Compressed Air & Gas

Handbook

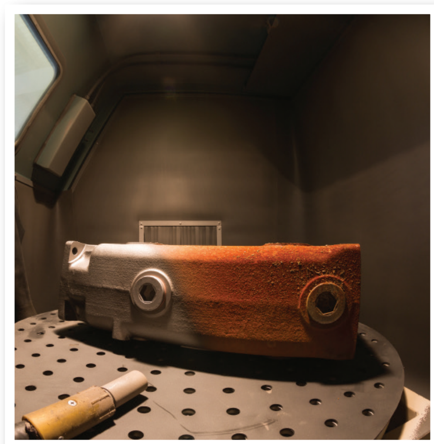
Seventh Edition

100 YEARS OF INDUSTRY LEADERSHIP

CAGI®

Compressed Air & Gas Institute

Compressed Air Applications
Industry's 4th Utility



Chapter 1

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Compressed Air Applications
Industry’s 4th Utility

Mention utilities and electricity, natural gas and water quickly come to mind. But in industry, compressed air is often referred to as the fourth utility that has many energy savings and environmental benefits. Compressed air is the energy of choice to power a great variety of applications and processes. Today’s businesses are finding that compressed air is a true source for innovative solutions and applications. The power of compressed air is used in thousands of applications and is vital to the productivity of industries around the globe.

The manufacture of compressors and compressed air system equipment is a large and essential industry that contributes greatly to the economy of all nations. Compressed air provides power for a multitude of manufacturing operations and processes. This chapter will cover just a sampling of the uses for compressed air.

Different Types of Compressors

There are many different types of compressors, and their applications are numerous. To help provide a certain perception of the equipment and its applications, we have grouped the types of compressors according to design objectives and differences. The following are the three groups of the different types of compressors that will be covered:

- 80-125 psig air compressors (general plant air or standard air)
- Gas compressors
- Oil and field gas compressors

80-125 psig Air Compressors

As we discuss the 80-125 psig air compressors, we note that the title of this book actually contains a slight technical error. Air is a gas, so the title is a bit redundant; however, air compressed to 100 or 125 psig is such a large class that air compressors are considered separately from compressors for other gases. Most plant air systems operate at or near this pressure, and many air tools may be plugged into the system using quick-disconnect fittings, in much the same way a homeowner plugs in a toaster or food processor.

The design of the 100 psig air compressor permits a wide range of standard models, from the small home air compressor used by the do-it-yourselfer to the large-flow-capacity centrifugal compressor. The machine or extended package is self-contained, meaning all components required in the compressor design are furnished in a neat, compact package.

The key components in the extended package include the airend, the primary driver (motor or engine), the cooling fan and motor, a variable speed drive if applicable and other components on a common skid or frame. The air compressor package should require the minimum amount of power per unit of flow. It may have one, two or more stages, depending on the type of compressor used and the specific application.

Air Brake
Air Chuck
Air Cylinder
Air Ejection
Air Jet
Air Motor
Air Vise
Atomizing
Boiler Tube
Cleaning
Buffing
Chipping
Conveying
Core Blowing
Die Casting
Drilling
Elevating
Forming
Gas Compression
Grinding
Hoisting
Media Blasting
Mixing
Nut Setting
Paint Spraying
Pavement
Pile Driving
Pressurizing
Process Control
Reaming
Riveting
Sanding
Sand Ramming
Scrap Baling
Screw Driving
Stapling
Thread Tapping
Transferring
Wire Brushing
Work Positioning

Figure 1.1: Typical major applications of compressed air in manufacturing

There are applications, where the targeted energy requirement demands pressures up to 500 psig. The mentioned packages have been adapted to safely and efficiently provide these required pressures. Examples include powering rock drilling machinery in water well drilling, water jet cutting, mining and large construction sites; some air separation applications; PET bottle manufacture or shallow oil and gas drilling.

Gas Compressors

The next group is made up of gas compressors. In this group, special compressors are designed to meet a chemical process requirement on pressure or flow and are capable of handling whatever gas or gas mixture is to be used. The gas compressor is the conveyor of the raw materials needed by the process. Within the process, the gas is chemically combined to produce the desired product. Several pressure levels are often required by the process. While the gas compressor may be similar in appearance to the 100-psig air compressor, much more engineering is generally involved. Such compressors will be discussed in a later chapter.

Oil and Field Gas Compressors

Oil and gas field compressors are another group of compressor types. These are separated from the gas compressor group for several reasons. First, they are units that can be moved from one oil field to another by truck. They are usually designed to operate at 100 rpm to match the gas-engine-drive rotation speed. The compressor and driver are on a combined support skid. This requirement imposes restrictions on the size of the unit and necessitates a more compact design. The oil and gas compressor is utilized to pressurize oil wells with natural gas to force the remaining oil out of the formation. The user may have many small wells positioned in various locations. These compact machines are also ideally suited for offshore platforms.

Compressor Applications: Power, Process and Control:

From the standpoint of applications, compressed air and gas may be divided into power, process, and control.

Power Service Applications:

Power service includes those applications in which air is used either to produce motion or to exert a force, or both. Examples are linear actuators, pneumatic tools, clamping devices, air lifts, and pneumatic conveyors.

Process Service Applications:

Process service is defined as any application in which air or other gas enters into a process itself. Examples are combustion, liquefaction and separation of gas mixtures into components, hydrogenation of oils, refrigeration, aeration to support biological processes, and dehydration of foods.

Control Applications:

Control applications are those in which air or gas triggers, starts, stops, modulates, or otherwise directs machines or processes. Control applications occur throughout power and process use. Some steady-flow process plants are virtually completely automatic. Detroit-style, batch-type manufacturing may be highly automatic and pneumatic controls have special attributes that make them ideal for many situations. These include control of pneumatic machines (Figure 1.2) or control with explosion-proof requirements.

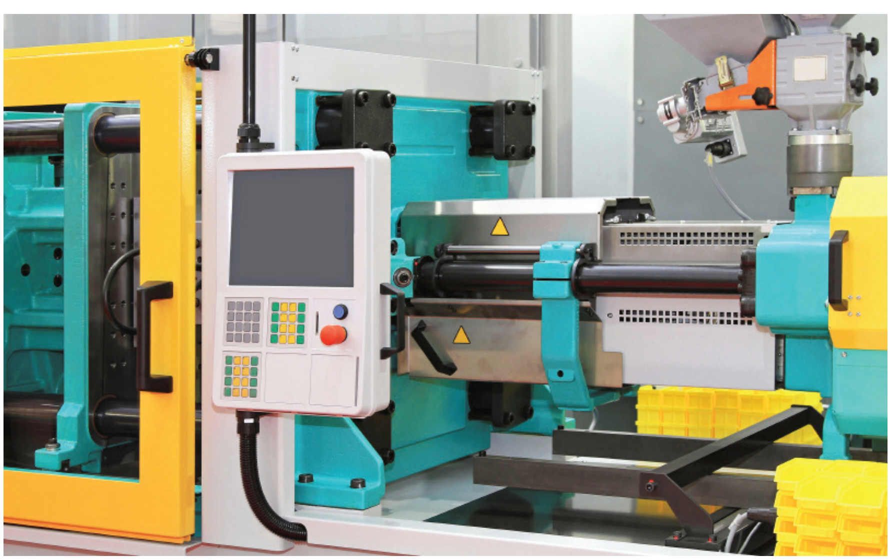

Figure 1.2: Plastic Inject Molding Machines like the one shown here, enable mass production of many forms and shapes due to pneumatic pressure in the process.

In some industries, compressed air may be limited to power service alone, as in construction, protective coating industry, quarrying, mining and road building (Figure 1.3). Others may use air only in process service. But, in many cases, compressed air is used in both power and process services with pneumatic control within a single plant.

Figure 1.3: Crawler mounted blast hole drill utilizing a compressor for drilling large diameter holes

Figure 1.4: Small portable installing guardrails

Figure 1.5: Large portable on site for oil refinery cracker unit overhaul

In addition to industrial plant applications, small portable air compressors for the home and job site have become very popular. These provide consumers and contractors with a productive alternative energy source to perform many jobs faster and more easily. Do-it-yourself and professional applications abound for small portable air compressors and pneumatic tools. (Figure 1.6)

Figure 1.6: Roofer using an efficient pneumatic nail gun operating off of a small gasoline powered or electric powered air compressor

Primary home site applications include inflating, cleaning, painting, wrenching, sanding, caulking and grinding. Standard air chucks and other attachments are readily available to inflate tires, shocks, air beds, etc. Air operated spray guns, typically connected to a small portable air compressor, can be used to apply finishes or paint to furniture, automobiles, shutters, trim and lawn equipment. Numerous woodworking related projects can be accomplished with nail guns, grinders, sanders and drills which are smaller and lighter than their electric counterparts. These small air compressors can be driven either by an electric motor or by a gasoline engine when electric power is unavailable or the application is in a wet environment. These can drive impact wrenches and ratchets for loosening or tightening stubborn bolts and lug nuts.

Job site applications for electric or gasoline engine driven small portable air compressors usually include nailing and fastening. Some of these are small and light enough to be hand carried and include up to a 4 gallon air receiver tank. With the growing popularity of these air compressors, conventional hammers and nails have been replaced by pneumatic framing, roofing, and finish nailers. Small portable air compressors also operate staplers which have replaced older manual staple guns. Roof shingles, molding, trim, flooring and industrial board are installed quickly and easily using the proper combination of a small portable air compressor and a pneumatic stapler combination. In most cases, the pneumatic tools speed the job completion with higher grades of quality. Compressors and tools for these applications have become popular rental items for both contractor and the DIY segments.

These introductory examples are given to provide the reader with an insight into the major divisions of the compressed air and gas industry. In this chapter, only air compressors and compressed-air applications will be discussed.

Some General Uses of Compressed Air

It is difficult to imagine a product or task where compressed air has not been involved at some stage. Let’s review some of the more typical applications. Compressed air can be found in virtually all fields of commerce and industry. It is used in the primary products industries supplying semi-finished raw materials to manufacturing industries and in the manufacture of heavy goods. It is important in the light goods or consumer products industries, as well as in the processing and packaging of consumer goods. Compressed air plays an important part in transportation, building, and construction, and in service operations for maintenance of all industries.

Compressed air is used in virtually every phase of manufacturing. In one medium-sized plant, there may be a hundred different uses of air. Air from the same compressed air system may actuate stamping presses, air wrenches, aerating equipment and pneumatic controls and, at the same time, be part of a chemical or manufacturing process. In addition to the well-known applications for air, individual manufacturers find many special uses tailored in their own techniques.

Compressed air is helping us to cope with some of the problems of our complex society. For example, in the production of food, orchards are sprayed by means of compressed air. Fish farming, with trout, salmon, tilapia and other fish already supplied in considerable quantity, depends on compressors to aerate the pools to keep the water fresh and keep the fish healthy. In water supplies, deep reservoirs and lakes are similarly aerated to improve quality.

In underwater geological exploration for minerals and oil, a sudden release of compressed air produces acoustic waves by which the sea bottom is probed without the damage to marine life which was the result when explosive charges were used.

In sewage-treatment plants, large volumes of air are used to speed the purification of the water so that it may be discharged directly back into streams where fish may live. (See Figure 1.7)

Figure 1.7: Water treatment plants use compressed air for aeration.

Some applications of compressed air are so widespread that to discuss them in detail under each industry where they apply would be unnecessarily repetitive. Several of these are taken up in the following sections without reference to specific industries.

Industrial Plant Maintenance

Although there are many ingenious special uses of compressed air in individual plants, practically all industries use compressed air for the same applications to resolve the common maintenance problems in buildings and machines.

Air tools such as pavement breakers, described more fully under the construction classifications are used for repairing concrete floors, opening masonry walls for various service lines, and similar work. Smaller air hammers are used for caulking and chipping. Plants with well-placed air outlets use air-operated drills, screwdrivers, and wrenches for other maintenance work. Portable paint-spraying outfits enable smaller crews to carry out this important maintenance job. Sprinkler systems, especially in unheated portions of a plant where freezing is a hazard, are controlled by air pressure, which prevents water from entering the pipes until heat breaks the eutectic seal, venting the compressed air and allowing water to flow through the system. The cleaning of machines, floors, remote ceiling areas, and overhead pipes progresses faster with the aid of air jets. Boiler tubes are quickly and thoroughly cleaned with air pressure. A familiar use of compressed air is tuck pointing of masonry walls.

Figure 1.8: Portable compressor operating a pavement breaker.

On the Production Line

Pneumatic tools have many advantages in industrial production. They have a low ratio of weight to power, which is especially important whenever human fatigue is a problem, and they may be used steadily for long periods without overheating and with low maintenance costs (Figure 1.9). Because of the unique design features and advantages of air tools, these products solve manufacturing, assembly and service dilemmas. The manufacturers of air tools have worked with end-users to design and develop a broad breadth of product offerings, which range from those products that have very broad application usage to customized products offering very unique customer solutions.

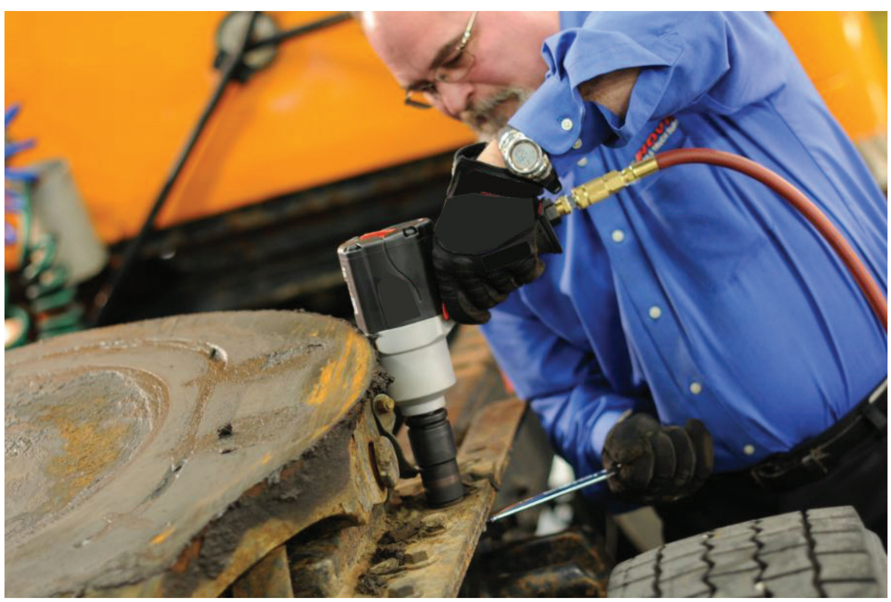

Figure 1.9: Impact tool used for assembly and maintenance.

General applications for air tools are chipping and scaling hammers used in railroads, oil refineries, chemical refineries, shipyards, and many other industries. These tools are used in the foundry for cleaning large castings. In other industries, these tools remove weld scale, rust, and paint. They are also useful in cutting and sculpturing stone.

Pneumatic drills are of special value in the machine shop for all classes of reaming, tapping, and drilling whenever the work cannot be conveniently carried to the drill press and for all classes of blast drill work. These machines are also frequently employed for operating special boring bar and, in emergency cases, for independent drive of a machine tool where the horsepower required is within their capacity.

Pneumatic drills, like other portable air tools, achieve great time and cost savings over the corresponding hand tools for reaming, tapping, and drilling, especially in the automotive, aircraft, rail car, locomotive, and other heavy machinery industries.

Figure 1.10: Pneumatic screwdrivers are used on an assembly line.

Grinding, sanding, wire brushing, buffing, and polishing are also used and facilitated in these same industries and many others. Finishing surfaces and preparing them for finishing operations are the prime objectives.

Driving screws and turning up nuts are regularly used in assembly operations and greatly increase the speed of these jobs. In some instances, magazine feed and attached locating fixtures further increase the speed of these operations.

Air-operated riveting hammers of either the percussion or compression type produce reliable, inexpensive joints. Riveting is extensively applied in aircraft manufacture which is explored later in this chapter.

Air Motors, Vacuum and Other Auxiliary Devices

Air motors are widely used as a source of power in operations that involve flammable or explosive liquids, vapors, or dust. They may be adapted to safely operate in hot, corrosive, or wet atmospheres without damage.

Air Motor

Air-motor speeds may be varied easily. Such motors may be started and stopped quickly and are not harmed by stalling and overloading.

In general, air motors may be classified as either a rotary sliding vane type or the piston type. Either type may be supplied with a gear-type speed reducer. Rotary sliding vane motors generally deliver lower torques at higher speeds, while piston motors, whether axial or radial; deliver higher torques at lower speeds.

A great many hand-held air tools are driven by rotary sliding vane motors, often with a speed-reducing gear train. Air hoists may be powered by either type of motor, the piston-type being especially suited for accurate positioning of loads. The safety aspects of both types led to many applications in underground tunnels and mines and in industrial areas in which there are solvents or other flammable substances. They drive many pumps used in construction and many positioning devices, such as indexing tables, used in manufacturing.

Vacuum

Vacuum has many applications in production. A vacuum pump is a compressor in which the intake vacuum rather than the pressurized air is the desired effect. For vacuum chucking, as an example of vacuum applications in production, the pump holds a vacuum in a tank located near the machine, while bleeder holes under the part to be machined are opened to hold the part in place. An intake filter on the inlet line to the vacuum pump cleans the air of any foreign material that could otherwise be picked up from the machining process.

Auxiliary Equipment

The extensive use of pneumatic auxiliary production equipment should be noted as well. Clamps, positioners, presses, feeders, lift tables, air chucks, and many other devices actuated by air cylinders are found to be effective in improving productivity and quality. By the time that the cost of accurate welding and millwrighting is taken into account, it is usually found that pneumatic cylinders, ratchets and/or stops provide reciprocating or rotating interrupted motions much more economically than they can be provided by many traditional mechanical devices. Vacuum devices perform similar functions for smaller or lighter parts. Air hoists and winches greatly facilitate the handling of heavier products in shipping, as well as in production, construction, and mining.

In areas of finishing and packaging, pneumatic devices find many important applications. For example, certain dry powders may be fluidized by compressed air and applied by electrostatic deposition. Preheating the surface can cause polymer powders to fuse on contact, producing a continuous plastic coating. Pneumatic staplers facilitate the closure of many packing cartons. Pneumatic sanders help provide a smooth finish on many appliances

Blast cleaning has been successfully applied to such jobs as putting a satin finish on completed work, removing scale, paint, and rust from surfaces, preparing metal surfaces for painting, enameling, tinting, sherardizing, or galvanizing, and cleaning and finishing castings. Cleaning castings, surface preparation for the protective coating industry and building exteriors are probably the most extensive applications.

In addition, it is used for cleaning pottery and crockery, bottle molds, forgings and steel plates, and sheets. Blast nozzles are used alone or are incorporated into varying designs for blast equipment. The common term sandblasting is a misnomer since many abrasives besides sand are used, resulting in a wider range of applications. New blasting media includes plastic pellets, frozen media like frozen carbon dioxide, and steel shot.

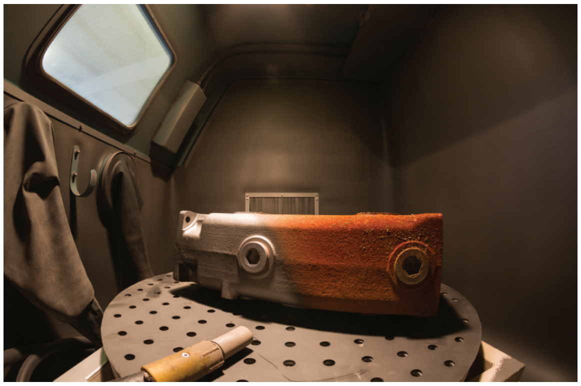

Figure 1.11: Media blasting pneumatic powered equipment provides an efficient means of surface preparation and cleaning.

Air Separation

An air separation plant separates atmospheric air into its primary components, typically nitrogen and oxygen, and sometimes also argon and other rare inert gases are targeted.

The most common method for air separation is cryogenic distillation. Cryogenic air separation units (ASUs) are built to provide nitrogen or oxygen and often co-produce argon. Other methods such as Membrane, pressure swing adsorption (PSA) and Vacuum Pressure Swing Adsorption (VPSA), are commercially used to separate a single component from ordinary air. High purity oxygen, nitrogen, and argon used for semiconductor device fabrication require cryogenic distillation.

Figure 1.12: Air Separation compressor application where compressed air powers the process to separate atmospheric air into a separate gas like Nitrogen.

The previous applications point out the versatility of the integral gear centrifugal compressor designed for air and nitrogen service in a large number of industries at varying volume and pressure ratings and in a considerable number of configurations of stages and intercooling arrangements. Also see "nitrogen".

Automation

Where production quantities warrant, production lines may be automated profitably. There have been many exciting trends in the field of automation by pneumatics.

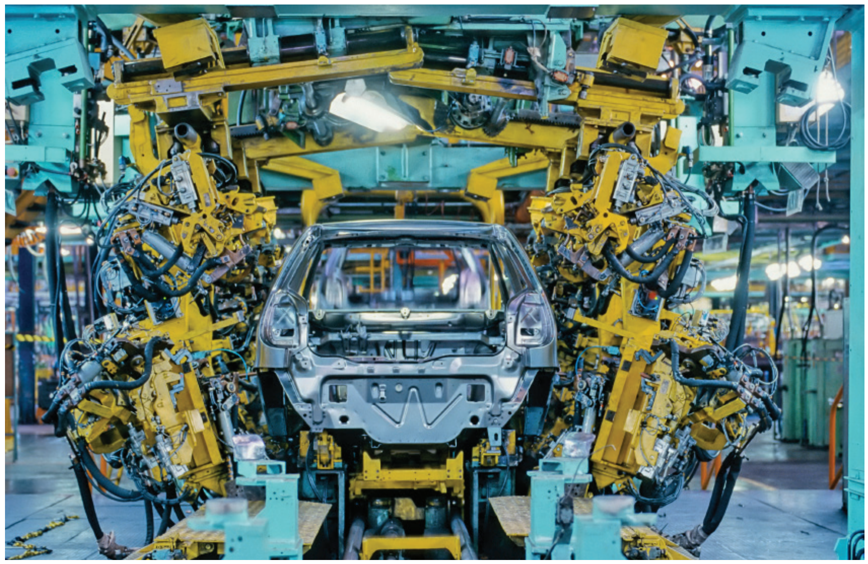

Figure 1.13: Pneumatic tools, switches, and solenoids are critical to automated production assembly lines like this automotive plant where robotic nut runners, impact guns and pneumatic actuators enable efficient and high quality work performance without human fatigue.

Other important developments in automation with compressed air include pneumatic handling of materials. Many substances in granular, chip, pelleted, or powdered form are very successfully handled in this way. The different methods utilized in pneumatic transfer of materials are discussed in a later section of this chapter under the heading Pneumatic-type Conveyors.

The range of solids transferred extends from cement to pelleted rubber. In cement production and in the unloading of grain ships, to mention only two examples, industry is highly dependent on pneumatic conveying; such applications are large consumers of compressed air. Refer to the specific topics in this chapter on these industries, as well as lumbering and woodworking, the food industries, and rubber manufacturing, for examples of this important materials-handling technique.

Painting is often automated using air circuitry and pneumatic controls in robot machines. Painters masks are automatically cleaned in a solvent and dried by air jet.


Figure 1.14: Compressed air propels the paint in paint booths.

Compressed air is used widely in automatic packaging machinery for sealing, locating the work, and actuating arms that fold paper to wrap the work. Pneumatic packaging is most commonly applied to small, mass-produced articles such as dry cells, candy bars, and writing tablets, but its use on other products is increasing. Vacuum devices find many similar applications, such as picking up and transferring sheet metal and sheet-metal parts as well as paper products like envelop manufacturing.

Automated Assembly Stations

Compressed air plays a vital role in the design and operation of automated assembly systems. Automated assembly stations (Figure 1.15) speed up assembly operations on high-volume production lines in the automotive, appliance, electronics, communications, and business machines industries.

Air power is especially suitable for automated systems because it is safe and clean, and the work it produces is easily controllable over a broad operating range by means of simple, low-cost control devices. Air power can produce either reciprocating or rotating motions, and the tool or feed mechanism being powered can be installed without injury to the system or the workers.

Typical air-power applications in automatic machines are the following:

1. To tighten threaded fasteners such as screws, nuts, and bolts to specified torque.
2. To drive plugs, pins, and rivets with air. There is the option of either pressing or hammering.
3. To feed fasteners or parts.
4. To actuate positioning cylinders, slides, or work heads.
5. To operate indicator lights showing such conditions as satisfactory completion of work cycle, reject, or the possible shutdown of feed, drive, or positioning components.
6. To transmit signals to recording computers.

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Figure 1.15: Automated assembly line.

Acid Manufacture, Agitating Liquids

Compressed air has important applications in agitating, elevating, and transferring acids and acid solutions. Agitating is usually accomplished by means of an air pipe run along the bottom of the tank. Air issues from the openings along the pipe and bubbles through the liquid to provide the desired turbulence. Corrosion problems in the acid industry require the proper selection of materials, and they are often expensive. The simplicity of the equipment needed for such air agitation thus gives it an economical advantage over mechanical equipment for the same purpose. Air or gas may also be a part of the process itself and may be very simply introduced during agitation.

In one process for making nitric acid, compressed air and ammonia are passed through a catalytic converter and the resulting gas, with additional air, is then passed through an absorption tower where nitric acid is formed. The process is included here because it utilizes air compressors. Waste gas for the process is put through an expander to provide power for the compressor and to improve the process efficiency.

Aeration Blending

Modern aeration blending uses a system that can blend dry, pulverized materials efficiently on an industrial scale. This method has been applied successfully to materials as varied as cement raw materials and polyvinyl chloride. By contrast, mechanical blending does not easily produce as uniform a mixture as the aeration method. Most dry, pulverized materials that can be fluidized by aeration can also be blended by this method. Blending aeration commonly reduces deviations from plus or minus 3 percent in the unblended materials to plus or minus 0.1 percent in the final product. Composition is homogeneous enough to permit discontinuing regular sampling and testing in many plants. Improved quadrant blending and the use of pulsating air are responsible for this progress.

The aeration blending system has demonstrated key advantages. Thorough homogenization can be accomplished economically even when the blended materials differ in bulk density, fineness, and specific gravity. As a result high tonnage and hourly capacity with rapid mixing and as well as continuous discharge of blended material following an initial mixing period can be economically completed.

The quadrant blending method incorporates a round, flat-bottomed silo that is filled with material to a level about equal to the silo diameter. The silo bottom is covered with aeration units closely spaced to give a uniform distribution of air into the material throughout the entire dispersion region. Each aeration unit is faced with a porous refractory block to release air into the material in innumerable fine jets.

To affect blending, enough compressed air is let into one-quarter of the silo bottom to expand and fluidize the material above that section. As a result, this material rises above the level of the adjacent quadrants and flows rapidly out across them, running off at a slope of 2 to 5 degrees. At the bottoms of the temporarily inactive quadrants, a small amount of compressed air is meanwhile released, with just enough air to make the material mushy but not enough to produce much change in bulk density.

The rising column of expanded material in the actively aerated quadrant is thus partly surrounded with heavier material, which tends to slump over into the active quadrant, where it subsequently becomes aerated, expands, rises, and flows outward in its turn. A strong, continuous rollover motion in a vertical circuit is obtained, which results in a very thorough mixing of the silo contents from top to bottom and throughout the active quadrant. The intensive aeration is automatically switched to a previously inactive adjacent quadrant under variable, timed control and then successively to each of the other quadrants in rotation, blending all the material in one cycle, although two circuits are often used to assure virtually perfect blending.

Following the blending of the initial charge, the process becomes continuous, because the incoming stream with variable analysis is rapidly mixed in the large mass of blended material in the silo, and a stream having uniform analysis can be withdrawn continuously from the bottom of the silo.

The time required may be from 1 to 2 hours following the establishment of a sufficient head of unblended material to initiate the fluid motion, depending on the character of the mix, the size of the silo, and the length of the period of air admission to each quadrant section. For fast blending, these periods may be from 5 to 15 minutes per quadrant. Results are improved when the flow to the active quadrant is pulsating flow.

Applications include blending of crystalline or other finely divided materials showing fineness or particulate sizes in the general range of 100 percent through 150 meshes and 85 percent or more passing 200 mesh, and especially those powdery materials that have been found to flow well in dense-stream conveyors.

In addition to the porous refractory blocks already described, there are several other important parts. Air-distribution pipes and headers are installed inside the silo for selective control of the air supply to the quarter-sections of the silo bottom.

Aeration, Air Screens, Agitation, And Bubbling De-Icing

For many years, the principle of releasing compressed air beneath the surface of a liquid and allowing the resulting bubbles to rise to the surface has been put to a multitude of uses. One is the agitation of the liquid itself, to stir it without mechanical equipment, either to mix several liquids of different viscosities or to mix solids with a liquid. This same principle of agitation may be used to distribute heat throughout the liquid, the same as is done by mechanical stirring.

Figure 1.16: Water treatment lagoon aeration.

A second application is the release of a compressed gas into a liquid for the purpose of mixing the gas with the liquid to speed up a chemical reaction. Frequently, air is bubbled through a liquid in order to use the oxygen content of the air to oxidize the liquid or material being carried by liquid. This is the principle of bubbling sewage to oxidize it more rapidly and, at the same time, keep the entire mass mixed sufficiently to be handled by pumping equipment, that is, to prevent setting of the solids. An aerated lagoon with air bubbling from a number of sources is shown in Figure 1.16. Also, water purification by oxidation of reservoirs is quite common. The reduction of algae that results means that much less chlorination is required, with resulting better taste.

Another application is the formation of a screen of air bubbles beneath the surface of the water that can act as a shock absorber to protect a subsurface such as a dam from explosive forces, such as blasting under water in the lake immediately behind the dam. Properly engineered air screens can absorb the explosive force, since the air is compressible while the water is not, and thus prevent this extreme hydraulic impact from being imparted to the underwater structure or device that is to be protected.

In pond or lagoon aeration, the compressed air supply at the lake bottom not only helps to oxidize impurities but also brings stagnant water to the surface from depths at which thermal currents may not be caused by the heat of the sun. Both actions contribute substantially to the quality of the water, reduction of algae growth and an improved aquatic plant and fish habitat result.

Air screens have been used successfully to divert schools of fish in commercial fishing. Also, air bubble screens have been tried for shark protection on bathing beaches.

For many years, the principle of releasing air bubbles to control wave action, the air thus serving as a breakwater, has been successfully used.

With the rapid growth of the boating industry in recent years, the increased number of marinas has brought another bubbling principle into common use. In those areas where freezing occurs during winter months, the formation of heavy ice around piles and docks can cause extreme damage. In the past, most boats were removed from the water to protect them in winter months where freezing could occur. The dry-land storage problem now has become a serious one because of space limitations and, at the same time, it is better to keep most boats in the water to prevent their drying out and to avoid the expensive re-caulking that would then be necessary.

Air bubbling can take advantage of the natural inversion that occurs as water cools down to near the freezing point. At approximately 39 deg. F, the warmer water no longer stays on the surface of a pond, lake, or stream; rather, it settles to the bottom. As the temperature continues to drop until it reaches the freezing point of 32 deg. F, the water will then finally freeze on the surface. If the natural inversion did not take place, water would freeze from the bottom up.

The release of air bubbles beneath the surface of a body of water will bring some of this warm water to the surface where the air and water mixture will rise above the surface of the water and tend to flow outward, thus spreading the warmer water over a larger area, thereby preventing freezing. This procedure can even melt ice that has previously formed. This principle is effective with any body of water having sufficient depth to maintain a temperature above freezing at its bottom. Large areas need not be included. Bubbler tubing along docks or around boats will maintain a sufficiently open area to afford protection against ice damage.

This same principle is used to keep ponds and lakes open for wildlife, such as birds that depend on open water to survive and fish located in ponds that might normally freeze over solid and possibly suffocate the fish by lack of oxygen in the water, the latter condition being also prevented by bubbling.

Finally, there are applications making use of the principle that rising bubbles will cause the water to reach a height above the surrounding water. One of these is the containment of oil spillage, and another is creation of a barrier against saltwater intrusion into freshwater streams because of tidal flow. In both of these applications, the rapidly rising bubbles actually make the water level higher at the point at which the bubbles break through the surface. Thus, the water at this higher point tends to flow back upon itself, causing, in effect, a barrier.

Agriculture

Applications of compressed air in agriculture are so numerous and varied that no attempt is made here to list them all. Only a few specific uses are mentioned.

Compressed air is widely used in farm equipment and for farm operations in most of the primary and auxiliary agricultural activities, such as erosion control, land drainage and irrigation, tilling, planting, insect and weed control, pruning, harvesting, and threshing. Compressed air performs useful services in connection with livestock raising and dairying. There are many compressed air applications around farm buildings, too, such as pumping, material handling, and primary processing, as well as maintenance and repair of farm machinery.

Additional applications of compressed air in agriculture include spraying trees, dusting insecticides and fungicides, feeding livestock in transit, disinfecting poultry houses, handling rice hulls, changing tractor tires, cleaning eggs, picking raw cotton, and seeding and fertilizing with compressed air guns.

Vacuum also finds many uses in agriculture, including milking machines. Vacuum lines can transport milk directly to tank trucks for improved sanitation. Vacuum egg lifters are also used to lift individual eggs gently for packaging. Vacuum seed planters deposit single seeds and eliminate later thinning. Vacuum is also used to impregnate eggs with medicinal solutions to reduce mortality rates of chicks.

An interesting compressed-air development is the use of foam to protect delicate crops from frost. Early tests indicate that the method is promising.

Aircraft

Several hundred thousand rivets go into the manufacturing of an airplane or helicopter. Powerful, lightweight, air-operated drills, wrenches, and riveting hammers are used in the assembly of airplane fuselages, wings, and other components. The importance of such air tools is seen in Figure 1.17, in which an air drill is being used in the construction of large commercial airliners.

Figure 1.17: Aircraft assembly.

Airplanes provide many applications for compressed air in addition to those used in the manufacturing stages. Compressed air stored in the air springs of the landing gear softens the shock when the airplane is landing or taxiing. Cabins are pressurized and air conditioned for high-altitude flights. Compressed air is used for de-icing plane wings, for heating the engines, for various actuating and control functions, and for operating the refueling equipment. The modern safety devices with which particularly the overseas airplanes are equipped, such as life belts, rafts, and emergency chutes, are inflated quickly and reliably, when needed, by compressed air or gas stored in high-pressure bottles.

Compressed air is used for starting jet engines and to provide cabin service for the comfort of passengers while the plane is at the terminal. A compressor specifically has been adapted for this purpose.

Most airlines have changed over to stationary versions of these units, electrically driven, thus reducing overall energy costs. The compressor in each case is a regular single-stage unit, but the control system is fairly critical due to the nature of the application.

Automobiles

From manufacture to maintenance, compressed air plays an important role in the automobile industry. Air-operated drills, nutsetters, grinders, buffers, pneumatic hammers, and impact wrenches are among the hand tools commonly used in both factory and garage. A pneumatic angle wrench is used (Figure 1.18) in automobile assembly.

Figure 1.18: Automobile production assembly line.

Air chucks, air-operated tailstocks for safe and quick travel, and other air devices are used on machine tools where a high rate of production is a factor. Air hoists to take heavy pieces to and from a machine are fast acting and easy to control. They permit assembly-line techniques to be used with parts and assemblies such as engines or transmissions that would otherwise be too heavy to handle.

The casual visitor to an automobile assembly plant may not be aware of the extent to which compressed air facilitates automation. An electric welding machine, for example, has air lines to supply the pneumatic clamps that hold the work in position during welding, and these are easily mistaken for electric cables. Few general visitors are aware that the machine for pressing recesses or dimples into automobile firewalls to strengthen them is pneumatically operated.

As production line operations become more and more automated, whether it be drilling holes or welding frames or bodies, the smooth power characteristics and compactness of air tools and auxiliaries assure that they will remain essential parts of the equipment with which the automobile is produced. Air circuitry and controls facilitate their incorporation into automatic assembly machines.

Servicing the automobile provides many more applications for compressed air such as painting. It is used in equipment for removing and inflating tires, in air lifts, air jacks, pneumatic grease guns, and air jets, in blowing out clogged gasoline lines, and in cleaning out car interiors. It is also used in air guns for spraying paint or antirust coatings and for oiling springs. Compressed air is also employed in retreading and re-grooving tires, sandblasting and cleaning pistons, and sandblasting spark plugs. Agitating solutions for cleaning metal parts is still another use.

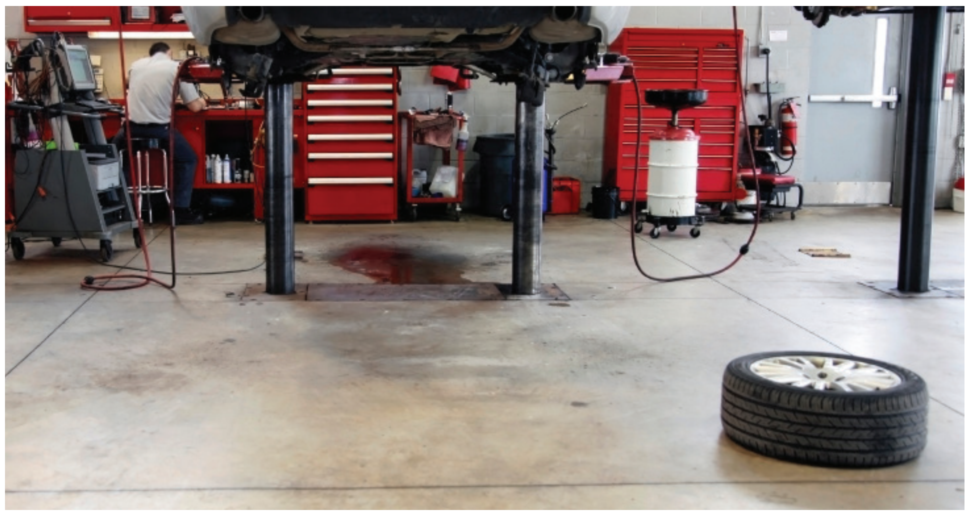

Figure 1.19: Numerous air tools are used in auto service facility.

The automobile industry is a field that has made widespread use of industrial robots. Among their many applications, these devices clamp and hold frame members while they are welded automatically. While robot control is usually electrical, pneumatic manipulators are in widespread use on robots because of the well-regulated movement of which they are capable.

Beverages

Both soft-drink bottlers and brewers depend on compressed air for a number of bottling operations, including capping bottles and kegging beer (Figures 1.20 and 1.21). The immediate, sensitive response of compressed air makes it the choice of power on many types of controls in production processes. Transferring liquids from vessel to vessel, unloading grain from cars and hoisting it to storage bins, and testing kegs for leaks are other applications for compressed air. Automatic bottling machines have many applications for compressed air in control and in actuating some of the necessary reciprocating and intermittent motions. Also see Distilleries.

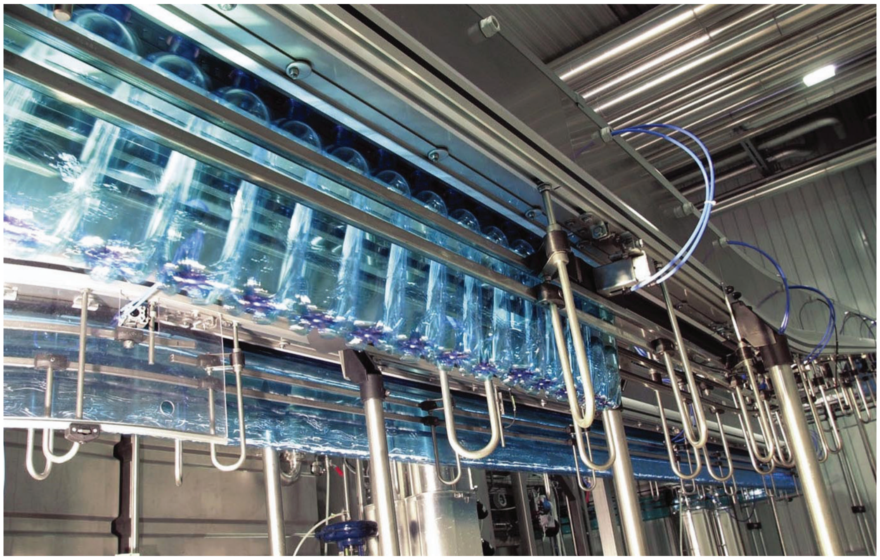

Figure 1.20: Plastic bottles often referred to as PET Bottles (Short for Polyethylene terephthalate) are produced with compressed air. They have replaced much heavier glass bottles for many beverages and are 100% recyclable.

Figure 1.21: A variety of plastic beverage bottles molded with the use of compressed air.

Blast Cleaning

Blast cleaning, also known as abrasive blasting, is a process in which abrasive material entrained in a jet is directed onto the surface to be cleaned and abraded. The particles may be natural sand, man-made mineral, plastic, steel abrasive granules, steel shot, frozen carbon dioxide and or similar particles. Blasting may be used for cleaning, controlling surface roughness, such as required when preparing for subsequent surface treatments or application of coatings, or carving a design upon a surface. Blasting of frozen media has been used to remove meat from bone in pet food production. As well as to remove dangerous mold from residences during mold remediation processes.

Similar applications are found in removing scale formed on steel during rolling, forging, or heat treatment. Most of the surface and protective coating processes, like painting, plating, and enameling, are much more effective if the surface to be treated has been properly prepared by blasting. Cleaning of building walls and caring of monuments are two other well-known applications.

Figure 1.22: Media blasting prepares cleans and prepares surfaces for protective coating.

Media machines are usually designed to operate on air at a pressure of 90-150 psig available from the shop or construction lines. Basically, the size of the nozzle aperture determines the air flow needed to operate the machine. For example, the air flow is 23.5 cfm for 1/8-in. nozzle and about 210 cfm for a 3/8-in. nozzle, assuming an air pressure of 90 psig. The larger air stream raises the productivity of the operation, but it is uneconomical if only small-sized parts have to be treated or if the equipment is operated only occasionally.

Wet media-type machines are mainly designed for outdoor work where they are widely used because of their many advantages. The main advantages are freedom from operating dust, independence from weather conditions, and eliminating the need for drying the sand. In some applications, the possibility of introducing liquid corrosion inhibitors into the sand mixture is another valuable feature of this system.

This system of media blasting has many applications in removing mill scale, marine scale, and fouling growth from marine hulls. It is also used in cleaning large tanks, pipe lines, bridges, and many other structures.

Figure 1.23: A pneumatic powered media blasting cabinet to remove rust and prepare surface for painting.

Some blast-cleaning machines use soft absorbent materials such as ground corn cobs, nutshells, and sawdust instead of abrasives. The soft action of the blast does not injure wiring and other delicate components, and because there is usually no need to dismantle the assembly, this type of cleaning is more convenient for many applications than the conventional method of washing individual parts in a solvent bath. Most types of blast-cleaning machines are manufactured either as stationary or portable units. Air blast cabinets designed for handling small-sized parts are usually stationary. There are also various types of rotary table blast cleaning machines used for continuous operations.

Operators should always check with federal, state and local requirements for safety equipment and blasting media usage before starting a project.

Breathable Air for Contaminated Environments

Workers in environments contaminated by toxic wastes, paint vapors, paint spray, or other potentially harmful substances are provided with a supply of clean breathable air by a specially designed system. The air is taken from a clean environment so that no cartridge replacement is required, and the compressor is most likely an oil-free, non-lubricated type. Besides painting, another wide field of application is the removal of asbestos from the walls and ceilings of old buildings.

Breathing applications must strictly follow the National and local regulations for breathing air applications. Special compressed air treatment equipment, filters and protective operator gear are frequently required.

Carpet Industry Application

Compressed air is used extensively in the yarn extrusion and yarn entanglement processes. The resulting texture of air entangled products has made them very popular in recent years and compressed air is the main ingredient. The yarn can be of several types (nylon, polyester, polypropylene, etc.), colors, and deniers (fineness or thickness) that are entangled through an air jet. Most air entangled products use air pressure up to 175 psig. Two stage rotary screw compressors and centrifugal compressors are the preferred choice to meet energy efficiency and high pressure requirements.

Figure 1.24: Yarn entanglement application.

Cement Production and Products

The Portland cement industry is one of the largest consumers of compressed air, and probably few industries surpass it in diversity of application, as seen in Figure 1.25. The largest portion of the compressed air required in a cement plant is utilized in conveying. All but a negligible portion of the Portland cement manufactured in the United States is transported from grinding mills to storage silos by compressed air pumps. Many mills also utilize the compressed-air pumping method for conveying cement from silos to packer bins, for loading and unloading cars, and for unloading and loading ships and barges. Kiln flue dust, packer spill, and pulverized coal are frequently handled in this manner.

Figure 1.25: Compressed air is a vital part in the production of cement. Large users of compressed air include bag houses, control air and conveying systems.

In many dry process plants, the raw materials are both conveyed and blended for precise chemical control of the composition by compressed-air pumping and aeration.

In wet process plants, compressed air is utilized to mix and blend the slurries and to maintain the individual mineral particles in intimate mixture and suspension. To decrease fuel consumption in burning, many mills dewater the slurry by filters served by vacuum pumps. To ensure free flow and discharge of dry pulverized materials, aeration of bins is a universal practice throughout the industry.

Rock drills are essential in cement-plant quarries, and compressed-air rock hoists and car dumpers are used by most crushing departments. Air-operated grinders and other tools are commonly used in the large maintenance shops that cement plants require, and compressed-air and vacuum lines are essential in plant laboratories.

Large volumes of air at relatively low pressures are required in cement manufacturing. Blowers and fans supply the fuel or primary combustion air stream to kilns, whether fired by pulverized coal or oil. The use of air-swept unit mills for pulverizing coal is rapidly increasing. Air, in large volumes and at fan pressure, quenches the hot clinker, reducing its temperature abruptly from 2500 deg. F to about 150 deg F for the purposes of improving cement quality, recovering heat, and reducing the clinker to a temperature suitable for grinding. Most modern plants employ air-swept pulverizers in closed grinding circuits to control cement fineness and to economize on power. Similar circuits are used in dry process plants for the preparation of raw materials. Fans also serve as dust collectors in almost every department of a modern cement plant.

Chemical Plants

Compressed air is used throughout chemical production and process management. In addition compressors are used in the maintenance and protective coating process to keep the plants safely operational; compressors are used to pressure check critical tanks and vessels after periodic checks. Other applications can include pneumatic conveying, instrument air and powering pneumatic actuators and mixing devices.

A two-stage, integral gear type centrifugal compressor to provide process air in an amino acid plant is shown in Figure 1.26. This unit is discharging at only 35 psig to match process requirements.

Figure 1.26: A low pressure two-stage centrifugal air compressor utilized in a chemical plant.

Figure 1.27: A chemical processing plant has hundreds of compressed uses including pneumatic conveying and maintenance.

Construction

Construction on roads, buildings, dams, bridges, and tunnels probably accounts for more of our gross national product than any other single phase of industrial activity (Figure1.28). In most construction operations, compressed air provides the power from the time ground is broken until the job is completed.

Figure 1.28: Pneumatic powered full face tunnel boring machines enable high productivity on major tunneling job.

The pavement breaker (Figure:1.29) was among the first pneumatic tools to find widespread use. One person with this tool can do the work of 15 workers working with hand sledges and chisels in cutting asphalt or concrete pavements or in demolishing concrete foundations, retaining walls, floors, partitions, and other structures.

Figure 1.29: The pavement breaker is one of the most widely used construction tools. It facilitates removal of old pavement so that new construction may proceed.

Similar tools equipped with spades, diggers, root cutters, drivers, and tampers are very widely used for more sophisticated tasks.

The reciprocating mass used in the pavement breaker with the added feature of a slow, revolving motion is used in the rock drill, one of the most important adjuncts of modern construction. Pneumatic rock drills are available in a wide range of sizes from comparatively light portable tools to heavy, propelled machines. These tools are capable of drilling blast holes at any angle, even drilling multiple holes into hard rock (Figure 1.30) to depths of many feet and at speeds that in the past would have been considered unbelievable. Drill points are cooled and the drill cuttings removed from the holes by means of an air stream directed at the spot where needed. Compressed air is also used to actuate the auxiliary motions of these units and even to propel these heavy-duty rock drilling machines. Thousands of these tools are being used in huge road construction jobs in many parts of the world.

Steelwork, essential in all modern construction, is joined by rivets or bolts and nuts, millions of which are used. Whatever fastener is selected, pneumatic tools are available to do the field drilling and reaming, riveting, or assembly of bolts and nuts.

Figure 1.30: Pneumatic gang drilling in a dimension stone quarry for a presplit application.

Pneumatic drills, reamers, riveters and holder-ons, nut runners, and highly advanced designs of impact wrenches are used because no other kinds of power tools are capable of exerting as much power per pound of tool or are so rugged and dependable in maintenance as pneumatic tools. Finally, the safe operation of pneumatic tools should be stressed, a feature of utmost importance when one considers the hazardous locations in which power tools are commonly used on steel construction jobs.

Compressed air is also used for many auxiliary operations in construction since it is a versatile and readily available source of power. Some uses are drilling, hoisting, pumping, riveting, forging, and there are many others. Air tools have sufficient power to enable them to perform difficult tasks without excessive weight for the operator to handle. There is no overheating from constant use, and tool maintenance is low. Backfilling excavations, tamping dirt and concrete, testing and caulking pipe lines, operating drainage pumps, power brushing of pipes to remove rust, driving metal road markers, brushing concrete surfaces, driving sheet pile, constructing caissons, casting concrete piles, sharpening drills, and cutting metals under water are all jobs for which air-operated tools and equipment are used by contractors.

Air guns to apply concrete on new construction and on repairs are a common application. Air guns for spray painting save time and money on innumerable projects. On tunnel projects, air-operated rock drills, clay diggers, and other pneumatic tools speed up many otherwise slow operations. Pneumatic placers are used to line tunnel interiors. Lightweight, air-operated pumps are used by contractors for pumping out sumps, trenches, manholes, caissons, cofferdams, tanks, and bilges.

Compressed air is used in the drilling of sand drains for stabilizing soft, wet soils such as saturated clays and silts. An annular pipe mandrel is driven into the ground by an air hammer or vibrator. Air is introduced just above the driving shoe and blows the soil to the surface through the center. Self-destructive drilling mud is fed through the outer, annular space as the mandrel is withdrawn. When the mud disintegrates, it leaves a sand-filled column through which water may drain when the soil is placed under load. Liquid nitrogen has been used successfully in freezing earth for underground construction. Injected into the ground in a series of holes, it can create an impervious front for the retention of ground water during construction.

Seeding and fertilizing after backfill operations can be done quickly by an air gun similar to a sandblast gun. Seed and granular fertilizer are picked up from bags carried in a small track and scattered by air from a portable compressor towed by a truck. Even steep banks along a highway may be seeded in this manner, the truck and compressor moving along at grade level. Seeding of highway banks at 10 acres per hour has been reported.

In construction work, there are important applications for compressed air other than those given here, and most of the pneumatic tools already referred to have other uses besides those specifically mentioned. The typical applications listed for compressed air can only suggest the variety of work that compressed air, as a versatile power, can successfully perform.

Computers and Business Machines

The development of small computers has led to greatly increased computer applications throughout industry for machine and process control and for many businesses, hospitals, and countless other applications. Manufacture of chips and microchips on which these computers are based is done in clean rooms where compressors are part of the equipment that maintains a controlled, virtually dust-free atmosphere. Compressed air and vacuum are used in molding of plastics from which computer cases are made. Many air tools find applications in computer manufacturing similar to those in other industries.

Pneumatic-type Conveyors

Pneumatic conveyors occupy a position of great importance in the materials-handling field. Materials may be transferred by air under pressure or partial vacuum depending on how the materials may best be handled in any given situation. In the pressure system, the compressor precedes the system, while in the vacuum system, it follows the system. Pneumatic conveying is especially suitable for many dry, free-flowing bulk materials that are handled by pneumatic pipeline conveyors (Figure 1.31) and for parts that may be placed in carriers of specific size and shape, the carriers to be transmitted through pneumatic-tube conveyors.

Figure 1.31: Bulk PVC product being pneumatically conveyed to storage silo. The air speed needed to keep material moving in conventional pneumatic systems depends on particle size, shape and weight, buoyancy, friction, turbulence, and other factors and is difficult to determine theoretically. If the air speed is great enough to convey material horizontally, it is generally more than ample for elevating. For grain and normal mill stocks, horizontal conveying speeds range from 3000 to 5000 fpm with conventional pneumatic systems.

Materials such as cement or flour depend for their successful handling on having enough air entrained throughout the material to give the mixture fluid properties. Such solids are said to be fluidized. The material remains generally in suspension in the air which carries it through the system, there being pressure and turbulence enough to re-aerate any of the material that may tend to settle out. A great many powder, chip, granular, and pelletized materials are successfully handled in this way (see Table 1.1).

TABLE 1.1 Some Materials Handled by Pneumatic Conveyors

Alum	Iron oxide
Alumina (calcined)	Lime (hydrated)
Ammonium sulfate	Lime (pebble)
Arsenic (trioxide)	Limestone (pulverized)
Asbestos dust	Magnesium chloride
Barium sulfate	Magnesium oxide
Barley	Malt
Beef cracklings	Meat scraps (dried)
Bentonite	Middlings
Blood (dried)	Oats
Bone char	Phenolic resin
Borax	Polyethylene (powdered)
Bran	Polystyrene beads
Calcium carbonate	Polyvinyl chloride
Carbon black	Resin (synthetic)
Catalysts	Rice
Cellulose acetate	Rubber pellets
Cement	Rye
Clay (dried)	Salt
Clay (air-floated)	Salt cake
Cocoa beans	Sawdust
Coffee beans (green)	Silex
Copra	Soap chips
Corn	Soap flakes
Corn flakes (brewers’)	Soda ash
Cottonseed hull bran	Sodium tetraphosphate
Cyanamid (pulverized)	Soybean meal
Dolomite (crushed)	Starch
Feldspar (pulverized)	Steel chips
Ferrous sulfate	Stucco (hydrocol)
Flax seed	Sugar
Flour	Titanium dioxide
Fly ash	Vinylite
Foundry sand (green and core)	Volcanic ash (pulverized)
Fuller’s earth	Water-conditioning chemicals
Grains (dry-spent)	Wood chips
Grain dust	Wood flour
Grits (corn)	Zinc sulfide
Gypsum (raw, pulverized)	
Gypsum (calcined)	
Hops	

Solids pumps, air locks, blow tanks, and many other units are available for feeding and aerating the solids handled in the various systems with pressures adapted to the requirements of the solids handled, the conveying distance, and other factors. Solids pumps are shown in Figure 1.32. An air-activated gravity conveyor depends on air to fluidize the solid and keep it fluidized so that it moves along the slide under only the force of gravity.

Figure 1.32: Compressed air is used to pneumatically convey material quickly & safely like the powdery material being loaded on this ship.

Air Versus Mechanical Systems

It is difficult to make a single comparison of pneumatic and mechanical systems. For short conveying distances, the mechanical conveyor is usually less expensive, but as length increases, pneumatic systems become relatively more favorable. Power consumption is also higher for pneumatic systems. These costs, however, often become less important than the savings in production costs that may result from pneumatic conveying. Dependability, low maintenance cost, and elimination of spillage are factors in this connection. The main advantage of pneumatic conveying is its flexibility. Materials may be taken around corners, through walls, or literally anywhere a pipe may be located, avoiding obstructions that would be serious obstacles in mechanical conveying. Safety and cleanliness are also important in certain cases. With air supply of sufficient capacity, most air conveyors are self-cleaning.

Air conveyors and mechanical conveyors both have uses that will remain exclusive to each. There are, however, overlapping areas where users may be able to benefit from a careful study of both types.

Dentistry

High-speed pneumatic drills (Figures 1.33 & 1.34) have greatly reduced the pain associated with dental operations. These drills are powered by an air turbine and rotate at speeds sometimes exceeding 200,000 rpm and permit faster cutting. To remove heat, the sensitive area is sprayed with an air-water mist. To keep the mirror clean, it is rotated so fast by a small air motor that moisture is thrown off by centrifugal force. Vacuum also removes accumulated moisture.

Figure 1.33: Pneumatics enable high-speed and efficient means of driving dental tools.

Figure 1.34: High rotative speeds achieved by air-turbine-driven dentists' drills permit faster cutting and alleviate the pain often associated with certain dentistry.

Die Casting

Injection of molten metal into die cavities is generally done hydraulically, but many auxiliaries are operated by compressed air. Small air grinders and impact wrenches are used to repair and assemble dies. Many trimming fixtures are air operated or have pneumatic clutches. Pneumatic clamps are used to hold castings during finishing operations, and in these operations, grinding and chipping hammers are extensively applied. Pneumatic tools are also utilized by maintenance and shipping departments.

Distilleries

Pneumatic power is used extensively in distilleries for conveying grain and malt. The entire system of handling grain can be dependent on pneumatic power from the boxcar to the grain elevator to storage in the distillery and, finally, to the production processes themselves.

Dry-cleaning Plants

Compressed air is one of the principal forms of power in dry cleaning plants. Collar, shirt, and garment presses use compressed air to press clothing against the steam-heated chest. Spotters spray cleaning solutions with small air guns, and dry cleaners use air-spray guns for mothproofing rugs and storage cabinets. The positive pressure of compressed air is considered by many rug and upholstery cleaners to be the best means of removing loose dirt. Furs that have been cleaned are given an "electric look" by a brief jet of compressed air against the fur. Filters for recovery of cleaning solvents employ compressed air to drive out gas and to cake sludge so that it can be handled conveniently. Cotton lint, which is a fire hazard in laundries, is easily removed by periodic cleaning of the building with air lines that reach to the ceiling and under machines. In commercial laundries that cater to the hospitality industry, clean, dry compressed air blasts are essential for making crisp folds in hotel linens, tablecloths, and chefs'aprons.

Electric Products

Actually, this is not a single industry but a group of industries extending from tiny instruments through the wide range of communication equipment and giant electric generators. It would be extremely difficult to assess the hundreds of applications in which compressed air facilitates the manufacture of electric products, in process service as well as in power service. Vacuum is indispensable for the production of electric bulbs and vacuum tubes. At the same time, it is also by air power that the various motions of automatic equipment used for manufacturing bulbs are actuated and controlled. Some electric machinery is protected against the corroding effects of the atmosphere in which they have to operate by impregnation using a sequence of vacuum and compression.

Pneumatic screwdrivers are often used in assembly operations, as are specialized tools such as wire wrapping tools and wire cutting and stripping machines. The latter have been automated using pneumatic controls so that a circuit board may be programmed and wired automatically. Fusion soldering machines are also powered by compressed air.

Farm Machinery

The makers of farm machinery find a great variety of production applications among those discussed in the earlier parts of this chapter, including the use of rapid-action air chucks, drills, grinders, and polishing machines, as well as air-blast equipment, and in the manufacture of farm equipment such as pruners, posthole augers, and other similar equipment.

Food Industries

Packers, bakers, millers, refiners, and many others in food industries use compressed air to expedite many processes. Transferring liquids and granular materials from trucks and railroad cars is a common application. A pneumatic conveyor can unload a carload of grain in three hours.

Sugar refineries and bakeries use compressed air for transferring syrups. Vegetable fats and other liquids are transferred in the same manner. The agitating of certain liquid or liquid-immersed foods such as pickles is accomplished by bubbling compressed air through them. Pressure filtering also uses the same source of power. Canneries use compressed air in can-filling machines and for cooking and sterilizing.

Nitrogen-enriched atmospheres in storage areas retard the spoilage of many foods, extending the storage life of apples, for example, by many months. The reduced level of oxygen is largely responsible for this, but carbon dioxide and other gases are added in small quantities to control enzyme reactions and retard fungus or mold growth. Examples in a system for charging rail cars with inert gases utilizes a supply truck.

Lettuce is chilled and crisped by subjecting it to a vacuum that evaporates free moisture from between the leaves, removing their latent heat. Nitrogen-enriched atmospheres are also used in rail and highway carriers especially adapted to the insulation and isolation requirements to bring lettuce and other perishable foods fresh to market.

Liquid nitrogen is also used as a refrigerant for trucks and rail cars transporting perishable foods. The liquid is stored in specially insulated containers and released to the cargo area as refrigeration is required.

Foods can be frozen much faster using liquid nitrogen than they can in a conventional refrigerated-air freezer.

Many foods are packaged in inert gases to exclude oxygen, to which most spoilage is directly related. Gases most commonly used are nitrogen and carbon dioxide, with nitrogen preferred in most cases since it is highly inert. Carbon dioxide is soluble in water so that, in some cases, it can impart an acid taste. Nitrogen is preferred for foods with high aroma. Carbon dioxide appears to retain the color of cured meats. Where vacuum packing may cause slices of food to crush or to adhere and be difficult to separate, gas packaging is preferred (Figure 1.35). Gas packaging is also especially suitable for fragile, freeze-dried foods.

Figure 1.35: Oil-free compressed air, specially treated oil-flooded compressors with food grade lubricants and vacuum are integral part of the food and beverage processing, manufacturing and packaging.

In bakeries, air is used for cleaning biscuit dies, spraying butter in pans, and pressing out dough in measured amounts from automatic roll machines. Air jets are the best method of cleaning crumbs from bread-slicing machines without having to stop the machines. Air hoists and lifts are also commonly used in the bakery and at the loading dock. Compressed air is also used to spray insecticides in bakery storage rooms.

One of the expanding and important applications of compressed air in bakeries is that of flour handling by means of pneumatic conveyors. Such conveyors do the complete flour handling automatically, starting with the unloading of freight cars or trucks. The whole flour-handling process is performed economically and hygienically in a tightly closed pipe system with no direct handling by warehouse personnel. Additional information is included under "packing houses."

Forging

Forge shops find extensive use for air hoists, grinders, chipping hammers, clamps, sandblast, and so on. Many plants have installed air-operated hammers or are converting steam-operated hammers to air operation. A study of the economy should be made comparing the cost of electric power to operate the compressors to the cost of generating steam. No standby power costs are involved with air during idle shifts or weekends, as is usual when steam is used.

Foundry

Most of the cast iron for our foundries is melted in the cupola furnace in which burning coke provides the necessary heat. The combustion of the coke requires a large volume of air, which is introduced into the cupola through the tuyeres. About 30,000 ft^3 of air is required to melt one ton of metal.

Foundries where most of the work was formerly done very inefficiently by hand are mechanized to a very large extent. Most of the equipment of the mechanized foundry relies on compressed air for its motive power because of its flexibility and the sturdiness of air-powered equipment.

Figure 1.36: Pneumatics enables large machinery in steel mills and foundries to operate efficiently and safely.

In one large foundry, prepared coremaking sand is handled at a rate of up to 960 tons per two-shift day by the blow-tank type of pneumatic conveyor, which delivers sand to any of 38 stations selected via a master control. Air also transports molding sand from delivery points to storage bins, supplies molding machines, and recovers used mold and core sand.

One of the most important pneumatic devices in the foundry is, in fact, the molding machine. Large-diameter cylinders provide the force necessary for squeezing sand into the mold, with squeeze pressure being regulated by a valve in the air supply line to suit conditions. The high-frequency jolting action needed to pack the sand evenly is produced by air cylinders with quick, reciprocating action. In several modern molding machines, particularly for use on higher floor levels or for producing very clear-cut impressions, jolting is replaced by vibration, also produced by compressed air. In heavy-type rollover molding machines, the rollover and draw operations are also air powered, working in combination with hydraulic booster devices. Sand is introduced into the molds with the air, and compressed air is used for auxiliary operations such as blowing and lifting.

Compressed air has long been used in foundries, and the trend toward mechanization and automatic control has only increased its use.

Cores are also made by blowing the sand into the core box instead of jolting or ramming. Core boxes with vents for the escape of air are used, and the core blowing machine, operated by compressed air, carries the sand, which is suspended in the air stream, into the core box from which the air escapes, leaving the sand. The sand is compacted enough for most purposes, and the process takes only a few seconds.

Furniture

Better production is obtained from many machines used in a furniture factory because of compressed air devices. A good example is a front-skirting operation for chairs. Two air pistons in the center of the machine raise and lower the saws. At either end of the sawing, boring, and framing machines are air pistons that furnish the drive for boring tools. Compressed air is used for these operations because its resilient pressure adjusts itself to varying stocks, thus avoiding breakage.

Air jets clean out sanding machines, exhaust and separate sawdust and shavings automatically from mortisers and boring machines, and blow off pumice after rubbing. Air clamps are used to hold work in such machines as automatic shapers and to straighten pieces in presses. Pneumatic screwdrivers, drills, and wrenches are used in assembly, and other pneumatic devices are used in buffing and carving wood. Painting, varnishing, and enameling are done with air spray guns.

Pneumatic sanders, buffers, polishing machines, discs, and belt grinders are particularly useful in furniture manufacturing. These tools are insensitive to the dust developed in woodworking because of the self-protecting properties of compressed air-driven machines and, in addition, are spark-free, thus avoiding fire hazards. Air tools used in furniture production are shown in Figure 1.37.

Figure 1.37: Final finish is applied to a fine furniture piece with a precise pneumatically powered and controlled spray gun.

Garages

Virtually every garage has a compressor at least for inflating tires. (Figure 1.38) But automotive garages also use compressed air to help with the more difficult jobs, such as changing tires with impact wrenches, tire changers, spreaders, and lifters, to greatly increase the facilitaiton of work production. Many of these same pneumatic devices are used in tire recapping plants along with air-operated molds. Refer to the section on"automobiles."

Air pressure is used for cleaning engine parts. Pneumatic sanders, grinders, polishers, and paint spray equipment are useful in auto-body repair shops.

Figure 1.38: Compressed air being used to inflate auto tires.

Gas Bearings

Gas bearings have configurations greatly similar to those of other hydrostatic and hydrodynamic bearings. In these bearings, however, air or another gas replaces the customary liquid lubricant, producing the film necessary to carry the bearing load and to separate the bearing surfaces for minimum friction under load.

A principal advantage of gas bearings is their extremely low friction torque. This torque tends to be very nearly constant as long as full film separation is maintained, since the viscosity of gases varies very little over a considerable range of temperature. Gas bearings may also be applied at temperatures where the viscosity characteristics of oil lubricants would be unsuitable.

There are two basic types of air or gas bearings, the externally pressurized and the self-acting types. Externally pressurized bearings receive gas under pressure from an outside source, such as a compressor or an accumulator, from which it is introduced under the journal so as to float the load and separate the bearing surfaces without dependence on relative motion to maintain the pressure in the film. The self-acting type does not depend on external pressurization but instead produces its own pressure in the same way that pressure is produced in an oil-lubricated bearing. The journal, slightly smaller than the bearing, has a varying clearance due to its eccentricity. The air or other gas is carried into the converging space because of its viscosity and is thus compressed, providing enough pressure to support the load.

Glassworks

The ancient art of glass blowing has been transferred to automatic machines that produce far greater quantities of glassware than were once possible through individual efforts. In this field, compressed air is an essential factor.

Typical applications are the handling of glass sand, blowing glass, operating molds and presses, operating sandblasts, supplying oil burners, etching glass, and molding and frosting lamp bulbs.

A machine for forming glass tumblers employs compressed air in several important ways, and each year millions of bottles are formed by compressed air in blow molding machines.

Compressed air and gas are mixed in glass-plant burners for high combustion rates. High-pressure air is applied to drive cleaning cloths through glass tubes and to blast holes in glass with abrasives. Designs are etched in glass by sandblast, which cuts the exposed surfaces not protected by a masking stencil. Some types of sheet glass are heated to high temperatures and then cooled by compressed air to chill the outside surface. This process gives shatterproof qualities and greater tensile strength. Glass sheets are lifted by vacuum cups, a method that has reduced the risk of breakage.

As the glass industry has continued to increase the variety of its products, it has greatly extended its need for compressed air.

Golf Courses

Golf courses and similar areas can be seeded and fertilized by using a portable compressor and a gun similar to a sandblast gun. A suction hose inserted into a bag of seed or granular fertilizer carries the material to the gun, where it is ejected and distributed by a jet of air. It is reported that 500 acres per week have been seeded and fertilized in this manner using two guns and one portable compressor and a truck.

Compressed air may be used to blow out sprinkler systems on golf courses to prevent frost damage. This usually permits lines to be installed in trenches of uniform depth without much regard to gravity drainage. A portable compressor rented by the day makes this an economical method. Care should be taken not to exceed the safe pressure for the system.

Heat-recovery System

Heat removed from a compressor during the compression process to improve the volumetric and compression efficiency may be used to meet part of the building heat load. Hot water can also be made available with inbuilt heat recovery option in water cooled air compressors and can be used as boiler feed or other process applications in the plant. Installations may be indoors or outdoors; an example of the latter is shown in Figure 1.39.

Figure 1.39: Compressors with heat recovery units used to heat the plant and process equipment in winter and exhaust excess heat in summer.

High Energy Rate Forming (HERF)

Compressed air has been used to replace dynamite or other charges in the explosive forming process, which is used for the manufacture of items like metal kegs with double curvature and formed rings. Releasing compressed air against the large piston in a HERF machine and applying the resulting force to a small piston or on water in the forming chamber produces more safely the same kind of irregular shapes for which explosive charges were originally used. The same degree of care must be taken as in handling other high-pressure gases.

Hospitals

Hyperbaric chambers, in which the patient breathes air or oxygen under pressure, have been constructed in several hospitals (Figure 1.40). Usually used where a higher than normal concentration of oxygen is desired in the patient's tissues or blood, hyperbaric treatment has been effective against carbon monoxide poisoning and respiratory disorders and other surgical operations. Hyperbaric chambers are not only used in the medical field but they are also being used for deep sea diving decompression.

Figure 1.40: A hyperbaric chamber.

For inhalation therapy, clean, dry air is provided at positive pressures of a few inches of water to breathing apparatus in unpressurized treatment rooms. Oil-free compressors providing air for hospital use are shown in the operating room in Figure 1.41.

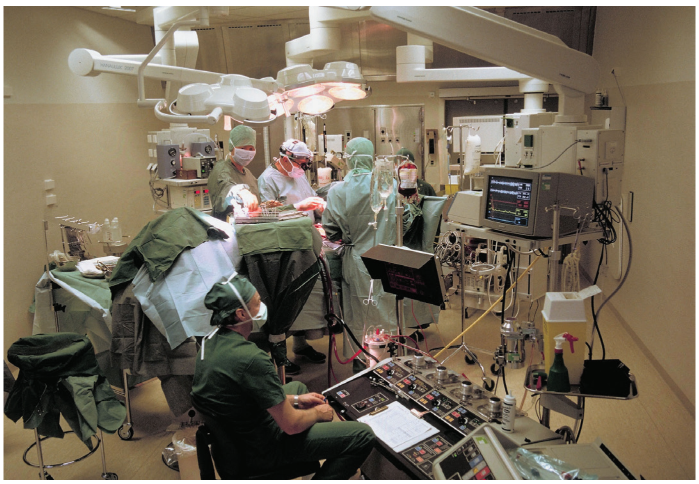

Figure 1.41: Oil-free compressors supply medically clean air for a hospital.

In an alternative system for supplying breathing air, which is convenient for the patient to use either in the hospital or at home, oxygen-enriched air is provided by a molecular sieve bed, which removes nitrogen from atmospheric air. Such oxygen concentrators achieve oxygen concentrations of 90 to 95 percent.

Many gases, especially anesthetics and oxygen, are supplied in pressurized cylinders. These are tested periodically at hydraulic pressures considerably above their service pressure. Color coding is used to avoid confusion among gases, and a distinctive valve and thread are used for each gas.

A high-speed, turbine-driven pneumatic surgical drill has exciting capabilities. In craneotomies, it permits removal of the top of the skull in as little as two minutes, compared with the half-hour needed by surgeons using hand tools. It has been used to carve transplanted chest cartilage to form a realistic artificial ear and to shape a grafted bone to rebuild a badly broken nose. Weighing less than 1 lb, the drill brings increased speed and power to bone cutting, drilling, and shaping. The compressed air or nitrogen that provides its power is exhausted at the drill tip to cool the area of the cut. Airtight seals permit ready sterilization of this surgical tool.

Instruments to control hospital air conditioning and humidity in operating rooms are operated by compressed air. Nurses use compressed air for cleaning catheters and other tubing and for spraying medication. Vacuums are used to draw off blood and secretions during operations when there is no way of clamping off and sponging to give the surgeon a clear operative field. Operating rooms are pressurized to keep out dust. Air-operated doors in surgery are manipulated by foot pedals. Hospital laboratory, laundry, and maintenance personnel also use compressed air for many purposes.

Industrial Applications of Portable Compressors

Portable compressors have often provided plant air during the interim when, for one reason or another, the regularly used stationary compressor was out of service.

Figure 1.42: A portable, oil free screw air compressor providing portable air power.

Although there is a clear trend toward stationary compressors at ski areas, as reported in a separate section on that topic later in this chapter, rented portable compressors have long provided air for snow making depicted in Figure 1.43.

Figure 1.43: Electric powered compressed air propelling snow-making guns at US Colorado ski resort.




Household Appliances

Manufacturers of refrigerators, stoves, vacuum cleaners, radios, television sets, kitchen sinks, cabinets, toasters, mixing machines, washing machines, fans, clocks, and other home appliances utilize compressed air for so many purposes that only a few will be named here. These are press clutches in sheet metal fabrication, air cylinders for process machinery, hand tools in appliance assembly, spray guns in appliance finishing, blow offs to purge liquids and solids from metal parts, air ejection of press products, air agitation in plating, pressure lead testing in refrigerator assembly, servopilots for hydraulic machine control, and instrument pilots to control pressure, temperature, and flow.

Iron and Steel

One of the largest process uses for air is in the manufacture of iron and steel. It takes about 100,000 ft3 of compressed air to make one ton of steel. Iron has been used for several thousand years in weapons, tools, and implements; early production depended on the use of hand-operated bellows. It was not until the advent of steam engines to drive large blowers that sufficient air could be provided for large-scale production.

The real evolution in steel making started with the invention of the Bessemer converter, which uses large quantities of compressed air to eliminate the foreign elements from the pig iron produced in the blast furnace. Air compressed to a pressure of 25 to 32 psig was forced through the molten metal of the converter for a period of 12 to 18 minutes to remove these impurities. Open-hearth furnaces are likewise very large users of compressed air.

Figure 1.44: Compressed air is an integral part of the steel production process.

Oxygen enrichment substantially raises the productive capacity of iron and steel manufacturing facilities. The oxygen, used in very large quantities for the process, is obtained by means of high-pressure compression and liquefaction of air.

Vacuum melting, which makes use of vacuum pumps, is a relatively new but very important method of producing the high-purity steel, alloys, and nonferrous metals required in certain special applications.

Compressed air is used in the iron and steel industry for many other purposes besides the basic process, particularly as motive power for functional equipment and for tools. Such applications include chipping and grinding billets, furnace notching and tapping, ladle dumping, operating hoists and lifts, agitating solutions, sandblasting, and caulking tanks. It also includes operating tamping machines, furnace door hoists, ore bin doors, steel coil lifting and traverse mechanisms, instrumentation and process controls, balance for lifting mill tables, billet turners and billet ganging tables, pinch rolls on processing lines, blast furnace bell operation, coke gates, lubrication systems, air clutches and brakes, mixing of materials, descaling, air clamps, blow downs, and more.

Lumbering and Woodworking

Wood is a material that serves a thousand purposes such as to build homes, panel walls, construct furniture, and make newsprint. Sawmills, woodworking shops, and lumber mills are dependent on compressed air in power service to do much of the heavy work. Unloading, splitting, cutting, sawing, and trimming logs are a few typical applications. Spark-free air hoists handle heavy loads easily and quickly without any hazard of fire in the presence of combustible materials. Compressed air conveys chips and sawdust from the mills and is used for cleaning rafters, timbers, and framework, as well as machines.

Air is required for the drying kilns of veneer plants. Pneumatic sanders, drills, and screwdrivers are used extensively in woodworking and finishing.

In process service, railroad ties, bridge timbers, poles, and other wood members that will be exposed to dampness are treated with creosote and other preservatives infused into the porous surface by means of compressed air.

Machinery Production

Pneumatic tools and auxiliary equipment have found countless applications in the production of machines of all types. It is customary to provide an air outlet at each work point in a machine shop so that the machinist or operator may make easy use of the many air tools usually available.

Pneumatic controls are frequently applied to machine production processes. Actuating mechanisms may be interlocked for safety, and hazards such as explosions and electrical shock are eliminated by the use of air. Devices such as pneumatic positioners, air circuitry, fluidics, and pneumatic logic controls have put compressed air even more into the manufacture of machines. Material feed as well as machining operations are subject to pneumatic control.

On regular production lines, air tools also accelerate manufacturing and assembly processes, and wide use is made of multiple or gang tools to improve personnel utilization. Gang drills and multiple nut runners and screwdrivers are examples. Dozens of profitable applications of air tools are discussed in Chapter 5. The simplicity and lightness of air tools, together with the fact that they do not burn out or overheat under constant heavy use, make them highly adaptable to the manufacture of machines.




Figure 1.45: Pneumatic impact wrench installing tires in final truck assembly operation.

Figure 1.46: An automotive nut runner being used in a Chinese Volvo plant.

Auxiliary equipment such as feeders, reciprocating motions, indexing devices, revolving tables, positioners, and many other devices actuated by pneumatic cylinders also find many ingenious applications. Air hoists greatly facilitate the handling of heavy machine parts.

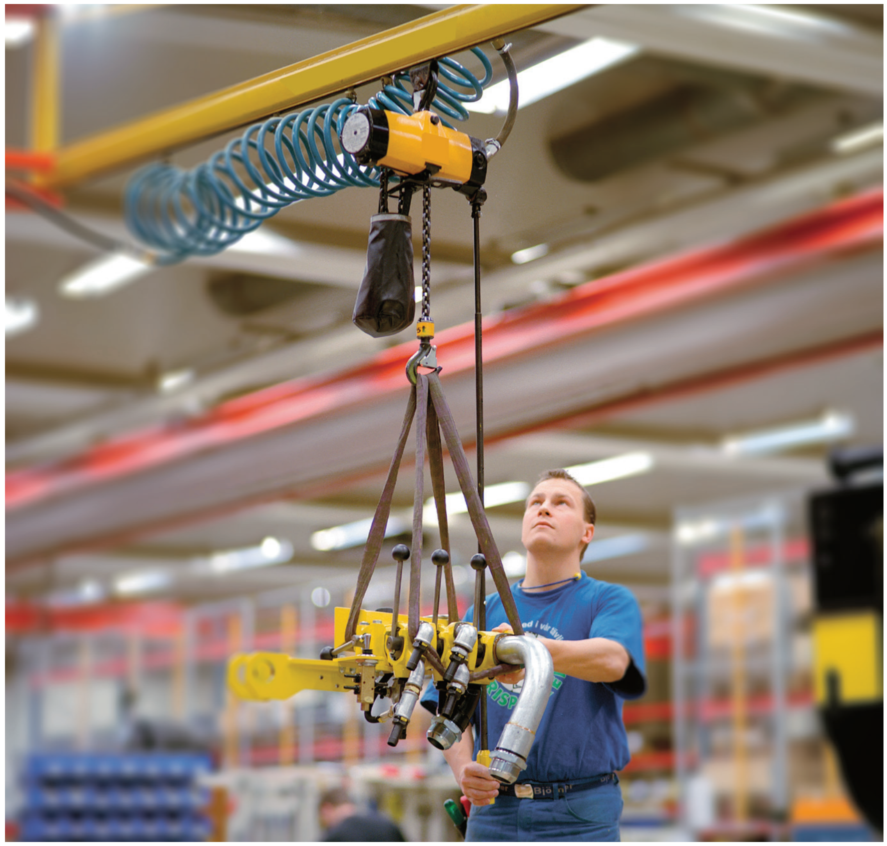

Figure 1.47: A hoist facilitating the handling of a heavy part.

For a discussion of materials handling by pneumatic means and the use of pneumatic tools in metalworking processes, reference the other paragraphs under the appropriate headings in this chapter.

In pressworking of metals, many different uses are found for compressed-air devices, including pneumatic clutches, air-actuated stock feeders, pneumatic holddowns, vacuum suction cups, and spray lubricators for metal strips preceding deep drawing operations. Presses may be powered or controlled by compressed air, although hydraulic actuation is usual.

The spraying of lubricants and coolants by means of compressed air is also common in many other areas of metalworking production. It provides an economical means to apply lubricant and avoids the accumulation of dirt on the machines and the spoilage of products. Points in obscure locations can be reliably lubricated by this method. Coolant application by means of air spraying is of particular importance whenever the conventional method of coolant flooding cannot be used. There are many cases, where liquid coolants are not needed or are for some reason not admissible, effective cooling and chip removal are attained by means of an air stream directed at the edge of the cutting tool.

Many machine parts and frames are fabricated by welding. Pneumatic scaling hammers are used for weld flux scaling.

Mining

Compressed-air tools in all types of mines have lightened the burden of the miner, made the job safer, and greatly increased output. Pneumatic tools like percussion and auger rock drills, coal drills, drifters, stopers, as well as air-actuated, powerfeeding appliances for most of these tools, are in general use as standard equipment for the miner. Unwatering by the air-lift system, unloading cars, running direct-acting pumps, loading ore, filling cracks and seams with cement, conveying, ventilating remote areas, pile driving for shaft work, operating coal punches, chain machines and radial-ax coal cutters, spreading stone dust to prevent dust explosions, removing methane from mine shafts for safety (this gas can then be sold to gas pipe lines), and operating pick and drill sharpeners are typical applications of compressed air in mining.

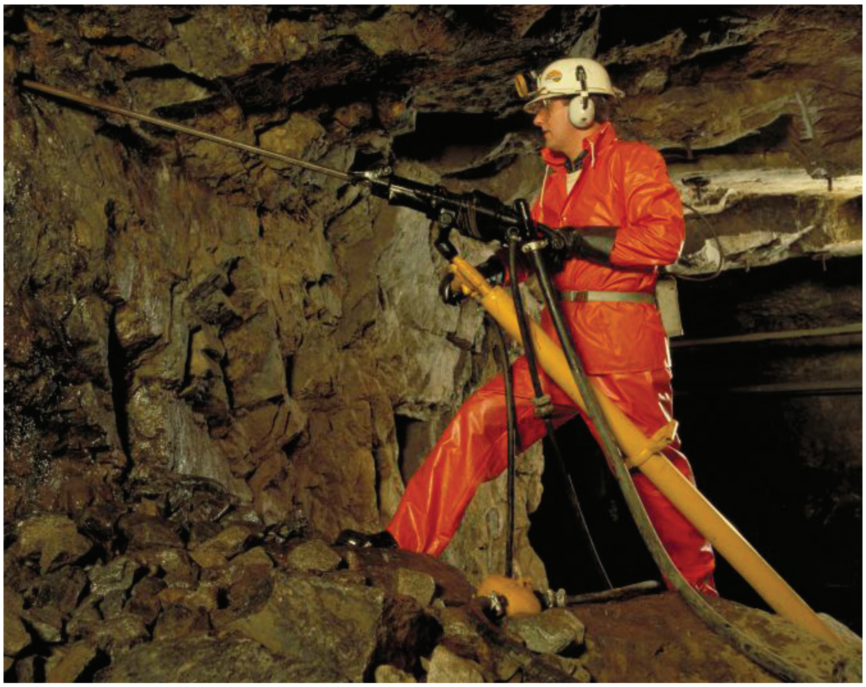

Figure 1.48: A pneumatic jackleg drill in underground mining operation.

Mobile Homes

There are many uses for air tools in the manufacture of mobile homes. In general, the applications of drills, riveters, nut runners, nibblers, screwdrivers, and the like, are similar to their uses in aircraft production.

Monuments and Cut Stone

It would be quite difficult to find any company in the stone-cutting field that does not rely on compressed air for its work. The task of cutting raised or carved lettering has been enormously reduced by the use of sandblasting to remove the part of the stone that is not protected by a stencil. Artisans carve figures and special letters in granite and marble with air chisels in one-third the time required by hand chisels. Air-operated surfacing machines are used to line up granite blocks, and air drills are used to prepare the blocks for plugs and feathers.

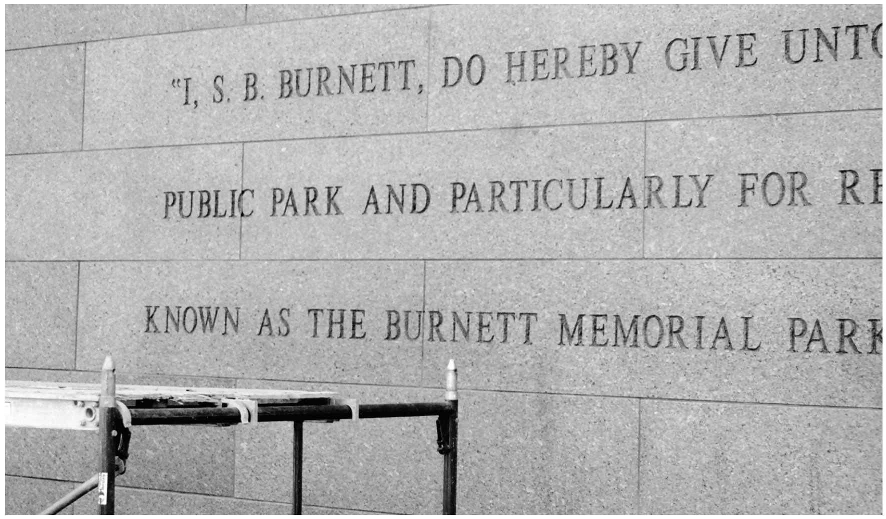

Figure 1.49: Pneumatically operated engraving tools are used for wording of monuments and headstones.

Nitrogen

The cost of producing an acceptable purity level of nitrogen has been greatly reduced by the introduction of membrane technology. Atmospheric air is composed primarily of nitrogen (78%) and oxygen (21%), the remaining 1% containing several constituents in various amounts. Compressed air at around 175 psig is passed to the outside of a tightly grouped pack of small-bore hollow fibers, made of a semi-permeable membrane. Oxygen, carbon dioxide and water vapor preferentially permeate the fiber wall, more readily than nitrogen, allowing relatively high purity nitrogen to be delivered. The reduced cost has opened up a wide variety of applications, including apple storage and food packaging, where the elimination of oxygen prevents oxidation and spoilage. Heat treatment also benefits from a nitrogen blanket to prevent oxidation in the product.

Nonferrous Metals

The metallurgical processing of nonferrous metals from the ore to the metal offers varied applications for compressed air. Typical of the industries in this field is the extraction of aluminum.

In the raw-material state, bauxite ore is refined to produce aluminum oxide. A major application of compressed air is the unloading of ore from oceangoing ships or from gondola cars. Another important use is the agitation of the material in the precipitators. The agitation is accomplished by bubbling air through .the material in a liquid suspension. Further applications include air conveyor systems, pneumatic instruments, and general maintenance equipment.

The aluminum oxide is next converted into aluminum metal by the electrolytic reduction process. In the reduction cell rooms, the anodes are lifted by means of pneumatic jacks. Air is used for metal-tapping siphons and for various service applications. In carbon plants where anodes and cathodes are produced for use in aluminum pots, air conveyors, pneumatic gates and controls, air hoists, and cranes are used, in addition to various service equipment including dust collectors, air-blast cleaners, tampers, vibrators, sanders, and wrenches.

Besides these specific applications, there is wide use of air power in supporting facilities such as shops, warehouses, administrative areas, boiler plants, and water treatment plants.

Office Buildings, Hotels, Stores, and Institutions

Compressed air has found many uses in building services. For example, elevator doors and other automatic doors are operated by compressed-air cylinders.

Pneumatic-tube systems for conveying cash and messages speed up office and commercial functions. Sprinkler systems in churches, hotels, stores, and many other buildings require compressed air to keep lines empty until fusible plugs melt to release the air and admit water.

Other typical uses of compressed air include operating sewage and drainage ejectors, removing ashes by electropneumatic systems, operating certain dental and medical services, cleaning electric motors by air jets, and operating hotel and institutional laundry machines.

Packing Houses

Stuffing sausages, testing sausage casings, pumping water, and operating loin presses and shoulder-cutting machines are but a few of the typical applications for compressed air in meat packing. Compressed air aids combustion in smokehouses, in burning hairs from hog snouts, and so on. Air hoists are used to lift calves from conveyor lines and for other lifting where speed and ease of operation are important.

Air entrained in meat during processing is removed by vacuum before the meat is canned. Inert gases, especially nitrogen and carbon dioxide, are also used in packing meat.

Paint Factories

Filling cans is one of the ways compressed air is used by paint manufacturers. Stamping cans and transferring liquids are other uses. Air hoists are especially chosen in the presence of flammable varnish to handle varnish filters because of the absence of electric sparks.

Paper Mills

Manufacturing of newsprint and molding, drying, and sterilizing pulp-paper containers are typical applications for compressed air in the manufacture of paper. The air cylinder, widely used throughout industry, is frequently used here to provide power for baling and packaging paper. Heavy bundles of paper are easily moved on machine tables of paper shears if they are provided with air-float equipment that creates a film of compressed air between load and table.

Petroleum

Many uses for compressors in the petroleum industry are for process compressors, which are covered in later chapters of the handbook. However, there are important uses for air compressors both in the oil fields and in petroleum product manufacturing.

An interesting use, referred to as *in situ* combustion, is made of compressed air in the secondary recovery of high-viscosity oil. Compressed air is pumped into the ground in oil-bearing sand or strata and the oil ignited. The resulting combustion is supported and regulated by the compressed air. Pressures up to 1000 psig are developed, and the heat generated reduces the viscosity of the oil so that it flows to the pumping location.

Figure 1.50: Compressed air is used in oil refining process, instrument controls and pneumatic actuators and mixers as well as maintenance and the continuous protective coating work in refineries.

Pharmaceuticals

Antibiotics, the miracle drugs that have almost eliminated some diseases, require large volumes of air for the fermentation process by which they are produced. Large oil-free compressors or centrifugal compressors are used in these critical processes.

Oil-free compressed air is also used as a transporting and drying vehicle in spray dryers. The liquid concentrate is sprayed in a uniformly atomized sheet into a stream of heated air where moisture is evaporated, leaving a solid powder that is removed in a collector.

Compressed air is used in packaging. One drug manufacturer uses air to pneumatically convey aspirin powder into tissue envelopes. Many drug manufacturers use pneumatics to assist in filling and sealing plastic containers of many kinds.

Plastics

The starting materials from which plastics are manufactured are usually gases such as acetylene, ethylene, propylene, methane, and natural gas. Large compressors are often required for air, as well as for the hydrocarbon gases. Only air applications will be discussed here.

Molding presses are sometimes operated by compressed air cylinders or air hydraulic cylinders. Parts are ejected and swept from the molds pneumatically, and many finishing operations, such as drilling, buffing, grinding, and painting, are done with compressed air equipment (Figure 1.51 & 1.52).

Figure 1.51: Using heat and pneumatic pressure, plastics can be molded items useful in industrial, medical and consumer applications.

Plastic molding and forming have become a very large and important industry. Air or vacuum exerting a uniform, controllable force against a softened plastic sheet gently molds it to the contours desired. Usually, this is not a simple process. Various techniques have evolved to achieve uniform thickness in the parts and to perform other functions. Sometimes air acts as the mold itself, as in the manufacture of helicopter bubbles and other similar optical plastic parts where contact with a solid mold could reduce or destroy the transparency of the plastic.

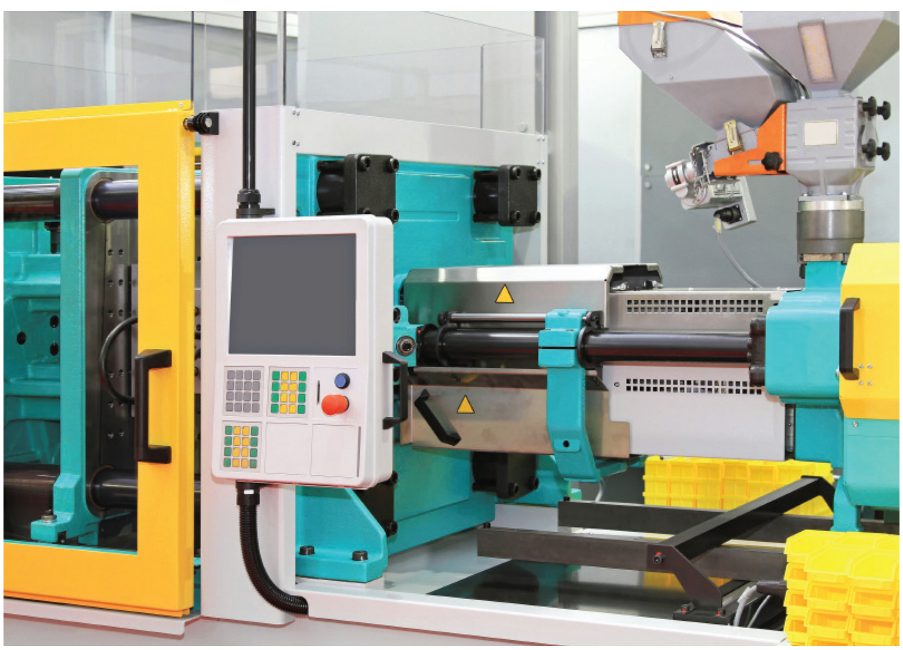

Figure 1.52: Pneumatically controlled plastic injection molding machine.

Pneumatic clamps hold sheets in place, and flashing is removed from molds by air tools. The plastic extrusion process uses compressed air to support thin-wall tubing, to size plastic tubing after it leaves the die, and to cool strips of flat plastic materials as they come out of the die.

Potteries and China Works

Sandblasting smooths away blemishes from bisque chinaware before glazing. Liquid glaze material is transferred from the grinding mill to the storage tank by compressed air, and air motors drive machines for forming clay bats on the molds.

Pottery dust and other dirt is removed from electric motors and machinery by air jets. Air-operated rattlers are used to recover material from containers used for firing. One maker of flower pots uses air to operate molds and for drying. Air hoists facilitate the handling of materials.

Power and Light Plants

Gas-turbine-driven generators are sometimes available to meet peak demands and emergencies. Such units can deliver full power in a matter of minutes from a cold start. To start a gas turbine, compressed air is usually used to bring the turbine up to a speed at which its own power can take over when fuel is injected into the combustion chamber and ignited. A relatively small compressor is usually used for charging the air receivers that supply the starting air.

Automatic controls, predominantly pneumatic, measure and regulate the fuel fed to the boilers and the necessary draft for complete combustion. They regulate the flow of acid and caustic in the right ratio to the makeup water in a closed system. In many stations, the use of compressed air for soot blowing is also very important to assure good heat transfer from flame to water or steam.

Air tools and air hoists are extensively used for erecting and caulking boilers and for maintenance. Condensers, for example, may be opened up by pneumatic impact wrenches and tubes cleaned by air-operated plugs.

In nuclear generating stations, the uses of air are much the same as those in fuel-burning stations, except those related directly to the fuel. However, there is one special need for air. The reactor is enclosed in a shield, and the shield, in turn, is enclosed in an airtight, steel-plate sphere. To be certain that there is no leakage to the atmosphere from within this sphere, air pressure of about 2 psig is maintained inside. Any drop in pressure is then sensed so that corrective measures may be taken immediately.

The use of portable oil-free compressors are employed in the leak-testing in a nuclear power plant both in the initial construction and during the overhaul and maintenance process. It must be remembered, however, that safety considerations dictate that pressure vessels when tested for strength must be tested hydraulically.

Figure 1.53: Numerous portable, dry screw, oil-free air compressors arranged in tandem to provide air for a leak tightness and structural integrity test of containment structure.

Utilities have many maintenance jobs for which air tools are especially useful in keeping trucks and other equipment in good operating condition. Compressed air and air tools are also needed along distribution lines. Utility companies also use portable compressors for emergency work as well as new construction.

Pneumatic Tools

There are many applications using a wide variety of pneumatic tools. These are covered in the air tool chapter.

Printing and Newspaper Plants

Compressed air is used for cleaning machinery, hoisting stereotype plates, pumping water, and operating steam tables and monotype machines. It is used to prevent wet labels from smudging and for powder dusting of freshly printed sheets. In the rotogravure pressroom, it is used in the tension system for brakes, imprinters, and folders, as well as for automatic strapping of the finished printed material. Pneumatic clamps facilitate wrapping and tying. Suction cups are used in feeding presses, and a gentle air blast riffles paper to assist in separating sheets. Pneumatic extrusion pumps supply printing ink in some types of presses (Figure 1.54).

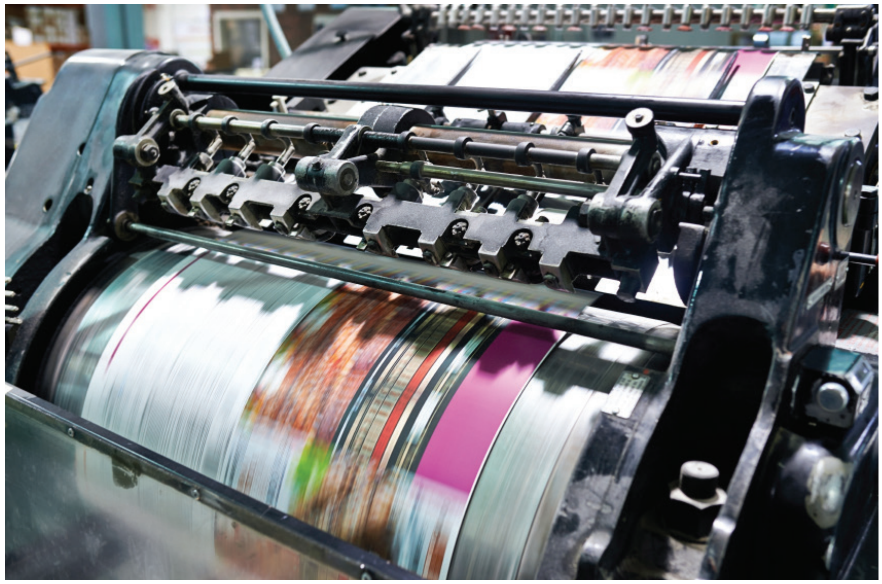

Figure 1.54: Air cylinders operate the ram-mounted extrusion pumps in a lithograph plant supplying printing ink to the ink fountains of four-color offset presses, Compressed air provides power to air actuators and conveying controls.

Quarries

Compressed air is the principal form of power for most quarrying operations. In power service, stone channelers, rock drills, and plug drills are all air operated. Air hoists move heavy stone slabs. In the quarry blacksmith shop, hammers, sharpening tools, and other cutters are operated by compressed air.

Railroads

Diesel and electric railroads have found that hundreds of operations can be performed best with compressed-air-operated tools and equipment. Along the tracks and in carshops, maintenance facilities, and railroad yards, this vital industry is doing essential work with compressed air.

A few of the many railroad applications for pneumatic tools include lubrication of locomotives and general maintenance operations on rolling stock such as drilling, wheel alignment, reaming, and surface grinding. There are also many applications in the maintenance of buildings and other fixed facilities. An extensive air-distribution system is a regular feature of the railroad yard.

A mechanized track crew uses air-operated tools for driving spikes, digging, grinding rails, tightening bolts, tamping, pulling spikes, and other jobs, which can thus be done much faster than by manual methods. Large pneumatic tamping machines utilize a number of tampers in simultaneous operation for tamping ballast along the track.




In connection with railways, perhaps the most universally known and appreciated application of compressed air is that of the air brake. The original basic system has been retained with modern refinements and additions and is still used on most railways throughout the world. The air brake is typical of many compressed-air applications in that air is used to perform several functions. Compressed air actuates the brakes so that all are applied simultaneously and controls operation so that braking can be regulated sensitively over a wide range of braking force. The remote control by means of air becomes automatic if the brake hose running from car to car along the train should rupture at any point, an outstanding safety feature. Air brakes are relatively simple, so maintenance is easy and inexpensive.

Favorable experiences with air brakes on railways contributed to their use in trucks and buses. Most heavy vehicles of this type are equipped with air brakes.

Figure 1.55: Railway maintenance vehicle utilizes compressed air to drive rail spikes as well as impact tools to remove rusted and stubborn bolts and fasteners.

Refrigeration Plants and Ice Plants

Pneumatic applications here include hoisting ice tanks and loading cars, pumping and aerating water by compressed air, descaling condenser coils, and cleaning boiler flues with compressed air. Standard types of compressors with special seals are essential to mechanical refrigeration systems.

Rubber

Compressors are essential in the process by which synthetic rubber is produced. Air blasts clean out the rubber molds. Small air drills clean out the vent hole in the wall of the mold to release gases from the heated rubber during vulcanizing. Air pistons press unvulcanized casings into the general contour of tires. They also are used to ram crude rubber into mixer rolls.

Temperatures in rubber mold presses and vulcanizers are subject to pneumatic control.

Sewage Plants

The activated sludge system of sewage treatment depends on compressed air to convey materials and to agitate sewage gently in preparation tanks so that particles of grease and oil will be coagulated. In deep aeration tanks, compressed air is used for violent agitation to supply oxygen to bacteria. Typical applications for pneumatic tools are for caulking pipe lines and for driving sheet pile. Pavement breakers and rock drills are used in maintenance.

Ships

Shipboard installations include compressors for air separation plants producing liquid oxygen and nitrogen for use on board. Other compressors supply air for ship maintenance, for vacuum-blast cleaning of salt from the skin of aircraft carriers, and cleaning the holds of cargo ships. (Figure 1.56).

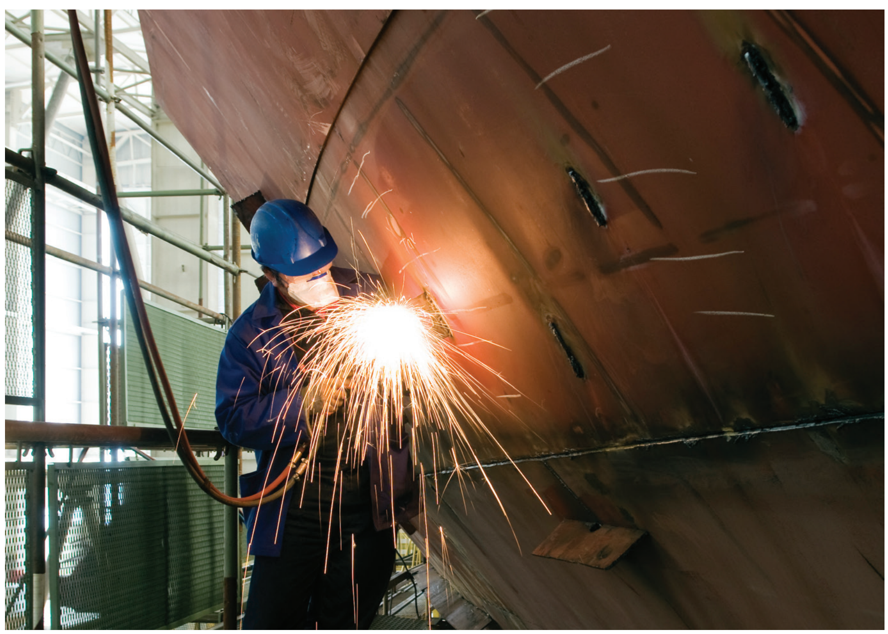

Figure 1.56: Air tools play an integral role in ship repair and maintenance.

Pneumatic controls are now used extensively on ships. As a typical example, one such system controls the diesel propulsion on a harbor tug with two propellers and two propulsion engines. For greater operating flexibility, the tug has a separate and independent set of these controls for each engine. With these controls, the tug can be maneuvered and steered from any of three positions, from either side of the pilot house, or from the afterdeck. This arrangement lets the tug operator handle the vessel with increased speed and facility from the point of best visibility.

There are, of course, many other applications for compressed air as the actuating or control medium on various naval vessels. Examples of the latter group of uses is the operation of torpedoes by compressed air motors and torpedo launching through pneumatic tubes.

Shipyards

Compressed air has long been essential in building and repairing ships. Pneumatic tools have eliminated many slow, tedious steps in ship construction.

Air hammers are used in driving nails and spikes in keel laying, for grooving plates prior to welding, for chipping weld scale, for riveting, and for caulking. Air grinders have innumerable applications in smoothing surfaces. Spraying speeds up the painting phase of shipbuilding to a rate 20 times faster than that achieved by the hand-brushing method. Air-operated reamers and drills are important for shipbuilders.

Since much of their work is done outdoors, shipbuilders find compressed air especially convenient and useful in blowing off snow, rain, or dirt from their work areas. Testing welded seams is made easier by blowing away water accumulated along the seams.

Air motors, hoists, and lifts are used in a number of shipbuilding operations. Compressed air is used to start diesel engines, operating dry docks, salvaging sunken wrecks, and various underwater operations.

Ski Areas

Uncertainties of the weather made operating a ski area rather a risky business until the advent of snow-making equipment. Portable compressors in capacities of 600-1900 cfm are well adapted to the high-volume air requirements for making snow. Stationary, electric-motor-driven compressors are also often used in snow-making systems. Some systems have heads consisting of a fan, nose cone, and nucleator mounted on a sled or carriage along with its own compressor (Figure 1.57). Such equipment enables operators to lengthen the skiing season and to compensate for periods with too little snow.

Figure 1.57: An integrated snow-making system combines compressed air and water to enable ski areas to maintain conditions regardless of snow fall amounts.

Figure 1.58: Large ski resorts have substantial centrifugal air compressor installations for snow-making when atmospheric conditions require it.

Soap and Detergents

The manufacture of soap is a progressive industry whose research activities have substantially eased some of the more laborious household chores. Modern production methods include the extensive application of compressed air for operating instruments, blowing out stock lines, agitating liquids, operating pneumatic cylinders and tools, aerating stock, general cleanup, ejecting cans, pressurizing enclosures and fluidizing granular solids.

Steel Mills

Steel mills typically have large compressed air stations providing air for a variety of high volume compressed air uses. The main compressed air system is vital for the steel plant's production process since it services and serves the Basic Oxygen Plant (BOP), the blast furnaces and as well as the powerhouse. The principal applications of compressed air are pneumatic actuators and pistons that actuate large cylinders. The compressors also provide instrument air for the master control systems.

Figure 1.59: Compressed air enables steel production in volume.

Tanneries

Handling tannic acid and pumping water are typical uses of compressed air in the tannery industry. Air hoists and lifts are production aids.

Textiles

Compressed air is especially suited to cleaning looms, spindles, and other machinery in cotton and woolen mills. Cotton-finishing works use air for cleaning such machinery as presses and slashers and for operating baling presses. Humidifying systems employ compressed air in their operation. Other textile-plant uses for compressed air are agitating, elevating, and transferring of dies or other solutions, pumping water, moistening goods, automatic control of steam and water lines, starting engines, and operating pressure accumulators. The tufting of rugs has improved from 45 percent to 95 percent by using compressed air to hold the thread in a hollow needle.

Figure 1.60: Compressed air provides the guiding direction to thread entanglement in large scale air-jet looms.

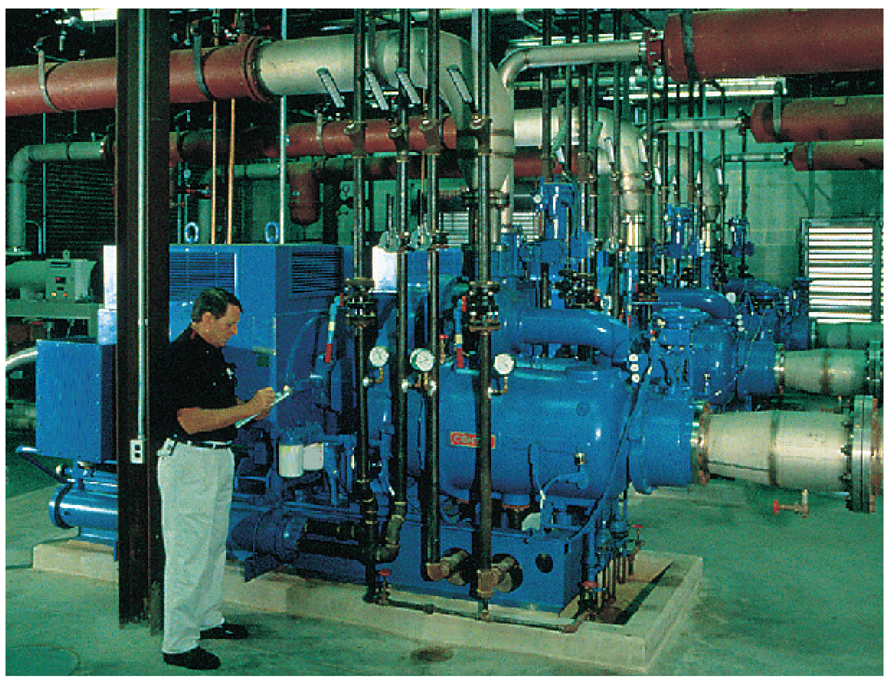

Figure 1.61: Centrifugal air compressors providing plant air pressure in a textile manufacturing facility.




Theaters and Amusement Parks

Permanently installed air jets and push-button valves permit the projectionist to blow dirt from TV movie projector gates without stopping the film. Thrilling rides at amusement parks make use of air brakes based on the same air-release principle used in brakes on railway trains. Compressed air has made faster, more thrilling ride experiences possible and safer. Compressed air is used in the actuation and releases of sophisticated safety harness where riders experience tremendous g-forces in unique and challenging positions. (Figures 1.62 and 1.63).

Figures 1.62 & 1.63: Many amusement park ride designers utilize compressed air to power their latest designs enabling high speed and gravity defying thrills with numerous built in safety features, many of which are pneumatic.

Underwater Exploration

Special air compressors with breathing-air treatment equipment has enabled recreational and commercial scuba and deep sea diving. Divers are able to explore new sea depths as a result of having air tanks for extended dive periods.

Figure 1.64: Divers need good, clean air when they are exploring the wonders of nature under the sea.

Compressed air is used in offshore seismographic exploration for oil and other minerals. An air gun automatically emits several pulses per second of air at about 2000 psig. These pulses, reflected from the strata below, supply useful information to the geologist conducting the exploration. This method as formerly conducted with rapid explosions of dynamite was dangerous and not acceptable to fish and game commissions. The compressed-air method is also reported to be more effective.

Waterworks

Compressed air jets have proved especially effective in several important cleaning and maintenance operations in waterworks. Washwater tanks and beam supports are quickly cleaned with air jets and corrosion is thus checked. Rust is cleaned from chlorinator machines and ammonia feeders with compressed air.

Water with a heavy iron content is treated by aerating it with compressed air to remove carbon dioxide and to cause the iron to separate when no other treatment is needed. Compressed air is also used for pumping water, for cleaning boiler flues, and for operating tools for caulking, sheet pile driving, and trenching.

Well Drilling

An increasingly vital role is being played by compressed air and gas in the recovery of oil and water. In oil-well drilling, compressed air is used increasingly in dry formations to replace mud for removal of cuttings. Compressed gas is used to increase the volume of oil brought to the surface by gas-lift techniques. Compressed-air oil-field drilling rigs are shown in Figure 1.65. The offshore drilling platform in Figure 1.66 uses a similar skid-mounted compressor.

Figure 1.65 Oil rig drilling for natural gas.

Figure 1.66: Off shore oil rig.

In water drilling, a common method of sand and gravel well development is to release surges of compressed air intermittently from the storage tank while pumping water by the air-lift method. This creates a uniform condition of gravel surrounding the screen. Since air lifts for pumping water have no moving parts in the well, pump maintenance cost is minimized.

Large volumes of air are required for removing chips and cooling the bits used in drilling large-diameter holes such as are used for atomic tests. These have diameters up to 90 in. and depths as great at 6000 ft. Atomic bombs exploded at the bottom of such wells produce vibrations that are sensed at distant points.

Wind Tunnels

Wind tunnels, especially those for research and development in supersonic aircraft, require very large volumes of air in pressures ranging up to 2500 psig. Other laboratory and research applications also often depend heavily on compressed air and gas.