Squeezing Money Out of Thin Air

It pays to apply best practices and a systems approach to your compressed air network
By Joe Ghislain

Compressed air is too costly to use as a prime mover. Consider the fact that the price of 100-psig air is in the range of 18 to 32 cents per 1,000 standard cubic feet of free air. In the automobile industry, compressed air is a significant part of the energy cost, ranging from 10% in component plants to as much as 40% in stamping plants. In a typical Ford plant, this can represent anywhere from several hundred thousand dollars to well over a million dollars per year.

One way to reduce this cost is by applying best practices and a systems approach to improve compressed air system efficiency. Analyzing the case from only the supply side limits the opportunities for improvement. Focus on air user demands because that is what drives system requirements. Concentrating on proper end-use application, design, operation and maintenance ensures higher operating efficiency, lower cost and reduced production losses. Review these aspects of your current air system:

- Consider electro-technology conversion.
- Align supply side with demand side.
- Reduce system pressure.
- Improve maintenance.
- Eliminate inappropriate uses.
- Think in terms of life-cycle cost.

Electrotechnology conversion

The history of compressed air in the auto industry goes back to Henry Ford's day. Then, it was a by product of electricity production: waste steam from the generator's turbines powered the steam engine-driven compressors that produced compressed air. Electricity was in its infancy and couldn't yet duplicate what could be accomplished with compressed air. But times have changed. Electricity now produces compressed air, and it can take 8 hp of input power to deliver only 1 hp of work where compressed air is being used. At that rate, it's obvious that it can be more economical to use electricity to drive mixers, dryers and blowers. Even direct-current nut runners are replacing air tools, not just because of the energy efficiency, but because of increased quality by being able to tie torque feedback to the line operation. The advances in electrotechnology now offer many efficient options for replacing compressed air applications.

Aligning supply with demand

System demand drives the supply requirements in any compressed air system. You need to know the true air demands and how to fulfill them using proper compressor operation (number and total horsepower, duration, pressure and flow). Because the system is dynamic, it requires monitoring and controlling both the compressors and air users.

First, develop a pressure profile that quantifies system demand characteristics. Take pressure readings after the main supply components, at the beginning and end of the main distribution system and at several points of use. Spread your readings out over a period of time to establish the high, low and average system demand. The pressure variation you document indicates how the system and compressor react to the demands. The adage, "If you can't measure it, you can't manage it," applies to establishing your baseline. While temperature and dew point are useful air system measurements, the key metrics are pressure, rate of air flow and electrical consumption. This trio helps to determine the cost, monitor system operation and establish a baseline for evaluating future modifications.

Determine real-time air system efficiency using the flow rate (cfm free air) and power (kW). Let system size, component location and estimated air flow range determine the flow meter type and its location. Get your electrical consumption by calculating kW or from a kWh meter. For smaller systems, use voltage and current readings and apply the motor power factor to estimate power consumption. Convert your kW/cfm reading to cost by applying your electrical rate. Converting compressed air usage into dollars puts the system operation and improvements into terms that everyone can understand.

Apply controls to the compressors and other supply-side components and to air users that have the greatest effect on the system. The type of compressor control and operation depends on compressor type and system dynamics.

Control of an individual compressor requires consideration of demand variation and control of air users to minimize their effect on the system. Operate a minimum number of compressors necessary to base load (operate at full capacity), and use only one trim compressor to track the overall varying load. If you have multiple compressors of the same type, use sequencing controls to run all but one at full capacity. These sequencers not only control trim compressor turndown, but also will start and stop compressors according to system demand.

For systems with multiple compressor types, it may be beneficial to separate the control for each type. Sophisticated sequencing controllers and global systems now available can control more than one compressor type. When using these control schemes, don't ignore compressor type. For example, rotary compressors with modulating, or load/unload, capacity control should be run fully loaded; variable-speed rotary compressors should be used only for trim; and centrifugal units have relatively efficient but limited, reduced capacity modulation.

Primary and secondary storage also can help align supply with demand by minimizing the effects that air users have on the system. Air receivers are vessels that store air that's needed to meet peak demand events with minimal effect on changes in pressure. Primary storage, located close to the compressors, reacts to any system event. Secondary storage, located close to an end use, minimizes the effect that a local high-volume, low time-duration event has on the upstream system.

In conjunction with storage, an application that requires a narrow pressure band can be equipped with a pressure/flow controller that monitors downstream pressure and reacts quickly to maintain line pressure stability.

As you can see, proper control and monitoring aligns air supply with demand. The correct control system must be able to handle a compressed air system that is almost always dynamic. If your production process or operating schedule changes, verify your baseline numbers again to ensure the change hasn't degraded your system dynamic.

Pressure reduction

Compressed air systems often operate at excessive output pressure to compensate for pressure fluctuations caused by changes in end use (high intermittent volume). Operating at elevated pressure increases the rate of air leaks, air consumption at users and energy consumption. The benefits of reducing your supply pressure follow the same logic that applies to pressure drop, except in reverse: every 2 psi increase in pressure costs an additional 1% in power. For example, running a 100-hp compressor at 80 psi rather than 100 psi saves approximately $3,500 per year at 5 cents per kWh. Operating a compressed air system at the lowest possible pressure is well worth the effort.

Often, only a small number of end uses require high pressure. These need to be addressed individually. Sometimes the need for high pressure is merely a perception that entered plant lore when someone once said, "We have problems with the equipment if it drops below this pressure." Question everything.

Any number of things can cause problems, including pressure drop and swings in the line feeding the equipment. If you suspect perception-based needs, address the cause. If a user truly requires high pressure, either modify the equipment or isolate it.

Because modification is equipment-specific, it can’t be addressed in this article, but there are techniques to isolate high-pressure loads. Air boosters or intensifiers can be used for intermittent loads. Booster compressors or separate, smaller compressors can be used for continuous or high-duty cycle loads.

Finally, if several loads require high pressure, it may be possible to separate them from the main system and supply them from one compressor, thus allowing the main system to be run at a lower pressure.

Maintenance

Proper supply-side and demand-side maintenance is critical to efficient operation. Often, system maintenance is considered a necessary evil, one of the first cuts to hit the budget, but it may be the wrong place to start.

On the supply side, pressure drops across dryers and filters can have adverse effects on system operation. The concept that “2 psi costs 1% in power” applies, so it’s critical to change filters and maintain dryers to minimize pressure drops. When ignored, inlet air filters will load up and reduce compressor capacity and efficiency. A good air filter guideline is that a pressure drop of 4 in. WC is equal to 1% of compressor capacity.

Air leaks are the biggest maintenance loss in any system. The Department of Energy suggests that a “tight” system still has a 10% leak rate. It’s common to find industrial compressed air systems with 20% to 30% leakage. Air leaks cause efficiency losses in several areas.

The obvious one is the leak itself. At 5 cents per kWh, the equivalent of a quarter-inch hole burns $8,382 per year. The additional rate of flow for compressed air leaks decreases system pressure. The resulting artificial load requires the system to operate at elevated pressure and can even prompt the purchase and running of more unneeded compressor capacity.

Air leaks cause supply side equipment to cycle too often, thus increasing maintenance and reducing equipment life. The only way to reduce these effects is to implement an aggressive and ongoing air leak program that identifies and fixes air leaks.

Inappropriate uses

Compressed air isn’t always the most appropriate energy source. Many times it’s used because it’s convenient, but this is a costly convenience. Blowing, drying and sparging are examples in which air may have been selected because it was easy or was a quick fix for a production problem. Blowing and drying are usually done at excessive pressure, which often can be reduced drastically by regulating it and using high-efficiency nozzles. Low-pressure electric blowers are a viable option.

Cooling workers and cabinets are two other examples of incorrect compressed air use. Purchasing a fan or a cooling unit can provide a payback in less than a year, perhaps within several months. Vacuum generation, diaphragm pumps and vacuum ventori’s also are applications that you should review.

Think life-cycle cost

While this may be a basic concept, it’s often overlooked. System design and the equipment purchased to implement it determine 80% to 90% of the ultimate operational costs. Total life cycle cost and benefits must be weighed carefully before selecting the most cost-effective option, not only for the compressed air supply system but also for the end uses. Where is the sense in making air compressor purchases based on first cost, while the unit’s life-cycle cost is less than 10% hardware and more than 80% energy?

Rarely is pressure drop a consideration when purchasing or designing equipment and systems, yet the pressure drop across dryers, filters and piping systems has a dramatic effect on energy costs. You’d be wise to analyze the incremental cost of increasing hardware size to reduce the pressure drop. Often, the incremental cost is small compared to the ongoing energy cost.

Specify air users that operate at the lowest possible pressure. I know of one instance where two identical large presses were purchased for two locations. One plant specified a 60- psi operating pressure, the other let the supplier dictate the operating pressure. The result was a press operating at 60 psi and the second operating at 80 psi. The difference in operating cost was more than $300,000 per year. This illustrates that using life-cycle cost to drive design, specification and purchasing is critical to efficient long-term operation.

Concentrating on proper application, design, operation and maintenance ensures the highest operating efficiency and lowest cost. It improves energy efficiency while reducing production losses. Reducing compressed air costs, like reducing any energy cost, has a direct effect on the bottom line. Making compressed air systems more efficient reduces costs and makes a company more competitive.

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