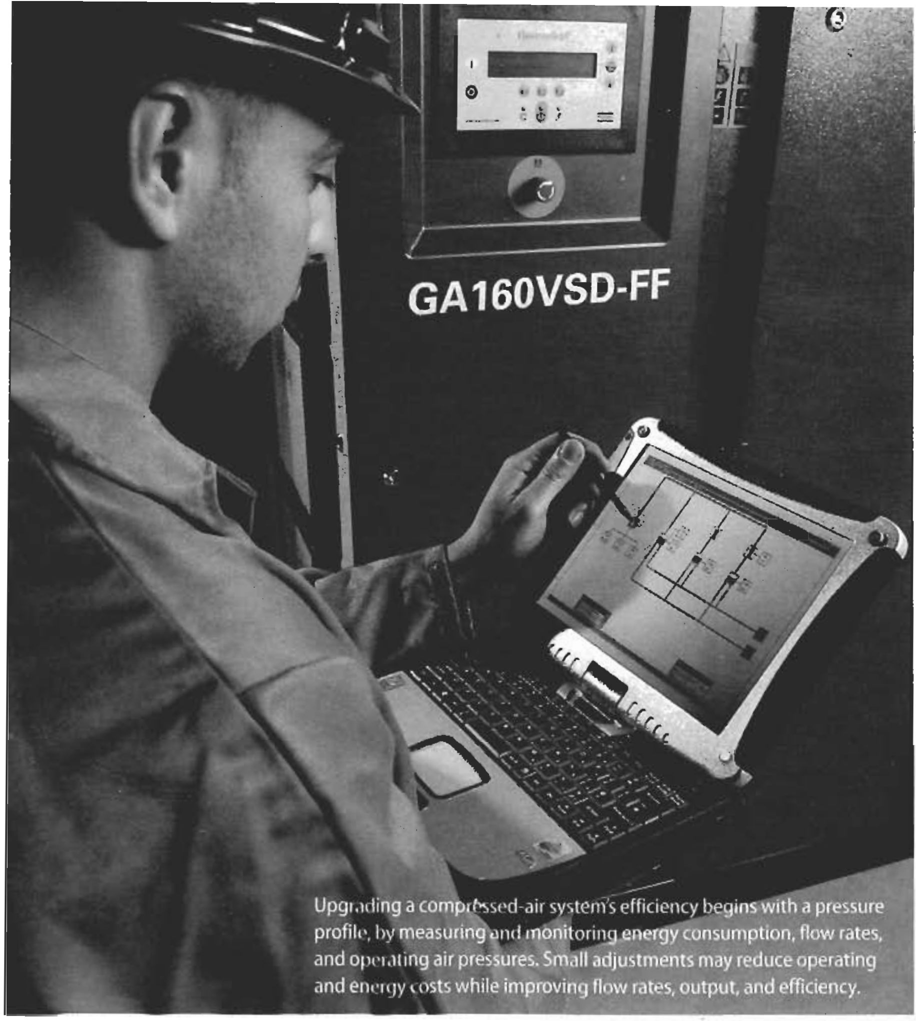

Upgrading a compressed-air system's efficiency begins with a pressure profile, by measuring and monitoring energy consumption, flow rates, and operating air pressures. Small adjustments may reduce operating and energy costs while improving flow rates, output, and efficiency.

The quest for compressed-air efficiency

It's the same old story: The energy to run an air compressor costs much more than the compressor itself. So why waste any of its output?

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It's no longer news that the growing emphasis on sustainability is leading the charge for higher efficiency. When discussing energy use in manufacturing environments, the Big Three – water, electricity, and natural gas – naturally monopolize the conversation.

However, overlooking compressed air in the pursuit of energy efficiency would be a major mistake. Estimates are that poorly designed and maintained compressed-air systems in the United States account for up to $3.2 billion in wasted energy costs annually.

A thorough assessment of a facility's compressed air system invariably reveals many opportunities for reducing energy consumption and operating costs without large capital expenditures. It's a step engineers and users should take because the most expensive component in the total cost of compressed air is energy. In fact, over the life of a typical compressor, energy generally costs several times more than the purchase price of the compressor.

For example, a 200-hp air compressor running 24 hours a day at $0.08/kWh will cost about $110,062 to operate every year, or more than $550,000 over a five-year span. Those costs are likely at least three times the compressor's purchase price per annum. Here's a look at some steps to significantly reduce those operating costs.

Design and operation

In the process of compressing air, most of the electrical energy the compressor consumes converts to waste heat. Even the most efficient compressed-air systems only convert 10 to 15% of the operating energy into energy stored as compressed air. When leaks, flow restrictions, and other inefficiencies are added to the equation, energy waste quickly adds up. Here are some key ways to boost system efficiency.

Pinpoint leaks. One 0.25-in. air leak at 100 psi, with electricity priced at $0.08/kWh, costs approximately $12,800 per year. Considering that compressed air systems older than five years on average leak about 25% of all the air that is pushed through them, losses can be astronomical.

Regularly evaluating a system for air leaks – and fixing them – is the first step toward reducing system energy requirements. Many consultants and manufacturers of compressors and pneumatic systems offer leak-detection services and energy audits, as well as add-on monitoring equipment. These check-ups and diagnostic tools often pay for themselves in short order.

Right-sizing. If an air compressor runs at 65% capacity or less, a smaller, more-efficient unit could pay for itself through lower utility payments in 18 to 24 months. And those savings continue to compound in subsequent years.

World's first carbon-zero compressor

Some of today's newest air compressors are built specifically with energy efficiency in mind. Case in point: Atlas Copco's Carbon Zero ZR Series of water-cooled, oil-free air compressors.

When the Carbon Zero compresses air, much of the input electrical energy is converted to heat. The challenge is to harvest this heat from all the compression-system components – low and high-pressure compression elements, oil cooler, intercooler, and aftercooler. A built-in energy recovery system circulates cool water through all these components and, as a result of the heat transfer, yields hot water at up to 90°C.

The units typically recover more than 90% of the electrical power needed for compression as hot water. And, according to Atlas Copco officials, under specific design conditions Carbon Zero compressors can recover 100% of the electrical input power.

Thus, energy costs to operate the compressor become revenue neutral through the offset or elimination of other energy costs.

Earlier this year, the independent German technical inspection association TUV (Technischer Überwachungs-Verein) supervised testing of Atlas Copco's ZR 55-750 water-cooled, oil-free screw compressors equipped with energy recovery systems. This involved real-time measurement of electrical power input and output power as compressed air and hot water. Results showed that under the specific design conditions of 40°C and 70% relative humidity, nearly 100% of the input electrical power could be recovered as heat.

Turn it off. The simplest way to save energy in a compressed-air system is a no-brainer: Turn it off. There are 168 hours in a week, yet most compressed-air systems only average 60 to 100 hours per week near full capacity. Turning compressors off evenings and weekends, or in relation to shift patterns, could reduce energy bills as much as 20%.

Variable-speed drives. For facilities operating 24/7, upgrading to variable-speed -drive (VSD) air compressors is the next best option. VSD compressors continually vary compressed-air production to meet changes in demand.

Variable-speed control uses an inverter to slow the compressor and reduce the amount of air compressed at partial load. Any loss in efficiency associated with reduced rotor-tip speed is more than compensated for by the efficiency gains from continuously generating the required volume without blowing excess air to atmosphere or running unloaded without producing any compressed air.

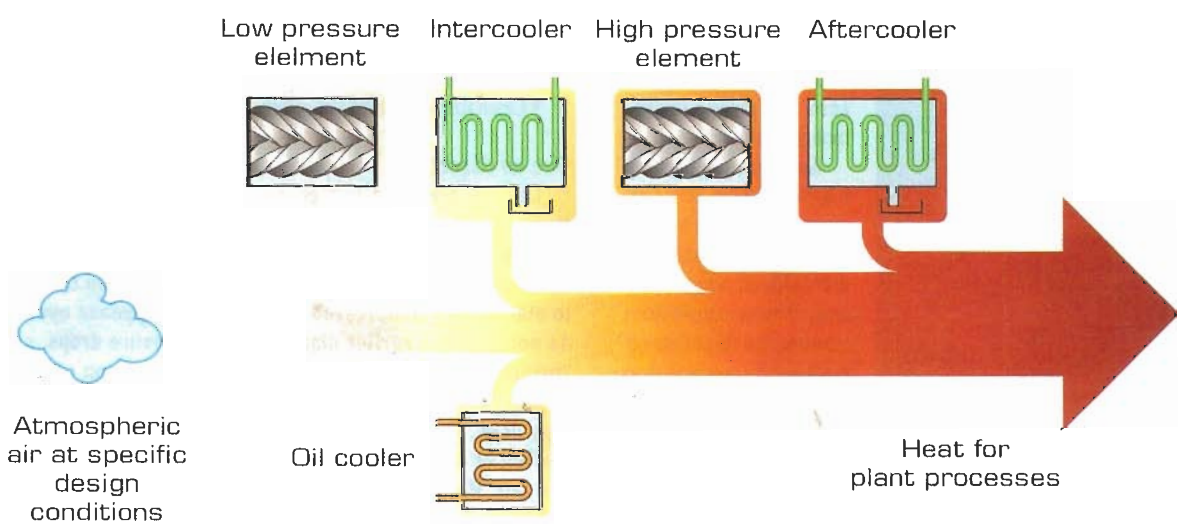
For best results, manufacturers do not simply add a VSD to an off-the-shelf compressor. Atlas Copco, for example, has designed compressors with a relatively flat efficiency curve. Rather than offering peak efficiency over a narrow operating speed, they are designed to reduce volumetric and mechanical losses across a range of speeds, and the inverter increases the power factor at low load. These units offer good efficiency over a wide speed range and are ideal for VSD control. Depending on the application, a VSD requires approximately 35% less power compared to a similarly sized, fixed-drive compressor. Revisiting the above example with a 200-hp compressor, switching to a VSD compressor would save the facility $38,521 annually or $192,608 over five years.

Regardless of facility up-time, analysis shows that more than 90% of all compressor applications are likely candidates for VSDs, and the return on investment is often within two years.

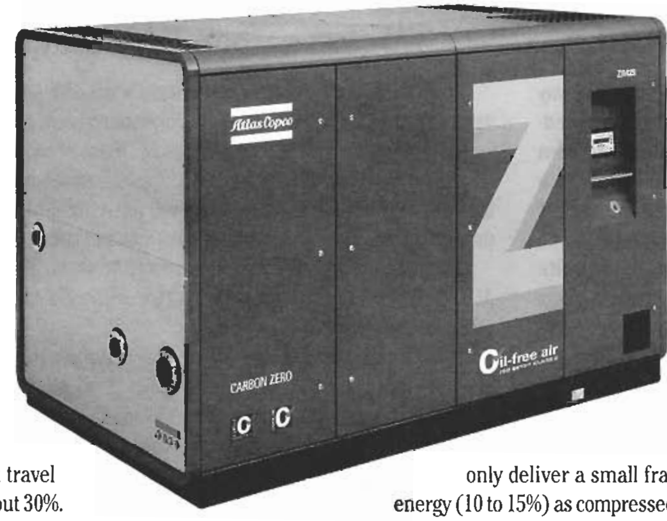
Piping and infrastructure

Piping systems should optimize the transfer of compressed air from the compressor to the point of use at the required flow and pressure. Developing a pressure profile that shows restrictions throughout a system lets engineers analyze the piping and infrastructure. The first step is to measure and monitor energy consumption, flow rates, operating pressure, and pressure drops across individual components. This data let compressed-air system professionals analyze operating pressures

RECOVERING HEAT



Air compression generates heat. The key to high efficiency is recovering heat from the low and high-pressure compression stages and various coolers, and using it elsewhere in a plant for heating or manufacturing processes.



Atlas Copco's Carbon Zero ZR Series of water-cooled, oil-free air compressors typically recover more than 90% of the electrical power needed for compression as hot water.

and make cost-saving-control adjustments. Small adjustments may reduce operating pressure and energy costs while improving flow rates, output, and efficiency, while larger system enhancements may be recommended for greater savings.

For instance, pressure drop in a pipe rises with the square of the flow, so increasing the pipe size from, say, two to three inches can reduce pressure drop up to 50%. Conversely, doubling flow causes a 4× larger pressure drop. This makes the size of air-distribution piping critical; piping should always be large enough in diameter to minimize pressure drop.

In addition, shortening the distance air must travel can further reduce pressure drop in the lines by about 30%.

On-going air pressure monitoring is critical to avoid spiking the pressure to compensate for leaks or pressure drops from piping problems or clogged filters. And a compressor controller can greatly reduce the operating pressure band and regulate air production more effectively.

And remember, each 2 psig reduction in output pressure cuts energy consumption 1%, a savings that quickly adds up.

Additional energy savings result from strategically locating compressed-air storage tanks in a facility. The tanks reduce fluctuating demands and pressure drops within the system, which reduces the number of times air compressors cycle.

Routine maintenance produces energy and cost savings, too. Technicians should regularly inspect and replace filters to maintain air quality and prevent costly flow restrictions and pressure drops. Most facilities have several air-line and point-of-use filters in addition to filters mounted at the compressor. All are important to the health of the system and should not be ignored.

Also periodically adjust condensate drains on timers to ensure they open as intended and don't stick. Replacing timer drains with zero-loss drains is even more effective.

And it goes without saying that a clean, dry, compressed-air piping network supplies high-quality air that helps eliminate corrosion, reduces maintenance, extends the life of air-operated tools and actuators and, perhaps most importantly, reduces the likelihood of contamination.

Energy recovery

As mentioned above, even the most-efficient compressed-air systems only deliver a small fraction of the input energy (10 to 15%) as compressed-air energy. Physically compressing air converts most of the input electrical energy into heat.

But heat has value. With air-cooled compressors, the hot discharged air can be routed to a warehouse or loading dock for supplemental heating during cool seasons.

Water-cooled compressors recover even more energy. Built-in energy recovery systems on the compressor circulate cooling water through the compression elements and air coolers to generate hot water at up to 90°C (194°F). Some of the latest designs recover almost all the electrical input power as hot water.

Most plants can use hot water for space heating, showers, and other such applications. However, industries that benefit most are those that need continuous hot water and steam in their processes. Typical users include:

- Food and milk processing plants, for scalding, cleaning, sterilization, and melting.
- Pulp and paper industry, in digesters and evaporators and for bleaching and pulping.
- Textiles, for dyeing and stabilization of man-made fibers.
- Pharmaceuticals, for fermentation and sterilization.
- Refineries and chemical and petrochemical plants, for steam distillation, enhanced recovery, stripping, and heat tracing.
- Power plants, for electricity generation.
- Clean rooms, for humidification.

Use as directed

Lack of pressure is a common complaint on the factory floor that too often results in impractical solutions. Floor personnel should not be charged with modifying air flows to accommodate more demand for air, or take it upon themselves to manipulate compressed-air systems to appease operators. As noted in the earlier discussion on pressure drops, simply "turning up the air" can have disastrous effects on efficiency.

Inappropriate uses of compressed air are also a huge energy draw. For example, too often compressed air is used for cooling or other applications that generally require low-pressure air. Many systems have been compromised with irregular add-on uses where there is likely a simple, cost-effective and conventional solution that can dramatically reduce the pressure draw in these situations. ■

More info:

Atlas Copco, *www.atlascopco.us*

Free guide to energy efficiency

Atlas Copco is well-versed in ways to maximize production while lowering energy use. Its service team offers free compressed-air system health checks that can help a plant's technical staff recognize areas of energy and operational inefficiencies and, more importantly, identify ways to reverse these costly trends.

The company also offers a free copy of the 156-page "Compressed-air best practices guide." To request a copy or to schedule a free compressed-air system health check, please send an e-mail titled "Manual-Energy Efficiency & Technology" to *paul.humphreys@us.atlascopco.com.*