Compressed Air System Basics

An Online Continuing Education Course for Engineers

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Compressed air is used widely throughout industry and is often considered the "fourth utility" at many facilities. Almost every industrial plant, from a small machine shop to an immense pulp and paper mill, has some type of compressed air system. In many cases, the compressed air system is so vital that the facility cannot operate without it. Plant air compressor systems can vary in size from a small unit of 5 horsepower (hp) to huge systems with more than 50,000 hp.

In many industrial facilities, air compressors use more electricity than any other type of equipment. Inefficiencies in compressed air systems can therefore be significant. Energy savings from system improve-ments can range from 20 to 50 percent or more of electricity consumption. For many facilities this is equivalent to thousands, or even hundreds of thousands of dollars of potential annual savings, depending on use. A properly managed compressed air system can save energy, reduce maintenance, decrease downtime, increase production throughput, and improve product quality.

Compressed air systems consist of a supply side, which includes compressors and air treatment, and a demand side, which includes distribution and storage systems and end-use equipment. A properly managed supply side will result in clean, dry, stable air being delivered at the appropriate pressure in a dependable, cost-effective manner. A properly managed demand side minimizes wasted air and uses compressed air for appropriate applications. Improving and maintaining peak compressed air system performance requires addressing both the supply and demand sides of the system and how the two interact.

COMPONENTS OF AN INDUSTRIAL COMPRESSED AIR SYSTEM

A compressor is a machine that is used to increase the pressure of a gas. The earliest compressors were bellows, used by blacksmiths to intensify the heat in their furnaces. The first industrial compressors were simple, reciprocating piston-driven machines powered by a water wheel.

A modern industrial compressed air system is composed of several major sub-systems and many sub-components. Major sub-systems include the compressor, prime mover, controls, treatment equipment and accessories, and the distribution system. The compressor is the mechanical device that takes in ambient air and increases its pressure. The prime mover powers the compressor. Controls serve to regulate the amount of compressed air being produced. The treat-ment equipment removes contaminants from the compressed air, and accessories keep the system operating properly. Distribution systems are analogous to wiring in the electrical world—they transport compressed air to where it is needed. Compressed air storage can also serve to improve system performance and efficiency. Figure 1.1 shows a representative industrial compressed air system and its components.

Compressor Types

Many modern industrial air compressors are sold "packaged" with the compressor, drive motor, and many of the accessories mounted on a frame for ease of installation. Provision for movement by forklift is common. Larger packages may require the use of an overhead crane. An enclosure may be included for sound attenuation and aesthetics.

As shown in Figure 1.2, there are two basic compressor types: positive-displacement and dynamic. In the positive-displacement type, a given quantity of air or gas is trapped in a compression chamber and the volume

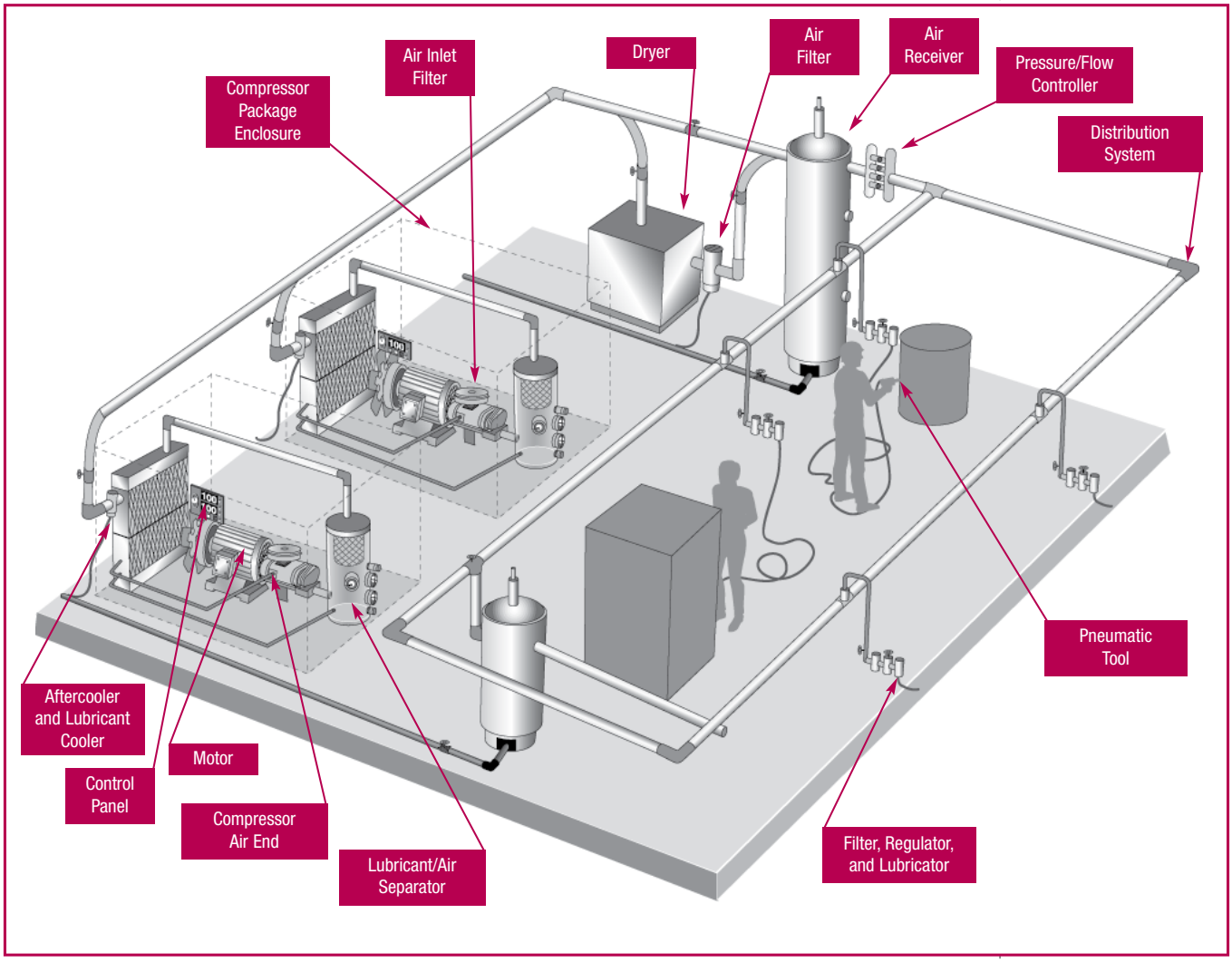

Figure 1.1 Components of a Typical Industrial Compressed Air System.

which it occupies is mechanically reduced, causing a corresponding rise in pressure prior to discharge. At constant speed, the air flow remains essentially constant with variations in discharge pressure. Dynamic compressors impart velocity energy to continuously flowing air or gas by means of impellers rotating at very high speeds. The velocity energy is changed into pressure energy both by the impellers and the discharge volutes or diffusers. In the centrifugal-type dynamic compressors, the shape of the impeller blades determines the relationship between air flow and the pressure (or head) generated.

Positive-Displacement Compressors

These compressors are available in two types: reciprocating and rotary. Reciprocating compressors work like bicycle pumps. A piston, driven through a crankshaft and connecting rod by an electric motor, reduces the volume in the cylinder occupied by the air or gas, compressing it to a higher pressure. Single-acting compressors have a compression stroke in only one direction, while double-acting units provide a compression stroke as the piston moves in each direction. Large, industrial reciprocating air compressors are double-acting and water-cooled. Multi-stage, double-acting compressors are the most efficient compressors available, and are typically larger, noisier, and more costly than comparable rotary units. Reciprocating compressors are available in sizes from less than 1 hp to more than 600 hp.

Rotary compressors have gained popularity

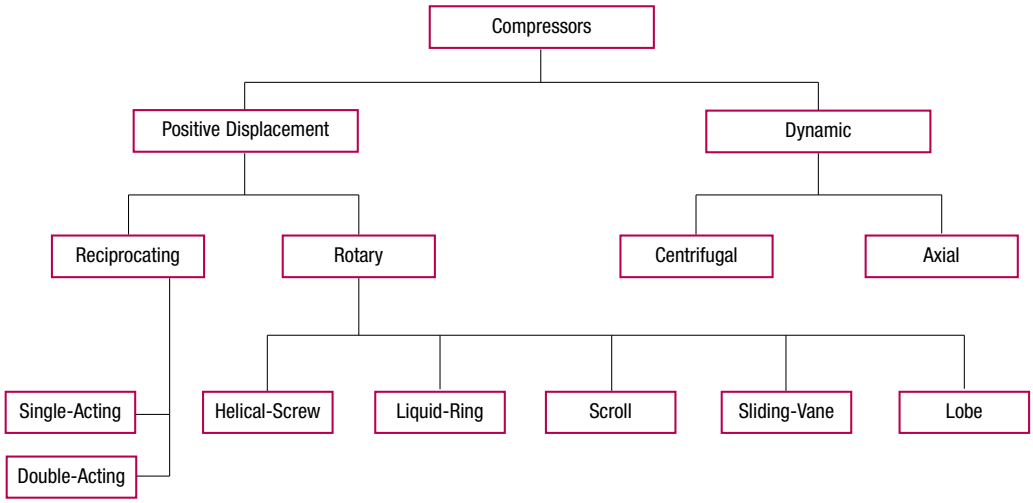

Figure 1.2 Compressor Family Tree.

and are now the "workhorse" of American industry. They are most commonly used in sizes from about 30 to 200 hp. The most common type of rotary compressor is the helical-twin, screw-type (also known as rotary screw or helical-lobe). Male and female screw-rotors mesh, trapping air, and reducing the volume of the air along the rotors to the air discharge point. Rotary screw compressors have low initial cost, compact size, low weight, and are easy to maintain. Rotary screw compressors may be air- or water-cooled. Less common rotary compressors include sliding-vane, liquid-ring, and scroll-type.

Single-Acting, Reciprocating Air Compressors

This type of compressor is characterized by its "automotive" type piston driven through a connecting rod from the crankshaft. Compression takes place on the top side of the piston on each revolution of the crankshaft. Single-acting, reciprocating air compressors may be air-cooled or liquid-cooled. These may be single-stage, usually rated at discharge pressures from 25 to 125 pounds per square inch gauge (psig), or two-stage, usually rated at discharge pressures from 125 psig to 175 psig or higher.

The most common air compressor in the fractional and single-digit hp sizes is the air-cooled, reciprocating air compressor. In larger sizes, single-acting reciprocating compressors are available up to 150 hp, but above 25 hp are much less common. Two-stage and multi-stage designs include inter-stage cooling to reduce discharge air temperatures for improved efficiency and durability.

Pistons used in single-acting compressors are of the "automotive" or "full skirt" design, the underside of the piston being exposed to the crankcase. Lubricated versions have a combination of compression and lubricant-control piston rings, which seal the compression chamber, control the lubricant to the compression chamber, and act (in some designs) as support for piston movement on the cylinder walls. Lubricant-free, or non-lube designs, do not allow lubricant in the compression chamber and use pistons of self-lubricating materials or use heat resistant, non-metallic guides and piston rings which, are self-lubricating. Some designs incorporate a distance piece or crosshead to isolate the crankcase from the compression chamber.

Lubricant-less designs have piston arrangements similar to lubricant-free versions but do not have lubricant in the crankcase. Generally these have a grease pre-packed crankshaft and connecting rod bearings.

Cooling. Single-acting air compressors have different arrangements for removing the heat of compression. Air-cooled versions have external finning for heat dissipation on the cylinder, cylinder head, and in some cases, the external heat exchanger. Air is drawn or blown across the fins and the compressor crankcase by a fan, which may be the spokes of the drive pulley/flywheel. Liquid-cooled compressors have jacketed cylinders, heads and heat exchangers, through which liquid coola[nt] circulated to dissipate th[e] Water, or an ethylene gly[col] freezing, may be employ[ed]

Drives. The most commo[n] is a belt drive from an elec[tric] compressor sheave also ac[ts] limit torque pulsations and [to] are used for cooling air circ[ulation] allow a great degree of flexi[bility] the desired speed of rotatio[n]

Flange-mounted, or direct-c[oupled] drives provide compactness [and] drive maintenance. Belts and [pulleys] be properly shielded for safet[y] Occupational Safety & Health [Administration] (OSHA) requirements in indu[stry]

Double-Acting, Reciproca[ting] Compressors

Double-acting reciprocating compressors use both sides of the piston for air compression, doubling the capacity for a given cylinder size. A piston rod is attached to the piston at one end and to a crosshead at the other end. The crosshead ensures that the piston travels concentrically within the cylinder. These compressors may be single- or multi-stage, depending on discharge pressure and hp size. These can range upwards from 10 hp and with pressures upwards from 50 psig.

Cooling. Double-acting air compressors generally h[ave] [jac]kets around [cy]linder head. [Be]ely slow speed [in]tercooling, [ef]fficiency. [It] is generally [a] lubricator, [pe]r minute, [re]ton [ma]nufacturer. [Su]itable [fo]r similar [co]mpression [be]tween [en]sure [wa]ters the [lu]bricant-

[T]ype generally require [a] substantial foundation due to unbalanced reciprocating forces.

Drives. Below 200 hp, belt drives and flange-mounted induction motors are normally used. For motors larger than 300 hp, flange-mounted, synchronous motors are sometimes

SINGLE-ACTING AIR COMPRESSORS HAVE DIFFERENT ARRANGEMENTS FOR REMOVING THE HEAT OF COMPRESSION. AIR-COOLED VERSIONS HAVE EXTERNAL FINNING FOR HEAT DISSIPATION ON THE CYLINDER, CYLINDER HEAD, AND IN SOME CASES, THE EXTERNAL HEAT EXCHANGER.