Block D: Compressed Air Systems

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Plumbing Apprenticeship Program Level 3

Industry Training Authority BC

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Competency D1: Install Compressed Air Systems

Compressed air is an essential utility in almost all mechanical, chemical and process industries. It drives tools and machinery, powers pneumatic controls and is used in variety of applications such as material handling, dust extraction, breathing air, laboratory air, industrial and process air. To function properly and cost effectively, the system must be carefully designed to fill the special needs of the application. This module provides an overview of basics, types and selection considerations of compressed air systems.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Describe compressed air systems, taking into consideration:
    - Science of Compressed Air
    - Hazards
    - Codes and regulations regarding vessels
    - Compressors − Types – Operation
    - Compressed Air System Auxiliary Equipment
    - Piping arrangements − Straight line − Loop
    - Compressed air tools and equipment
    - Draining of moisture
    - Safety devices
    - Safety alarm systems
- Plan and install compressed air systems, taking into consideration:
    - Codes and regulations
    - Compressor Installation
    - Types of compressed air piping
    - Sizing
    - Pitch and grade
    - Piping jointing methods
        - Tools and equipment

- Supports and Protection
- Connection of equipment to piping
  - Vibration isolation

Learning Task 1

Describe Compressed Air Systems

Compressed air is atmospheric air which has been mechanically forced (by a compressor) into a storage chamber and then, with a means of control, released to perform a specific task. Compressed air is used by many industries in a large variety of applications – one of the major uses is the spray painting industry for atomizing materials. Other uses are air-operated tools, air control devices, agitating operations, pneumatic water supply systems, temperature and instrument control, fire protection sprinkler systems, liquid or solid transfer by compressed air, and even rodent control.

Science of Compressed Air

Atmospheric air, (the air we breathe) consists of approximately 78% nitrogen and 21% oxygen. Air has weight and this weight is called atmospheric pressure. At sea level, this pressure is 101.3 kPa (14.7 psi). This means that the air pressure exerted on every square inch of the earth's surface and everything on the earth's surface at sea level is 14.7 pounds per square inch. This pressure is also exerted to the sides and upwards from the earth; therefore, air at the compressor intake, enters at the pressure of 14.7 psi (absolute pressure).

Compressed air is measured on the basis of volume of air used at a given pressure. The reference to volume of compressed air is always a measurement of air in its free state; or standard atmospheric condition (SCFM). Standard air has been defined as being 200 Celsius (680 F), having an atmospheric pressure of 101.3 kPa (14.7 psi), and 36 % relative humidity. Standard air is used when tests are made and efficiencies computed; standard air is also the basis for rating compressors as to volume deliver capabilities.

Altitude

Atmospheric pressure and density of air decrease as the altitude increases. Due to the lower pressure and lesser density of the air, a smaller (output) quantity of air is would be delivered by the compressor at the higher elevation. Air delivery of a compressor is reduced by approximately 3 percent for every 1000 feet in elevation above sea level.

Temperature

There is an adverse effect on an air compressor's performance when the inlet air temperature rises above normal. Should the temperature rise above 200 Celsius there will be a loss of air delivery equivalent to 2% for every 5.60 C increase in air temperature. For example: if a compressor is operating on a summer day, or in a heated room with an air temperature of 370 C, there would be a 6 percent drop in the volume of air delivered from its rated capability. Therefore, have the compressor installed in a cool section of the plant or near a window, where good air circulation can be had, or install the air intake outside the building on the cool side (North) and pipe the air intake directly into the compressor.

Heat of Compression

Air from the discharge side of a compressor is hot because it has been compressed. The temperature of discharged air ranges, depending upon the type of compressor and the working pressure. The higher the working pressure, the higher the amount of heat generated.

When this heated air enters the air receiver, we sometimes get a false reading on the air pressure gauge. As the heat is dissipated from the air receiver, the temperature drops and the pressure will drop even though no air is being used. This is because hot air requires more space and, conversely, cold air, having greater density, requires less space.

In order to have a true volume or pressure of air in the storage tank or air receiver, the temperature must be brought to room or ambient temperature. This is done by means of an aftercooler. With a true volume of air in the receiver, the on-off cycle of the compressor is kept to a minimum. When air is expanded, due to high intake temperatures, the on-off cycle will be increased as the air in the receiver cools.

Hazards

The hazards associated with compressed air systems are not easily recognized, as air is often perceived as harmless. As with any compressible fluid under pressure, this perception is far from reality. Some examples of the types of injury that a compressed air system can cause are:

- When used to remove dust and debris from a worker’s body, air may be forced through the skin and could result in an air embolism with potentially fatal results. Also, by driving particles of bacteria under skin, a serious condition such as flesh-eating disease can occur.
- Exhausting air can produce noise levels that may result in damage to a person’s hearing. Exhaust air released by the tools is often not muffled, exposing workers to high decibel levels.
- Particles may be accelerated to a velocity that can result in injury.
- Operating at the incorrect pressure or flow can cause excessive force, resulting in serious injury.
- Air hoses that are the wrong size for the tool or in poor condition with kinks can cause variations in the pressure exerted to the tool. This may cause injury to the operator.
- Severed or broken hoses can thrash violently until the air supply is isolated.
- The tool may discharge air contaminated with oil or antifreeze, causing a respiratory hazard.
- Pneumatic tools may not be grounded or double insulated. Contact with an electrical source could cause shock.

System Equipment and Components

Compressed air systems generally are separated into two subsystems (Figure 1): the supply side and the demand side.

The supply side includes the equipment at the source such as compressors, air treatment devices and primary storage. The supply side produces air flow rates that are measured in standard cubic feet per minute (SCFM), a specification that indicates the volume of air an air compressor can provide at a certain pressure.

The demand side is basically distribution piping, secondary treatment equipment, and the end use tools. A properly designed and installed demand-side system minimizes air pressure differentials and reduces waste of air due to leakage and drainage.

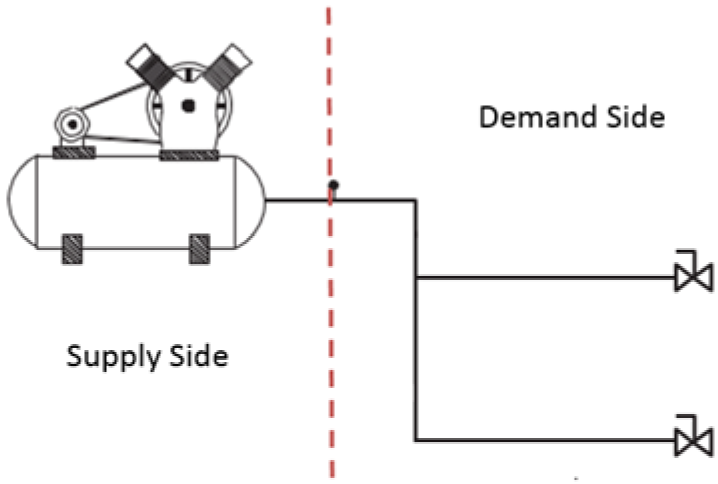

Figure 1 Basic Compressed Air System

The supply side includes the equipment at the source such as compressors, air treatment devices and primary storage. The supply side produces air flow rates that are measured in standard cubic feet per minute (SCFM), a specification that indicates the volume of air an air compressor can provide at a certain pressure.

The demand side is basically distribution piping, secondary treatment equipment, and the end use tools. A properly designed and installed demand-side system minimizes air pressure differentials and reduces waste of air due to leakage and drainage.

Supply Side Components

Supply-side components (Figure 2) could include the following:

- air intake
- air compressor
- motor and controls

- intercooler
- aftercooler
- moisture separators
- receivers
- primary treatment equipment and accessories

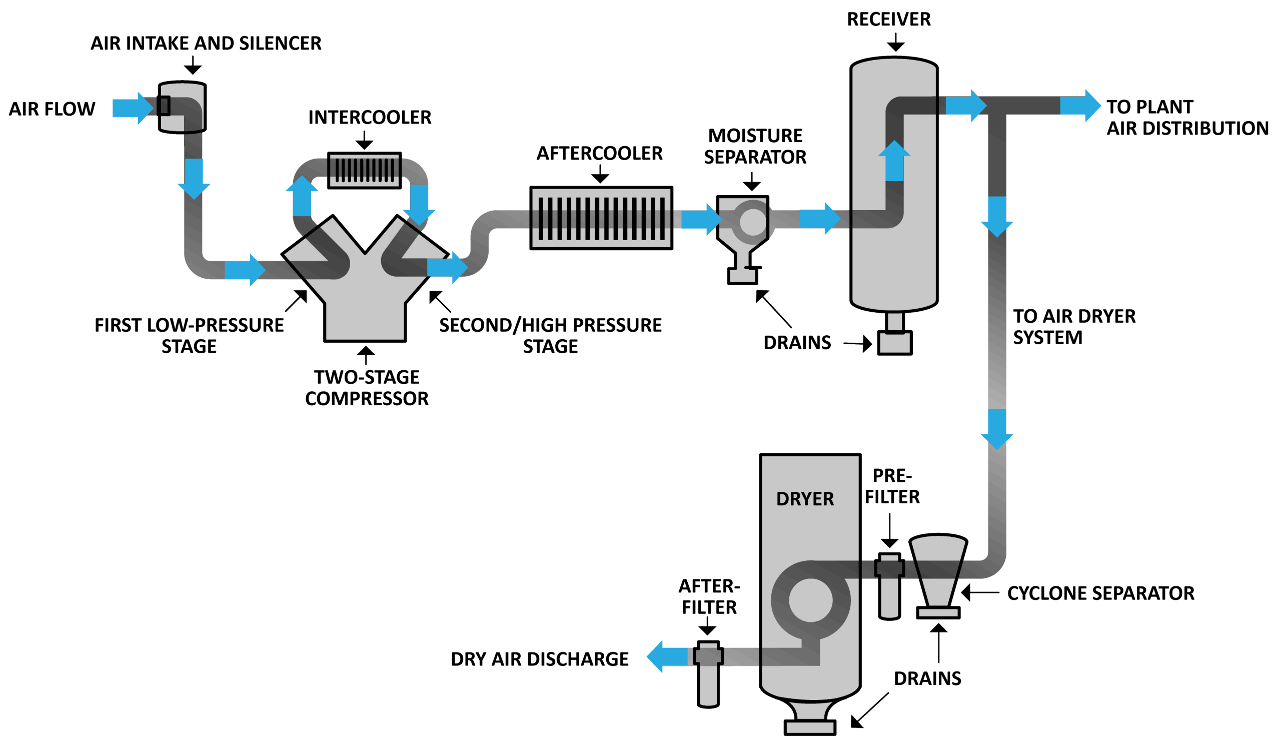

Figure 2 Supply Side Components

Compressed air supply auxiliary equipment includes the compressor intercooler, aftercooler, filters, separators, air dryers, heat recovery equipment, lubricators, pressure regulators, air receivers, condensate drains and automatic drains. These devices associated with the air compressor help to condition compressed air to the required specifications.

Compressor types and operation

There are two basic compressor types, which compress air in different ways:

- reciprocating
- rotary

Reciprocating compressors

Major types of reciprocating compressors include:

- reciprocating single acting (single- and two-stage)
- reciprocating double acting
- reciprocating diaphragm
- reciprocating rocking piston type

Reciprocating single acting single-stage

Reciprocating single acting (single-stage): Air is drawn in from the atmosphere and compressed to final pressure in a single stroke (Figure 3). Single-stage compressors are generally used for pressures of 70 to 135 psi (490 to 945 kPa).

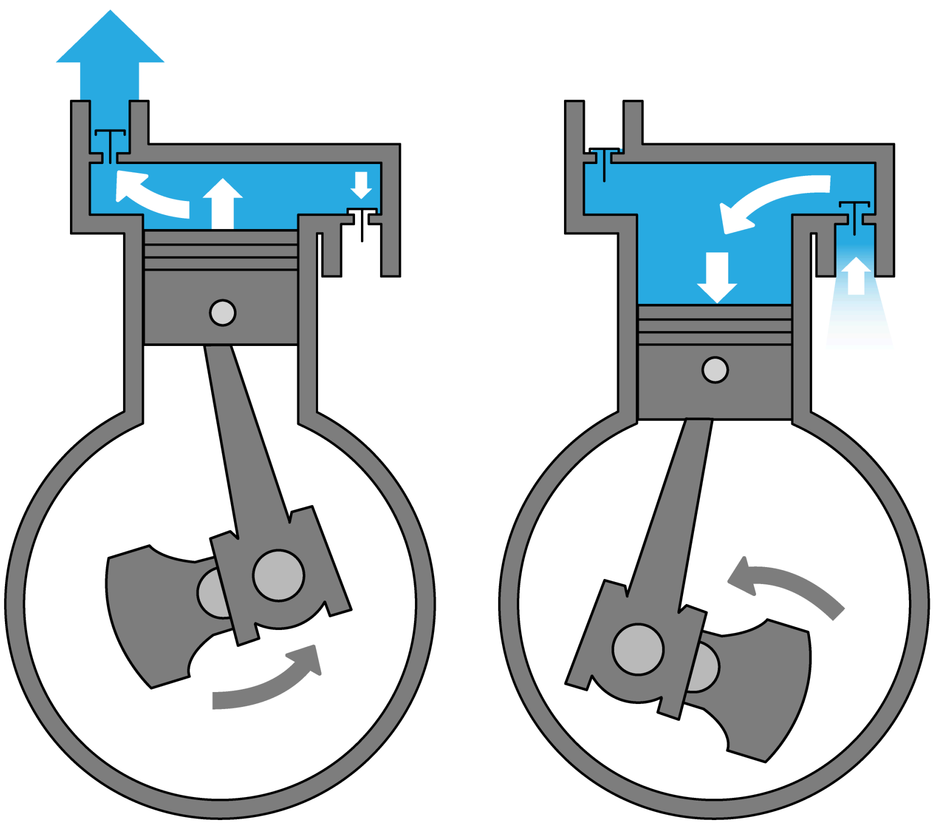

Figure 3 Single-stage reciprocating single acting air compressor

Reciprocating single acting (two-stage)

Reciprocating single acting (two-stage): This design (Figure 4) has a minimum of two cylinders in series:

- low-pressure cylinder (largest)
- high-pressure cylinder (smallest)

The reason why the cylinders are different sizes is that, as the air is passed from cylinder to cylinder it requires less space at each stage. Air is compressed once in the large cylinder and then sent through an intercooler, which reduces discharge air temperatures. The air is compressed again in the smaller cylinder. Two-stage air compressors produce a larger volume of air at higher pressures than smaller single-stage compressors.

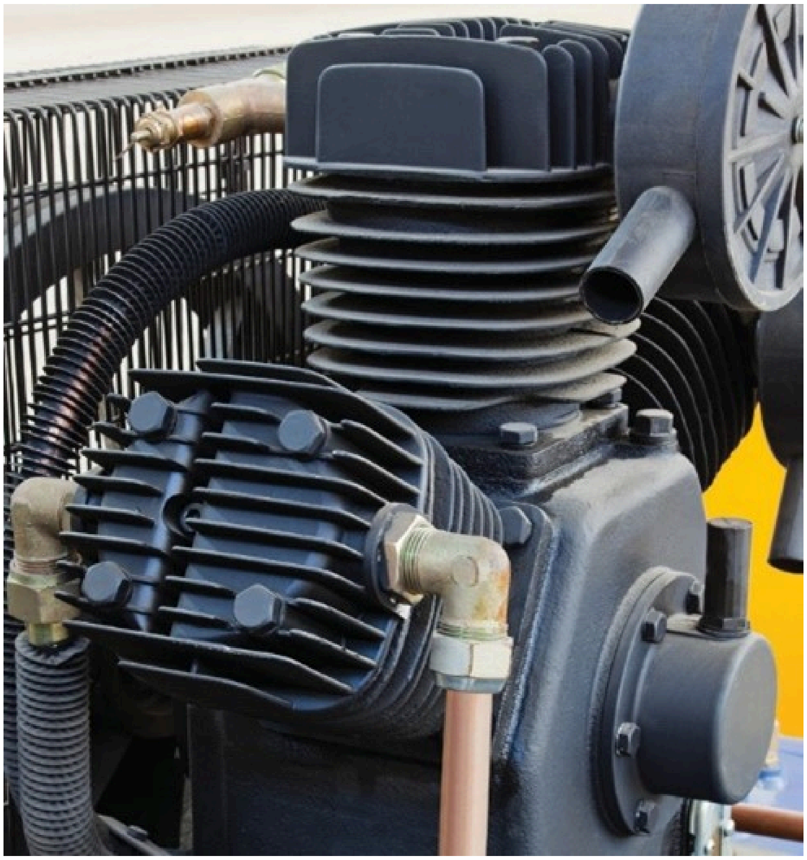

Figure 4 Two-stage reciprocating single acting air compressor

Reciprocating double acting

Reciprocating double acting: This design has compression chambers on both sides of the piston (Figure 5). On the downstroke, air is drawn in at the top end of the piston while air is compressed at the bottom end. On the upstroke, air is drawn into the bottom end while air is compressed at the top end. Double acting reciprocating compressors may have one or more stages and are typically water-cooled. Sizes range from around 40 horsepower (30 kW) to over

1000 horsepower (745 kW). Very few manufacturers still produce the double acting reciprocating compressor because it is quite expensive to produce, requires special foundations to handle vibration and requires frequent extensive maintenance.

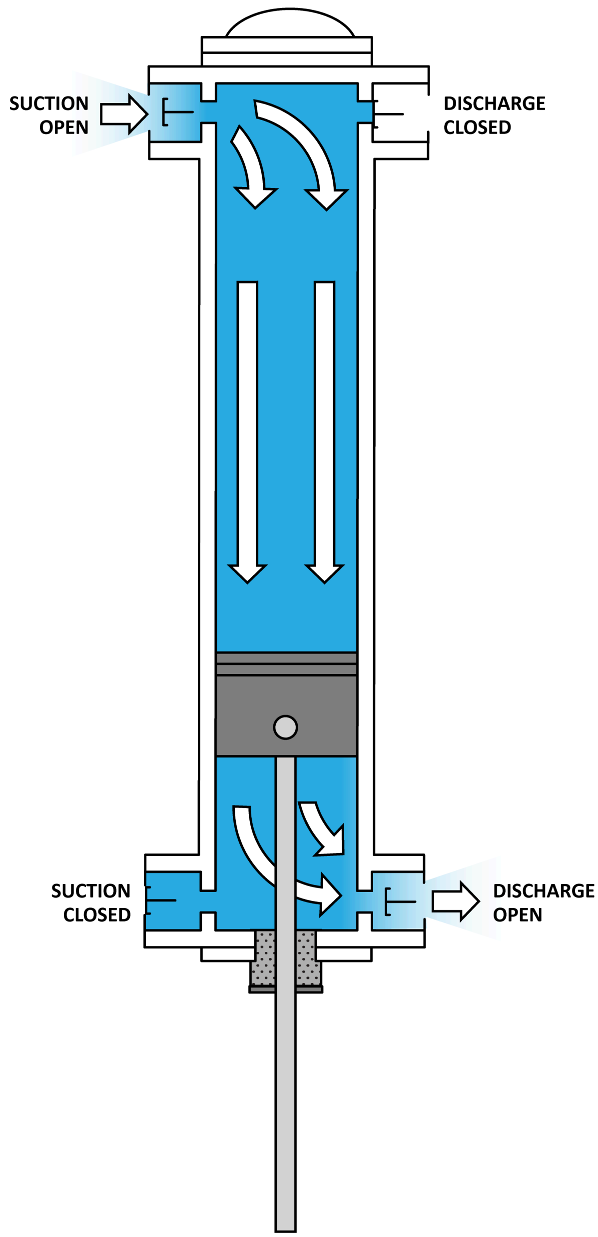

Figure 5 Single-stage reciprocating double acting air compressor

Reciprocating diaphragm

Reciprocating diaphragm: This design is a variation of the reciprocating compressor. The reciprocating diaphragm compressor (Figure 11) develops pressure through the reciprocating or oscillating action of a flexible disk actuated by an eccentric cam. Since a sliding seal is not required between moving parts, this design is not lubricated. Diaphragm compressors are often selected when no contamination is allowed in the output air line or atmosphere. Diaphragm compressors are limited in output volume and pressure, and they are used most for light-duty applications.

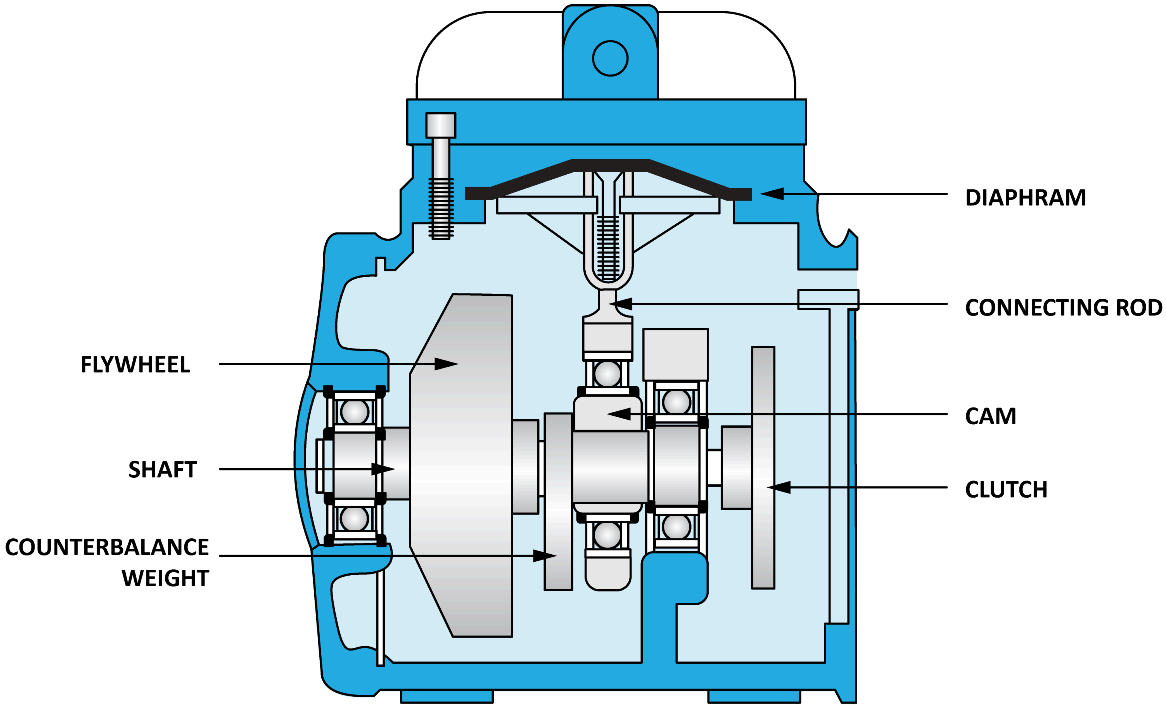

Figure 6 Reciprocating diaphragm single acting air compressor

Reciprocating rocking piston

Reciprocating rocking piston: This design is a variation of the reciprocating piston compressor. It develops pressure through the reciprocating action of a one-piece connecting rod and piston. The piston head rocks as it reciprocates. These compressors (Figure 7) use non-metallic, low- friction rings and do not require lubrication. Rocking piston compressors are available in single and dual stage and are generally used for pond irrigation systems.

Rotary air compressors

Major types of rotary air compressors include:

- rotary sliding vane
- rotary helical screw
- rotary scroll air

Rotary sliding vane

In this design, pumping action is produced by a series of sliding, flat vanes as they rotate in a cylindrical housing. As an eccentrically mounted rotor turns, the individual vanes slide in and out of their slots by centrifugal and pressure-loading forces (Figure 8). This creates a series of air compartments of unequal volume against the wall of the housing. These compartments get larger during the suction part of the cycle, creating vacuum at the intake port, and smaller during the discharge portion of the cycle, creating pressure at the exhaust port. The vacuum and pressure flows are free of pulsation because the inlet and exhaust ports do not have valves, and the air is moved continuously rather than intermittently.

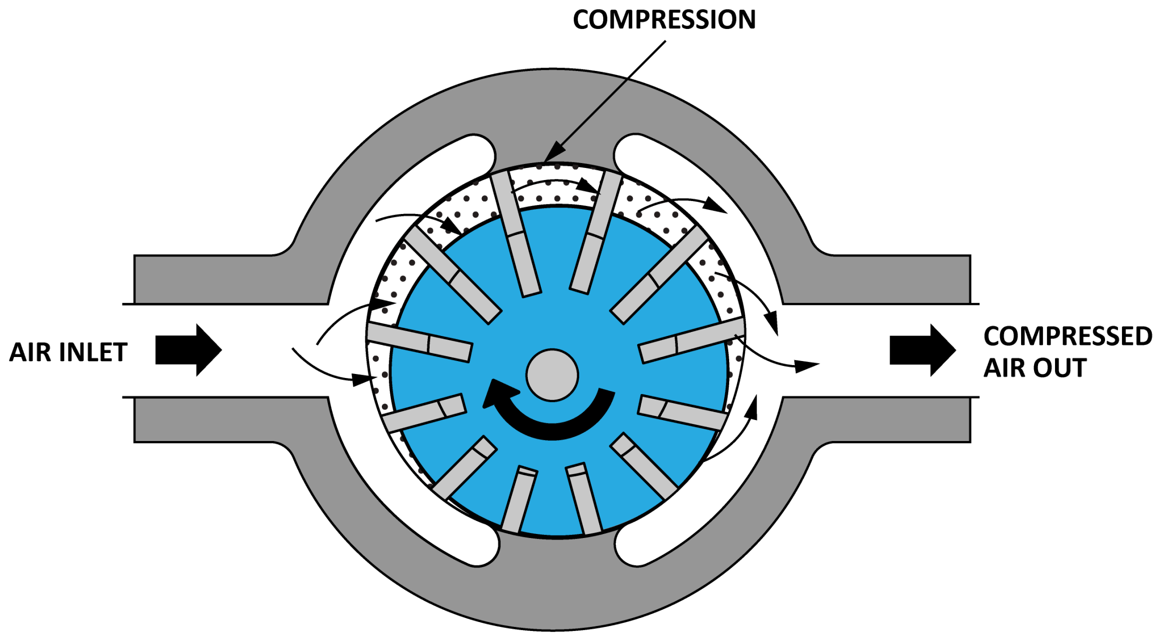

Figure 6 Reciprocating diaphragm single acting air compressor

Rotary screw

This design uses two rotors (helical screws) to compress the air (Figure 9). The rotors are of different shape but are machined to mesh together with a small clearance space between them. When the rotors start turning, air is drawn in on one side (the suction side), where it is trapped between the rotors. Since the rotors are continuously turning, the air is pushed to the other end of the rotors (the pressure side) and new fresh air enters to replace it.

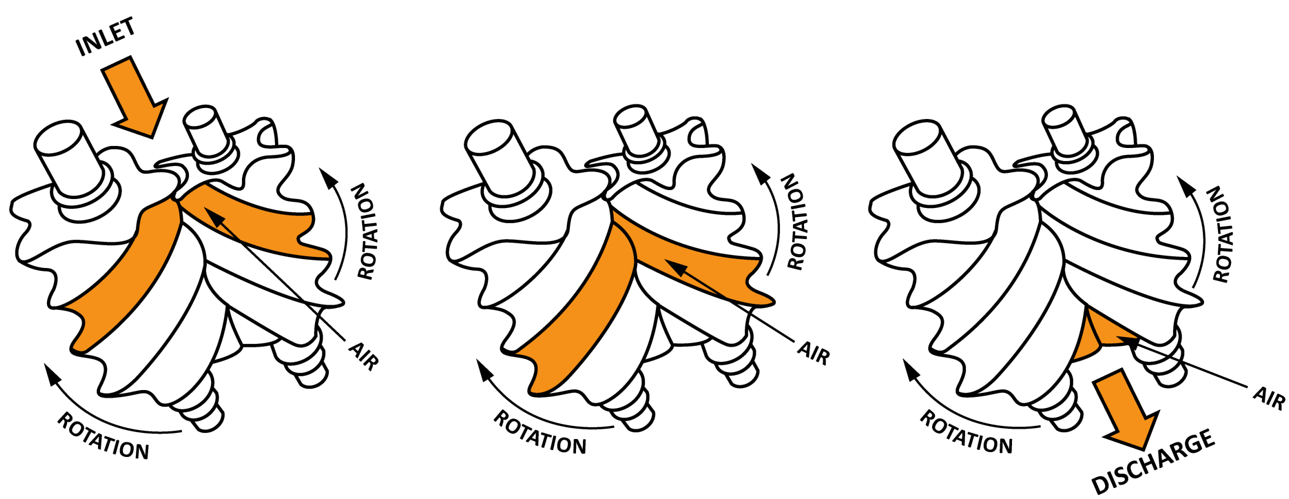

Figure 9 Compression in a twin-screw compressor

Advantages of the rotary screw compressor include smooth, pulse-free air output in a compact size with high output volume over a long life. For manufacturing processes that require 100% duty cycle a rotary screw compressor is often used, as they are designed to go all day without stopping, whereas a piston compressor normally works better when it can take a break.

Rotary screw compressors are either oil injected or oil free. In the oil injected type a motor drives the male rotor which in turn drive the female rotor, with a thin film of oil between them to lubricate and seal the gaps between the rotors to provide compression. Oil lubricated compressors will have an internal oil handling system to separate and treat the air/oil mixture that leaves compressor (Figure 10), so that the oil can be recovered and injected back into the compressor (Figure 10).

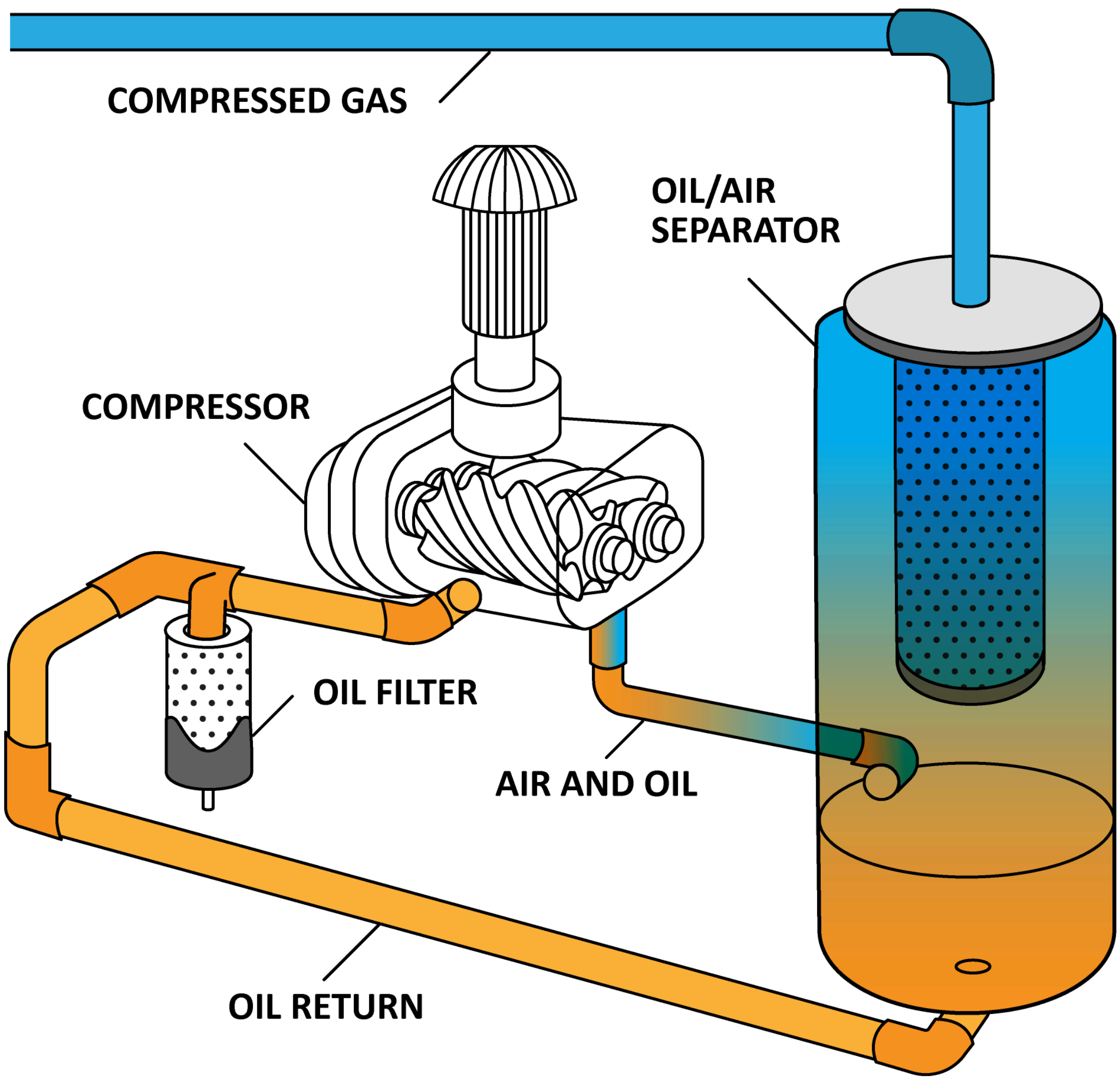

Figure 10 Oil injected rotary screw compressor

Oil free rotary screw compressors have rotors with tighter tolerances to achieve compression. There are additional timing gears to maintain alignment as they must spin at much higher speeds than an equivalent oil injected type (Figure 11). Although oil is not used in the compression stage it is still required to lubricate and cool the bearing and gears.

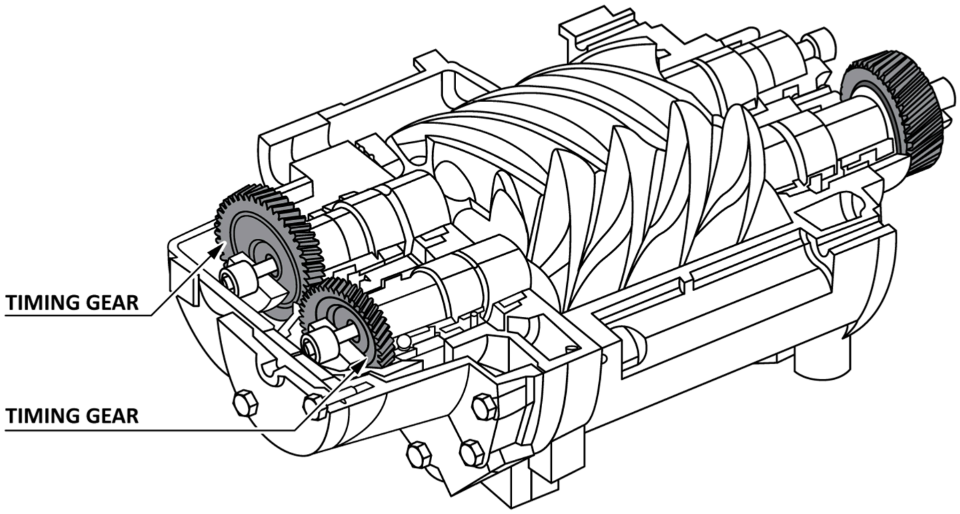

Figure 11 Oil-free screw compressor with synchronizing helical screws to maintain very small rotor clearances

Rotary scroll

In this design, the compressor contains two spiral elements (Figure 12). One moves in eccentric circles and the other is stationary. Air is drawn in between the two spiral elements on the suction side and is transported to the centre of the spiral. Due to the reduced volume at the spiral centre, the air is compressed. It takes about 2.5 turns for the air to reach the centre exhaust pipe.

The big advantage of this type of compressor is the quiet operation. Since there is only one moving part and there is no oil, maintenance is very easy.

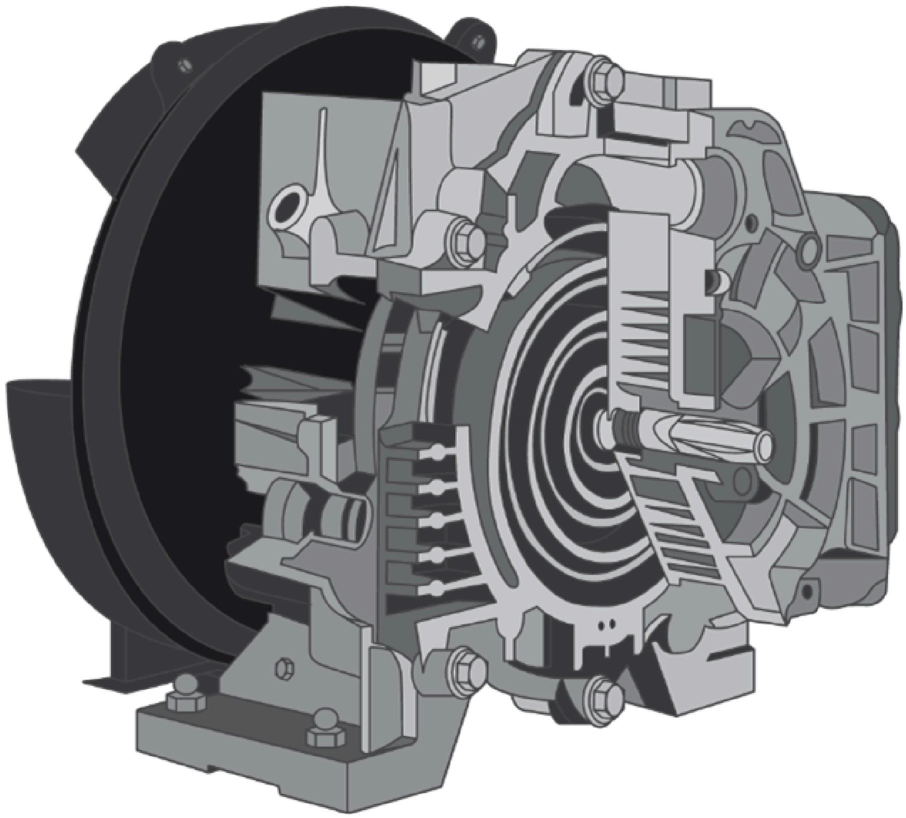

Figure 12 Rotary scroll compressor cross section

Intercooler

In a multi-stage unit compressor (Figure 13), the air is compressed in succeeding cylinders (stages), absorbing heat along the way. An intercooler is installed between the stages to help cool the air before it is introduced into the next stage for further compression. This heat rejection process contributes to the compressor's efficiency.

Intercoolers in multi-stage units may use air cooling or water cooling. In air cooling the compressed air passes through a chamber equipped with cooling fins that are exposed to the ambient air. The fins provide an increased surface area that allows the heat energy to move more readily to the surface and to escape into an area of lower temperature.

Water cooling is achieved by passing the compressed air through a water-cooled heat exchanger. Cool water flows around the outside of the air line, quickly taking heat away and cooling the compressed air rapidly.

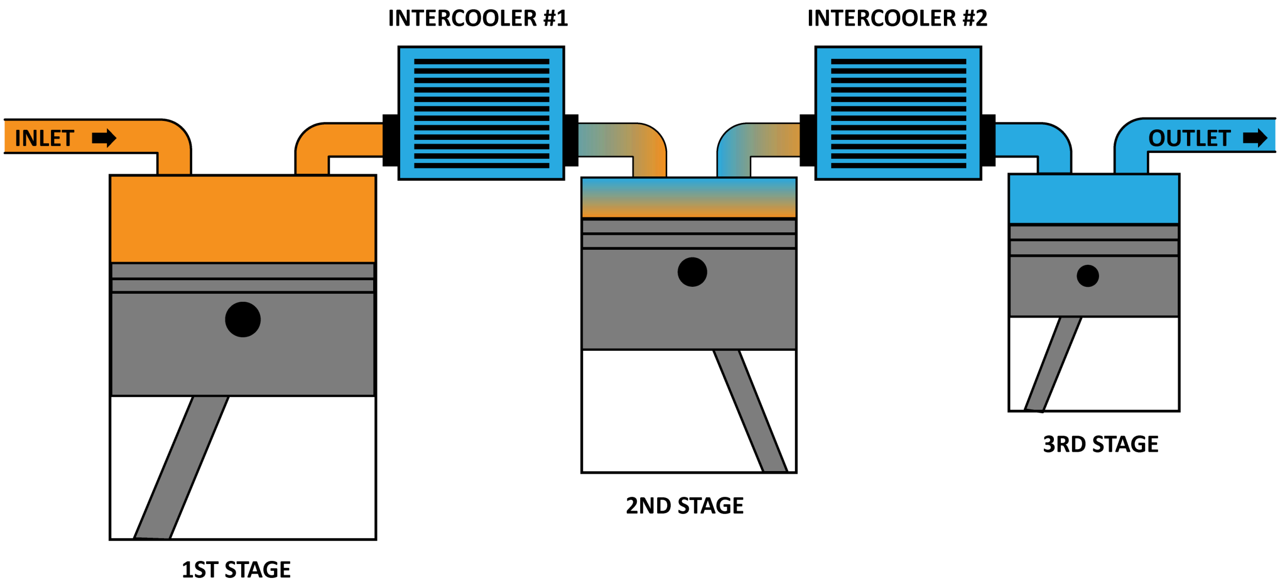

Figure 13 Three-stage compressor with twin intercoolers

Aftercooler

An aftercooler is a heat exchanger that cools the hot compressed air to condense the water vapour that otherwise would condense in the piping system. The aftercooler can be either air or water cooled (Figures 14) and is installed after the last stage of compression. They are generally equipped with a water separator with automatic drainage. Approximately 80–90% of the condensate is collected in the aftercooler's water separator.

Figure 14 Air-cooled aftercooler (left) Water cooled after cooler (right)

Compressor manufacturers may include aftercoolers within the compressor package. In general these compressors are referred to as integral aftercoolers. A stand-alone or freestanding aftercooler is also available for some installations and should be placed close to the compressor.

Air filters

Compressor air filters can be found in two places in the compressed air system:

- at the air-intake to the air compressor
- in the compressed-air piping, between the compressor and the end user's equipment, air tools, etc.

The intake-air filter (Figure 15) is the most important filter on your compressor because dust will cause wear to the compressor element, valves and other moving parts.

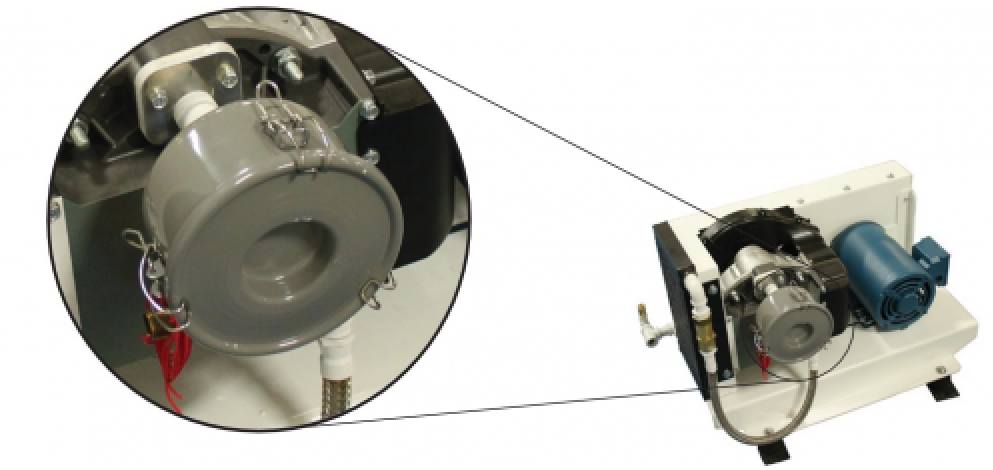

Figure 15 Air compressor intake filter

Compressed air filters downstream of the air compressor, also known as line filters, are generally required to remove contaminants, such as particulates, condensate and lubricant. Numerous choices for filtering are available; the choice depends on the application of the air and the required degree of cleanliness.

Generally, the finer the filter, the greater the pressure differential (pressure drop) across the element. Particulate filters are used to remove solid particles and have the lowest differential. Coalescing filters that are used to remove lubricant and moisture usually have the highest differential. For oil and particulate filters, use filtration only to the level required by each application.

Moisture Separators

Untreated compressed air is saturated with water vapour which can cause system problems such corrosion and growth of micro-organisms. Moisture separators are devices that remove entrained liquids from the air. They are installed following aftercoolers to remove the remaining condensed moisture. Moisture separators should not be confused with oil separators, which are used within lubricated rotary screw compressors to recover lubricant from the compressed air discharge, and return it to the compressor injection chamber.

Moisture separators come in two types:

- Centrifugal (Cyclone)

- Coalescing

Centrifugal separators direct the air at an angle into a cone shaped chamber which creates a spinning vortex. The rotary motion forces the higher density moisture to the outside, which then falls by gravity to a bowl where it can then be drained off (Figure 16). Auto drains help empty the filter bowl regularly, otherwise the bowls do need to be manually drained regularly to prevent water and other debris from being forced back into the air stream.

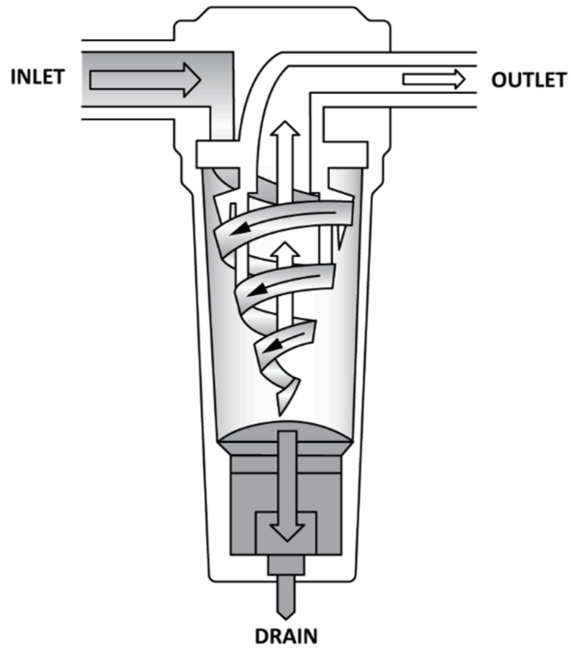

Figure 16 Centrifugal separator

A coalescing separator flows the air from the inside to the outside of a filter element. Solid particles get captured in the filter cartridge. Fluid particles, such as condensate or oil, coalesce or attach to larger droplets, which flow off and are caught in the filter bowl (Figure 17). The filter cartridges must be replaced regularly.

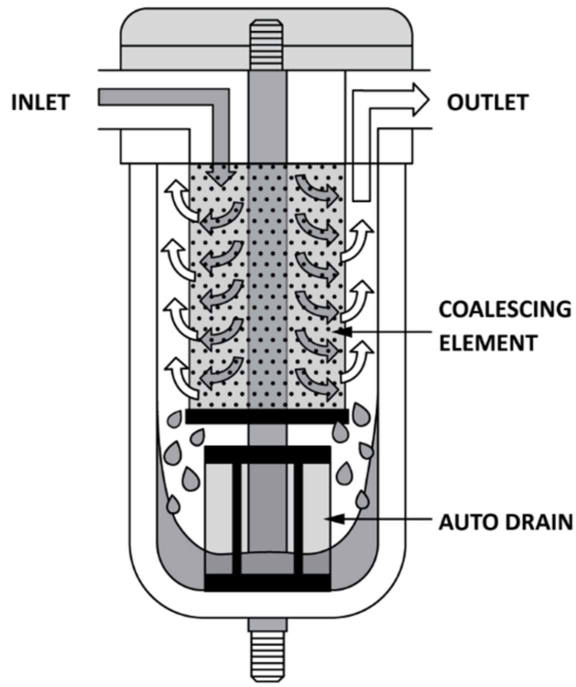

Figure 17 Coalescing separator

Oil and Water Separation

The moisture withdrawn by separators or refrigerant dryers contain oils from the ambient air drawn into the compressor intake. The amount of oil in the compressed air is primarily dependent upon the ambient air quality, which can vary depending on the intake location. Discharging even a small quantity of oil into the sewage system is illegal. An oil and water condensate separation system (Figure 18) removes all of the contaminated condensate from the compressed air and then separates the oils and water through a multistage cascade filtration system. The clean water can then be discharged into the sewage system and the captured oil is properly disposed when it is time to change the filter.

Figure 18 Oil/water condensate separator

Receivers and air storage

An air receiver tank (Figure 19) is an extremely important part of any compressed air system and provides the following benefits:

- It acts as a reservoir of compressed air for periods of peak demand.
- It reduces wear and tear on the motor by reducing excessive compressor cycling.
- It helps to remove water from the system by allowing the air a chance to cool.
- It minimizes pulsation in the system caused by a reciprocating compressor or a cyclic process downstream.

Much the same as a water reservoir provides water during times of drought and stores water during the wet times, an air receiver tank compensates for peak demand and helps balance the supply of the compressor with the demand of the system. You will need to calculate the correct tank size for the air requirements to avoid installing an undersized receiver, which would result in insufficient air volume and cause excessive cycling. An oversized receiver wastes energy by requiring the compressor motor to run longer. A general sizing guideline is three to five gallons per cfm at full load.

It is important to note that receiver tanks are pressure vessels and are required by law to have a pressure relief valve and a pressure gauge. The relief valve should be set to 10% higher than the operating pressure of the system.

It is also important to install either a manual or automatic drain on the receiver tank to remove water from the system. A coalescing filter and air dryer are best placed downstream of the receiver tank. Some systems use two receivers, the additional tank, also known as the dry tank, is placed downstream of the treatment components to store clean dry air.

The receiver piping should enter low and exit high, to promote moisture separation and prevent accumulated condensate from traveling downstream. The tank should be located in a cool area and not in the path of the compressor or dryer's exhaust flow.

Figure 19 High-pressure air receiver

System drains

Drains are needed at all separators, filters, dryers and receivers in order to remove the liquid condensate from the compressed air system. Failed drains can allow slugs of moisture to flow downstream which can overload the air dryer and foul end-use equipment.

Air dryer

Compressed air leaving the compressor aftercooler and moisture separator is normally warmer than the ambient air and fully saturated with moisture. As the air cools, the moisture will condense in the compressed air lines. If the air is subject to freezing temperatures or is used in an application where water vapour in the air can be harmful to the process, an air dryer is required.

There are four general types of air dryers used in compressed air systems:

Refrigeration dryers

The dew point is the temperature at which the air is fully saturated and cannot hold additional water vapour. As the name implies refrigerated dryers (Figure 20) work by cooling the air to lower temperatures, below the dew point, thus condensing and collecting much of the water vapour. These dryers can not be installed in areas exposed to freezing environments.

Figure 20 Refrigerant air dryer

Deliquescent dryers

A deliquescent dryer (Figure 21) is basically a tank full of salt tablets. As the compressed air passes through the salt, the salt attracts water and dissolves into a brine that can be drained off. These are the least expensive dryers to purchase and maintain because they have no moving parts and require no power to run. The operating cost consists of the cost of more salt tablets once they are depleted. The fact that they need no electricity to run and that the water they remove from compressed air is part of a salt brine with a lower freezing point also makes them desirable for winter operation outdoors.

Figure 21 Deliquescent air dryer

Desiccant dryers

Desiccant dryers, also known as regenerative dryers, have two towers filled with desiccant (Figure 22). Desiccant materials are porous and absorb water vapour molecules. That process is reversible, and when the pores contain enough water vapour, exposure to heat or dry air will cause the water vapour to be released. In operation, one tower is drying the incoming air while diverting a percentage of that super dry air to the other tower to purge it of previously accumulated moisture. The towers switch their roles constantly and therefore the term “regenerative” is used to describe this system. This technology is a good choice when the compressed air will be exposed to freezing conditions or where instrument quality air is required, as they virtually ensure that downstream compressed air lines are protected from moisture, condensation and freeze ups.

Figure 22 Desiccant air dryer

Membrane air dryers

Membrane air dryers use specially formulated membrane microtubes (Figure 23) that are an excellent medium for producing dry air from standard compressed air.

Figure 23 Membrane dryer microtubes

As air passes through a bundle of hollow membrane tubes, the water permeates the membrane walls (Figure 24). The dried air continues down the tubes and into the downstream air system. A small fraction of the dry air is then directed along the outside surface of the membrane to “sweep” the moisture-laden air away from the membrane.

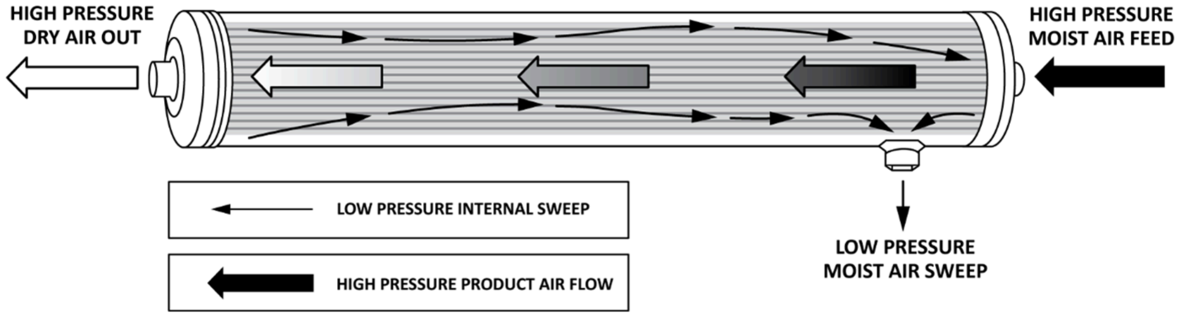

Figure 24 Cactus membrane dryer process

The membranes are highly susceptible to oil and dirt, which cause the membranes to break down quickly. As the structure is microscopic, it cannot be cleaned and has to be replaced.

Membrane dryers come in lightweight modular designs (Figure 25), which are easy to install, making them good for small to medium systems when space is at a premium or for mobile applications.

Figure 25 Selection of membrane dryers

Heat recovery equipment

As mentioned earlier, when air is compressed it gives off heat, and this heat must be removed to preserve system performance. Excess heat could be discarded as waste or recovered by transferring it to a cooling medium before the air goes out into the pipe system. As much as 90% of that heat can be recovered to create hot water for washrooms or warm air for a workspace.

An example of this is using a plate heat exchanger to capture heat from the compressor to heat process water in a plant. Double-wall heat exchangers provide additional protection against contamination, which in turn make them more suitable for heating applications in the food and pharmaceutical industries as well as for heating potable water. Some compressor manufacturers offer built-in heat recovery heat exchangers as options. In some cases, they are fully integrated inside the compressor cabinet and require very little on-site design. The heat recovery control unit shown in Figure 26 is for water-cooled, oil-free air compressors.

Figure 26 Heat recovery control unit for water-cooled oil-free air compressors

Demand Side Components

The demand side includes:

- distribution piping
- secondary receiver
- condensate drain trap configurations
- end-use equipment

Distribution piping

The air distribution piping links the various components of the compressed air system to deliver air to the points-of-use with minimal pressure loss. The specific configuration of a distribution system depends on the needs of the individual plant, but frequently consists of an extended network of main lines, branch lines, valves, and air hoses.

The main source of performance problems associated with industrial compressed air systems is often the piping layout. Most systems are usually one of two common types supplying design flow and pressure requirements:

- straight line networks
- closed loop networks

Straight line network

A straight network (Figure 27) maintains the pressure at the point of use by reducing the size of the central pipe as it moves away from the compressor. The problem with this design is that the flow rate must be sacrificed in order to preserve the downstream pressure. As a result, the equipment using the most air flow must be located nearest to the compressor. This generates production problems, as industrial processes are not necessarily designed this way. Although this system layout is comparatively inexpensive, is not the optimal network design.

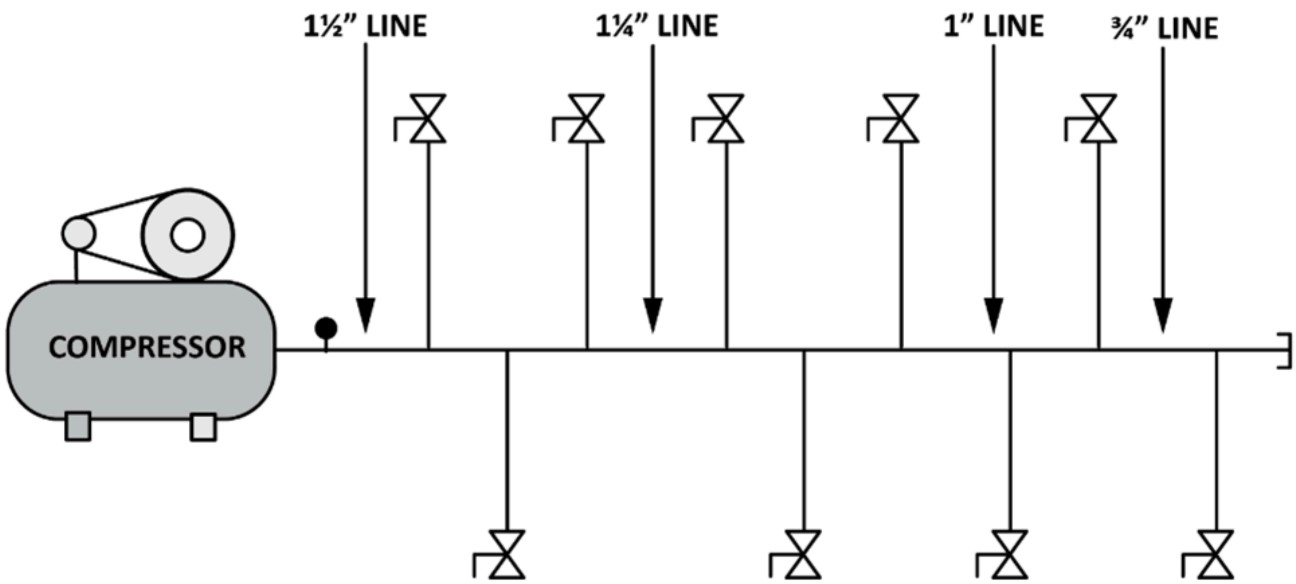

Figure 27 Straight line network

Over time, straight line networks often evolve into “octopus” networks (Figure 28). As new branch lines and equipment are added to an existing straight line network, the additional line and extension piping does not necessarily match the initial configuration. Air flow fluctuations caused by pneumatic equipment usage create problems maintaining pressure and flow requirements at the point of use. This type of network, while quite common, inherits all of the problems of the existing straight line network and makes them worse.

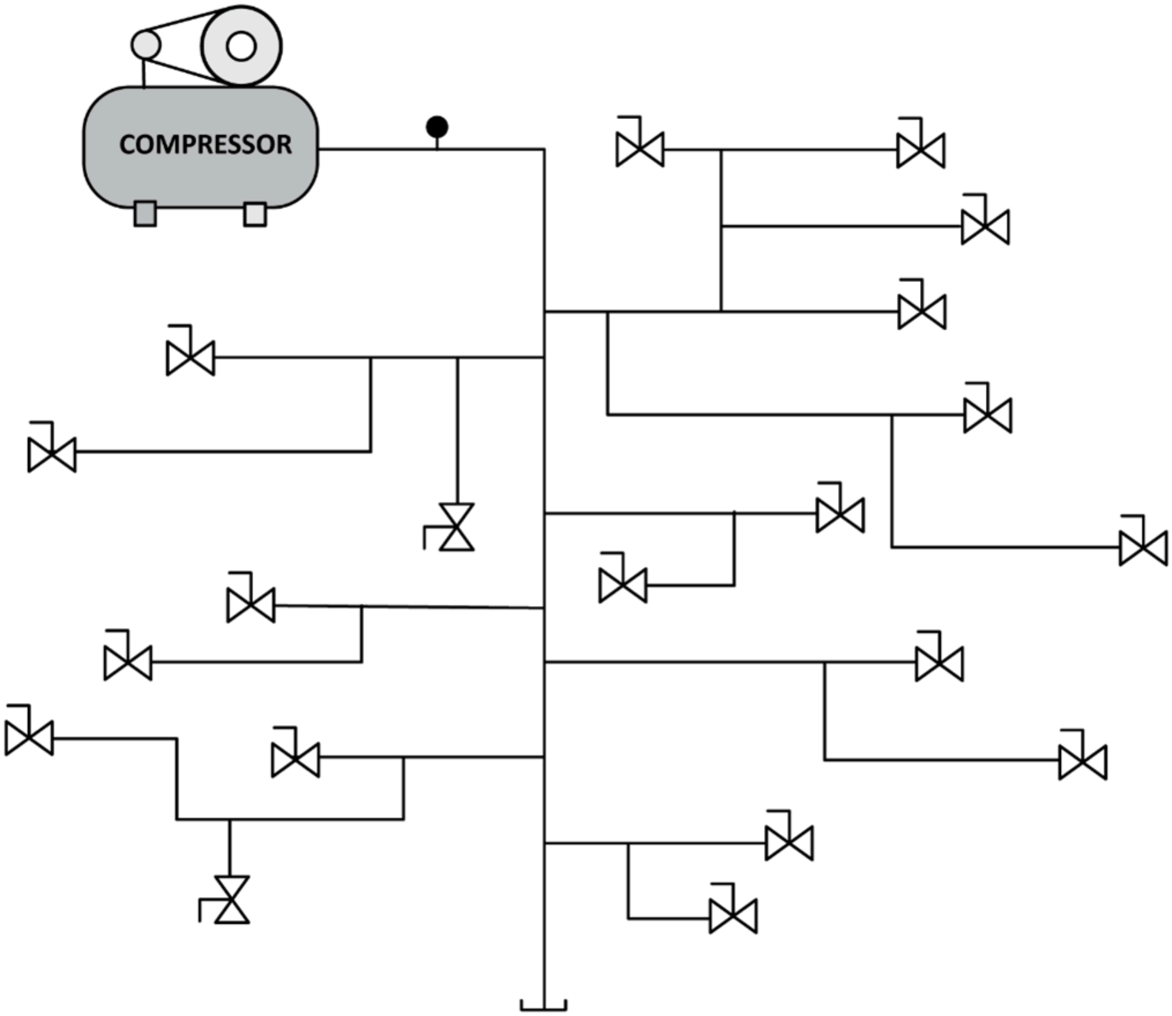

Figure 28 "Octopus" network

Closed-loop network

A properly designed distribution network should provide a balance between flow rate and pressure at all points of use in the system. The system should demonstrate flexibility during varying system demands and allow for future expansion. The best piping layout to achieve this performance is the closed-loop network design (Figure 29).

A closed-loop network allows the air supply to flow through several lines at a time with at least two different supply routes available simultaneously for each feeder pipe descending toward a tool or piece of equipment that could be located at any point in the system such as indicated by the letter "A" in the diagram.

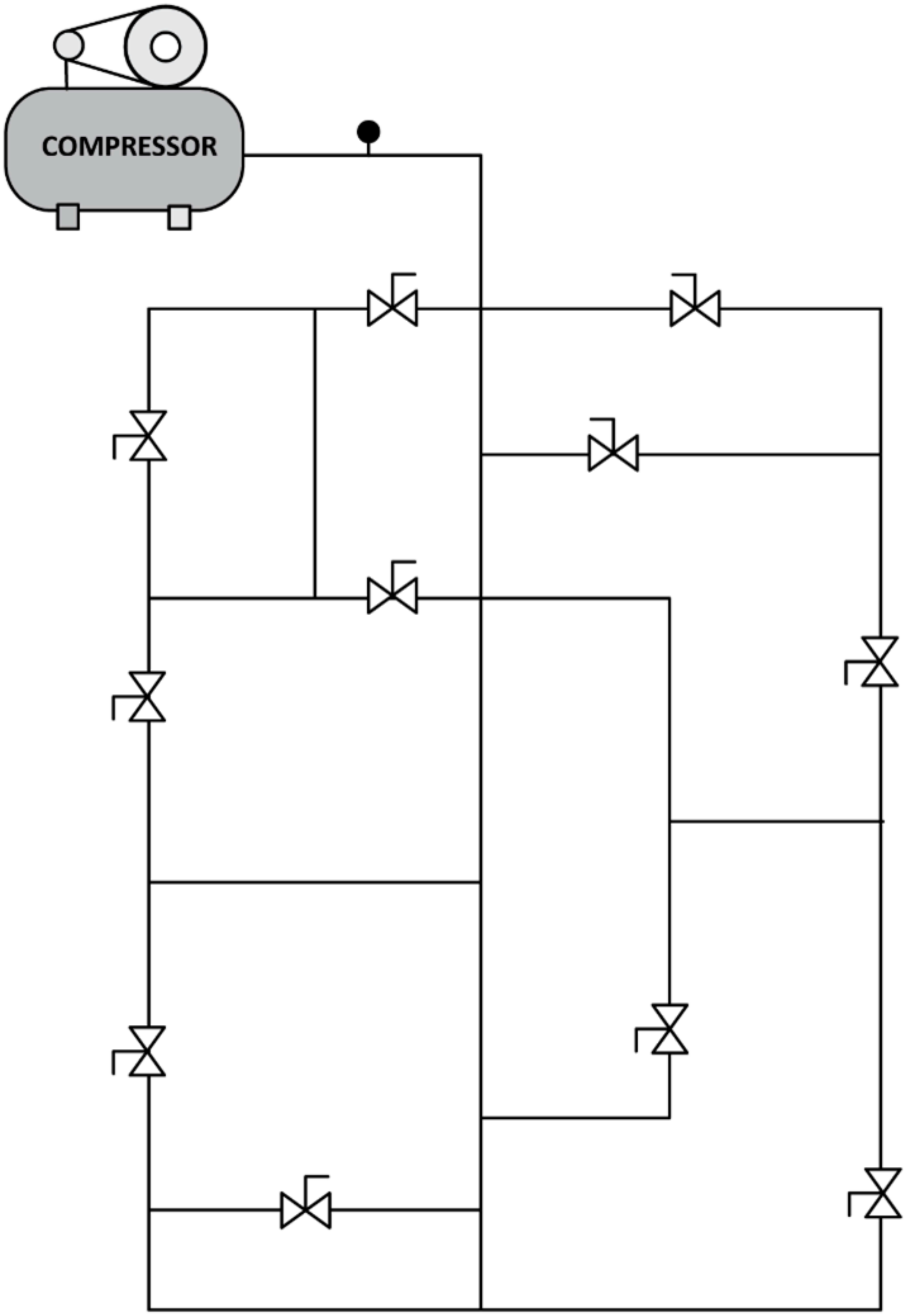

Figure 29 Closed-loop network

A well-built closed-loop network is therefore most often the ideal choice for the distribution of compressed air. In addition to being easy to plan and to modify when needed, this type of distribution system becomes an immense compressed air reservoir that:

- Offers a constant air flow at all times.
- Guarantees a uniform pressure throughout.

- Contributes to the life of the compressor by limiting functioning time.
- Reduces the electrical consumption of the compressor.

Secondary receivers

Some distribution systems provide additional receiver tanks in the process area. This creates an intermediate compressed air reservoir to dampen remote discharge pulsations in the system. These (usually smaller) air receiver tanks can be placed close to applications where there are requirements for relatively short, high air consumption events. So, instead of drawing from the primary storage and compressed air piping system to blast out a huge volume of air for only one short application, the secondary receiver acts as a system shock absorber and turns it into a continuous, smaller system demand.

Secondary receivers are also used to improve the performance of single line systems that have expanded beyond the original design or were a single main line has a considerable distance to travel.

Draining of moisture

Atmospheric air always contains some water vapour. As the air is compressed, the water vapour is compressed along with it, and the increased pressure causes much of the water vapour in the air to condense and drop out in liquid form. When the distribution mains travel outside the compressor room, temperatures are typically lower, which promotes condensation. This water is harmful to the distribution system and the pneumatic equipment. In less-sophisticated systems, manual drains are used at system low points. They are essentially a ball or gate valve that is manually opened to drain the accumulated condensate. Because they depend on human interaction, they are either neglected or completely ignored. To eliminate this problem, a liquid drain trap is used to drain off the water while preventing the escape of compressed air.

Compressed air condensate drain traps automatically discharge moisture and oil from compressed air systems without the loss of any system air during the draining process. This feature is referred to as zero loss. Drain traps are installed throughout the system at locations that may include system low points, receiver tanks, intercoolers, aftercoolers, dryers, filters and drip legs. Unattended drain lines in the compressed air system can fill with liquid, flood the system and interfere with production equipment.

Modern compressed air drain equipment typically uses four main drain technologies:

- internal float drains
- pneumatic/mechanical drains
- timed solenoid electric drains
- electronic level-sensing drains

Internal float drains

Internal float drains are typically located at the end-user filter housings and are available in normally open and normally closed configurations (Figure 30). The normally closed version is automatic; it operates when the float rises due to accumulated liquid, discharging condensate and debris from within the filter bowl. The normally open version is semi-automatic; it operates when the air-line is depressurized, for example at the end of a shift. When the system is pressurized, it will remain closed but the drain may be operated manually through an internal bypass.

Figure 30 Internal float drain

Timed solenoid electric drains

Timed solenoid electric drains operate by using two timers that a user can program according to their application and drain needs (Figure 31). One timer is set for the interval between each time the drain opens. The second timer is set for the amount of time that the drain is open. These drains are more resistant to clogging than internal float drains, although the orifice within the valve through which fluids flow is small, usually 3–5 mm (1/8″ to 3/16″). This orifice can plug up and should be protected with a y-strainer, which itself needs periodic cleaning. Timed solenoid drains are not a zero loss design as they also purge compressed air along with liquids.

Figure 31 Series timed electric condensate drain

Electronic level-sensing condensate drain

Electronic level-sensing drains are a zero-loss design that operates based on the level of demand, not on a specific time setting where demand is not considered (Figure 32). This approach eliminates the biggest drawback to solenoid timer drains, which is the loss of compressed air. Level-sensing drains are called demand drains because they only activate when liquid is present.

Figure 32 Electronic level-sensing condensate drains

Pneumatic/mechanical drains

Pneumatic/mechanical drains are also a zero-loss design powered by air rather than electricity, so they are ideally suited for remote or portable applications (Figure 33). An external condensate reservoir collects liquid. When the liquid rises to a set point, a mechanical switch sends pilot air to an air cylinder that opens a ball valve, draining the reservoir. As the level of liquid in the reservoir drops, the mechanical switch closes, shutting off the pilot signal and closing the ball valve. No compressed air is wasted in the process, except for the tiny amount of pilot air. The ball valve has a straight-through flow pattern, so these drains are resistant to clogging and blockage.

Figure 33 Pneumatic/mechanical condensate drain

End use equipment

Compressed air has many end use applications, including:

- Operating pneumatic cylinders or actuators
- Pneumatic hand tools
- HVAC control systems
- Air brakes
- Underwater diving
- Medical air
- Refilling portable compressed air tanks eg SCUBA or ammunition propulsion
- Sandblasting
- Spray painting

Tool and equipment performance depends on whether they receive the required rate of air flow. It is important to know whether the flow rate specified for a certain tool is stated in unpressurized terms (SCFM; standard cubic feet per minute) or in pressurized terms (CFM; cubic feet per minute), as there can be a great difference in the actual flow rate.

SCFM differs from CFM in that the “S” indicates that the air is “standardized” at 14.7 psia (103 kPa). SCFM establishes standard conditions used in the comparison of the air consumption of air tools and the output capacity of compressors. CFM, on the other hand, must be stated at a specified gauge pressure.

Secondary treatment

Secondary treatment of compressed air refers to the equipment outside of the supply side components. This can include additional filtration, pressure reduction, or lubrication. The final application will ultimately determine secondary treatment that will be installed to ensure the necessary quality of compressed air that is required. For example one installation may be using equipment that requires oil lubrication for air tools; then an automatic line lubricator should be installed. In another case, where paint spraying is done, a lubricator would create a problem.

Filters need to be serviced regularly; cartridges need to be cleaned or replaced depending on the manufacturers instructions. Some filters come with differential pressure indicating gauges (Figure 34). Pressure drop is determined by measuring the difference between the inlet and the outlet pressures of a filter element. Once the pressure drop reaches 10psi, the element is starting to become clogged, which can begin to adversely affect system performance.

Figure 34 Secondary filter bank

Filter regulator lubricator devices (FRL)

Before air can be used to drive tools and equipment it needs to be filtered, regulated and lubricated. In many cases these air treatments are provided at the connection point with an assembly called a *filter*, *regulator*, *lubricator* (FRL) (Figure 35).

- **Filters:** These purify the air by filtering out moisture and other impurities.
- **Regulators:** Pneumatic equipment must operate at the pressure for which it was designed or equipment damage may occur. Regulators are designed to provide constant pressure to ensure that an established pressure is not exceeded.

- **Lubricators:** Many pneumatic applications require an air supply that contains a lubricant. Lightly lubricating a tool's moving parts allows the tool to perform at optimal levels and increases its lifespan.

The FRL unit must be installed in the air line in the correct position in order to prevent contaminant damage. If an FRL is installed backwards, the oil from the lubricator will gum up the regulator and the filter.

Figure 35 Filter, regulator, lubricator (FLR)

Safety Devices

Every air compressor is fitted with safety features to avoid abnormal and dangerous operational errors of the equipment. If safety alarms and trips are not present on the air compressor, abnormal operation may lead to breakdown of the compressor and may also injure a person working on or around it. Depending on the size and application, an air compressor may have any or all of the following devices.

Pressure relief valve (PRV)

When the pressure inside the system reaches the PRV set point, the air pressure acting on the piston inside the PRV overcomes the spring pressure, forcing the piston out and opening the flow path from the air line or tank to atmosphere, venting excess pressure. Once the over- pressure condition has been reduced below the PRV set point, the valve re-seats and returns to service (Figure 36).

Figure 36 Pressure relief valve

Bursting disk

Also known as a rupture disk, this is an “engineered weak spot” within a pressurized system that is designed to burst at a predetermined pressure (Figure 37). It is a one-time device used to protect a system from overpressure damage.

Figure 37 Bursting disk

Fusible plug

Generally located on the discharge side of the compressor, this is a single-use device that operates as a safety valve in response to dangerous temperatures, rather than dangerous pressures. A tapered hole is drilled completely through its length and sealed with a metal of low melting point that flows away if a predetermined high temperature is reached.

Safety alarm systems

Many large industrial applications have specialty alarm systems interlocked into the control system. A safety shutdown of the system will occur under any of the following events:

- Low oil pressure
- Water high temperature
- Water no-flow
- Motor overload

Low oil pressure alarm and trip: If the lubricating oil pressure falls below normal, an alarm sounds, followed by a cut-out or “trip” signal that shuts off power to the compressor to avoid damage to the bearings and crankshaft.

Water high temperature trip: If the intercoolers are choked or the flow of water is restricted, the air compressor will overheat. To avoid this situation, a high water temperature trip is activated that shuts off the compressor.

Water no-flow trip: If the attached pump is not working or the flow of water inside the intercooler is insufficient to cool the compressor, then moving parts inside the compressor will overheat and seize. A no-flow trip is provided to continuously monitor the flow of water and trips the compressor when there is no flow.

Motor overload trip: If the current to the motor during running or starting is very high, the motor may sustain damage. An overload trip will avoid such a situation.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

1. What is the standardized pressure for the SCFM performance indicator used in the compressed air industry?
    a. SCFM is standardized using 0 psia (0 kPa ab)
    b. SCFM is standardized using 14.7 psia (103 kPa ab)
    c. SCFM is standardized using 14.7 psig (103 kPag)
    d. SCFM is standardized using 25 psig (173 kPag)
2. Which of the following choices best describes the piston configuration in a multi-stage air compressor?
    a. Identical size and assembled in series
    b. Identical size and assembled in parallel
    c. Different sizes and assembled in parallel
    d. Different sizes and assembled in series
3. What type of air compressor uses both sides of the piston to compress the air?
    a. Two faced
    b. Double acting
    c. Multi-stage
    d. Twin stroke
4. Within a two-stage air compressor, what device is used to cool the air as the air moves from the first stage to the second stage?
    a. Aftercooler
    b. Bypass valve
    c. Stage transfer channel
    d. Intercooler

5. What type of compressor develops pressure through the oscillations of a flexible disk?
    a. Rocking piston
    b. Reciprocating diaphragm
    c. Rotary sliding vane
    d. Rotary helical screw
    e. Rotary scroll
6. What type of compressor is used when contamination is not allowed in the discharge air stream?
    a. Rocking piston
    b. Reciprocating diaphragm
    c. Rotary sliding vane
    d. Rotary helical screw
    e. Rotary scroll
7. What type of compressor uses two spinning rotors to trap and compress the air?
    a. Rocking piston
    b. Reciprocating diaphragm
    c. Rotary sliding vane
    d. Rotary helical screw
    e. Rotary scroll
8. What type of compressor uses two spiral elements to trap and compress the air?
    a. Rocking piston
    b. Reciprocating diaphragm
    c. Rotary sliding vane
    d. Rotary helical screw
    e. Rotary scroll
9. Which filter installed as part of a compressed air system is considered the most important?
    a. Compressor exhaust filter
    b. Receiver filter
    c. FLR filter
    d. Intake air filter
10. Where would a water separator be installed in relation to the aftercooler in a compressed air system?
    a. Downstream of the aftercooler

   b. Upstream of the aftercooler

11. Where would an aftercooler be installed in relation to the compressor in a compressed air system?
    a. Downstream of the compressor
    b. Upstream of the compressor
12. What two methods are used to reject the heat absorbed by the aftercooler?
    a. Radiant cooling and water cooling
    b. Air cooling and fan cooling
    c. Air cooling and water cooling
    d. Refrigerant cooling and fan cooling
13. What effect does an intercooler have on compressor performance?
    a. The compressor runs quieter.
    b. It improves compressor efficiency.
    c. The compressor output pressure is increased.
    d. The compressor intake volume is reduced.
14. What is the disadvantage of an undersized receiver tank?
    a. It wastes energy because the compressor has to run longer.
    b. It causes excessive compressor cycling.
    c. It causes excessive wear on end-user tools.
    d. It requires larger system piping.
15. What is the disadvantage of an oversized receiver tank?
    a. It wastes energy because the compressor has to run longer.
    b. It causes excessive compressor cycling.
    c. It promotes air stagnation in the system.
    d. It requires higher tool lubrication volumes.
16. What material absorbs the water vapour from the compressed air inside a deliquescent air dryer?
    a. Wood fibres
    b. Charcoal particles
    c. Membrane filters
    d. Salt tablets
17. Why is a double-wall heat exchanger used when recovering heat used for domestic water heating from an air compressor?
    a. It has the ability to withstand system pressure.

b. It provides additional protection from contamination.
c. It can exchange twice as much heat as a similar single-wall heat exchanger.
d. Double-wall heat exchangers can accommodate twice the air volume as a similar single- wall heat exchanger.

18. A straight line piping configuration has limitations when providing proper downstream pressure and flow rates. When considering equipment locations, what strategy will minimize these shortcomings?

    a. Place the equipment with high flow requirements near the end of the system.
    b. Place the equipment with high flow requirements near the compressor.
    c. Place the equipment with high flow requirements on a separate looped system.

19. Of the three listed compressed air piping arrangements, which one should be considered to provide optimal performance?

    a. Straight line networks
    b. Octopus networks
    c. Closed-loop networks

20. Of the three listed compressed air piping arrangements, which network provides the worst performance?

    a. Straight line networks
    b. Octopus networks
    c. Closed-loop networks

21. What is the name given to a moisture drain trap used in industry that eliminates the loss of system air during the draining process?

    a. Can't leak seals
    b. Zero-loss drains
    c. Tight unite drains
    d. Dependo drains

22. What are the three main technologies that manufacturers of compressed air drains use in their product lines?

    a. Pneumatic/mechanical drains; electronic demand drains; series timed electronic drains
    b. Open end gravity drains; electronic demand drains; series timed electronic drains
    c. Pneumatic/mechanical drains; electronic demand drains; parallel timed drains
    d. Electronic demand drains; parallel timed drains; manually actuated drains

23. What damage could result if an FRL is installed backwards?

    a. The oil from the lubricator could cause other components to plug and become inoperable.

b. The regulator will pass full system air and will cause an increase in air pressure.

c. The filter will not function due to the reverse air flow through the unit.

24. Which safety device found on compressed air systems has an engineered “weak spot” that will fail at a predetermined pressure?

    a. Fusible plug
    b. Pressure reducing valve
    c. Pressure relief valve
    d. Bursting disk

25. Which safety device found on compressed air systems is used to protect against high discharge air temperatures?

    a. Fusible plug
    b. Pressure reducing valve
    c. Pressure relief valve
    d. Bursting disk

26. Which of the following safety devices found on compressed air systems will reset once the condition has been rectified?

    a. Fusible plug
    b. Pressure relief valve
    c. Bursting disk

Check your answers using the Self-Test Answer Keys in Appendix 1.

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Learning Task 2

Install Compressed Air Systems

Installing a quality compressed system requires that attention is paid to many design details such as proper equipment selection and piping layout as well as the installation instructions and or specifications.

Codes and Regulations Regarding Pressure Vessels

A compressed air system receiver is probably the most common type of unfired pressure vessel used by industry. Due to minimum size inspection thresholds employed by the vast majority of jurisdictions, many of the smaller air receivers do not qualify for a mandatory in-service inspection, but they do require a label certifying they are manufactured to a minimum standard. Larger installations fall under the requirements of the Boiler and Pressure Vessel Program administered by the Technical Safety BC.

The Boiler and Pressure Vessel Program is a safety program that regulates the safe design, manufacture, operation, maintenance, repair, inspection and alteration of pressure equipment in British Columbia. Generally, the program oversees pressure equipment by enforcing the Safety Standards Act and the Power Engineers, Boilers, Pressure Vessel and Refrigeration Safety Regulation.

Compressed Air Hazards

Compressed air systems pose risks to workers in the form of high-velocity air and excessive noise. In many Canadian jurisdictions, cleaning with compressed air is not allowed by law. Although many people know using compressed air to clean debris or clothes can be hazardous, it is still used because of old habits and the easy availability of compressed air in many workplaces.

However, cleaning objects, machinery, bench tops, clothing and other things with compressed air is dangerous. Injuries can be caused by the air jet and by combustible dust re-entering the air.

There are certain regulations in BC that deal with these two risk areas.

WorkSafeBC Regulation 4.42 (4) “Cleaning with compressed air” states that:

> Compressed air may be used in specially designated areas for blowing dusts or other substances from clothing being worn by workers, provided that
>
> a. the substances have an exposure limit greater than 1.0 mg/m3, as established by Section 5.48,
> b. appropriate respirators and eye protection are worn, and
> c. the compressed air supply pressure is limited to a pressure of 70 kPa gauge (10 psig), or safety nozzles which have the same pressure limiting effect are used.

Large reciprocating air compressors that produce high noise levels at low frequencies can be found in a wide range of manufacturing plants, and this can be hazardous to workers in the area.

WorkSafe BC Guideline G7.6-(2) “Implementing Controls” requires that:

> the employer, when practicable, to implement one or more options for engineered noise control to reduce worker exposure to or below the exposure limits. An example of an engineered noise control strategy for a compressed air system would be to install compressed air exhaust mufflers, air jet noise silencer nozzles, etc.

System Design

The purpose of compressed air piping systems is simple: to deliver compressed air to where it is needed. However, designing a compressed air system is more difficult one might imagine — the compressed air has to be delivered with sufficient volume, good enough quality and enough pressure to power the components that require compressed air. When designing an air distribution system layout, it is best to place the air compressor and its related accessories where temperature inside the plant is the lowest (but not below freezing). A projection of future demands and tie-ins to the existing distribution system should also be considered.

If the compressed air piping design is not well done, the energy costs will go up, equipment may fail, production efficiencies may be reduced and more maintenance may be required.

Pipe Sizing

Owners of compressed air systems tend to focus on the compressor and think of the piping as less of a concern. However, just as hearts can fail due to clogged arteries, compressors can fail due to under sized piping.

Pressure drop is a term used to characterize the reduction in air pressure from the compressor discharge to the actual point-of-use. Pressure drop occurs as the compressed air travels through the treatment and distribution system. A properly sized piping system should have a pressure loss of much less than 10 percent of the compressor’s discharge pressure, measured from the receiver tank output to the point-of-use.

System Installation

In addition to the considerations of appropriate sizing of equipment and layout, it is necessary follow all manufacturers specifications and installation instructions to ensure proper air supply, good tool performance, and optimal production.

Compressor Installation

Oversized air compressors are extremely inefficient because most compressors use more energy per unit volume of air produced when operating at part-load. In many cases, it makes sense to use multiple, smaller compressors with sequencing controls to allow for efficient operation at times when demand is less than peak.

Proper installation of the air compressor is essential for safe and trouble-free operation. Air compressors are easy to install, provided the installation is done in accordance with the manufacturer's recommendations and with all applicable AHJ requirements.

The compressor unit must be located in a dry, clean, cool and well-ventilated area. If possible, the compressor should be located in a separate room or area, away from the general operations of the facility. A compressor unit releases a great deal of heat that could cause severe problems. It is very important that the unit be located in a relatively large area or, when in an enclosed area, cool air is introduced and the heat is removed by means of intake and exhaust fans. The amount of heat generated by an air compressor is calculated by simply multiplying the unit's horsepower by 2500 BTU/hr. Many systems will recover this energy for space or water heating. Water cooled compressors are excellent for heat recovery applications.

Ensure that the floor under the unit is smooth and level. The compressor must sit squarely on its base. If anchoring a compressor base to the floor, make sure that a vibration isolation system is used. **Do not bolt down tightly.**

Allow room for easy access to the unit for maintenance purposes. Should it be necessary to service the unit, ensure the power source has been shut down and locked out. This must be done to prevent personal injury or damage to the unit.

The compressor must be correctly connected to the building's electrical services. Any electrical work must be carried out by a qualified electrician and be done in such a way that it meets all applicable codes and regulations.

Summary of installation recommendations

Following are some common installation recommendations:

- Smaller rotary and tank-mounted reciprocating compressors require a floor capable of supporting the static weight of the compressor package.
- Larger reciprocating compressors may require a concrete foundation or structural steel support designed to stabilize forces that are present during normal operation.
- Locate the compressor in an area where the added noise will not interfere or violate the WorkSafeBC Regulation.
- All compressors produce heat during the compression process. This heat must be removed from the compressor room for proper operation of the compressor. It is very important to provide sufficient ventilation for all equipment that may be installed in the compressor room. All compressor manufacturers publish the range of allowable operating temperatures.
- Properly vent the exhaust from engine-driven compressors. Be sure that the exhaust cannot be redrawn into the plant through HVAC systems or drawn into the air inlet of compressors.
- Leave sufficient space around the compressor to permit routine maintenance. It is also suggested to provide space for the removal of major components during compressor

overhauls.

- Select piping systems that have low pressure drop and provide corrosion-free operation. When selecting the main air headers, size for a maximum pressure drop of 1 to 2 psig (7 to 14 kPa). It is good to oversize the header, as the one size higher will not add much to the cost but will provide additional air storage capacity and allow for future expansion.
- Maximize energy efficiency by minimizing pipe runs and associated pressure drops. A closed-loop distribution header has the advantage of allowing more than one path for air flow and reduces pressure drop.
- Ample compressed air storage in air receivers is desirable close to the compressor to prevent frequent loading and unloading. Secondary storage, close to points of intermittent but substantial demand, prevents sudden pressure drops in the system and allows recovery time before the next demand cycle.
- Provide a means to drain moisture that may accumulate in piping. Headers should be pitched to enhance drainage and drip legs installed in all low points.
- Connect all drain valve outlets to an approved drain. Be sure the drain is vented. Do not pipe drain valves into a common closed pipe or header upstream of the approved drain.
- Condensed moisture may contain compressor lubricants and other chemicals that must be disposed of in accordance with all AHJ regulations.
- If equipment, piping or drains are exposed to freezing temperatures, be sure to insulate and heat trace to prevent freezing.

Vibration isolation

Air compressors are a major source of vibration. If this vibration is transferred to the structure, it can create serious noise problems in many different areas. Vibration can travel through the structure as well as through the connecting piping. Isolation mounts reduce the transmission of the vibration, but care must be taken when selecting these devices, as an improper mount for an application can actually make the problem worse.

For proper installation, vibration pads should be placed between the baseplate (or tank feet supports) and a level floor. A high temperature–rated steel-braided, vibration isolation flex hose should be used to connect the compressor to the air distribution line (Figure 1 and 2). A rigid connection will not allow any movement between two components.

Figure 1 Vibration pad

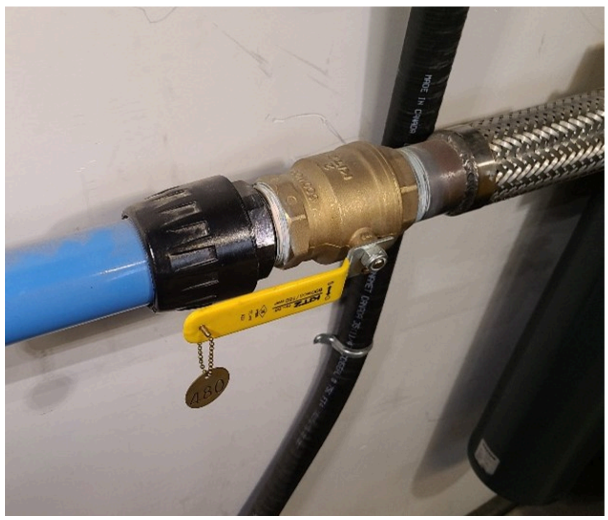

Figure 2 Flex hose

Piping Installation

The length of the network should be kept to a minimum to reduce pressure drop. Air distribution piping should be large enough in diameter to minimize pressure drop.

Distribution piping design

For reliable and trouble-free air distribution, it is important to correctly size the lines and consider; the piping material, flow resistance, maintenance, future expansion and pipe layout.
When installing any compressed air piping arrangement, keep in mind the following design recommendations:

- Always use full port valves that do not reduce pipe diameter. Ball valves are preferred, but butterfly valves can be used if the piping mains are large enough to warrant their use.
- Discharge piping should be at least the same diameter as the compressor discharge outlet.
- A flexible connection between the rigid air piping and compressor discharge outlet is

recommend.

- Install isolation valves at many locations in the air mains. This allows small sections of the main to be shut down to accommodate expansions, additional drops or pipe modifications without shutting down the entire air system. This reduces the temptation to split undersized air drops to many machines whenever an additional drop is required.
- Install an additional tee and fitting to allow temporary connection of mobile or backup compressor for uninterrupted air flow during maintenance/repair service.
- Connect pipe drops off of the top of the air main. This reduces contamination of tools and machinery in the event of an air treatment equipment (dryer and filter) failure, as the contamination will remain at the bottom of the pipe.
- Install periodic drip legs from the bottom of the air mains. These should be used only for draining contaminants and/or checking air quality.
- Mount liquid separator, particulate and oil coalescing filters so the the inlet and outlet connections are horizontal and the filter bowls are vertical.
- If the system is being installed new and is not of an easily modified material, consider placing a tee and valve at each pipe coupling to limit the distance between outlets to 6 m (20 ft.).

Types of piping

Compressed air piping materials can be divided into two basic types: metal (black iron, galvanized iron, stainless steel, copper, aluminum, etc.) and plastic. When design as piping system there are many material selection considerations such as; materials cost, ease of installation, corrosion resistance, flow restriction, pressure rating, durability against external damage. Regardless of the type of piping materials used, it must be rated for at least the maximum working pressure and meet all applicable codes.

Black iron or steel pipe: Compared to copper and aluminum, it is much heavier, more durable, and harder to work with, but less expensive. In sizes 2″ NPS and smaller this pipe is usually threaded; larger diameters are welded. The main limitation with this material is the possibility of corrosion when exposed to condensate (H2O), which would create a problematic source of system contamination.

Galvanized steel piping: This material has the advantage of resisting corrosion better than standard iron pipe. However, over time when corrosion does set in, the galvanizing material peels off. This property is especially harmful on the supply side of the system, as it is now a producer of potentially very damaging solid contaminants between the intake filter and the compressor.

Stainless steel: Stainless steel pipe is often lighter than black iron pipe that has the same pressure and temperature ratings. It is generally a good selection when corrosion is an issue due to high acidity levels in the condensate. Ring gaskets such as those used in groove-and-shoulder type connections are better suited for this material than threaded connections, which often tend to leak.

Copper tube: When selected and connected correctly it is very rugged. Many piping handbooks list the working pressure of copper tubing as 250 psi (1750 kPa) for Type M hard, Type L hard and Type K soft, and 400 psi (2800 kPa) for Type K hard. Due to the potentially high internal pressures and

vibration potential, 95-5 soldered or brazed joints are recommended.
Aluminum: This material has become very popular because its smooth inner surface reduces pressure loss due to friction, and manufactures offer custom fittings and support systems (Figure 1 and 2).

Plastic pipe: This has been used as compressed air piping for many years because the labour costs are less than most metals so the total installation may often be less expensive. However plastic pipes do not have the strength and durability of metal piping systems. PVC and CPVC should never be used for compressed air due to the fact that if it breaks it can shatter and fling sharp fragments of hard plastic through the air. ABS, PP, PE and HDPE plastics are appropriate for use in compressed air piping systems (Figure 3). Typically the mention of ABS makes people think of drainage pipe and fittings but manufacturers produce a specially engineered formulation of ABS that is designed specifically for compressed air systems.

Figure 3 Polypropylene (PP) underground compressed air line

Joining methods

Maintaining the efficiency of a compressed air system is a constant battle, with leaks being a large part of the problem. Pipe joints and fittings are two of the most common areas where leakage occurs in a compressed air system. The type of joining method used usually depends on the system pressure and the material used. In applications using copper, soldering or brazing is standard for small-diameter tubing, while roll grooved joints can be found in larger diameter applications. Plastic compression-type fittings, solvent welding and heat fusion are typically proprietary to the manufacturer.

Many plants now prefer thin wall aluminum tubing due to its lightweight and ease of installation (Figure 4a and 4b). Smaller sizes are often simple push to connect fittings whereas larger diameters may be pressed or grooved. As there are an assortment of connection methods used by different manufacturers it is imperative that you make sure to follow manufacturers assembly instructions for the type of fitting being used.

Figure 4a Aluminum compressed air fittings

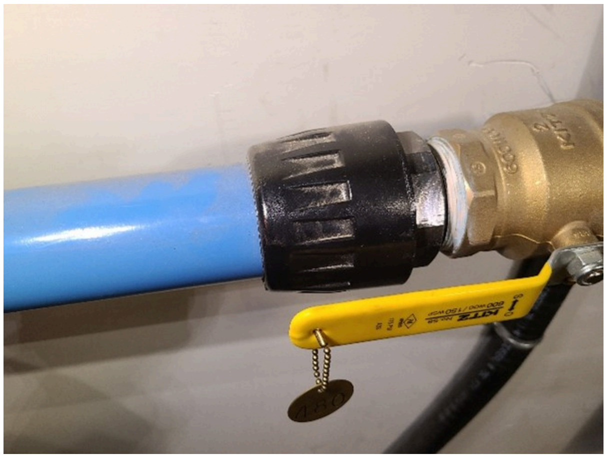

Figure 4b Aluminum compressed air fittings

Connection of Equipment to Piping

Figure 5 shows a typical drop for an air line and the parts required for the system to work properly. Note that a line sloping toward a water leg alleviates the moisture problem and the drop is taken off the top of the main line. After compression and before use, it is often necessary to condition the air and rid it of contaminants, adjust system pressure to match the end use, and either add or remove oil. It is common to use a single unit, an FRL (filter, regulator and lubricator), for this.

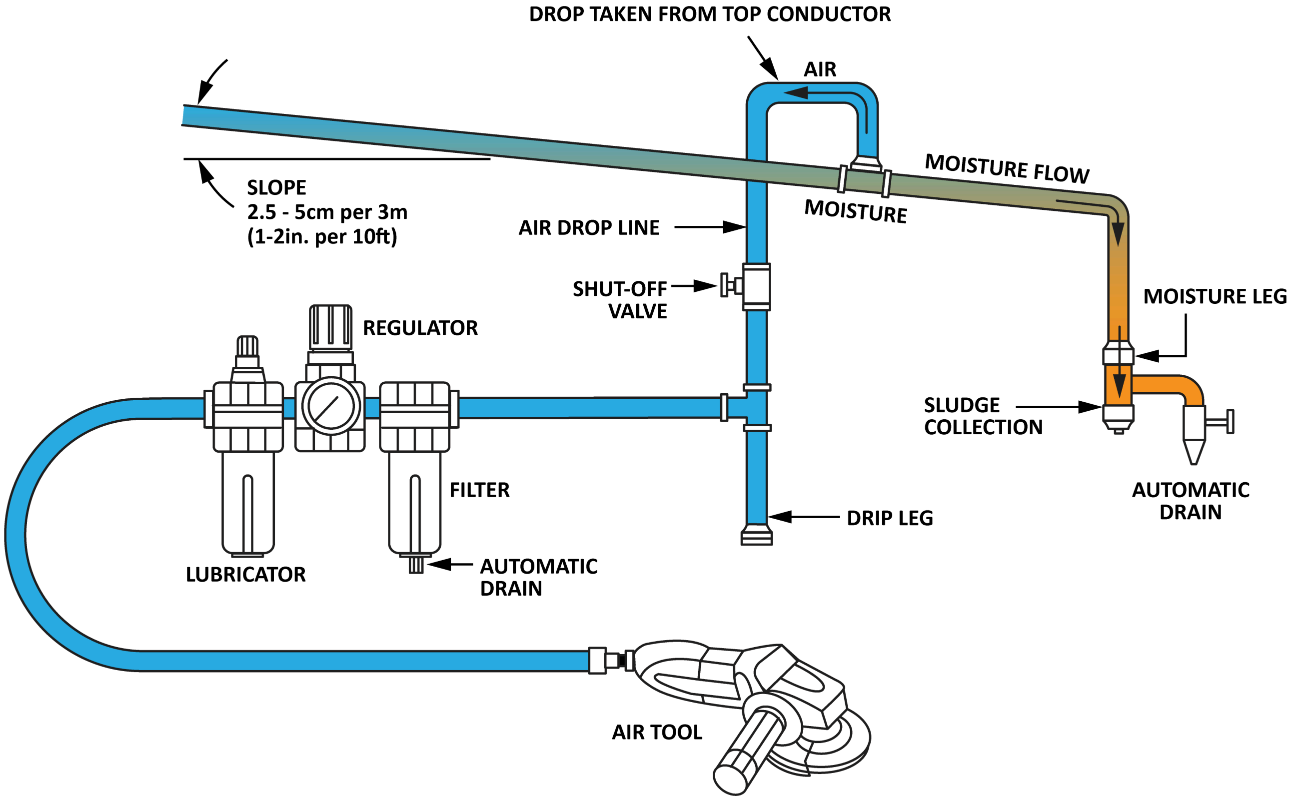

Figure 5 Air line drop components

Flexible hose is often used between drop points in the distribution system and air tools as well as between valves and actuators where some sort of pivot mount (Figure 6) is used to mount the actuator.

Figure 6 Compressed air pivot connector

Hoses used to power pneumatic tools should be fitted with a velocity fuse. A velocity fuse (Figure 7) is a valve that closes when excessive flow begins to pass through it. This prevents an air hose from whipping if it is severed, ruptured or otherwise fails.

Figure 7 Air hose velocity fuse

Pneumatic equipment is typically attached to the hose system with quick disconnect couplings (Figure 8). Quick disconnect couplers are the fastest, easiest and most reliable means of joining tools to the distribution system. Usually, quick disconnects are selected based on the size of the supply line pipe threads. However, many quick disconnects are not full-port-designed. Often the female half of a quick disconnect coupling uses a spring-loaded ball-against-seat design to prevent compressed air from escaping to atmosphere when disengaged.

Quick disconnect couplings will cause a pressure loss created by force used to lift the ball and spring off its seat. As well as the fact that the internal orifice size of a ½” quick disconnect might be only ¼” or less.

Figure 8 Quick disconnect coupler

The importance of the size and type of hose used to connect equipment is often overlooked. Although a small-diameter hose is cheaper, a larger diameter hose will improve system performance. Also, minimize the length of the air hose from the FRL connection point to the equipment location to reduce the pressure drop in the line.

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

1. When selecting the size of the supply header in a closed-loop piping configuration, what is the maximum pressure drop that should be allowed in the header?

a. 2 psi (14 kpa)
b. 5 psi (35 kPa)
c. 7 psi (50 kPa)
d. 10 psi (70 kPa)

2. Approximately how much heat energy would be generated by a 20 hp air compressor?
    a. 20 000 BTU/hr.
    b. 30 000 BTU/hr.
    c. 40 000 BTU/hr.
    d. 50 000 BTU/hr.
3. The WorkSafeBC Regulation allows for blowing dusts or other substances from clothing being worn by workers in specially designated areas. What type of PPE must be worn by the workers?
    a. Safety glasses and face shield
    b. Air respirators
    c. Eye protection and air respirators
    d. Dust masks and earplugs
4. Referring to the previous question, what is the maximum supply pressure of the compressed air allowed by the Regulation?
    a. 7 kPa gauge (1 psig)
    b. 35 kPa gauge (5 psig)
    c. 70 kPa gauge (10 psig)
    d. 105 kPa gauge (15 psig)
5. Moisture drains that are subject to freezing should be protected by either of what two methods?
    a. Insulation and heat tracing
    b. Glycol bath and heat tracing
    c. Insulation and radiant heaters
    d. Burst plugs and electrical air heaters
6. What device should be installed when connecting a compressor to a rigid distribution piping system?
    a. Spring isolators
    b. Roller hangers
    c. High temperature–rated steel-braided, vibration isolation flex hose
    d. Rigid compressor mounts to eliminate compressor vibration
7. What device is installed in a pneumatic hose to prevent flow when the air velocity becomes

excessive due to hose failure?

a. Excess flow valve
b. Velocity harness
c. Emergency quick disconnect coupling
d. Velocity fuse

8. What type of device is used to provide ease of use when connecting pneumatic tools to a compressed air hose?

a. A threaded union fitting
b. A quick disconnect coupling
c. A ring seal coupling
d. An air seal coupling

9. Where should the branch take-offs be connected when piping the main air discharge header from the receiver?

a. Off the top of the main
b. Off the bottom of the main
c. Off the side of the main
d. It doesn't matter where they are connected.

10. Automatic drain traps should be installed in which of the following locations?

a. At the bottom of the air receiver
b. At the bottoms of drip legs
c. At low points in the system
d. All of the above

11. What is the main limitation in using black iron pipe as a compressed air piping material?

a. Possibility of corrosion when exposed to condensate
b. The initial cost of the material
c. The special hangers required due to the weight of the material
d. Leak-susceptible threaded fittings are required on small-diameter piping

12. What is the main limitation in using PVC or CPVC as a compressed air piping material?

a. Possibility of corrosion when exposed to condensate
b. The initial cost of the material
c. Possibility the material may shatter when pressurized
d. The pressure drop associated with this type of material

13. What is the recommended joining method when using copper as a compressed air piping material?
    a. 50/50 solder
    b. Threaded joints
    c. Flare fittings
    d. 95-5 soldered or brazed connections

Check your answers using the Self-Test Answer Keys in Appendix 1.

Media Attributions

Competency D2: Test and Commission Compressed Air Systems

System commissioning is the process of assuring that all components of piping system are designed, installed, tested, operated, and maintained according to the operational requirements of authoritative codes, designers and owners alike. This module provides an overview of the basic testing and commissioning procedures for compressed air systems.

Learning Objectives

After completing the learning tasks in this competency, you will be able to:

- Describe the testing and commission of compressed air systems according to manufacturers' documentation, including:
    - air quality tests,
    - leak tests, and
    - the effect of pressure settings.
    - initial start checks

Learning Task 1

Describe the Testing and Commissioning of Compressed Air Systems

Testing and commissioning of compressed air systems includes the necessary testing, measuring, adjusting, and documenting that the performance of an entire compressed air system to ensure it operates as designed. As modern compressed air systems are often packaged units supplied by one manufacturer the equipment supplier will often send out their technician and go through all their standard check-outs. The focus of this technician is usually to flush out any issues with their equipment, as the installer you will need to work with this equipment technician as well as the project engineer to ensure that entire system checks out.

Manufacturers' Documentation

Compressed air systems are made up of complex pieces of equipment. When commissioning these systems, it is important to read instructional guides provided by manufacturers in order to understand how to best use the equipment. Manufacturers go to great lengths to produce operation and maintenance manuals containing technical data regarding the operation of systems and system components. Following are examples of such data:

- equipment clearances
- placement requirements
- ventilation
- electrical supply and systems
- maintenance
- operation
- start-up
- shutdown
- troubleshooting

Manuals and guides provide the commissioning personnel with data about the equipment that are not readily available anywhere else. Without this information, they may not understand how to properly assemble, commission, test or operate a piece of equipment.

Air Quality Tests

The quality of compressed air is very important for the good operation of equipment like air tools and pneumatic machines. Although it is important, compressed air quality is often neglected or not given enough attention.

The quality of compressed air is determined primarily by measuring three contaminants:

- solid particles as measured by their size or concentration
- water vapour content as measured by pressure dew point temperature
- oil content as measured by concentration

It is possible to test the quality of the air on-site, but this is usually quite an expensive option, as the equipment needed to measure all the variables is quite expensive. Typically, air-testing laboratories provide compressed air testing kits for the end user to take a sample on-site and ship it to the laboratory for analysis.

Leak Test

When commissioning the air system can be checked for leaks by simply charging the system with air and then not using any air. If the pressure drops or the compressor cycles on to recharge the system, there are leaks. There are three common methods of leak detection: listening and feeling, the soapy water technique and ultrasonic leak detection.

Ultrasonic leak detection is explained in more detail in Competency D3: Test and Commission Compressed Air Systems.

Pressure Control Schemes

Among compressors, there are multiple control schemes, each with differing advantages and disadvantages. It is important to know the control that was used for the system design when commissioning a system. The different pressure control schemes are:

- Start/stop
- Load/unload
- Modulation
- Variable displacement
- Variable speed

Start/Stop

In a start/stop control scheme, compressor sensors actuate relays, or pressure switches actuate contacts (Figure 1a and 1b), to apply and remove power to the motor according to compressed air needs.

Figure 1a Pressure sensor

Figure 1b Pressure switch

Some pressure switches are capable of directly switching on and off the electric motor. Other pressure switches can only switch on and off a small control signal. The control signal is then fed into the central controller or is used directly to switch on and off large contactors or motor starters.

For a direct motor switching the power rating of the pressure switch contacts has to exceed the power rating of the compressor motor (Figure 2), therefore direct motor switching pressure switches are only seen on smaller air compressor, with relatively small motors.

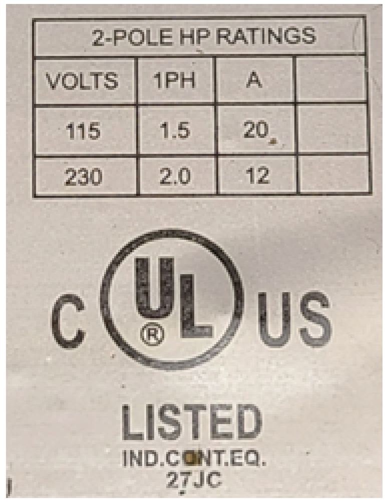

Figure 2 Pressure switch electrical contact ratings

On start/stop reciprocating piston compressors, a blow down valve/unloader valve is used to blow-down air pressure from the compressor discharge line. It will blow off any pressure in the pipe between the compressor and the receiver, this is the ssssssh sound heard, when the compressor stops. By bleeding this discharge line down to atmospheric pressure, when the compressor starts up again, the electric motor doesn't have to overcome the resistance of the system pressure and can start easily. There will also be a check valve, often located right at the point where the compressor discharge pipe is connected to the storage tank(Figure 3), to ensure the whole tank doesn't drain.

Figure 3 Angle check valve with pressure switch/ unloading line connection

On smaller units, this blowdown valve is often mounted on, or inside the pressure switch (Figure 4). When the pressure switch switches off the compressor, the unloader valve is also actuated by a lever inside the pressure switch.

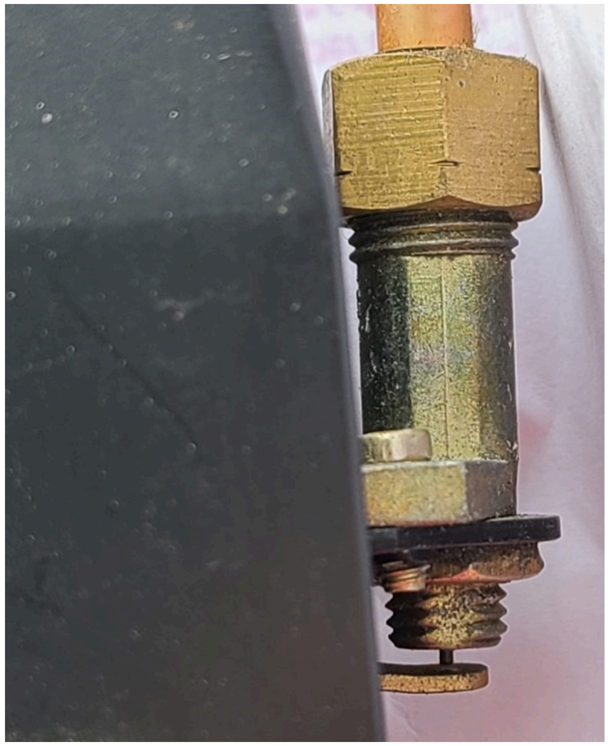

Figure 4 Pressure switch activated, blow down valve

On newer compressors, a simple solenoid valve is sometimes used to blow down the pressure

Load/Unload

In a load/unload control scheme, a screw compressor remains continuously powered. However, when the demand for compressed air is satisfied or reduced, instead of disconnecting power to the compressor, a device known as an inlet valve is activated (Figure 5). This device proportionately regulates the amount of air that is sucked into the compressor, reducing the capacity of the machine down to typically 25% of the compressor's capability, thereby unloading the compressor. This reduces the number of start/stop cycles for electric motors over a start/stop control scheme improving equipment service life with a minimal change in operating cost. This scheme is utilised by nearly all industrial air-compressor manufacturers.

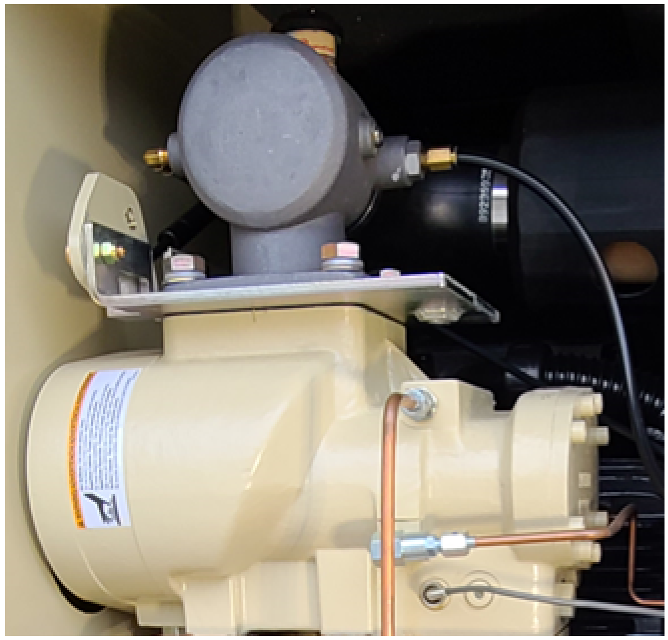

Figure 5 Screw Compressor with inlet/unload valve

When a load/unload control scheme is combined with a timer to stop the compressor after a predetermined period of continuously unloaded operation, it is known as a dual-control or auto-dual scheme. This control scheme still requires storage since there are only two production rates available to match consumption, although significantly less storage than a start/stop scheme.

Modulation

A similar inlet valve as described above continuously modulates capacity to the demand rather than being controlled in steps. This way the compressor can work at any point between 0 and 100%. While this yields a consistent discharge pressure over a wide range of demand, overall power consumption may be higher than with a load/unload scheme, so it is not often used for stationary compressors. But it is often seen in portable diesel engine driven compressors where it is not readily possible to frequently cease and resume operation of the compressor. The continuously variable production rate also eliminates the need for significant storage if the load never exceeds the compressor capacity.

Variable Displacement

Variable displacement alters the percentage of the screw compressor rotors working to compress air by allowing air flow to bypass portions of the screws. While this does reduce power consumption when compared to a modulation control scheme, a load/unload system can be more effective with large amounts of storage (10 gallons per CFM). If a large amount of storage is not practical, a variable-displacement system can be very effective, especially at greater than 70% of full load.

Variable Speed

This type of compressor uses a special drive to control the speed (RPM) of the unit, which in turn saves energy. The benefits of this technology included reducing power cost, reducing power surges (from starting AC motors), and delivering a more constant pressure. The compressor will still have to enter start/stop mode for very low demand as efficiency still drops off rapidly at low production rates.

In harsh environments (hot, humid or dusty) the electronics of variable-speed drives will have to be protected to retain expected service life. Therefore the electronic controls will typically be housed in a separate sealed chamber/cabinet of the compressor packaged unit (Figure 6).

Figure 6 Compressor self contained electronic controls chamber

Pressure Settings

Many plant air compressors operate with a full-load discharge pressure of 100 psig (700 kPa) and a no-load discharge pressure of 110 psig (770 kPa) or higher. Many types of machinery and tools can operate efficiently with an air supply at the point-of-use of 80 psig (560 kPa) or lower. If the air compressor discharge pressure can be reduced, significant savings can be achieved.

Reducing system pressure also can have a cascading effect in improving overall system performance, reducing leakage rates and helping with capacity and other problems. Reduced pressure also reduces stress on components and operating equipment. However, a reduced system operating pressure may require modifications to other components, including pressure regulators, filters and the size and location of compressed air storage.

Lowering average system pressure requires caution because large changes in demand can cause the pressure at points-of-use to fall below minimum requirements, which can cause equipment to function improperly. These problems can be avoided by carefully matching system components, controls and compressed air storage capacity and location. Any change to the pressure setting of an electronically controlled package unit are typically done by the manufacturers technician as the control will typically require a passcode or connection to separate computer. For smaller systems operated by a mechanical pressure switch pressure setting adjustments can be made if the system is not running at the designed pressure.

Pressure Switch Adjustments

There are two common types of pressure switches. One can adjust only the pressure setting, with a fixed differential, the other can adjust both the pressure setting and the differential. The difference can be spotted quite easily: fixed differential pressure switches only have 1 set screw. Pressure switches with an adjustable differential have a smaller second set-screw.
Pressures setting are increased by adjusting the set screws in (clockwise). For a fixed differential switch turning the single adjustment screw will change both the cut-in and cut out pressure equally. For an adjustable differential switch the small screw will change the maximum pressure (cut-out) only Therefore if both the cut –in and the differential need to be adjusted you should set the cut-in pressure first using the large screw then set the cut-out using the small screw.

Initial Start Checks

As was previously mentioned the initial system start up will often involve the equipment supplier technician, the project engineer, and the installer. Every compressor package is given a test run in the factory and checked before shipment. The test run confirms that the compressor package conforms to the specification data. However, independent of the checks made at the factory, the compressor package could be damaged during transport. For this reason, we recommend that the compressor package is examined for such possible damage. Observe the compressor package carefully during the first hours of operation for any possible malfunction.

Important functional components in the compressor package (such as minimum pressure/check valve, pressure relief valve, inlet valve and combination valve) are adjusted and fitted to precise setting up regulations. Alterations to these components are not allowed without previous consultation with the manufacturer.

The following represent a typical start-up checklist for a compressed air system:

- Do not operate the compressor package in spaces where heavy dust conditions, toxic or flammable gasses could exist
- Do not connect the compressor package to a supply voltage other than that stated on the

nameplate.

- Do not install the compressor package in a space subject to freezing temperatures.
- If exhaust air ducts are to be installed they must be at least the cross-section of the cooling air outlet of the compressor package
- Ensure the air intake is clear and installed the required minimum distance from a wall
- Check the oil level in the oil separator tank
- For initial start of a screw compressor add the prescribed quantity of oil to the filler plug on the air inlet valve
- Bump the motor to check rotation direction
- Check the tension of the V-belts
- Check the door interlock safety switch
- Check or oil leaks
- Check the air pressure set points
- Test emergency stop pushbutton

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

1. Which leak detection method is considered the compressed air industry standard?
   a. Listen and feel
   b. Ultrasonic testing
   c. Soapy water
2. When testing for leaks in a compressed air system, where are the leaks frequently found?
   a. At the compressor
   b. At the point of use
   c. The entire piping network
   d. The last 9 m (30 ft.) of piping before the point of use
3. In a poorly maintained industrial compressed air system, what percentage of a compressor's output could be lost from air leaks?
   a. 10–20%

b. 20–30%
c. 30–40%
d. 40–50%

4. What advantages are there to reducing the system air pressure to a full-load setting just above the maximum system requirement?
    a. Cost savings
    b. Improved system performance
    c. Reduced leakage rates
    d. Reduced stress on system components
    e. All of the above
5. What problem could occur when reducing the system air pressure to a full-load setting just below the minimum system requirement?
    a. Equipment malfunction
    b. High air velocities
    c. Excessive compressor vibration
    d. Excessive condensation formation
6. Which of the air quality parameters listed below is not measured?
    a. Solid particle content
    b. Water vapour content
    c. Oil vapour content
    d. Discharge temperature

Check your answers using the Self-Test Answer Keys in Appendix 1.

Media Attributions

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- Figure 6 Compressor self contained electronic controls chamber by Rod Lidstone, Camosun College is licensed under a CC BY 4.0 licence.

Competency D3: Maintain Compressed Air Systems

Like all electro-mechanical equipment, industrial compressed air systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. The compressed air system should be maintained in accordance with manufacturers' specifications. Manufacturers provide inspection, maintenance, and service schedules that should be followed strictly. This module provides an overview of the areas where periodic maintenance should be performed on a compressed air system.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Maintain and repair compressed air systems, according to manufacturers' instructions, taking into consideration the following:
- Compressor maintenance
- Condensate draining
- Filters
- Air dryer maintenance
- Quick connects
- Periodic maintenance areas

Learning Task 1

Maintain and Repair Compressed Air Systems

Industrial compressed air systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. Inadequate maintenance can have a significant impact on energy consumption due to lower compression efficiency, air leakage or pressure variability. It can also lead to high operating temperatures, poor moisture control and excessive contamination. Most problems are minor and can be corrected by simple adjustments, cleaning, replacing parts or eliminating adverse conditions.

Manufacturers' Instructions

All equipment in the compressed air system should be maintained in accordance with manufacturers' specifications. Manufacturers provide inspection, maintenance and service schedules that should be followed strictly. In many cases, it makes sense from efficiency and economic standpoints to maintain equipment more frequently than at the intervals recommended by manufacturers, which are primarily designed to protect equipment.

Operators should review the equipment information and keep it handy for future reference.

Observe all cautionary references before carrying out any maintenance. Equipment must be locked out before carrying out any repairs and pipework under pressure should be vented or shut off if not stated otherwise in the service manual.

Areas requiring periodic maintenance

Conducting routine preventive maintenance on a schedule is a useful way to perform necessary inspections and maintenance in a way that will minimize disruption to plant operations.
Taking a few minutes to check the following areas and there components should be part of a regular maintenance routine.

- Compressor package
    - Air filters
    - V-belts
    - Electrical connections
    - Oil level
    - Oil filter
    - Oil separator

    - Operating temperature
    - Cooling system
    - Pressure relief valve
    - Compressor drive
- External after coolers
- External oil and water separators
- Air Dryers
- Drain traps
- System leaks
- FLR’s

Maintenance contracts have become a popular method for compressor users to plan and budget for equipment maintenance.

Compressor Package Maintenance

The main areas of the compressor package in need of maintenance are the compressor, heat exchanger surfaces, air lubricant separator, lubricant, lubricant filter and air inlet filter.

Inspect and clean or replace air inlet filters. A dirty filter can reduce compressor capacity and efficiency. Filters and inlet ducting should be maintained at least per manufacturer’s specifications, taking into account the level of contaminants in the facility’s air. Some air filters cartridge housings may have a maintenance indicator (Figure 1)or gauge which measures the flow restriction created by a dirty filter.

Figure 1 Compressor inlet filter gauge

If the compressor is belt driven, check for wear and that the belts are correctly tensioned as per the manufacturer’s recommendation. If they are slack, energy loss will occur due to belt slippage. If they are too tight, the belts will be subject to excessive stress and the compressor and motor bearings will be placed under extra load.

The compressor and intercooling surfaces need to be kept clean and foul-free. If they are dirty, compressor efficiency will be adversely affected. Fans and water pumps should also be inspected to ensure that they are operating at peak performance.

Inspect the compressor lubricant level daily and top off as needed with the manufacturers approved product. The compressor lubricant and lubricant filter need to be changed as per manufacturer’s specifications (Figure 2). Lubricant can become corrosive and harm the equipment, reducing system efficiency. For lubricated-injected rotary compressors, the lubricant lubricates bearings, gears and intermeshing rotor surfaces, acts as a seal and removes most of the heat of compression.

Figure 2a Manufactures compressor lubricant

Figure 2b Compressor oil filters

Lubricated rotary screw compressors will also have an oil separator (Figure 3) which recovers lubricant from the compressed air discharge, and returns it to the compressor injection chamber. The service life of the oil separator filter cartridge is influenced by the degree of contamination of inlet air, it is recommend that the oil separator cartridge is changed at the same time as the oil. The compressor package will need to be depressurized so that the air lines will need to be disconnected. Once the cover plate is removed the old gaskets and separator cartridge can be replaced.

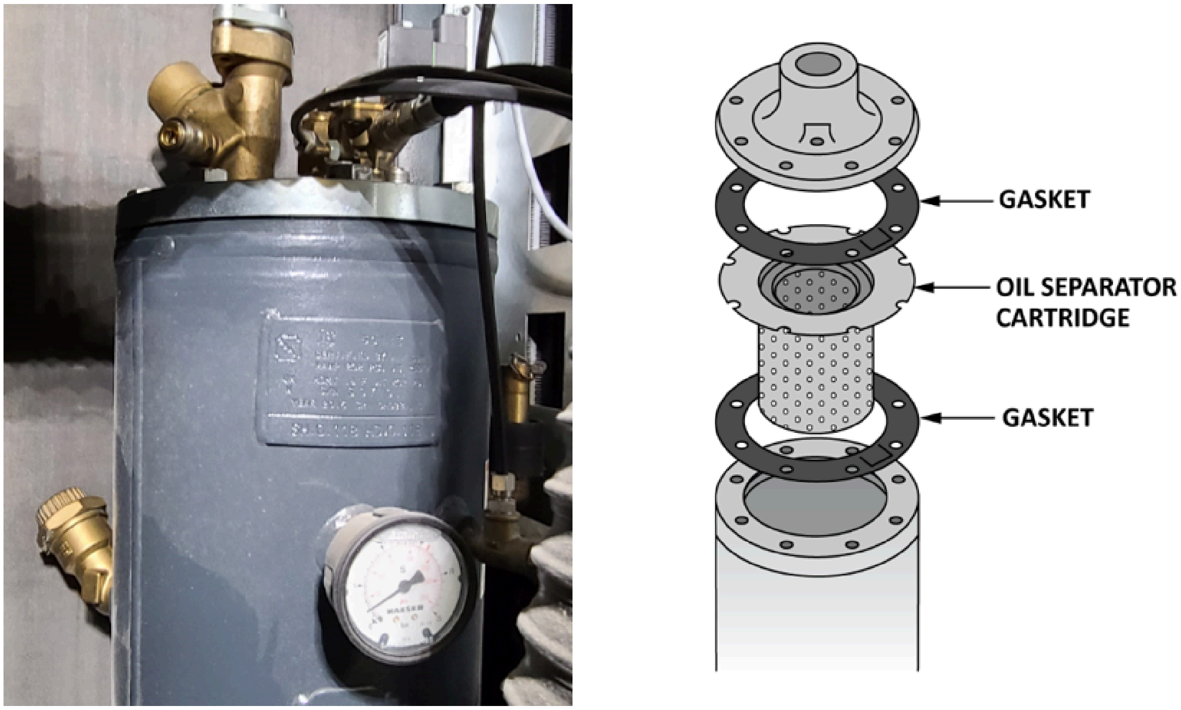

Figure 3 Oil separator (left) and cartridge components (right)

Grease and clean electric motors. Poor maintenance will waste energy and may cause failure before the end of its expected lifetime. Check the manufacturers instructions as many motors now have greaseless bearings.

Check the operating temperature of the compressor. Air compressors are often subject to temperature extremes, especially if they are installed outdoors or in a warehouse without temperature controls. Large swings in temperature can lead to air compressor overheating in the summer or freezing in the winter. Operating at the optimal operating temperature range will and extend the life of the compressor. The ideal operating temperature for an air compressor is between 50 and 85-degrees Fahrenheit. Within this range, mechanical components are not at risk of freezing or overheating due to ambient conditions.

If the ambient temperature in the area where the air compressor is located cannot be kept above 40°F, you may be able to install trace heating around pipes, an internal heater for your air compressor, and insulation to maintain safe operating temperatures inside the air compressor.

The compressor temperature may be high due either external or internal conditions.

External environmental conditions that lead to air compressor overheating include:

- High ambient temperatures
- Inadequate ventilation around the compressor
- Positioning the compressor next to heat-generating equipment

Some of the most common internal causes of air compressor overheating include:

- Dirty or blocked oil filter

- Blockage of oil cooler
- Failed fan
- Low sump oil level
- Thermal valve failure

For water-cooled systems, check the quality of water, especially pH and TDS (total dissolved solids), flow and temperature differential. Regularly clean and replace filters.

Condensate Draining

Condensate drains are possibly the least glamorous and most ignored component of a compressed air system. Nevertheless, there are very few things that can cause more trouble than the condensation that accumulates in the system.

Condensate drains can be found in numerous locations in a system, including:

- intercooler
- aftercooler
- filter
- dryer
- receiver
- drip leg
- point of use

There are many types of drains, and all have specific issues that demand attention. The following are the main types of drains and some of their shortcomings. These issues should be addressed as part of the maintenance/inspection routine.

Manual drains

These are opened manually to remove the accumulated condensation. Certain considerations should be noted when using these drains:

- Avoid leaving manual valves partly open to constantly drain the condensation. This is tempting on drain points that have a high volume of condensation, such as the aftercooler, separator and the air receiver tank.
- Leaving the valve open will eliminate the need for continued attention, and it will effectively remove condensation from the system. However, this creates an obvious compressed air leak and, depending on the size of the system, might actually incur the waste of thousands of dollars on energy.
- Map out the drain locations on your entire system to avoid forgetting about manual drains on remote or low-volume drain points. This might include inline filter drains that are located

high in the air piping and drip lines on the outer reaches of the pipe distribution system.

- Create a maintenance schedule for draining based on system use/demand.

Internal float drains

Internal float drains use a float mechanism in a housing to control the valve that dumps the condensation (Figure 4).

- Remember to clean the housing and the float mechanism regularly.
- The moving parts of this drain are always in contact with the condensation. This liquid becomes contaminated by dirt, rust, pipe scale and oil from the carryover on lubricated compressors. This mixture will cause the float mechanism to malfunction.
- The float will jam in either the open or closed position. You will be able to hear the air leak if the float becomes stuck in the open position. However, if the float sticks in the closed position, you may not realize that there is a problem until liquids begin to back up into the system.

Figure 4 Internal float drain

Pneumatic/mechanical drains

For pneumatically operated drains (Figure 5) ensure that the pilot air supply is installed correctly to the actuating cylinder. The float mechanism is always in contact with the condensation, so it must be cleaned regularly.

Figure 5 Pneumatic/mechanical drain

Series timed electric drains

These use an electronic timer that activates a valve to dump the condensation (Figure 6).

- You can adjust the drain cycles by setting the number of cycles per hour and the length of time the valve will stay open during each cycle. The theory is to set the timer for a long enough period to completely drain the condensation without setting it long enough to waste compressed air.
- The problem is that the amount of condensation will vary according to changes in the temperatures and relative humidity of the ambient environment. This means that the settings will have to be adjusted to compensate for climate and seasonal changes.
- Take the time to change the settings on your timer drains to match the changes in the ambient temperature and humidity.
- Avoid the temptation of using settings that will keep the valve open longer than necessary. This approach may get the condensation out of the system, but it sets up an automatic leak point for compressed air.

Figure 6 Series timed electric drain

Electronic demand drains

Electronic demand drains have electronic sensors that monitor the level of condensation within a reservoir (Figure 7). One sensor opens the outlet valve to dump the condensation when the housing registers as being full. Another sensor closes the outlet valve before completely draining the condensate to avoid wasting air.

Figure 7 Selection of electronic demand drains

Maintaining electronic demand drains:

- Clean the sensors and the housing of an electronic drain regularly.
- The sensing devices are in constant contact with the contaminants found in compressor condensation. This will foul the sensors and reduce the reliability of the drain.

Oil/Water Separators

The condensate that is drained from the system is not just water, but usually contains oil and solid particles. This oil/water mixture is classified as hazardous waste and cannot be discharged into municipal wastewater systems unless the oil and contaminants are removed. A condensate management system will pipe all of the drains to an oil/water separator (Figure 8) before draining to the sewer. The separated oil is captured in an adsorption filter which will need to be monitored, replaced, and appropriately disposed of when necessary.

Figure 8 Oil/water separator

Filters

Filter maintenance and monitoring are crucial to system performance. Any contaminants not trapped in the filter will eventually damage tools and equipment. When selecting filters, ensure that the liquid loading (amount of water or oil) as well as the solid particle size do not exceed the filter rating. Typically, you should start with a bulk filter to remove contaminants at the aftercooler, followed by a fine or extra-fine filter downstream of a refrigerated dryer or upstream of a desiccant dryer.

Filter maintenance recommendations:

- Use the proper micron rating as specified by the OEM.
- Check the pressure differential (Figure 9) and, change the filter cartridge when the pressure drop exceeds 8–10 psid (56 to 70 kPad).
- Check for worn/damaged seals.
- Check for structural integrity.
- Replace the filter after it has been cleaned two or three times.

Figure 9 Filter differential pressure indicating gauge

Air Dryer Maintenance

Hot compressed air contains large amounts of water vapour. When travelling downstream, the water vapour condenses into liquid and causes corrosion in piping, components, air tools and production equipment. Compressed-air dryers are an indispensable part of any clean air treatment process and must be maintained to ensure they remove harmful moisture.

Refrigerated dryers

A refrigerated dryer consists of heat exchangers, refrigeration compressor, condenser, separator/ drain and control system. Clogged condensers are the common cause for most dryer problems.

- Periodically clean the fins with compressed air or a bristle brush to ensure enough refrigerant is transformed into a liquid state for proper heat removal in the evaporator.
- Do not bend or damage the fins of the heat exchanger during cleaning.
- Check separator and drain function regularly by monitoring the discharge amount. Even the best drain needs to be serviced or rebuilt at least once a year.

Desiccant dryers

Pre-filtration is essential to protect the desiccant from oil and bulk water.

- Check the pressure drop across the filters and change the filter cartridge when the pressure drop exceeds 8–10 psid (56 to 70 kPad).
- Check drains for proper operation and rebuild them at least once a year.

Desiccant is very sensitive to oil as well as “dusting,” which occurs when desiccant is subjected to excessive air flow through the dryer.

- Sample the desiccant (drain port on bottom of tower) and examine it for proper size (dusting reduces size) and discoloration, which indicates oil contamination.
- Replace the desiccant every two to three years.

Regenerative desiccant dryers use a variety of control valves to operate. These normally include an inlet switching valve, purge exhaust valves, check valves, and solenoid valves.

Purge exhaust mufflers reduce the noise level during depressurization and purging. Over time the mufflers will become clogged with desiccant dust. A higher than normal back pressure on the regenerating desiccant tower is an indication of clogged mufflers. If the off stream tower is showing a few pounds of pressure during regeneration, the muffler could be clogged.

Deliquescent dryers

Check the dryer’s sight window periodically to ensure its filled with manufacturers recommended tablets, and drain the vessel at regular intervals (once per 8-hour shift).

Membrane dryers

These are completely maintenance-free but require reliable pre-filtration. Check requirements for pre-filtration and drain traps and service per instruction manual.

Quick Disconnects

Most manufacturing plants that employ compressed air use quick-disconnect couplings at equipment locations. Proper selection and sizing of these connectors are usually not given the consideration they deserve. Although these inexpensive devices are not a major maintenance expense, poorly chosen couplings can create unexpected problems with productivity, energy conservation and safety.

If pressure drop through the coupling is an issue, a good alternative to the standard quick disconnect is a version with a full-port design. These disconnects are similar to a full-port ball valve. The internal orifice is the same size as the pipe thread size, and there is no ball and spring to introduce pressure drop.

Reducing pressure drops in the coupling and hose assembly allows a system to operate more efficiently at lower pressures. Not only does operating the compressor at a lower pressure save energy, but reduced pressure means less air is wasted through any unregulated leaks, further reducing energy requirements and associated costs.

A maintenance-saving solution is to minimize the effect of vibration or shock from equipment by using a 60-cm (2 ft.) whip hose between the tool and the coupling. Check couplings periodically for leaks in the coupled and uncoupled positions. Compressed air leaks are expensive in terms of energy cost and excessive compressor capacity. Replace couplings that are not performing properly. Although repairable, their initial cost does warrant the cost of labour to repair them.

System Leaks

Leaks can be found throughout the system from the compressor all the way to the points of use. Check lines (joints), fittings, drains, relief valves, clamps, drain valves, hoses, disconnects, regulators, filters, lubricators, gauge connectors and end-use equipment for leaks. A common area to encounter leaks is within the last 9 m (30 ft.) of piping before the point of use. This is generally the location of the smallest piping and hose sizes, which cause high air velocities. This section is also subject to the most vibration and stress from the end user.

Generally, the more fittings and hoses you have in the system, the more leaks you are likely to have. They may occur in poorly installed fittings or in joints that have loosened or degraded over time.

Leak detection methods

Too many users simply accept leaks as an unavoidable aspect of using compressed air—in other words, just a cost of doing business. While it may not be practical to eliminate all leaks, it is not difficult to greatly reduce them. First, you must find them. There are three common methods of leak detection: listening and feeling, the soapy water technique and ultrasonic leak detection.

Listen and feel: A simple way to detect leaks is by listening for and then feeling leaks. This is only effective for large leaks that you can get close enough to feel, and you must be able to hear them above the noise of plant equipment. This technique will not work for most leaks.

Do not place your bare skin too close to a compressed air leak.

Soapy water: In this method, soapy water is applied with a brush or spray bottle to areas where a leak is suspected. If a leak is present, soap bubbles will form. Although reliable, it is time consuming and requires direct physical access to the entire piping system. Leaks in overhead piping or in hard-to-access areas may not be detected. Further, this method does not provide information on the relative volume of each leak.

Ultrasonic: The industry standard and best practice is to use ultrasonic leak detection. This is the most versatile form of leak detection and can detect leaks as small as a pinhole. Because background noise does not interfere with its results, this method is both fast and accurate and does not require plant downtime to conduct a leak detection audit. Unlike the first two methods, it can be done without physical contact with the leaks. When compressed air is released into the atmosphere, the turbulence creates ultrasonic noise inaudible to the human ear but detectable with the right equipment. Ultrasonic leak detection equipment typically consists of directional microphones, amplifiers and audio filters, and it usually has either visual indicators or earphones to help the auditor identify the leaks.

Air leaks can be a significant contributor to energy wastage in a compressed air system, and in some instances they can lead to productivity losses. It is not unusual at typical industrial facilities to encounter 20 to 30 percent of a compressor's output being lost in the form of air leaks. Proactive leak management programs (detection and repair) can reduce leaks to less than 10 percent of a plant's compressed air production.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

1. What are two advantages to servicing compressed air equipment more frequently than recommended by the manufacturer?
    a. Higher system capacity and plant production gains
    b. Higher efficiency and economic gains
    c. Higher system pressures and smaller distribution piping costs
2. What two adverse effects are present when the compressor air intake filter is not maintained regularly?
    a. Reduced capacity and reduced efficiency
    b. Lower system pressure and larger distribution piping costs
    c. Higher condensate accumulation and loss of end-user pressure
3. What is the most often ignored component of a compressed air system when it comes to proper maintenance?
    a. The aftercooler heat rejection fins
    b. The FLR assemblies
    c. The condensate drains
    d. The air intake filters
4. Which type of condensate drain is most prone to air leakage due to neglect?
    a. Electronic demand drains
    b. Manual drains
    c. Series timed electric drains
    d. Pneumatic/mechanical drains
5. How many cleanings should a filter undergo before it is replaced?

a. 1 or 2
b. 2 or 3
c. 3 or 4
d. 5 or 6

6. What is the common cause of most refrigerated air dryer problems?

   a. A clogged condenser
   b. A clogged separator
   c. Membrane media clogging
   d. Waterlogging

7. What is the maximum acceptable range of pressure drop across a pre-filter cartridge serving a desiccant air dryer before it must be replaced?

   a. 1–2 psi (7 – 14 kPa)
   b. 2–4 psi (14 – 28 kPa)
   c. 4–6 psi (28 – 42 kPa)
   d. 8–10 psi (56 – 70 kPa)

8. What is the term given to a desiccant material when it is exposed to excessive air flow through a dryer?

   a. Air binding
   b. Saturation
   c. Scrubbing
   d. Dusting

9. What device is installed between the pneumatic tool and a quick-disconnect coupling to minimize the effect of vibration or shock from equipment?

   a. A quick disconnect
   b. A spring isolator
   c. A 30-cm (2 ft.) whip hose
   d. An isolation union

10. If a quick-disconnect coupling is of a full port design, what does this imply?

   a. The internal orifice is smaller than the pipe size and does have a ball or a spring.
   b. The internal orifice is the same size as the pipe size and does have a ball or a spring.
   c. The internal orifice is the same size as the pipe size and does not have a ball or a spring.
   d. The internal orifice is smaller than the pipe size and does not have a ball or a spring.

11. When testing for leaks in a compressed air system, where are the leaks frequently found?
    a. At the compressor
    b. At the point of use
    c. The entire piping network
    d. The last 9 m (30 ft.) of piping before the point of use
12. In a poorly maintained industrial compressed air system, what percentage of a compressor's output could be lost from air leaks?
    a. 10–20%
    b. 20–30%
    c. 30–40%
    d. 40–50%
13. Which leak detection method is considered the compressed air industry standard?
    a. Listen and feel
    b. Ultrasonic testing
    c. Soapy water

Check your answers using the Self-Test Answer Keys in Appendix 1.

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Appendix 1: Self-Test Answer Keys

Competency D1

Self-Test 1

1. b. SCFM is standardized using 14.7 psia (103 kPa ab)
2. d. Different sizes and assembled in series
3. b. Double acting
4. d. Intercooler
5. b. Reciprocating diaphragm
6. b. Reciprocating diaphragm
7. d. Rotary helical screw
8. e. Rotary scroll
9. d. Intake air filter
10. a. Downstream of the aftercooler
11. a. Downstream of the compressor
12. c. Air cooling and water cooling
13. b. It improves compressor efficiency.
14. b. It causes excessive compressor cycling.
15. a. It wastes energy because the compressor has to run longer.
16. d. Salt tablets
17. b. It provides additional protection from contamination.
18. b. Place the equipment with high flow requirements near the compressor.
19. c. Closed-loop networks
20. b. Octopus networks
21. b. Zero-loss drains
22. a. Pneumatic/mechanical drains; electronic demand drains; series timed electronic drains
23. a. The oil from the lubricator could cause other components to plug and become inoperable.
24. d. Bursting disk
25. a. Fusible plug
26. b. Pressure relief valve

Self-Test 2

1. 2 psi (14 kpa)
2. d. 50 000 BTU/hr.
3. c. Eye protection and air respirators
4. c. 70 kPa gauge (10 psig)
5. a. Insulation and heat tracing
6. c. High temperature–rated steel-braided, vibration isolation flex hose
7. d. Velocity fuse.
8. b. A quick disconnect coupling
9. a. Off the top of the main
10. d. All of the above
11. a. Possibility of corrosion when exposed to condensate
12. c. Possibility the material may shatter when pressurized
13. d. 95-5 soldered or brazed connections

Competency D2

Self-Test 1

1. b. Ultrasonic testing
2. d. The last 9 m (30 ft.) of piping before the point of use
3. b. 20–30%
4. e. All of the above
5. a. Equipment malfunction
6. d. Discharge temperature

Competency D3

Self-Test 1

1. b. Higher efficiency and economic gains
2. a. Reduced capacity and reduced efficiency
3. c. The condensate drains
4. b. Manual drains

5. b. 2 or 3
6. a. A clogged condenser
7. d. 8–10 psi (56 – 70 kPa)
8. d. Dusting
9. c. A 30-cm (2 ft.) whip hose
10. c. The internal orifice is the same size as the pipe size and does not have a ball or a spring.
11. d. The last 9 m (30 ft.) of piping before the point of use
12. b. 20–30%
13. b. Ultrasonic testing

Versioning History

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.01. If the edits involve substantial updates, the version number increases to the next full number.

The files posted by this book always reflect the most recent version. If you find an error in this book, please fill out the Report an Error form.

Version	Date	Change	Details
1.00	Jan 11, 2023	Book published.	