLE NOISE EXPOSURE	
Duration per Day, Hours	Sound level dBA
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4	115

Compressed air system sound may have many different sources. The following are factors which may increase the noise levels near compressors: the position of the compressor in the room (i.e. against a wall), the sound characteristics of the room, items in the room that may absorb or reflect sound, and the location of the compressor inlet.

D. COMPRESSOR VENTILATION

The amount of ventilation needed will depend on the type of compressor installed. The compressor or housing area should be well ventilated to prevent overheating of components and to prolong the life of the compressor. Good ventilation will also curb excess energy consumption. For proper ventilation, air should be pulled from low points and exhausted at opposing high points. This will prevent interference with compressor operation and workers.

E. COMPRESSOR INSTALLATION

Compressors should be placed close to where they will be used, so that pressure drops are lower and versatility of the compressor is increased. When installing a compressor, intake air should be cool, dry, and drawn from a clean external source. The intake duct should have a flow area that is larger than the piston area. This will allow smooth air flow to the compressor. Additionally, the intake air should be filtered to help prevent contaminants from being introduced into the system. Air filters should be serviced regularly so they maintain their qualities to prevent dirt and other particulate matter from entering the compressor.

QUESTIONS -- COMPRESSORS

Select the best answer for the following:

1. Radial and axial are the two basic groups of compressors.

   T or F

2. The following are types of positive displacement compressors:

   a. Centrifugal air compressor
   b. Reciprocating piston compressor
   c. Vane compressor
   d. Both a and b
   e. All of the above

3. The helical compressor is also referred to as a screw compressor, and operates by the meshing of two rotors.

   T or F

4. <u>Impellers</u> are:

   a. Vanes on motor
   b. Housing parts
   c. Lobes of rotors
   d. Pistons

5. The two types of dynamic compressors are:

   a. Axle and vane
   b. Radial and axial
   c. Axial and inlet
   d. Helical and radial

6. Which of the following are methods of output control (unloading):

   a. Inlet valve regulation
   b. Bypass
   c. Inlet throttling
   d. Start-stop
   e. All of the above

7. Intake air should not be filtered to prevent contaminants from entering the system with regards to installation.

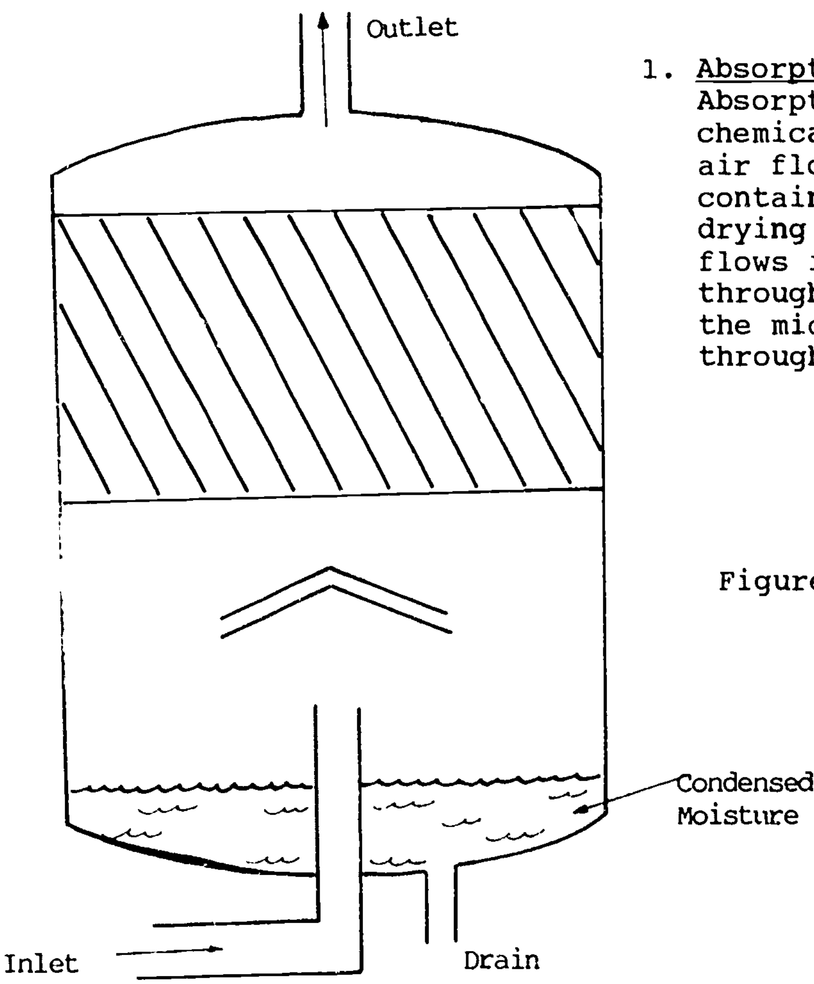
   T or F

IV. AIR TREATMENT

In a pneumatic system, moisture presents the greatest threat. Moisture is introduced to the system simultaneously with the air. The amount of moisture varies depending on the amount of the relative humidity in the air. As the air is compressed, the moisture in the condenses. As the amount of air in the system incr es, so does the moisture. An after cooler is placed next to the system since warm air holds more moisture than cool air. The cooler air flows through a separator, condensing and removing most of the moisture. In-line dryers and filters are then used to further remove moisture before the air enters the system. The air may also contain particulate matter that was not picked up by the intake filter, and this must also be removed. Complete treatment of compressed air includes drying, refrigerating, aftercooling, and filtering.

A. DRIERS

Three types of driers are used to remove moisture; absorption driers, adsorption driers, and low-temperature driers.



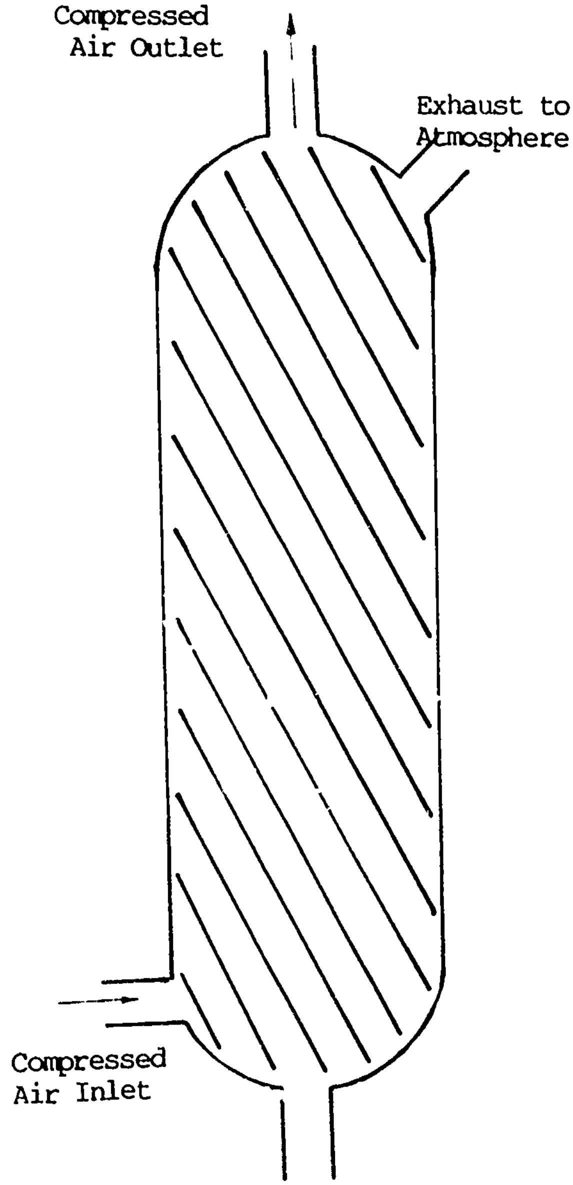
1. <u>Absorption drying</u>
   Absorption drying is a chemical process in which air flows through a container which contains a drying agent. The air flows in at the bottom through a hemical agent in the middle, and out through the top.

Figure 11 - Absorption Drier

The drying agent will also filter out oils and oil vapors. Therefore, an intake oil filter must be installed on the intake to the absorption dryer to extend the life of the chemical.

2. Adsorption drying
   Adsorption drying is a physical process in which a drying agent collects or adsorbs water on its surfaces. The drying agent eventually becomes saturated with water. Hot air can be pumped through the dryer and vented to the room atmosphere. This process then removes the moisture from the drying agent and the agent may be used again.

Figure 12 - Adsorption Drier



3. Low temperature drying

Low temperature drying is a mechanical method of removing moisture. First the air is moved through an air/air heat exchanger and through a separator to remove water. The air is then passed through a refrigeration process to cool the air to its dew point. More moisture is condensed and run through a second separator where more water is removed. Finally, the compressed air is run back through the air/air heat exchanger and out to the system.

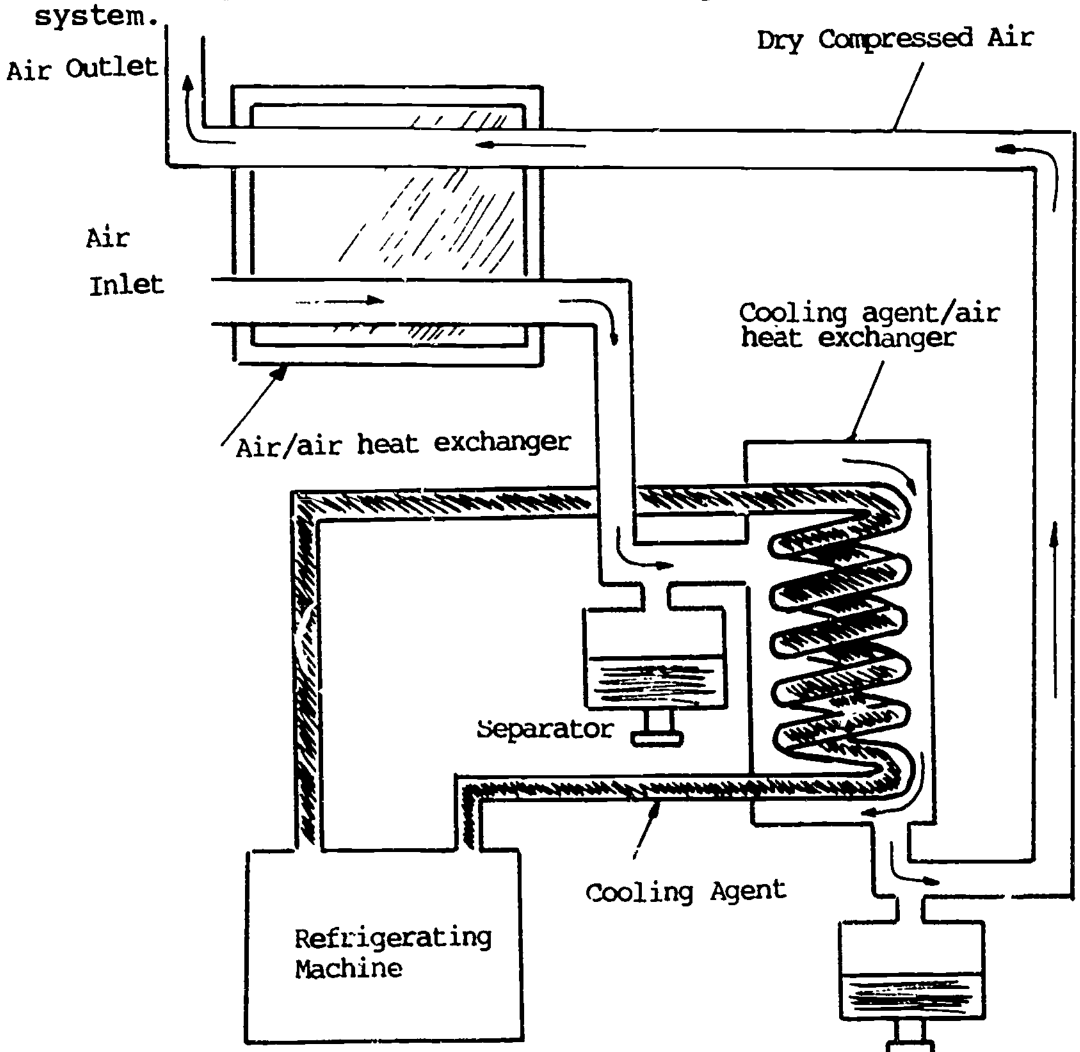


Figure 13 - Low-temperature Drier

B. AFTERCOOLING

Aftercoolers are used frequently to cool air which has been heated by the compression process. The aftercooling process may be accomplished by passing cool water or air over an aftercooling chamber. Dirt and oil vapor fall out of suspension in this chamber and are removed with a separator or filter.

C. FILTERS

1. Air Filters

Air filters remove airborne particulate and may also remove water from the air. Air flows downward over a baffle section which starts a swirling motion in the bowl and throws the particles out of the air. A second baffle collects the particulate under it while deflecting air upwards towards a porous type filter on its way out. A draw plug at the bottom of the filter may be used to manually remove water or it may also be removed automatically. Another type of air filter contains a filter bowl and porous filter. In this type, the air is driven through the walls of the filter and to the outlet of the filter housing.

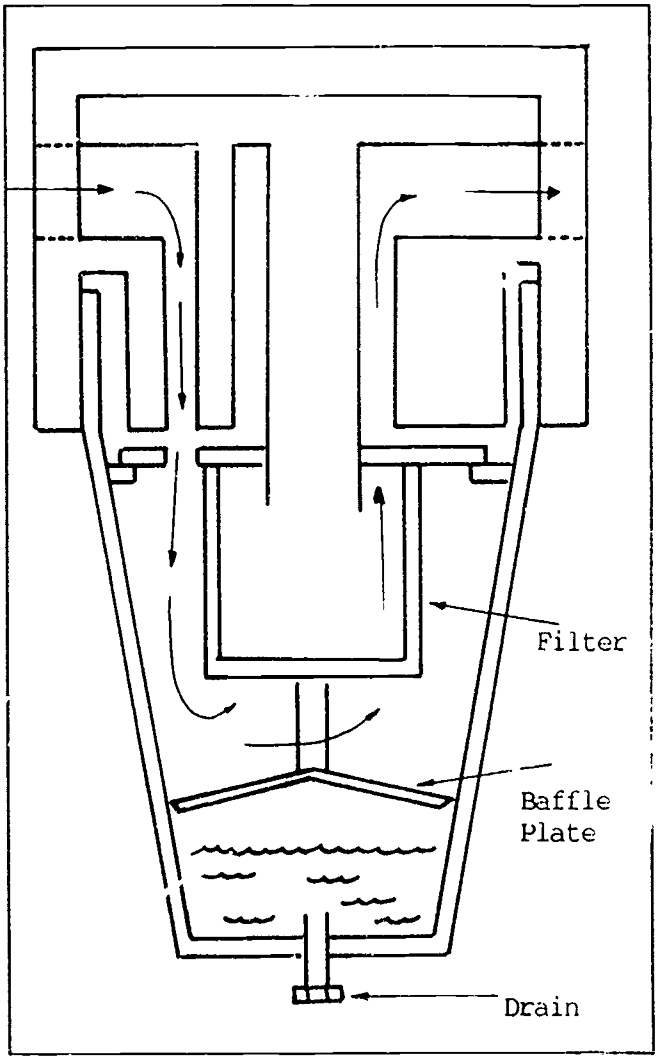


Figure 14 - Manual drain air filter

2. Dry Filters

Dry filters are made in many different shapes and sizes. Most of these filters have a cotton or felt insert packed into a wire screen or other open container. The packed materials can be cleaned with a recommended solvent and dried with compressed air. Most can be cleaned by compressed air, or can be washed with a mild detergent and dried. Many are simply replaced with new elements.

D. RECEIVER TANK

After the air has gone through the aftercooler and/or dryer, it is piped to a receiver or storage tank. The receiver tank stores the clean and compressed air. The receiver tank must have a drain at its lowest point so that contaminants can be expelled periodically.

QUESTIONS -- AIR TREATMENT

Select the best answer for the following:

1. What presents the greatest threat in a pneumatic system?

   a. Heat
   b. Moisture
   c. Cold air
   d. None of the above

2. The three types of driers used to remove moisture are:

   a. Absorption, adsorption, high temperature
   b. Low temperature, porous, hand-held
   c. After cooler, high temperature, in-line
   d. Adsorption, absorption, low temperature

3. ______________ is a physical process in which a drying agent collects water on the surface.

   a. High temperature drying
   b. Low temperature drying
   c. Adsorption drying
   d. Absorption drying

4. ______________ cools air to its dew point, causing water vapor to condense.

   a. Filtering
   b. Freezing
   c. Aftercooling
   d. Refrigeration

5. A/an ______________ is designed to remove particulate matter and also water from air.

   a. Adsorption filter
   b. Air filter
   c. Refrigeration coil
   d. Oil filter

V. PNEUMATIC PIPING SYSTEMS

After air is compressed, conditioned, and stored in a receiver tank, it is then ready for the piping system.

A. TYPES OF PIPE

There are several types of pipe available for use in pneumatic systems. The two types to be discussed are plastic and copper pipe.

1. Plastic Pipe
Plastic pipe is also known as PVC (polyvinyl chloride). This is a rigid pipe which is noncorrosive, possesses high tensile and impact strength, has good weathering characteristics, is lightweight with low flow-resistance Its joints can be made quickly and easily, often becoming stronger than the pipe itself, and it does not support combustion. Plastic pipe is also inexpensive to install.

2. Copper Pipe
Copper pipe possesses the same design and installation requirements as PVC piping systems. The difference lies in the way the pipes are joined, as well as the cost compared to plastic pipe.

B. PIPE SYSTEMS

1. Grid system
This is also known as the dead end system, and is the simplest of the piping systems. Its construction is simple, consisting of small feeder lines running off of a central main. This allows only one flow path to be available, which may result in work stations near the end of the system receiving a deficient air supply when the demand of previous work stations is high.

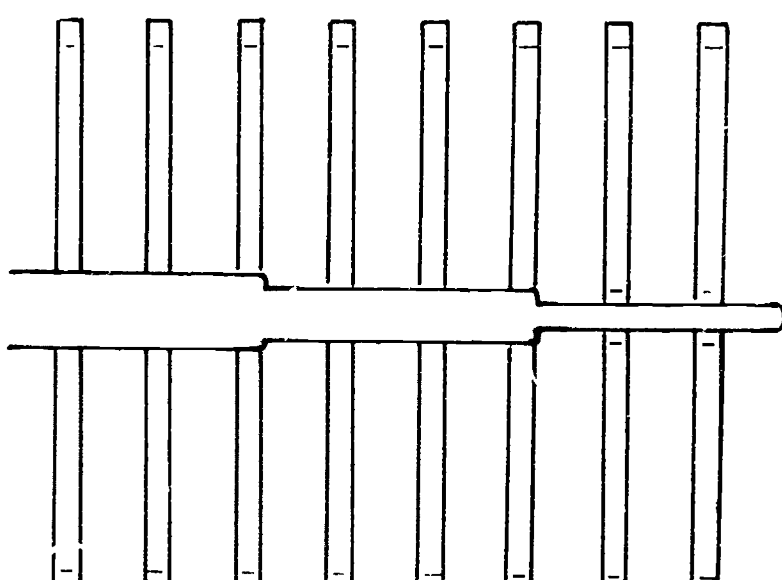


Figure 15- Dead End Piping System

2. Decentralized system
This is also known as the unit system, and consists of two or more grid systems with their own compressors. Individual grid units can be connected to provide a more centralized air flow. Additionally, decentralized systems can easily adapt to changing system requirements.

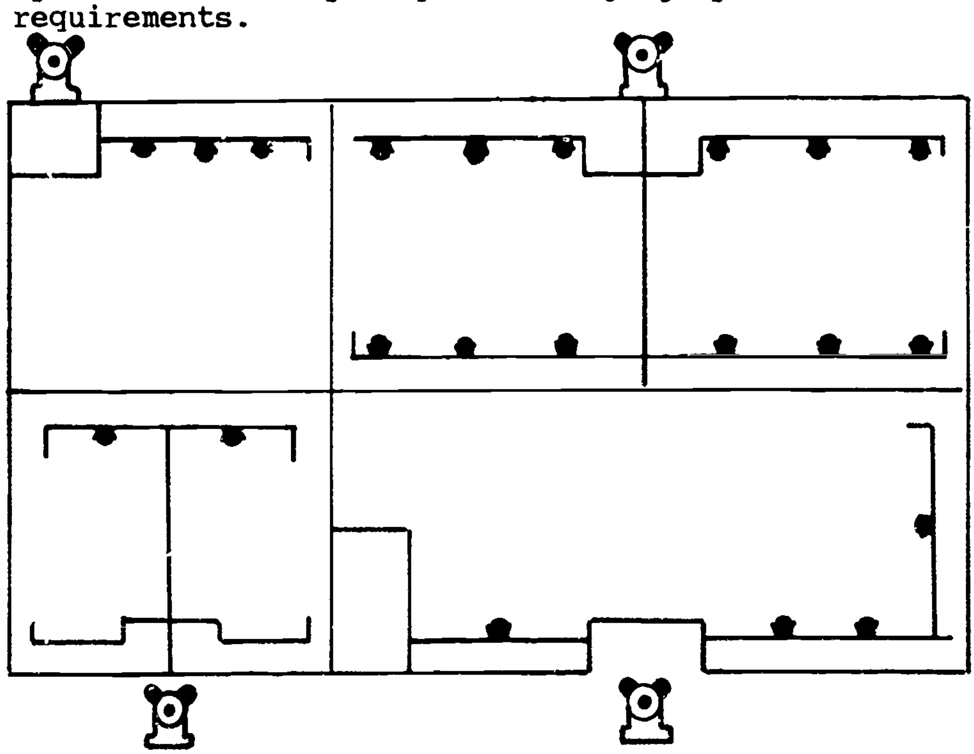


Figure 16 - Decentralized Piping System

3. Loop system
This system allows for optimum conductor pipe size and ensures equal air distribution throughout the system. This system also provides a parallel path to system components. The loop system is recommended over other systems.

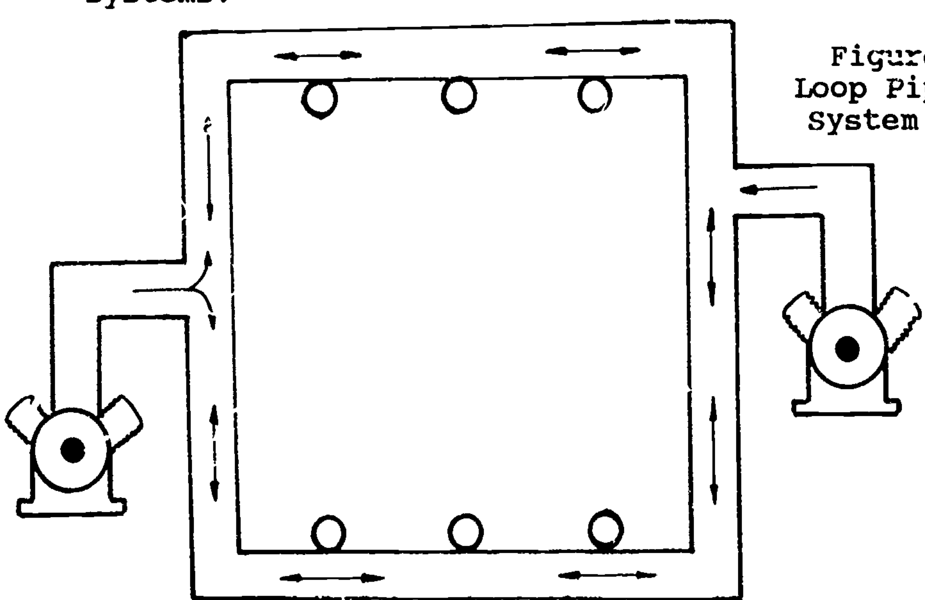


Figure 17 - Loop Piping System

C. JOINT TYPES

The procedures for joining pipes will differ depending on whether plastic or copper pipes are to be joined. Solvents, cements, and compounds must be compatible with the type of pipe being used. Plastic pipe requires solvent for assembly of joints, while copper pipe does not.

1. <u>Joining Plastic Pipe</u>
   To join plastic pipe to a fitting, the pipe should be cut square and ridges smoothed with the end of the pipe slightly rounded. Pipe and fittings should be free of dirt, oil, grease, and other contaminants before they are joined. Solvent cement must then be applied to the surfaces of the pipe and the fitting to be joined. When the surfaces are softened, the pipe is inserted into the fitting. Once joined, the surfaces harden again and are welded into one piece. The joint becomes stronger than the pipe or the fitting.

2. <u>Joining Copper Pipe</u>
   The methods of joining copper pipe are different from those of joining plastic pipe. These are three methods used to join copper pipe:

   a. <u>Compression joint</u>
   This is the simplest of the three methods of joining copper pipe. The tubing is cut and rough edges are removed using a pipe reamer and file. A compression nut is placed over the end of the tubing so that the threads face the joint. Then a compression ring is installed over the tubing, placed into the fitting and tightened snugly. Do not overtighten, as this promotes leaks and restricts air flow.

   b. <u>Flared joint</u>
   The tubing is cut and burrs are removed in the same manner as the compression joint. A special flaring tool is used to flare the pipe end so that it will fit the joint and hold the pipe in place. The tubing nut must be tightened securely.

   c. <u>Soldered joint</u>
   Soldering is a method of joining pipe through the use of an intermetallic bonding (soldering). The pipe is cut and all burrs removed. All surfaces must then be thoroughly cleaned to accomplish soldering properly. Cleaning may be accomplished easily with steel wool, fine grit emery paper, or a

steel brush. After the pipe and joint are cleaned, a flux is used on both the fitting and the pipe before they are joined. The use of a flux achieves two purposes: it removes oxidation and aids in the flow of molten solder. Once the tubing and fitting is assembled, heat is applied with solder to the joint. Lastly, solder is applied to the joint until a ring of solder appears at the end of the fitting. Excess solder should be wiped off with a wet cloth or sponge before it cools.

D. INSTALLATION REQUIREMENTS

Attention should be paid to minimize the number of fittings in a system, and also hold bending of pipe to a minimum. Smooth tubing is preferred over pipe as it provides a constant flow and minimizes decreases in pressure. Pipe fittings cause several times the pressure loss as an equivalent 90 degree bend in tubing. The tubing also gives greater flexibility and the reduction in the number of fittings required, thus reducing the number of leaks possible. <u>Distribution lines</u> should be at a slight slope (up to 1/4" per foot) so that water will sweep into drains throughout the system. <u>Drop lines</u> should come from the top of the main. This minimizes the travel of dirt and water down the drop line. At the bottom of the drop lines drains should be provided for water removal.

E. AIR LEAKS

Checking the piping system for air leaks is important on a constant maintenance routine. The fewer the leaks, the better the performance of tools and equipment. Air leaks also waste compressor energy and increase electrical costs due to the running of the compressor to make up for the loss of air. Both air flow and pressure that are available to tools are lowered when there are leaks in the air system.

The following is a list of procedures used to check for air leaks:

1. Most air leaks are audible and can be heard while the system is in operation. One should check for air leaks when noise from operating machinery is at a minimum, such as during scheduled shift changes or other times when plant machinery is not operating.

2. Soapy solutions or leak detection fluids can be utilized by applying the fluid to the connection and watching for bubbles of air.

3. An air leak may be detected by pressuring the system to see how long it holds its pressure before the compressor turns on to compensate for its loss. One should shut the system down completely to determine how long it will take for the system to drop to a minimum pressure.

QUESTIONS -- PIPING

Select the best answer for the following:

1. Which of the following pneumatic piping systems is the simplest?

   a. Decentralized system
   b. Grid system
   c. Unit system
   d. Loop system

2. Which of the following pneumatic piping systems is recommended over the others?

   a. Unit system
   b. Dead end system
   c. Loop system
   d. Centralized system

3. Which of the following are methods to check for air leaks?

   a. Using leak detection fluids
   b. Listening for leaks
   c. Pressurize the system and monitor system pressure
   d. All of the above

4. Which of the following are <u>copper</u> joint types?

   a. Squared joint
   b. Flared joint
   c. Compression joint
   d. Soldered joint
   e. b, c, and d

5. The use of ____________ removes oxidation and aids in the flow of molten solder when joining pipes.

   a. Compression ring
   b. Fluoride
   c. Flux
   d. Coolant

VI. PNEUMATIC VALVES

Valves regulate the operation of pneumatic systems. They regulate pressure throughout the system, direct air to its proper circuits, and moderate the volume of air each circuit receives and uses. There are two main categories of pneumatic valves: pressure control valves and directional control valves. These two categories have many types of valves in them. Their functions and operations follow.

A. PRESSURE CONTROL VALVES

These types of valves limit pressure within the pneumatic system, unload excess pressure when required, and control the pressure at which air enters circuits. The following are types of pressure control valves:

1. Relief valves

These valves are used to protect the pneumatic system when extreme amounts of pressure develop. Relief valves each possess a valve body, a valve seat, and a spring with calibrated tension.

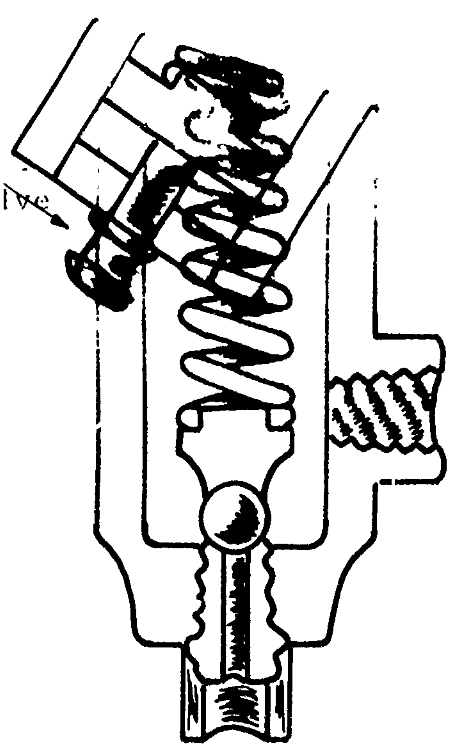


Figure 16 - Relief Valve

While the system remains under the calibrated tension of the spring, the valve will not open. Once the pressure increases over the tension of the spring, the spring will compress and the valve will open, venting the amount of air into the atmosphere until the pressure is relieved to a safe operating level. Once this occurs, the spring will reset itself and the valve will close. Mechanical adjustment screws can also be utilized to obtain proper pressure relief settings on relief valves. When large volumes of air are being utilized, a pilot-operated relief valve maybe used to regulate the amount of pressure that affects the relief valve. The pilot valve opens and closes at different pressures providing a set range of pressure that is further regulated by the relief valve.

2. Reducing valves
Reducing valves are required when the system delivers high or fluctuating pressures.

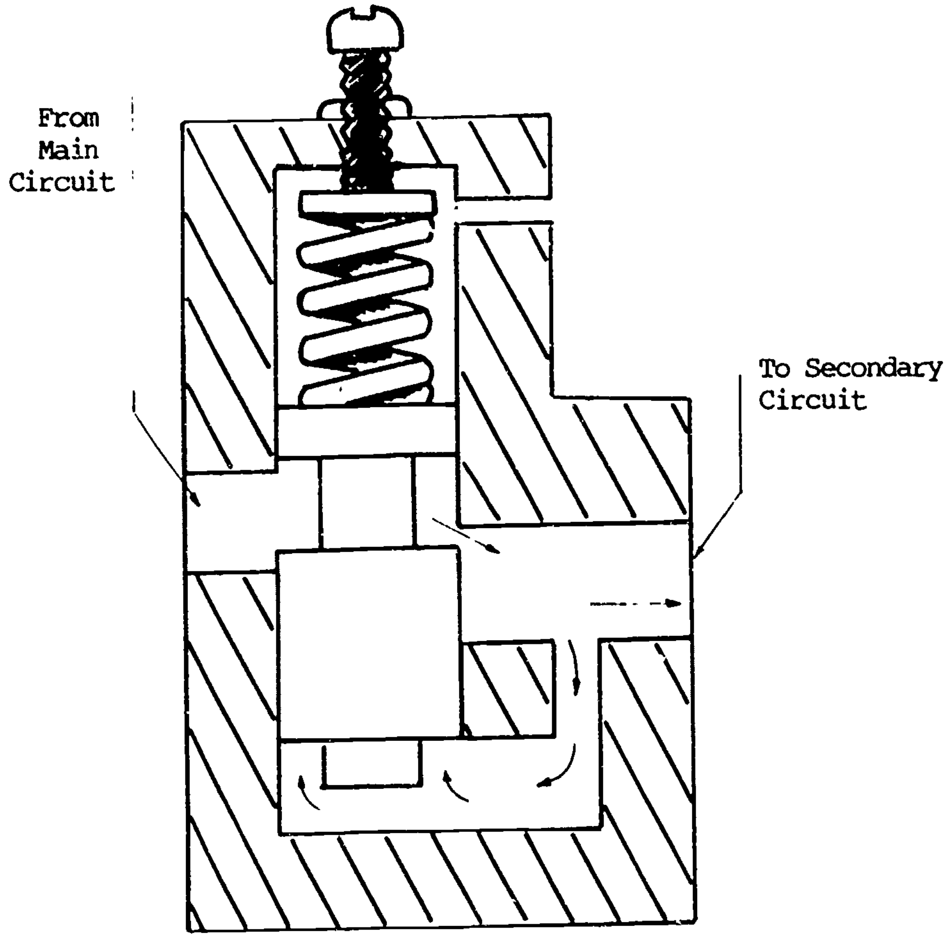


Figure 19 - Pressure Reducing Valve

a. Constant Reduced Pressure Valve
A constant reduced pressure valve always has the same amount of pressure in the secondary circuit no matter what the pressure reading is in the primary circuit.

b. Fixed Amount Reduction Valve

A fixed-amount reduction valve operates by maintaining a balance between the pressures of the main and secondary systems.

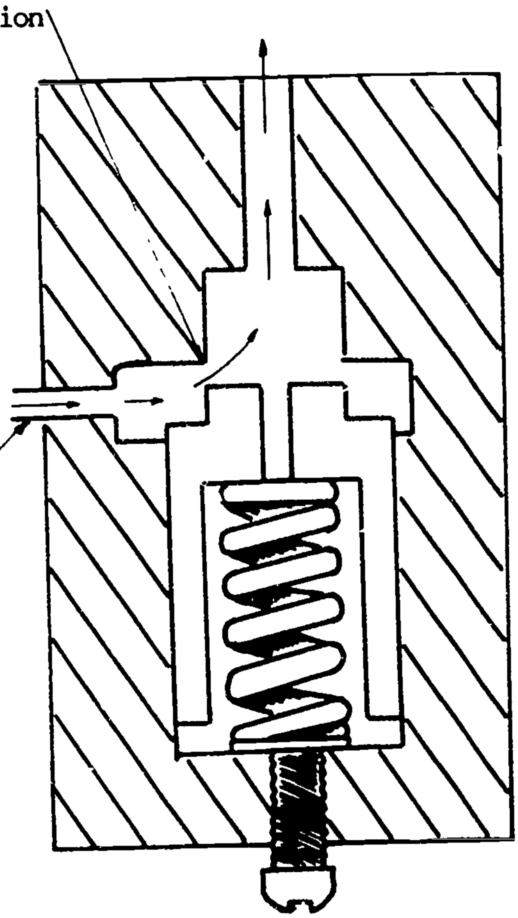


Figure 20 Fixed Amount Reduction Valve

Although the amount of pressure reduction from primary circuit to secondary circuit will stay the same, when the main system pressure fluctuates, so will the secondary system pressure.

3. Directional Control Valves

These types of valves are used to direct compressed air flow from one circuit or branch to another within a pneumatic system. There are three types of directional control valves: check valves, rotary valves, and spool valves.

a. <u>Check valves</u>

Check valves only allow air flow in one direction. Air flowing in one direction opens the valve and allows it to free flow through the valve. Air flowing in the opposite direction closes the valve and prevents airflow.

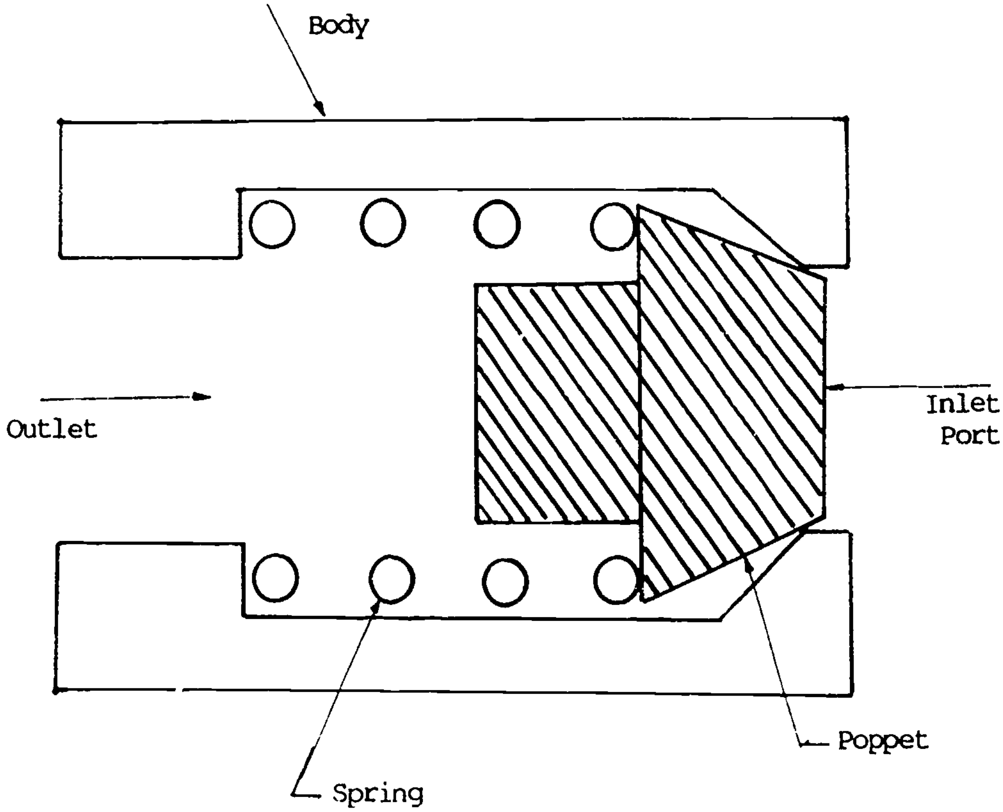


Figure 21 - Check Valve

b. <u>Rotary valves</u>

Rotary valves are finely matched cylinders that fit into housing ports so that work can be accomplished. Cylinder holes are aligned so that air is transferred to and from the actuator. This procedure may be controlled mechanically or manually.

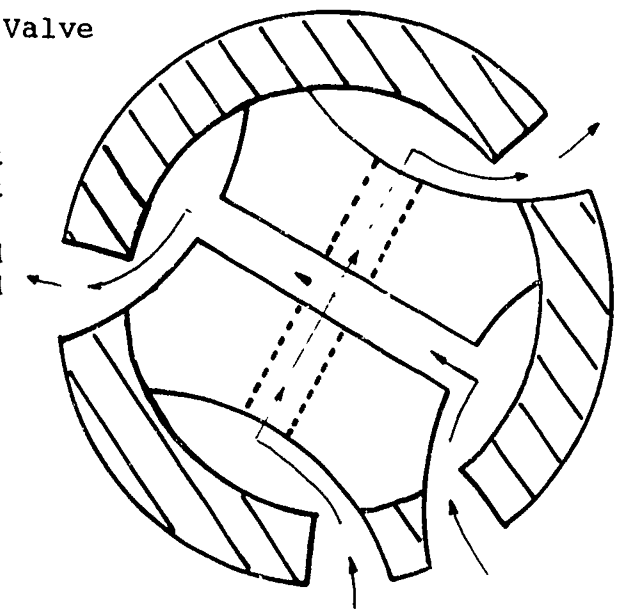


Figure 22 - Rotary Valve

c. Spool valves

Spool valves are frequently used to regulate all aspects of the system. These valves are easily adaptable and compact, which make them more desirable for use in pneumatic systems than other t types of valves. Spool valves can be adapted for different functions by adding ports and lands. Directional valves may be classified by means of their flow paths utilized to operate the pneumatic system. Items to be considered in this type of classification include the number of individual ports, the number of flow paths the valves are designed for, and the internal connection of the ports with the movable part. Valves included in this type of classification are two-way, three-way, and four-way directional valves.

d. Two-way directional valve

A two-way directional valve consists of two ports directly connected to one another internally that can be both connected and disconnected.

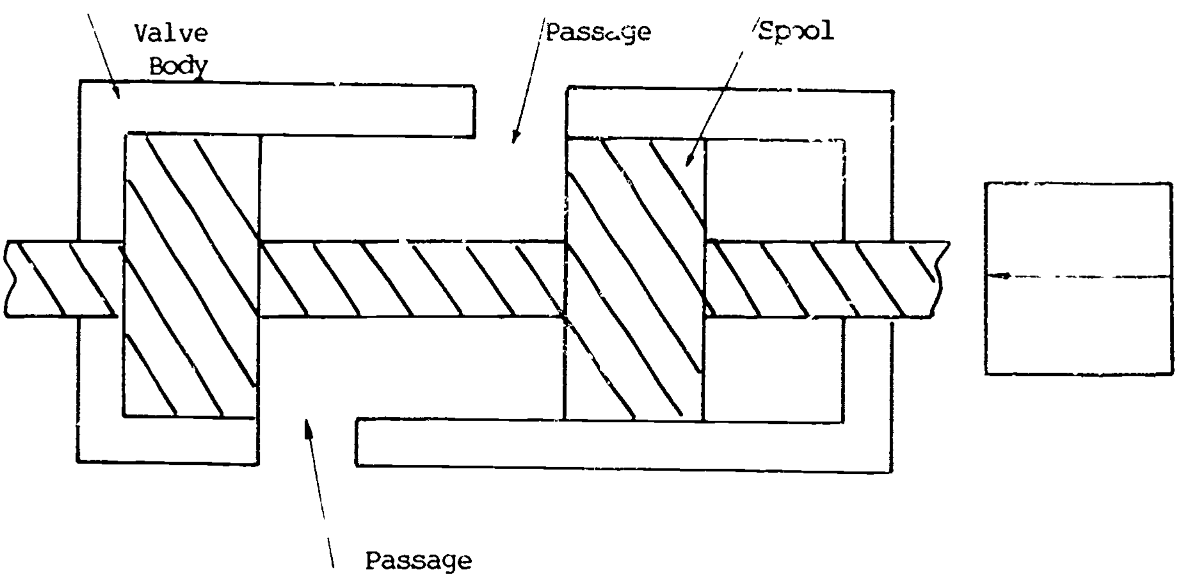


Figure 23 - Two-Way Valve (Open)

A two-way directional valve may function as an on-off valve, because of its ability to restrict the flow path between the two ports.

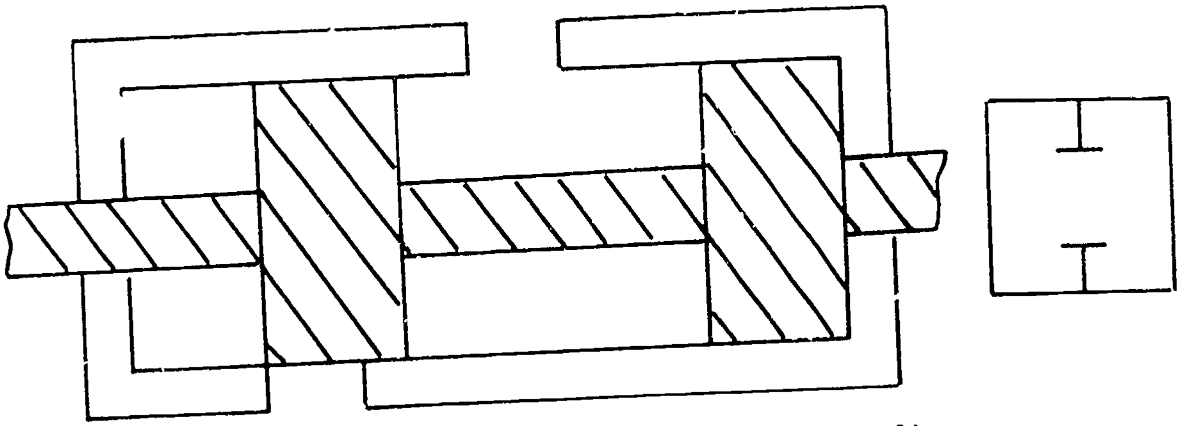


Figure 24 - Two-way valve (closed)

e. Three-way directional valve
A three-way directional valve consists of three ports connected to each other internally.

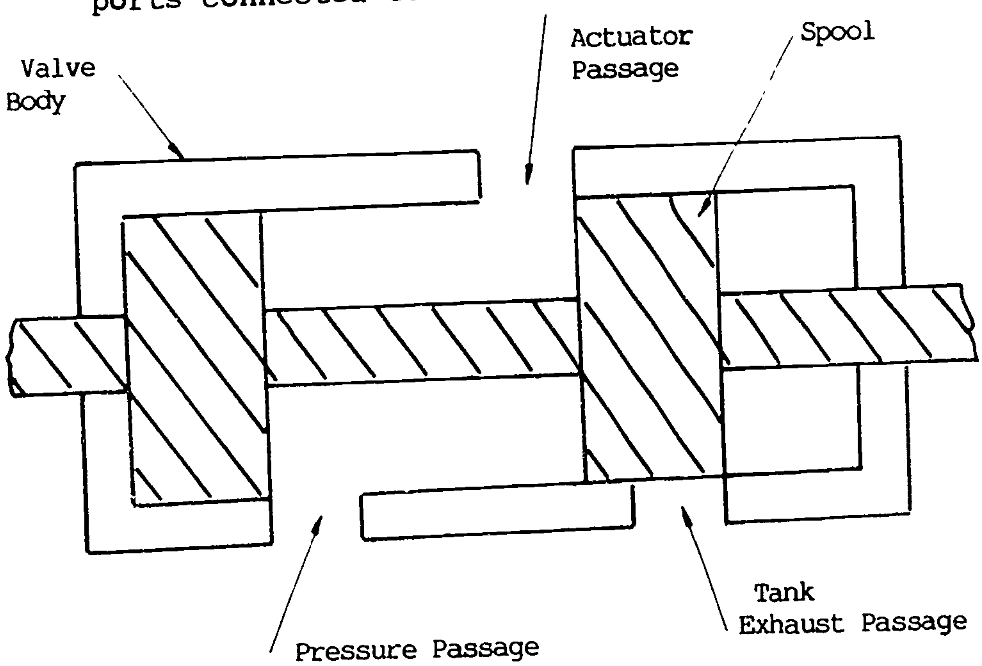
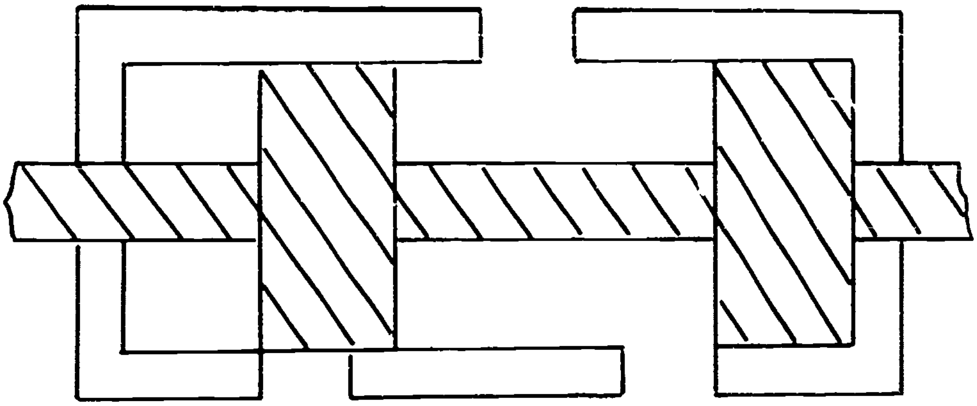
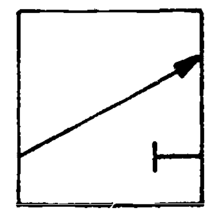


Figure 25 - 3-way valve

This valve functions to both pressurize and exhaust one actuator port. The valve will connect and disconnect both the air flow and the exhaust from the actuator being utilized.



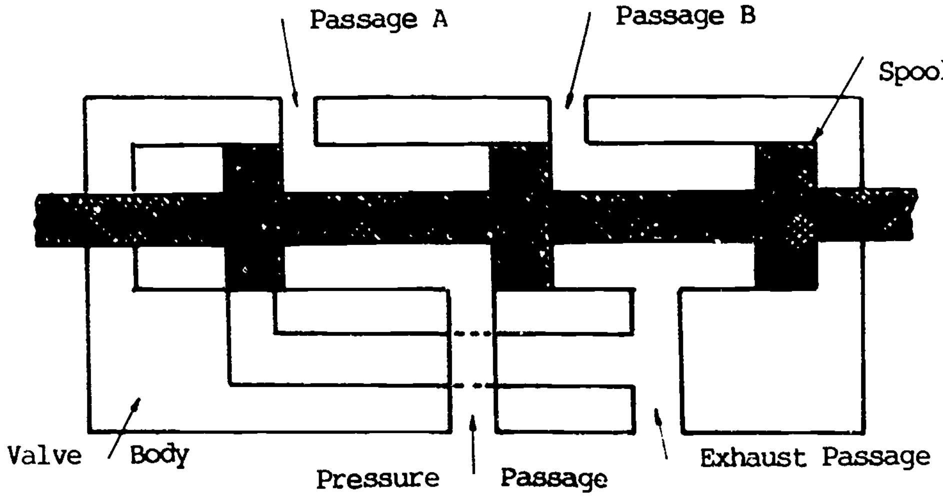


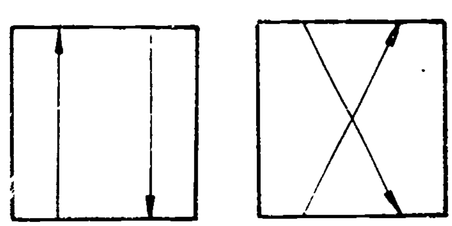
Schematic Symbol

Figure 26 - 3-Way Valve - Exhaust Position

f. Four-way directional valve
A four-way directional valve consists of one pressure port, two actuator ports, and one or more exhaust ports.

Figure 27 - 4-Ported, 4-Way Valve





schematic symbols

These valves have four flow paths within the valve itself, and are perhaps the most common of the directional valves.

g. Valve Operation and Control
Pneumatic valves may be constructed to operate manually, mechanically, or automatically.

h. Manually Operated Valves
Manually operated valves are usually two-way valves. Manual operation may be achieved using a variety of manually operated de‵ .ces including push buttons, levers, and foot pedals.

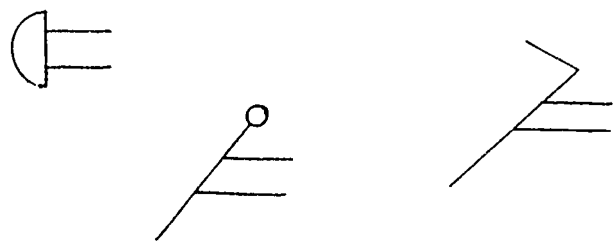


Figure 28 - Manually Operated Valve Symbols

i. Automatically Operated Valves
These valves can be of several types, with the most common being electrically operated by the use of a solenoid. These valves may also be operated either pneumatically or hydraulically. In addition, a vacuum operated valve may be used in some instances.

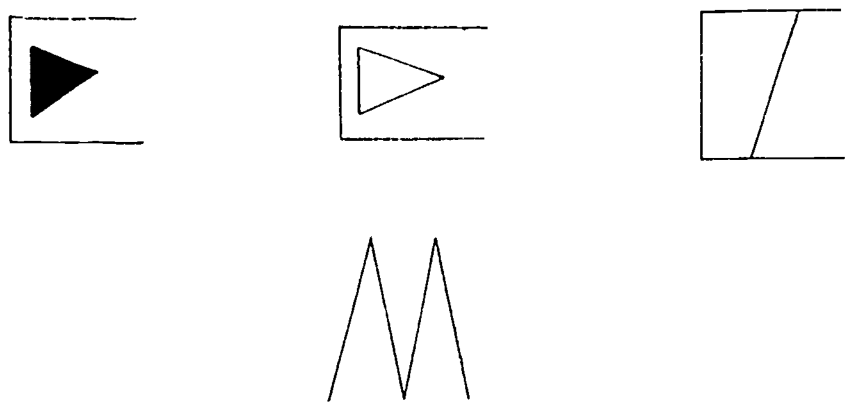


Figure 29 - Automatically Operated Valve Symbols

j. Solenoid valves

Direct-acting solenoid valves possess a plunger which is held against the valve seat, thus restricting the air flow, when the solenoid coil is deenergized. When the coil is energized, the plunger shifts the valve spool activating the pneumatic circuit.

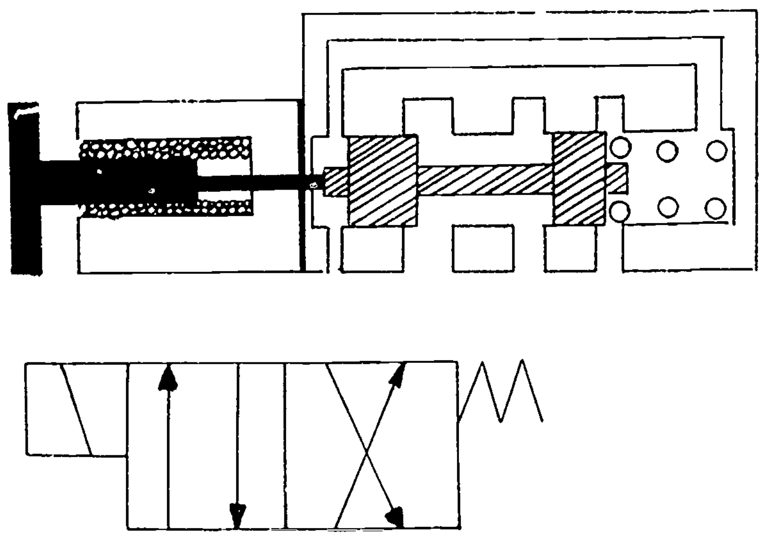


Figure 30 - Solenoid Activated Valve

k. <u>Pilot actuated valves</u>

Pilot actuated valves may use air pressure to control the movement of the valve spool. Speed of the shift in spool position may be controlled by the amount of pressure in the pilot circuit. The pilot circuit may receive its air supply from within the valve itself (internally piloted valve) or from an external air circuit. A simple externally piloted valve is shown in Figure 34.

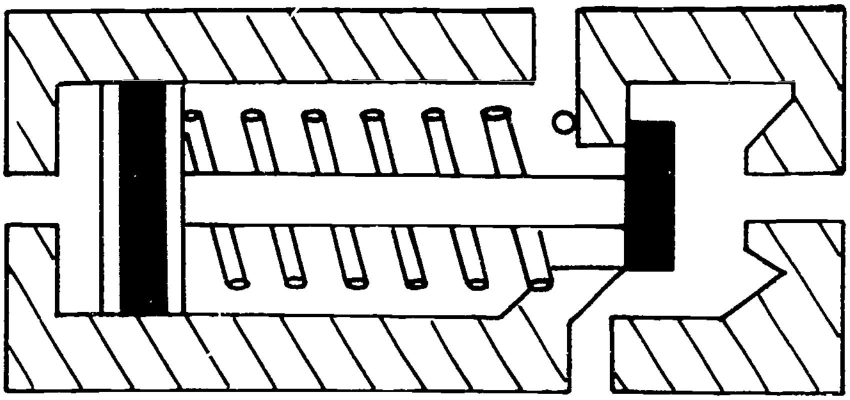


Figure 31 - Externally Piloted Valve

QUESTIONS -- VALVES

Select the best answer for the following:

1. The purposes of valves are:

   a. Direct air to proper circuits
   b. Moderate volume of air for circuits
   c. Regulate pressure throughout the system
   d. All of the above
   e. None of the above

2. Types of pressure control valves include:

   a. Spool valves
   b. Constant reduced pressure valves
   c. Relief valves
   d. Both b and c
   e. All of the above

3. What type of valve only allows air flow in one direction?

   a. Rotary valve
   b. Reduction valve
   c. Check valve
   d. Main valve
   e. Czech valve

4. Valves may be activated by various methods including:

   a. Manual
   b. Electrical solenoid
   c. Pneumatic pilot circuit
   d. All of the above

There are two types of single-acting cylinder types.

a. Diaphragm cylinder
in this cylinder, a diaphragm replaces the shaft and seal of the single-acting cylinder. Pressure underneath the diaphragm will cause the diaphragm and the piston to rise and descend. This cylinder is ideal for use when only small piston movement is required.

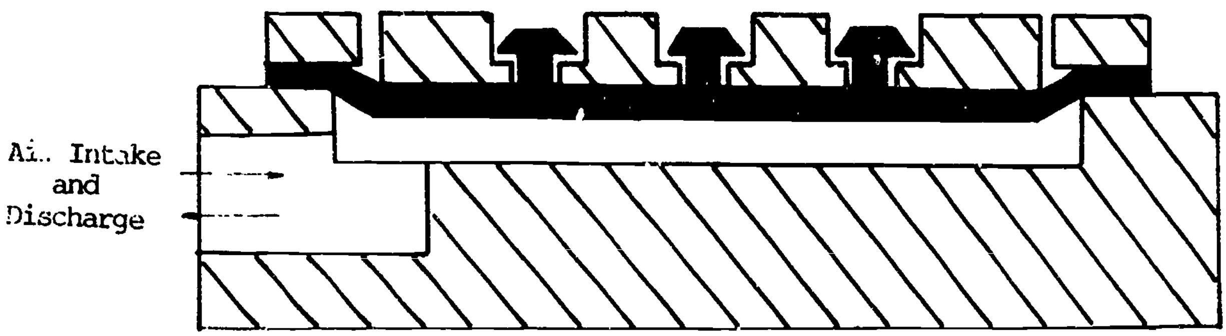
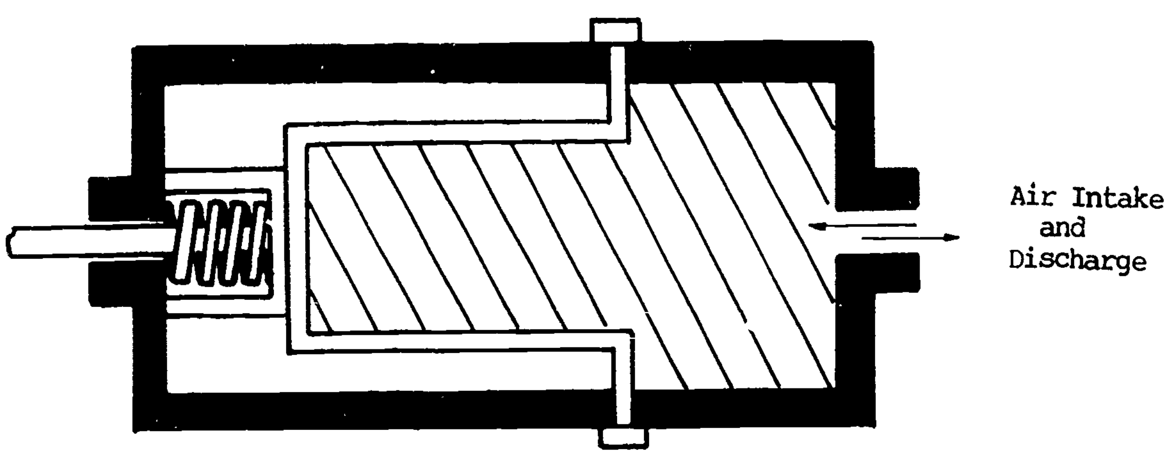


Figure 33 - Diaphragm Cylinder

b. Rolling diaphragm cylinder
This cylinder uses the same technique as in the diaphragm, but the diaphragm is rolled up and is located between the piston and the air chamber. As the piston moves outward, the diaphragm unrolls, thus giving the cylinder a larger stroke than the typical single-acting cylinder.

Figure 34 - Rolling Diaphragm Cylinder



2. Double-acting cylinders
These cylinders can apply force in two directions. Air pressure is supplied into one side and extends the piston. The air flows outward and expends itself from the port on the opposite end into the atmosphere. Once the stroke has been completed, the direction of movement may be reversed by applying air pressure to the opposite end and reversing the process.

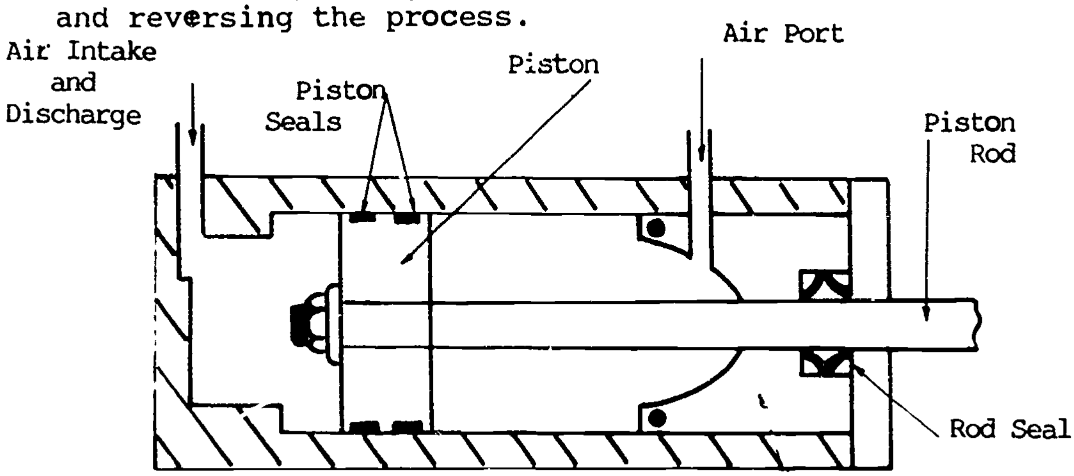


Figure 35 - Double-Acting Cylinder

There is one type of double-acting cylinder.

a. Vane cylinders
These types of cylinders possess vanes which rotate from side to side, rather than in a back and forth motion as the pistons previously mentioned.

Within the vane cylinder there are two vanes. A fixed vane on the cylinder wall forms a seal with the rotating shaft, while a second vane is attached to the cylinder shaft and forms a seal with the inner cylinder surfaces. Air is admitted or discharged through ports on each side of the cylinder. An arm may be attached to the rotating vane when the cylinder is in operation to produce either a clockwise or counterclockwise motion.

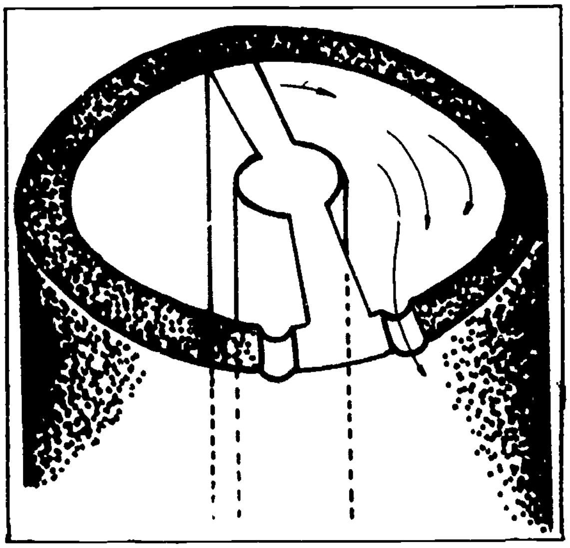


Figure 36 - Vane in Vane Cylinder

B. CYLINDER MOUNTING STYLES

Cylinders are mounted in numerous and varied ways. There are three primary mounting techniques.

1. <u>Fixed centerline mounting</u>
   With this type of mounting, the centerline of the cylinder absorbs force. Flanges and tie rods mounted on the end of the cylinder or centerline lug mounts are used to mount the cylinder. Fixed centerline mounting prevents bending stress from developing in both the mounting framework and the cylinder. This type of mounting is recommended for cylinders with long strokes and heavy-duty applications.

2. <u>Fixed noncenterline mounting</u>
   This type of mounting does not provide for absorption of force on the centerline of the cylinder, instead the force is transmitted through the cylinder in an offcenter manner. To mount the cylinder, side lugs or feet, and side-tapped holes are utilized.

3. <u>Pivoted cylinder mountings</u>
   These mountings can effectively absorb force on the centerline of the cylinder. A pivot type of mounting is utilized when the cylinder must be free to rotate and maintain accurate alignment between the cylinder and the connecting component. The rod-end connection must be mounted to a pivot to prevent the piston rod from binding or bending. The pivoted cylinder mountings are classified as trunnion or clevis mountings, and must be lubricated to work effectively and efficiently.

QUESTIONS -- CYLINDERS

Select the best answer for the following:

1. The three cylinder mounting styles are:

   a. Fixed noncenterline mounting
   b. Pilot mounting
   c. Fixed centerline mounting
   d. Pivot mounting
   e. a, b, and d

2. Which of the following utilizes a single port to both receive and discharge air from the cylinder?

   a. Single-acting prot
   b. Double-acting cylinder
   c. Single-acting cylinder
   d. None o. the above

3. Vane cylinders can apply force in two directions.

   T or F

4. A ______________ cylinder does not have a back and forth motion.

   a. Double-acting
   b. Diaphragm
   c. Single-acting
   d. Vane

5. The (lower/higher) the pressure, the greater the force applied to an object.

VIII. MISCELLANEOUS VALVES/AIR LOGIC AND DIAGRAMS

A. QUICK EXHAUST VALVES

These valves are used with three or four way control valves to increase exhaust to control cylinder speed.

B. SILENCERS OR MUFFLERS

Due to exhausting air and the noise factors involved with pneumatic systems, silencers or mufflers are used to meet OSHA noise requirements.

C. AIR BOOSTERS

There are two types of air boosters, air to air and air to oil. Both will increase pressure to desired level above system pressure.

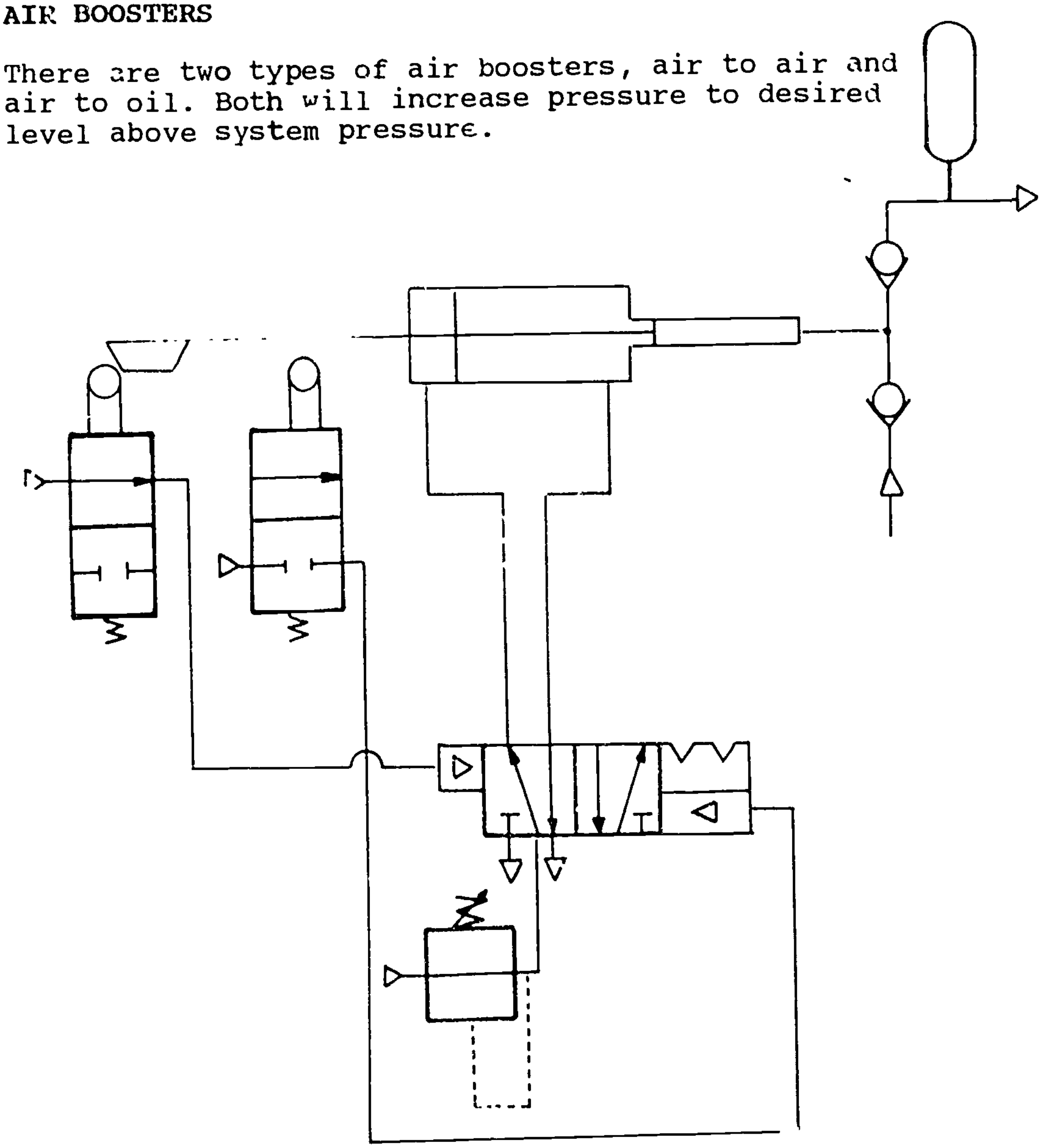
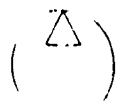


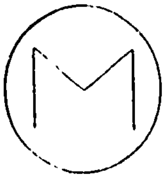
Figure 37 - Air to Oil Booster

D. AIR LOGIC SYMBOLS

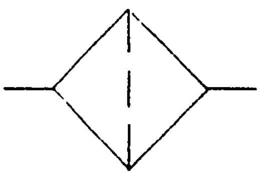
1. Compressor



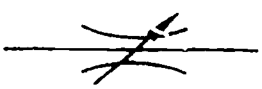
2. Electric Motor



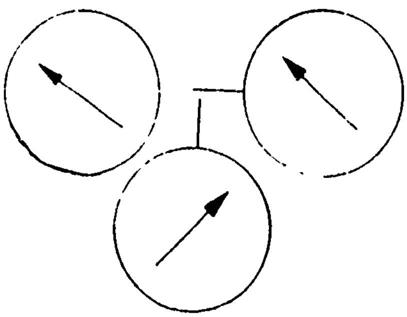
3. Filter



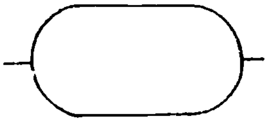
4. Flow Control Valve



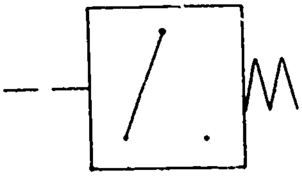
5. Pressure Gage



6. Air Receiver

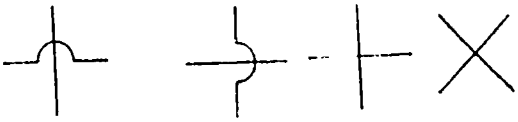


7. Pressure Switch

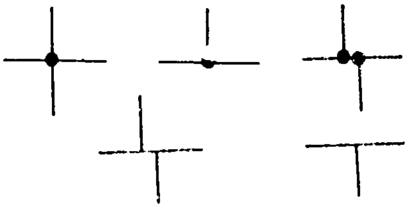


8. Pilot Line

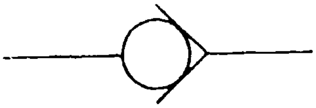
9. Crossed Lines



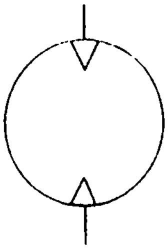
10. Joining Lines



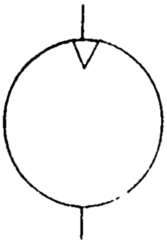
11. Check Valve



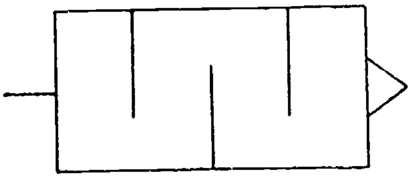
12. Bidirectional Motor



13. Unidirectional Motor

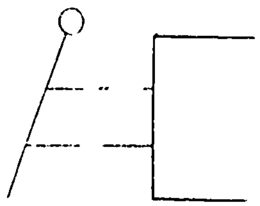


14. Silencer

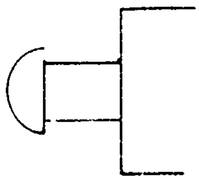


ACTUATING DEVICES SYMBOLS

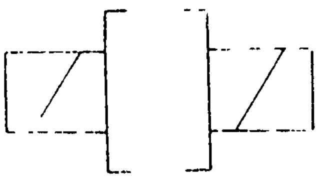
1. Hand Lever



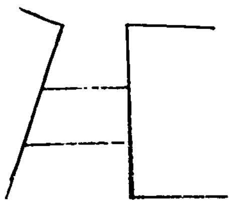
5. Push Button



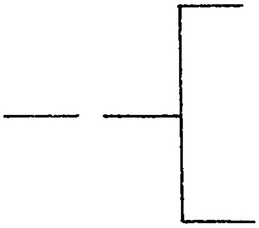
2. Solenoid



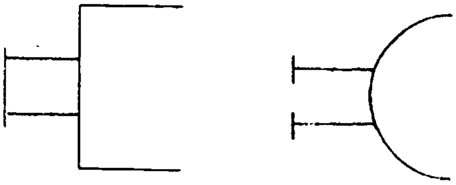
6. Foot Pedal - Trottle



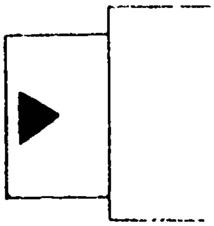
3. Pilot Pressure-Remote Supply



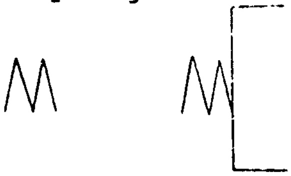
7. Manual



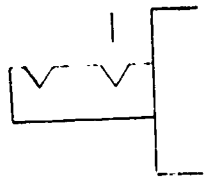
4. Pilot Pressure-Internal Supply



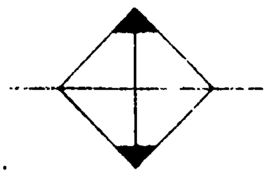
8. Spring



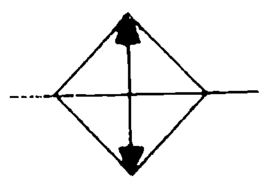
9. Detent



10. Cooler



A.



B.

F. SCHEMATIC DIAGRAMS

Schematic Diagrams for Air Logic are drawn to help designers and technicians to change, locate and identify aspects of a working pneumatic system.

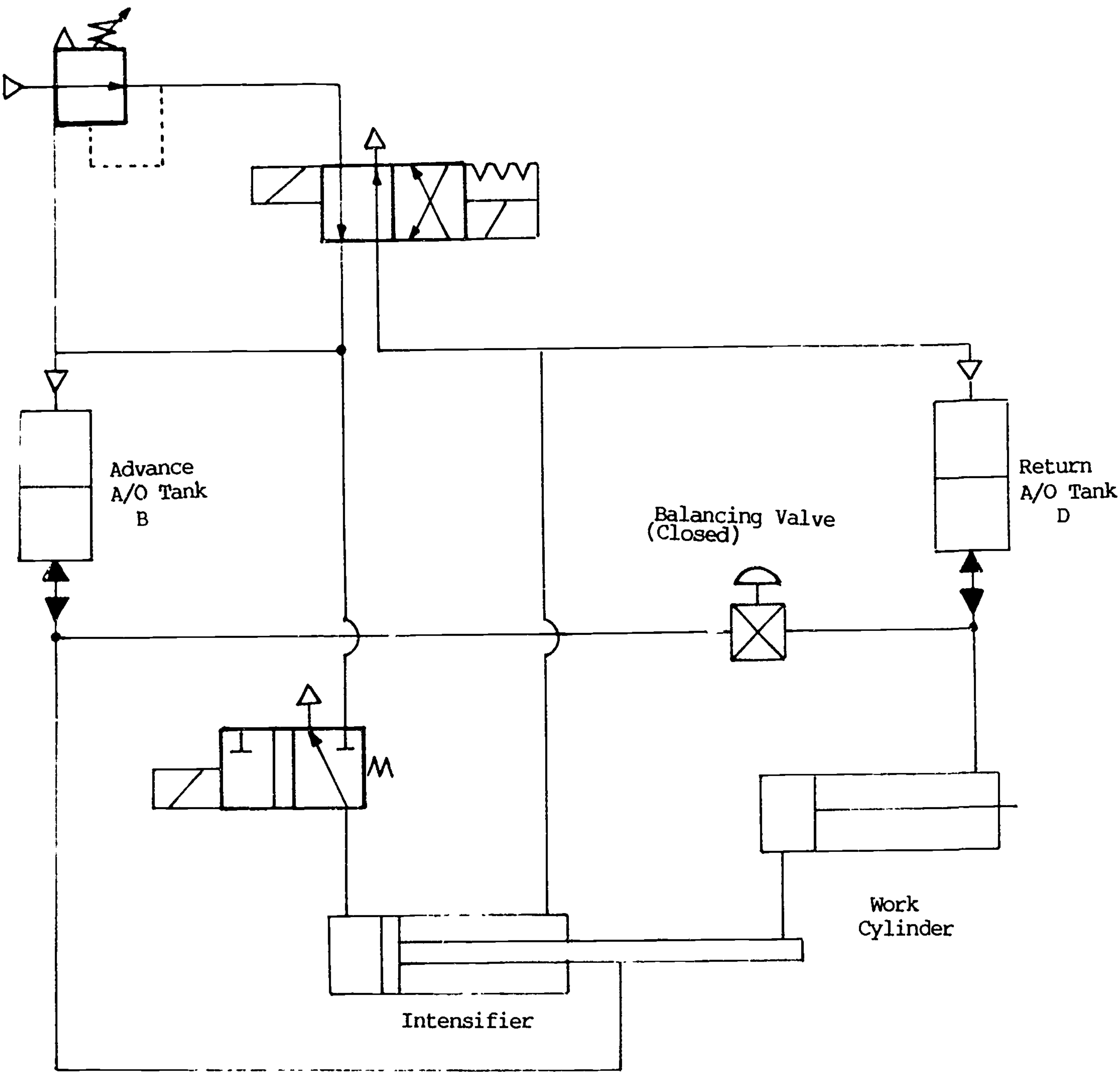


Figure 38 - Schematic Diagram

ANSWERS TO QUESTIONS--PNEUMATICS

INTRODUCTION

1. C
2. B
3. B
4. A
5. D

SAFETY

1. C
2. D
3. A
4. B
5. D

COMPRESSORS

1. FALSE
2. B
3. TRUE
4. C
5. B
6. E
7. FALSE

AIR TREATMENT

1. B
2. D
3. C
4. D
5. B

PIPING SYSTEMS

1. B
2. C
3. D
4. E
5. C

VALVES

1. D
2. E
3. C
4. A

CYLINDERS

1. E
2. C
3. FALSE
4. D
5. HIGHER

END

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