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COMPRESSED AIR CONTROLS:

A COMPREHENSIVE GUIDE TO COMPRESSOR SETTINGS AND SYSTEM MANAGEMENT

Baselining Compressed Air Systems

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Integrated Compressor Controls

Baselining compressed air systems

Simple measurements, a calculator, a pad of paper and a telephone are the tools needed to start reducing energy costs

By Wayne Perry

Before beginning any type of energy efficiency improvement program for a compressed air system, it's important to know something about its current energy consumption and operational characteristics. Without this information, it'll be impossible to measure any improvements.

Baselining—the term currently in vogue for this process—either estimates or measures the base data. Measuring is by far the most accurate and reveals operational characteristics that may lead to inexpensive changes that can reduce energy savings greatly. Knowing what, when and where to measure are the keys to establishing a good baseline.

Of course, measuring everything always establishes the best baseline. In a new facility, it's quite easy and cost-effective to include the monitoring equipment in the plant design. In an existing facility, a few simple measurements, a calculator, a pad of paper and a telephone are the tools one needs to start reducing energy costs. The primary measurements are power and pressure. Flow measurements add to understanding the dynamics of the system, but are not an absolute requirement for baselining energy consumption.

Don't confuse this simplified baseline with a compressed air system audit. A complete audit performed by a qualified compressed air specialist gathers much more data concerning system dynamics and user characteristics. The information gathered in the simplified baseline is important to the specialist and may reduce audit costs by reducing the time spent collecting and analyzing data.

What to measure

The first priority is determining the plant-specific factors that might affect power consumption. Do different shifts or different days have different production levels? If production is stable, data collected at any time is representative of the overall power used. If production varies by shift or day, you'll need to collect data at each production level.

Do production levels show seasonality? It's a characteristic that can be difficult to model. Compressed air systems are nonlinear. A 50 percent reduction in production will probably not reduce system power by 50 percent. If it's the busy season, look for a shift or day that runs at production levels similar to the slow season. For example, a Saturday during the busy season might be similar to a weekday during the slow season. Data collected on Saturday could serve as a proxy for slow season power consumption.

In addition to variations in power consumption, power cost may vary by time of day or season. It may be possible to average, or blend, power costs to simplify calculations. However, if you are subject to a substantial demand charge imposed at a certain time of day or season, using a blended power cost is inappropriate. Small changes to operation during peak times may yield short paybacks that can't be correlated to a blended power cost. Moving an operation or process from one shift to another also may dramatically change power costs without a corresponding physical modification to the compressed air system.

Develop a plan

Believe the adage that states, "If you can't draw it, you don't understand it" because it certainly holds true for a compressed air system. Draw a simple block diagram of the compressed air system. It doesn't need to be P&ID-quality because its purpose is to identify locations where pressure readings are to be taken. Don't rely on OEM pressure gauges supplied with the compressors. Most have an accuracy that may result in as much as a five-psig difference in readings between compressors.

Pressure readings are taken at the compressor discharge, before and after filters, before and after dryers, at the main air distribution pipe and at the most critical user. If possible, take readings in several locations throughout the distribution system. When taking pressure readings at the critical end user, read both the pressure in the distribution piping and the pressure at the point of use. Many times, the largest pressure drop occurs between the distribution pipe and the point of use. Simultaneous pressure readings help identify potential problem areas.

If the system has multiple compressors, verify the pressure range for each controller. This may require compressors to be isolated from the system and run through their entire control pressure range. If each compressor has dedicated dryers and filters, isolate the entire supply subsystem and record pressures at various points. Use a single, calibrated pressure gauge to measure each compressor.

From these readings, develop a pressure profile showing each compressor's control pressure range, pressure drop across treatment equipment, pressure drop through the distribution system and final pressure at the critical point of use.

Finding the tools

Most manufacturing operations lack an extensive collection of recording power meters, pressure transducers and data loggers. The local utility may help with recording compressor power consumption. Other sources for assistance are state energy offices and local universities.

Recording power meters also can be rented. If the plant air pressure is stable, a meter that records the power level every 10 seconds and averages the data once a minute probably will work fine. On the other hand, sampling every second may be required if there are abrupt swings in system pressure. Keep in mind this is merely a simple baseline and not a complete system audit. Collecting too much data only makes analyzing and understanding it that much more difficult.

Proper data analysis requires knowing how much power the system is supposed to use. Call the compressor vendor and ask for the unit's full-load power consumption. Just because a compressor has a 200-hp motor doesn't mean it should be running at the full-load current shown on the motor nameplate. Changes in pressure settings affect power requirements. The unit may be designed to run slightly into the service factor or significantly below. Given the pressure settings, a qualified compressor distributor or manufacturer can provide a reasonable estimate of full-load power for the particular model of compressor.

Collecting pressure data can help identify problem areas in the facility. Pressure data often can identify the operation or process that determines supply-side pressure requirements. It's not uncommon to find a pressure drop of 25 psig or more between the distribution pipe and the point of use. If that pressure drop forces the entire system to operate 25 psig higher than necessary, the power required may be 10 percent to 12 percent higher than needed, depending on how the compressor controls are set.

System pressure behaves dynamically

Using a calibrated gauge to take static pressure readings provides a snapshot of the system. This may be useful in identifying problem areas, such as plugged filters or restricted supply lines, that can be corrected inexpensively and easily. A snapshot of the system tells you little about where it's going, how fast it's moving, whether it's full and, most importantly, whether it's in control. Getting more than a snapshot requires equipment that shows how the system responds to events and suggests ways to improve the response.

Data loggers and pressure transducers can be rented. Recording and interpreting the information is a little more complex than reading and recording the power. Before renting this equipment, contact local compressor suppliers. They may be able to help with rental, installation and data interpretation. State energy offices and local power companies also may know where to find instruments to monitor system pressure.

Getting results

After establishing the baseline, start making system improvements. Begin by implementing the energy efficiency measures a qualified air system supplier or system specialist suggests.

In a typical system, a good baseline and minimal effort can result in 15 percent to 25 percent energy savings.

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Selecting air compressor and system controls

The next step in achieving optimum system efficiency

By Harold Wagner

The purpose of any compressor control system is to match compressed air supply to the compressed air demand as efficiently as possible. Although old style electro-pneumatic controls have been supplanted by microprocessor-based controls and software updates that optimize system and control parameters, any control type can be put into one of two categories—fixed speed controls and variable speed controls.

Fixed speed compressor controls

As the name implies, the idea is to hold compressor speed constant. The exact speed is a function of the speed of the drive motor and the ratio of the gearing or V-belt system in use, if any. The capacity output control is based on either modulation or a poppet valve.

Modulation control

This form of control modulates the compressor's inlet valve according to the compressor's outlet pressure. When the controller detects rising outlet pressure, it causes the inlet valve to start closing. While this control is effective, it's the least efficient. The reason is that compressor efficiency is inversely proportional to the compression ratio, which is the ratio of inlet pressure to outlet pressure. The closing inlet valve produces a vacuum at the compressor's inlet side while the outlet pressure remains relatively constant. This has the same effect as raising the compression ratio.

A compromise is to restrict the modulation control range to something like 40 percent and automatically convert the scheme to a load/no load control any time output drops below 60 percent (see Figure 1). Unfortunately, this form of control doesn't lend itself to use with multiple machines.

Variable displacement control

Controlling the effective rotor length varies the compressor's output. This is accomplished with internal bypasses machined into the airend housing and controlled by either poppet valves or a turn (or spiral) valve. While the efficiency is better than with modulation control, poppet-style controls are effective only above 50 percent to 60 percent of capacity. Also, they can be complex and difficult to troubleshoot.

Online - idle/offline (dual-control)

This simple, effective control uses a pressure switch at the compressor discharge to close the inlet valve completely at a high limit (cut-out) pressure and open it

Various compressor controls

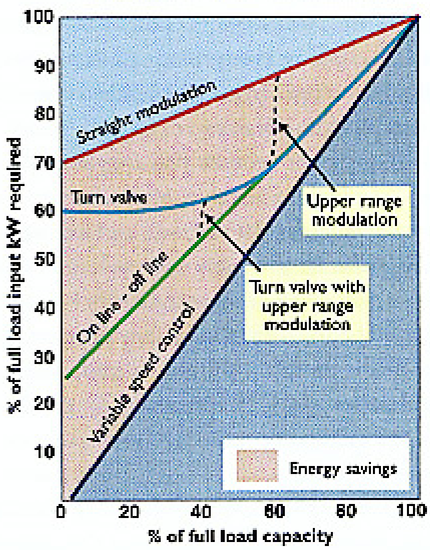

Figure 1. This approach to compressor control converts from modulation control to a load/no load any time output drops below 60 percent.

completely at a low limit (cut-in) pressure. The difference between this approach and the modulation control is that, in this case, the compressor is internally unloaded. The reduced compression ratio reduces idle power consumption. This type of control can connect multiple compressor installations easily using a sequencer (master) controller. On the other hand, the air system will need a properly sized air receiver tank.

Start/stop control

This is the most efficient control scheme. The compressor runs either fully loaded or off, depending on the signal from the pressure switch. Unfortunately, motors larger than five to 10 hp can't be started and stopped as often as this control may require without overheating. This control is used on small piston compressors, which typically are mounted on a storage receiver. They use a relatively wide pressure differential of 15 psig to 25 psig.

Variable speed control

Advanced and affordable technology brought variable frequency drives into compressor applications. The principle seems simple—adjust the compressor/motor speed and output to match system demand exactly. Designed correctly, variable frequency control is the most advanced and energy-efficient trim compressor control. However, the following issues must be considered:

- The airend must be designed to be efficient over the complete speed range. Airend efficiency is a function of rotor tip speed and may be greatly reduced at lower or higher rpm (see Figure 2).
- The variable speed drive controller needs to be efficient, as it represents an additional link between the power supply and the drive motor. The drive system and motor cables need to be free of power distortions and electromagnetic emissions to prevent electromagnetic interference to computers or other sensitive electronic equipment.
- The drive motor must be able to handle the higher speeds as well as the lower speeds, where bearing design and cooling issues may be problematic.
- An intelligent controller makes efficient and reliable connections among air pressure, the drive and the compressor inlet valve. A well-engineered device can control compressor outlet pressure to within one psi, despite wildly fluctuating air demands.

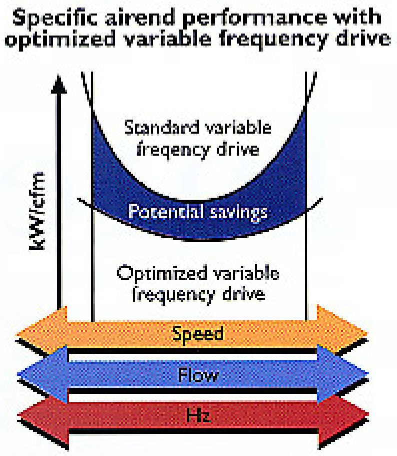

Figure 2. Variable speed control efficiently compensates for fluctuating air demand.

Variable speed control is suited for trimming in multi-compressor applications. It allows a sequencer/controller to operate multiple compressors efficiently. Needed machines are loaded fully. Unneeded compressors are in stand-by mode. And the variable speed control efficiently compensates for fluctuating air demand (see Figure 3).

The most efficient control, however, can't compensate for an improperly designed system. Conduct a comprehensive air system audit and give your control system a fighting chance to deliver the efficiency gains it promises. ⓑ

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Figures: Kaeser Compressors

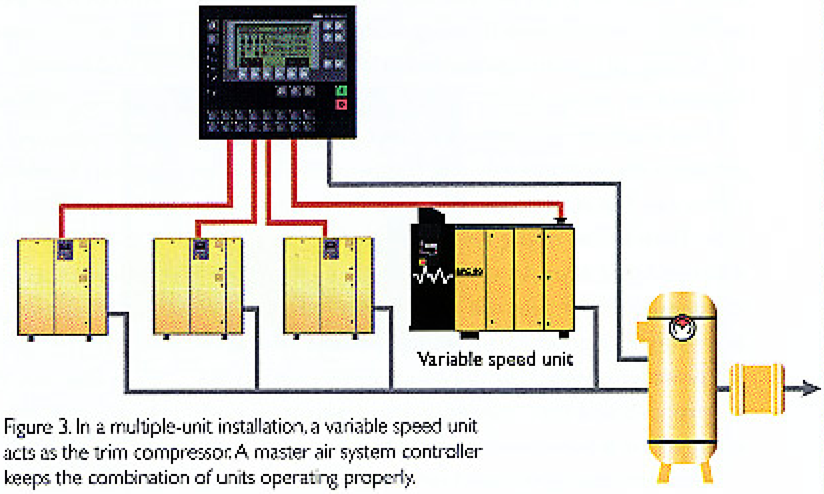
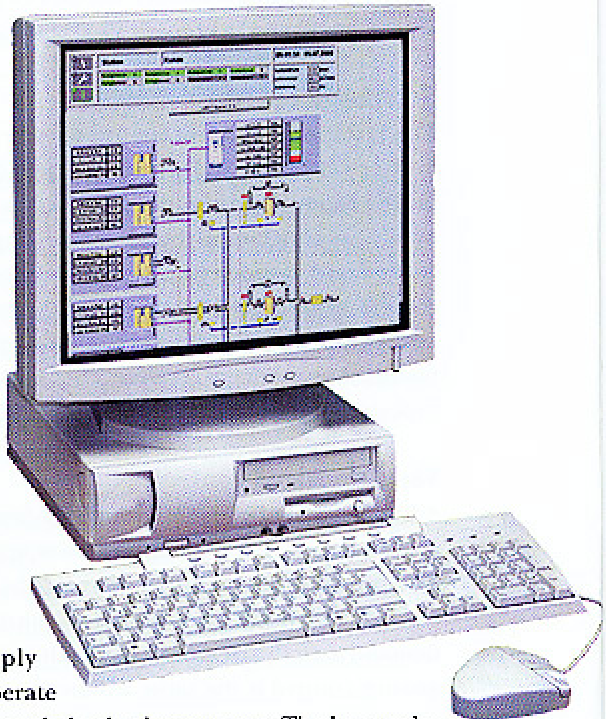


Figure 3. In a multiple-unit installation, a variable speed unit acts as the trim compressor. A master air system controller keeps the combination of units operating properly.

Integrated compressor controls

They free the operator to make better air system decisions



By Wayne Perry

"I don't understand. I attended the classes, both Fundamentals and Advanced. I read every article and book I could find on improving compressed air system efficiency. I developed great ideas about reducing compressed air consumption. We fixed leaks, changed piping, moved some processes to shifts that used less compressed air, bought low consumption nozzles and educated our entire workforce. We did this work and I still have six out of six compressors running nearly continuously. Reducing air consumption doesn't appear to have reduced air production."

This is not an uncommon lament. Major improvements to the demand side of a compressed air system often can fail to yield desired results on the supply side. Both halves of the system require action before energy costs start to drop. Additionally, future changes to either side will require the entire system be re-tuned. A good start is having a compressor service provider ensure that the compressor controls are set properly and the complete control system on each compressor is functioning properly.

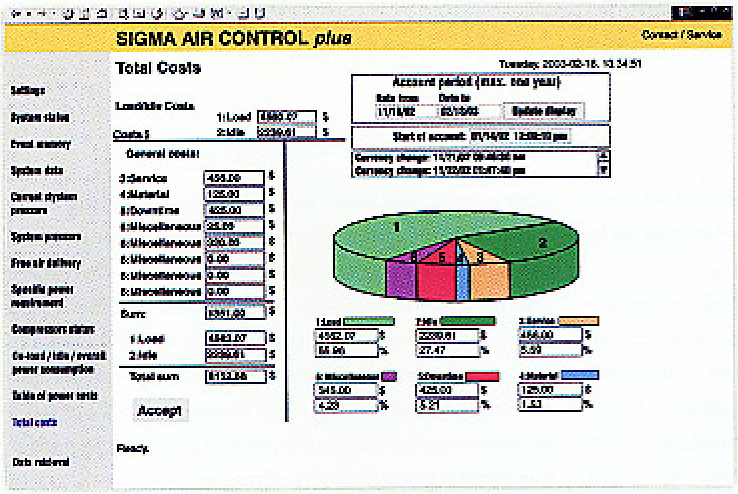
After addressing demand side issues and tweaking the supply side to operate as it was intended, take the next step. Tie the supply side components into an integrated controller that can minimize run times, maximize savings, maintain a stable air pressure and provide constant data feedback for the whole system.

Historical perspective

Ten or 15 years ago, integrated controllers were priced from $25,000 to more than $50,000. The units required software written specifically for the individual application. Each air system modification required rewriting the program. It was expensive, but it also was worthwhile for large systems.

The cost of a modern integrated controller has dropped considerably. High-tech electronics, experience and competition have resulted in controllers superior to previous generations and packed with more features. Payback in energy savings can be as little as a few months.

Cascading controls that required from 15 to 25 psig are obsolete and should be replaced. Contem-



porary integrated controllers can stabilize a properly designed system to within one or two psi. Controlling in a tight pressure band allows the compressors to operate at lower pressures, which saves energy. Remember, every two-psi reduction in compressor pressure yields a one-percent reduction in power consumption. Reducing system pressure also reduces air consumption at unregulated users—blow-off nozzles, leaks and the like. Use a simple orifice chart to estimate demand reduction.

Knowledge is power

Better information fosters better decisions, and controllers can provide that information. The features to look for in an integrated controller are listed below.

Remote monitoring—Several controllers can act as Web servers. This allows operating personnel to connect the controller to the company intranet to monitor the air system from any computer having a Web browser. Many controllers have modems, as well, allowing monitoring from outside the facility.

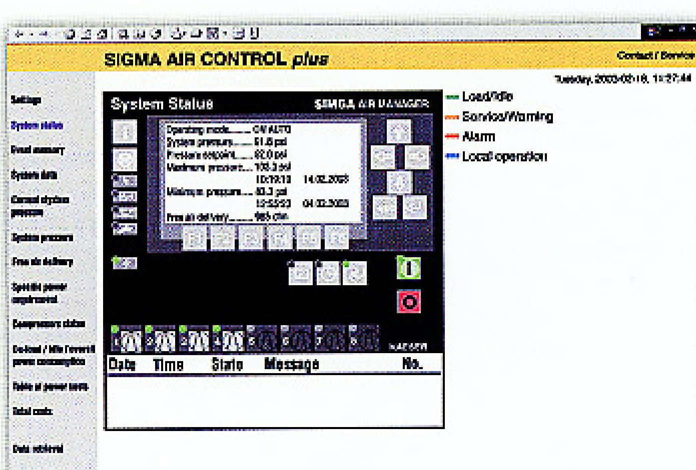
Fully integrated air system components, not just the compressors—filters, dryers and drains—need to be monitored, too. Many are available with contacts to activate remote alarms. Pick a controller that allows ancillary components to be tied together. Problems in one part of the system may be the result of a failure of one of these components. Problem solving is much easier if sufficient information is readily available.

System status display—These screens provide an at-a-glance view of system status and its service and alarm messages. Think of the system status display as the controller's home page that displays the operating status of each compressor and presents links to other related displays.

Message history—Look for controllers that include a message history display. Message histories are a system's black box that captures events as they occur. Knowing exactly what was happening right up to the moment of a sudden drop in pressure or the shutdown of some system component greatly simplifies troubleshooting.

System data—This display gives operators a look at individual component settings and controller settings. If that's too much data to display on one screen, the controller should have links to supplementary screens that show system settings. Having settings easily available allows evaluating and changing control schemes to accommodate changes in either the system's supply or demand side. If production increases, a process moves to a different shift or a new compressor is installed, one can reevaluate the control scheme easily and make changes to optimize air system efficiency.

Some data is more easily understood if it's displayed as a graph. Examples include system pressure and a selectable history. Showing system pressure as a function of time can be a great benefit when trying to optimize supply side controls. Having real-time graphing, as well as the ability to pull up a day's worth, or a week's worth, or even a year's worth of data in a graphical format makes it easy to identify



how changes to either side of the system affect pressure. Evaluating this data regularly also can help avoid production problems.

Another useful graph is compressor air delivery—individual and aggregate, instantaneous and historical. As with the pressure, graphing airflow helps operators optimize the supply side. For example, if one compressor operates only briefly and shuts off for an extended period, compressor sequencing might need to be changed to have a smaller compressor handle that particular load. Another possible solution might be to add storage so the system can ride through the event without having to turn on a compressor at all. Operators will know this only if they have historical data. Seeing it in a graphical format is the easiest way to review system performance.

Graphing specific power consumption, current and historical, allows operators to shuffle sequences to make the most efficient machines run most of the time with the least efficient machines on standby.

Overall operating costs—Because controller software monitors power and flow conditions, the next logical step is an analysis module that allows operators to track actual air system operating costs. If it's given the power costs, including seasonal or daily changes in power costs, the controller can calculate how much is spent for electricity to power the system. Improvements can be documented easily without having to resort to separate power meters for each compressor. Some controllers even allow operators to enter other maintenance costs and display the total air system cost in tabular and graphical formats.

Outbound calling—Another valuable feature on some of the latest controllers is a call-out function. Equipped with a modem, they can call or fax trouble messages to either plant maintenance personnel or the plant's service provider. Using a laptop computer and a phone line, the person notified can dial into the controller and monitor the entire system. This is especially useful in the middle of the night. The information provided to the service technician can support a decision to give it immediate attention versus waiting until morning. Remote troubleshooting also allows the service provider to gather the correct parts before arriving on site.

Better decisions

Fifteen years ago, compressor controllers consisted of a box with a few remote pressure switches, a timer or two and some lights to indicate that compressors were supposed to be running. If operators wanted more information, they had to go to each compressor and write down the temperature and pressure, the only data they could access.

Today's integrated controllers manage the compressed air system. As with any good manager, they also provide reports and data to help others make correct compressed air system decisions.⊗

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Figures: Kaeser Compressors, Inc.