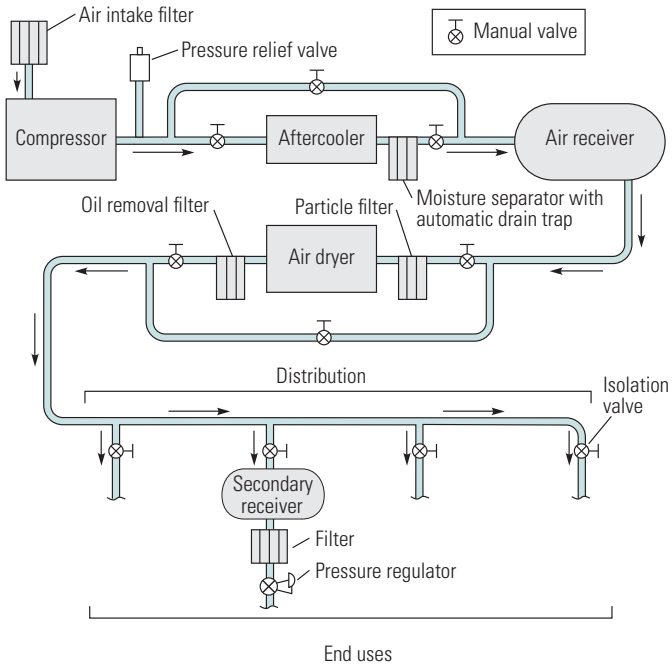
Optimizing Compressed Air Systems

Compressed air (CA) is a critical energy source for many industrial applications, providing mechanical motion, cooling, pressurization, and other functions for such equipment as air-powered hand tools, actuators, and sophisticated pneumatic robotics. CA systems account for 10 percent of total industrial electricity consumption and are found in 70 percent of all manufacturing facilities in the United States, according to the U.S. Department of Energy (DOE).

Although it is often viewed as an essentially free resource, CA is anything but free. In fact, in many industrial plants, air compressors consume more energy than any other single end use. And the energy consumption of CA doesn't stop at the compressor. Once air is compressed to the desired pressure, it often has to be dried and cooled before it is sent through the distribution system to the end use, requiring even more energy (**Figure 1**).

Figure 1: Compressed air system diagram

This shows a typical compressed air system with compression, cooling, storage, and distribution equipment.



Source: Scales Air Compressor Corp.

Quick Fixes

CA can be quite energy intensive and costly. Fortunately, in most industrial facilities there are many opportunities to improve CA system efficiency with rapid paybacks. A DOE study found that about 15 percent of CA system usage can be saved with simple paybacks of less than 2 years in small- to medium-sized industrial facilities, and that, in larger facilities, these savings could range from 30 to 60 percent of current system usage. Although a comprehensive optimization of your CA system usually requires the services of a highly trained professional, there are a number of cost-effective steps you can take today, without the aid of an expert, to make your CA system more efficient.

Reduce System Pressure

Operating your CA system above the minimum necessary pressure is wasteful for three reasons. First, it takes more compressor energy to pump air to higher pressure. One general rule is that for systems operating at about 100 pounds per square inch (psi), every increase of 2 psi raises input power to the compressor by 1 percent at full flow. Second, for CA end uses without regulating devices, the volume of air consumed is highly dependent upon the air pressure—the higher the pressure, the more air consumed—so CA requirements and energy costs can often be reduced significantly without affecting performance simply by reducing system pressure to the minimum necessary. Third, leaks can be considered as unregulated end uses, and the higher the system pressure, the more air is driven through the leaks. Reducing system pressure to the minimum

Measure Your Progress

Note that some of the suggestions provided here, such as eliminating leaks, can result in higher air pressure at the end use, so it's important to measure and record air pressure at each end use both before and after you make any improvements to the system—you may be able to save even more energy by further reducing system pressure.

that is absolutely necessary is frequently the most cost-effective and quickest payback opportunity for energy savings in a CA system, and it should be your first step in system optimization. Reducing pressure without affecting production processes requires that you be aware of the minimum pressure at which each CA end use can operate. If you find that none of the CA end uses in your plant requires the pressure being delivered, you can save energy at almost no cost by dialing back compressor discharge pressure in small increments to the minimum that maintains satisfactory equipment performance. Often, though, it's not just a matter of turning down the discharge pressure setpoint. Sometimes elevated pressures are maintained to compensate for unacceptable pressure drops that occur when large, intermittent CA consumers operate on the same distribution system. In such cases, adding secondary storage capacity at or near the point of use is an inexpensive solution to smooth out system-wide pressure fluctuations.

Another common reason CA systems operate at pressure that is unnecessarily high for most of the system is that just one or more end uses require this pressure. In such cases, it can often be profitable to install either a booster compressor with local storage or a separate compressor and air-distribution system dedicated to specific high-pressure end uses. Finally, an excessive drop in pressure through the components of the air treatment and distribution system can necessitate higher compressor discharge pressure to ensure that the pressure will be adequate by the time it gets to the end use. Causes of pressure drop can include dryers and filters on the supply side and undersized distribution piping, undersized equipment hoses, disconnect couplings, filters, regulators, or lubricators on the demand side. If you find pressure at the end use significantly below 90 percent of compressor discharge pressure, work upstream one component at a time to identify where the major pressure drops are occurring.

Find and Eliminate Leaks

It's not unusual for leaks to consume 20 to 30 percent of compressor output, which can add up to thousands of dollars per year in unnecessary electricity costs. Moreover, leaks reduce system pressure, which can cause air tools to operate inefficiently, which in turn could affect production. Finally, all of the air that leaks out must be replaced by the compressor, causing compressors to run longer and reducing their lifetimes.

After estimating the amount of leakage occurring, the next step is to find and eliminate the leaks. Your goal should be to bring the leakage rate down well below 10 percent. Follow these steps:

- The easiest and fastest way to find leaks is with a tool called an ultrasonic leak detector (available from a number of manufacturers), but many leaks are audible and easily located, especially during nonproduction periods.
- Once you've found a leak, eliminating it is often a matter of simply tightening the connection. Sometimes it will be necessary to open a joint, clean the threads, and apply the appropriate thread sealant. In some cases you may find that you need to remove and replace faulty equipment.
- Ensure that the air supply to all equipment is shut off when that equipment is not in use. Solenoid valves are available to automate that process.
- Then reevaluate the leakage rate to determine the effect you've had on the system and to estimate the resulting savings. You should also remeasure the system pressure

during normal plant operation—you may find that you are now able to further reduce the compressor discharge setpoint and gain additional savings.

Identify and Eliminate Inappropriate Uses of Compressed Air

Compressed air is used in a wide variety of applications that could be performed more efficiently (and in many cases more effectively) in other ways. **Table 1** lists several common misapplications of compressed air, along with better alternatives. You'll find a more comprehensive discussion of this issue in the DOE's *Sourcebook* (see Resources section below).

Although up-front capital investment will be necessary to eliminate some inappropriate applications, the efficiency of performing them with compressed air is so low that the required investment will usually be repaid quickly. Eliminating inappropriate uses will reduce CA consumption and may allow you to shut down one or more compressors entirely. This can save capital in the future as well—should expanded production require additional compressor capacity, you'll have it ready and waiting.

Table 1: Common inappropriate uses for compressed air

This table lists some of the common misapplications of compressed air and provides more efficient alternatives.

Inappropriate application	Description	Alternative
Open blowing	Used for cooling, drying, cleanup, and other purposes.	Low-pressure blowers or fans
Sparging	Aerating, agitating, oxygenating, or percolating liquid with compressed air.	
Aspirating	Using compressed air to induce the flow of another gas.	
Atomizing	Using compressed air to deliver a liquid to a process as an aerosol.	
Dilute phase transport	Using compressed air to transport solids, such as powdered material, in a diluted format.	
Personnel cooling	Using compressed air to cool personnel.	Fans
Vacuum generation	Applications that use compressed air with a venturi, eductor, or ejector to create a vacuum. Examples are shop vacuums, drum pumps, palletizers, depalletizers, box makers, packaging equipment, and automatic die-cutting equipment.	Vacuum pumps
Diaphragm pumps	Often installed without a shutoff valve or regulator.	Mechanical pumps
Cabinet cooling	Open blowing and air bars (tubes with holes drilled into them), sometimes used for cabinet cooling.	Fans or dedicated cabinet coolers

Source: Compressed Air Challenge

Improve System Control

Optimizing CA system control normally requires careful analysis by a trained professional. However, there is one symptom of a poorly controlled CA system that even the untrained eye can identify. All air compressors operate most efficiently when running at full load. Unfortunately, it is a rare application indeed for which CA demand precisely matches the full load output of its air compressor. Much more frequently, some type of control system operates one or more compressors to match CA supply with demand. There are numerous types of control technologies and strategies, some of which are specific to the type of compressor in use. Regardless of compressor type, though, system efficiency will be maximized by operating as many compressors as necessary at full load and operating only one "trim" compressor with good part-load efficiency to follow the load. If you find that you've got two or more compressors feeding into the same CA system that are simultaneously running under partial load, it's probably time to revamp your control strategy.

Resources for Further Information

As noted above, comprehensive optimization of CA systems usually requires the services of a CA expert. Because most CA systems have opportunities for cost-effective savings, it is a good idea to hire a trained professional to perform an audit of your CA system. But whether you're looking to hire an expert or planning to work on your CA system yourself, you'll find the following resources quite helpful.

U.S. Department of Energy Industrial Technologies Program web site: www1.eere.energy.gov/industry/bestpractices/compressed_air.html. This web site provides a variety of resources, including tip sheets, guidelines for selecting a CA service provider, free software for assessing your existing CA system and estimating potential savings from efficiency measures, and *Improving Compressed Air System Performance: A Sourcebook for Industry,* which contains greater detail on many of the concepts presented here.

Compressed Air Challenge (CAC) web site: www.compressedairchallenge.org. The CAC is a voluntary collaboration of industrial users; manufacturers, distributors, and their associations; consultants; state research and development agencies; energy-efficiency organizations; and utilities. On its web site, you can learn about upcoming CAC training opportunities and download documents that cover a wide variety of CA concepts and maintenance practices as well as case studies that demonstrate these concepts.