Basic Efficiency Steps Help Total Plant Electrical Costs

BY PAUL EDWARDS

When seeking to enhance a plant's compressed air efficiency, practicing the fundamental techniques of reducing compressed air energy consumption can help your operation save thousands of dollars a year in energy bills.

The greatest managers and coaches in sports — Casey Stengel, Don Shula, John Wooden and Red Auerbach — all stress the fundamentals: keep your eye on the ball, block and tackle, and make your free throws. Similarly, when seeking to enhance a plant's compressed air efficiency, practicing the fundamental techniques of reducing compressed air energy consumption can help your operation save thousands of dollars a year in energy bills.

This article addresses methods and guidelines to identify and evaluate areas within your compressed air system that can produce savings. Think of this it as a systematic road map to help guide you toward reduced compressed air energy costs.

BOTTOM LINE RESULTS

Many facilities have experienced staff reductions, streamlined operations and growing task lists, placing efforts beyond those that keep operations in full swing onto the back burner. Therefore, this article will focus on top line opportunities, or within energy reduction efforts referred to as the Pareto Principle, which suggests that the top 20% of actions to reduce energy consumption can produce 80% of the results.

Energy efficiency is definitely in the spotlight in a variety of areas. In fact, energy efficiency for compressed air systems has reached a new height recently. To realize its goal of lowering the country's energy consumption and reducing greenhouse gases, the U.S. Department of Energy in January announced the launch of the Compressed Air Challenge. This initiative is designed to build awareness among users of compressed air about the benefits and approaches for improving and maintaining compressed air system efficiency.

Through industry effort and ongoing research, the DOE has indicated that there is a significant energy reduction opportunity within compressed air systems. A common utility, compressed air transcends industry lines and can account for as much as 10% to 20% of a manufacturing facility's electricity bill. In fact, compressed air systems are probably one of the most abused systems within the plant operation. However, this energy cost is rarely evaluated within the total cost of the operation, and is commonly overlooked when energy reduction opportunities are assessed. Careful selection of efficient components can help save energy, but even greater efficiency opportunities exist within the compressed air system design and implementation. By adhering to some of the recommended actions, your facility can help reduce an additional 2% to 5% of the total plant electrical costs.

ANATOMY OF A COMPRESSED AIR SYSTEM

To help define all of the opportunities for enhancing compressed air system energy efficiency, let's categorize the three basic areas of a compressed air system: demand, transmission and supply.

Demand is what really causes the power plant's meter to turn. It is the actual point of use, whether it is pneumatic tools, hoists, cylinders, blow-offs or diaphragm pumps. If the compressed air is never removed from the system, the pressure would remain stable and there would not be a reason for the compressor to turn on. Demand drives the system and the compressor reacts. Therefore, effective energy reduction starts with demand. Transmission is the method of getting air to the point of use, which includes the pipe, hose, fittings, valves and dedicated storage. The goal of the piping system is to get the compressed air to the point of use in a timely manner while maintaining the proper quality, which includes pressure and quantity. To save energy in the transmission stage, focus needs to be directed toward minimizing the pressure drop in the system. Supply could be summed up as the compressor room. It's where the air is compressed, treated and sent out into the system. Since demand drives the system, supply must be reactive and fill the required needs. To effectively manage energy reduction efforts within this phase requires replacing the consumed supply using a minimum amount of energy.

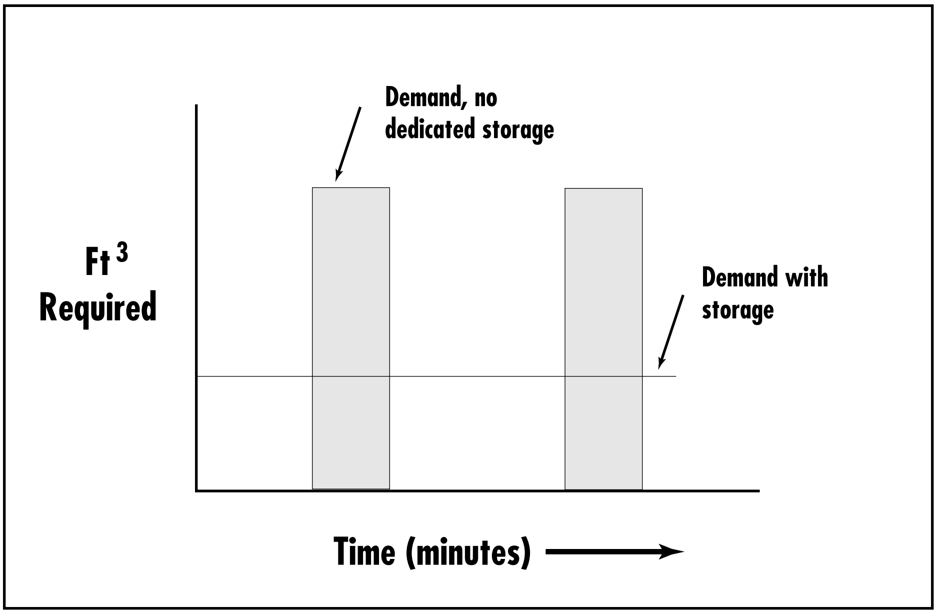

Fig. 1
"Shock loads" can be handled with a dedicated tank, evening out energy usage.

REDUCTION OPPORTUNITIES IN DEMAND

Since the way we curtail excess energy waste within any system is to evaluate demand first, let's identify several common areas where energy savings might be available.

- Find and fix current leaks and prevent future ones. Addressing leaks and appropriate control modes are undoubtedly the two most important action items one can take to save compressed air energy. Since leaks are constantly occurring in a running system, they usually constitute between 10% and 30% of the total demand in a plant. Check all of the plant's point-of-use connections for the slightest hissing sound.

- Avoid the improper, yet common, practice of cracking drains in an effort to ensure moisture-free performance at a particular point of use. Even something as simple and small as a cracked drain can cost hundreds of dollars per year in lost air. For example, a municipality customer had so many cracked drain valves that it exceeded the recommended duty cycle for its compressors, causing the units to fail every six months and need extensive repair. The cracked drain valves also cost the customer in an additional $10,000 of energy charges. By installing simple, pressure-driven drain valves the customer was able to save thousands of dollars.

- Regulate all point-of-use operations at the lowest possible pressure using a quality regulator. Each and every point of use in the plant needs a regulator. Consider a cylinder that is supposed to operate at 85 psig, but instead is filled by air at a line pressure of 110 psig. Twenty five percent more molecules are required to fill that cylinder at 110 psig vs. 885 psig. (The percentage is determined by the ratio of the density of the gases.) This 25% greater "artificial" demand forces the compressor to operate for a longer period of time to suck in those molecules. This would hold true for any point of use that is either unregulated or isn't regulated to its lowest possible pressure. Be sure to use a quality regulator, as poor quality regulators tend to drive and track. If the regulator tracks or drifts up to 5 psig, then the application will use more air.

- Modify, and if possible, eliminate blow-offs. Since many blow-off applications use compressed air simply because it is there, check to see whether a blower or fan could accomplish the same objective. If it cannot, then try using one of the many blow-off products that reduce air consumption by entraining ambient air. This type of product can reduce air consumption at a particular point of use by one-third or more.

- Shut off the air supply to "off-line" production equipment. This step is especially critical for production machinery that is consuming air even when it isn't producing. For example, one customer was using compressed air to cool a part that was going through a heating process. The particular machine operated in a way that a part was always in position to be cooled. Hence, that particular design always had been set up to blow air continuously under the assumption that the machine would always be in production. In practice, however, the customer's incoming orders weren't high enough to keep the machine running 24 hours a day, causing the machine to sit idle for several hours per day, consuming air. The company's simple solution was to install a solenoid valve on the incoming air supply that went to a closed position when the machine wasn't producing. If the company wants a more low-tech solution the operator could have simply turned off an inlet valve at the end of a production run.

- If one point of use requires air pressure at a much higher level than the rest of the system, consider putting it on its own dedicated system. Don't run the entire system's pressure for a single use or point-of-use application. Consider using a separate compressor or booster that is sized for the function.

- Focus on singular events that drive the system. Singular events can range extensively across industries and are often unique to particular plants. For example, bag houses can consume high volumes of air in a very short time. The consumption, if uncontrolled, can look like a step function, as shown in Fig. 1. If the bag house is a significant proportion of the load of the plant, it may drive the system to require an off-line compressor to come on-line specifically to handle the additional load to the system. Once on-line, this last compressor may stay on-line primarily in an unloaded mode, consuming energy. If its demand is stored in a dedicated storage or receiver tank and the replacement air metered in, it is then possible to make this shock load look like a much smaller, continuous demand, shown by the "demand with storage" line. If the buffer is big enough it is possible to keep that last compressor off-line.

Other strategies to handle this type of singular event include staggering their occurrence, operating the processes at off-peak periods, and adding a slip stream booster with a dedicated storage system.

TRANSMISSION AND PIPING

While many opportunities to reduce energy consumption exist in the demand area, there also are measures to take within the compressor system's piping network to ensure that the air gets where it needs to get, when it needs to get there, and in the quality and quantity required.

- Monitor pressure drops in piping systems. The greater the pressure drop in the piping, the higher the operating pressure of the compressor. The higher the operating pressure, the higher the horsepower consumption. Imagine restricting the exhaust on your car engine. The engine will have to work harder to push the exhaust out, making it less efficient and reducing the miles the car will travel on a gallon of gas. Undersized piping in a compressed air system has the same effect on a compressor, since the compressor has to work harder to overcome the restriction. The rule of thumb is that every extra psig results in an increase in energy consumption of 0.5%

For example, one circuit board manufacturer was operating two 50-hp compressors at 140 psig rather than addressing the pressure drop problems with the piping system. If the piping system had been fixed, the manufacturer could have run his plant at a level between 110 and 115 psig. The excess pressure drop of roughly 30 psig translated into a 15% energy penalty on roughly 100 hp of air, which translates to 15 hp. At five cents per kilowatt hour, this piping problem cost the customer more than $3,000 per year for his two-shift operation.

An ounce of prevention is worth a pound of cure. There are new piping products specifically designed to eliminate leaks by using non-corrosive materials and leak-free fittings. While these products are justifiable on labor savings alone, their true value is realized when one calculates the long-term elimination of leaks from the transmission side of the system.

SUPPLY

There are numerous ways to focus on the compressors themselves to help lower energy bills. Now that the plant has been addressed, it's time to get in the compressor room and maximize your results.

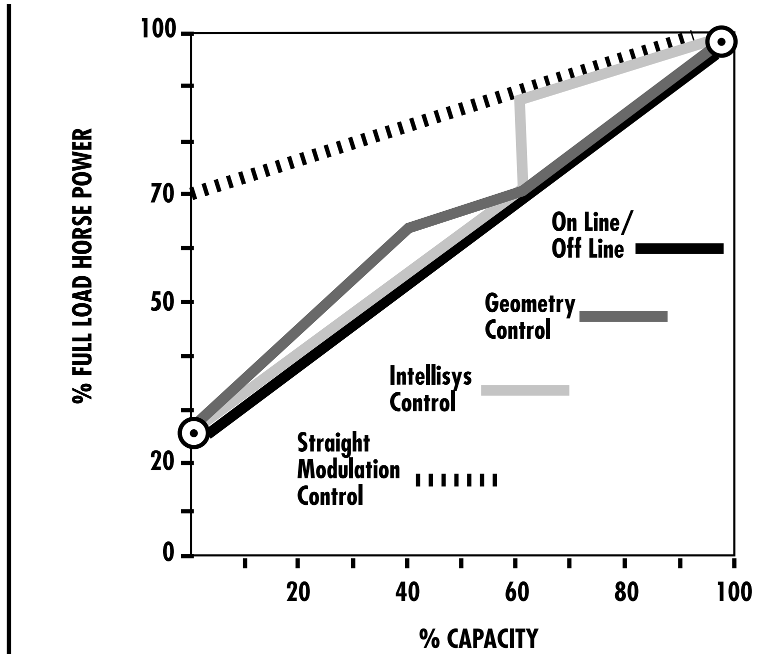

Fig. 2:
Evaluate your need for modulating compressors; know the power consequences.

- Evaluate your need for modulating compressors. One high priority for most plants is to eliminate modulating screw compressors if demand of the plant varies to any great extent. If the demand is sufficiently high, the power penalty associated with the modulating screw compressor may be acceptable. However, it is important to choose this mode only with full knowledge of the power consequences.

Let's say your trim compressor averages at an 80% load. Depending on the power cost and the horsepower size of the compressor, you may find there is a power penalty that you are willing to accept. However, if the new load on the trim compressor is 50% after the leaks in the plant are fixed, then the compressor is running in a range where the power penalty is significant. (See Fig. 2.)

When selecting a control mode, remember that on-line/off-line (auto start/stop) geometry controllers and variable speed drives all have relatively the same efficiency levels. Choosing between them should be determined by the load profile the compressor would see, combined with how you pay for power. An industrial user that pays by the kilowatt may end up selecting a different control mode than another user who pays by the Kva. A plant that has significant periods at full load and significant periods of no-load may choose a different control than a plant with a machine that operates consistently near 50% load.

When switching a modulating control compressor to another control method, the supplier should be consulted to ensure that the receiver capacity is adequate for the new control method. Depending on the demand, units using on-line/off-line control and most geometry controllers can cycle more often and can increase bearing wear. (Some geometry controllers unload at roughly 40% to prevent rotor rumble.) A receiver tank is the cheapest insurance one can buy to increase the reliability of the compressed air system.

- Consider multiple staged compressors. Two-stage flooded rotary screw compressors are now available in sizes as small as 100 hp and offer significant power savings over single-stage compressors. Unless power is extremely inexpensive or the operational time is a very small proportion of the day, two-stage compressors typically provide a return on the investment within the first two years of operation and often within the first.

- Evaluate the CFM rating. When evaluating compressor designs, it is important to understand how the compressor's performance was determined. Unlike the automobile industry, in which the federal government sets standards on how to measure miles per gallon, the compressor industry does not have a legal standard on how to report performance data. This loophole allows manufacturers to rate their products with the best possible light and, therefore, limits customers' abilities to use "apples to apples" comparisons. However, many manufacturers do adhere to a standard developed by the Compressed Air and Gas Institute (CAGI). Ask your vendor if he or she complies with CAGI standards.

- Lower the output pressure. If your plant does not use intermediate controls, then consider lowering the pressure set points on the compressor. This has two effects on the energy being consumed. First, the compressor operates more efficiently at lower pressures. Second, the lower the pressure delivered to the plant, the lower the leakage rate and the artificial demand. Note that if you use intermediate controls the intermediate controller is the first point at which one limits pressure. The compressor is the second point.

- Use waste heat off the compressor to help the rest of the plant save energy. Compressor systems give off high volumes of low-grade heat which, with some ingenuity, can be used efficiently by some industrial processes, heating or ventilation systems. There are many ways that this waste heat can be used within industrial processes.

- Avoid delivering higher pressure to the entire plant just to meet the requirements of one user. If one point of use or a minority of users require higher pressures than the remainder of the plant, consider putting those operations on its own system or add a booster package at the point of use. Therefore, you can keep the larger system operating at lower pressures.

- Understand multiple compressor system controls. The basics of multiple compressor controls are fairly simple. Whenever possible, turn off compressors and prevent them from turning on. Cascading compressors can be a very expensive method of control. The current trend is to target a pressure point and bring on compressors as required. Algorithms are often used to determine whether a particular demand will need to be met with storage or another compressor.

- Use intermediate controls/expanders/high-quality back pressure regulators. The higher the pressure delivered to the plant, the higher the artificial demand and the leakage. Intermediate controllers are sophisticated pressure regulators installed on the supply side of the compressed air system. Intermediate controls have two simple effects on compressed air systems — the creation of stored air volume to handle peak requirements and the lowering of system pressure to reduce artificial demand and leaks.

For instance, if a battery is placed within an electrical system that has the same potential as the battery, there is no useful charge. So if the air pressure in the receiver tank is the same as what the point-of-use requires, there isn't any useful stored volume in the tank. By creating a differential pressure between the tank and the point of use, a differential is built into the air system.

As discussed above, the higher the air pressure in the plant, the higher the artificial demand and leakage. Therefore, by reducing the pressure, you are reducing the artificial demand and leakage.

- Evaluate sector controls. If differing parts of the plant have different pressure requirements, then consider regulating pressure to the various sections. If one area of the plant has a maximum required air pressure of 60 psig, then it only receives 60 psig. In this way, each section has the minimum artificial demand while creating an even greater differential upstream.

- Understand the requirements for clean-up equipment. Minimizing energy consumption in the clean-up section of the supply starts with understanding the needs of the system. When surveying the production equipment's air quality requirements, the recommendation of the production equipment manufacturer generally should be followed. However, they might not always know the best option. For example, the supplier of ink jet printers specified the compressed air system for a printer and insisted that the printer had to be fed oil-free air at a -40 degrees F. pressure dew point. The end customer questioned the compressed air system requirements and learned that the vendor just knew that if he used air of exceptional quality, the ink jet printer would operate better. The customer almost purchased a dedicated oil-free compressor, and a desiccant dryer with filtration. And while the initial investment was significant, the power and maintenance costs on this particular system would have driven the cost substantially higher. Once researched, the customer took air from a flooded screw compressor that had a coalescing filter and a refrigerated dryer, and added additional filtration and a backup dryer at the point of use. The printer has never had a problem and the customer saved a bundle. Lesson learned? Do not be afraid to double-check a vendor's requirements.

- Use the drying technology that gives you the maximum allowable pressure dew point. Why use a desiccant dryer when your process can operate flawlessly on air from a refrigerated air dryer? Why operate with a 35-degree F. dew point when a 50-degree dew point suffices? Why not use a water-cooled aftercooler with chilled water as its cooling medium? Consider using a dryer with a floating dew point that includes such technologies as rotary drum desiccant dryers, solid core desiccant dryers or even some refrigerated air dryers. A rule of thumb is that desiccant dryers consume 7% to 14% of the total energy of the compressor. Refrigerated dryers consume 1% to 2% as much energy as the compressors they operate with.

- Choose "Best in Class" Products. One corollary to that rule is "Don't run the entire system for a minor user." If part of your plant requires a -100 degrees F. dew point, another part requires a -40 degrees F. dew point and the majority can get away with a 35 degrees dew point, don't use a single dryer producing a -100 degrees F. dew point on the entire system. In this case, the answer would be to have a refrigerated dryer on the main system and to run an individual desiccant or thermal mass refrigerated dryers wherever needed.

When selecting a dryer, look for the best selection in that class that fits your air quality requirements, particularly how much energy it uses at partial load. For example, there are several methods of reducing the energy consumption of a desiccant dryer. When looking at desiccant dryers, explore all the different types. When evaluating refrigerated dryers look for a thermal mass or cycling type. Thermal mass dryers operate like your air conditioner at home, turning on and off according to the demand. Direct expansion dryers (non-cycling) operate like your air conditioner at home as if you left them on all day and you opened and closed the doors to maintain the temperature in the house. Imagine the power bill.

Finally, meet the cleanup need with as few dryers and filters as possible. One larger dryer is usually more efficient than multiple units. The use of energy efficient dryers reduces the importance, but there are still economies of scale. Where energy becomes much too high is in multiple dryer systems where the dryers have poor part load efficiencies.

- Excessive pressure drop in filters also wastes energy. As you evaluate filtration systems, watch the differential pressure at clean and dirty conditions. Pressure drop in filters increases the pressure that the compressor has to overcome, thus increasing the systems' horsepower consumption. Many filters have a recommended changeout at 8-10 psig. Stacking a particulate filter with a coalescing filter of this type, and maintaining the element according to standards, may result in a pressure drop across the two of 15 psig or more, resulting in a 7.5% power penalty. For general industry, one should look at any of the several manufacturers whose coalescing filters have a 1 psig pressure drop over the approximate 10-year element life. The justification on power and maintenance on this type of filter is usually under two years.

- Religiously adjust solenoid and ball type automatic drains or eliminate them. As inlet humidity, temperature and demand change, so will the amount of water being pulled through the drainage system. Think of the last time you heard your auto drains open. Did you hear a hiss of air? The longer you hear the air, the greater your energy cost. Many solenoid and many ball valves have openings of 1/4 inch (104 cfm at 100 psig) or even 3/8 inch (234 cfm at 100 psig). That means your system would lose roughly one to four cubic feet for every second that any of your auto drains would be blowing air. If you are not adjusting the drains frequently, then you are wasting air.

CYCLING AND NON-CYCLING DRYERS

It is common to see a cycling or thermal mass dryer operating no more than 25% of the time and using one-quarter of the energy that a non-cycling dryer would use. Why does this happen?

Consider the four factors that influence the heat load on the dryer — flow, inlet temperature, pressure and humidity. The impact of pressure is minimal since the water content of air at 100 psig is within a few percentage points of air at 125 psig.

Flow is a different story. Most dryers are sized to handle the output of a compressor. Most compressors are somewhat oversized. And the typical plant demand can very significantly and can drop to less than 50% during second and third shifts.

Humidity can be a factor, especially in cooler climates. The inlet air to the compressor may not have enough water in it to cause the air to have 100% humidity when it is compressed. For example, the moisture content of the air on a 30-degree F day with 60% RH is roughly 0.18 lbm/1,000 ft.3. Air at 120 psig and 100 degrees F can hold 0.3 lbm/1,000 feet3. In this case, since the water content coming in to the dryer is less than the content that the air can hold, the load on the dryer is significantly less.

The impact of the inlet temperature is often overlooked. One rule of thumb states that the amount of moisture doubles approximately every 20 degrees F. As air-cooled compressors have become more common, the average inlet temperature to the dryer now has much more variation. If the compressor is in a compressor room with a constant 75 degrees F and the aftercooler CTD is 10 degrees F, then the inlet temperature to the dryer might be 85 degrees F or less (there is often some cooling effect in the piping).

In warmer climates, where compressors are regularly placed outside, the ambient temperature may be 55 degrees F in the morning and 80 degrees F in the afternoon. The wide difference in ambient temperature can cause a swing in the inlet temperature to the dryer. In such situations, during the third shift, the plant load may drop to 50% and the inlet temperature might be 65 degrees F on a dryer that was sized to handle the load with an inlet of 100 degrees F.

This change in inlet temperature represents a reduction in load, due to temperature only, of 35% compared to design conditions. Here, the combined effect from the reduced load and the reduced temperature results in a total load of 18%. The same logic also applies to desiccant drying systems.

— Paul Edwards

There are many types of auto drains that do not waste air. Most are float switch or electronically operated. When the water level in the drain gets high enough, a signal is sent to a valve that opens, draining the condensate. Before the drain empties a second signal is sent that closes the valve, maintaining a positive seal on the drain and preventing any air from escaping.

ADMINISTRATION ISSUES

Most of the aforementioned issues deal with the design of the entire system. Even with proper design, it is possible to waste energy if the system is not properly maintained. For example, one should change out filter elements when necessary, whether they are at the point of use or in the compressor room. Maintain the coolers on the compressor to ensure that the dryer gets the lowest possible inlet temperature. Start a leak program with benchmarking. And above all, do not treat this process as a one-time fix. It is an ongoing process that needs to be adjusted on a regular basis.

SUMMARY

Before addressing your compressed air consumption, consider using an appropriate mix of compressed air, hydraulics and electrics, since the best power option may vary from one piece of equipment to another. It is possible to save 25%-50% of the energy consumed by a compressed air system but to do so, the focus must start with the points of use. All the actions you take at the points of use result in the power meter in the compressor room turning more slowly. And the final savings are realized by efficiently replacing the air already removed by the system.

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