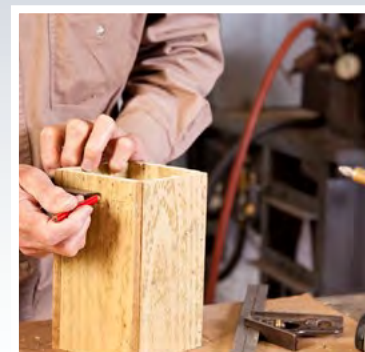


Air Compressor Selection & Application

¼ through 30 HP



Preface

The purpose of this publication is to help users understand the basics of compressed air as a power source and to provide initial technical guidance for selecting the right air compressor for specific applications. The central focus is on packaged complete unit air compressors, most commonly used in sizes 30 horsepower and below as measured according to standards for continuous duty compressors.

Content has been provided by members of the Reciprocating Compressor and Rotary Positive Compressor Sections. Products within the scope of these sections are most frequently used for general purpose industrial air supply, but they also find use in off-shore drilling, construction jobs, locomotives, ships, mining and other specialized applications.

Membership of the Reciprocating Compressor and Rotary Positive Compressor Sections:

ALMiG USA Corporation
Atlas Copco Compressors LLC
BOGE America
Chicago Pneumatic
ELGi Compressors USA, Inc.
FS-Curtis
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Mattei Compressors
Quincy Compressor
Saylor-Beall Manufacturing Co.
Sullair Corporation
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Visit www.cagi.org for the most up-to-date listing of members.

If you require additional information that is not contained in this document, contact a compressor manufacturer of your choice for additional information and instructions.

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Compressed Air

How Can Air Generate Power?

When air is compressed, it is under pressure greater than that of the normal atmospheric pressure and it characteristically attempts to return to its normal state. Since energy is required to compress the air, energy is released as the air expands and returns to atmospheric pressure.

Air compressors were designed to compress air to higher pressures and harness this potential energy source. Unlike other sources of power, no conversion from another form of energy such as heat is involved at the point of application. Compressed air or pneumatic devices are therefore characterized by a high power-to-weight or power-to-volume ratio.

Not as fast as electricity or as slow as hydraulics, compressed air finds a broad field of applications for which its response and speed make it ideally suited. Where there is an overlap, the choice often depends on cost and efficiency and air is likely to hold the advantage.

It is a utility that is generated in-house, so owners have more control over it than any other utility. In addition, air does not possess the potential shock hazard of electricity or the potential fire hazard of oils. However, compressed air is under pressure and can cause harm and bodily damage if not respected. Safety codes and regulations should be followed when working with compressed air. The advantages of air power will be discussed further in the proceeding pages.

Where is Compressed Air Used?

Compressed air powers many different kinds of devices. It can be used to push a piston, as in a jackhammer; it can go through a small air turbine to turn a shaft, as in a dental drill; or it can be expanded through a nozzle to produce a high-speed jet, as in a paint sprayer.

Compressed air provides torque and rotation power for pneumatic tools, such as drills, brushes, nut runners, riveting guns and screwdrivers. Such tools are generally powered by some form of rotary air motor such as the vane or lobe type or by an air turbine.



Equally common are devices producing lateral motion and direct force, either steady or intermittent. Common examples are clamps, presses and automatic feeds. Air pressure can also be used to accelerate a mass, which then exerts an impact upon an anvil, as in paving breakers and pile drivers.

Common applications in industrial plants and on construction sites are air-powered nail guns, staplers, torque wrenches, screwdrivers, paint spraying and conveying of material. In paint spraying and in air conveying, the dynamic pressure of the air imparts motion.

Advantages of Air Power

When there are a dozen or more forms of energy to choose from, what advantages does air power offer? Here, compressed air stacks up against two of its competitors – electricity and hydraulics.

Air Power versus Electric Power

Cost: Air tools have fewer moving parts and are simpler in design, providing lower cost maintenance and operation than electric tools.



Flexibility: Air tools can be operated in areas where other power sources are unavailable, since engine-driven portable compressors are their source of air power. Electric power requires a stationary source.

Safety: Air-powered equipment eliminates the dangers of electric shock and fire hazard. Air tools also run cooler than electric tools and have the advantage of not being damaged from overload or stalling.

Weight: Air tools are lighter in weight than electric tools, allowing for a higher rate of production per man-hour with less worker fatigue.

Air Power versus Hydraulic Power

Cost: An air system has fewer parts than a hydraulic system, lowering service and maintenance costs. Also, the use of a single compressed air supply permits operation of many separate systems at once. Hydraulic systems require more complex and costly controls.

Flexibility: Compressed air systems offer simpler installation than hydraulics, particularly where tools are frequently interchanged. Compressed air systems also offer better adaptability for automation and flexibility for changing or expanding operations.



Maintenance: Air systems have less downtime than hydraulic systems because they have less complex controls. Less preventive maintenance is required with air, whereas hydraulic fluids must be monitored and replaced periodically.

Safety: Hydraulic devices operating near open flame or high temperatures present fire hazards, unless fire-resistant fluids are used. Leakage in hydraulic systems can result in the presence of dangerous hydraulic fluids and even complete system shutdown. In contrast, compressed air devices operate with lower system pressures and accidental air leaks release no contaminants.

Weight: Lighter weight air tools contribute to a lower operating fatigue as compared to heavier hydraulic tools.

Types of Compressors

Air compressors in sizes 30 horsepower and below include both reciprocating and rotary compressors, which compress air in different ways. Major types of reciprocating compressors include reciprocating single acting, reciprocating diaphragm and reciprocating rocking piston type. Major types of rotary air compressors include rotary sliding vane, rotary helical screw and rotary scroll air compressors.

Reciprocating Single Acting Compressors

Reciprocating single acting compressors are generally of one-stage or two-stage design. Compressors can be of a lubricated, non-lubricated or oil-less design.

In the single-stage compressor, air is drawn in from the atmosphere and compressed to final pressure in a single stroke. The single-stage reciprocating compressor is illustrated in (Figure 1). Single-stage compressors are generally used for pressures of 70 psi (pounds per square inch) to 135 psi.

Reciprocating Single Stage

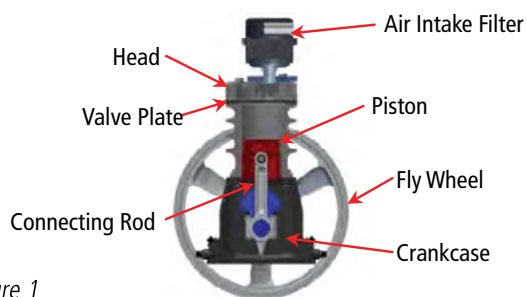


Figure 1

In the two-stage compressor, air is drawn in from the atmosphere and compressed to an intermediate pressure in the first stage. Most of the heat of compression is removed as the compressed air then passes through the intercooler to the second stage, where it is compressed to final pressure. Two-stage compressors can include two cylinder designs. The two-stage reciprocating compressor is illustrated in (Figures 2a and 2b).

Reciprocating Two-stage, Four Cylinder

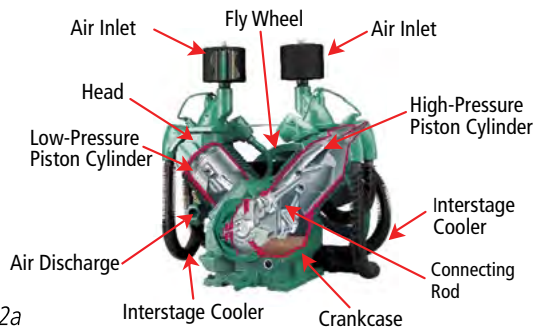


Figure 2a

Reciprocating Two-stage, Two Cylinder

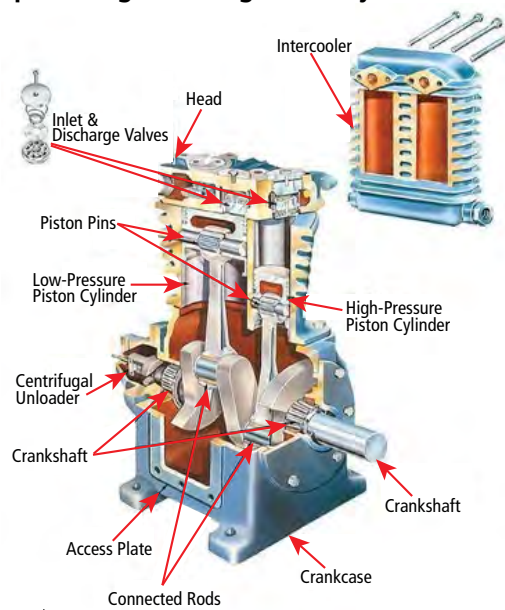


Figure 2b

Single and two-stage reciprocating compressors are frequently used in auto and truck repair shops, body shops, service businesses and industrial plants. Although this type of compressor is usually oil lubricated, hospitals and laboratories can purchase oil-less versions of the compressors as illustrated in (Figure 3).

Reciprocating Single Stage, Oil-less

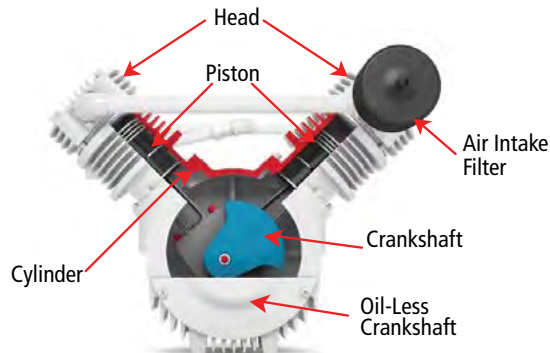


Figure 3

Rocking Piston Type

Rocking piston compressors are variations of reciprocating piston type compressors (Figure 4). This type of compressor develops pressure through a reciprocating action of a one-piece connecting rod and piston. The piston head rocks as it reciprocates. These compressors utilize non-metallic, low friction rings and do not require lubrication. The rocking piston type compressors are generally of a smaller size and lower pressure capability.

Rocking Piston Type

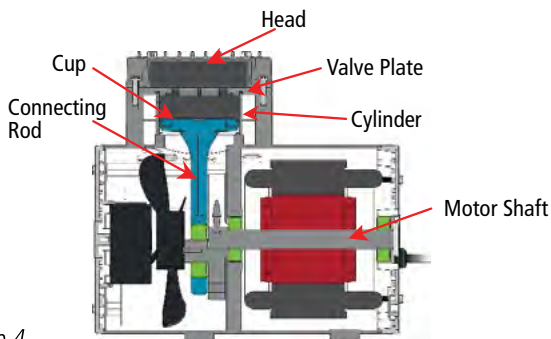


Figure 4

Diaphragm Type

Diaphragm compressors (Figure 5) are a variation of reciprocating compressors. The diaphragm compressor develops pressure through a reciprocating or oscillating action of a flexible disc actuated by an eccentric. 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 or atmosphere, such as hospital and laboratory applications. Diaphragm compressors are limited in output and pressure and they are used most often for light-duty applications.

Diaphragm Type

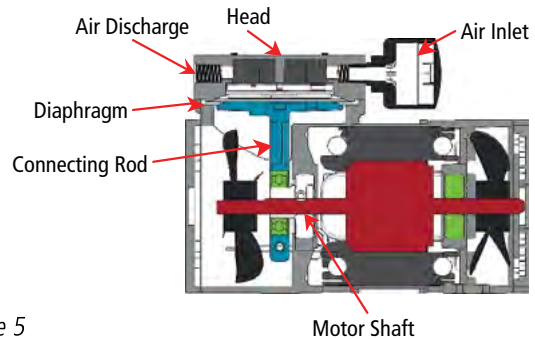


Figure 5

Rotary Sliding Vane Type

The rotary vane compressor consists of a rotor mounted eccentrically in a housing (Figure 6). As the rotor turns, the vanes slide out by centrifugal force until they seal against a thin film of lubricant coating the stator wall. There is no metal-to-metal contact as the blade tip glides on the surface of the lubricant. Air compression occurs when the volume of the spaces between the sliding vanes is reduced as the rotor turns in the eccentric cylinder. Single-stage rotary vanes are oil injected and are most common in industrial applications ranging in pressure from 60 psi to 200 psi. Multi-stage versions range in pressure from 60 psi to 150 psi, use flow-through lubrication that "consumes" lubricant and are most typically used in moving bulk material i.e., concrete. While there are oil-free rotary vane blowers and vacuum pumps, rotary vane compressors are not oil free.

Some of the advantages of rotary vane compressors are smooth and pulse-free air output, low noise, high output volume, low vibrations, prolonged service intervals and long life.

Rotary Sliding Vane Type

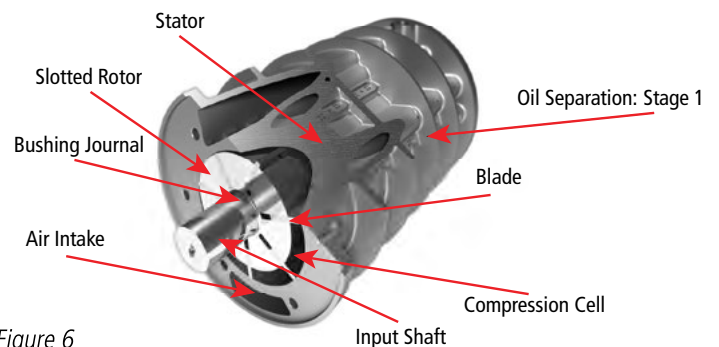


Figure 6

Rotary Helical Screw Type

Rotary helical screw compressors (Figure 7) utilize two intermeshing helical rotors in a twin-bore case. In a single-stage design, the air inlet is usually located at the top of the cylinder near the drive shaft end. The discharge port is located at the opposite end of the cylinder. As the rotors unmesh at the air inlet end of the cylinder, air is drawn into the cavity between the main rotor lobes and the secondary rotor grooves. As rotation continues, the rotor tips pass the edges of the inlet ports, trapping air in a cell formed by the rotor cavities and the cylinder wall. Compression begins as further rotation causes the main rotor lobes to roll into the secondary rotor grooves, reducing the volume and raising cell pressure.

Rotary Helical Screw Type

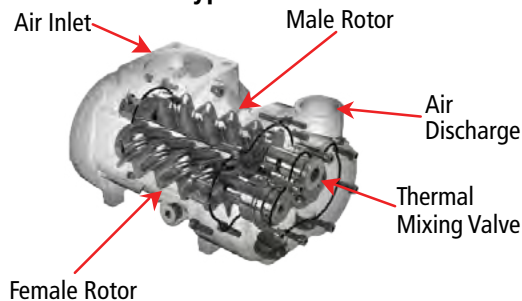


Figure 7

Oil is injected after cell closing to seal clearances and remove heat of compression. Compression continues until the rotor tips pass the discharge porting and release of the compressed air and oil mixture is obtained. Single or multi-stage versions are available. This type of compressor can be oil lubricated, water lubricated or oil-free. Some advantages of the rotary helical screw compressors are smooth and pulse-free air output, compact size, high output volume, low vibrations, prolonged service intervals and long life.

Rotary Scroll Type

Air compression within a scroll is accomplished by the interaction of a fixed and an orbiting helical element that progressively compresses inlet air (Figure 8). This process is continuously repeated, resulting in the delivery of pulsation-free compressed air. With fewer moving parts, reduced maintenance becomes an operating advantage. Scroll compressors can be of lubricated or oil-free design.

Rotary Scroll Type

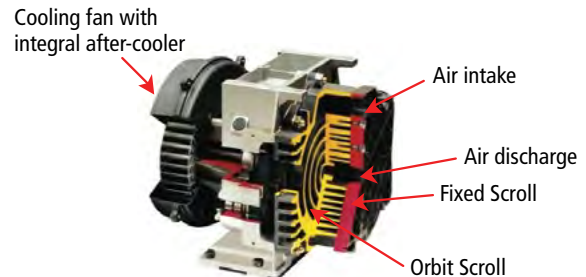


Figure 8

Types of Controls

Controls are required for all compressors in order to regulate their operation in accordance with compressed air demand. Different controls should be chosen for different types of compressor applications and requirements.

For continuous operation, when all or most of the air requirements are of a steady nature, **constant speed controls** are required. Use constant speed controls whenever the air requirement is 75 percent or more of the free air delivery of the air compressor or when motor starts per hour exceed motor manufacturer recommendations. Constant speed controls include load/unload control for all types of compressors and inlet valve modulation for rotary compressors.

Start-stop controls are recommended for a compressor when adequate air storage is provided and air requirement is less than 75 percent of the compressor free air delivery.

Variable speed controls are utilized when energy efficiency is an important criteria in selecting an air compressor. This type of control is most commonly found in rotary screw and rotary vane compressor packages. A variable speed drive will control the speed of the motor and dynamically adjust the speed (increase or decrease) in order to meet the air demand required by the application.

Dual controls allow for switching between constant speed and start-stop operation by setting a switch. With dual controls, the operator can select a different type of control to suit his or her specific air requirements each time the compressor is used. Dual controls are helpful when a compressor is used for a variety of applications that vary between intermittent and continuous-duty.

Sequencing controls provide alternate operation of each compressor at each operating cycle and dual operation during peak demands. Sequencing controls are ideal for operating duplex air compressors or a group of compressors at peak efficiency levels or when 100 percent back-up air might be required for critical applications.

Types of Drives

Most compressors are driven by electric motors, internal combustion engines or engine power takeoffs. Typically, power is transmitted by one of these sources with V-Belt, gear or direct drive configurations. Alternatively, a compressor can have an engine drive. However, an engine drive must use one of the traditional drive types to transmit power. Three common types of drives are used with these power sources.

V-Belt Drives are most commonly used with electric motors and internal combustion engines. V-Belt drives provide great flexibility in matching compressor load to power source load and speed at minimum cost. Belts must be properly shielded for safety.

Gear Drives are commonly used with electric motors and provide a reduction of the axial load on the compressed air producing element, extending the operational lifetime. More working points in the optimal working range provide a reduction in shear force.

Direct Drives provide compactness and minimum drive maintenance. Compressors can be flange-mounted or direct-coupled to the power source. Couplings must be properly shielded for safety. Lower horsepower compressors also are built as integral assemblies with electric motors.

Engine Drives gasoline or diesel engine or power takeoff drives are used primarily for portability reasons. A gearbox, V-Belt or direct drive is used to transmit power from the source to the compressor.

Air Compressor Packaged Units

Air compressor packaged units are fully assembled air compressor systems, complete with air compressor, electric motor, belt, direct or gear drive and automatic controls. Optional equipment includes air receiver, dryer, aftercoolers, automatic moisture drain, low oil safety control, magnetic starter, water separator and particulate filters and pressure reducing valve.

Air compressor units also come with a variety of configurations: gasoline or diesel engines, optional direct drive, optional separate mounted air receivers and more.

Common types of packaged unit compressors include base mount, tank mount, tank mount duplex and tank mount with integrated or mounted dryer. Electric motors or gas engines drive the compressors. Typical examples of the packages are shown in Figures 9 through 12.

Most compressors available in this horsepower range are air cooled. Installation is convenient because the unit requires only a connection to electrical power and a connection to the compressed air system.

Base Mounted Packages

Reciprocating Base Mount Package



Rotary Screw Base Mount Package



Rotary Vane Base Mount Package



Base Mounted/Tank Mounted Package Units

Base Mounted Package Units



Tank Mounted Package Units



Figure 9

Base Mounted / Tank Mounted Package Units are Available with Integrated Dryers or Separate Dryer Options.

Tank Mounted Simplex Package

Reciprocating Tank Mount Packages



Figure 10

Rotary Screw Tank Mount Package with Integrated Dryer



Tank Mounted Duplex Package

Reciprocating Duplex Package



Figure 11

Rotary Vane Duplex Package



Rotary Screw Duplex Package



Gasoline Engine Drive Package

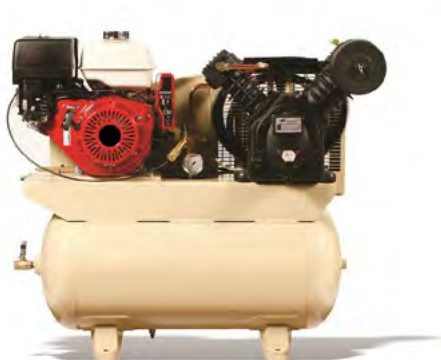


Figure 12



Air Compressor Performance

Delivery (ACFM/SCFM)

The volume of compressed air delivered by an air compressor at its discharge pressure normally is stated in terms of prevailing atmospheric inlet conditions (acfm). The corresponding flow rate in Standard cubic feet per minute (scfm) is measured at 14.5 psi (1 bar,) 68°F (20°C) and 0% relative humidity.

Varying flow rates for more than one discharge pressure simply reflect the reduction in compressor volumetric efficiency that occurs with increased system pressure (psig). For this reason, the maximum operating pressure of a compressor should be chosen carefully.

Displacement (CFM)

For a reciprocating (piston) compressor displacement (cfm) is defined as the volume of the first stage cylinder(s) of a compressor multiplied by the revolutions of the compressor in one minute. For a rotary screw compressor, displacement (cfm) is the volume at suction per thread times the number of lobes on the driving rotor.

Accessories

Standard accessories are available to help ensure reliable and trouble-free compressor operation. Some special purpose devices also are available to meet unusual requirements. Below is a list of commonly used accessories.

Air Receiver

A receiver tank is used as a storage reservoir for compressed air. The receiver prevents the compressor from operating in a continuous run cycle. The receiver allows the compressed air an opportunity to cool. The receiver can be a separate item or can be integrated as part of the compressor package.

Air Treatment Products

Compressed air treatment products are designed to remove oil and water in a liquid or gaseous state from the compressed air stream. These products include, but are not limited to, moisture separators, air dryers, air filters and oil/water separators. The use and implementation of these products are highly dependent on the specific process and application. Further details can be found in the Air Compressor System section of this document. A compressed air expert should be contacted or consulted when working through any compressed air system requirements.

Belt Guard

A belt guard's primary function is safety and it is only utilized on belt drive machines. The belt guard prevents access to fast moving and potentially dangerous components on the compressor from both sides of the drive. The belt guard is a mandatory feature for all V-belt driven compressor units where flywheel, motor pulley and belts are used. Compressors 30 horsepower and below are available as direct or gear drive and do not require belts or belt guards.

Diagnostic Controls

Protective devices are designed to shut down a compressor in the event of malfunction. Devices may include high air temperature shut down, low oil level shut down and low oil pressure shut down, preventive maintenance shut down, etc. These protective devices may be individual sensors or may be monitored by a compressor controller depending on make and model of compressor.

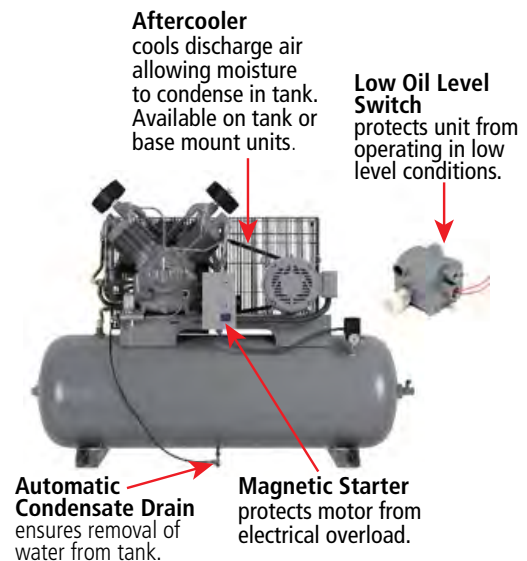


Figure 13

Intake Filter

The intake filter eliminates foreign particulate matter from the ambient air at the intake suction of the air compressor system.

Magnetic Motor Starters

Magnetic starters provide thermal over-load protection for motors and are recommended for integral horsepower and all three-phase motors. Many compressors come standard with starters, however, when a starter is purchased separately from the compressor, local electrical codes should be checked prior to purchasing and installation.

Duplex Tank Mounted Compressor with Alternator Panel

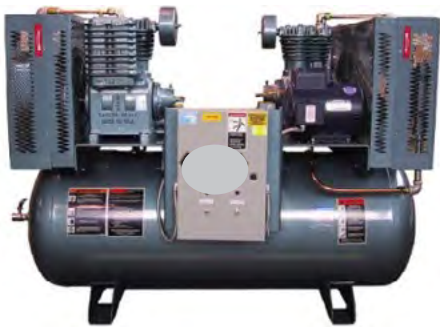


Figure 14

Starters can be configured as full-voltage or reduced voltage. A common type of reduced voltage starter is a wye-delta. A wye-delta starter will reduce the amount of in-rush current to the motor upon initial turn on as compared to a full-voltage starter. A wye-delta starter is also commonly referred to a star-delta configuration. As a note, the motor must be wired to support a wye-delta starter; not all motors support this type of starter configuration.

Variable Speed Drives

This type of drive is most commonly found in rotary screw and rotary vane compressor packages. A variable speed drive will control the speed of the motor and dynamically adjust the speed (increase or decrease) in order to meet the air demand required by the application. In addition, this type of drive reduces in-rush currents upon initial start-up below that of full-voltage or wye-delta starters.

Air Compressor Installation

Location

The air compressor location should be as close as possible to the point where the compressed air is to be used. It is also important to locate the compressor in a dry, clean, cool and well-ventilated area. Keep it away from dirt, vapor and volatile fumes that may clog the intake filter and valves. If a dry, clean space is unavailable, a remote air intake is recommended.

On reciprocating type compressors the flywheel side of the unit should be placed toward the wall and protected with a totally enclosed belt guard, but in no case should the flywheel be closer than 12 inches to the wall. Allow space on all sides for air circulation and for ease of maintenance.

Rotary type compressor installations should follow the manufacturer's installation requirements, which are typically supplied with the compressor in an installation drawing. Be sure to verify that there is enough space in the room or area where the compressor is to be installed to allow for air flow and compressor maintenance. The inlet grids and ventilation fan should be installed in such a way that any recirculation of cooling air to the compressor is avoided. A proper condensate drain system is essential. Also, be aware of the maximum air temperature at the compressor intake, as this can effect compressor operation and life.

Always refer to the manufacturer operational and user's manual for installation guidelines. Make sure that the unit is mounted level, on a solid foundation, so that there is no strain on the supporting feet or base. Solid shims may be used to level the unit. In bolting or lagging down the unit, be careful not to over-tighten and impose strain.

Ambient temperature conditions can vary by manufacturer and should be reviewed prior to purchasing a compressor. Typical ambient conditions can range from 32°F to 115°F. Special precautions are usually required when operating outside this range and the manufacturer of the equipment should be consulted.

Operation at altitudes above 4000 feet may also require special consideration. Consult the manufacturer when operating a unit at a higher altitude to ensure proper operation can be achieved.

Motor Overload Protection

All compressor motors should be equipped with overload protection to prevent motor damage. Some motors are furnished with built-in thermal overload protection and many compressor packages come standard with overload protection integral to the package. Larger motors should be used in conjunction with starters, which include thermal overload units. Such units ensure against motor damage due to low voltage or undue load imposed on the motor.

Care should be taken to determine the proper thermal protection or heater element. The user should consider the following variables: the load to be carried, the starting current, the running current and ambient temperature. Remember to recheck electric current characteristics against nameplate characteristics before connecting wiring.



CAUTION: Fuses and circuit breakers are for circuit protection only and are not to be considered motor protection devices. Consult your local power company regarding proper fuse or circuit breaker size.

Air Compressor System

A compressed air supply can consist of one compressor that can meet the overall air requirements or alternatively multiple smaller horsepower compressors positioned at strategic points throughout the plant or shop. The solution that best fits the application or process will be dependent on a lot of variables that include initial purchase cost of the system, redundancy requirements, process requirements and overall air demand. The entire system requirements need to be fully understood prior to defining the best system to meet the application.

In the central system, the compressor is of a size to supply total compressed air requirements. This option has one compressor, one point of maintenance and one electric power connection.

An alternate approach would have a single small compressor installation. Then, as expansion takes place, instead of replacing the single unit with a larger capacity single unit, another unit of the same size is installed. This would support the increased demand, as well as, provide a level of redundancy to the system. Compressed air system designs vary dependent upon application and installation requirements.

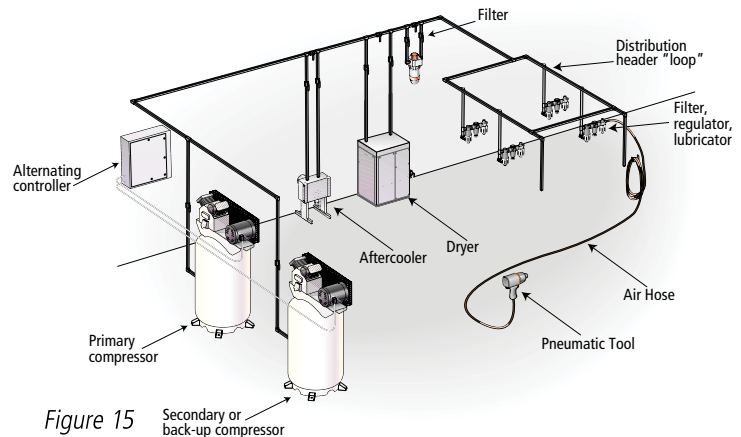


Figure 15 Secondary or back-up compressor

The compressed air system's design begins with the proper selection of the compressor. Selection must address compressor's type and size based upon the application. The compressor must be sized to support all compressed air requirements. Determine your flow (cfm) and pressure (psi) during the busiest time of the business day.

Other important considerations include the physical location of compressor, including space limitations, with appropriate access to compressor and accessories for proper operation, periodic inspections and routine maintenance.

Know the electrical service controlling the compressor. The compressor should be installed on a separate electrical circuit, which should be protected with a properly sized breaker and disconnect. The breaker should be sized for twice full load amps.

Since voltage drops over distance, electrical wiring that runs longer than 50' will require use of larger wire size to avoid voltage drop. Always use a licensed electrician when configuring your electrical requirements.

If your application requires an uninterrupted air supply, a back-up air compressor is recommended. This will ensure compressed air is available during scheduled maintenance and repair. With a second compressor, sequencing controls can be supplied, allowing the compressors to operate in a "lead-lag" mode of operation providing additional compressed air during peak demand periods.

Sequencing controls can be supplied to balance the run time between the two compressors. Incorporating hour meters will allow scheduling of periodic maintenance. Air treatment is the next concern in designing a compressed air system. A by-product of the air compression process is oil and water. The clean up of compressed air begins with cooling. An air receiver allows the initial cooling of compressed air as it exits the compressor. Cooling allows oil and water vapor to condense into a liquid state where these contaminants can be drained from the system. Disposal of liquid condensate must comply with local, state and federal requirements. Compressed air treatment products are designed to remove oil and water in a liquid or gaseous state from the compressed air stream.

Hot, saturated compressed air from the compressor's discharge is routed through an aftercooler. A cooling medium (ambient air or water) is passed across piping, conveying compressed air towards its intended use. Cooling of compressed air allows gross moisture in a vapor state to condense into a liquid. Liquid is separated from the compressed air stream and mechanically removed from the compressed air system.

The aftercooler's performance is based upon its ability to cool the compressed air stream to a lower temperature. The aftercooler can be supplied as a stand-alone unit or be supplied with the compressor.

All compressed air treatment components should be installed with bypass valving. This allows an individual component to be taken offline for maintenance or repair without interrupting the compressed air supply.

Secondly, once compressed air is cooled, further drying can be accomplished through the use of a compressed air dryer. There are many types of dryers. Dryers can be typically grouped into two major categories: refrigerant or desiccant. The design, performance and cost of a dryer will depend upon the application.

With a desiccant dryer, water vapor is removed through absorption and adsorption processes. In the event compressed air lines are exposed to temperatures below 32°F (or 0°C), the use of a desiccant dryer is required to eliminate the hazard of a compressed air line freezing.

Desiccant Dryer



Figure 16

Refrigerant type air dryers are the most economical compressed air dryers in terms of initial purchase price, cost of installation and operation. Within a refrigerant air dryer, compressed air is cooled, water vapor is condensed into liquid water where it is mechanically separated and drained from the compressed air system. Refrigerant air dryers are supplied with automatic condensate drains.

NOTE: An aftercooler and/or dryer can be supplied within a stand-alone air compressor package eliminating the additional field expense of installation (piping and wiring).

A properly sized dryer will prevent liquid water within a compressed air system. All dryers are rated for inlet conditions of 100°F, 100 percent relative humidity and 100 psi. Increasing inlet pressure and lowering inlet temperature will improve dryer efficiency.

Once liquid condensate has been removed from the compressed air stream through the effective use of an aftercooler and dryer, a compressed air filter is recommended for removal of solid particulates, aerosol mists and gaseous vapors.

A compressed air filter is designed with a replaceable element that allows contaminants to impinge upon the elements surface area. As the element becomes wet, filtration efficiency actually improves. As liquids, aerosols and particulates randomly collide on small diameter fibers, the filtration process coalesced invisible contamination into larger droplets that gravitate to the base of the filter housing.

Silent Fully Enclosed Oil-free Piston Compressor with Refrigerated Dryer



Figure 17

Lastly, liquids are drained from the filter through a drain valve. Compressed air filters are designed for specific applications. A properly sized and positioned compressed air filter eliminates contaminants from passing downstream. An electric drain provides a reliable alternative to float-type, gravity-feed drains that corrode and clog over time. Electric drains can be viewed as a low-cost alternative to manually draining the individual components of a compressed air system. Operation of all drains should be checked regularly to avoid costly loss of compressed air.

The compressed air piping system should be designed to deliver compressed air to the pneumatic application at the appropriate flow and pressure. The air distribution system should incorporate a leak-free piping system sized to minimize air pressure drop from its supply – the compressor and compressed air treatment components – to the point of use. Minimizing the number of 90-degree elbows will maximize delivered air pressure. It is estimated each elbow equates to 25' of additional compressed air piping. Pipe diameter should not be less than the discharge port of your compressor. If multiple compressors are being utilized, pipe diameter should equal the sum of each compressor's discharge. Avoid straight runs that dead end. The most efficient design incorporates a "LOOP" that minimizes pressure drop at any one work station.

Different materials can be used for compressed air headers; materials include steel, black iron, stainless or anodized aluminum. It is critical that the material being installed has a pressure and temperature rating with an appropriate safety factor to support the compressed air pressure requirement. Do not undersize pipe. The cost difference between one pipe diameter and the next larger size is minimal. The larger the pipe diameter, the lower the pressure loss will be due to friction. A larger diameter pipe allows for additional compressed air during peak use periods and positions the system for future expansion. The compressed air velocity in the main distribution header should not exceed 30 ft/sec.

A compressed air drop leg, also referred to as a feeder line, begins with a TEE assembly that directs the compressed air in a vertical path. This unique flow pattern will guard against liquid or particulate contamination passing to a pneumatic process.

Each compressed air drop should include a TEE directing compressed air supply to its specified use. The base of the drop leg incorporates a drain valve. Each drop leg might include an FRL (point-of-use filter, regulator and lubricator).

The point-of-use filter is designed to trap any particulate matter that may have been generated in the distribution header. The regulator is designed to provide controlled, consistent air pressure as required for specific pneumatic equipment or application.

The lubricator ensures that the pneumatic device receives required lubrication to maintain operating performance, reduce wear and prolong service life. It is important to understand that lubricating oil carried over from the air compressor has gone through the compression process where it has been exposed to heat, water vapor and particulate matter. Oxidation has allowed this oil to become tacky and corrosive.

The entire compressed air treatment process and the FRL eliminate the possibility of contamination entering pneumatic equipment and processes.

How to Select an Air Compressor

You will need to determine what is most important to you when selecting the appropriate technology. As we discovered earlier there are many options to what kind of air compressor you can select. The Compressed Air & Gas Institute members can provide direction after a review of the job site compressed air applications, conditions and duty cycles. It is always best to consult with a compressed air expert. This is a brief overview of the benefits of each kind of compressor.

Piston or Reciprocating compressors can, in many cases, provide an economical compressed air solution. Designs can range from inexpensive consumer duty models to more rugged industrial products. They are ideally suited for intermittent duty cycles and are simple in design. Piston air compressors are available as oil-free and oil-lubricated.

Rotary screw compressors provide many application benefits and can operate at 100 percent duty cycle. Rotary screw compressors are available with lower sound levels, and can offer higher efficiency for an array of demand profiles. Additionally, rotary screw systems can deliver various levels of ISO-rated compressed air quality. They are available in oil cooled and oil-free technologies. Oil-free rotary screw compressors can also offer a higher quality of ISO-rated compressed air quality that may be required in some critical applications.

Rotary sliding vane compressors provide 100 percent duty cycle and are low sound level due to slow rpm and optional enclosures. Rotary vanes have long design life, do not require bearings, can operate in dirty environments due to forgiving tolerances in their design and operate up to 200 psi. As lubricated compressors, rotary vanes require downstream filtration to meet various oil-free air quality standards in some critical applications.

Diaphragm compressors are a variant of a reciprocating compressor. The compression of gas occurs by means of a flexible membrane, instead of an intake element. Diaphragm compressors are well suited for pumping toxic and explosive type gases and can be limited in output flow and pressure.

Rotary scroll compressors are oil-less compressors that are available up to 10 horsepower in a single pump configuration. Multiple pumps can be multiplexed to provide higher horsepower operation up to 50 HP and can be used in a wide variety of industrial, medical and laboratory applications.

Air Consumption Chart for Industrial Type Tools

Cubic Feet Per Minute Required to Operate Various Pneumatic Equipment at Pressure Range 70-90 psig

MISCELLANEOUS PORTABLE TOOLS	Consumption (cfm) 15% Use FACTOR	Consumption (cfm) 25% Use FACTOR	Consumption (cfm) 35% Use FACTOR
Drill, 1/16" to 3/8"	4.0	6.0	9.0
Drill, 3/8" to 5/8"	5.0	9.0	12.0
Screwdriver # 2 to # 6 Screw	2.0	3.0	4.0
Screwdriver # 5 to 5/16" Screw	4.0	6.0	8.0
Trapper, to 3/8"	4.0	6.0	8.0
Nutsetters, to 3/8"	4.0	6.0	8.0
Nutsetters, to 9/16"	8.0	13.0	18.0
Nutsetters, to 3/4"	9.0	15.0	21.0
Impact Wrench, 1/4"	2.0	4.0	5.0
Impact Wrench, 3/8"	3.0	5.0	7.0
Impact Wrench, 1/2"	5.0	8.0	11.0
Impact Wrench, 5/8"	5.0	8.0	11.0
Impact Wrench, 3/4"	5.0	9.0	12.0
Impact Wrench, 1"	7.0	11.0	16.0
Impact Wrench, 1 1/4"	8.0	14.0	19.0
Die Grinder, Small	2.0	4.0	5.0
Die Grinder, Medium	4.0	6.0	8.0
Horizontal Grinder, 2"	5.0	8.0	11.0
Horizontal Grinder, 4"	9.0	15.0	21.0
Horizontal Grinder, 6"	11.0	18.0	25.0
Horizontal Grinder, 8"	12.0	20.0	28.0
Vertical Grinders and Sanders, 5" Pad	5.0	9.0	12.0
Vertical Grinders and Sanders, 7" Pad	11.0	18.0	25.0
Vertical Grinders and Sanders, 9" Pad	12.0	20.0	28.0

MISCELLANEOUS PORTABLE TOOLS	Consumption (cfm) 15% Use FACTOR	Consumption (cfm) 25% Use FACTOR	Consumption (cfm) 35% Use FACTOR
Burring Tool, Small	2.0	4.0	5.0
Burring Tool, Large	4.0	6.0	8.0
Rammers, Small	4.0	3.0	9.0
Rammers, Medium	5.0	9.0	12.0
Rammers, Large	6.0	10.0	14.0
Backfill Tamper	4.0	6.0	9.0
Compression Riveter	.2 cu. ft. per cycle		
Air Motor, 1 Horsepower	5.0	9.0	12.0
Air Motor, 2 Horsepower	11.0	18.0	25.0
Air Motor, 3 Horsepower	14.0	24.0	33.0
Air Motor Hoist, 1000 #	1 cu. ft. per foot of lift		
Air Motor Hoist, 2000 #	1 cu. ft. per foot of lift		
Paint Spray Gun (Production)	3.0	5.0	7.0
HAMMERS			
Scaling Hammer	2.0	3.0	4.0
Chipping Hammer	5.0	8.0	11.0
Riveting Hammer (Heavy)	5.0	8.0	11.0
Riveting Hammer (Light)	2.0	4.0	5.0
SAWS			
Circular, 8"	7.0	11.0	16.0
Circular, 12"	10.0	16.0	24.0
Chain, Lightweight	4.0	7.0	10.0
Chain, Heavy Duty	13.0	22.0	31.0

Always check with tool manufacturers for actual air consumption of tools being used. The above is based on averages and should not be considered accurate for any particular make of tool.

Above tools are rated based upon typical "on-load" performance characteristics.

For other use factors adjust the cfm air consumption on a proportional basis. (Example: 30 seconds on, 30 seconds off use, 50 percent as use factor).

Air Consumption Chart for Automotive Service Shops

Cubic Feet Per Minute Required to Operate Various Pneumatic Equipment at Pressure Range 70-90 psig

Equip. Air Pressure Range in psi	Portable Tools	Compressor (cfm) Required Per Unit
70-100	**Air Filter Cleaner	3.0
70-100	**Body Polisher	20.0
70-100	**Body Sander (Orbital)	10.0
70-100	Brake Tester	4.0
70-100	**Carbon Remover	3.0
90-100	Dusting Gun (Blow Gun)	2.5
70-100	Panel Cutter	4.0
70-90	**Drill, 1/16" to 3/8"	4.0
70-90	**Impact Wrench 3/8" sq. dr.	3.0
70-90	**Impact Wrench 1/2" sq. dr.	4.0
70-90	**Impact Wrench 5/8" sq. dr.	5.0
70-90	**Impact Wrench 3/4" sq. dr.	8.0
70-90	**Impact Wrench 1" sq. dr.	12.0
70-90	**Die Grinder	5.0
90-100	**Vertical Disc Sanders	20.0
90-100	**Filing and Sawing Machine, (Small)	3.0
90-100	**Filing and Sawing Machine, (Large)	5.0
90-100	**Burring Tool	5.0
TIRE TOOLS		
125-150	Rim Stripper	6.0
125-150	Tire Changer	1.0
125-150	Tire Inflation Line	2.0
125-150	Tire Spreader	1.0
125-150	**Vacuum Cleaner	7.0

Equip. Air Pressure Range in psi	Portable Tool	Compressor (cfm) Required Per Unit
HAMMERS		
90-100	**Air Hammer	4.0
90-100	Tire Hammer	12.0
125-150	Bead Breaker	12.0
90-100	Spring Oiler	4.0
SPRAY GUNS		
90-100	**Engine Cleaner	5.0
90-100	**Paint Spray Gun (production)	8.0
90-100	**Paint Spray Gun (touch up)	4.0
90-100	**Paint Spray Gun (undercoat)	19.0
OTHER EQUIPMENT		
120-150	**Grease Gun	3.0
145-175	Car Lift* (air powered hydraulic)	6.0
125-150	Floor Jacks (air powered hydraulic)	6.0
120-150	Pneumatic Garage Door	3.0
90-100	Radiator Tester	1.0
90-100	Spark Plug Cleaner	5.0
90-100	Spark Plug Tester	.5
70-100	Transmission and Differential Flusher	3.0
70-100	**Fender Hammer	9.0
70-100	**Car Washer	9.0
70-100	**6" Medium Duty Sander	40.0

*This is for 8,000 lbs. capacity. Add .65 cfm for each 1,000 lbs. capacity over 8,000 lbs.

**These devices are rated based upon typical "on-load" performance characteristics.

Always check with tool manufacturers for actual consumption of tools being used.
The above is based on averages and should not be considered accurate for any particular make of tool.

Compressor Selector Chart

Compressor Pressures per square inch		Air Consumption in Cubic Feet Per Minute of Total Equipment		
Cut In	Cut Out	Average Use*	Continuous Operation**	Horsepower of Compressor Required
80	100	Up to – 6.6	Up to – 1.9	1/2
80	100	6.7 – 10.5	2.0 – 3.0	3/4
80	100	10.6 – 13.6	3.1 – 3.9	1
80	100	Up to – 14.7	Up to – 4.2	1
80	100	13.7 – 20.3	4.0 – 5.8	1 1/2
80	100	14.8 – 22.4	4.3 – 6.4	1 1/2
80	100	20.4 – 26.6	5.9 – 7.6	2
80	100	22.5 – 30.4	6.5 – 8.7	2
80	100	26.7 – 32.5	7.7 – 10.2	3
80	100	30.5 – 46.2	8.8 – 13.2	3
80	100	32.6 – 38.0	10.3 – 18.0	5
80	100	46.3 – 60.0	13.3 – 20.0	5
80	100	60.1 – 73.0	20.1 – 29.2	7 1/2
80	100	73.1 – 100.0	29.3 – 40.0	10
80	100	100.1 – 150.0	40.1 – 60.0	15
80	100	150.1 – 200.0	60.1 – 80.0	20
80	100	201.0 – 250.0	80.1 – 100.0	25
120	150	Up to – 3.8	Up to – 1.1	1/2
120	150	3.9 – 7.3	1.2 – 2.1	3/4
120	150	7.4 – 10.1	2.2 – 2.9	1
120	150	Up to – 12.6	Up to – 3.6	1
120	150	10.2 – 15.0	3.0 – 4.3	1 1/2
120	150	12.7 – 20.0	3.7 – 5.7	1 1/2
120	150	15.1 – 20.0	4.4 – 5.7	2
120	150	20.1 – 25.9	5.8 – 7.4	2
120	150	26.0 – 39.2	7.5 – 11.2	3
120	150	39.3 – 51.9	11.3 – 17.3	5
120	150	52.0 – 67.5	17.4 – 27.0	7 1/2
120	150	67.6 – 92.5	27.1 – 37.0	10
120	150	92.5 – 140.0	37.1 – 57.0	15
120	150	140.1 – 190.0	57.1 – 77.0	20
120	150	190.1 – 240.0	77.1 – 97.0	25
145	175	Up to – 11.9	Up to – 3.4	1***
145	175	12.0 – 18.5	3.5 – 5.3	1 1/2
145	175	18.6 – 24.2	5.4 – 6.9	2
145	175	24.3 – 36.4	7.0 – 10.4	3
145	175	36.5 – 51.0	10.5 – 17.0	5*
145	175	51.1 – 66.0	17.1 – 26.4	7 1/2
145	175	66.1 – 88.2	26.5 – 35.3	10
145	175	88.3 – 135.0	35.3 – 55.0	15
145	175	135.1 – 185.0	55.1 – 75.0	20
145	175	185.1 – 235.0	75.1 – 95.0	25

*These figures are not to be regarded as the capacity of the compressor in free air output, but instead, are the combined free air consumption of all the tools in the establishment, as well as tools anticipated for future added equipment. (A factor has been introduced to take into account intermittent operation of tools likely to be in use simultaneously in the average garage or industrial plant.) (See Example 1 on page 20 for the use of the figures given in this column.)

**These figures are to be employed when the nature of the device is such that normal operation requires a continuous supply of compressed air. Therefore, no factor for intermittent operation has been used and the figures given represent the compressor capacity in free air output. (See example 2 on page 20 for the use of the figures given in this column.)

***Do not recommend a compressor of less than 1 1/2 HP if the pneumatic equipment includes a lift of 8,000 lbs. capacity.

Example Number One

It is required to supply a compressor to operate the equipment listed below such as might be found in an average service station. Add the cfm required by all the devices.

2 – Car Lifts	@ 6.0 cfm – 12.0 cfm	145 to 200 psi
2 – Grease Guns	@ 3.5 cfm – 8.0 cfm	90 to 125 psi
1 – Spring Oiler	@ 4.0 cfm – 4.0 cfm	90 to 100 psi
1 – Spark Plug Cleaner	@ 5.0 cfm – 5.0 cfm	90 to 100 psi
2 – Tire Inflators	@ 2.0 cfm – 4.0 cfm	125 to 150 psi
1 – Dusting Gun	@ 3.0 cfm – 3.0 cfm	90 to 100 psi
1 – Trans. and Diff. Flusher	@ 3.0 cfm – 3.0 cfm	70 to 100 psi
Total	26.5 cfm – 39 cfm	

On page 19, under the column “Average Use” and opposite the pressure range required (145 psi to 175 psi), find the line indicating 39 cfm or more. The compressor required will be a 5 HP unit.

Example Number Two

A compressor is needed to operate the following equipment, all of which is to be in operation continuously or nearly so. Total of cfm required for all the devices and the pressure ranges.

1 – Fender Hammer	@ 9.0 cfm	70 to 100 psi
1 – Paint Spray Gun (Production Type)	@ 8.0 cfm	90 to 100 psi
1 – Body Polisher	@ 20 cfm	70 to 100 psi
1 – Touch-Up Spray Gun	@ 3.5 cfm	90 to 100 psi
1 – Vacuum Cleaner	@ 7.0 cfm	125 to 150 psi
Total	47.5 cfm	

On page 19, under the column “Continuous Operation” and opposite the pressure range required (120 psi – 150 psi), find the line indicating 47.5 cfm or more. The compressor needed will be a 15 HP unit.

Example Number Three

In the case of an industrial plant where some of the pneumatic equipment will be operated under “Average Use” and part will be in operation continuously, total the cfm required, as well as the pressure ranges of each group, as follows:

Page 19, under column “Average Use,” select a unit having delivery of 12.5 cfm at 145 – 175 psi as that pressure range required to operate the equipment shown. It will be a 1 1/2 HP unit.

Page 19, under column “Continuous Operation,” select a unit having a delivery of 10.75 cfm at 80-100 psi as that pressure range required to operate the equipment shown. This unit will be a 3 HP compressor.

To supply one compressor rather than two for the above equipment, total the HP, which in this case would be 5 HP operating at a pressure range of 145 to 175 psi.

“Average Use”

1 – Car Lift	@ 6.0 cfm	145 to 175 psi
5 – Dusting Guns	@ 2.5 cfm	90 to 100 psi
1 – Panel Cutter	@ 4.0 cfm	70 to 100 psi
Total	12.5 cfm	

“Continuous Operation”

1 – Paint Spray Gun (Production Type)	@ 7.00 cfm	70 to 90 psi
1 – Impact Wrench	@ 3.75 cfm	70 to 90 psi
Total	10.75 cfm	

Note: Pressure regulators must be used to regulate to the allowable maximum pressure of the devices.

Selecting the Proper Air Compressor to Use with an Air Cylinder

Air cylinders use compressed air to produce force or motion. The compressed air is directed into a cylinder chamber and it forces a piston to move in a linear direction. The distance the piston travels is called the length of stroke. A piston rod attached to the piston exerts a force in pounds to produce work or motion to a mechanism at a rate of so many strokes per minute.

In commercial and industrial uses, a piece of equipment using an air cylinder of a given diameter will be rated as to force (thrust load) in pounds, length of stroke and the number of strokes per minute and you should obtain this information from your supplier.

From the selector charts, determine your air compressor selection.

Using the thrust load and cylinder diameter figures, make your choice of a compressor and determine the pressure needed from chart "A."

Determine the cfm of free air needed by the air cylinder from chart "B" by using the factor shown opposite your cylinder diameter and pressure requirement (see example for explanation of how to determine factors not shown). Multiply this factor by the number of inches of stroke and the number of strokes per minute to determine the cfm requirement.

Chart A cylinder diameter required to develop power to overcome the load indicated:

Thrust Load in Pounds	Pressure in Cylinder-psi															
	70	80	90	100	110	120	125	130	140	150	160	170	175	180	190	200
500	3 1/8	2 7/8	2 3/4	2 1/2	2 1/2	2 3/8	2 3/8	2 1/4	2 1/4	2 1/8	2	2	2	2	1 7/8	1 7/8
1000	4 3/8	4	3 7/8	3 5/8	3 1/2	3 3/8	3 1/4	3 1/4	3 1/8	3	2 7/8	2 3/4	2 3/4	2 3/4	2 5/8	2 5/8
1500	5 1/4	5	4 5/8	4 3/8	4 1/4	4	4	3 7/8	3 3/4	3 5/8	3 1/2	3 3/8	3 3/8	3 3/8	3 1/4	3 1/8
2000	6 1/8	5 3/4	5 3/8	5 1/8	4 7/8	4 5/8	4 5/8	4 1/2	4 3/8	4 1/8	4	3 7/8	3 7/8	3 7/8	3 3/4	3 5/8
2500	6 7/8	6 3/8	6	5 3/4	5 1/2	5 1/8	5 1/8	5	4 7/8	4 5/8	4 1/2	4 3/8	4 3/8	4 1/4	4 1/8	4
3000	7 1/2	7	6 5/8	6 1/4	6	5 3/4	5 5/8	5 1/2	5 1/4	5 1/8	5	4 3/4	4 3/4	4 5/8	4 1/2	4 3/8

Chart B cubic feet of air required for single acting air cylinder*:

Piston Dia. (in.)	90 psi	125 psi	Piston Dia. (in.)	90 psi	125 psi	Piston Dia. (in.)	90 psi	125 psi	Piston Dia. (in.)	90 psi	125 psi
1 3/4	.0102	.0131	3 1/4	.0350	.0454	4 3/4	.0748	.0970	6 1/4	.1300	.1681
1 7/8	.0115	.0149	3 3/8	.0378	.0489	4 7/8	.0789	.1020	6 3/8	.1346	.1742
2	.0133	.0172	3 1/2	.0405	.0524	5	.0832	.1076	6 1/2	.1402	.1813
2 1/8	.0150	.0194	3 5/8	.0434	.0562	5 1/8	.0872	.1127	6 5/8	.1460	.1888
2 1/4	.0168	.0217	3 3/4	.0467	.0605	5 1/4	.0913	.1180	6 3/4	.1510	.1955
2 3/8	.0187	.0242	3 7/8	.0496	.0642	5 3/8	.0957	.1237	6 7/8	.1570	.2060
2 1/2	.0207	.0268	4	.0530	.0685	5 1/2	.1004	.1299	7	.1630	.2105
2 5/8	.0228	.0296	4 1/8	.0564	.0730	5 5/8	.1050	.1361	7 1/8	.1684	.2181
2 3/4	.0250	.0324	4 1/4	.0599	.0775	5 3/4	.1096	.1416	7 1/4	.1746	.2257
2 7/8	.0275	.0355	4 3/8	.0635	.0822	5 7/8	.1146	.1482	7 3/8	.1802	.2332
3	.0299	.0386	4 1/2	.0672	.0870	6	.1200	.1550	7 1/2	.1870	.2419
3 1/8	.0323	.0418	4 5/8	.0708	.0915	6 1/8	.1250	.1623			

*To obtain CFM required; multiply factor above by 2 if cylinder is double acting; then multiply by number of inches of stroke; then multiply by number of strokes per minute.

Example: A 2 1/4 dia. cylinder, double acting, with an 8" stroke is required to clamp a casting during machining. A pressure of 100 psi will be required and it is expected that 16 castings will be clamped every minute. To determine cfm required, multiply factor opposite 2 1/4 dia. cylinder in 90 psi column by 2 for double acting ($2 \times .0168$), then multiply this by 8 for 8" stroke ($2 \times .0168 \times 8$), then multiply this by strokes per minute ($2 \times .0168 \times 8 \times 16$). The result is 4.3 cfm of free air required at 90 psi. This same calculation is repeated using the factor in the 125 psi column.

The result is ($2 \times .0217 \times 8 \times 16$) 5.56 cfm required at 125 psi. Since the cfm at 100 psi is required and it is known that 100 psi is about 1/3 the way from 90 psi to 125 psi, it can be estimated that the cfm required at 100 psi will be about 1/3 the difference of that required at 90 and 125 psi.

$$\frac{(5.56 - 4.3)}{3} = .42$$

The approximate cfm required at 100 psi will then be 4.3 plus this difference ($4.3 + .42$) or 4.72 cfm.

Air Flow Chart

Another industrial use for compressed air is using a blast of compressed air, released at the proper moment, to blow away small parts from a punch after forming and blanking.

An automatic valve allows air to flow from a properly positioned and aimed nozzle against the work pieces. The pressure employed and the diameter of the passage through the nozzle determine the volume of free air which will flow through the nozzle.

The chart below indicates the rate of flow (volume) per minute, through various sizes of orifices at definite pressures.

Flow is expressed in cubic feet per minute (cfm) and is assumed to take place from a receiver or other vessel, in which air is contained under pressure, into the atmosphere at sea level. Temperature of air in receiver is assumed at 60 deg. F. This table is only correct for orifices with narrow edges; flow through even a short length of pipe would be less than that given below.

Gage Pres. in Receiver (lbs.)	Flow of Free Air (cfm) Through Orifices of Various Diameters							
	1/64"	1/32"	3/64"	1/16"	3/32"	1/8"	3/16"	1/4"
1	.027	.107	.242	.430	.97	1.72	3.86	6.85
2	.038	.153	.342	.607	1.36	2.43	5.42	9.74
3	.046	.188	.471	.750	1.68	2.98	6.71	11.9
5	.059	.242	.545	.965	2.18	3.86	8.71	15.4
10	.084	.342	.77	1.36	3.08	5.45	12.3	21.8
15	.103	.418	.94	1.67	3.75	6.65	15.0	26.7
20	.119	.485	1.07	1.93	4.25	7.7	17.1	30.8
25	.133	.54	1.21	2.16	4.75	8.6	19.4	34.5
30	.156	.632	1.40	2.52	5.6	10.	22.5	40.0
35	.173	.71	1.56	2.80	6.2	11.2	25.0	44.7
40	.19	.77	1.71	3.07	6.8	12.3	27.5	49.1
45	.208	.843	1.9	3.36	7.6	13.4	30.3	53.8
50	.225	.914	2.05	3.64	8.2	14.5	32.8	58.2
60	.26	1.05	2.35	4.2	9.4	16.8	37.5	67
70	.295	1.19	2.68	4.76	10.7	19.0	43.0	76
80	.33	1.33	2.97	5.32	11.9	21.2	47.5	85
90	.364	1.47	3.28	5.87	13.1	23.5	52.5	94
100	.40	1.61	3.66	6.45	14.5	25.8	58.3	103
110	.43	1.76	3.95	7.00	15.7	28.0	63	112
120	.47	1.90	4.27	7.58	17.0	30.2	68	121
130	.50	2.04	4.57	8.13	18.2	32.4	73	130
140	.54	2.17	4.87	8.68	19.5	34.5	78	138
150	.57	2.33	5.20	9.20	20.7	36.7	83	147
175	.66	2.65	5.94	10.6	23.8	42.1	95	169
200	.76	3.07	6.90	12.2	27.5	48.7	110	195

The capacity of an air compressor cannot be checked accurately by use of this table and a narrow edge orifice. Specialized equipment is necessary to check compressor capacity.

Example: An air ejector is being used on a punch press. It is connected to an air line with pressure at 120-150 psi. It has a nozzle orifice 3/32 in. in diameter and, through use of a stop watch, it delivers compressed air for a total of 30 seconds out of each one minute of operation.

Useful Formulae

1. Comp. RPM = $\frac{\text{motor pulley dia.} \times \text{motor rpm}}{\text{comp. pulley dia.}}$
2. Motor Pulley pd = $\frac{\text{comp. pulley dia.} \times \text{comp rpm}}{\text{motor rpm}}$
3. Comp. Pulley pd = $\frac{\text{motor pulley dia.} \times \text{motor rpm}}{\text{comp. rpm}}$
4. Motor RPM = $\frac{\text{comp. pulley dia.} \times \text{comp. rpm}}{\text{motor pulley pd}}$
5. Free Air = piston displacement \times volumetric eff. (%)
6. Required Piston Displacement = $\frac{\text{free air}}{\text{vol. eff.}}$
7. Piston Displacement in Cu. Ft. per Min.* = $\frac{\text{Cyl. bore in In.} \times \text{Cyl. bore} \times \text{stroke in In.} \times \text{rpm}}{2200}$
8. Cu. Ft. Compressed Air = $\frac{\text{cu. ft. free air} \times 14.7}{(\text{psig} + 14.7)}$
9. Cu. Ft. Free Air = $\frac{\text{cu. ft. compressed air} \times (\text{psig} + 14.7)}{14.7}$
10. Cu. Ft. Free Air Req'd to Raise Rec. From 0 Gage to Final Pressure = $\frac{\text{vol. of rec. in cu. ft.} \times \text{psig}}{(\text{atmospheric pressure}) \text{ psia}}$
11. Cu. Ft. Free Air Req'd to Raise Rec. From Some Press. Greater Than 0 Gage To A Final High Higher Pressure = $\text{vol. of rec. in cu. ft.} \times \frac{(\text{final psig} - \text{initial psig})}{(\text{atmospheric pressure}) \text{ psia}}$
12. Piston Speed in Ft. Per Min. = $\frac{2 \times \text{stroke (in inches)} \times \text{rpm}}{12}$
13. Gallons = $\frac{\text{cu. ft.}}{0.134}$
14. Cu. Ft. = gallons \times 0.134
15. Total Force in lbs. of Air Cylinder = $\left(\frac{\text{Area of the Cylinder}}{\text{Dia. in sq. inches}} \right) \times \left(\frac{\text{psig of air}}{\text{press. used}} \right)$
16. CFM of Free Air req'd to Operate Air Cylinder (Single Acting) = $\left(\frac{\text{Vol. of Cyl.}}{\text{in cu. ft.}} \right) \times \left(\frac{\text{Cycles}}{\text{Per Min.}} \right) \times \frac{(\text{Gage Press psig} + 14.7)}{14.7}$
17. Pump Up Time (Min) = $\frac{V (\text{tank size in gal.}) \times (\text{final tank press.} - \text{initial tank press.})}{7.48 \times \text{atmos. press. (psia)} \times \text{pump delivery (cfm.)}}$

*Piston displacement for multi-stage compressors – only the low pressure cylinders are considered.

Glossary

Absolute Pressure – Total pressure measured from zero. Gauge pressure plus atmospheric pressure. For example, at sea level, the gauge pressure in pounds per square inch (psi) plus 14.7 gives the absolute pressure in pounds per square inch (psi).

Absolute Temperature – See Temperature, Absolute.

Absorption – The chemical process by which a hygroscopic desiccant, having a high affinity with water, melts and becomes a liquid by absorbing the condensed moisture.

Actual Capacity – Quantity of air or gas actually compressed and delivered to the discharge system at rated speed and under rated conditions. It is usually expressed in cubic feet per minute (acfm) at compressor inlet conditions. Also called Free Air Delivered (FAD).

Adiabatic Compression – See Compression, Adiabatic.

Adsorption – The process by which a desiccant with a highly porous surface attracts and removes the moisture from compressed air. The desiccant is capable of being regenerated.

Aftercooler – A heat exchanger used for cooling air discharged from a compressor. Resulting condensate may be removed by a moisture separator following the aftercooler.

Air Receiver – See Receiver.

ASME National Board (U Type) – An air tank made, tested by a third party, inspected and registered to meet ASME standards. A certificate is supplied with each tank to indicate compliance and show register number. The ASME certificate is required by law in many cities and states to pass safety codes. It assures that (1) code-approved materials are used, (2) the steel plate is without defects and is of specified thickness, (3) proper welding techniques are employed by experienced operators, (4) openings and support are the correct size and (5) the tank has passed rigid tests. ASME tanks must be used where OSHA compliance is required.

ASME Standard (UM Type) – an air tank made and tested by the manufacturer in accordance with the American Society of Mechanical Engineers standards. ASME certificate of compliance is furnished with each tank.

Atmospheric Pressure – The measured ambient pressure for a specific location and altitude.

Automatic Sequencer – A device that operates compressors in sequence according to a programmed schedule.

Booster Compressor – Machine for compressing air or gas from an initial pressure that is above atmospheric pressure to an even higher pressure.

Brake Horsepower (bhp) – See Horsepower, Brake.

Capacity – The amount of air flow delivered under specific conditions, usually expressed in cubic feet per minute (cfm).

Capacity, Actual – Quantity of air or gas actually compressed and delivered to the discharge system at rated speed and under rated conditions. It is usually expressed in cubic feet per minute (acfm) at compressor inlet conditions. Also called Free Air Delivered (FAD).

Capacity Gauge – A gauge that measures air flow as a percentage of capacity, used in rotary screw compressors.

CFM, Free Air – Cubic feet per minute of air delivered to a certain point at a certain condition, converted back to ambient conditions.

CFM, Standard – Flow of free air measured and converted to a standard set of conditions of pressure, temperature and relative humidity.

Check Valve – A valve which permits flow in only one direction.

Clearance – The maximum cylinder volume on the working side of the piston minus the displacement volume per stroke. Normally it is expressed as a percentage of the displacement volume.

Clearance Pocket – An auxiliary volume that may be opened to the clearance space, to increase the clearance, usually temporarily, to reduce the volumetric efficiency of a reciprocating compressor.

Compressed Air – Air from atmosphere which has been reduced in volume, raising its pressure. It then is capable of performing work when it is released and allowed to expand to its normal free state as it passes through a pneumatic tool or other device.

Compression, Adiabatic – Compression in which no heat is transferred to or from the gas during the compression process.

Compression, Isothermal – Compression in which the temperature of the gas remains constant.

Compression, Polytropic – Compression in which the relationship between the pressure and the volume is expressed by the equation PV^n is a constant.

Compression Ratio – The ratio of the absolute discharge pressure to the absolute inlet pressure.

Constant Speed Control – A system in which the compressor is run continuously and matches air supply to air demand by varying compressor load.

Cut-In/Cut-Out Pressure – Respectively, the minimum and maximum discharge pressures at which the compressor will switch from unload to load operation (cut-in) or from load to unload (cut-out).

Cycle – The series of steps that a compressor with unloading performs: 1) fully loaded, 2) modulating (for compressors with modulating control), 3) unloaded, 4) idle.

Cycle Time – Amount of time for a compressor to complete one cycle.

Degree of Intercooling – The difference in air or gas temperature between the outlet of the intercooler and the inlet of the compressor.

Deliquescent – Melting and becoming a liquid by absorbing moisture.

Demand – Flow of air at specific conditions required at a point or by the overall facility.

Desiccant – A material having a large proportion of surface pores, capable of attracting and removing water vapor from the air.

Dew Point – The temperature at which moisture in the air will begin to condense if the air is cooled at constant pressure. At this point the relative humidity is 100%.

Diaphragm – A stationary element between the stages of a multi-stage centrifugal compressor. It may include guide vanes for directing the flowing medium to the impeller of the succeeding stage. In conjunction with an adjacent diaphragm, it forms the diffuser surrounding the impeller.

Discharge Pressure – Air pressure produced at a particular point in the system under specific conditions.

Discharge Temperature – The temperature at the discharge flange of the compressor.

Displacement – The volume swept out by the piston or rotor(s) per unit of time, normally expressed in cubic feet per minute.

Efficiency – Any reference to efficiency must be accompanied by a qualifying statement which identifies the efficiency under consideration, as in the following definitions of efficiency:

Efficiency, Compression – Ratio of theoretical power to power actually imparted to the air or gas delivered by the compressor.

Efficiency, Isothermal – Ratio of the theoretical work (as calculated on a isothermal basis) to the actual work transferred to a gas during compression.

Efficiency, Mechanical – Ratio of power imparted to the air or gas to brake horsepower (bhp).

Efficiency, Polytropic – Ratio of the polytropic compression energy transferred to the gas, to the actual energy transferred to the gas.

Efficiency, Volumetric – Ratio of actual capacity to piston displacement.

Filters – Devices for separating and removing particulate matter, moisture or entrained lubricant from air.

Flange Connection – The means of connecting a compressor inlet or discharge connection to piping by means of bolted rims (flanges).

Free Air – Air at atmospheric conditions at any specified location, unaffected by the compressor.

Full-Load – Air compressor operation at full speed with a fully open inlet and discharge delivering maximum air flow.

Gas – One of the three basic phases of matter. While air is a gas, in pneumatics the term gas normally is applied to gases other than air.

Gauge Pressure – The pressure determined by most instruments and gauges, usually expressed in psig. Barometric pressure must be considered to obtain true or absolute pressure.

Horsepower, Brake – Horsepower delivered to the output shaft of a motor or engine, or the horsepower required at the compressor shaft to perform work.

Horsepower, Indicated – The horsepower calculated from compressor indicator diagrams. The term applies only to displacement type compressors.

Horsepower, Theoretical or Ideal – The horsepower required to isothermally compress the air or gas delivered by the compressor at specified conditions.

Humidity, Relative – The relative humidity of a gas (or air) vapor mixture is the ratio of the partial pressure of the vapor to the vapor saturation pressure at the dry bulb temperature of the mixture.

Humidity, Specific – The weight of water vapor in an air vapor mixture per pound of dry air.

Indicated Power – Power as calculated from compressor-indicator diagrams.

Indicator Card – A pressure-volume diagram for a compressor or engine cylinder, produced by direct measurement by a device called an indicator.

Inlet Pressure – The actual pressure at the inlet flange of the compressor.

Intercooling – A heat exchanger for cooling the air between stages of compression.

Intercooling, Degree of – The difference in air or gas temperatures between the inlet of the compressor and the outlet of the intercooler.

Intercooling, Perfect – When the temperature of the air or gas leaving the intercooler is equal to the temperature of the air or gas entering the inlet of the compressor.

Isentropic Compression – If a compression or expansion of a gas takes place with no flow of heat energy either into or out of the gas – the process is said to be isentropic or adiabatic. The isentropic (adiabatic) process can be expressed with the [Ideal Gas Law](#).

Isentropic Efficiency – Isentropic efficiency is sometimes called adiabatic efficiency. It is the ratio of the minimum isentropic work to the actual work. Compressors are steady-flow devices which operate under adiabatic conditions, and the ideal process for these devices is the isentropic process. Under the ideal conditions, no heat is transferred during the compression process. Isentropic efficiency is the parameter that describes how efficiently a device approximates a corresponding isentropic device.

Isothermal Compression – See Compression, Isothermal.

Leak – An unintended loss of compressed air to ambient conditions.

Load Factor – Ratio of average compressor load to the maximum rated compressor load over a given period of time.

Load Time – Time period from when a compressor loads until it unloads.

Load/Unload Control – Control method that allows the compressor to run at full load or at no load while the driver remains at a constant speed.

Magnetic Starter – A magnetic starter is an assembly consisting of a magnetic contactor (switch) and an overload relay. Its purpose is to apply power to the electric motor driving the compressor and provide overcurrent protection for the motor.

Modulating Control – System which adapts to varying demand by throttling the compressor inlet proportionally to the demand.

Multi-stage Compressors – Compressors having two or more stages operating in a series.

Perfect Intercooling – When the temperature of the air or gas leaving the intercooler is equal to the temperature of the air or gas entering the inlet of the compressor.

Performance Curve – Usually a plot of discharge pressure versus inlet capacity and shaft horsepower versus inlet capacity.

Piston Displacement – The volume swept by the piston; for multistage compressors, the piston displacement of the first stage is the overall piston displacement of the entire unit.

Pneumatic Tools – Tools that operate by air pressure.

Polytropic Compression – See Compression, Polytropic.

Positive Displacement Compressors – Compressors in which successive volumes of air or gas are confined within a closed space and the space mechanically reduced, resulting in compression. These may be reciprocating or rotating.

Power, Theoretical (polytropic) – The mechanical power required to compress polytropically and to deliver, through the specified range of pressures, the gas delivered by the compressor.

Pressure – Force per unit area, measured in pounds per square inch (psi).

Pressure, Absolute – The total pressure measured from absolute zero (i.e. from an absolute vacuum).

Pressure Dew Point – For a given pressure, the temperature at which water will begin to condense out of air.

Pressure, Discharge – The pressure at the discharge connection of a compressor. (In the case of compressor packages, this should be at the discharge connection of the package)

Pressure Drop – Loss of pressure in a compressed air system or component due to friction or restriction.

Pressure, Intake – The absolute total pressure at the inlet connection of a compressor.

Pressure Range – Difference between minimum and maximum pressures for an air compressor. Also called cut-in, cut-out or load-no load pressure range.

Pressure Ratio – See Compression Ratio.

Pressure Rise – The difference between discharge pressure and intake pressure.

Pressure Static – The pressure measured in a flowing stream in such a manner that the velocity of the stream has no effect on the measurement.

Pressure, Total – The pressure that would be produced by stopping a moving stream of liquid or gas. It is the pressure measured by an impact tube.

Pressure, Velocity – The total pressure minus the static pressure in an air or gas stream.

Rated Capacity – Volume rate of air flow at rated pressure at a specific point.

Rated Pressure – The operating pressure at which compressor performance is measured.

Required Capacity – Cubic feet per minute (cfm) of air required at the inlet to the distribution system.

Receiver – A vessel or tank used for storage of gas under pressure. In a large compressed air system there may be primary and secondary receivers.

Reciprocating Compressor – Compressor in which the compressing element is a piston having a reciprocating motion in a cylinder.

Relative Humidity – The ratio of the partial pressure of a vapor to the vapor saturation pressure at the dry bulb temperature of a mixture.

Rotary Helical Screw Compressors have male and female rotors, which rotate in opposite directions while the volume between them and their housing decreases resulting in an increase in pressure.

Seals – Devices used to separate and minimize leakage between areas of unequal pressure.

Sequence – The order in which compressors are brought online.

Shaft – The part by which energy is transmitted from the prime mover through the elements mounted on it, to the air or gas being compressed.

Sole Plate – A pad, usually metallic and embedded in concrete, on which the compressor and driver are mounted.

Specific Gravity – The ratio of the specific weight of air or gas to that of dry air at the same pressure and temperature.

Specific Humidity – The weight of water vapor in an air-vapor mixture per pound of dry air.

Specific Power – A measure of air compressor efficiency, usually in the form of bhp/100 acfm.

Specific Weight – Weight of air or gas per unit volume.

Speed – The speed of a compressor refers to the number of revolutions per minute of the compressor drive shaft or rotor shaft.

Stages – A series of steps in the compression of air or a gas.

Standard Air – The Compressed Air & Gas Institute and PNEUROPE have adopted the definition used in ISO standards. This is air at 14.5 psia (1 bar); 68°F (20°C) and dry (0% relative humidity).

Start/Stop Control – A system in which air supply is matched to demand by the starting and stopping of the unit.

Temperature, Absolute – The temperature of air or gas measured from absolute zero. It is the Fahrenheit temperature plus 459.6 and is known as the Rankine temperature. In the metric system, the absolute temperature is the Centigrade temperature plus 273 and is known as the Kelvin temperature.

Temperature, Discharge – The total temperature at the discharge connection of the compressor.

Temperature, Inlet – The total temperature at the inlet connection of the compressor.

Temperature Rise Ratio – The ratio of the computed isentropic temperature rise to the measured total temperature rise during compression. For a perfect gas, this is equal to the ratio of the isentropic enthalpy rise to the actual enthalpy rise.

Temperature, Static – The actual temperature of a moving gas stream. It is the temperature indicated by a thermometer moving in the stream and at the same velocity.

Temperature, Total – The temperature which would be measured at the stagnation point if a gas stream were stopped, with adiabatic compression from the flow condition to the stagnation pressure.

Theoretical Power – The power required to compress a gas isothermally through a specified range of pressures.

Torque – A torsional moment or couple. This term typically refers to the driving couple of a machine or motor.

Total Package Input Power – The total electrical power input to a compressor, including drive motor, cooling fan, motors, controls, etc.

Unit type Compressors – Compressors of 30 bhp or less, generally combined with all components required for operation.

Unload – (No load) Compressor operation in which no air is delivered due to the intake being closed or modified not to allow inlet air to be trapped.

Vacuum Pumps – Compressors which operate with an intake pressure below atmospheric pressure and which discharge to atmospheric pressure or slightly higher.

Valves – Devices with passages for directing flow into alternate paths or to prevent flow.

Water Cooled Compressor – Compressors cooled by water circulated through jackets surrounding cylinders or casings and/or heat exchangers between and after stages.