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Compressed Air:

Your Most Expensive Utility

Attention to air-system basics can save thousands of dollars in energy costs

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Compressed air is your most expensive utility. This is a fact that has been documented time and time again. It takes 7 to 8 hp of electricity to produce 1 hp in an airtool. In many plants, the compressed air system is the largest user of electricity. Yet, despite rising utility rates, compressed-air-system efficiency is frequently misunderstood or too often overlooked.

Every plant or processing facility manager should know the following:

- The actual cost of producing compressed air
- The volume of compressed air that is really required for the plant
- The specific operating pressure required in the plant

In addition, does the person or department responsible for selecting compressed air equipment do so with energy costs in mind? And do you monitor the use of compressed air like your other utilities?

Armed with this information, you are in a better position to put a plan in place to calculate power costs, review and select compressor and system controls, provide intermediate storage and control, identify and correct air leaks and eliminate artificial demand.

Calculate power costs

Depending on plant location and local power costs, the annual cost of electrical power can be equal to — or as much as two times greater than — the initial cost of the air compressor. Over a ten-year operating period, a 100-hp compressed air system that you bought for $40,000 can accumulate up to $800,000 in electrical power costs.

To judge the magnitude of the opportunities that exist to save electrical-power costs in your compressed air system, it is important to identify the electrical cost of compressed air. The following formulas will help identify and calculate the true cost of your compressors.

First begin by calculating the input kilowatt (or electrical power consumption) per compressor. If it is a current model, the manufacture's website should list a CAGI (Compressed Air and Gas Institute; Cleveland, Ohio; www.cagi.org) data sheet, which provides performance data, including kW. For older models, consult with the manufacture or distributor for specific performance data. Then calculate the annual power cost for that compressor by multiplying the input power (kW) times the hours of operation per year times the plant's utility rate:

$$\text{Input kW} = 0.7457 \text{ X } (\text{BHP/Motor Efficiency}) \quad (1)$$

where BHP is the brake horsepower, the hp delivered to the output shaft of a motor (a measure of the motor's hp without loss in power caused by accessories, such as the gearbox).

$$\text{Annual power cost (\$/yr)} = \text{Power Cost (\$/kWh) X Input power (kW) X 8,760 (h/yr)} \quad (2)$$

While not specific for your facility, Figure 1 shows the relationship between compressor power and energy costs.

In addition, consider the following:

Direct cost of pressure. Every 10- psig increase of pressure in a plant system requires about 5% more power to produce.

For example, a 520 cfm (ft^3/min) compressor, delivering air at 110 psig, requires about 100 hp However, at 100 psig, only 95 hp is required. Potential power cost savings (at 10¢/kW; 8,760 h [*1*]) is $7,025/yr.

Indirect cost of pressure. System pressure affects air consumption. If there is no real need for increasing the pressure from a process or production standpoint, then the air is wasted. Increased air consumption caused by higher than needed pressure is called artificial demand.

An unregulated system using 520 cfm at 110-psig system pressure will consume only 400 cfm at 80 psig. The potential power cost savings (520 cfm – 400 cfm = 120 cfm = 24 h.p., at 10¢/kWh; 8,760 h) is $16,864/yr.

Also remember that the leakage rate will be significantly reduced at lower pressures — *but will increase at higher pressures*.

The cost of wasted air volume. When wasted compressed-air volume is calculated and evaluated as extra compressor hp, it becomes a clear and identifiable cost. As shown in Figure 1, if this waste can be avoided or recovered, the result will be about $750/hp per year in lower energy costs.

Compressor control

Once the cost of the air system has been calculated, then evaluate the type of compressor control used. According to the Compressed Air Challenge (*CE*, February 1998, p. 48; www.compressedairchallenge.org), compressor controls are designed to match compressor delivery with compressed-air demand by maintaining the compressor-discharge pressure within a specified range. This discharge pressure should be set as low as possible to minimize energy use. Control strategies need to be developed using a systems approach, taking into account system dynamics and storage. There are six basic types of individual compressor controls [2] as follows.

Modulating. Modulating control restricts inlet air to the compressor to progressively reduce compressor output to a specified minimum throttling or capacity control. This method maintains a narrow pressure band at the compressor.

Variable displacement. Also known as rotor-length adjustment, variable displacement allows progressive reduction of the compressor displacement without reducing the inlet pressure (turn, spiral, or poppet valves).

Variable frequency drive (VFD). A VFD adjusts the compressor capacity by varying the speed of the electric motor driving the compressor in response to pressure signals. This technique maintains a narrow pressure band.

Start/stop. Start stop control turns the motor driving the compressor on or off in response to a pressure signal.

Load/unload. This method of control allows the motor to run continuously, but unloads the compressor when a predetermined pressure is reached. The compressor reloads at a predetermined lower

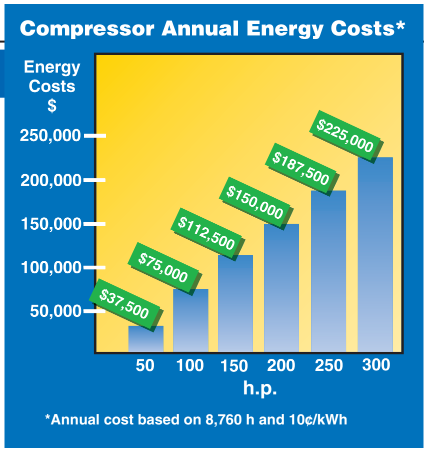

FIGURE 1. Energy costs can be more important than the initial investment for the compressor itself. Calculating the annual energy costs is the first step in reducing overall operating costs

discharge pressure. The inlet valve is either fully open or fully closed.

Dual/auto dual. This is the same as load-unload control with the addition of an over-run timer to stop the compressor after running unloaded at idle for a pre-set time.

Figure 2 shows the relationship between the full-load power required for a compressor at various air demands and common control types. Assuming a system has adequate storage, online-offline control (dual control) is superior to other controls in translating savings in air consumption into real power savings. Looking at our example of reducing air consumption from 520 to 400 cfm (77%), the compressor operating on dual control requires 83% of full-load power. That is 12% less energy than when operated on modulation control. If the air consumption drops to 50%, the difference (dual versus modulation) in energy consumption is increased even further, to 24%.

Many system engineers recommend variable frequency drive machines. These popular machines feature many advantages such as near unity power factor, power reductions for part-load applications, lowest starting inrush current, and unlimited starts. However, this type of control may not be the most efficient, depending on the specific system parameters.

Variable frequency drives function best for the following:

- For single-unit applications averaging 40 to 85% load
- As a trim unit in multiple-unit installations
- When a narrow pressure band is required
- Where the power cost is high
- Where utilities offer incentives or rebates
- Where utilities charge a power factor penalty

Find and reduce leaks

Numerous studies in a variety of industries prove that 25 to 35% of the

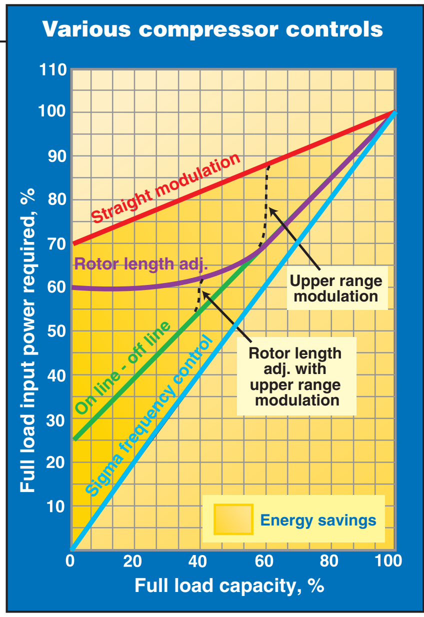

FIGURE 2. Selecting the right compressor control will influence the power required to operate the compressed air system

compressed air produced in the average air system is lost to leaks. Routine leak monitoring and continuous search and repair efforts are essential to control costs. Create a plant-wide "Leak Taskforce," and equip maintenance personnel with proper leak-detection equipment so they can quickly identify and repair these energy wasters. Ultrasonic leak detection equipment is widely available and ideally suited for this purpose. With the equipment in place, establish a plan for periodic leak inspections that incorporates both maintenance and production personnel.

As a start, measure the leak rate during non-operating hours. Pump the system up to operating pressure, turn off the compressors and measure how long it takes for the pressure to drop from operating pressure to the chosen level. From this you can calculate the leak rate. A good rule of thumb is a 10-psig decrease in system pressure results in an approximate 10% decrease in leakage. Conversely, every 10-psig increase of pressure in a plant system not only increases leakage by approximately 10%, *but also requires about 5% more power*.

Getting specific about leakage costs; a 3/8-in. leak at 100 psi may cost $30,000/yr (Figure 3). And remember, the higher the system pressure, the more air lost to leaks. *And every facility has leaks.*

Artificial demand

Artificial demand causes air users to consume more air than is needed to perform a specific task with no added value. It is important to identify unnecessary and wasteful practices.

One example of a wasteful practice is using compressed air to "blow-off" an area or work surface. Though common, it is also a serious OSHA (U.S. Occupational Safety and Health Administration)

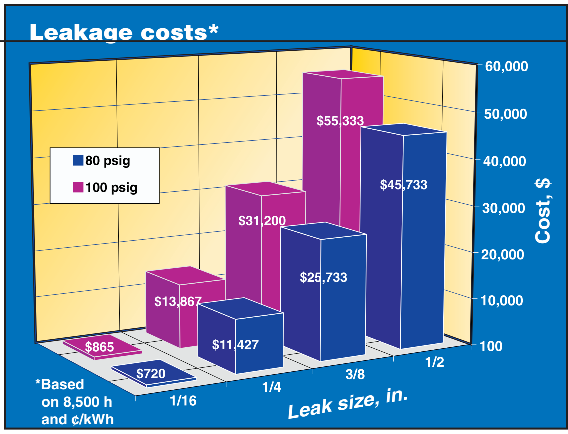

FIGURE 3. Leaks in a compressed air system are more than a waste of air; they are a waste of energy, and thus money. And the cost increases with pressure

violation when the compressed air is over 30 psig. Even small pieces of debris flying through the air at higher pressures can cause injury and perhaps permanent injury. Further, this random and unpredictable use of compressed air can divert air away from critical points in the plant's process and strain the system.

Additionally, users waste energy by running their systems at unnecessarily high pressures, and the elevated amount of energy consumption results in higher operating costs. This artificial demand can be reduced by minimizing system operating pressure to meet, but not exceed, process demands.

Receiver tanks

Properly sized and located receiver tanks are critical to system efficiency. In addition to storing air for periods of high demand and preventing excessive compressor cycling, they also provide a first stage of moisture separation and protect downstream equipment from oil slugs.

A properly designed system features a "wet tank" after the compressor and before the dryer, as well as a "dry tank" after all air treatment. Depending on the specific facility configuration and application, additional tanks may be placed at points of use with high volume and intermittent demand. Care should be taken not to place tanks in the path of hot cooler exhausts.

Receivers should be sized to provide a total storage of at least 4–6 gal/cfm of compressor capacity — this can be shared among multiple tanks. Ensure that all tanks have a pressure rating that exceeds the highest system pressure and equip them with safety-relief valves sized for pressure and total flow. Large liquid-filled pressure gauges are also helpful.

Piping

Improperly sized or poorly designed compressed-air piping systems can increase pressure drop and decrease system efficiency. Piping that must travel long distances or where the diameter is too small can cause friction. Closed-loop piping systems that provide two-way flow to any point offers the best performance and efficiency. In addition, carefully consider piping materials, as these have significant impact beyond initial purchase and installation.

Black iron:

- Advantages — Moderate material cost, many sizes available
- Disadvantages — Heavy, rusts (air quality), scales, rough interior (pressure drop), leaks at joints, difficult to install and modify

Galvanized:

- Advantages — Moderate material cost, many sizes available, corrosion resistant
- Disadvantages — Heavy, rough interior (pressure drop), leaks and rusts at joints, difficult to install and modify

Copper:

- Advantages — No rust, smooth interior, no leaks with well-made joints, lightweight, easily installed and modified, common materials, low installation cost
- Disadvantages — Relatively expensive material cost

Aluminum (modular):

- Advantages — No rust, smooth interior, lightweight, easily installed and modified, competitive materials costs and low labor costs
- Disadvantages — Cannot be aquired at the local plumbing shop

Plastics (ABS or PVC):

- Disadvantages — Risk of rupture, damage, and injury; may degrade due to contact with compressor lubricants; does not meet code in most area
- ***Not recommended***

Additional tips include using braces to secure piping to walls and ceilings to prevent movement of piping as well as overhead takeoffs, and using drip-legs at points of use to reduce moisture carryover. Minimizing "T"s and right angles will also reduce friction losses.

Drains

Drain traps are critical to both system performance and air quality, but are an often overlooked component. Their primary function is to remove oily water from tanks, dryers and filters tank, and prevent that condensate from re-entering the compressed air stream and contaminating products and processes. They also are a great way to keep tanks available for air storage.

Types:

- Manual operation
- Timed electric traps
- Demand traps
  - Float actuated
  - Electronic capacitance

Final remarks

Nearly every compressed air system can be tweaked to become more efficient. Sometimes new compressors are not required, just a review of system design and making improvements to the areas discussed are needed.

However, there are times when investing in a new efficiency system will bring a significant return on investment. There are many reputable compressor manufacturers. The CAGI, a non-profit organization composed of compressed-air and gas equipment manufacturers, provides a uniform reporting standard for member companies. The resulting "CAGI data sheets" are readily available online from most major compressor manufacturer's Websites. These simple, straight-forward forms provide an apples-to-apples performance comparison between the various brands.

Also, most CAGI members now participate in independent, third-party laboratory tests that offer end-users an additional level of comfort. Units from participating manufacturers are selected at random and tested according to CAGI/PNEUROP or ISO standards. To compare manufacturers tested by an independent third party, be sure to look for the official CAGI Performance Verification logo when reviewing published performance data.

Remember too that an experienced compressed-air professional can add real value when it comes to retrofitting an existing system or designing a new one. Ask him or her to relate how the manufacturer's equipment addresses your specific needs and optimizes your day-to-day operations. A consultative, collaborative approach, including auditing your compressed air usage, often yields the best results. ■

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References

1. Based on operating 24 h/d, 7 d/wk, 52 wk/yr
2. Courtesy of Compressed Air Challenge, www.compressedairchallenge.org

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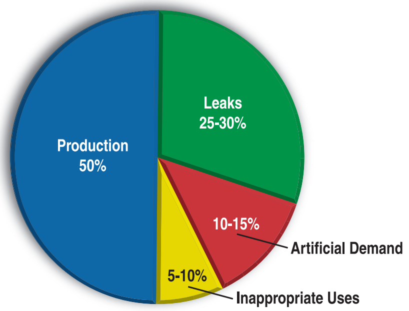
Roy Stuhlman is vice president of sales at Kaeser Compressors, Inc. (P.O. Box 946, Fredericksburgh, VA 22404; Phone: 540-898-5500; Fax: 540-898-5520; Email: roy.stuhlman@kaeser.com), the U.S. subsidiary of Kaeser Kompressoren GmbH (Coburg, Germany). With over 35 years of compressed air experience, he is nationally recognized for his ability to provide in-depth training on all types of compressed air systems in a wide range of industries. Stuhlman has been instrumental in educating thousands of end users on the fundamentals of air system design and function as well as implementing strategies for improving overall air-system performance. He is a master system specialist in Kaeser's Factory Certified Training (KFaCT) program.

At Kaeser, our tradition of saving energy goes back generations.

Energy costs have never been higher. That's why it's so important to get maximum efficiency out of your compressed air system. And with as much as 50%* of compressed air being wasted, you could save a bundle.

Trust the specialists at Kaeser to find energy savings by reducing inefficiency in your air system, while also cutting maintenance costs and delivering process improvements. We are the industry leader in conducting *true, comprehensive* air system audits, so you know you'll get the best possible advice and recommendations.

Visit **www.kaeser.com/ada** to see if you'll benefit from an Air Demand Analysis (ADA) - and how we've helped other plants significantly improve their bottom line.



*Only 50% of compressed air is actually put to productive use.**

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* Source: *U.S. Department of Energy; Compresed Air Challenge®*.

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